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 1991-2016 were updated, and preliminary catch data for 2017 were 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: 2017	2018	As estimated or *recommended this* year for: 2018	2019
M (natural mortality rate)	0.36	0.36	0.38	0.38
Tier	5	5	5	5
Biomass (t)	79,600	79,600	79,600	79,600
F_{OFL}	0.36	0.36	0.38	0.38
$maxF_{ABC}$	0.27	0.27	0.285	0.285
F_{ABC}	0.27	0.27	0.285	0.285
OFL (t)	28,700	28,700	30,200	30,200
maxABC (t)	21,500	21,500	22,700	22,700
ABC (t)	21,500	21,500	22,700	22,700
Status	As determined *last* year for: 2015	2016	As determined *this* year for: 2016	2017
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 (note that numbering of comments here is continuous with numbering of comments in the preliminary assessment; note also that SSC comments directed to the Plan Teams rather than the assessment authors are not included here):

SSC1 (12/16 minutes): "*In an effort improve record keeping as assessment authors formulate various stock status evaluation models, the Plan Team has recommended a systematic cataloging convention.... The SSC recommends this method of model naming and notes that it should reduce confusion and simplify issues associated with tracking model development over time*." The prescribed model naming convention is used in this assessment.

SSC2 (10/17 minutes): "*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 involved. 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. 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 areas of concern*." Once the processes for producing the integrated analysis of indices and explicit consideration and documentation of ecosystem and stock assessment status have been developed, any features of those processes identified for inclusion in the assessment will be added to future assessments.

Responses to SSC and Plan Team Comments Specific to this Assessment

Following a review of the EBS and AI Pacific cod stock assessments by the Center of Independent Experts (CIE) in February of 2016 and during the process of developing and reviewing the 2016 assessments, a large number of comments on the assessments and the assessment process were provided by the BSAI Plan Team ("Team"), the Team Subcommittee on Pacific Cod Models ("Subcommittee"), and the SSC. Recommendations pertaining to the 2016 assessments were all addressed in those assessments.

Following what has become standard practice for the EBS and AI Pacific cod assessments, all comments from the previous year that were directed at the current year's assessments were vetted by the Subcommittee at its annual meeting, which this year was held in June (https://www.npfmc.org/wp-content/PDFdocuments/membership/PlanTeam/Groundfish/BSAIPcod_subcommittee617minutes.pdf). Comments that were vetted by the Subcommittee are listed below, including comments that were directed at the assessments of Pacific cod in both the EBS and AI, or at the assessments of Pacific cod in all three regions (EBS, AI, and Gulf of Alaska). The final comment (Sub5, from the June 2017 meeting) provides the Subcommittee's disposition of the other 15 comments.

Sub1 (5/16 minutes, originally from the 2016 review by CIE member Jean-Jacques Maguire, labeled as comment 2e.06 in the minutes of the May 2016 Subcommittee meeting): "*Only those parameters where there is external information suggesting that changes are occurring should be allowed to vary, probably one at a time to avoid incorrect interpretation.*"

Sub2 (5/16 minutes; originally from the 2016 review by CIE member Neil Klaer, labeled as comment 2a.07 in the minutes of the May 2016 Subcommittee meeting): "*While there has been some recent narrowing down of agreed procedures among US west-coast stock assessors, it has also been recognized that it is not currently possible to recommend default procedures for composition and conditional age-at-*

length (CAAL) data. There is agreement that the Francis weighting approach is more appropriate in cases where the model is not correctly specified as it takes autocorrelation among composition data into account. It is also agreed that for a correctly specified model, the McAllister-Ianelli harmonic mean weighting method works well."

Sub3 (5/16 minutes, originally from the 2016 review by CIE member Neil Klaer, labeled as comment 2b.03 in the minutes of the May 2016 Subcommittee meeting): *"Further work on choice of a more appropriate selectivity function other than double-normal (or by changing the freedom of certain double-normal parameters) would probably improve the overall fit…."*

Sub4 (5/16 minutes, originally from the 2016 review by CIE member Robin Cook, labeled as comment 2i.17 in the minutes of the May 2016 Subcommittee meeting): *"While developing the Tier 3 model, consideration should also be given to enhancing the Tier 5 model to include a simple population model in order to obtain a little more information from the data as opposed to simply smoothing the time series."*

BPT1 (9/16 minutes): *"The Team recommends that the mid-year meetings cease unless exceptional circumstances necessitate such a meeting."*

BPT2 (9/16 minutes): *"It is recognized by the Plan Team that per SSC comments and the author's discretion, that the author may bring forward a better model than 16.1. The Plan Team has concerns regarding the form of the selectivity and the new data sources. We feel that these issues cannot be fully examined by November, but the Team recommends that they be addressed in the next cycle (2017)."*

SSC3 (10/16 minutes): *"The observed discrepancies among different models in these assessments are a good—if perhaps extreme—example of the model uncertainty that pervades most assessments. This uncertainty is largely ignored once a model is approved for specifications. We encourage the authors and Plan Teams to consider approaches such as multi-model inference to account for at least some of the structural uncertainty. We recommend that a working group be formed to address such approaches."*

SSC4 (10/16 minutes): *"Regarding the mid-year model vetting process, the SSC re-iterates its recommendation from June to continue for now. The process has proven useful for the industry as an avenue to provide formal input and for the author to prioritize the range of model options to consider."*

SSC5 (10/16 minutes): *"With regard to data weighting, the SSC recommends that the authors consider computing effective sample sizes based on the number of hauls that were sampled for lengths and weights, rather than the number of individual fish."*

SSC6 (10/16 minutes): *"Although there is genetic evidence for stock structuring within the Pacific cod population among regions, the uncertainty in model scale for all three regions seems to suggest that some sharing of information among the three assessments might be helpful. Over the long term, authors could consider whether a joint assessment recognizing the population structuring, but simultaneously estimating key population parameters (e.g., natural mortality, catchability or others) might lend more stability and consistency of assumptions for this species.*"

BPT3 (11/16 minutes): *"The Team recommends that the analyst propose age-structured models for consideration at the spring model specification meeting to be used in Tier 3 calculations."*

SSC7 (12/16 minutes): *"All three cod assessments could benefit from a formal prior on M based on the variety of studies referenced in each. The SSC recommends that a prior for use in all cod assessments be developed for 2017."*

SSC8 (12/16 minutes): *"The SSC supports the author's observation that ageing bias needs to be further investigated for cod, with results potentially applicable to all three assessments."*

SSC9 (12/16 minutes): *"The SSC continues to support the spring Pacific cod workshop to review and plan for model development each year, and also supports all of the technical PT recommendations for future model development."*

SSC10 (12/16 minutes): *"The SSC also supports the PT recommendation to continue development of an age-structured model for the next assessment cycle in an effort to move the stock to Tier 3."*

Sub5 (6/17 minutes): *"The Subcommittee decided not to develop a list of models to be included in the preliminary 2017 AI assessment, thus allowing the assessment author to devote more time to the preliminary 2017 EBS assessment. The Subcommittee notes that a similar recommendation was made by both the full BSAI Team and the SSC with respect to the final 2016 assessments. The Subcommittee also notes that the author has the discretion to bring forward one or more models for the preliminary 2017 AI assessment if he so chooses. If he does not, the Subcommittee anticipates that AI Pacific cod will continue to be managed under Tier 5 in 2018."* In response to comment BPT3, descriptions of age-structured models for consideration by the Subcommittee at its June meeting were included in the background document provided in advance of that meeting (attached to the minutes of that meeting as Appendix A). The main purpose of the annual Subcommittee meeting is to review the relevant comments provided by previous meetings of the Subcommittee, Team, and SSC; and, on the basis of that review, recommend models and non-model analyses for inclusion in the current year's assessments. Given that no models or non-model analyses were requested by the Subcommittee (other than an implicit request for inclusion of the standard Tier 5 random effects model), and that neither the Team nor SSC made any new requests for either models or non-model analyses at their respective September and October meetings, this assessment has been prepared accordingly.

INTRODUCTION

General

Pacific cod (*Gadus macrocephalus*) is a transoceanic species, occurring at depths from shoreline to 500 m. 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). 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 is 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 EBS.

Review of Life History

Pacific cod eggs are demersal and adhesive. Eggs hatch in about 15 to 20 days. Spawning takes place in the sublittoral-bathyal zone (40 to 290 m) near bottom. Eggs sink to the bottom after fertilization and are somewhat adhesive. Optimal temperature for incubation is 3° to 6°C, optimal salinity is 13 to 23 parts per thousand (ppt), and optimal oxygen concentration is from 2 to 3 ppm to saturation. Little is known about the optimal substrate type for egg incubation.

Little is known about the distribution of Pacific cod larvae, which undergo metamorphosis at about 25 to 35 mm. Larvae are epipelagic, occurring primarily in the upper 45 m of the water column shortly after hatching, moving downward in the water column as they grow.

Juveniles occur mostly over the inner continental shelf at depths of 60 to 150 m. Adults occur in depths from the shoreline to 500 m, although occurrence in depths greater than 300 m is fairly rare. Preferred substrate is soft sediment, from mud and clay to sand. Average depth of occurrence tends to vary directly with age for at least the first few years of life. Neidetcher et al. (2014) have identified spawning locations throughout the Bering Sea and Aleutian Islands.

It is conceivable that mortality rates, both fishing and natural, may vary with age in Pacific cod. In particular, very young fish likely have higher natural mortality rates than older fish (note that this may not be particularly important from the perspective of single-species stock assessment, so long as these higher natural mortality rates do not occur at ages or sizes that are present in substantial numbers in the data). For example, 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.*).

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 so far in 2017 pot gear has accounted for 17% of the catch (as of October 29). 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 less than 23 t since 1991, and no catch at all after 2012. The breakdown of catch by gear during the most recent complete year (2016) is as follows: trawl gear accounted for 87% of the catch, and longline gear accounted for 13%.

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 2015-2017 (through October 29, 2017) was 53%, 21%, and 26%, respectively.

Catches of Pacific cod taken in the AI for the periods 1964-1980, 1981-1990, and 1991-2017 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 1994-2017 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.2. Year-to-date CPUEs for both gear types (through October 29) are just above their respective long-term averages, 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 1991-2017 in Table 2A.2. Amendment 49, which mandated increased retention and utilization of Pacific cod, was implemented in 1998. From 1991-1997, 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.

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

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, each of the three most recent point estimates has represented an increase over the preceding estimate.

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 0.38. To be consistent, a value of 0.38 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 0.17 with a coefficient of variation equal to 0.37.

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.

The model's fit to the survey biomass time series is shown in Figure 2A.2. The root-mean-squared-error is 0.103, compared to an average log-scale standard error of 0.182. The mean normalized residual is 0.056, the standard deviation of normalized residuals is 0.625, and the correlation between the survey biomass data and the model's estimates is 0.975.

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)	79,600	79,600
M	0.38	0.38

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 2018 and 2019 are shown below:

Quantity	2018	2019
OFL (t)	30,200	30,200
maxABC (t)	22,700	22,700
F_{OFL}	0.38	0.38
$maxF_{ABC}$	0.285	0.285

Under the estimate of M used in last year's assessment (0.36), OFL would be reduced to 28,700 t, maxABC would be reduced to 21,500 t, F_{OFL} would be reduced to 0.36, and $maxF_{ABC}$ would be reduced to 0.27 (both years, for all quantities).

ABC Recommendation

The authors' recommended ABCs for 2018 and 2019 are the maximum permissible values: 22,700 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 1991-2016 average proportion from the raw survey data (26.2%), 2) the most recent proportion from the raw survey data (23.4%), 3) the 1991-2016 average proportion from Model 13.4 (25.5%), and 4) the most recent proportion from Model 13.4 (25.6%). All of these estimates are quite close to one another, with an average value of 25.2%. If Model 13.4 is used to set the 2018 and 2019 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 (25.6%).

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 (2016) is 13,238 t. This is less than the 2016 AI OFL of 23,400 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.

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 2017 in each of these tables are incomplete. Table 2A.7 shows incidental catch of FMP species taken from 1991-2017 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 2003-2017, aggregated across gear types. Table 2A.9 shows incidental catch of prohibited species taken from 1991-2017, aggregated across gear types. Note that all entries for 2003 are marked "n/a" in Table 2A.9, due to problems in the database for that year, which are under investigation. Table 2A.10 shows incidental catch of non-target species groups taken from 2003-2017, 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 1991-2017 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 2017 are through October 29.

	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	1,779	8,780	4,793	13,573
2014	5,715	429	6,144	4,451	10,595
2015	5,968	3,085	9,053	161	9,214
2016	10,654	1,703	12,356	882	13,238
2017	8,329	3,781	12,110	2,563	14,673

Table 2A.1d—Summary of 1994-2017 catches (t) of Pacific cod in the AI, by NMFS 3-digit statistical area (area breakdowns not available prior to 1994). Catches for 2017 are through October 29.

	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	2,873	10,650	0.004	0.212	0.785
2014	30	1,043	9,522	0.003	0.098	0.899
2015	3,170	2,366	3,678	0.344	0.257	0.399
2016	2,551	1,609	9,078	0.193	0.122	0.686
2017	3,373	3,768	7,533	0.230	0.257	0.513

Table 2A.2—Discards (t) and discard rates of Pacific cod in the AI Pacific cod fishery for the period 1991-2017 (2016 data are current through October 29). 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	10,214	0.007

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 2014-2017. Catch for 2016 is through October 29. 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	10,595	6,997	15,100	20,100
2015	9,214	9,422	17,600	23,400
2016	13,238	12,839	17,600	23,400
2017	14,673	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, 1991-2016.

	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	44,261	36,456	47,117	127,834
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

	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	0.346	0.285	0.369	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

	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	0.423	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

Table 2A.6—Comparison of biomass (t) estimated by Model 13.4 in the 2014-2015 and 2016-2017 assessments, with lower and upper 95% confidence bounds. Color scale: red = low, green = high.

	2014-2015 assessments			2016-2017 assessments		
Year	Mean	L95%CI	U95%CI	Mean	L95%CI	U95%CI
1991	171,637	131,586	223,879	171,063	131,250	222,952
1992	158,994	110,631	228,499	158,448	111,091	225,993
1993	147,282	101,221	214,304	146,763	101,715	211,762
1994	136,433	99,759	186,588	135,940	99,846	185,083
1995	115,818	80,527	166,577	115,740	81,146	165,082
1996	98,318	69,377	139,333	98,541	70,100	138,522
1997	83,463	64,498	108,004	83,898	65,034	108,235
1998	89,714	63,684	126,385	89,858	64,296	125,581
1999	96,434	67,642	137,482	96,241	68,098	136,015
2000	103,657	76,612	140,250	103,077	76,655	138,607
2001	91,773	66,335	126,968	91,613	66,687	125,855
2002	81,252	62,827	105,080	81,424	63,142	104,999
2003	80,844	58,305	112,097	80,916	58,753	111,438
2004	80,439	60,311	107,284	80,411	60,488	106,895
2005	78,661	54,753	113,007	78,602	55,126	112,074
2006	76,921	53,841	109,895	76,833	54,117	109,084
2007	72,373	47,738	109,719	72,422	48,243	108,718
2008	68,093	44,469	104,268	68,263	45,047	103,446
2009	64,067	43,355	94,673	64,344	43,905	94,297
2010	60,278	44,959	80,818	60,650	45,318	81,169
2011	60,701	43,837	84,052	61,233	44,463	84,327
2012	61,126	48,014	77,817	61,822	48,618	78,611
2013	64,887	46,763	90,035	66,577	48,817	90,799
2014	68,880	50,604	93,757	71,699	54,757	93,882
2015				75,524	54,100	105,432
2016				79,553	58,520	108,145

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, 1991-2017 (2017 data current through October 29). 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			
Short/Rough/Sharp/North	0.09	conf												
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	
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, 1991-2017 (2017 data current through October 29). 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
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	0.114
Atka Mackerel	0.07	0.14	0.02	0.01	0.01	0.00	0.00	0.00	conf	conf	conf	conf	conf
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	0.526
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	0.011
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	0.017
Octopus							conf	0.17	conf	conf	conf	conf	conf
Other Flatfish	0.45	0.51	0.39	0.81	0.07	0.09	0.01	0.28	0.32	0.26	conf	0.08	conf
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
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	0.30	0.17	conf	0.31	0.117
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	0.003
Pollock	0.82	0.89	0.58	0.47	0.06	0.03	0.01	0.65	0.16	0.04	conf	0.12	0.338
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	0.424
Rougheye Rockfish	0.11	0.02	0.01	0.00	conf	0.01	0.04	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
Shark							conf			conf	conf	conf	
Sharpchin/Northern Rockfish													
Short/Rough/Sharp/North													
Shortraker Rockfish	conf	0.00	0.00	conf		conf		conf	conf			conf	conf
Shortraker/Rougheye Rockfish													
Skate							0.01	0.03	0.02	0.01	conf	0.02	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			

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, 1991-2017 (2017 data current through October 29). 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			
Short/Rough/Sharp/North	0.02	conf												
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	
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, 1991-2017 (2017 data current through October 29). 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
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
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
Flathead Sole	0.01	0.03	0.12	0.21	0.23	0.16	conf	0.12	conf	conf	conf	conf	0.18
Flounder													
Greenland Turbot	conf	0.01	0.02	0.01	0.00	0.02	0.00	0.03	conf	conf	conf		conf
Kamchatka Flounder							conf	0.01	0.01	conf	0.01	conf	0.04
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
Octopus							0.79	0.50	0.89	conf	0.77	conf	0.55
Other Flatfish	conf	0.01	0.01	0.04	0.52	0.15	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	0.18
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	0.13	conf	0.42	conf	0.35
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
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
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
Rougheye Rockfish	0.27	0.08	0.28	0.73	0.35	0.44	conf	0.52	conf	conf	0.84	conf	0.77
Sablefish	conf	0.15	0.01	0.10	0.12	0.09	0.00	0.32	0.04	conf	conf		conf
Sculpin							0.17	0.39	0.43	conf	0.40	conf	0.32
Shark							0.02	0.12	conf	conf	0.24	conf	0.06
Sharpchin/Northern Rockfish													
Short/Rough/Sharp/North													
Shortraker Rockfish	0.22	0.08	0.06	0.18	0.09	0.59	0.02	0.10	0.18	conf	0.19	conf	0.23
Shortraker/Rougheye Rockfish													
Skate							0.09	0.36	0.17	conf	0.26	conf	0.31
Squid													
Yellowfin Sole		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, 1991-2017 (2017 data current through October 29). 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
octopus, North Pacific	0.96	0.94	0.77	0.89	0.97	0.97	0.93	0.67	0.89	0.33	0.80	conf	0.60
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	0.84	conf	0.17
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	0.60	0.10	0.39	0.19	0.02	0.26	0.28	0.32
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 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, 1991-2017 (2017 data current through October 29). Color shading: red = row minimum, green = row maximum (minima and maxima computed across both panels of the table). Note that all entries for 2003 are marked “n/a”, due to problems in the database for that year, which are under investigation.

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	n/a	1.00
Blue King Crab													n/a	
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	n/a	0.73
Golden (Brown) King Crab													n/a	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	n/a	0.66
Herring			conf							conf			n/a	
Non-Chinook Salmon	conf	0.22			0.00	conf	0.07	0.03	conf	0.11	0.22	0.76	n/a	0.43
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	n/a	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	n/a	
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	n/a	0.97

Species	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Bairdi Tanner Crab	0.98	0.99	1.00	1.00	1.00	0.98	0.50	1.00	0.98	0.98	0.00	0.00	0.97
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
Chinook Salmon	0.80	0.86	0.72	0.80	0.82	0.76	0.55	0.65	0.94	0.62	0.44	0.57	0.25
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	0.29
Halibut	0.70	0.50	0.76	0.70	0.58	0.56	0.35	0.34	0.16	0.18	0.41	0.24	0.40
Herring	1.00	0.05	0.19	0.00	0.00	0.00		0.00	1.00	1.00			0.00
Non-Chinook Salmon	0.11	0.28	0.56	0.17	0.17	0.02	0.36	0.00	0.02	0.00	0.00	0.01	0.00
Opilio Tanner (Snow) Crab	0.84	0.99	1.00	1.00	1.00	1.00	0.98	0.99	0.91	0.81	0.00	0.00	0.99
Other King Crab													
Red King Crab	0.84	0.06	0.82	0.75	0.34	0.22	0.32	0.20	0.91	0.16	0.00	0.00	0.65

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, 2004-2017 (2017 data are current through October 29). 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
Benthic urochordata	0.06	0.16	0.38	0.12	0.05	conf	conf	conf		0.00	0.15	conf	conf	conf	
Bivalves	0.99	0.93	0.98	0.99	0.97	0.96	0.73	0.33	0.41	0.53	0.05	conf	conf	conf	conf
Brittle star unidentified		0.05	conf	0.24	0.69			0.00	conf	0.00	0.00	conf	conf		conf
Capelin					conf	conf				conf	0.10	1.00			
Corals Bryozoans - Corals Bryozoans Unidentified	0.40	0.35	0.24	0.33	0.44	0.28	0.19	0.07	0.00	0.00	0.03	conf	conf	0.06	conf
Corals Bryozoans - Red Tree Coral		0.01	0.98		0.91										
Dark Rockfish						conf									
Eelpouts	0.14	0.69	conf	0.09	0.30		0.02			0.01	0.00	conf	conf		
Eulachon			conf	0.01	conf	conf				1.00					
Giant Grenadier											conf				
Greenlings	0.73	0.06	conf	0.32	0.15	0.23	0.02	conf	conf	0.29		conf			
Grenadier - Ratail Grenadier Unidentified		conf	conf												
Hermit crab unidentified	0.84	0.99	0.09	0.76	0.84	0.47	0.66	0.07	conf	0.56	0.18	conf		conf	
Invertebrate unidentified	0.09	0.00	0.02	0.62	0.16	0.05	0.01	conf	0.01	0.00	0.00	conf		conf	
Lanternfishes (myctophidae)													conf		
Large Sculpins	0.43	0.27	0.21	0.31	0.30										
Large Sculpins - Bigmouth Sculpin						0.09	0.11			0.04					
Large Sculpins - Great Sculpin						0.90	0.94			0.95					
Large Sculpins - Hemilepidotus Unidentified						0.38				0.00					
Large Sculpins - Myoxocephalus Unidentified						0.43				0.30					
Large Sculpins - Plain Sculpin						conf				1.00					
Large Sculpins - Red Irish Lord										0.04					
Large Sculpins - Warty Sculpin						conf	conf			1.00					
Large Sculpins - Yellow Irish Lord						0.17	0.11			0.09					
Misc crabs	0.81	0.64	0.61	0.50	0.28	0.27	0.14	0.05	0.03	0.05	0.05	conf	conf	conf	
Misc crustaceans	1.00	0.29	0.98	0.93	0.33	conf	conf	0.20	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
Misc inverts (worms etc)		conf	conf	1.00	conf					conf	0.00	conf			
Other osmerids				0.00	conf					conf	1.00				
Other Sculpins	0.34	0.01	0.04	0.10	0.06	0.01	0.03			0.00					
Pacific Sand lance	conf		conf			conf		conf					conf		
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	0.11	0.04	0.01	conf	0.24	conf	0.26	0.86	conf	conf	0.05	
Sea anemone unidentified	0.88	0.42	0.78	0.47	0.13	0.07	0.02	conf	conf	0.01	0.00	conf	conf	conf	conf
Sea pens whips	0.65	1.00	0.81	0.62	0.74	conf	0.05	conf	conf						
Sea star	0.57	0.52	0.22	0.38	0.26	0.10	0.05	0.04	0.02	0.04	0.04	0.02	conf	0.03	0.07
Snails	0.73	0.67	0.36	0.55	0.63	0.20	0.33	0.13	conf	0.03	0.03	conf	conf	conf	conf
Sponge unidentified	0.30	0.13	0.30	0.21	0.08	0.02	0.05	0.01	0.02	0.01	0.00	0.00	conf	0.02	conf
State-managed Rockfish								conf							
Stichaeidae			conf	0.08	conf		conf								
urchins dollars cucumbers	0.42	0.51	0.15	0.18	0.36	0.04	0.17	0.01	0.00	0.01	0.01	0.02	conf	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, 2004-2017 (2017 data are current through October 29). 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
Benthic urochordata	0.53	conf	1.00	0.82	1.00	1.00	0.69	0.81	0.36	0.99	conf	0.66	conf	conf	
Bivalves	0.90	1.00	1.00	0.99	1.00	1.00	1.00	0.99	0.94	0.98	1.00	0.25	0.98	conf	0.62
Brittle star unidentified	0.00	0.44	0.03	0.98	0.00	0.99	0.34	0.27	0.04	0.00	0.20	0.04	conf		
Corals Bryozoans - Corals Bryozoans Unidentified	0.69	0.78	0.76	0.41	0.98	0.49	0.84	0.73	0.57	0.37	0.19	conf	0.50	conf	0.98
Corals Bryozoans - Red Tree Coral	0.84	conf		0.34		1.00	1.00								
Dark Rockfish						1.00	0.94			0.86					
Eelpouts	0.02	conf	0.17	0.03	0.11	0.03	0.00	0.09	0.04	0.10	conf		conf		0.32
Giant Grenadier	0.30	conf	0.00	0.08	0.02	0.03	0.01	0.15	0.02	0.04	conf	conf	conf		conf
Greenlings	0.81	0.97	1.00	1.00	1.00	0.99	0.95	1.00	1.00	1.00		0.77	1.00	conf	0.78
Grenadier - Pacific Grenadier		conf						conf							
Grenadier - Ratail Grenadier Unidentified	0.02	0.01	0.00	0.03	0.21	0.01	0.02								
Grenadier - Rattail Grenadier Unidentified								0.27	0.00	0.04	conf				
Gunnels			1.00												
Hermit crab unidentified	0.10	0.13	0.66	0.30	0.70	0.98	0.94	0.67	0.19	0.50	0.69	0.18	conf		0.97
Invertebrate unidentified	0.20	1.00	0.98	1.00	1.00	1.00	0.92	1.00	0.90	0.15	0.14	conf	conf	conf	conf
Large Sculpins	0.94	0.92	0.99	0.98	1.00										
Large Sculpins - Bigmouth Sculpin						0.83	0.99			1.00					
Large Sculpins - Great Sculpin						1.00	1.00			0.95					
Large Sculpins - Hemilepidotus Unidentified						0.97	0.99			1.00					
Large Sculpins - Myoxocephalus Unidentified						1.00	1.00			1.00					
Large Sculpins - Plain Sculpin						1.00	1.00			1.00					
Large Sculpins - Red Irish Lord						0.95	1.00			1.00					
Large Sculpins - Warty Sculpin						1.00	1.00			1.00					
Large Sculpins - Yellow Irish Lord						0.98	0.98			0.99					
Misc crabs	0.02	0.07	0.07	0.46	0.88	0.82	0.78	0.53	0.03	0.79	0.73	0.22	conf	conf	0.87
Misc crustaceans	0.01		1.00		1.00	1.00		0.99	conf	conf		conf	conf		
Misc fish	0.46	0.50	0.61	0.36	0.62	0.87	0.76	0.90	0.59	0.94	0.43	0.72	0.64	conf	0.78
Misc inverts (worms etc)		conf	1.00		1.00		0.00								
Other osmerids			1.00												
Other Sculpins	0.92	1.00	0.93	0.92	0.88	0.99	0.99			0.99					
Pacific Sandfish												1.00			
Pandalid shrimp								conf							
Polychaete unidentified	1.00		1.00			0.00		conf	conf	conf					
Scypho jellies	0.16	conf	0.32	0.89	1.00	1.00	0.87	0.99	0.86	1.00	1.00	0.99			1.00
Sea anemone unidentified	0.79	0.81	1.00	0.97	0.99	0.93	0.97	0.91	0.91	0.97	0.42	0.04	0.77	conf	0.93
Sea pens whips	0.98	conf	0.97	1.00	0.73	1.00	1.00	1.00	0.96	1.00	conf		0.53	conf	0.58
Sea star	0.76	0.93	0.97	0.88	0.96	0.93	0.99	0.97	0.77	0.98	0.81	0.61	0.70	conf	0.52
Snails	0.04	0.12	0.18	0.65	0.38	0.74	0.83	0.46	0.72	0.36	0.37	0.23	0.12	conf	0.57
Sponge unidentified	0.82	0.85	0.86	0.80	0.84	0.11	0.95	0.97	0.37	0.90	0.42	0.34	0.69	conf	0.78
State-managed Rockfish								1.00	1.00		1.00	0.02	1.00		1.00
Stichaeidae	1.00														
urchins dollars cucumbers	0.37	0.63	0.75	0.86	0.89	0.55	0.38	0.51	0.34	0.57	0.20	0.05	0.22	conf	0.73

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, 2004-2017 (2017 data are current through October 29).

Trawl gear:

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Birds - Auklets	conf														
Birds - Gull	conf				1.00										
Birds - Laysan Albatross	1.00		conf				conf								
Birds - Northern Fulmar		0.05	0.89	0.99		0.72	conf	0.54						1.00	
Birds - Unidentified				1.00											
Birds - Unidentified Albatross				1.00											

Fixed gear:

Row Labels	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Birds - Auklets										1.00		1.00			1.00
Birds - Black-footed Albatross	1.00			0.00				conf							
Birds - Cormorant															
Birds - Gull	1.00	0.11	0.59	0.46	0.51	1.00	0.59	0.54	0.08	0.06	conf		conf		
Birds - Kittiwake	1.00		1.00						1.00	1.00	conf				
Birds - Laysan Albatross	0.06	conf	0.30	0.45	0.23	0.40	0.16	0.30	0.00	0.00	conf		conf		
Birds - Murre	1.00		1.00							1.00					
Birds - Northern Fulmar	0.01	0.68	0.86	0.81	0.96	0.82	0.66	0.70	0.25	1.00	0.25	0.03	conf		0.24
Birds - Other	1.00														
Birds - Other Alcid															
Birds - Puffin								conf							
Birds - Shearwaters	0.10	1.00	0.89	1.00	1.00	1.00	0.96	conf	0.26	1.00	conf				0.90
Birds - Short-tailed Albatross								conf	1.00						
Birds - Storm Petrels	1.00			1.00											
Birds - Unidentified	1.00	1.00	1.00	0.05	0.27	1.00	1.00	0.62	1.00	1.00	conf				

FIGURES

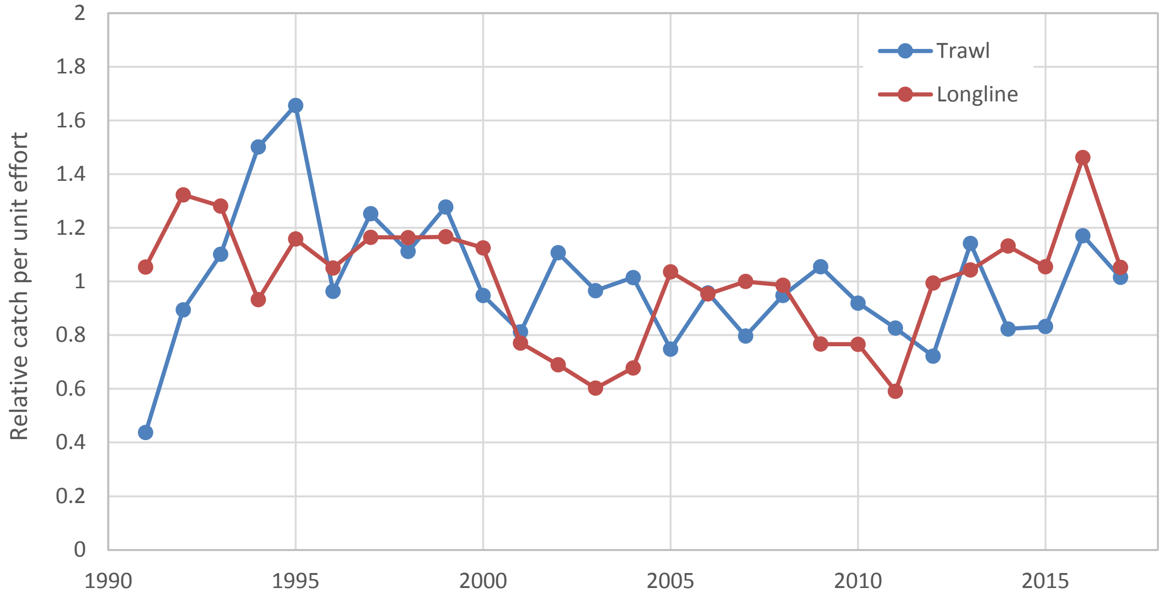

Figure 2A.1—Catch per unit effort for the trawl and longline fisheries, 1991-2017 (2017 data are partial).

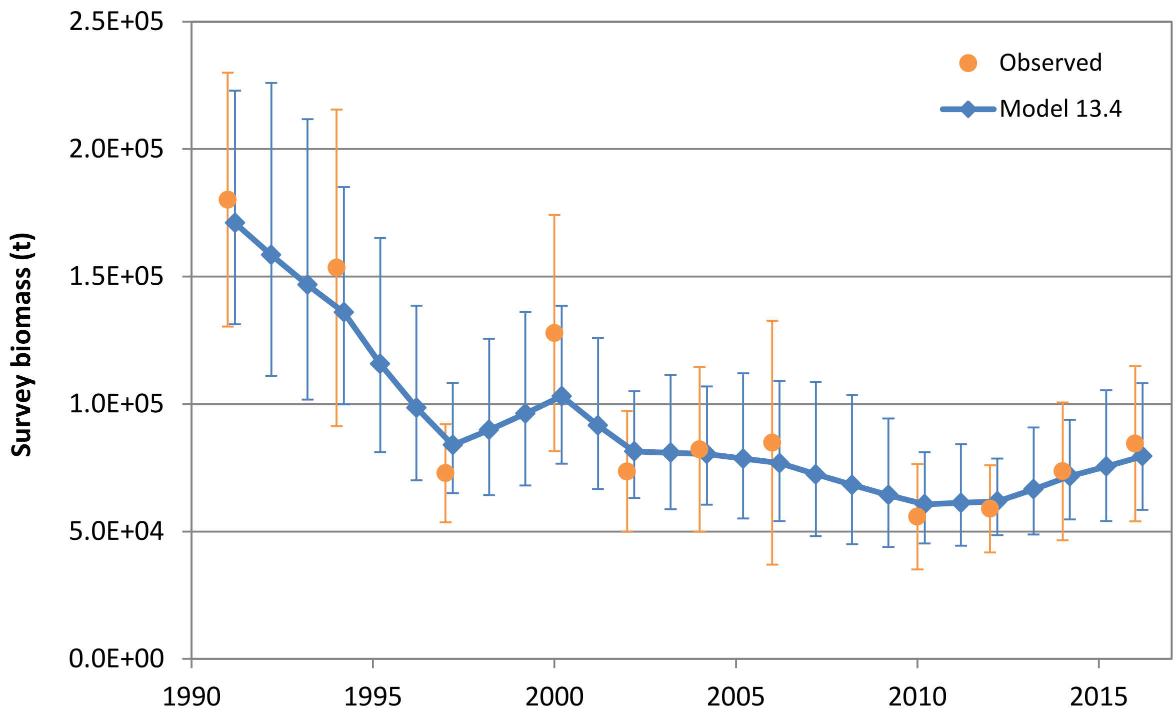

Figure 2A.2—Fit of Model 13.4 to survey biomass time series, with 95% confidence intervals for the observations and the estimates.

APPENDIX 2A.1: BSAI PACIFIC COD ECONOMIC PERFORMANCE REPORT FOR 2016

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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 80% of the total Pacific cod harvest in Alaska. Retained catch of Pacific cod increased 8% to 257.5 thousand t in 2016 and was 43% higher than the 2007-2011 average (Table 2A.1.1). The products made from BSAI Pacific cod had a first-wholesale value of $387 million in 2016, which was up from $365 million in 2015 and above the 2007-2011 average of $307 million (Table 2A.1.2). The higher revenue is the result of increased catch and production levels and strong first-wholesale fillet price 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 1.85 million t in 2014 as catch in the Barents Sea has rebounded and U.S. catch has remained strong at over 300 thousand t since 2011. 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 26% increase to 86 thousand t. The value of these deliveries (shoreside ex-vessel value) totaled $44.6 million in 2016, which was up 31% from 2015, as ex-vessel prices also increased 6% to $0.26 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 $0.03 per pound.

The first-wholesale value of Pacific cod products was up 6% to $386.8 million in 2016, and revenues in recent years remain high as result of strong catch levels (Table 2A.1.2). The average price of Pacific cod products in 2016 increased 1% to $1.39. 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 80% of value and fillets approximately 10% 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 down 5% at $1.30 per pound in 2016. Fillet prices steady declined from over $3 in 2011 to $2.67 in 2015, but prices increased 23% in 2016 to $3.29. Changes in global catch and production account for much the trends in the cod markets. In particular, the 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 Pacific cod prices were soft in early 2016 with weak demand from Japan, an important consumer market for Pacific cod. By the middle of the year prices had begun to rise with strong demand from the U.S., Japan, and other markets. High prices of common fish protein substitutes such as salmon were also cited as contributing to the strong cod demand. Strong demand globally coupled with tight supply have resulted in high prices continuing throughout 2017. The market for H&G products was comparatively weaker than the market for fillets which is reflected in decreased H&G price and increased fillet price which affected the BSAI Pacific cod fisheries which produce a higher proportion of H&G.

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 2A.1.3). 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 from the U.S. and globally have contributed to high prices. With the Barents Sea quota reduced by 13% 2018 the global cod supply is expected to remain constrained relative to recent levels which could result in continued high price levels through 2018.

Table 2A.1.1. 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); 2007-2011 average and 2012-2016.

	Avg 07-11	2012	2013	2014	2015	2016
Total catch K mt	182.7	251	250.2	249.3	242	260.8
Retained catch K mt	179.8	246.5	243.5	244.4	238.9	257.5
Vessels #	189	175	175	156	149	162
CP H&L share of BSAI catch	53%	52%	50%	50%	54%	49%
CP trawl share of BSAI catch	17%	15%	18%	14%	15%	14%
Shoreside retained catch K mt	51.0	75.2	71.1	79.0	68.3	85.9
Shoreside catcher vessels #	131	121	125	109	100	110
CV pot gear share of BSAI catch	9%	11%	11%	14%	12%	15%
CV trawl share of BSAI catch	18%	20%	18%	17%	16%	18%
Shoreside ex-vessel value M $	$36.6	$49.0	$37.0	$44.7	$34.1	$44.6
Shoreside ex-vessel price lb $	$0.326	$0.323	$0.244	$0.274	$0.248	$0.264
Shoreside fixed gear ex-vessel price premium	$0.06	$0.03	$0.01	$0.03	$0.03	$0.03

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 2A.1.2. 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); 2007-2011 average and 2012-2016.

		Avg 07-11	2012	2013	2014	2015	2016
All products	**volume K mt**	88.96	122.67	121.70	123.51	120.47	126.36
All products	**Value M $**	$ 306.6	$ 380.9	$ 303.7	$ 353.8	$ 365.1	$ 386.8
All products	**price lb $**	$ 1.56	$ 1.41	$ 1.13	$ 1.30	$ 1.37	$ 1.39
Fillets	**volume K mt**	4.72	6.76	8.79	8.42	6.28	10.03
Fillets	**value share**	11%	12%	18%	14%	10%	19%
Fillets	**price lb $**	$ 3.14	$ 3.10	$ 2.84	$ 2.68	$ 2.67	$ 3.29
Head & Gut	**volume K mt**	73.29	104.24	97.76	100.56	100.82	98.65
Head & Gut	**value share**	82%	82%	74%	79%	83%	73%
Head & Gut	**price lb $**	$ 1.56	$ 1.37	$ 1.05	$ 1.26	$ 1.36	$ 1.30
At-sea	**value share**	74%	71%	69%	69%	76%	70%
At-sea	**price premium ($/lb)**	-$0.03	-$0.13	-$0.28	-$0.01	$0.07	-$0.29

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 2A.1.3. 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; 2007-2011 average and 2012-2017.

		Avg 07-11	2012	2013	2014	2015	2016	2017 (thru July)
Global cod catch K mt		1,272	1,600	1,831	1,853	1,764	-	-
U.S. P. cod share of global catch		19.7%	20.7%	17.0%	17.7%	18.1%	-	-
Europe share of global catch		72.3%	73.2%	76.7%	75.9%	74.8%	-	-
Pacific cod share of U.S. catch		96.7%	98.6%	99.3%	99.3%	99.5%	-	-
U.S. cod consumption K mt (est.)		80	97	104	114	107	113	-
Share of U.S. cod not exported		25%	30%	31%	31%	26%	29%	-
Export volume K mt		90.3	111.1	101.8	107.3	113.2	105.2	67.7
Export value M US$		$286.3	$363.6	$308.0	$314.2	$335.0	$311.7	$208.0
Export price lb US$		$1.439	$1.485	$1.373	$1.328	$1.342	$1.344	$1.393
Frozen (H&G)	**volume Share**	68%	80%	91%	92%	91%	94%	94%
	value share	68%	80%	89%	91%	90%	92%	92%
Fillets	**volume Share**	13%	9%	4%	2%	3%	3%	5%
	value share	16%	11%	5%	4%	4%	4%	6%
China	**volume Share**	27%	46%	51%	54%	53%	55%	59%
	value share	25%	43%	48%	51%	51%	52%	57%
Japan	**volume Share**	18%	16%	13%	16%	13%	14%	12%
	value share	18%	16%	13%	16%	14%	15%	13%
Netherlands & Germany	**volume Share**	11%	8%	8%	9%	8%	5%	3%
	value share	12%	9%	9%	10%	8%	5%	3%

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.

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 (2014-2016) is 108 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
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
IPHC Annual Longline Survey	15	15	15	15	15	9	23	9	13	15	21	15
Subsistence Fishery	0	0	0	0	0	0	0	0	0	0	0	0