Assessment of the Pacific cod stock in the Aleutian Islands

Ingrid Spies, Grant G. Thompson, Ivonne Ortiz, Elizabeth Siddon and Wayne A. Palsson
Alaska Fisheries Science Center, National Marine Fisheries Service
National Oceanic and Atmospheric Administration
7600 Sand Point Way NE., Seattle, WA 98115-6349
19 November, 2020

Executive summary

Summary of changes in assessment inputs

The following substantive changes have been made in the Aleutian Islands (AI) Pacific cod stock assessment relative to the 2019 assessment.

Changes in the Input Data

Catch data for 2019 was updated, and preliminary catch data for 2020 was included.

Changes in the Assessment Methodology

There were no changes in the assessment methodology that is proposed for use in setting the 2021-2022 harvest specifications. Appendix 2A.4 in the 2019 Aleutian Islands Pacific cod assessment describes an age-structured model that has potential for use in next year's specifications process. This model was not updated for this assessment.

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 metric tons (t) and compared with the corresponding quantities from last year's assessment.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2020	2021	2021	2022
M (natural mortality rate)	0.34	0.34	0.34	0.34
Tier	5	5	5	5
Biomass (t)	80,700	80,700	80,700	80,700
F_{OFL}	0.34	0.34	0.34	0.34
$maxF_{ABC}$	0.255	0.255	0.255	0.255
F_{ABC}	0.255	0.255	0.255	0.255
OFL	27,400	27,400	27,400	27,400
$maxABC$	20,600	20,600	20,600	20,600
ABC	20,600	20,600	20,600	20,600
Status	2018	2019	2019	2020
Overfishing	No	n/a	No	n/a

Responses to SSC and Plan Team Comments on Assessments in General

SSC December 2018

The SSC requests that all authors fill out the risk table.

SSC December 2019

. . . risk tables only need to be produced for groundfish assessments that are in 'full' year in the cycle. The SSC requests the the GPTs, as time allows, update the risk tables for the 2020 full assessments.

Plan Team November 2019

The Teams recommended that authors continue to fill out the risk tables for full assessments. The Teams recommended that adjustment of ABC in response to levels of concern should be left to the discretion of the author, the Team(s), and/or the SSC, but should not be mandated by the inclusion of a >1 level in any particular category. The Teams request clarification and guidance from the SSC regarding the previously noted issues associated with completing the risk table, along with any issues noted by the assessment authors.

Authors' response: We have included a risk table in this assessment.

Responses to SSC and Plan Team Comments Specific to this Assessment

SSC December 2019

The SSC received a presentation from Grant Thompson (NOAA-AFSC) on Aleutian Islands Pacific cod. There was no survey of the Aleutian Islands for 2019 so there were no changes to this Tier 5 assessment. The SSC supported the authors' and GPT's recommendation for a Tier 5 status determination and the associated OFL/ABC as well as the use of the random effects model for apportionment. The SSC noted that there may be other apportionment methods if smoother outcomes are desirable such as multiple survey averaging or the use of a VAST model.

Authors' response

Noted, and no VAST models were provided for Aleutian Islands stocks this year.

SSC December 2019

There was a risk table overall score of 2 based on ecosystem concerns. Unlike the EBS, the condition factor for the AI is quite low and continues to be low. However, given the Tier 5 estimates are more conservative than what was estimated for all of the Tier 3 models presented, the SSC concluded that no ABC reduction was necessary.

Authors' response

Noted.

SSC, December 2019

There were several age-structured models presented in an appendix and we appreciate these efforts. It appears that the models were almost viable for consideration this year. We look forward to seeing a vetted alternative in September [2020] that takes into account current GPT and past SSC recommendations. In addition to those recommendations the authors should consider fitting the two maturity curves inside the model similar to some of the GOA rockfish assessments.

The SSC also recommends exploring the "Barefoot Ecologist" online tool for developing an appropriate prior distribution when estimating natural mortality in next year's age-structured model.

Authors' response

The age structured model was not updated this year due to COVID-19 and no new survey data. An updated age structured model will be provided when requested by Plan Team or SSC.

Introduction

Pacific cod (*Gadus macrocephalus*) ranges across the northern Pacific Ocean from Santa Monica Bay, California, northward along the North American coast, Gulf of Alaska, Aleutian Islands, and Bering Sea north to Norton Sound; and southward along the Asian coast from the Gulf of Anadyr to the northern Yellow Sea. Cod occurs at depths from shoreline to 500 m (Ketchen 1961, Bakkala et al. 1984). The southern limit of the species' distribution is about 34°N latitude, with a northern limit of about 65°N latitude (Stevenson and Lauth 2019). Pacific cod is distributed widely over the eastern Bering Sea (EBS) as well as in the Aleutian Islands (AI) area. A recent study indicated large scale movement into the northern Bering Sea (NBS) by Eastern Bering Sea stocks since 2017 (Spies et al. 2020). Tagging studies (e.g., Shimada and Kimura 1994) have demonstrated significant migration both within and between the EBS, AI, and Gulf of Alaska (GOA). Genetics research indicates the existence of discrete spawning stocks in the EBS and AI (Cunningham et al. 2009, Canino et al. 2010, Spies 2012). Pacific cod likely return to their natal origin to spawn during winter months (January - April) but perform feeding migrations during other months.

Separate harvest specifications for Pacific cod have been set for the Bering Sea and Aleutian Islands regions since the 2014 season. Pacific cod were managed in the combined EBS and AI (BSAI) region from 1977 through 2013.

Life history

Pacific cod in the EBS form large spawning aggregations, and typically spawn once per year (Sakurai and Hattori 1996, Stark 2007), from February through April (Neidetcher et al. 2014). Shimada and Kimura (1994) identified major spawning areas between Unalaska and Unimak Islands, and seaward of the Pribilof Islands along the shelf edge. Neidetcher et al. (2014) identified spawning concentrations north of Unimak Island, in the vicinity of the Pribilof Islands, at the shelf break near Zhemchug Canyon, and adjacent to islands in the central and western Aleutian Islands along the continental shelf. Pacific cod are known to undertake seasonal migrations as part of an annual migration between summer feeding grounds and winter spawning grounds, the timing and duration of which may be variable (Savin 2008). Travel distances have been observed in excess of 500 nautical miles (nmi), with a large number of travel distances in excess of 100 nmi (Shimada and Kimura 1994).

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

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

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

Cold environments allow Pacific cod larvae to bridge gaps in prey availability (i.e., timing and magnitude), but negatively impact survival over longer periods (Laurel et al. 2011). Under warmer conditions, mismatches in prey significantly impacted growth and survival; however, both yolk reserves and compensatory growth mechanisms reduced the severity of mismatches occurring in the first 3 weeks of development (Laurel et al. 2011). Larval retention of Pacific cod during the month of April appears to be important to late spring abundance in the Gulf of Alaska, but it is unknown whether this result holds elsewhere in the species' range (Doyle et al. 2009).

Juvenile Pacific cod typically settle near the seafloor (Abookire et al. 2007, Laurel et al. 2007). Some studies of Pacific cod in the Gulf of Alaska, and also some studies of Atlantic cod, suggest that young-of-the-year cod are dependent on eelgrass, but this may not be the case elsewhere in the species' range. Key nursery habitat for age-0 Pacific cod across most of its range typically consists of sheltered embayments. Age-0 Pacific cod have also been observed in the shelf-pelagic zone (Hurst et al. 2012, Parker-Stetter et al. 2013). Habitat use of age-0 Pacific cod in the EBS occurs along a gradient from coastal-demersal (bottom depths < 50 m) to shelf-pelagic (bottom depths 60-80 m), with densities near the coastal waters of the Alaska peninsula much higher than elsewhere (Hurst et al. 2015). Hurst et al. (2012) found evidence of density-dependent habitat selection at the local scale, but no consistent shift in distribution of juvenile Pacific cod in response to interannual climate variability. Habitat use by age-0 Pacific cod in the EBS may be related to temperature and the distribution of large-bodied demersal predators (Hurst et al. 2015). Similarly, the habitat distribution of age-0 Atlantic cod is influenced by predators (Gotceitas et al. 1997).

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.).

Adult Pacific cod in the EBS are strongly associated with the seafloor (Nichol et al. 2007), suggesting that fishing activity has the potential to disturb habitat. Diel vertical migration has also been observed (Nichol et al. 2013). Patterns varied significantly by location, bottom depth, and time of year, with daily depth changes averaging 8 m. Although little is known about the likelihood of age-dependent natural mortality in adult Pacific cod, it has been suggested that Atlantic cod may exhibit increasing natural mortality with age (Greer-Walker 1970). At least one study (Ueda et al. 2006) indicates that age 2 Pacific cod may congregate more, relative to age 1 Pacific cod, in areas where trawling efficiency is reduced (e.g., areas of rough substrate), causing their selectivity to decrease. Also, Atlantic cod have been shown to dive in response to a passing vessel (Ona and Godø 1990, Handegard and Tjøstheim 2005), which may complicate attempts to estimate catchability (q) or selectivity. It is not known whether Pacific cod exhibit a similar response.

Fishery

Description of the directed fishery

During the early 1960s, Japanese vessels began harvesting Pacific cod in the AI. However, these catches were not large, and by the time the Magnuson Fishery Conservation and Management Act went into effect in 1977, foreign catches of Pacific cod in the AI had not exceeded 4,200 t (Table 2A.1). 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 (Table 2A.2). Domestic fishing for AI Pacific cod began in 1981, with a peak catch of over 43,000 t in 1992 (Table 2A.3).

Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including primarily trawl and longline components (Figure 2A.1). 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 from 2017 through 2020 (as of October 31, 2020), pot gear accounted for 34% of the catch. 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 12 t since 1991. The breakdown of catch by gear during the most recent complete year (2019) is as follows: trawl gear accounted for 54% of the catch, longline gear accounted for 13%, and pot gear accounted for 33% of the catch.

Historically, Pacific cod were caught throughout the AI. For the last five years prior to enactment of additional Steller sea lion (*Eumetopias jubatus*) protective regulations in 2011, the proportions of Pacific cod catch in statistical areas 541 (Eastern AI), 542 (Central AI), and 543 (Western AI) averaged 58%, 19%, and 23%, respectively. For the period 2011-2014, the average distribution has was 84%, 16%, and 0%, respectively. In 2015, area 543 was reopened to limited fishing for Pacific cod (see "Management History" below). The average catch distribution for 2017-2020 (through October 31, 2020) was 61% from the eastern Aleutian Islands (NMFS area 541), 26% from the central Aleutian Islands (NMFS area 542), and 13% from the western Aleutian Islands (NMFS area 543).

Catches of Pacific cod taken in the AI for the periods 1964-1980, 1981-1990, and 1991-2020 are shown in Table 2A.1, Table 2A.2, and Table 2A.3, respectively. The catches in Table 2A.1 and Table 2A.2 are broken down by fleet sector (foreign, joint venture, domestic annual processing). The catches in Table 2A.2 are also broken down by gear to the extent possible. The catches in Table 2A.3 are broken down by gear. Table 2A.4 breaks down catches from 1994-2020 by statistical area (area breakdowns not available prior to 1994), both in absolute terms and as proportions of the yearly totals.

Effort and CPUE

CPUE aggregated over gear types for the number and weight of fish show similar trends, indicating that there has been no large shifts in the weight of individual fish (Figure 2A.2). Recently, CPUE has decreased, but this may be related to several factors, including timing of the fishery relative to spawning season. Although trawl CPUE has trended downward recently, there is little indication of long-term trends. The relationship between CPUE and abundance is not clear for cod, as they may hyperaggregate during spawning when stock sizes are smaller (Rose and Kulka 1999).

Discards

The catches shown in Table 2A.2 and Table 2A.3 include estimated discards. Discard amounts and rates of Pacific cod in the AI Pacific cod fisheries are shown for each year 1991-2020 in Table 2A.5. Amendment 49, which mandated increased retention and utilization of Pacific cod, was implemented in 1998. From 1991-1998, discard rates in the Pacific cod fishery averaged about 5.6%. Since then, they have averaged about 1.0%.

Management History

Appendix 1 lists all implemented amendments to the BSAI Groundfish FMP that reference Pacific cod explicitly. The most recent is Amendment 120/108, which was finalized January 20, 2020.

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.6. 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, Table 2A.2, and Table 2A.3, which pertain to the AI only. Total catch has been less than the OFL in every year since 1993. Instances where catch exceeds TAC can typically be attributed to the fact that the catches listed in Table 2A.6 are total catches (i.e., Federal plus State), whereas the TAC applies only to the Federal catch.

In the 7 years that AI Pacific cod have been managed separately from EBS Pacific cod, the ratio of Federal catch to TAC has ranged from 0.58 to 0.98. The catch/TAC ratio in 2020 (complete through October 31) was 0.37, which is the lowest ratio observed since 2014, 0.37.

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 ten 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 the Eastern Bering Sea Pacific cod stock assessment for a history of changes in that model. During the period of separate AI and EBS management, the assessment of the AI stock has been based on a simple, random effects (Tier 5) model.

History with Respect to the State Fishery

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

Year	Formula
2014	0.03*(EBS ABC + AI ABC)
2015	0.03*(EBS ABC + AI ABC)
2016	0.27*AI ABC
2017	0.27*AI ABC
2018	0.27*AI ABC
2019	0.31*AI ABC
2020	0.35*AI ABC or 6,804 t, whichever is less
2021	0.39*AI ABC or 6,804 t, whichever is less

The Aleutian Islands GHL increases 4% if the catch reaches 90% of the GHL the previous year. The GHL cannot exceed 39% or 6,804 t. If the 2021 ABC remains at the value that was specified last year (20,600 t), the above formula would result in a GHL of 6,804 t in 2021. 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 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.7. These estimates pertain to the Aleutian management area, and so are smaller than the estimates pertaining to the Aleutian survey area that were reported in BSAI Pacific cod stock assessments prior to 2013.

Over the long term, the biomass data indicate a decline. Simple linear regression on the time series estimates a negative slope coefficient that is statistically significant at the 1% level. However, the trend since 2010 has been largely positive Figure 2A.3.

Analytic Approach

Model Structure (General)

From 2012 through the preliminary 2016 draft, a total of 22 unique age-structured models were fully vetted in the assessments of AI Pacific cod. However, none of them were accepted by either the Team or SSC for the purpose of recommending harvest specifications. Given that there were so many outstanding issues with respect to the assessments of Pacific cod in both the EBS and AI as of September/October 2016, the Team and SSC recommended suspending efforts to develop an age-structured model of the AI stock until such time as the issues with respect to the EBS assessment had been resolved. In December 2018, the SSC requested that an age-structured model be developed for the AI stock (comment SSC5). In response, an age-structured model was presented in the 2019 assessment.

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 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.

Parameter Estimates

Natural Mortality

A value of 0.34 was used for the natural mortality rate M in all BSAI Pacific cod stock assessments from 2007 (Thompson et al. 2007) through 2015. 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 correct, 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). In the 2018 EBS assessment (Thompson 2018), another new model was recommended for the EBS Pacific cod stock, which estimated M at a value of 0.34, and the value of M for the AI stock was updated accordingly (Thompson and Palsson 2018). Although another new estimate of M (0.35) is available from this year's EBS assessment (chapter 2, this volume), given the Team's and SSC's concerns that the practice of equating the AI estimate of M with the EBS estimate (see comments BPT1 and SSC3), this has been discontinued (i.e., the value of M has not been updated here), pending development of a more suitable estimator.

Results

Model Output

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

The time series of biomass estimated by the model, with 95% confidence intervals, is shown in Table 2A.8, along with the corresponding estimates from the 2019 assessment (Thompson and Palsson 2019), which comprised the most recent previous update of the time series. The estimates were the same and based on the same time series of survey biomass, except for wider 95% confidence intervals in the most recent year.

The model's fit to the survey biomass time series is shown in Figure 2A.3. The root-mean-squared-error is 0.105, compared to an average log-scale standard error of 0.180. The mean normalized residual is 0.054, the standard deviation of normalized residuals is 0.633, and the correlation between the survey biomass data and the model's estimates is 0.972.

Harvest Recommendations

Amendment 56 Reference Points

Amendment 56 to the BSAI Groundfish Fishery Management Plan (FMP) defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (FOFL), 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.

Under Tier 5, F_{OFL} is set equal to the natural mortality, F_{OFL} = M, and the fishing mortality rate to achieve the acceptable biological catch is 75% of M, $F_{ABC} \leq 0.75 \times$M.

The following table includes estimates needed for harvest specifications, estimates of OFL, maximum permissible ABC, and the associated fishing mortality rates for 2021 and 2022. Note that the 95% confidence interval for the estimate of biomass estimate is 48,234 t - 134,998 t. The confidence intervals are larger than in 2019 due to the lack of survey data since 2018. The values are the same as for 2019 because the random effects model provides the same biomass estimates when the same survey data is used, and there is no new survey data. The numbers in the following table were rounded to the nearest 100 tons in the summary table on page 1.

Quantity	2021	2022
Biomass (t)	80,694	80,694 t
M	0.34	0.34 t
F_{OFL}	0.34	0.34
maxF_{ABC}	0.255	0.255
OFL (t)	27,436	27,436
maxABC (t)	20,577	20,577

Risk Table

Assessment Considerations

This stock been assessed using Tier 5 methodology since 2013. The standard Tier 5 random effects model fits the survey data well. Appendix 2A.4 in the 2019 Aleutian Islands cod assessment presented a new age-structured model that was similar to some of the age-structured models for the Aleutian Islands stock of Pacific cod that were developed between 2012 and 2016. One feature of that model is a positive retrospective pattern (ρ=0.206), meaning that, on average over the past 10 assessment years, the model's estimates of female spawning biomass in the terminal year would have exceeded the model's current estimate of female spawning biomass in that year by about 20%. This may suggest that the model could benefit from further development, although it should also be noted that Hurtado-Ferro et al. (2015) determined that this level of retrospective bias does not rise to the level that should be cause for concern.

The estimate of biomass that would have resulted during each of the past survey years (2010-present) with and without the recent survey biomass estimate averaged 573 tons, and results are presented below. The most extreme differences were in 2016, 10,641 t lower than the true value, and 2010, 24,452 t higher than the true value.

Year	No Data Estimate	True (with new survey data)	Difference
2018	79,511 t	80,694 t	-1183 t
2016	68,870 t	79,511 t	-10,641 t
2014	59,036 t	68,870 t	-9,834 t
2012	59,109 t	59,036 t	74 t
2010	83,561 t	59,109 t	24,452 t

Assessment considerations were rated as level 1 (normal).

Population Dynamics Considerations

Although the long-term (1991-2018) survey biomass trend is downward, the trend since 2010 has been largely positive. Population dynamics considerations were rated as level 1 (normal).

Environmental/Ecosystem Considerations

Due to lack of 2020 surveys and fieldwork, many ecosystem indicators were not measured this year. Thus, much of the ecosystem information available for this year is derived from remote sensing. Pacific cod are typically found between 3.5–5.7°C in the Aleutian Islands survey. Temperature anomalies for the 100–250 m depth range show that significantly warmer temperatures have remained since 2016 in the Aleutian Islands (National Centers for Environmental Prediction Global Ocean Data Assimilation System, GODAS). In 2016, temperatures were found up to 7°C, in part reflecting residual conditions from the 2014–2016 heatwave in the Gulf of Alaska. The number of days per season where sea surface temperatures have been above the heatwave threshold has been higher since 2013–2014 throughout the Aleutians. The number of heatwave days declined in 2020 compared to 2019, which was a record warm year in the eastern AI. The pattern of heatwave years differs from that in the adjacent Gulf of Alaska.

In general, higher ambient temperatures incur bioenergetic costs for ectothermic fish such that, all else being equal, consumption must increase to maintain fish condition. Pacific cod are particularly sensitive to the impacts of increased temperatures due to a combination of their energetic demands and diet, as was seen in the Gulf of Alaska during the 2014–2016 heatwave (Barbeaux et al. 2020). Thus, the persistent higher temperatures are considered a negative indicator for Pacific cod.

Recent examinations of Pacific cod diets in the Aleutian Islands have shown changes in diet type and potentially, quality. Pacific cod stomachs collected in the bottom trawl survey in the western and central Aleutians (areas 543, 542) have shown decreases in Atka mackerel, previously one of their primary prey items, over the past few years. This has coincided with the declining biomass and body condition of Atka mackerel in these areas according to survey estimates (Laman and Rohan, AI ESR), potentially reflecting scarcer and lower quality prey available for Pacific cod. The reverse has happened in area 541, where Atka mackerel was not generally a common prey in earlier years, but has now increased to over 20% of Pacific cod diet by biomass since 2014, replacing sculpins.

In addition to the lower prey quality, availability may have also decreased given that the combined proportion of pelagic predators is now dominated by rockfish (POP and Northern Rockfish), where Atka mackerel and walleye pollock used to comprise the larger proportion of this group across the entire Aleutians. As a generalist, Pacific cod is able to offset the lower availability of any one type of prey, having the ability to easily switch between fish and benthic crustacean prey. The observed body condition of Pacific cod in the AI bottom trawl survey (Laman and Rohan, AI ESR) has been lower than the survey mean from 2012–2018 in the entire Aleutians, with mean or slightly lower body condition since 2000 in the southern Bering Sea survey area, suggesting that Pacific cod have not been able to meet their energetic demands sufficiently.

Taken together, the few indicators available this year combined with the updated diet for Pacific cod, suggest there are some adverse signals relevant to the stock, but the pattern is not consistent across all areas. In particular, recent years of increased warm temperatures are of particular concern for Pacific cod.

Environmental/ecosystem considerations were rated as level 2 (substantially increased concern).

Fishery Performance Considerations

Since 1991, fishery CPUE shows less of a long-term trend than survey biomass, although since about the early 2000s both time series are essentially trendless. Trawl fishery CPUE has declined markedly since 2016, while survey biomass in 2018 was nearly unchanged from 2016. There does not appear to have been any unusual spatial patterns of fishing, or changes in the percent of TAC taken. The winter fishery targets spawning populations of Pacific cod. Pacific cod aggregate to spawn, implying that a reduction in stock size is unlikely to cause lower CPUE. Rather, hyperaggregation may exist, in which higher CPUE is observed under low stock sizes (Rose and Kulka 1999). Fishery performance considerations were rated as level 1 (normal).

Risk Summary

The ratings of the four categories are summarized below:

Assessment consideration	Population dynamics	Environmental ecosystem	Fishery performance	Overall
Level 1: Normal	Level 1: Normal	Level 2: Substantially increased concern	Level 1: Normal	Level 2: Substantially increased concern

Because the overall score is greater than level 1, ABC may need to be reduced from the maximum permissible value. In 2019 the risk table score was also 2 and the SSC concluded that no ABC reduction was necessary because Tier 5 estimates are more conservative than Tier 3 models presented in 2019.

Area Allocation of Harvests

As noted in the “Management History” subsection of the “Fishery” section, the current Steller sea lion protection measures require an estimate of the proportion of the AI Pacific cod stock residing in Area 543, which will be used to set the harvest limit in 543 after subtraction of the State GHL from the overall AI ABC. The Area 543 proportion could be computed on the basis of the survey observations themselves, or by running Model 13.4 once for Area 543 and again for the entire AI, then computing the ratios of the resulting estimates. More specifically, some possible estimators of this proportion are: 1) the 1991-2018 average proportion from the raw survey data (25.1%), 2) the most recent proportion from the raw survey data (14.1%), 3) the 1991-2018 average proportion from Model 13.4 (24.5%), and 4) the most recent proportion from Model 13.4 (15.7%). If Model 13.4 is used to set the 2021 and 2022 ABCs based on the model’s most recent estimate of biomass, it seems reasonable to estimate the biomass proportion in Area 543 accordingly, by using the most recent estimate from Model 13.4 (15.7%). This was the percentage adopted last year for setting the 2020 specifications.

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? The official AI catch estimate for the most recent complete year (2019) is 19,162 t. This is less than the 2018 AI OFL of 28,700 t (and also the AI ABC of 21,500). Therefore, the AI Pacific cod stock is not being subjected to overfishing. 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 common 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 common dietary items have been euphausids, miscellaneous fishes, and amphipods. In terms of weight of organisms consumed, common dietary items include 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 several tables. For the purpose of generating these tables, Pacific cod targets were those identified as such in the AKFIN database (https://akfin.psmfc.org/). Catches for 2020 in each of these tables are incomplete. The Pacific cod fishery using trawl gear Table 2A.9 and fixed gear Table 2A.10 take a small proportion of the incidental catch of FMP species (1991-2020). During some years from 1991-2020, the proportional catch of octopus and longnose skate was high in the Pacific cod trawl (Table 2A.11) and longline (Table 2A.12) fisheries, although incidental catch of squid and members of the former "other species" complex taken by trawl gear was lower. Similarly, the Pacific cod fishery accounts for a large proportion of several crab species bycatch (Table 2A.13). Discard mortality of halibut taken in the Pacific cod fishery from 1991-2020, aggregated across gear types, has declined during this time period. The proportion of incidental catch of non-target species groups taken from 2003-2020, excluding bird species, aggregated across gear types Table 2A.14 varies from very little to almost all of the bycatch in a given year.

Steller Sea Lions

Pacific cod is 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 is especially important in winter in the GOA and BSAI (Pitcher 1981, Calkins 1998, Sinclair and Zeppelin 2002). 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). 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 two weeks (Rand et al. 2015).

Seabirds

In the BSAI and GOA, the northern fulmar (*Fulmarus glacialis*) comprises the majority of seabird bycatch, primarily in the longline fisheries, including the fixed gear fishery for Pacific cod (Livingston (ed.) 2002). 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 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 significantly reduce seabird incidental take. Typically bycatch of bird species in the Pacific cod trawl and longline fisheries is low, although in some years a large proportion of certain species were taken in the Pacific cod fisheries (Table 2A.15.

Fishery Usage of Habitat

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 (Livingston (ed.) 2002). During the period 1998-2001, the total number of observed sets by gear type 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 assessment models of the EBS stock since 2009 have estimated a positive ageing bias, at least for otoliths aged prior to 2008. 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.

Acknowledgements

Thank you to Mary Furuness for assistance with updating regulations, Paul Spencer for the code for Model 13.4, staff of the AFSC RACE Division who conducted the trawl surveys, and Cody Szuwalski and the BSAI Groundfish Plan Team who provided reviews of this assessment.

References

Albers, W. D., and P. J. Anderson. 1985. Diet of Pacific cod, *Gadus macrocephalus*, and predation on the northern pink shrimp, *Pandalus borealis*, in Pavlof Bay, Alaska. Fish. Bull., U.S. 83:601-610.

Abookire, A. A., J. T. Duffy-Anderson, C. M. Jump. 2007. Habitat associations and diet of young-of-the-year Pacific cod (*Gadus macrocephalus*) near Kodiak, Alaska. Marine Biology 150:713-726.

Abookire, A. A., J. F. Piatt, B. L. Norcross. 2001. Juvenile groundfish habitat in Kachemak Bay, Alaska, during late summer. Alaska Fishery Research Bulletin 8(1).

Bakkala, R. G., S. Westrheim, S. Mishima, C. Zhang, E. Brown. 1984. Distribution of Pacific cod (*Gadus macrocephalus*) in the North Pacific Ocean. International North Pacific Fisheries Commission Bulletin 42:111-115.

Barbeaux, S., K. Aydin, B. Fissel, K. Holsman, B. Laurel, W. Palsson, K. Shotwell, Q. Yang, and S. Zador. 2018. Assessment of the Pacific cod stock in the Gulf of Alaska. In Plan Team for Groundfish Fisheries of the Gulf of Alaska (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, chapter 2, p. 1-160. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Barbeaux, S.J., Holsman, K. and Zador, S., 2020. Marine heatwave stress test of ecosystem-based fisheries management in the Gulf of Alaska Pacific Cod Fishery. Frontiers in Marine Science, 7, p.703.

Bian, X., X. Zhang, Y Sakurai, X. Jin, T. Gao, R. Wan, J. Yamamoto. 2014. Temperature-mediated survival, development and hatching variation of Pacific cod *Gadus macrocephalus* eggs. Journal of Fish Biology 84:85-105.

Bian, X., X, Zhang, Y. Sakurai, X. Jin, R. Wan, T. Gao, J. Yamamoto. 2016. Interactive effects of incubation temperature and salinity on the early life stages of Pacific cod *Gadus macrocephalus*. Deep-Sea Research II 124:117-128.

Blackburn, J.E., Jackson, P.B., 1982. Seasonal composition and abundance of juvenile and adult marine finfish and crab species in the nearshore zone of Kodiak Islands' eastside during April 1978 through March 1979. Alaska Department of Fish and Game, Final Report 03-5-022-69. Kodiak, Alaska.

Calkins, D. G. 1998. Prey of Steller sea lions in the Bering Sea. Biosphere Conservation 1:33-44.

Canino, M. F., I. B. Spies, K. M. Cunningham, L. Hauser, and W. S. Grant. 2010. Multiple ice-age refugia in Pacific cod, *Gadus macrocephalus*. Molecular Ecology 19:4339-4351.

Conners, M. E., and P. Munro. 2008. Effects of commercial fishing on local abundance of Pacific cod (*Gadus macrocephalus*) in the Bering Sea. Fishery Bulletin 106:281-292.

Cunningham, K. M., M. F. Canino, I. B. Spies, and L. Hauser. 2009. Genetic isolation by distance and localized fjord population structure in Pacific cod (*Gadus macrocephalus*): limited effective dispersal in the northeastern Pacific Ocean. Can. J. Fish. Aquat. Sci. 66:153-166.

Doyle, M. J., S. J. Picquelle, K. L. Mier, M. C. Spillane, N. A. Bond. 2009. Larval fish abundance and physical forcing in the Gulf of Alaska, 1981-2003. Progress in Oceanography 80:163-187.

Farley, E. V. Jr., R. A. Heintz, A. G. Andrews, T. P. Hurst. 2016. Size, diet, and condition of age-0 Pacific cod (*Gadus macrocephalus*) during warm and cold climate states in the eastern Bering Sea. Deep-Sea Research II 134:247-254.

Fournier, D. A., H. J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software 27:233-249.

Gotceitas, V., S. Fraser, J. A. Brown. 1997. Use of eelgrass beds (*Zostera marina*) by juvenile Atlantic cod (*Gadus morhua*). Canadian Journal of Fisheries and Aquatic Sciences 54:1306-1319.

Greer-Walker, M. 1970. Growth and development of the skeletal muscle fibres of the cod (*Gadus morhua* L.). Journal du Conseil 33:228-244.

Handegard, N.O., and D. Tjøstheim. 2005. When fish meet a trawling vessel: examining the behaviour of gadoids using a free-floating buoy and acoustic split-beam tracking. Canadian Journal of Fisheries and Aquatic Sciences 62:2409–2422.

Hare, S. R., and N. J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. Progress in Oceanography 47:103-146.

Hurst, T. P., D. W. Cooper, J. T. Duffy-Anderson, E. V. Farley. 2015. Contrasting coastal and shelf nursery habitats of Pacific cod in the southeastern Bering Sea. ICES Journal of Marine Science 72:515-527.

Hurst, T. P, D. W. Cooper, J. S. Scheingross, E. M. Seale, B. J. Laurel, M. L. Spencer. 2009. Effects of ontogeny, temperature, and light on vertical movements of larval Pacific cod (*Gadus macrocephalus*). Fisheries Oceanography 18:301-311.

Hurst, T. P., B. J. Laurel, L. Ciannelli. 2010. Ontogenetic patterns and temperature-dependent growth rates in early life stages of Pacific cod (*Gadus macrocephalus*). Fishery Bulletin, U.S. 108:382-392.

Hurst, T. P., J. H. Moss, and J. A. Miller. 2012. Distributional patterns of 0-group Pacific cod (*Gadus macrocephalus*) in the eastern Bering Sea under variable recruitment and thermal conditions. ICES Journal of Marine Science 69:163-174.

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

Jensen, A. L. 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. Can. J. Fish. Aquat. Sci. 53:820-822.

Jung, S., I. Choi, H. Jin, D.-w. Lee, H.-k. Cha, Y. Kim, and J.-y. Lee. 2009. Size-dependent mortality formulation for isochronal fish species based on their fecundity: an example of Pacific cod (*Gadus macrocephalus*) in the eastern coastal areas of Korea. Fisheries Research 97:77-85.

Ketchen, K. S. 1961. Observations on the ecology of the Pacific cod (*Gadus macrocephalus*) in Canadian waters. Journal of the Fisheries Research Board of Canada 18:513-558.

Lang, G. M., C. W. Derrah, and P. A. Livingston. 2003. Groundfish food habits and predation on commercially important prey species in the Eastern Bering Sea from 1993 through 1996. Alaska Fisheries Science Center Processed Report 2003-04. Alaska Fisheries Science Center, 7600 Sand Point Way NE., Seattle, WA 98115-6349. 351 p.

Laurel, B. J., L. A. Copeman, C. C. Parish. 2012. Role of temperature on lipid/fatty acid composition in Pacific cod (*Gadus macrocephalus*) eggs and unfed larvae. Marine Biology 159:2025-2034.

Laurel, B. J., T. P. Hurst, L. Ciannelli. 2011. An experimental examination of temperature interactions in the match-mismatch hypothesis for Pacific cod larvae. Canadian Journal of Fisheries and Aquatic Sciences 68:51-61.

Laurel, B. J., T. P. Hurst, L. A. Copeman, M. W. Davis. 2008. The role of temperature on the growth and survival of early and late hatching Pacific cod larvae (*Gadus macrocephalus*). Journal of Plankton Research 30:1051-1060.

Laurel, B. J., A. W. Stoner, C. H. Ryer, T. P. Hurst, A. A. Abookire. 2007. Comparative habitat associations in juvenile Pacific cod and other gadids using seines, baited cameras and laboratory techniques. Journal of Experimental Marine Biology and Ecology 351:42-55.

Lauth, R. R. 2011. Results of the 2010 eastern and northern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate fauna. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-227, 256 p.

Livingston, P. A. 1989. Interannual trends in Pacific cod, *Gadus macrocephalus*, predation on three commercially important crab species in the eastern Bering Sea. Fish. Bull., U.S. 87:807-827.

Livingston, P. A. 1991. Pacific cod. In P. A. Livingston (editor), Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1984 to 1986, p. 31-88. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-207.

Livingston, P. A. (editor). 2002. Ecosystem Considerations for 2003. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Moss, J. H., M. F. Zaleski, R. A. Heintz. 2016. Distribution, diet, and energetic condition of age-0 walleye pollock (Gadus chalcogrammus) and Pacific cod (*Gadus macrocephalus*) inhabiting the Gulf of Alaska. Deep-Sea Research II 132:146-153.

National Marine Fisheries Service (NMFS). 2005. Final environmental impact statement for essential fish habitat identification and conservation in Alaska. National Marine Fisheries Service, Alaska Region. P.O. Box 21668, Juneau, AK 99802-1668.

National Marine Fisheries Service (NMFS). 2010. Essential Fish Habitat (EFH) 5-Year Review for 2010 (Final summary report). National Marine Fisheries Service, Alaska Region. P.O. Box 21668, Juneau, AK 99802-1668.

National Marine Fisheries Service (NMFS). 2017. Essential Fish Habitat (EFH) 5-Year Review Summary Report. National Marine Fisheries Service, Alaska Region. P.O. Box 21668, Juneau, AK 99802-1668.

Neidetcher, S. K., Hurst, T. P., Ciannelli, L., Logerwell, E. A. 2014. Spawning phenology and geography of Aleutian Islands and eastern Bering Sea Pacific cod (*Gadus macrocephalus*). Deep-Sea Research II: Topical Studies in Oceanography 109:204-214.

Nichol, D. G., T. Honkalehto, G. G. Thompson. 2007. Proximity of Pacific cod to the sea floor: using archival tags to estimate fish availability to research bottom trawls. Fisheries Research 86:129-135.

Nichol, D. G., S. Kotwicki, M. Zimmerman. 2013. Diel vertical migration of adult Pacific cod *Gadus macrocephalus* in Alaska. Journal of Fish Biology 83:170-189.

Ona, E., and O. R. Godø. 1990. Fish reaction to trawling noise: the significance for trawl sampling. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer 189: 159–166.

Parker-Stetter, S. L., J. K. Horne, E. V. Farley, D. H. Barbee, A. G. Andrews III, L. B. Eisner, J. M. Nomura. 2013. Summer distributions of forage fish in the eastern Bering Sea. Deep-Sea Research II 92:211-230.

Pitcher, K. W. 1981. Prey of the Steller sea lion, *Eumetopias jubatus*, in the Gulf of Alaska. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 79:467-472.

Poltev, Yu. N., D. Yu. Stominok. 2008. Feeding habits the Pacific cod *Gadus macrocephalus* in oceanic waters of the northern Kuril Islands and southeast Kamchatka. Russian Journal of Marine Biology 34:316-324.

Rand, K. M., P. Munro, S. K. Neidetcher, and D. Nichol. 2015. Observations of seasonal movement of a single tag release group of Pacific cod in the eastern Bering Sea. Marine and Coastal Fisheries: Dynamics, Management and Ecosystem Science 6:287-296.

Rose, G.A. and Kulka, D.W., 1999. Hyperaggregation of fish and fisheries: how catch-per-unit-effort increased as the northern cod (*Gadus morhua*) declined. Canadian Journal of Fisheries and Aquatic Sciences, 56(S1), pp.118-127.

Rugen, W.C., and Matarese, A.C. 1988. Spatial and temporal distribution and relative abundance of Pacific cod (Gadus macrocephalus) larvae in the western Gulf of Alaska. Vol. 88, no. 18. Resource Assessment and Conservation Engineering Division, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration.

Sakurai, Y., T. Hattori. 1996. Reproductive behavior of Pacific cod in captivity. Fisheries Science 62:222-228.
Savin, A. B. 2008. Seasonal distribution and Migrations of Pacific cod *Gadus macrocephalus* (Gadidae) in

Anadyr Bay and adjacent waters. Journal of Ichythyology 48:610-621.

Shimada, A. M., and D. K. Kimura. 1994. Seasonal movements of Pacific cod (*Gadus macrocephalus*) in the eastern Bering Sea and adjacent waters based on tag-recapture data. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 92:800-816.

Sinclair, E. S. and T. K. Zeppelin. 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (*Eumetopias jubatus*). Journal of Mammalogy 83(4).

Spies I. 2012. Landscape genetics reveals population subdivision in Bering Sea and Aleutian Islands Pacific cod. Transactions of the American Fisheries Society 141:1557-1573.

Spies, I., K. M. Gruenthal, D. P. Drinan, A. B. Hollowed, D. E. Stevenson, C. M. Tarpey, L. Hauser. 2019. Genetic evidence of a northward range expansion in the eastern Bering Sea stock of Pacific cod. Evolutionary Applications 0:000-000.

Stark, J. W. 2007. Geographic and seasonal variations in maturation and growth of female Pacific cod (*Gadus macrocephalus*) in the Gulf of Alaska and Bering Sea. Fish. Bull. 105:396-407.

Strasburger, W. W., N. Hillgruber, A. I. Pinchuk, F. J. Mueter. 2014. Feeding ecology of age-0 walleye pollock (*Gadus chalcogrammus*) and Pacific cod (*Gadus macrocephalus*) in the southeastern Bering Sea. Deep-Sea Research II 109:172-180.

Thompson, G., J. Ianelli, M. Dorn, D. Nichol, S. Gaichas, and K. Aydin. 2007. 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. 209-327. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G., J. Ianelli, R. Lauth, S. Gaichas, and K. Aydin. 2008. 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. 221-401. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and W. A. Palsson. 2016. Assessment of the Pacific cod stock in the Aleutian Islands. 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. 545-638. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and W. A. Palsson. 2018. Assessment of the Pacific cod stock in the Aleutian Islands. 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, chapter 2, p. 1-48. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thompson, G. G., and W. A. Palsson. 2019. Assessment of the Pacific cod stock in the Aleutian Islands. 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, chapter 2, p. 1-48. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Thomson, J. A. 1963. On the demersal quality of the fertilized eggs of Pacific cod, *Gadus macrocephalus* Tilesius. Journal of the Fisheries Research Board of Canada 20:1087-1088.

Ueda, Y., Y. Narimatsu, T. Hattori, M. Ito, D. Kitagawa, N. Tomikawa, and T. Matsuishi. 2006. Fishing efficiency estimated based on the abundance from virtual population analysis and bottom-trawl surveys of Pacific cod (*Gadus macrocephalus*) in the waters off the Pacific coast of northern Honshu, Japan. Nippon Suisan Gakkaishi 72:201-209.

Westrheim, S. J. 1996. On the Pacific cod (*Gadus macrocephalus*) in British Columbia waters, and a comparison with Pacific cod elsewhere, and Atlantic cod (*G. morhua*). Can. Tech. Rep. Fish. Aquat. Sci. 2092. 390 p.

Yang, M-S. 2004. Diet changes of Pacific cod (*Gadus macrocephalus*) in Pavlof Bay associated with climate changes in the Gulf of Alaska between 1980 and 1995. U.S. Natl. Mar. Fish. Serv., Fish. Bull. 102:400-405.

Zador, S. (editor). 2011. Ecosystem considerations for 2012. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Zador, S. (editor). 2016. Ecosystem considerations 2016: Status of the Aleutian Islands marine ecosystem. 109 p.

Tables

Table 2A.1: Catch of Pacific cod in the Aleutian Islands by foreign, domestic, and joint venture fisheries, 1964-1980.

Year	Foreign	Joint Venture	Domestic	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.2: Summary of catches of Pacific cod (t) in the Aleutian Islands by gear type. All catches include discards. Domestic annual catch by gear is not available prior to 1988.

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

Table 2A.3: Federal and state fishery catch in metric tons by year, 1991-2020. To avoid confidentiality problems, federal 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 2020 are through October 31.

Year	Federal		State	Total
	Trawl	Longline+Pot	Total	
1991	3,414	6,383		9,797
1992	14,587	28,481		43,068
1993	17,328	16,876		34,204
1994	14,383	7,156		21,539
1995	10,574	5,960		16,534
1996	21,179	10,430		31,609
1997	17,411	7,753		25,164
1998	20,531	14,196		34,727
1999	16,478	11,653		28,131
2000	20,379	19,306		39,685
2001	15,836	18,372		34,208
2002	27,929	2,872		30,801
2003	31,478	978		32,456
2004	25,770	3,103		28,873
2005	19,624	3,069		22,693
2006	16,956	3,535	3,721	24,212
2007	25,714	4,495	4,146	34,355
2008	19,404	7,506	4,319	31,229
2009	20,277	6,245	2,060	28,582
2010	16,759	8,280	3,967	29,006
2011	9,359	1,263	266	10,888
2012	9,786	3,201	5,232	18,219
2013	7,001	1,811	4,793	13,605
2014	5,716	439	4,451	10,606
2015	5,968	3,087	161	9,216
2016	10,654	1,710	882	13,246
2017	8,530	3,727	2,946	15,203
2018	9,282	5,437	5,695	20,414
2019	9,843	3,098	6,221	19,162
2020	2,764	2,378	6,776	11,918

Table 2A.4: Summary of 1994-2019 catches (t) of Pacific cod in the AI, by NMFS statistical area (area breakdowns not available prior to 1994). Catches for 2020 are through October 31.

Year	Total Catch			Proportions		
	Western	Central	Eastern	Western	Central	Eastern
1994	2,059	7,441	12,039	0.096	0.345	0.559
1995	1,713	5,086	9,735	0.104	0.308	0.589
1996	4,023	4,509	23,077	0.127	0.143	0.730
1997	894	4,440	19,830	0.036	0.176	0.788
1998	3,487	9,299	21,940	0.100	0.268	0.632
1999	2,322	5,276	20,532	0.083	0.188	0.730
2000	9,073	8,799	21,812	0.229	0.222	0.550
2001	12,767	7,358	14,082	0.373	0.215	0.412
2002	2,259	7,133	21,408	0.073	0.232	0.695
2003	2,997	6,707	22,752	0.092	0.207	0.701
2004	3,649	6,833	18,391	0.126	0.237	0.637
2005	4,239	3,582	14,873	0.187	0.158	0.655
2006	4,570	4,675	14,967	0.189	0.193	0.618
2007	4,974	4,692	24,689	0.145	0.137	0.719
2008	7,319	5,555	18,355	0.234	0.178	0.588
2009	7,929	6,899	13,754	0.277	0.241	0.481
2010	8,213	6,292	14,501	0.283	0.217	0.500
2011	24	1,770	9,095	0.002	0.163	0.835
2012	29	2,816	15,374	0.002	0.155	0.844
2013	50	2,874	10,684	0.004	0.211	0.785
2014	30	1,042	9,532	0.003	0.098	0.899
2015	3,170	2,365	3,681	0.344	0.257	0.399
2016	2,551	1,609	9,085	0.193	0.121	0.686
2017	3,373	3,772	8,058	0.222	0.248	0.530
2018	2,694	4,065	13,655	0.132	0.199	0.669
2019	1,340	5,265	12,557	0.070	0.275	0.655
2020	1,167	4,523	6,228	0.098	0.380	0.523

Table 2A.5: Discards (t) and discard rates for the Aleutian Islands Pacific cod fishery, for the period 1991-October 31, 2020 . Note that Amendment 49, which mandated increased retention and utilization, was implemented in 1998.

Year	Discards (t)	Total catch (t)	Proportion discarded
1991	526	9,798	0.054
1992	2,236	43,068	0.052
1993	5,889	34,205	0.172
1994	3,484	21,539	0.162
1995	3,180	16,534	0.192
1996	3,137	31,609	0.099
1997	2,107	25,164	0.084
1998	638	34,726	0.018
1999	514	28,130	0.018
2000	692	39,685	0.017
2001	471	34,207	0.014
2002	734	30,801	0.024
2003	332	32,457	0.010
2004	317	28,873	0.011
2005	489	22,694	0.022
2006	310	24,211	0.013
2007	554	34,355	0.016
2008	204	31,229	0.007
2009	208	28,582	0.007
2010	203	29,006	0.007
2011	91	10,889	0.008
2012	70	18,220	0.004
2013	249	13,608	0.018
2014	142	10,603	0.013
2015	102	9,217	0.011
2016	118	13,245	0.009
2017	183	15,202	0.012
2018	273	20,414	0.013
2019	150	19,162	0.008
2020	116	11,918	0.010

Table 2A.6: Fishery catch in metric tons by year, total allowable catch (TAC), acceptable biological catch (ABC), and overfishing limit (OFL), 1990-2020. Note that specifications were combined for the Bering Sea and Aleutian Islands cod stocks through 2013 and are shown for the Aleutian Islands alone for 2013 onwards. Catch for 2020 is through October 31. ABC and OFL for 2020 are based on this year's model output. TAC from 2020 is based on harvest specifications from 2019.

Year	Catch (t)	TAC	ABC	OFL
1990	7,541	179,608	417,000	-
1991	9,798	220,038	229,000	-
1992	43,068	207,278	182,000	188,000
1993	34,205	167,391	164,500	192,000
1994	21,539	193,802	191,000	228,000
1995	16,534	245,033	328,000	390,000
1996	31,609	240,676	305,000	420,000
1997	25,164	257,765	306,000	418,000
1998	34,726	193,256	210,000	336,000
1999	28,130	173,998	177,000	264,000
2000	39,685	191,060	193,000	240,000
2001	34,207	176,749	188,000	248,000
2002	30,801	197,356	223,000	294,000
2003	32,457	207,907	223,000	324,000
2004	28,873	212,618	223,000	350,000
2005	22,694	205,635	206,000	365,000
2006	24,211	193,025	194,000	230,000
2007	34,355	174,486	176,000	207,000
2008	31,229	171,277	176,000	207,000
2009	28,582	175,756	182,000	212,000
2010	29,006	171,875	174,000	205,000
2011	10,889	220,109	235,000	272,000
2012	18,220	251,055	314,000	369,000
2013	13,606	250,274	307,000	359,000
2014	10,605	10,605	15,100	20,100
2015	9,217	9,217	17,600	23,400
2016	13,245	13,245	17,600	23,400
2017	15,204	15,204	21,500	28,700
2018	20,414	19,558	21,500	28,700
2019	19,162	14,214	20,600	27,400
2020	11,918	13,796	20,600	27,400

Table 2A.7: Aleutian Islands bottom trawl survey biomass estimates and standard error for Pacific cod, for all years used in the model.

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

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

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

Table 2A.8: Comparison of biomass (t) estimated by Model 13.4 in the 2016-2017 and 2018-2019 assessments, with lower and upper 95% confidence bounds.

	2019 Model			2020 Model		
Year	Biomass	LCI	UCI	Biomass	LCI	UCI
1991	169,669	130,207	221,090	169,669	130,207	221,090
1992	157,157	111,812	220,891	157,157	111,812	220,891
1993	145,567	102,580	206,568	145,567	102,580	206,568
1994	134,832	99,904	181,971	134,832	99,904	181,971
1995	115,515	82,448	161,844	115,515	82,448	161,844
1996	98,965	71,605	136,781	98,965	71,605	136,781
1997	84,787	65,982	108,952	84,787	65,982	108,952
1998	89,988	65,473	123,683	89,988	65,473	123,683
1999	95,509	68,821	132,547	95,509	68,821	132,547
2000	101,368	76,177	134,890	101,368	76,177	134,890
2001	90,998	67,212	123,201	90,998	67,212	123,201
2002	81,688	63,719	104,726	81,688	63,719	104,726
2003	80,987	59,651	109,954	80,987	59,651	109,954
2004	80,291	60,838	105,964	80,291	60,838	105,964
2005	78,401	55,854	110,049	78,401	55,854	110,049
2006	76,555	54,615	107,310	76,555	54,615	107,310
2007	72,365	49,211	106,414	72,365	49,211	106,414
2008	68,405	46,155	101,381	68,405	46,155	101,381
2009	64,661	44,942	93,033	64,661	44,942	93,033
2010	61,123	45,955	81,296	61,123	45,955	81,296
2011	61,649	45,371	83,768	61,649	45,371	83,768
2012	62,180	49,091	78,760	62,180	49,091	78,760
2013	66,768	49,715	89,670	66,768	49,715	89,670
2014	71,695	55,363	92,843	71,695	55,363	92,843
2015	75,517	55,666	102,449	75,517	55,666	102,449
2016	79,544	61,132	103,502	79,544	61,132	103,502
2017	80,117	58,848	109,073	80,117	58,848	109,073
2018	80,694	61,710	105,518	80,694	61,710	105,518
2019	80,694	53,535	121,632	80,694	53,535	121,632
2020	NA	NA	NA	80,694	48,234	134,998

Table 2A.9: Incidental catch of FMP species taken by trawl gear in the Aleutian Islands target fishery for Pacific cod, expressed as a proportion of the incidental catch of that species taken in all AI FMP fisheries, 1991-2020 (2020 data current through November 4). Note: RE=rougheye, NR=northern, SR=shortraker, SC=sharpchin. Continued on next page.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Arrowtooth Flounder	0.00	0.08	0.07	0.04	0.01	0.07	0.04	0.12	0.09	0.08	0.11	0.22	0.24	0.24	0.29
Atka Mackerel	0.01	0.06	0.05	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
Alaska Plaice												0.75		1.00	1.00
Kamchatka Fl.															
Other Flatfish													0.29	0.29	0.25
RE Rockfish														0.01	0.04
SR Rockfish														0.03	0.02
Skate															
Squid													0.10	0.11	0.07
Demersal Shelf Rockfish			0.77												
Flathead Sole		0.00			0.42	0.41	0.66	0.88	0.92	0.88	0.69	0.95	0.80	0.90	0.72
Flounder	0.01	0.59	0.45	0.35											
Greenland Turbot	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Non TAC Species									0.02	0.00	0.02	0.01			
Northern Rockfish												0.03	0.04	0.03	0.05
Octopus													0.00		
Other	0.07	0.12	0.09	0.05	0.04	0.07	0.10	0.13	0.13	0.12	0.04	0.16			
Other Flatfish					0.00	0.01	0.03	0.80	0.47	0.48	0.19	0.53			
Other Rockfish	0.00	0.03	0.01	0.01	0.01	0.04	0.25	0.13	0.04	0.03	0.02	0.03	0.03	0.04	0.03
Other Species													0.23	0.16	0.13
Pacific Cod	0.08	0.24	0.36	0.33	0.35	0.38	0.60	0.48	0.49	0.46	0.40	0.86	0.90	0.81	0.77
Pacific Ocean Perch	0.01	0.02	0.03	0.01	0.00	0.00	0.01	0.03	0.00	0.01	0.01	0.01	0.01	0.01	0.02
Pollock	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.48	0.63	0.38	0.61	0.48	0.46	0.41
Rock Sole	0.13	0.68	0.56	0.38	0.52	0.55	0.74	0.86	0.93	0.95	0.88	0.93	0.82	0.85	0.80
Sablefish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sculpin															
Shallow Water Flatfish		0.24													
Shark															
SC/NR Rockfish		0.13	0.07	0.03	0.01	0.02	0.04	0.04	0.03	0.05	0.03				
SR/RE Rockfish		0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.02		
SR/RE/SC/NR Rockfish	0.02	0.65	0.00		0.00		0.00								
Slope Rockfish		0.16													
Squid	0.00	0.01	0.02	0.00	0.00	0.00	0.01	0.03	0.01	0.05	0.33	0.05			
Yellowfin Sole		0.00		0.05	0.00	0.36	0.00	0.00	0.20	0.90	0.97	1.00	0.72	1.00	1.00

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Arrowtooth Flounder	0.14	0.16	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.03	0.01	0.02	0.00
Atka Mackerel	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Alaska Plaice	1.00	0.27	1.00	0.24	0.00		1.00	1.00	1.00		1.00	0.00	0.00	0.97	0.99
Kamchatka Fl.						0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Flatfish	0.29	0.37	0.28	0.06	0.04	0.01	0.16	0.09	0.16	0.00	0.03	0.01	0.10	0.07	0.09
RE Rockfish	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR Rockfish	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Skate						0.01	0.02	0.01	0.00	0.00	0.02	0.01	0.00	0.01	0.01
Squid	0.07	0.02	0.00	0.00	0.00										
Demersal Shelf Rockfish															
Flathead Sole	0.86	0.76	0.55	0.61	0.58	0.46	0.73	0.49	0.26	0.31	0.53	0.23	0.19	0.45	0.09
Flounder															
Greenland Turbot	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non TAC Species															
Northern Rockfish	0.05	0.02	0.02	0.02	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00
Octopus						0.14	0.16	0.00	0.00	0.02	0.04	0.01	0.00	0.01	0.00
Other															
Other Flatfish															
Other Rockfish	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00
Other Species	0.14	0.16	0.06	0.07	0.03										
Pacific Cod	0.76	0.78	0.66	0.65	0.58	0.70	0.59	0.49	0.52	0.35	0.64	0.26	0.31	0.37	0.11
Pacific Ocean Perch	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pollock	0.18	0.16	0.04	0.03	0.01	0.05	0.08	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01
Rock Sole	0.78	0.77	0.75	0.76	0.73	0.70	0.67	0.70	0.65	0.26	0.71	0.59	0.40	0.59	0.01
Sablefish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sculpin						0.05	0.06	0.04	0.02	0.00	0.05	0.01	0.01	0.00	0.01
Shallow Water Flatfish															
Shark						0.06	0.00	0.00	0.00	0.11	0.01	0.00	0.00	0.00	0.00
SC/NR Rockfish															
SR/RE Rockfish															
SR/RE/SC/NR Rockfish															
Slope Rockfish															
Squid						0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Yellowfin Sole	0.79	0.05	0.23	0.03	0.09	0.00	0.11	0.08	0.01	0.00	0.00	0.00	0.05	0.03	0.15

Table 2A.10: Incidental catch of FMP species taken by longline gear in the Aleutian Islands target fishery for Pacific cod, expressed as a proportion of the incidental catch of that species taken in all AI FMP fisheries, 1991-2020 (2020 data current through November 4). Note: RE=rougheye, NR=northern, SR=shortraker, SC=sharpchin. Continued on next page.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Arrowtooth Flounder	0.02	0.14	0.05	0.03	0.02	0.02	0.04	0.09	0.06	0.13	0.18	0.03	0.01	0.02	0.04
Atka Mackerel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alaska Plaice												0.00		0.00	0.00
Kamchatka Fl.															
Other Flatfish													0.00	0.32	0.00
RE Rockfish														0.14	0.02
SR Rockfish														0.03	0.09
Skate															
Squid													0.00	0.00	0.00
Demersal Shelf Rockfish			0.00												
Flathead Sole		0.00			0.03	0.08	0.06	0.10	0.01	0.06	0.14	0.01	0.00	0.01	0.01
Flounder	0.00	0.08	0.07	0.02											
Greenland Turbot	0.02	0.06	0.03	0.01	0.01	0.01	0.03	0.04	0.06	0.03	0.02	0.01	0.02	0.01	0.00
Non TAC Species									0.04	0.06	0.08	0.00			
Northern Rockfish												0.01	0.00	0.01	0.00
Octopus													0.00		
Other	0.07	0.33	0.54	0.30	0.27	0.22	0.43	0.57	0.44	0.61	0.75	0.25			
Other Flatfish					0.00	0.01	0.22	0.06	0.06	0.13	0.29	0.01			
Other Rockfish	0.10	0.29	0.07	0.11	0.02	0.08	0.12	0.25	0.09	0.11	0.16	0.06	0.03	0.16	0.04
Other Species													0.13	0.33	0.37
Pacific Cod	0.22	0.51	0.49	0.32	0.24	0.18	0.28	0.40	0.28	0.40	0.52	0.09	0.03	0.10	0.12
Pacific Ocean Perch	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pollock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.09	0.00	0.01	0.01	0.00
Rock Sole	0.00	0.01	0.02	0.02	0.01	0.04	0.02	0.03	0.00	0.01	0.01	0.00	0.00	0.00	0.01
Sablefish	0.04	0.05	0.03	0.04	0.01	0.09	0.04	0.02	0.02	0.02	0.03	0.06	0.01	0.00	0.00
Sculpin															
Shallow Water Flatfish		0.00													
Shark															
SC/NR Rockfish		0.03	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02				
SR/RE Rockfish		0.31	0.17	0.11	0.02	0.12	0.06	0.30	0.21	0.31	0.23	0.08	0.04		
SR/RE/SC/NR Rockfish	0.21	0.01	0.00		0.00		0.00								
Slope Rockfish		0.01													
Squid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
Yellowfin Sole		0.00		0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Arrowtooth Flounder	0.02	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.02	0.01
Atka Mackerel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alaska Plaice	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
Kamchatka Fl.						0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Other Flatfish	0.01	0.00	0.01	0.35	0.05	0.05	0.13	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
RE Rockfish	0.01	0.18	0.27	0.12	0.14	0.01	0.16	0.05	0.01	0.11	0.04	0.33	0.12	0.06	0.05
SR Rockfish	0.05	0.06	0.06	0.05	0.17	0.01	0.03	0.04	0.00	0.04	0.00	0.05	0.08	0.32	0.03
Skate						0.12	0.29	0.18	0.03	0.23	0.15	0.22	0.21	0.21	0.12
Squid	0.00	0.00	0.00	0.00	0.00										
Demersal Shelf Rockfish															
Flathead Sole	0.02	0.08	0.13	0.14	0.09	0.01	0.09	0.00	0.00	0.01	0.01	0.06	0.20	0.01	0.02
Flounder															
Greenland Turbot	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Non TAC Species															
Northern Rockfish	0.00	0.01	0.02	0.02	0.03	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Octopus						0.79	0.50	0.43	0.32	0.74	0.42	0.19	0.04	0.14	0.03
Other															
Other Flatfish															
Other Rockfish	0.05	0.12	0.12	0.19	0.16	0.02	0.03	0.02	0.00	0.05	0.00	0.03	0.02	0.01	0.02
Other Species	0.26	0.36	0.34	0.43	0.50										
Pacific Cod	0.14	0.14	0.18	0.20	0.27	0.11	0.18	0.12	0.03	0.33	0.12	0.24	0.16	0.12	0.12
Pacific Ocean Perch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pollock	0.00	0.00	0.01	0.02	0.04	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Rock Sole	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
Sablefish	0.03	0.02	0.03	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sculpin						0.17	0.39	0.39	0.12	0.40	0.14	0.31	0.23	0.26	0.13
Shallow Water Flatfish															
Shark						0.02	0.12	0.01	0.01	0.24	0.00	0.06	0.03	0.01	0.00
SC/NR Rockfish															
SR/RE Rockfish															
SR/RE/SC/NR Rockfish															
Slope Rockfish															
Squid						0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Yellowfin Sole	0.00	0.00	0.23	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00

Table 2A.11: Incidental catch of selected “Other Species” complex species taken in the AI Pacific cod trawl fisheries, 1991-2020 (2020 data current through November 4), expressed as a ratio of bycatch in all fisheries and gears.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
octopus, North Pacific									1.00	1.00
Pacific sleeper shark										0.06
shark, salmon										1.00
shark, spiny dogfish										
skate, Alaskan										
skate, Aleutian										
skate, big										
skate, longnose										
skate, other									0.98	1.00
skate, Whiteblotched										
squid, majestic	0	0.01	0.02	0	0	0	0.01	0.03	0.01	0.05

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
octopus, North Pacific	1.00	0.76	0.30	0.31	0.65	0.07	0.14	0.18	0.07	0.02
Pacific sleeper shark		1.00	0.00	0.30	0.62	0.00	0.01	0.00	0.00	0.07
shark, salmon			0.00		0.00	0.00	0.00		0.29	0.00
shark, spiny dogfish		0.00	0.26	0.00	0.00	0.09	0.00	0.00	0.00	0.02
skate, Alaskan										0.06
skate, Aleutian										
skate, big				1.00	1.00	0.22	0.02	0.25	0.01	0.00
skate, longnose				0.01	0.49	0.00		0.00	0.76	0.00
skate, other	1.00	0.29	0.14	0.10	0.10	0.10	0.10	0.03	0.04	0.01
skate, Whiteblotched										
squid, majestic	0.33	0.05	0.10	0.11	0.07	0.07	0.02	0.00	0.00	0.00

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
octopus, North Pacific	0.14	0.16	0.00	0.00	0.02	0.04	0.01	0.00	0.01	0.00
Pacific sleeper shark	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00
shark, salmon	0.39	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00
shark, spiny dogfish	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
skate, Alaskan	0.11	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.00
skate, Aleutian	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
skate, big		1.00			0.00				1.00	0.00
skate, longnose		0.00			0.00					0.00
skate, other	0.01	0.03	0.02	0.01	0.00	0.02	0.01	0.01	0.01	0.02
skate, Whiteblotched	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
squid, majestic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

Table 2A.12: Incidental catch of selected "Other Species" complex species taken in the AI Pacific cod longline fisheries, 1991-2020 (2020 data current through November 4), expressed as a ratio of bycatch in all fisheries and gears.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
octopus, North Pacific									0	0
Pacific sleeper shark										0
shark, salmon										0
shark, spiny dogfish										
skate, Alaskan										
skate, Aleutian										
skate, big										
skate, longnose										
skate, other									0	0
skate, Whiteblotched										
squid, majestic	0	0	0	0	0	0	0	0	0	0

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
octopus, North Pacific	0	0.14	0.43	0.42	0.32	0.27	0.45	0.23	0.50	0.47
Pacific sleeper shark		0.00	0.00	0.00	0.02	0.38	0.01	0.04	0.07	0.00
shark, salmon			0.00		0.00	0.00	0.00		0.00	0.00
shark, spiny dogfish		0.00	0.45	0.96	1.00	0.66	0.87	0.55	0.84	0.92
skate, Alaskan										0.52
skate, Aleutian										
skate, big				0.00	0.00	0.11	0.00	0.00	0.00	0.55
skate, longnose				0.02	0.51	1.00		1.00	0.24	1.00
skate, other	0	0.04	0.16	0.46	0.48	0.34	0.54	0.38	0.58	0.58
skate, Whiteblotched										
squid, majestic	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
octopus, North Pacific	0.79	0.50	0.43	0.32	0.74	0.42	0.19	0.04	0.14	0.03
Pacific sleeper shark	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00
shark, salmon	0.00	0.00	0.00	0.00	0.84	0.00	0.00	0.00	0.00	0.00
shark, spiny dogfish	0.43	0.66	0.21	0.04	0.85	0.03	0.14	0.78	0.35	0.03
skate, Alaskan	0.11	0.08	0.10	0.07	0.17	0.03	0.07	0.19	0.29	0.22
skate, Aleutian	0.23	0.24	0.07	0.04	0.13	0.01	0.03	0.04	0.13	0.02
skate, big		0.00			0.59				0.00	1.00
skate, longnose		0.00			1.00					0.00
skate, other	0.12	0.41	0.22	0.03	0.30	0.26	0.33	0.29	0.29	0.15
skate, Whiteblotched	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.01	0.00
squid, majestic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		

Table 2A.13: Incidental catch (herring and halibut in t, salmon and crab in number of individuals) of prohibited species and discard mortality of halibut taken in the AI fisheries for Pacific cod (all gears), expressed as a proportion of the total for that species taken in all FMP AI fisheries, 1991-2020 (through November 4).

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Bairdi Tanner Crab	0.30	0.57	0.70	0.96	0.87	0.91	0.94	1.00	1.00	1.00
Blue King Crab										
Chinook Salmon	0.01	0.02	0.15	0.03	0.23	0.17	0.46	0.71	0.90	1.00
Golden (Brown) King Crab										
Halibut	0.52	0.81	0.42	0.44	0.46	0.57	0.53	0.82	0.57	0.48
Herring	0.00	0.00	1.00	0.00	0.00		0.00			1.00
Non-Chinook Salmon	0.01	0.22	0.00	0.00	0.00	0.03	0.07	0.03	0.04	0.11
Opilio Tanner (Snow) Crab	0.40	0.30	0.51	0.02	0.01	0.19	0.25	0.52	0.30	0.26
Other King Crab	0.08	0.24	0.04	0.05	0.04	0.10	0.00	0.06	0.23	0.07
Red King Crab	0.21	0.08	0.33	0.14	0.11	0.05	0.89	0.83	0.98	0.43

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Bairdi Tanner Crab	0.86	0.99	0.95	1.00	0.98	1.00	1.00	1.00	1.00	0.94
Blue King Crab			0.02		0.30	1.00	1.00	0.78	0.92	1.00
Chinook Salmon	0.46	0.68	0.80	0.73	0.80	0.87	0.72	0.83	0.82	0.75
Golden (Brown) King Crab			0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01
Halibut	0.74	0.28	0.56	0.68	0.72	0.57	0.79	0.83	0.78	0.57
Herring			0.01		1.00	0.05	0.19	0.25	0.07	0.00
Non-Chinook Salmon	0.22	0.76	0.18	0.44	0.12	0.34	0.56	0.21	0.17	0.02
Opilio Tanner (Snow) Crab	0.34	0.69	0.82	1.00	0.85	0.99	1.00	1.00	1.00	0.99
Other King Crab	0.13	0.03								
Red King Crab	0.94	0.97	0.84	0.97	0.84	0.06	0.84	0.77	0.34	0.22

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Bairdi Tanner Crab	0.45	1.00	0.98	0.98	0.00	0.00	0.97	0.99	0.99	1.00
Blue King Crab	1.00	1.00	1.00		0.00	0.00	0.99	0.98	0.99	0.00
Chinook Salmon	0.55	0.65	0.94	0.62	0.43	0.57	0.21	0.05	0.05	0.00
Golden (Brown) King Crab	0.00	0.01	0.00	0.00	0.00	0.00	0.24	0.06	0.05	0.08
Halibut	0.39	0.38	0.19	0.18	0.42	0.27	0.36	0.30	0.41	0.26
Herring		0.00	1.00	1.00			0.00	0.00	0.01	0.98
Non-Chinook Salmon	0.36	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.01	0.00
Opilio Tanner (Snow) Crab	0.98	0.99	0.91	0.81	0.00	0.00	0.99	0.98	0.95	0.99
Other King Crab										
Red King Crab	0.32	0.20	0.91	0.16	0.00	0.00	0.61	0.97	0.69	0.92

Table 2A.14: Bycatch of Nontarget and Ecosystem Species for the Aleutian Islands Pacific cod fishery (all gear types), divided by the bycatch in all fisheries and gears in the same region. Bird bycatch is not included in this table. Data is from 1991-2020, and current through November 4 of the final year. Table is continued on the next page.

	2003	2004	2005	2006	2007	2008	2009	2010	2011
Benthic urochordata	0.14	0.16	0.42	0.13	0.06	0.03	0.05	0.06	0.01
Bivalves	0.99	0.94	0.99	0.99	0.97	0.96	0.78	0.64	0.53
Brittle star unidentified	0.00	0.06	0.03	0.39	0.64	0.20	0.01	0.01	0.00
Capelin	0.00			0.00	0.00	1.00	0.00		
Bryozoan Corals	0.41	0.38	0.24	0.33	0.47	0.29	0.38	0.27	0.08
Bryozoan Red Tree Coral	0.72	0.01	0.49	0.01	0.91	0.14	0.88	0.00	0.00
Dark Rockfish						0.65	0.53		
Eelpouts	0.09	0.51	0.14	0.04	0.15	0.02	0.02	0.02	0.00
Eulachon			0.68	0.01	0.00	0.05	0.00	0.00	
Giant Grenadier	0.30	0.00	0.00	0.08	0.02	0.01	0.00	0.06	0.00
Greenlings	0.74	0.20	0.04	0.88	0.24	0.64	0.39	0.50	0.75
Grenadier - Pacific Grenadier		1.00		0.00	0.00		0.00	0.61	0.00
Rattail Grenadier Unid.	0.02	0.01	0.00	0.03	0.21	0.01	0.01	0.15	0.00
Gunnels			0.01			0.00			
Hermit crab unidentified	0.80	0.98	0.11	0.68	0.81	0.86	0.85	0.42	0.24
Invertebrate unidentified	0.09	0.13	0.05	0.62	0.18	0.09	0.01	0.22	0.04
Large Sculpins	0.51	0.40	0.39	0.45	0.44				
Large Sculpins - Bigmouth Sculpin						0.12	0.14		
Large Sculpins - Great Sculpin						0.94	0.95		
Large Sculpins - Hemilepidotus Unidentified						0.96	0.98		
Lg. Sculpins - Myoxocephalus Unid.						0.88	1.00		
Large Sculpins - Plain Sculpin						1.00	0.97		
Large Sculpins - Red Irish Lord						0.12	0.32		
Large Sculpins - Warty Sculpin						1.00	1.00		
Large Sculpins - Yellow Irish Lord						0.34	0.20		
Misc crabs	0.73	0.56	0.52	0.50	0.65	0.48	0.47	0.38	0.01
Misc crustaceans	0.99	0.29	0.98	0.93	0.33	0.88	0.13	0.38	0.06
Misc fish	0.23	0.11	0.12	0.06	0.09	0.06	0.08	0.09	0.05
Misc inverts (worms etc)	0.00	0.28	1.00	1.00	0.00	0.00	0.00	0.00	0.00
Other osmerids	0.00		0.07	0.00	0.00	0.00	0.00	0.00	0.00
Other Sculpins	0.39	0.40	0.08	0.31	0.17	0.11	0.26		
Pacific Sand lance	1.00		1.00			1.00		0.01	
Pacific Sandfish									
Pandalid shrimp	0.06	0.01	0.03	0.00	0.06	0.00	0.00	0.00	0.00
Polychaete unidentified	1.00	0.13	1.00		0.15	0.76	0.11	0.00	1.00
Scypho jellies	0.17	0.48	0.45	0.19	0.06	0.22	0.11	0.21	0.25
Sea anemone unidentified	0.85	0.53	0.93	0.78	0.37	0.32	0.47	0.38	0.08
Sea pens whips	0.80	1.00	0.96	0.96	0.73	0.36	0.64	0.94	0.94
Sea star	0.59	0.73	0.49	0.57	0.57	0.61	0.52	0.63	0.11
Snails	0.53	0.52	0.25	0.60	0.48	0.62	0.74	0.35	0.45
Sponge unidentified	0.32	0.16	0.33	0.22	0.09	0.03	0.12	0.09	0.03
State-managed Rockfish								0.61	0.13
Stichaeidae	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
urchins dollars cucumbers	0.42	0.53	0.17	0.28	0.42	0.11	0.18	0.11	0.01

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Benthic urochordata	0.04	0.15	0.01	0.01	0.04	0.00	0.03	0.00	0.00
Bivalves	0.76	0.14	0.10	0.32	0.30	0.04	0.21	0.05	0.00
Brittle star unidentified	0.00	0.04	0.01	0.00	0.00	0.12	0.00	0.00	0.10
Capelin	1.00	0.11	1.00						0.00
Bryozoan Corals	0.09	0.08	0.02	0.10	0.08	0.13	0.25	0.05	0.42
Bryozoan Red Tree Coral	0.00	0.00	0.00				0.00		
Dark Rockfish									
Eelpouts	0.01	0.00	0.00	0.00	0.00	0.06	0.01	0.02	0.00
Eulachon	1.00								0.00
Giant Grenadier	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Greenlings	0.46		0.62	1.00	0.62	0.47	0.47	0.20	0.05
Grenadier - Pacific Grenadier									
Rattail Grenadier Unid.	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.56
Gunnels		0.00		0.00		0.00			0.00
Hermit crab unidentified	0.54	0.38	0.10	0.00	0.14	0.78	0.54	0.78	0.71
Invertebrate unidentified	0.00	0.00	0.01	0.76	0.00	0.51	0.00	0.01	0.03
Large Sculpins									
Large Sculpins - Bigmouth Sculpin									
Large Sculpins - Great Sculpin									
Large Sculpins - Hemilepidotus Unidentified									
Lg. Sculpins - Myoxocephalus Unid.									
Large Sculpins - Plain Sculpin									
Large Sculpins - Red Irish Lord									
Large Sculpins - Warty Sculpin									
Large Sculpins - Yellow Irish Lord									
Misc crabs	0.10	0.58	0.19	0.00	0.04	0.59	0.61	0.45	0.77
Misc crustaceans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Misc fish	0.04	0.05	0.04	0.01	0.01	0.01	0.01	0.01	0.02
Misc inverts (worms etc)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Other osmerids	1.00	1.00					0.00	0.00	0.00
Other Sculpins									
Pacific Sand lance				1.00					0.00
Pacific Sandfish			1.00						0.00
Pandalid shrimp	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
Polychaete unidentified	0.25	1.00	0.00		0.00	0.00	0.00	0.00	0.00
Scypho jellies	0.83	0.97	0.65	0.00	0.05	0.85	0.70	0.30	0.36
Sea anemone unidentified	0.14	0.03	0.01	0.03	0.07	0.05	0.15	0.02	0.01
Sea pens whips	1.00	0.03	0.00	0.33	0.01	0.53	0.30	0.19	0.08
Sea star	0.33	0.22	0.22	0.14	0.09	0.32	0.19	0.25	0.33
Snails	0.28	0.29	0.14	0.05	0.08	0.67	0.52	0.43	0.57
Sponge unidentified	0.05	0.01	0.00	0.02	0.10	0.03	0.06	0.01	0.01
State-managed Rockfish	0.09	0.21	0.01	0.18	0.00	0.15	0.49	0.02	0.32
Stichaeidae	0.00	0.00	0.00	0.00	0.00	0.00	0.06		0.00
urchins dollars cucumbers	0.04	0.02	0.02	0.02	0.07	0.06	0.04	0.02	0.05

Table 2A.15: Bycatch of Nontarget and Ecosystem bird species for the Aleutian Islands Pacific cod fishery, expressed as a proportion of the incidental catch of that species group taken in all FMP AI fisheries 1991-2020 (through November 4).

Longline																		
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Birds - Auklets	0.00									1.00		0			0.00	0.00		
Birds - Gull	0.01	0.11	0.59	0.46	0.42	1.00	0.59	0.53	0.08	0.06	0.17		0.08	0		1.00	1	1
Birds - Laysan Albatross	0.04	0.00	0.17	0.45	0.23	0.40	0.12	0.30	0.00	0.00	0.00	0	0.22	0	0.00	0.00		0
Birds - Northern Fulmar	0.01	0.23	0.25	0.72	0.76	0.26	0.26	0.21	0.10	0.46	0.13	0	0.82	0	0.06	0.01	0	0
Birds - Unidentified	1.00	1.00	1.00	0.00	0.27	1.00	0.10	0.62	1.00	0.11	0.00				0.00	1.00		1
Birds - Unidentified Albatross				0.00								0						

Non-pelagic trawl																		
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Birds - Auklets	1.00									0		0			0	0		
Birds - Gull	0.99	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0	0	0		0	0.00		0	0	0
Birds - Laysan Albatross	0.35	0.00	0.43	0.00	0.00	0.00	0.26	0.00	0	0	0	0	0	0.00	0	0		0
Birds - Northern Fulmar	0.00	0.04	0.63	0.10	0.00	0.49	0.05	0.37	0	0	0	0	0	0.77	0	0	0	0
Birds - Unidentified	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0	0	0				0	0		0
Birds - Unidentified Albatross				1.00								0						

Figures

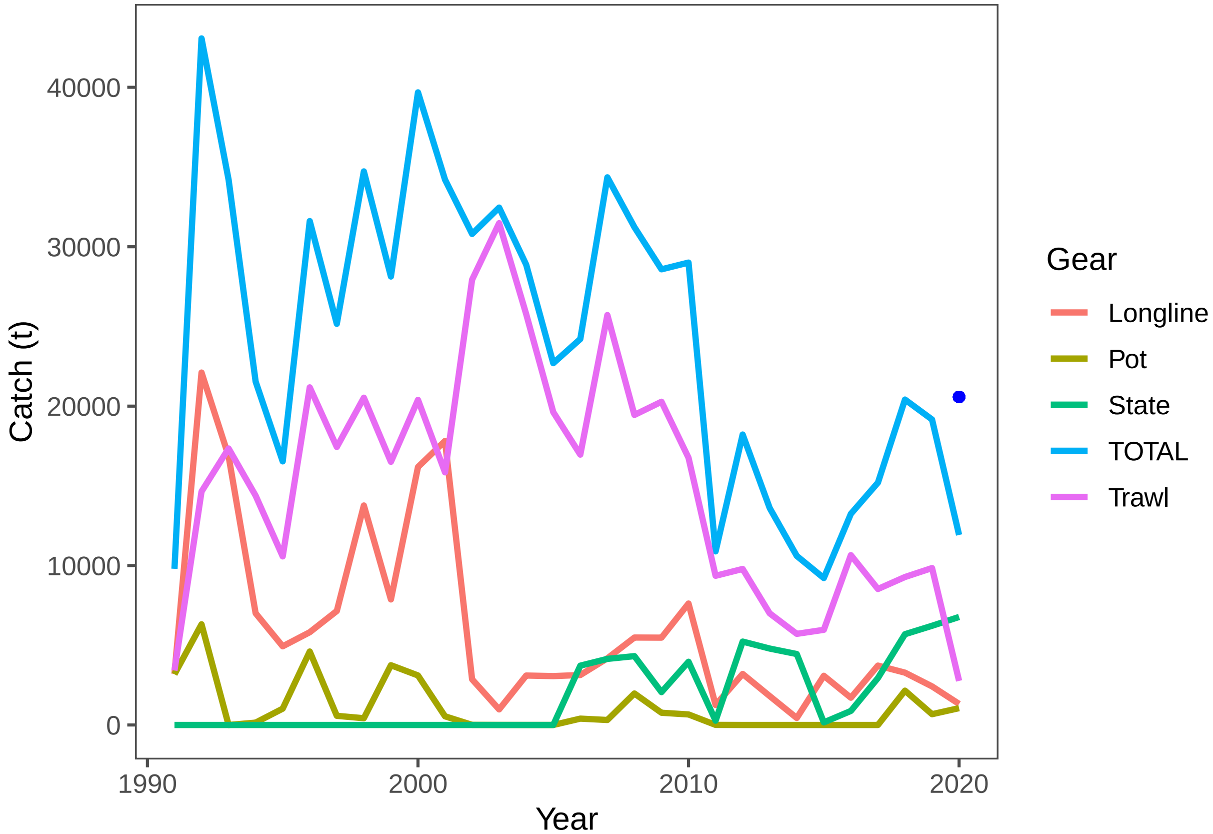

Figure 2A.1: Aleutian Islands Pacific cod catch history, with Federal catches broken down by gear type, from 1991-2020 (through November 4). The blue dot represents the ABC for 2020.

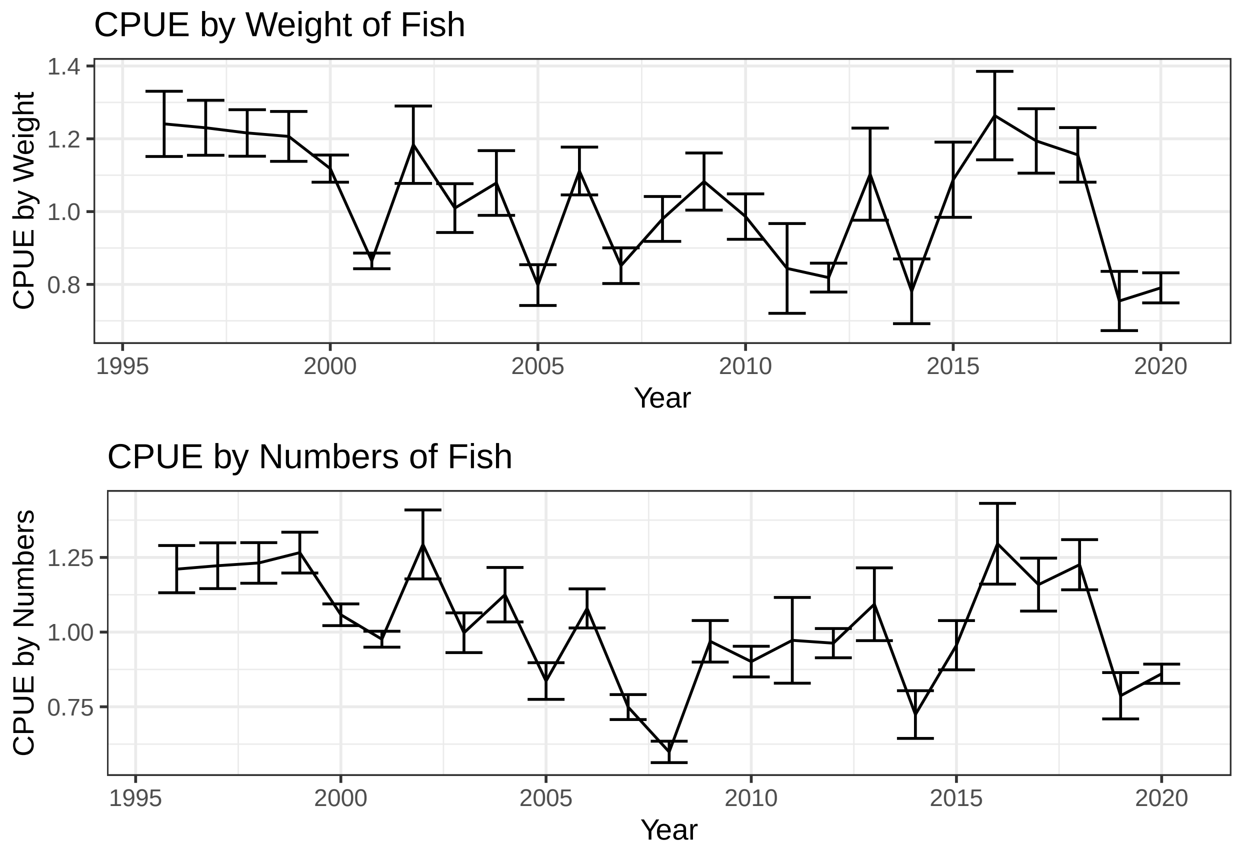

Figure 2A.2: Catch per unit effort for all AI cod fisheries, scaled relative to the long-term average, 1996-2020. Estimates of relative CPUE were complete through October 31, 2020.

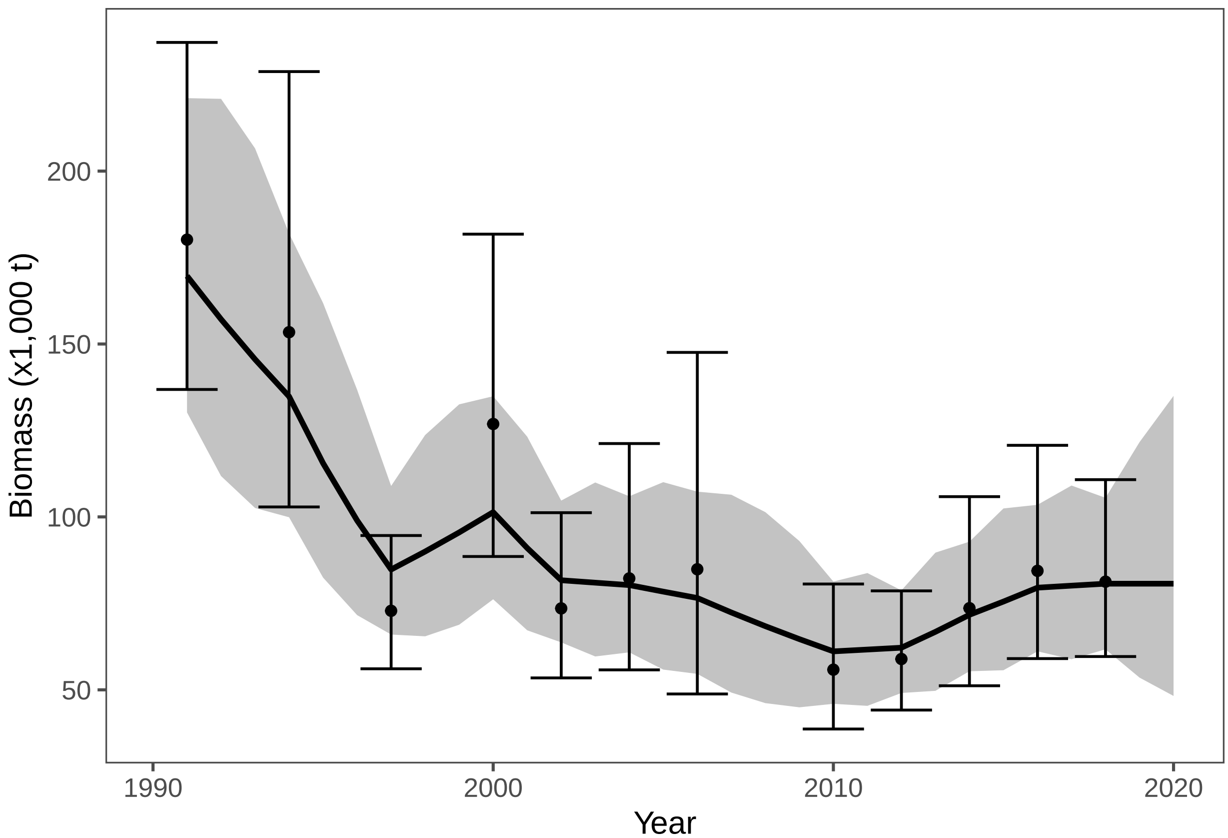

Figure 2A.3: Fit of Model 13.4 to survey biomass time series, with 95% confidence intervals for the observations and the estimates. Dots indicate survey estimates and black line represents the model estimate.

Appendix 1: Amendments to the BSAI Fishery Management Plan (FMP) that reference Pacific cod explicitly (excerpted from Appendix A of the FMP, except that Amendment 113, which is listed in Appendix A of the FMP, is omitted here, due to the fact that the final rule implementing that amendment was vacated by the U.S. District Court for the District of Columbia on March 21, 2019).

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%), hook and line catcher vessels (0.3%), pot catcher processors (3.3%), pot catcher vessels (15%), and catcher vessels (pot or hook and line) less than 60 feet (1.4%).

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 greater than or equal to 60' LOA using hook-and-line gear (0.2 percent); catcher processors using pot gear (1.5 percent); catcher vessels greater than or equal to 60' LOA using pot gear (8.4 percent); and catcher vessels less than 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.

Amendments 120/108, implemented January 20, 2020.

A C/P acting as a mothership receiving deliveries of BSAI non-CDQ Pacific cod from CVs engaged in directed fishing with trawl gear must be designated on a groundfish LLP license with a "BSAI Pacific cod trawl mothership endorsement." Passage of the amendment was motivated by an increase in mothership activity since 2016 in the BSAI non-CDQ Pacific cod trawl CV directed fishery, which was linked to trawl CVs delivering to C/Ps operating as motherships, thereby decreasing Pacific cod landings at BSAI shoreside processing facilities.