Assessment of the Pacific cod stock in the Aleutian Islands

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Executive summary

Harvest specifications for Aleutian Islands (AI) Pacific cod have been based on Tier 5 methodology since the AI and eastern Bering Sea (EBS) stocks were first managed separately in 2014. Several age-structured models of this stock have been explored in assessments since 2012. This document presents two age structured models for the Aleutian Islands Pacific cod stock using data from 1991 through 2022 (Model 22.0 and Model 22.1) as well as a Tier 5 harvest specification model which has been used since 2013. A preliminary version of these models was presented to the BSAI Plan Team in September, 2022 and to the SSC in October, 2022.

Summary of changes in assessment inputs

The following substantive changes have been made in the Aleutian Islands Pacific cod age structured assessment relative to the November 2021 assessment.

Changes in the input data (age structured models) The age structured models presented in this assessment are new this year so this section lists data used in the models.

- Catches for 1991 - 2021 were used, as well as a preliminary catch estimate for 2022.
- Commercial fishery size compositions for 1991 - 2021, as well as a preliminary size composition from the 2022 commercial fisheries.
- Biomass index and size compositions from the 1991 - 2022 Aleutian Islands survey.
- Age composition data compositions from the 1991 - 2018 Aleutian Islands survey and age data from the fishery.
- A script was developed for pulling and processing data, the script included weighting catch for commercial fishery size compositions. This same script is used to pull data for the Gulf of Alaska and eastern Bering Sea assessment models for consistency.

Changes in the input data (Tier 5 model)

- A new biomass index was available from the 2022 Aleutian Islands trawl survey and was added to existing biomass estimates from 1991 - 2018.

Changes in the assessment methodology The Tier 5 methodology has not changed, but the age structured models were implemented using the Stock Synthesis platform rather than Automatic Differentiation Model Builder (ADMB). The following age structured models were presented this year.

- Model 22.0 combined all fishery data incorporated into a single fishery from 1991 - 2022, as well as data from the Aleutian Islands trawl survey.
- Model 22.1 incorporated data from the three commercial fisheries that occur in the Aleutian Islands: trawl, longline, and pot, from 1991 through 2022. In addition, data from the Aleutian Islands trawl survey and longline survey were incorporated in the model.

- Model 13.4: is the Tier 5 random effects model recommended by the Survey Averaging Working Group, which has been accepted by the Plan Team and SSC since the 2013 assessment for the purpose of setting AI Pacific cod harvest specifications.

Summary of Results

We recommend retaining Model 13.4 for the 2023 - 2024 harvest recommendations. We do not recommend the age-structured models at this time for the following reasons. Model 22.1 did not fit the survey data well, despite trawl survey catchability fixed near 1. Model 22.1 estimated a total biomass of 116,652 t, which was approximately twice the survey estimate of biomass, 51,539 t. Model 22.0 fit the survey index well, with a 2022 estimate of 58,865 t, but produced a positive retrospective pattern resulting in Mohn's ρ outside of acceptable bounds, 0.316 (Table 1, Table 2).

The Tier 5 ABCs and OFLs for 2023 and 2024 are lower than 2021 estimates, due to the reduction in estimated Aleutian Islands Pacific cod trawl survey biomass in 2022, which represented a 37% decline. Model 13.4 incorporates this biomass estimate directly in the calculation of reference points; therefore, the random effects model estimated exploitable biomass of 54,166 t produced OFLs (18,416) and ABCs (13,812) that were were reduced by 37% for 2023 and 2024.

Catch of Pacific cod as of October 1, 2022 was 10,547 t. Over the past 5 years (2017 - 2021), 94.7% of the catch has taken place by this date. Therefore, the full year's estimate of catch in 2022 was extrapolated to be 11,138 t. This is lower than the average catch over the past five years of 16,600 t.

We recommend the Tier 5 Model 13.4 for management quantities and no additional reduction in ABC due to Risk Table concerns.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2022	2023	2023	2024
M (natural mortality rate)	0.34	0.34	0.34	0.34
Tier	5	5	5	5
Biomass (t)	80,700	80,700	54,165	54,165
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	18,416	18,416
$maxABC$	20,600	20,600	13,812	13,812
ABC	20,600	20,600	13,812	13,812
Status	2020	2021	2021	2022
Overfishing	No	n/a	No	n/a

Responses to SSC and Plan Team Comments on Assessments in General

SSC December 2021

The SSC recommends that groundfish, crab and scallop assessment authors do not change recommendations in documents between the Plan Team and the SSC meetings, because it makes it more difficult to understand the context of the Plan Team's rationale and seems counter to the public process without seeing a revision history of the document… *However, this recommendation is not meant to prevent correcting typos, transcription errors, figure labels and other editorial issues for the final posted documents.*

Authors' response

Noted.

SSC December 2021

With respect to Risk Tables, the SSC would like to highlight that "risk" is the risk of the ABC exceeding the true (but unknown) OFL, as noted in the October 2021 SSC Risk Table workshop report. Therefore, for all stocks with a Risk Table, assessment authors should evaluate the risk of the ABC exceeding the true (but unknown) OFL and whether a reduction from maximum ABC is warranted, even if past TACs or exploitation rates are low.

Authors' response

Noted.

Plan Team November 2021

The Team recommends all GOA authors evaluate any bottom trawl survey information used in their assessment prior to 1990 including the 1984 and 1987 surveys and conduct sensitivity analyses to evaluate their usefulness to the assessment. This may apply for Aleutian Islands surveys but this was only raised during GOA assessment considerations.

Authors' response

Noted.

Plan Team September 2022

Both the Joint Plan Team and the SSC are fully supportive of the Random effects (RE) meta-analysis (MA) framework and its implementation. However, it is the Joint Plan Team's recommendation that authors should bridge to rema when they could get to it, and not necessarily before Nov 2022.

Authors' response

Noted.

Responses to SSC and Plan Team Comments Specific to this Assessment

SSC December 2021

The SSC appreciates the authors continuing to try to move forward with an age-structured model. There has not been a new survey data point since 2018, which makes both adopting a new model and Tier 5 estimates problematic and the SSC continues to stress the importance of a 2022 AI survey.

Authors' response

The current assessment presents two new age structured models that incorporate data from the 2022 AI survey.

SSC December 2021

Without a firm justification and resolution of the natural mortality value, the authors might choose the prior point estimate (M = 0.36) calculated using the multi-method Barefoot Ecologist tool (http://barefootecologist.com.au/shiny_m.html), or using that prior and attempting to estimate it within the model.

Authors' response

In the assessment models presented in the current assessment, natural mortality was estimated within the model.

SSC December 2021

I terms of maturity… The SSC reiterates that fitting both data sets within the model would improve the perception of maturity uncertainty and use all the data available, as it is unknown whether the macroscopic scans of maturity are as accurate as histological at this time; nor is it known whether the large change in maturity is from the methods, spatial extent, or a temporal change.

Authors' response

The lead author worked with the AFSC Age and Growth group during 2021 and 2022 to plan for and implement a histological-based maturity curve specific to Aleutian Islands cod. This maturity curve has not yet been developed. In September 2022 the Plan Team supported the author's recommendation to use the Aleutian Islands observer data to estimate a maturity curve. In October 2022 the SSC supported this recommendation. This maturity curve is implemented in the current assessment model.

SSC December 2021

The SSC recommends further examination of the AFSC longline survey for potential use in this assessment, particularly because there have now been multiple spans of four years between AI bottom trawl surveys.

Authors' response

The AFSC longline survey has been incorporated in the two age structured assessment models.

SSC December 2021

There were specific comments (#2-7) that are addressed below.

Authors' response

Specific points 2-7 refer to models presented in 2021 which are not used in the current assessment.

SSC October 2021

Assessment model updates and BSAI GPT recommendations were provided for EBS Pacific cod, AI Pacific cod, Pacific ocean perch, Other Rockfish, shortraker rockfish, Greenland turbot, yellowfin sole, and EBS pollock. All the updates were minor to moderate, and the SSC concurred with the BSAI GPT recommended models to be brought forward for SSC review in December. Further, the SSC supported all the BSAI GPT's recommendations for data exploration and model refinement.

Authors' response

Noted.

Plan Team September 2022

The Team supported the use of SS3 in moving this stock to a Tier 3 model because the platform is consistent across assessments and there is consistency and systematic review of the SS3 platform.

Authors' response

This assessment includes a Tier 5 as well as two Tier 3 stock assessment models in SS3.

Plan Team September 2022

The Team supported the author's recommendations to consider parameterizations for $sigmaR$, and data weighting and to work with EBS and GOA authors to standardized tuning of $sigmaR$ in future assessments.

Authors' response

The Tier 3 assessment models presented here tuned *sigmaR* using the same methodology as the EBS P.cod models. Data weighting was performed using Francis (2011) methodology for composition data.

Plan Team September 2022

The Team also supported the author's recommendation to use the Aleutian Islands observer data to estimate maturity at age because AI cod have different growth, are genetically distinct, and the observer records are unique to the AI and more numerous. The Team discussed the start date for the model and supported beginning both Model 22.0 and 22.1 in 1991 as there were no survey data in the model until 1991. (One of the models presented in September 2022 extended back to 1978).

Authors' response

The 2022 Tier 3 models use a start date of 1991 and the observer index of maturity at age.

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. In 2017, large scale movement was noted into the northern Bering Sea (NBS) by Eastern Bering Sea stocks (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, Spies et al. 2022). Pacific cod likely return to their natal origin to spawn during winter months (January - April) but perform feeding migrations during other months. High assignment success (>80%) was demonstrated among five spawning populations of Pacific cod throughout their range off Alaska using 6,425 single-nucleotide polymorphism (SNP) loci (Drinan et al. 2018). The three spawning groups examined in the Gulf of Alaska, Hecate Strait, Kodiak Island, and Prince William Sound, were all genetically distinct and could be assigned to their population of origin with 80-90% accuracy (Fig. 2.4; Drinan et al. 2018).

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.).

The most recent genomic analysis of Pacific cod includes a new publication that used pooled whole genome sequencing (Pool-Seq), as well as a new study conducted during 2021 and 2022 that used low coverage whole genome sequencing (lcWGS). The Pool-Seq manuscript (Spies et al. 2022) is the culmination of several years of effort, while the lcWGS is more recent and provides a more powerful approach to gather individual-based sequence data from the whole genome. Here, we focus on how the two studies contribute to our knowledge of the population structure of Pacific cod throughout Alaskan waters.

Low-coverage whole-genome sequencing analysis of 429 samples of Pacific cod from known spawning regions during spawning season indicated population structure similar to what was previously known, but with finer resolution and greater power owing to the larger number of markers. Using 1,922,927 polymorphic SNPs (Figure 1), the pattern of population structure mostly resembles isolation-by-distance, in which samples from proximate spawning areas are more genetically similar than samples from more distant areas. Isolation-by-distance was observed from western Gulf of Alaska (Kodiak and the Shumagin Islands) through Unimak Pass and the eastern Aleutian Islands. Previous studies have reported an isolation-by-distance pattern in Pacific cod using microsatellite markers (Cunningham et al. 2009 and Spies 2012) and reduced-representation sequencing (Drinan et al. 2018). Within the isolation-by-distance pattern, there were some distinct breaks in the population structure. The most significant genetic break occurs between western and eastern Gulf of Alaska (GOA) spawning samples, and was supported by previous research that highlighted the zona pellucida gene region (Spies et al. 2021). Aleutian Island populations are highly diverged at a few genomic regions that we believe are adaptively significant (Spies et al. 2022, Figure 2). These adaptive differences provide further support for the Aleutian Island management unit that was established as distinct from the Bering Sea in 2013.

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 Aleutian Islands. 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 3). 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 4). Domestic fishing for AI Pacific cod began in 1981, with a peak catch of over 43,000 t in 1992 (Table 5).

Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including pot, trawl and longline components (Figure 1). Pacific cod in the Aleutian Islands are exploited in the federal and state fisheries. The management quantities in this document pertain to the federal fishery; however, a proportion of the federal quota is allocated to the state fishery. In 2022 (as of October 30, 2022), the federal fishery consisted of 16% pot gear, 31% longline gear, and 53% trawl gear. In 2022, 51% of the catch was taken in the state fishery (Figure 1).

Historically, Pacific cod were caught throughout the Aleutian Islands. 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 2017-2022 (through October 31, 2022) was 52% from the eastern Aleutian Islands (NMFS area 541), 23% from the central Aleutian Islands (NMFS area 542), and 9% from the western Aleutian Islands (NMFS area 543) (Figure 2).

Catches of Pacific cod taken in the AI for the periods 1964-1980, 1981-1990, and 1991-2022 are shown in Table 3, Table 4, and Table 5, respectively. The catches in Table 3 and Table 4 are broken down by fleet sector (foreign, joint venture, domestic annual processing). The catches in Table 4 are also broken down by gear to the extent possible. The catches in Table 5 are broken down by gear. Table 6 breaks down catches from 1994-2022 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 3). CPUE has decreased by all metrics since approximately 2015, including seasonally by trawl gear and for longline gear (Figure 4). Recent declines in CPUE may be attributed to the timing of the fishery relative to spawning season or other factors such as hyperaggregation during spawning in the trawl fishery (Rose and Kulka 1999). Standardized surveys are needed to understand whether declines in fishery CPUE represent declines in Aleutian Islands Pacific cod stock size.

Discards

The catches shown in Table 4 and Table 5 include estimated discards. Discard amounts and rates of Pacific cod in the AI Pacific cod fisheries are shown for each year 1993-2022 in Table 7. 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 1998, they have averaged about 1.0%.

Management History

Appendix 1 from the 2021 Aleutian Islands stock assessment and fishery evaluation lists all implemented amendments to the BSAI Groundfish FMP that reference Pacific cod explicitly. The most recent was 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 8. 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 3, Table 4, and Table 5, 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 8 are total catches (i.e., Federal plus State), whereas the TAC applies only to the Federal catch.

In the 9 years that AI Pacific cod have been managed separately from EBS Pacific cod, the ratio of Federal catch to TAC has ranged from 0.37 to 0.96. The catch/TAC ratio in 2022 (complete through October 31) was 0.37, which is the lowest ratio observed since 2014.

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). 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.

The Aleutian Islands GHL increases 4% if 90% of the GHL is harvested by November 15 of the preceding year. The GHL cannot exceed 39% or 6,804 t. If the 2023 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 2022, which is the maximum allowed

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
2022	0.39*AI ABC or 6,804 t, whichever is less

(39%) of the ABC. During the period in which a State fishery has existed: 1) TAC has been set 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 the Aleutian Islands Pacific cod stock assessment.

The data used in the age structured models include fishery catch and size compositions, survey biomass and standard error, and age compositions from survey data (Table 9).

Partial catch information for 2022 was available and was extrapolated to estimate the catch for the full year. On average, 94.7 % of the annual catch occurs by this date, as estimated by catch statistics in 2017 - 2021. The catch of Pacific cod in the Aleutian Islands as of the end of October, 2022, was 11,138 t.

The data used in the Tier 5 Model included 13 years of biomass estimates and associated error for the NMFS Aleutian Island research surveys, 1991-2022 (Table 10).

Survey

The National Marine Fisheries Service (NMFS) conducts biennial daytime summer trawl surveys in the Aleutian Islands. Survey biomass is estimated by extrapolating the weight from individual trawls with the measured path of the trawl area to the total area surveyed. The net used in the Aleutian Islands survey is a high-rise poly-Noreastern 4 seam bottom trawl (27.2 m headrope, 36.8 m footrope) (Nichol et al. 2007). Survey biomass estimates and standard error for Pacific cod are available for the survey years 1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018, and 2022 (Table 11). Aleutian Islands surveys prior to 1991 were not used in the model because they were not standardized to current survey methodology; therefore, data from the 1980, 1983, and 1987 surveys were excluded. Survey data includes NMFS areas 541, 542, and 543. The Aleutian Islands bottom trawl survey does include NMFS areas 518 and 519, but these were not included in data for this model.

Survey age data is available for each survey, 1991-2022, except for the current survey year. The number of cod aged from the survey has ranged between 500 and 1,200 and the number of hauls 76-173 Table 12. Length composition data from the fishery and surveys was also used in the model (Figure 5).

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 10. 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 survey biomass data indicate a decline, and the 2022 estimate of biomass is the lowest in the time series. The total biomass estimate for Pacific cod in the Aleutian Islands declined from over 180,000 t in 1991 to 51,539 t in the current year. Recent declines took place in the eastern Aleutians (>50% decline) and in the central Aleutians (32% decline) from the last survey in 2018 to the current survey in 2022. The western Aleutian Islands stock of Pacific cod increased from 11,425 t to 13,661 t (20% increase) between 2018 and 2022 (Figure 6).

In addition to the NMFS Aleutian Islands trawl survey, the relative population numbers (RPN) estimated from the NMFS Longline survey were included in Model 22.1 (Figure 7, Table 11). The longline survey was not incorporated into the Tier 5 model or Model 22.0. The 2022 longline survey index for 2022 was the lowest in the survey history. The longline survey was designed to target sablefish, and how well it documents the abundance of Pacific cod is uncertain. Further discussion on this topic is presented in the Risk Table.

Fishery

There are three predominant gear types in the Aleutian Islands Pacific cod fishery; pot, trawl, and longline, which are implemented at different times of the year (Figure 8). During spawning season (January - April), mature Pacific cod aggregate for spawning at known locations. During these months, over the past 5 years (January 1, 2018 - October 31, 2022), pot and trawl gear were primarily used (1.2% longline, 40.5% trawl, 58.3% pot). After spawning, Pacific cod tend to disperse for feeding; during May through December, cod were caught more commonly with longline gear, followed by trawl and pot gear (51.2% longline, 39.2% trawl, 9.6% pot). While the spawning season is approximately half the time of non-spawning (4 vs. 8 months), the majority, 65.8%, of the annual catch (2017 - October 31, 2022) took place during spawning season.

Catches have exceeded TAC harvest recommendations in five of the nine years since 2013, but have never exceeded the OFL (Table 8).

Length frequencies from the fishery

Fishery lengths are taken throughout the year by observers during commercial fishing operations (Figure 8). The length frequency composition ranges from approximately 40-120 cm and varies over time (Figure 9, Figure 10, Figure 11), and also varies by season, with mature fish typically caught in the winter surveys. Observer length records are taken during summer/non-spawning (May-December) and during winter/spawning (January-April) on boats using all gear types. The number of hauls from which length observations from catch data by year is shown in Table 13. Most lengths by fisheries observers have been collected on longline and trawl vessels (Table 13).

Starting in 2019, Pacific cod net excluders were implemented in EBS summer trawl fisheries to reduce incidental take of Pacific cod, particularly in the flatfish fisheries (Rand et al. 2022). The use of cod excluders are not considered to bias length compositions used here because data was selected from fisheries that were targeting Pacific cod. Fishery length frequencies were weighted by the relative catch by year, area (NMFS areas 541, 542, and 543), gear, and quarter. Fishery length frequencies in which sample sizes were fewer than 70 were omitted because inclusion of smaller sample sizes resulted in a spiky distribution. Larger samples were also incorporated to select for boats targeting Pacific cod. In 2020 and 2021 there were no samples greater than 100 fish.

General Model Structure

The Aleutian Islands stock of Pacific cod was managed jointly with the eastern Bering Sea stock through 2012. During that time, the stock assessment model was configured for the EBS stock only. Aleutian Islands Pacific cod have been managed using Tier 5 methodology since 2013. An age structured model for Aleutian Islands cod was first presented to the SSC in 2012 and age structured models were presented in 2013-2015, 2020, 2021, and in the current assessment, but management quantities after 2013 have been set using the Tier 5 model.

Tier 5 model structure

Model 13.4 is the Tier 5 random effects model recommended by the Survey Averaging Working Group, 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) as a "random walk" state-space model. 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.

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.

Age structured models

In this assessment, age structured models Model 22.0 and Model 22.1 are presented, which were built using Stock Synthesis version 3.30.17.00 (Methot and Wetzel 2013). The Stock Synthesis user manual is available at: https://nmfs-stock-synthesis.github.io/doc/).

Models 22.0 and 22.1 fit survey abundance estimates, survey and fishery age data, survey length data, fishery catch, and fishery length composition data. Survey age data was used to calculate conditional age at length compositions. The model incorporated ages 1-10, where 10 is considered a "plus group" including all ages 10 and above. The model also incorporated lengths from 1 to 117 cm as compositional data from the fisheries and surveys (Figure 5). Length frequencies for Model 22.0 combined all fisheries into a single length composition (Figure 9) and Model 22.1 used separate fishery length compositions (Figure 10).

Ageing bias was not incorporated in the model, as all ages used were aged subsequent to 2007, after which time ageing methodology has been consistent and considered non-biased.

Model features:

- Single sex model, 1:1 male female ratio.
- A Von Bertalanffy growth curve was estimated within the model.
- An ageing error matrix for ages 1 through 10+.
- All parameters were constant over time except for recruitment and fishing mortality.
- Internal estimation of fishing mortality, catchability, and selectivity parameters.
- Recruitment estimated as a mean with lognormally distributed deviations.
- Natural mortality was estimated within the model.
- Trawl survey catchability was estimated within the model but used a small prior around 1.
- Maturity at age was estimated using observer data, as recommended by the September 2022 Plan Team meeting.

Data Weighting

Model-based age and length composition data from survey and fishery were weighted using the methodology of Francis (2011). The number of hauls from which otoliths were taken in each year of the survey is considered the number of independent observations and was used as the first stage of data weighting in the age-structured models Table 12. The number of hauls was used as the stage 1 weights for fishery data, while stage 1 survey weights were 100.

Parameter Estimation

Models 22.0 and 22.1

Stock Synthesis requires that prior distributions and initial values be associated with all internally estimated time-invariant parameters. For age structured models presented in this assessment, uniform prior distributions were used for estimation of all such parameters, with bounds set at values sufficiently extreme that they were non-constraining (with the exception of survey catchability, discussed in the Results section), or extending the bounds to even more extreme values would have no practical impact (because, when the parameter is back-transformed to the natural scale, the resulting quantity is indistinguishable from a logical constraint; e.g., selectivity cannot fall outside the (0,1) range). Such parameters are referred to here as being “freely estimated.”

Parameters Estimated Outside the Assessment Model

Maturity

The maturity-at-age is governed by the relationship:

$$Maturity_{age} = \frac{1}{1 + e^{-(A+B*age)}},$$

where A and B are parameters in the relationship.

A study based on a collection of 129 female fish in February, 2003, from the Unimak Pass area, NMFS area 509, found that 50% of female fish become mature at approximately 4.88 years ($L_{50\%}$) and 58.0 cm, A=-4.7143, B=0.9654 (i.e. Tables 2 and 4 in Stark 2007). This maturity ogive is used in the Bering Sea Pacific cod assessment but was not used in this assessment, because the fish in the sample were not from the Aleutian Islands.

An alternative maturity curve was developed based on observer records of maturity from the Aleutian Islands. This model is advantageous because it is based on more records that were taken from Aleutian Islands cod, and this was used in the model presented here. Observers routinely collect maturity at length from Pacific cod. There are 1,331 records from the Aleutian Islands (see table below) during the months January – March since 2008. These were used to estimate a maturity ogive by length using the R package *sizeMat*, which estimates the length of fish at gonad maturity. Maturity was considered a binomial response varable and variables were fitted to the logistic function above for maturity, and the length at which 50% of cod are mature is $L_{50\%} = -A/B$. The formula used to fit proportion mature by length was

$$Maturity_{length} = \frac{1}{1 + e^{-(A+B*length)}}$$

(Table 14). This method was approved by the Plan Team (September 2022) and SSC (October 2022).

Length at Age (Growth model selection)

In the 2021 assessment, several growth curves were fit to raw data to explore which best fit growth patterns of Pacific cod from the Aleutian Islands. The growth curves were Von Bertalanffy, Gompertz, logistic, and Richards. The first three curves had three parameters, and the Richards had four parameters. The Gompertz growth function described growth as slowest at the start and end of a given time period. This model avoids the extra parameter used in the Richards growth curve while allowing for non-symmetric growth at the beginning and maximum ages. In the Gompertz growth equation, the point of inflection is always at about 36.8% of the asymptotic size. In cod the growth inflection point occurs later, age 8, which is approximately 2/3 of the asymptotic size. The logistic growth function approaches the early life stage growth and the maximum age growth asymptotes symmetrically. The Richards growth curve adds an additional parameter to the logistic growth curve to account for non-symmetrical growth at early ages and maximum ages Table 15, (Figure 12). The four growth curves were evaluated based on the sum of squared residuals (SSR), number of parameters, and Akaike Information Criterion, AIC (Akaike, 1974). The SSR was evaluated in two ways. First it was evaluated by comparing the fitted vs. observed lengths for each of the 9,075 length at age records in the raw dataset. Second, it was compared using the fitted vs. observed lengths for each age 1-13 based on mean length at age in the dataset.

We ruled out the Richards growth curve because a. the fourth parameter increases the AIC significantly and does not make up for the improvement to the fit; b. the Gompertz equation has an inflection point at 36.8% of the asymptotic size, and c. the logistic model has symmetrical growth at early and maximum ages. Therefore, Von Bertalanffy was the equation of choice.

Natural mortality

Model 13.4

Recent estimates of natural mortality indicates that estimates have ranged from 0.20 to 0.96 for Pacific cod (Table 16). A natural mortality estimate of 0.34 been used in the most recent Aleutian Islands Pacific cod assessment, as well as the 2022 and prior BSAI cod assessments (Thompson et al. 2018). This value was based on Equation 7 of Jensen (1996) and an age at maturity of 4.9 years (Stark 2007). 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 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). 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 for natural mortality was used for the 2022 Tier 5 Model 13.4, as in previous years.

Parameters Estimated Inside the Assessment Model

Length at age

Pacific cod do not exhibit sexually dimorphic growth; males and females grow at the same rate. Therefore, the model did not distinguish between males and females. Growth is rapid at younger ages (Figure 13) and was estimated within the model using the Von Bertalanffy growth curve as described above. Age data used in the model was aged after 2007, as there was a shift in our understanding of the first two checks deposited at early ages in Pacific cod. Prior to 2007 they were thought to be true annuli, but subsequently determined not to be. Therefore, ageing bias was not incorporated within the model, although ageing error was incorporated.

Catchability

Literature and previous studies can inform choices for catchability. Somerton (2004) found no evidence for herding in Pacific cod. This experiment took place using the 83-112 Eastern Trawl trawl net in the eastern Bering Sea and the Poly Noreastern trawl net in the Bering Sea (Somerton et al. 2004). Another study estimated that 47.3% of cod in the water column to be available to the trawl used on the eastern Bering Sea trawl survey and 91.6% are available to the trawl used on the Gulf of Alaska and Aleutian Islands surveys (Nichol et al. 2007). This study was based on results showing that 95% of cod were found within 10 m of the seafloor, based on 286 archival tagged cod off Kodiak Island in the Gulf of Alaska and off Unimak Pass in the eastern Bering Sea, Alaska (Nichol et al. 2007). More recently Rand et al. (2022) found no evidence for difference in mean size of Pacific cod caught by the survey and the fishery in the eastern Bering Sea.

Survey catchability (q) was estimated within Models 22.0 and 22.1 as a constant multiplier on the survey selectivity, but with an initial value close to 1 and a small standard deviation (0.01).

Selectivity

For Model 22.0, selectivity for the fishery and the survey were fit (separately) using a monotonically increasing asymptotic growth curve. For Model 22.1, selectivity for the survey and the three fisheries were fit using monotonically increasing asymptotic growth curves (Figure 14). The exception was that for the longline survey in Model 22.1, dome shaped selectivity was used due to a lower proportion of older fish in the catch (Figure 15). All selectivity curves were implemented as double normal, except where monotonically increasing asymptotic selectivity was desired, the second double normal defining the descending slope was at the upper bound so that only the first upward sloping normal was used to model selectivity.

Natural mortality

For Models 22.0 and 22.1, natural mortality was estimated within the model. Estimation within the model framework provides a maximum likelihood estimate that incorporates all data sources.

Other parameters

Model 22.0 contained 164 parameters (Table 17) and Model 22.1 contained 274 parameters (Table 18). The value of $sigmaR$, the standard deviation of recruitment, was tuned iteratively using the same process as Thompson et al. (2008).

Results

Tier 5 Model Evaluation

Model 13.4 estimated the 2022 biomass estimate to be 54,165 t, with a log-scale process error standard deviation of 0.12 and a coefficient of variation equal to 0.14.

The time series of biomass estimated by Model 13.4 for 2022 and 2021, with 95% confidence intervals, is shown in Table 19, which comprised the most recent previous update of the time series. The 2021 Model 13.4 estimates are higher than the 2022 estimates, due to the inclusion of new 2022 trawl series data. The model's fit to the survey biomass time series is shown in Figure 16, as well as the fit to the data used from 2018 through 2022.

Age structured model evaluation

Two age structured models were presented in this assessment.

- Model 22.0 combined all fishery data incorporated into a single fishery from 1991 - 2022, and used data from the Aleutian Islands trawl survey.
- Model 22.1 incorporated data from the three commercial fisheries that occur in the Aleutian Islands: trawl, longline, and pot, from 1991 through 2022. In addition, data from the Aleutian Islands trawl survey and longline survey were incorporated in the model.

Likelihood components for Model 22.0 and 22.1 are shown in Table 20 for recruitment, survey age, survey biomass, catch, fishery length, and total likelihood. The likelihoods are not comparable because they are configured with different datasets.

The trawl survey catchability coefficient, which relates the biomass abundance to the survey fishing mortality, was not estimated freely in Models 22.0 and 22.1. Model 22.1 estimated very low («1) survey catchability when the bounds on this parameter were extended, which was not consistent with the expectation that the trawl survey catchability is close to 1. This expectation is supported by recent literature which indicates that surveys for cod are capable of sampling fish that are present (Weinberg et al. 2016, Rand et al. 2022). Therefore, survey catchability was constrained close to 1. Model 22.0 fit the trawl survey relatively well, with some negative and some positive residuals and fell within confidence intervals for 9 of the 13 data points (Figure 17). Model 22.1 consistently overestimated the trawl survey index , Figure 18, but it did fall within confidence intervals for 8 of the 13 data points.

A likelihood profile was conducted over $\log(R_0)$, or mean recruitment for Models 22.0 and 22.1 (Figure 19) to look for trends in the influence of various data sources. Ideally all data components would show a smooth unimodal curve that is maximized at the same local maximum likelihood estimate (or minimized at the -log(Likelihood)). For Model 22.0, the fishery data indicated smooth trend to a maximum likelihood estimate of $\log(R_0)$. The survey data had no local minimum, but showed an increase in likelihood to a higher value than indicated by fishery data. Overall the model fit $\log(R_0)$ intermediate between the survey and fishery estimates. Estimates of $\log(R_0)$ for Model 22.1 also showed some disagreement among various data components. The trawl fishery indicated much higher $\log(R_0)$ but the longline fishery indicated the same local minimum as the trawl survey. The pot fishery and the longline survey showed an increasing likelihood as $\log(R_0)$ increased but no local minimum. Estimates of $\log(R_0)$ were very similar for Model 22.0 (10.38) and Model 22.1 (10.57), although they are presented on a log scale and when exponentiated result in over 20% difference.

Estimates of natural mortality were similar and very close to the expected values, 0.35 for Model 22.0 and 0.36 for Model 22.1. The 2022 EBS cod model also estimated M = 0.34 in the preferred model.

Retrospective analysis

A retrospective analysis was performed on Models 22.0 and 22.1 extending back 10 years to evaluate the model, with data from 2012-2022. The spawning biomass estimates and error bars showed a positive retrospective bias (Figure 20). Retrospective plots of (B/B_0) show the relationship between spawning biomass estimates and B_0 for Models 22.0 and 22.1 (Figure 21). Relative differences in spawning biomass were generally positive. Mohn's ρ was evaluated for all models as a diagnostic tool to quantify retrospective bias. For Model 22.1, Mohn's ρ was 0.252, and for Model 22.0, Mohn's ρ was 0.316. By comparison, Mohn's ρ values for EBS Pacific cod from 2016 - 2020 are 0.147, 0.243, 0.207, -0.061, and -0.021. Retrospective patterns often arise form either arise from unaccounted-for time-varying processes, or contradictory or incomplete data (Hurtado-Ferro 2015). While further work is required to understand the retrospective bias observed in Models 22.0 and 22.1, the lack of survey data in 2020 likely affects the retrospective pattern.

Hurtado-Ferro (2015) provides some guidance on the range of acceptable values for Mohn's ρ. For a flatfish-like species with M = 0.2, the lower and upper bounds were given as -0.15 and 0.2. For a sardine-like species with M = 0.4, the lower and upper bounds were given to be -0.22 and 0.3. If Mohn's ρ were entirely dependent on M (likely an oversimplification), then an equation for the lower and upper limits could be developed from these guidelines as follows: $Rho_{lowerbound} = -0.08 - 0.35 * M$ and $Rho_{upperbound} = 0.10 + 0.50 * M$. This results in a lower and upper bound for Model 22.0, in which the model estimates M = 0.35, of -0.203 and 0.275. This would indicate that the positive bias observed in Model 22.0 is outside the acceptable bounds. For Model 22.1, with M = 0.36, the lower and upper bounds on Mohn's ρ would be similar to that of the sardine-like species, -0.206 and 0.28. By this criteria, Mohn's ρ is not outside the acceptable bounds for Model 22.1.

Overall, Model 22.1 provides a poor fit to the trawl survey biomass, which is considered one of the most reliable estimates of the Aleutian Islands Pacific cod stock status. While natural mortality estimates for this model were close to expected values, selectivity curves seemed to match data sources, and retrospective patterns were within acceptable bounds, the results of this model seem to disproportionately inflate the stock size. This may be due to different data components such as the trawl survey possibly influencing the model towards larger stock sizes. The data sources in the likelihood profile did not show a smooth approach to a local minimum -log(Recruitment) (Figure 19). This model used the longline trawl survey, which may not be indicative of the relative size of the cod stock in the Aleutian Islands.

Model 22.0 appears to have several positive qualities; it estimated natural mortality close to expected values and fit the trawl survey biomass index to a reasonable degree. The likelihood profile indicated a smooth approach to the maximum likelihood of log(Recruitment) by the fishery data. While the retrospective pattern indicated positive bias outside acceptable bounds, this is likely due to three years without survey data from 2019 - 2021. Research has indicated that data-poor methodology does not necessarily result in better performance than the age structured model with retrospective adjustment (Legault et al. 2022). Furthermore, this model indicates that the spawning biomass stock size has declined below $B_{35}\%$ since 2008 and below $B_{20}\%$ during 2020 and 2021.

Time Series Results

Based on Model 22.0, total biomass declined from approximately 252,704 t in 1992 to a timeseries low of 58,865 t in 2020 (Table 21). Based on Model 22.1, total biomass declined from approximately 272,494 t in 1992 to a low over the timeseries of 94,407 t in 2014 (Table 21). Total biomass estimates according to Model 22.0 have since increased to an estimate of 64,293 t in 2022. According to Model 22.1, total biomass has increased to 117,618 t in 2022. The trawl survey estimate of biomass was 51,539 t in 2022.

Female spawning biomass has followed a similar overall declining trend as total biomass in Models 22.0 and 22.1 (Table 22 and Figure 22), with the peak spawning biomass occurring in 1991 for both models. For Model 22.1, spawning biomass reached its lowest point of 67,393 t in 2011, and spawning biomass reached its lowest point of 40,312 t in 2020 for Model 22.0.

Phase plane plots for Model 22.0 and 22.1 (Figure 23) show that spawning biomass has been below $B_{40\%}$ since approximately 2009. For Model 22.0, spawning biomass fell below $B_{20\%}$ from during 2020 and 2021 but increased to $B_{20\%}$ in 2022. Model 22.1 does not indicate that B/B_0 fell below $B_{20\%}$ during the timeseries (Table 23).

Recruitment estimates indicate overall higher recruitment in Model 22.1 than 22.0, and higher levels of recruitment in the early part of the timeseries, 1990-2000, Figure 24, and Table 24. Model 22.1 estimates considerably more numbers at age for ages 1 to 10+ in the population than Model 22.0, throughout the time series. But the two models track similar trajectories with higher numbers in the population through approximately 2000, and then a decline through 2020, followed by an increase starting in 2020 (Table 25, Table 26 and Figure 25). Recent increases in numbers at age may be due to favorable recruitment in 2019 and earlier (Figure 24).

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 2023 and 2024 for the Tier 5 reference points. Note that the 95% confidence interval for the estimate of biomass estimate is 42,782 t - 68,577 t. Reference points for Models 22.0 and 22.1 are given in Table 1 and Table 2.

Tier 5

Quantity	2023	2024
Biomass (t)	54,165	54,165 t
M	0.34	0.34 t
F_{OFL}	0.34	0.34
maxF_{ABC}	0.255	0.255
OFL (t)	18,416	18,416
maxABC (t)	13,812	13,812

Age Structured model(s) - Projected catch and abundance

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

For each scenario, the projections begin with the vector of 2022 numbers at age estimated in the assessment, for Model 22.0 and 22.1. This vector is then projected forward to the beginning of 2035 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2022. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1,000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

- Scenario 1: In all future years, F is set equal to max F_{ABC} . (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
- Scenario 2: In all future years, F is set equal to a constant fraction of max F_{ABC} , where this fraction is equal to the ratio of the F_{ABC} value for the assessment two years ago recommended in the assessment to the max F_{ABC} for the current year. (Rationale: When F_{ABC} is set at a value below max F_{ABC}, it is often set at the value recommended in the stock assessment.)
- Scenario 3: In all future years, the upper bound on F_{ABC} is set at $F_{60\%}$. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
- Scenario 4: In all future years, F is set equal to the average of the five most recent years. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
- Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.) Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):
- Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is 1) above its MSY level in 2022 or 2) above 1/2 of its MSY level in 2022 and expected to be above its MSY level in 2032 under this scenario, then the stock is not overfished.)
- Scenario 7: In 2023 , F is set equal to max F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is 1) above its MSY level in 2024 or 2) above 1/2 of its MSY level in 2024 and expected to be above its MSY level in 2034 under this scenario, then the stock is not approaching an overfished condition.)

These projections are shown as figures for Model 22.0 (Figure 26, Figure 27) and Model 22.1 (Figure 28, Figure 29), and as tables (Table 27 and Table 28).

ABC and OFL for 2023 and 2024

Models 13.4, 22.0, and 22.1 all indicate that the Aleutian Islands Pacific cod stock is being not subjected to overfishing and not overfished. If fishing continues at its average rate for the past 5 years, female spawning biomass is predicted to be above $B_{35\%}$ (Table 27, Table 28, Figure 26, Figure 27, Figure 28, Figure 29, Figure 30, Figure 31).

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 reasonably well. A trawl survey was conducted in 2022 for the first time since 2018. Age structured models provide a much more comprehensive picture of the state of the stock than the random effects model, which simply fits the survey biomass indices.

Assessment considerations were rated as level 1 due to recent survey data and a range of assessment models that provide relatively consistent results.

Population Dynamics Considerations

The long-term (1991-2022) trawl survey biomass trend is downward and the 2022 index is the lowest of the entire time series. The AFSC longline survey index shows a strong decline since 2020, and the 2022 index is also the lowest of the entire time series (Figure 18).

How well the longline survey targets Pacific cod uncertain, given that the gear is designed to target sablefish. The depth range of sablefish is deeper than cod, 150-2500 m, whereas Pacific cod prefer 100-200 m. Nonetheless, the longline survey does fish in depths preferred by Pacific cod. The hook size used on the longline survey is 13.0, and the fishery generally uses the same size, although it can range between 12/0 and 14/0. The longline survey does not sample throughout the entire Aleutian Islands (covering only roughly half of the area) and is notorious for variable sampling due to gear loss.

Overall, fishery CPUE indicates a decline in CPUE in the past several years (Figure 3, (Figure 4). Interpretation of population dynamics using fishery CPUE can be complicated, and there is not necessarily a clear relationship between the two. Fishery length frequencies also provide information on the relative size of fish encountered, and in 2021 the fish appeared to be smaller than average, but larger than fish encountered in 2020.

Population dynamics considerations were rated as level 2.

Environmental/Ecosystem Considerations

Environment: The average bottom temperature from the Aleutian Islands bottom trawl survey (165°W – 172°E, 30-500 m) was ~4.4°C, similar to 2018 and cooler than the highest observed in 2016 but still above the long term mean, as have the last four surveys (2014 onwards). Mid-depth (100-300m) and water column temperature (surface to bottom) from the longline survey (164°W to 180°W) and bottom trawl survey, respectively show a similar pattern, with warmer temperatures throughout the water column starting in 2014. Surface temperature also reflects an increasing trend in temperatures in the Aleutian Islands (Figure 32). Most of the year through August has been under some level of heatwave in the central and western Aleutians, less so in the eastern Aleutians. This is in sharp contrast to the GOA where only a few days were under marine heatwave (Bond et al. 2022).

Pacific cod are typically found between 3.5–5.7°C (range 2.8 to 6.9°C) and an average depth of 164 m (range 22 – 435) in the Aleutian Islands based on data from the bottom trawl survey. In general, higher ambient temperatures incur bioenergetic costs for ectothermic fish. However, Holsman and Aydin (2015) found adult Pacific cod consumption in the Aleutian Islands increases up to 4°C and decreases past 5°C. Above long-term average temperatures throughout the water column and during both winter and summer is considered to have negative effect. 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).

Prey: Atka mackerel are primarily planktivorous fish, feeding largely on copepods and euphausiids followed by pelagic amphipods and pelagic gelatinous filter feeders. The high reproductive success of planktivorous seabirds such as auklets in Buldir 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 (Bond et al. 2022), 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. Both the biomass and condition of Atka mackerel improved this year compared to 2018 and this might have in turn contributed to the improved condition of Pacific cod. The increase of sculpin and shrimp biomass, towards the eastern Aleutians may have also supported this improvement. Compared to that in 2018, the condition of cod improved across all areas but not enough to match the long-term average, which means cod condition has now remained below average since 2012, except potentially in the Southern Bering

Sea (slighty above average). Walleye pollock, still an important prey in the southern Bering Sea, remains below the long-term average in terms of biomass and condition and this may be hindering its recovery.

As a generalist, Pacific cod is able to compensate the lower availability of any one type of prey, having the ability to easily switch between fish and benthic crustacean prey. The increase in prey quantity and quality may be offset by the dominance of rockfish (POP and Northern Rockfish) within the pelagic foragers, comprised of a larger proportion of pollock and Atka mackerel in the early 1990s. This year, piscivorous/cephalopod-eating tufted puffins continued to have above average reproductive success at Buldir (western Aleutians) as in Aiktak (eastern Aleutians) along with piscivorous common murres, indicating that forage fish to support chick-rearing was available this year. Seabird success suggests broad availability of prey, particularly in the eastern Aleutians where at least half the Pacific cod stock is typically distributed (Rojek et al. 2022).

Taken together, improved condition, prey quantity and quality, as well as seabird data suggest that conditions are potentially improving for Pacific cod. However, the increased temperatures may have a negative effect, as was seen in the Gulf of Alaska during the most recent series of heat waves. The next few years will confirm whether conditions will sustain the reversal of the negative trend in fish condition and bring it back to average or above average despite temperatures remaining above those at or before 2012. Considering both this year and past trends in indicators suggests there still remain some adverse signals relevant to the stock, but the pattern is not consistent across all areas.

Competitors and predators: Among the fish apex predators, piscivores and invertivores continue declining except for sculpins and sablefish (Ortiz, 2022). As of 2018, Steller sea lions were declining in the western Aleutians offset by increases in the east (Sweeney and Gelatt 2018), and harbor seals are also declining (London et al. 2018). Tufted puffins are reproducing successfully but their abundance trend is unknown as is that of common murres, particularly given the die-offs in recent years (Rojek et al. 2022).

Environmental/ecosystem considerations were rated as level 2 (some indicators showing an adverse signal relevant to the stock but the pattern is not consistent across all indicators).

Fishery Performance Considerations

Trends in CPUE can be examined for evidence of population trends, although other factors can affect CPUE besides population dynamics. The trends in CPUE are available from fishery data through 2022, and consistently indicate a downward trend (Figure 3, Figure 4). However, a single report from the Aleutian Islands state GHL fishery indicated good fishing in 2022.

However, the fishery reports that lack of CV trawl effort in the Aleutian Islands is not due to lack of interest. The Aleutian Islands fishery often gets pre-empted by the Bering Sea fishery given the later timing of aggregation in the Aleutians and the lack of an Aleutian set-aside of the CV sector appointment. For the trawl CVs, the early part of the A season catch rates in the Bering Sea are often better. By March, CPUE for trawl CVs is generally better in the Aleutian Islands. Unfortunately the CV trawl cod fishery in the Aleutian Islands is often closed by then.

In some years (e.g. 2020) the BSAI CV trawl fleet took a large portion or all of their A season quota in the Bering Sea before the Aleutian Islands cod aggregate (for spawning). The Adak processor was closed in 2020 through 2022, and is unlikely to open for the 2023 A season, so no local processing plant is available. This results in fewer smaller pot and hook-and-line vessels unless a floating processor or tender is available to assist.

Fishery performance considerations were rated as level 1.

Risk Summary

The ratings of the four categories are summarized below:

Because some components of the Risk Table are greater than level 1, ABC may need to be reduced from the maximum permissible value. In 2020 and 2021 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. While

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

the authors request consideration of the age structured models presented here, the recommended ABC is the Tier 5 ABC.

Area Allocation of ABC

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 Aleutian Islands 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. Since 2018, the Area 543 proportion has been calculated the Model 13.4 most recent estimate of biomass in Area 543 relative to the estimate from the total area. Using Aleutian Islands trawl survey data from 1991 - 2022, this proportion is 25%. This represents an increase, as 15.7% has been used since 2018.

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 (2021) is 14264 t. This is less than the 2020 AI OFL of 27,400 t (and also the AI ABC of 20,600). 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. If the status changes to Tier 3, it would not be considered subjected to overfishing.

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 2022 in each of these tables are incomplete, through the end of October 2022. The Pacific cod fishery using trawl gear Table 29 and fixed gear Table 30 take a small proportion of the incidental catch of FMP species (1991-2022). During some years from 1991-2022, the proportional catch of octopus and longnose skate was high in the Pacific cod trawl (Table 31) and longline (Table 32) 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 33). Discard mortality of halibut taken in the Pacific cod fishery from 1991-2022, aggregated across gear types, has declined during this time period. The proportion of incidental catch of non-target species groups taken from 2003-2022, excluding bird species, aggregated across gear types Table 34 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 35.

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

Gear	EBS	AI	GOA
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

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. Resolving poor retrospective patterns will improve the age structured models.

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Tables

Table 1: Reference points based on Model 22.0 for Aleutian Islands Pacific cod.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2022	2023	2023	2024
M (natural mortality rate)	0.34	0.34	0.35	0.35
Tier	5	5	3b	3b
Projected total (age 1+) biomass (t)	80,700	80,700	69,589 t	82,581 t
Projected female spawning biomass (t)	-	-	25,313	27,978
$B_{100\%}$	-	-	108,231	108,231
$B_{40\%}$	-	-	43,292	43,292
$B_{35\%}$	-	-	37,880	37,880
F_{OFL}	0.34	0.34	0.287	0.472
$maxF_{ABC}$	0.255	0.255	0.235	0.263
F_{ABC}	0.255	0.255	0.235	0.263
OFL	27,400	27,400	10,908	17,237
$maxABC$	20,600	20,600	9,071	11,385
ABC	20,600	20,600	9,071	11,385
Status	2020	2021	2021	2022
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Note: Last year's assessment incorporated a Tier 5 model. Projections were based on annual catches of 11,138 t for 2022 and the ABC for 2023.

Table 2: Reference points based on Model 22.1 for Aleutian Islands Pacific cod.

	As estimated or *specified* *last* year for:		As estimated or *recommended* *this* year for:	
Quantity	2022	2023	2023	2024
M (natural mortality rate)	0.34	0.34	0.36	0.36
Tier	5	5	3b	3b
Projected total (age 1+) biomass (t)	80,700	80,700	119,058 t	105,517 t
Projected female spawning biomass (t)	-	-	44,208	38,402
$B_{100\%}$	-	-	116,421	116,421
$B_{40\%}$	-	-	46,568	46,568
$B_{35\%}$	-	-	40,747	40,747
F_{OFL}	0.34	0.34	0.536	0.391
$maxF_{ABC}$	0.255	0.255	0.444	0.325
F_{ABC}	0.255	0.255	0.444	0.325
OFL	27,400	27,400	34,562	22,507
$maxABC$	20,600	20,600	29,479	19,113
ABC	20,600	20,600	29,479	19,113
Status	2020	2021	2021	2022
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Note: Last year's assessment incorporated a Tier 5 model. Projections were based on annual catches of 11,138 t for 2022 and the ABC for 2023.

Table 3: Catch of Pacific cod in the Aleutian Islands by foreign, domestic, and joint venture fisheries, 1964-1980. Note that joint venture fisheries did not commence until 1981, and domestic catch information is not available prior to 1988.

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 4: 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 5: Federal and state fishery Pacific cod catch in metric tons by year, 1991-2022. 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 2022 are through October 23.

Year	Federal		State	Total
	Trawl	Longline+Pot	Total	
1	1991	3,414	3,203	9,798
2	1992	14,559	22,108	43,068
3	1993	17,312	16,860	34,205
4	1994	14,383	7,009	21,539
5	1995	10,574	4,935	16,534
6	1996	21,179	5,819	31,609
7	1997	17,349	7,151	25,164
8	1998	20,531	13,771	34,726
9	1999	16,437	7,874	28,130
10	2000	20,362	16,183	39,685
11	2001	15,827	17,817	34,207
12	2002	27,929	2,865	30,801
13	2003	31,478	976	32,457
14	2004	25,770	3,103	28,873
15	2005	19,613	3,067	22,694
16	2006	20,062	3,584	24,211
17	2007	28,631	4,711	34,355
18	2008	21,826	5,705	31,229
19	2009	20,822	5,749	28,582
20	2010	18,872	7,719	29,006
21	2011	9,382	1,277	10,889
22	2012	12,139	3,376	18,220
23	2013	8,123	1,817	13,612
24	2014	6,766	417	10,583
25	2015	6,129	3,080	9,210
26	2016	11,535	1,696	13,232
27	2017	8,537	3,781	15,170
28	2018	10,119	3,282	20,414
29	2019	10,294	2,427	19,187
30	2020	4,319	3,587	14,264
31	2021	3,422	3,366	13,966
32	2022	3,176	1,588	10,547

Table 6: Summary of 1994-2022 catches (t) of Pacific cod in the AI, by NMFS statistical area (area breakdowns not available prior to 1994). Catches for 2022 are through October 23.

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	47	2,884	10,682	0.003	0.212	0.785
2014	29	1,039	9,514	0.003	0.098	0.899
2015	3,170	2,364	3,676	0.344	0.257	0.399
2016	2,550	1,607	9,074	0.193	0.121	0.686
2017	3,371	3,768	8,031	0.222	0.248	0.529
2018	2,695	4,066	13,654	0.132	0.199	0.669
2019	1,339	5,293	12,555	0.070	0.276	0.654
2020	1,972	5,131	7,161	0.138	0.360	0.502
2021	1,715	3,750	8,502	0.123	0.268	0.609
2022	725	2,823	6,999	0.069	0.268	0.664

Table 7: Discards (t) and discard rates for the Aleutian Islands Pacific cod fishery, for the period 1993-October 23, 2022 . Note that Amendment 49, which mandated increased retention and utilization, was implemented in 1998.

Year	Discards (t)	Total catch (t)	Proportion discarded
1993	1,508	4,208	0.358
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	253	13,612	0.019
2014	122	10,583	0.012
2015	95	9,210	0.010
2016	104	13,232	0.008
2017	150	15,170	0.010
2018	273	20,414	0.013
2019	137	19,187	0.007
2020	142	14,264	0.010
2021	179	13,966	0.013
2022	138	10,547	0.013

Table 8: Pacific cod catch in metric tons by year, total allowable catch (TAC), acceptable biological catch (ABC), and overfishing limit (OFL), 1991-2022. 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 2022 is through October 23. ABC and OFL for 2022 are based on this year's model output. TAC from 2022 is based on harvest specifications from 2021.

Year	Catch (t)	ABC	TAC	OFL
1991	9,797	229,000	229,000	-
1992	43,067	182,000	182,000	188,000
1993	34,204	164,500	164,500	192,000
1994	21,539	191,000	191,000	228,000
1995	16,534	328,000	250,000	390,000
1996	31,609	305,000	270,000	420,000
1997	25,164	306,000	270,000	418,000
1998	34,726	210,000	210,000	336,000
1999	28,130	177,000	177,000	264,000
2000	39,684	193,000	193,000	240,000
2001	34,207	188,000	188,000	248,000
2002	30,800	223,000	200,000	294,000
2003	32,456	223,000	207,500	324,000
2004	28,873	223,000	215,500	350,000
2005	22,693	206,000	206,000	365,000
2006	24,211	194,000	189,768	230,000
2007	34,354	176,000	170,720	207,000
2008	31,228	176,000	170,720	207,000
2009	28,581	182,000	176,540	212,000
2010	29,006	174,000	168,780	205,000
2011	10,888	235,000	227,950	272,000
2012	18,220	314,000	261,000	369,000
2013	13,608	307,000	260,000	359,000
2014	10,603	15,100	6,997	20,100
2015	9,216	17,600	9,422	23,400
2016	13,245	17,600	12,839	23,400
2017	15,202	21,500	15,695	28,700
2018	20,414	21,500	15,695	28,700
2019	19,200	20,600	14,214	27,400
2020	14,250	20,600	13,796	27,400
2021	12,882	20,600	13,796	27,400
2022	10,547	20,600	13,796	27,400

Table 9: Sources of data used in the age structured models, Model 22.0 and 22.1.

Source	Type	Years
Fishery (Trawl, Pot, LL)	Catch biomass	1991-2022*
Fishery (Trawl, Pot, LL)	Length composition	1991-2022
AI bottom trawl survey	Biomass estimate + Length composition	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018, 2022
Longline survey	Abundance index + Length composition	1996, 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012, 2014, 2016, 2018, 2020, 2022
AI bottom trawl survey	Age composition	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018
Fishery (Trawl)	Age composition	2020
Fishery (Pot, LL)	Age composition	2020, 2021

Table 10: Aleutian Islands bottom trawl survey biomass estimates and standard error by NMFS area 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
2022	13,661	14,041	23,837	51,539

Proportion by area				
Year	Western	Central	Eastern	Total
1991	0.419	0.221	0.360	1
1994	0.155	0.336	0.509	1
1997	0.197	0.415	0.388	1
2000	0.341	0.287	0.371	1
2002	0.321	0.336	0.343	1
2004	0.117	0.252	0.631	1
2006	0.230	0.260	0.511	1
2010	0.382	0.201	0.417	1
2012	0.229	0.251	0.519	1
2014	0.246	0.115	0.639	1
2016	0.234	0.231	0.535	1
2018	0.141	0.253	0.606	1
2022	0.265	0.272	0.463	1

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
2022	0.202	0.159	0.227	0.126

Table 11: Aleutian Islands bottom trawl biomass estimates (t) and longline survey relative population numbers and standard error for Pacific cod, for all years used in the model.

Year	Trawl Survey		Longline Survey	
Year	Biomass (t)	S.E.	Index	S.E..1
1991	180,170	0.140		-
1992		-		-
1993		-		-
1994	153,416	0.204		-
1995		-		-
1996		-	88,627	0.113
1997	72,848	0.133		-
1998		-	131,813	0.086
1999		-		-
2000	126,870	0.183	167,593	0.099
2001		-		-
2002	73,551	0.163	84,667	0.137
2003		-		-
2004	82,219	0.198	69,171	0.148
2005		-		-
2006	84,861	0.282	102,621	0.096
2007		-		-
2008		-	77,184	0.164
2009		-		-
2010	55,826	0.187	83,973	0.132
2011		-		-
2012	58,911	0.147	82,422	0.111
2013		-		-
2014	73,608	0.185	98,559	0.200
2015		-		-
2016	84,409	0.182	129,751	0.120
2017		-		-
2018	81,272	0.158	168,708	0.141
2019		-		-
2020		-	109,521	0.086
2021		-		-
2022	51,539	0.126	63,701	0.137

Table 12: The number of hauls in which otoliths were taken for the fishery age composition data and used in the current model, by year, followed by the number of individual fish per year and survey or fishery gear type. Note no age data was available for the current year.

Year	Trawl	Pot	Longline	Trawl.Survey
1991	0	0	0	121/575
1992	0	0	0	0
1993	0	0	0	0
1994	0	0	0	150/681
1995	0	0	0	0
1996	0	0	0	0
1997	0	0	0	99/557
1998	0	0	0	0
1999	0	0	0	0
2000	0	0	0	111/598
2001	0	0	0	0
2002	0	0	0	173/673
2003	0	0	0	0
2004	0	0	0	107/754
2005	0	0	0	0
2006	0	0	0	105/775
2007	0	0	0	0
2008	0	0	0	0
2009	0	0	0	0
2010	0	0	0	94/1270
2011	0	0	0	0
2012	0	0	0	83/828
2013	0	0	0	0
2014	0	0	0	76/845
2015	0	0	0	0
2016	0	0	0	95/1174
2017	0	0	0	0
2018	0	0	0	80/919
2019	0	0	0	0
2020	1/6	27/46	6/194	0
2021	0	23/31	4/165	0
2022	0	0	0	0

Table 13: The number of hauls in which length observations were taken for the fishery length composition data, by year.

Year	Trawl	Longline	Pot
1991	47	137	57
1992	171	200	200
1993	174	340	-
1994	115	398	3
1995	109	267	210
1996	128	317	415
1997	150	241	22
1998	258	1167	36
1999	455	663	491
2000	713	1624	165
2001	469	2297	169
2002	731	421	-
2003	1002	207	-
2004	707	540	-
2005	564	435	-
2006	468	525	28
2007	776	622	-
2008	478	672	-
2009	472	732	-
2010	486	1161	110
2011	271	178	-
2012	289	320	-
2013	195	306	-
2014	143	99	-
2015	100	378	-
2016	283	122	-
2017	144	454	-
2018	134	440	109
2019	115	249	21
2020	7	340	73
2021	5	311	89
2022	11	65	18

Table 14: Maturity at age ogives based on Stark (2007) and observer maturity at length data from 2008-2021. Observer-based maturity curves were used in Models 22.0 and 22.1.

Age	Stark 2007	Observer data
1	0.0230021	0.0069392
2	0.0582223	0.0739067
3	0.1396620	0.2914285
4	0.2988668	0.5947725
5	0.5281452	0.8288139
6	0.7461343	0.9378730
7	0.8852892	0.9771243
8	0.9529746	0.9904192
9	0.9815542	0.9951047
10	0.9928941	0.9973929

Table 15: Comparison of the Richards, Von Bertalanffy, Gompertz, and Logistic growth curves fit to raw length at age data for Pacific cod. The sum of squared residuals were fit to each individual data point (SSR) and the mean of the data at each age (SSRmean). The Akaike Information criterion, AIC (Akaike, 1974) and the number of parameters are presented for each model.

	Richards	Von Bertalanffy	Gompertz	Logistic
SSR	696.649853	700.963949	700.664739	713.820945
SSRmean	6.673260	3.603178	4.135476	7.188336
Number of parameters	4.000000	3.000000	3.000000	3.000000
AIC	-5.092566	-7.104913	-7.104059	-7.141264

Table 16: Estimates of natural mortality, M, for Pacific cod throughout their range. Values marked with asterisks * have been used in stock assessments.

Region	Reference Author	Year	M estimate
EBS*	Low	1974	0.375
EBS	Wespestad et al.	1982	0.700
EBS	Bakkala and Wespestad	1985	0.450
EBS	Thompson and Shimada	1990	0.290
EBS	Thompson and Methot	1993	0.370
EBS*	Shimada and Kimura	1994	0.960
EBS*	Shi et al.	2007	0.450
EBS	Thompson et al.	2007	0.340
EBS	Thompson	2016	0.360
GOA	Thompson and Zenger	1993	0.270
GOA	Thompson and Zenger	1995	0.500
GOA	Thompson et al.	2007	0.380
GOA*	Barbeaux et al.	2016	0.470
BC*	Ketchen	1964	0.595
BC*	Fournier	1983	0.650
Korea*	Jung et al.	2009	0.820
Japan*	Ueda et al.	2004	0.200

Table 17: Key parameter values estimated in Model 22.1.

	X	Number	Parameter	Value	StDev
1	1	1	NatM_uniform_Fem_GP_1	0.3623210	0.0125412
2	2	2	L_at_Amin_Fem_GP_1	11.6698000	1.2977200
3	3	3	L_at_Amax_Fem_GP_1	113.4960000	0.5162950
4	4	4	VonBert_K_Fem_GP_1	0.2342230	0.0043392
5	5	5	SD_young_Fem_GP_1	8.8102800	0.4795030
6	6	6	SD_old_Fem_GP_1	4.4589300	0.2453800
7	7	7	Wtlen_1_Fem_GP_1	0.0000056	-
8	8	8	Wtlen_2_Fem_GP_1	3.1756000	-
9	9	9	Mat50%_Fem_GP_1	54.9000000	-
10	10	10	Mat_slope_Fem_GP_1	-0.1472000	-
11	11	11	Eggs/kg_inter_Fem_GP_1	1.0000000	-
12	12	12	Eggs/kg_slope_wt_Fem_GP_1	0.0000000	-
13	13	13	CohortGrowDev	1.0000000	-
14	14	14	AgeKeyParm1	3.0000000	-
15	15	15	AgeKeyParm2	0.0000000	-
16	16	16	AgeKeyParm3	0.0000000	-
17	17	17	AgeKeyParm4	0.0000000	-
18	18	18	AgeKeyParm5	0.5700000	-
19	19	19	AgeKeyParm6	1.1600000	-
20	20	20	AgeKeyParm7	0.0000000	-
21	21	21	FracFemale_GP_1	0.5000000	-
22	22	22	SR_LN(R0)	10.5689000	0.0997626
23	23	23	SR_BH_steep	1.0000000	-
24	24	24	SR_sigmaR	0.6360000	-
25	25	25	SR_regime	0.0000000	-
26	26	26	SR_autocorr	0.0000000	-
27	27	27	Main_RecrDev_1991	0.0172014	0.1204140
28	28	28	Main_RecrDev_1992	-0.7506520	0.2150820
29	29	29	Main_RecrDev_1993	0.6399190	0.0805537
30	30	30	Main_RecrDev_1994	0.2257630	0.1081670
31	31	31	Main_RecrDev_1995	-0.1608900	0.1300210
32	32	32	Main_RecrDev_1996	0.5640580	0.0794452
33	33	33	Main_RecrDev_1997	0.7642040	0.0674153
34	34	34	Main_RecrDev_1998	-0.3215400	0.1306770
35	35	35	Main_RecrDev_1999	0.3890880	0.0836864
36	36	36	Main_RecrDev_2000	0.6234930	0.0729424
37	37	37	Main_RecrDev_2001	-0.0044762	0.1029430
38	38	38	Main_RecrDev_2002	-0.4306410	0.1232520
39	39	39	Main_RecrDev_2003	-0.1444910	0.0972293
40	40	40	Main_RecrDev_2004	-0.6929730	0.1518480
41	41	41	Main_RecrDev_2005	-0.0075123	0.0887930
42	42	42	Main_RecrDev_2006	-0.7794540	0.1530110
43	43	43	Main_RecrDev_2007	0.1364270	0.0902202
44	44	44	Main_RecrDev_2008	-0.1486220	0.1093250
45	45	45	Main_RecrDev_2009	-1.0664100	0.1934970
46	46	46	Main_RecrDev_2010	-0.6128970	0.1481050
47	47	47	Main_RecrDev_2011	-0.3010670	0.1294140
48	48	48	Main_RecrDev_2012	-0.2677700	0.1274960
49	49	49	Main_RecrDev_2013	-0.3529880	0.1379230
50	50	50	Main_RecrDev_2014	-0.0843030	0.1246870
51	51	51	Main_RecrDev_2015	-0.1166460	0.1362230

52	52	52	Main_RecrDev_2016	-0.3584190	0.1497250
53	53	53	Main_RecrDev_2017	-0.3279130	0.1535740
54	54	54	Late_RecrDev_2018	-0.8815680	0.2267010
55	55	55	Late_RecrDev_2019	-0.2628330	0.1993380
56	56	56	Late_RecrDev_2020	-0.6223680	0.3747710
57	57	57	Late_RecrDev_2021	-0.5809200	0.4402840
58	58	58	Late_RecrDev_2022	0.0000000	0.6360000
59	59	59	ForeRecr_2023	0.0000000	0.6360000
74	74	74	LnQ_base_Srv(4)	-0.0198271	0.0099061

Table 18: Key parameter values estimated in Model 22.0.

	X	Number	Parameter	Value	StDev
1	1	1	NatM_uniform_Fem_GP_1	0.3515650	0.0143484
2	2	2	L_at_Amin_Fem_GP_1	11.2578000	1.0902300
3	3	3	L_at_Amax_Fem_GP_1	113.4910000	0.6914860
4	4	4	VonBert_K_Fem_GP_1	0.2427270	0.0046606
5	5	5	SD_young_Fem_GP_1	9.7146100	0.4724320
6	6	6	SD_old_Fem_GP_1	4.7262200	0.2947400
7	7	7	Wtlen_1_Fem_GP_1	0.0000056	-
8	8	8	Wtlen_2_Fem_GP_1	3.1756000	-
9	9	9	Mat50%_Fem_GP_1	54.9000000	-
10	10	10	Mat_slope_Fem_GP_1	-0.1472000	-
11	11	11	Eggs/kg_inter_Fem_GP_1	1.0000000	-
12	12	12	Eggs/kg_slope_wt_Fem_GP_1	0.0000000	-
13	13	13	CohortGrowDev	1.0000000	-
14	14	14	AgeKeyParm1	3.0000000	-
15	15	15	AgeKeyParm2	0.0000000	-
16	16	16	AgeKeyParm3	0.0000000	-
17	17	17	AgeKeyParm4	0.0000000	-
18	18	18	AgeKeyParm5	0.5700000	-
19	19	19	AgeKeyParm6	1.1600000	-
20	20	20	AgeKeyParm7	0.0000000	-
21	21	21	FracFemale_GP_1	0.5000000	-
22	22	22	SR_LN(R0)	10.3824000	0.1086450
23	23	23	SR_BH_steep	1.0000000	-
24	24	24	SR_sigmaR	0.6360000	-
25	25	25	SR_regime	0.0000000	-
26	26	26	SR_autocorr	0.0000000	-
27	27	27	Main_RecrDev_1991	0.1479170	0.1104360
28	28	28	Main_RecrDev_1992	-0.2200340	0.1382600
29	29	29	Main_RecrDev_1993	0.6619030	0.0887016
30	30	30	Main_RecrDev_1994	0.2841420	0.1140870
31	31	31	Main_RecrDev_1995	0.2001380	0.1115110
32	32	32	Main_RecrDev_1996	0.6748410	0.0880654
33	33	33	Main_RecrDev_1997	0.7284630	0.0807968
34	34	34	Main_RecrDev_1998	0.2267270	0.1016420
35	35	35	Main_RecrDev_1999	0.4126010	0.0905497
36	36	36	Main_RecrDev_2000	0.4426070	0.0887388
37	37	37	Main_RecrDev_2001	0.3035070	0.0918650
38	38	38	Main_RecrDev_2002	-0.4383050	0.1334870
39	39	39	Main_RecrDev_2003	-0.1349290	0.1054480
40	40	40	Main_RecrDev_2004	-0.8846910	0.1777340
41	41	41	Main_RecrDev_2005	-0.0264533	0.0963821
42	42	42	Main_RecrDev_2006	-0.7430760	0.1458110
43	43	43	Main_RecrDev_2007	-0.0232619	0.0930203
44	44	44	Main_RecrDev_2008	-0.1324800	0.1030980
45	45	45	Main_RecrDev_2009	-0.7834720	0.1426680
46	46	46	Main_RecrDev_2010	-0.7998350	0.1352760
47	47	47	Main_RecrDev_2011	-0.5907840	0.1181600
48	48	48	Main_RecrDev_2012	-0.7552320	0.1286220
49	49	49	Main_RecrDev_2013	-0.5409890	0.1183020
50	50	50	Main_RecrDev_2014	-0.5080760	0.1253140
51	51	51	Main_RecrDev_2015	-0.5351310	0.1416790

52	52	52	Main_RecrDev_2016	-0.9824800	0.2058030
53	53	53	Main_RecrDev_2017	-0.4250740	0.1861960
54	54	54	Late_RecrDev_2018	-0.6131820	0.2660090
55	55	55	Late_RecrDev_2019	-0.3449520	0.2828600
56	56	56	Late_RecrDev_2020	-0.9007210	0.3990550
57	57	57	Late_RecrDev_2021	-0.5839750	0.4600500
58	58	58	Late_RecrDev_2022	0.0000000	0.6360000
74	74	74	LnQ_base_Srv(2)	-0.0154397	0.0099196

Table 19: Biomass (t) estimated by Model 13.4, 1991 - 2022, with lower (UCI) and upper (UCI) 95% confidence bounds.

Year	Model 13.4 (2022)			Model 13.4 (2021)		
Year	Biomass	LCI	UCI	Biomass	LCI	UCI
1991	170,412	131,161	221,409	169,669	130,207	221,090
1992	157,871	111,872	222,783	157,157	111,812	220,891
1993	146,253	102,574	208,531	145,567	102,580	206,568
1994	135,489	100,338	182,955	134,832	99,904	181,971
1995	115,674	82,021	163,134	115,515	82,448	161,844
1996	98,757	71,032	137,304	98,965	71,605	136,781
1997	84,314	65,809	108,023	84,787	65,982	108,952
1998	89,856	64,974	124,266	89,988	65,473	123,683
1999	95,762	68,543	133,791	95,509	68,821	132,547
2000	102,057	76,706	135,786	101,368	76,177	134,890
2001	91,215	67,032	124,121	90,998	67,212	123,201
2002	81,524	63,532	104,613	81,688	63,719	104,726
2003	80,943	59,321	110,447	80,987	59,651	109,954
2004	80,366	60,815	106,203	80,291	60,838	105,964
2005	78,539	55,680	110,782	78,401	55,854	110,049
2006	76,753	54,613	107,868	76,555	54,615	107,310
2007	72,424	48,903	107,258	72,365	49,211	106,414
2008	68,339	45,739	102,104	68,405	46,155	101,381
2009	64,484	44,547	93,344	64,661	44,942	93,033
2010	60,847	45,775	80,881	61,123	45,955	81,296
2011	61,382	45,020	83,691	61,649	45,371	83,768
2012	61,923	48,936	78,355	62,180	49,091	78,760
2013	66,480	49,261	89,718	66,768	49,715	89,670
2014	71,373	54,984	92,647	71,695	55,363	92,843
2015	74,778	54,756	102,122	75,517	55,666	102,449
2016	78,346	59,957	102,376	79,544	61,132	103,502
2017	77,234	56,560	105,465	80,117	58,848	109,073
2018	76,137	58,905	98,410	80,694	61,710	105,518
2019	69,924	49,488	98,799	80,694	53,535	121,632
2020	64,218	44,432	92,817	80,694	48,234	134,998
2021	58,978	42,053	82,714	80,694	44,240	147,187
2022	54,165	42,782	68,577	-	-	-

Table 20: Likelihood component values and lambdas used in Model 22.0 and 22.1.

	Model 22.0		Model 22.1	
Parameter names	Value	Lambda	Value	Lambda
TOTAL	1.59315e+03	-	2.03022e+03	-
Catch	0.00000e+00	-	0.00000e+00	-
Equil_catch	0.00000e+00	-	0.00000e+00	-
Survey	5.22022e+01	-	6.77303e+01	-
Length_comp	3.88286e+02	-	8.01255e+02	-
Age_comp	8.97521e+02	-	1.12293e+03	-
Size_at_age	2.25784e+02	-	0.00000e+00	-
Recruitment	3.21754e+00	1	3.68011e-01	1
InitEQ_Regime	0.00000e+00	1	0.00000e+00	1
Forecast_Recruitment	3.36533e+00	1	3.16641e+00	1
Parm_priors	1.94967e+00	1	2.92170e+00	1
Parm_softbounds	5.69290e-03	-	2.09765e-02	-
Parm_devs	2.08174e+01	1	3.18297e+01	1
Crash_Pen	0.00000e+00	1	0.00000e+00	1

Table 21: Estimates of total biomass for Models 22.0 and 22.1, with upper and lower 95% confidence intervals.

Year	Model 22.0	Model 22.1
	Biomass (t)	Biomass (t)
1989	261,521	281,350
1990	261,521	281,350
1991	261,521	281,350
1992	252,704	272,494
1993	215,699	234,851
1994	192,518	208,932
1995	185,722	197,661
1996	189,889	197,814
1997	183,615	187,763
1998	186,772	186,747
1999	186,509	183,800
2000	196,385	192,237
2001	194,197	187,624
2002	192,683	186,141
2003	192,925	189,924
2004	187,366	187,374
2005	177,746	179,835
2006	166,757	170,897
2007	149,128	156,350
2008	121,642	131,644
2009	100,666	113,809
2010	87,183	103,865
2011	76,639	95,064
2012	81,279	99,962
2013	75,945	95,035
2014	73,032	94,407
2015	72,720	98,593
2016	73,853	105,435
2017	72,833	111,733
2018	70,546	117,328
2019	63,238	117,295
2020	58,865	116,652
2021	61,028	117,721
2022	64,293	117,618

Table 22: Estimates of female spawning biomass for Models 22.0 and 22.1, with upper and lower 95% confidence intervals.

Year	Model 22.0			Model 22.1		
	Biomass (t)	LCI	UCI	Biomass	LCI	UCI
1989	219,576	201,582	237,569	232,842	216,218	249,465
1990	219,576	201,582	237,569	232,842	216,218	249,465
1991	218,061	200,065	236,056	231,334	214,707	247,960
1992	204,452	186,410	222,493	217,823	201,135	234,510
1993	171,558	153,604	189,511	184,997	168,284	201,709
1994	152,187	134,777	169,596	165,302	149,042	181,561
1995	146,241	130,140	162,341	156,921	142,191	171,650
1996	143,114	128,304	157,923	148,446	135,358	161,533
1997	138,081	124,111	152,050	139,429	127,449	151,408
1998	139,404	125,938	152,869	138,687	127,413	149,960
1999	135,621	122,383	148,858	131,168	120,295	142,040
2000	140,662	126,882	154,441	133,343	122,252	144,433
2001	144,044	129,735	158,352	136,556	125,225	147,886
2002	145,289	130,892	159,685	135,864	124,486	147,241
2003	144,990	130,708	159,271	135,745	124,276	147,213
2004	143,889	130,159	157,618	139,623	128,450	150,795
2005	142,278	129,521	155,034	141,425	130,940	151,909
2006	135,838	124,349	147,326	136,394	126,886	145,901
2007	119,613	109,516	129,709	122,389	113,891	130,886
2008	94,029	85,287	102,771	99,569	91,850	107,287
2009	74,897	67,195	82,600	83,253	75,712	90,794
2010	60,491	53,336	67,646	71,368	63,681	79,056
2011	54,212	47,359	61,065	67,393	59,494	75,292
2012	60,307	53,270	67,345	75,218	66,903	83,534
2013	58,296	51,120	65,473	72,857	64,409	81,304
2014	56,137	48,969	63,306	70,564	62,126	79,002
2015	55,871	48,751	62,991	72,882	64,165	81,599
2016	55,459	48,411	62,507	77,349	68,180	86,518
2017	53,311	46,143	60,479	80,683	70,850	90,516
2018	50,634	42,944	58,323	83,992	73,231	94,752
2019	44,736	36,067	53,404	85,248	73,445	97,052
2020	40,312	30,534	50,090	87,347	74,650	100,044
2021	41,290	30,515	52,064	90,263	77,068	103,457
2022	44,425	32,985	55,864	90,114	76,607	103,621

Table 23: Estimates of spawning biomass relative to unfished (B/B_0) for Models 22.0 and 22.1.

Year	Model 22.0	Model 22.1
1991	0.99	0.99
1992	0.93	0.94
1993	0.78	0.79
1994	0.69	0.71
1995	0.67	0.67
1996	0.65	0.64
1997	0.63	0.60
1998	0.63	0.60
1999	0.62	0.56
2000	0.64	0.57
2001	0.66	0.59
2002	0.66	0.58
2003	0.66	0.58
2004	0.66	0.60
2005	0.65	0.61
2006	0.62	0.59
2007	0.54	0.53
2008	0.43	0.43
2009	0.34	0.36
2010	0.28	0.31
2011	0.25	0.29
2012	0.27	0.32
2013	0.27	0.31
2014	0.26	0.30
2015	0.25	0.31
2016	0.25	0.33
2017	0.24	0.35
2018	0.23	0.36
2019	0.20	0.37
2020	0.18	0.38
2021	0.19	0.39
2022	0.20	0.39
2023	0.23	0.38
2024	0.28	0.33

Table 24: Estimates of recruitment for Models 22.0 and 22.1, with upper and lower 95% confidence intervals.

Year	Model 22.0			Model 22.1		
	Recruitment	LCI	UCI	Recruitment	LCI	UCI
1989	32,286	26,110	39,923	38,907	32,012	47,286
1990	32,286	26,110	39,923	38,907	32,012	47,286
1991	37,433	28,985	48,344	39,582	30,653	51,111
1992	21,559	15,737	29,534	15,282	9,842	23,729
1993	52,077	41,808	64,868	61,391	49,940	75,468
1994	35,693	27,194	46,849	40,573	31,918	51,576
1995	32,817	25,294	42,578	27,562	20,755	36,603
1996	52,755	42,801	65,024	56,906	46,974	68,939
1997	55,661	45,012	68,830	69,516	57,987	83,337
1998	33,701	26,478	42,894	23,472	17,671	31,177
1999	40,586	32,386	50,861	47,772	38,561	59,182
2000	41,822	33,138	52,782	60,391	49,176	74,164
2001	36,391	28,651	46,222	32,229	24,938	41,651
2002	17,331	12,803	23,460	21,046	15,951	27,768
2003	23,474	18,275	30,152	28,018	22,233	35,308
2004	11,091	7,669	16,039	16,189	11,822	22,170
2005	26,163	20,843	32,841	32,131	25,910	39,846
2006	12,778	9,352	17,459	14,848	10,824	20,369
2007	26,247	20,964	32,861	37,106	29,671	46,403
2008	23,531	18,346	30,182	27,903	21,605	36,035
2009	12,272	8,964	16,801	11,144	7,462	16,642
2010	12,073	8,933	16,315	17,539	12,689	24,242
2011	14,880	11,338	19,529	23,957	17,974	31,933
2012	12,623	9,478	16,813	24,768	18,557	33,058
2013	15,710	12,083	20,426	22,847	16,958	30,781
2014	16,980	12,932	22,296	31,261	23,671	41,284
2015	17,285	12,850	23,249	31,654	23,569	42,511
2016	11,557	7,636	17,492	25,995	18,863	35,824
2017	21,106	14,561	30,593	28,029	20,391	38,530
2018	17,487	10,401	29,401	16,112	10,232	25,371
2019	22,867	13,255	39,446	29,914	19,893	44,983
2020	13,117	6,101	28,200	20,880	10,162	42,901
2021	18,005	7,511	43,157	21,764	9,358	50,613
2022	32,286	10,158	102,610	38,907	12,268	123,383

Table 25: Estimated numbers at age for Aleutian Islands Pacific cod, Model 22.0.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Total
1991	0	31354	22060	15521	10921	7684	5406	3804	2676	1883	4469	101309
1992	0	36353	22059	15492	10799	7478	5198	3641	2560	1801	4275	105379
1993	0	20936	25564	15350	10258	6603	4328	2957	2066	1452	3447	89515
1994	0	50574	14724	17842	10331	6461	3915	2489	1685	1176	2788	109197
1995	0	34663	35575	10309	12182	6724	4029	2393	1513	1024	2408	108413
1996	0	31870	24385	24963	7140	8199	4370	2545	1486	933	2108	105891
1997	0	51232	22416	17055	16982	4579	4902	2473	1396	804	1636	121839
1998	0	54054	36041	15723	11753	11198	2843	2884	1403	777	1344	136677
1999	0	32729	38015	25149	10556	7310	6434	1554	1544	747	1128	124038
2000	0	39414	23024	26626	17147	6765	4367	3667	868	858	1041	122736
2001	0	40615	27715	16061	17933	10739	3874	2314	1845	424	912	121520
2002	0	35341	28565	19293	10590	10833	6149	2189	1306	1041	754	115306
2003	0	16831	24863	20039	13238	6842	6478	3474	1205	713	978	93683
2004	0	22796	11840	17439	13796	8671	4163	3664	1859	623	852	84851
2005	0	10771	16033	8283	11911	8963	5296	2409	2045	1017	796	66727
2006	0	25408	7577	11249	5704	7833	5578	3173	1420	1200	1063	69144
2007	0	12409	17871	5299	7654	3680	4784	3291	1845	823	1310	57656
2008	0	25490	8728	12480	3567	4761	2085	2525	1672	924	1061	62231
2009	0	22852	17924	6085	8351	2188	2629	1056	1213	783	917	63080
2010	0	11918	16071	12495	4045	4989	1147	1242	470	527	731	52905
2011	0	11725	8381	11196	8266	2363	2461	484	470	167	429	45514
2012	0	14451	8249	5882	7721	5422	1439	1399	263	249	312	45076
2013	0	12259	10166	5778	3982	4765	2981	730	686	128	272	41475
2014	0	15257	8625	7140	3993	2609	2866	1647	381	347	199	42865
2015	0	16490	10734	6062	4967	2679	1643	1683	916	205	287	45380
2016	0	16786	11596	7509	4155	3274	1685	991	986	527	279	47510
2017	0	11224	11810	8140	5176	2713	1967	935	521	504	406	42990
2018	0	20497	7894	8252	5492	3231	1540	1035	471	258	447	48669
2019	0	16982	14409	5462	5296	3074	1597	715	472	214	320	48219
2020	0	22207	11944	10025	3548	2962	1481	711	311	204	231	53393
2021	0	12738	15619	8297	6424	1978	1525	750	360	157	220	47848
2022	0	17486	8958	10843	5383	3698	1040	776	379	182	191	48744
2023	0	31354	12299	6264	7344	3394	2139	563	405	195	191	63959
2024	0	31354	22058	8638	4359	5007	2259	1397	364	260	248	75697

Table 26: Estimated numbers at age for Aleutian Islands Pacific cod, Model 22.1.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Total
1991	0	37750	26276	18290	12731	8861	6168	4293	2988	2080	4764	119438
1992	0	38405	26276	18271	12614	8636	5944	4122	2867	1995	4569	119129
1993	0	14828	26729	18189	12108	7673	4993	3397	2352	1636	3745	91905
1994	0	59566	10320	18521	12177	7653	4656	2936	1952	1334	3027	119116
1995	0	39367	41459	7164	12600	7968	4834	2864	1780	1176	2623	119213
1996	0	26743	27399	28800	4910	8376	5150	3063	1789	1101	2328	107330
1997	0	55214	18612	19000	19429	3116	5006	2941	1695	971	1835	125984
1998	0	67449	38431	12929	12959	12726	1950	2982	1675	934	1498	152035
1999	0	22774	46942	26601	8596	8008	7393	1076	1578	862	1221	123830
2000	0	46352	15851	32579	17959	5439	4759	4192	590	850	1110	128572
2001	0	58596	32259	10986	21780	10969	3034	2491	2090	284	904	142489
2002	0	31271	40780	22269	7187	13186	6279	1666	1336	1110	629	125083
2003	0	20420	21766	28328	15184	4643	7863	3468	875	685	883	103231
2004	0	27185	14213	15124	19417	9980	2833	4380	1775	419	700	95325
2005	0	15708	18920	9852	10273	12674	6140	1626	2360	910	540	78463
2006	0	31176	10934	13144	6742	6778	7952	3661	934	1327	806	82647
2007	0	14407	21699	7590	8962	4429	4249	4739	2087	515	1143	68677
2008	0	36003	10027	15051	5127	5710	2617	2314	2402	1004	754	80255
2009	0	27073	25057	6946	10050	3173	3261	1383	1141	1121	774	79206
2010	0	10813	18843	17362	4641	6230	1796	1666	643	494	769	62488
2011	0	17018	7526	13046	11469	2767	3303	841	700	251	462	56921
2012	0	23245	11845	5232	8966	7630	1746	1960	473	380	375	61478
2013	0	24032	16179	8222	3534	5652	4441	950	1020	241	381	64272
2014	0	22168	16728	11245	5613	2289	3446	2579	534	563	340	65165
2015	0	30331	15430	11633	7729	3719	1449	2095	1516	306	508	74209
2016	0	30713	21112	10718	7964	5165	2426	916	1277	894	457	81184
2017	0	25222	21377	14676	7360	5279	3245	1437	517	700	727	79815
2018	0	27196	17556	14848	9976	4750	3231	1898	810	284	767	80548
2019	0	15634	18929	12187	10006	6225	2745	1771	1006	421	541	68923
2020	0	29025	10881	13138	8219	6267	3624	1528	964	542	517	74188
2021	0	20259	20201	7542	8834	5217	3815	2166	906	569	625	69511
2022	0	21117	14101	14012	5086	5623	3187	2294	1295	541	712	67256
2023	0	37750	14698	9796	9559	3312	3527	1970	1411	795	769	82818
2024	0	37750	26274	10177	6481	5702	1791	1779	946	656	708	91556

Table 27: Projections of Aleutian Islands Pacific cod female future catch, full selection fishing mortality rates (F), and spawning biomass (SSB) for seven future harvest scenarios, based on Model 22.0. Estimates of SSB and catch are in metric tons (t).

Year	Scenarios						
Catch	1	2	3	4	5	6	7
2022	10547.1	10547.1	10547.1	10547.10	10547.1	10547.1	10547.1
2023	25591.0	25591.0	15323.5	6751.08	13600.7	30291.1	25591.0
2024	19308.3	19308.3	14200.1	7385.64	12980.0	20733.9	19308.3
2025	17737.5	17737.5	14226.1	7981.96	13348.7	18580.6	21144.6
2026	19984.2	19984.2	16251.9	8713.65	15613.4	21079.5	22202.9
2027	24027.8	24027.8	18760.6	9732.55	18215.9	25471.9	25852.6
2028	27280.2	27280.2	20252.7	10768.90	19475.0	28765.0	28804.0
2029	29164.4	29164.4	21578.3	11766.30	20492.5	30438.1	30395.8
2030	29743.2	29743.2	22479.7	12520.20	21174.0	30828.1	30791.8
2031	29894.8	29894.8	23117.9	13118.90	21668.3	30875.0	30857.8
2032	29932.7	29932.7	23564.1	13586.10	22028.7	30871.2	30865.9
2033	29871.9	29871.9	23810.1	13884.60	22240.3	30812.0	30812.1
2034	29829.7	29829.7	23946.6	14075.30	22365.6	30780.8	30781.9
2035	29813.5	29813.5	24022.7	14197.20	22440.1	30772.4	30773.1
2036	29810.6	29810.6	24065.1	14275.10	22484.4	30772.8	30773.0
2037	29811.8	29811.8	24088.7	14324.80	22510.7	30774.6	30774.6

Year	Scenarios						
F	1	2	3	4	5	6	7
2022	0.128040	0.128040	0.128040	0.1280400	0.128040	0.128040	0.128040
2023	0.401796	0.401796	0.219722	0.0954191	0.153426	0.489635	0.401797
2024	0.344428	0.344428	0.210903	0.0999145	0.149660	0.396897	0.344428
2025	0.329037	0.329037	0.210861	0.1024290	0.150572	0.373937	0.401256
2026	0.353226	0.353226	0.226955	0.1024290	0.161914	0.403374	0.414726
2027	0.392538	0.392538	0.240388	0.1024290	0.172445	0.449956	0.453429
2028	0.421061	0.421061	0.240388	0.1024290	0.172445	0.481502	0.481774
2029	0.436328	0.436328	0.240388	0.1024290	0.172445	0.496326	0.495927
2030	0.440714	0.440714	0.240388	0.1024290	0.172445	0.499490	0.499170
2031	0.441789	0.441789	0.240388	0.1024290	0.172445	0.499771	0.499624
2032	0.442053	0.442053	0.240388	0.1024290	0.172445	0.499709	0.499665
2033	0.441564	0.441564	0.240388	0.1024290	0.172445	0.499188	0.499190
2034	0.441233	0.441233	0.240388	0.1024290	0.172445	0.498919	0.498929
2035	0.441108	0.441108	0.240388	0.1024290	0.172445	0.498849	0.498856
2036	0.441087	0.441087	0.240388	0.1024290	0.172445	0.498855	0.498857
2037	0.441097	0.441097	0.240388	0.1024290	0.172445	0.498871	0.498871

Year	Scenarios						
SSB	1	2	3	4	5	6	7
2022	41794.35	41794.35	41794.35	41794.35	41794.35	41794.35	41794.35
2023	40927.70	40927.70	41835.35	42518.95	42015.55	40483.55	40927.70
2024	35654.70	35654.70	40292.55	44390.40	41076.15	33616.65	35654.70
2025	34205.40	34205.40	40281.10	46760.30	41272.65	31856.90	33918.50
2026	36423.45	36423.45	43092.70	51409.50	44043.10	34029.15	34885.75
2027	40043.55	40043.55	47393.10	57824.50	48112.40	37495.85	37756.20
2028	42657.25	42657.25	51246.00	64009.50	51623.50	39833.75	39854.45
2029	44049.60	44049.60	54534.50	69680.00	54710.50	40928.70	40899.45
2030	44448.60	44448.60	56724.00	73861.50	56825.50	41162.50	41139.00
2031	44546.35	44546.35	58271.00	77155.00	58414.00	41183.80	41173.00
2032	44570.40	44570.40	59359.50	79729.00	59607.50	41179.50	41176.25
2033	44526.05	44526.05	59960.00	81373.50	60307.00	41141.20	41141.35
2034	44495.90	44495.90	60293.00	82424.50	60721.00	41121.40	41122.15
2035	44484.60	44484.60	60478.50	83096.00	60967.00	41116.25	41116.75
2036	44482.70	44482.70	60582.00	83525.50	61113.50	41116.65	41116.80
2037	44483.65	44483.65	60639.50	83799.50	61200.50	41117.85	41117.85

Table 28: Projections of Aleutian Islands Pacific cod female future catch, full selection fishing mortality rates (F), and spawning biomass (SSB) for seven future harvest scenarios, based on Model 22.1. Estimates of SSB and catch are in metric tons (t).

Year	Scenarios						
Catch	1	2	3	4	5	6	7
2022	10547.1	10547.1	10547.1	10547.10	10547.1	10547.1	10547.1
2023	25591.0	25591.0	15323.5	6751.08	13600.7	30291.1	25591.0
2024	19308.3	19308.3	14200.1	7385.64	12980.0	20733.9	19308.3
2025	17737.5	17737.5	14226.1	7981.96	13348.7	18580.6	21144.6
2026	19984.2	19984.2	16251.9	8713.65	15613.4	21079.5	22202.9
2027	24027.8	24027.8	18760.6	9732.55	18215.9	25471.9	25852.6
2028	27280.2	27280.2	20252.7	10768.90	19475.0	28765.0	28804.0
2029	29164.4	29164.4	21578.3	11766.30	20492.5	30438.1	30395.8
2030	29743.2	29743.2	22479.7	12520.20	21174.0	30828.1	30791.8
2031	29894.8	29894.8	23117.9	13118.90	21668.3	30875.0	30857.8
2032	29932.7	29932.7	23564.1	13586.10	22028.7	30871.2	30865.9
2033	29871.9	29871.9	23810.1	13884.60	22240.3	30812.0	30812.1
2034	29829.7	29829.7	23946.6	14075.30	22365.6	30780.8	30781.9
2035	29813.5	29813.5	24022.7	14197.20	22440.1	30772.4	30773.1
2036	29810.6	29810.6	24065.1	14275.10	22484.4	30772.8	30773.0
2037	29811.8	29811.8	24088.7	14324.80	22510.7	30774.6	30774.6

Year	Scenarios						
F	1	2	3	4	5	6	7
2022	0.128040	0.128040	0.128040	0.1280400	0.128040	0.128040	0.128040
2023	0.401796	0.401796	0.219722	0.0954191	0.153426	0.489635	0.401797
2024	0.344428	0.344428	0.210903	0.0999145	0.149660	0.396897	0.344428
2025	0.329037	0.329037	0.210861	0.1024290	0.150572	0.373937	0.401256
2026	0.353226	0.353226	0.226955	0.1024290	0.161914	0.403374	0.414726
2027	0.392538	0.392538	0.240388	0.1024290	0.172445	0.449956	0.453429
2028	0.421061	0.421061	0.240388	0.1024290	0.172445	0.481502	0.481774
2029	0.436328	0.436328	0.240388	0.1024290	0.172445	0.496326	0.495927
2030	0.440714	0.440714	0.240388	0.1024290	0.172445	0.499490	0.499170
2031	0.441789	0.441789	0.240388	0.1024290	0.172445	0.499771	0.499624
2032	0.442053	0.442053	0.240388	0.1024290	0.172445	0.499709	0.499665
2033	0.441564	0.441564	0.240388	0.1024290	0.172445	0.499188	0.499190
2034	0.441233	0.441233	0.240388	0.1024290	0.172445	0.498919	0.498929
2035	0.441108	0.441108	0.240388	0.1024290	0.172445	0.498849	0.498856
2036	0.441087	0.441087	0.240388	0.1024290	0.172445	0.498855	0.498857
2037	0.441097	0.441097	0.240388	0.1024290	0.172445	0.498871	0.498871

Year	Scenarios						
SSB	1	2	3	4	5	6	7
2022	41794.35	41794.35	41794.35	41794.35	41794.35	41794.35	41794.35
2023	40927.70	40927.70	41835.35	42518.95	42015.55	40483.55	40927.70
2024	35654.70	35654.70	40292.55	44390.40	41076.15	33616.65	35654.70
2025	34205.40	34205.40	40281.10	46760.30	41272.65	31856.90	33918.50
2026	36423.45	36423.45	43092.70	51409.50	44043.10	34029.15	34885.75
2027	40043.55	40043.55	47393.10	57824.50	48112.40	37495.85	37756.20
2028	42657.25	42657.25	51246.00	64009.50	51623.50	39833.75	39854.45
2029	44049.60	44049.60	54534.50	69680.00	54710.50	40928.70	40899.45
2030	44448.60	44448.60	56724.00	73861.50	56825.50	41162.50	41139.00
2031	44546.35	44546.35	58271.00	77155.00	58414.00	41183.80	41173.00
2032	44570.40	44570.40	59359.50	79729.00	59607.50	41179.50	41176.25
2033	44526.05	44526.05	59960.00	81373.50	60307.00	41141.20	41141.35
2034	44495.90	44495.90	60293.00	82424.50	60721.00	41121.40	41122.15
2035	44484.60	44484.60	60478.50	83096.00	60967.00	41116.25	41116.75
2036	44482.70	44482.70	60582.00	83525.50	61113.50	41116.65	41116.80
2037	44483.65	44483.65	60639.50	83799.50	61200.50	41117.85	41117.85

Table 29: 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, 1991-2021 (2022 data current through October 30). Note: RE=rougheye, NR=northern, SR=shortraker, SC=sharpchin.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Alaska Plaice	-	-	-	-	-	-	-	-	-	-	-	0.75	-	1.00	1.00
Other Flatfish	-	-	-	-	0.00	0.01	0.03	0.80	0.47	0.48	0.19	0.53	0.29	0.29	0.25
RE Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.04
SR Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.02
Skate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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	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 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	-	-
Shortraker/Rougheye/Sharpchin/Northern Rockfish	0.02	0.65	0.00	-	0.00	-	0.00	-	-	-	-	-	-	-	-
Slope Rockfish	-	0.16	-	-	-	-	-	-	-	-	-	-	-	-	-
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	2021
Alaska Plaice	1.00	0.27	1.00	0.24	0.00	-	1.00	1.00	1.00	-	1.00	0.00	0.00	0.98	1.00	-
Other Flatfish	0.29	0.37	0.28	0.06	0.04	0.01	0.16	0.05	0.16	0.00	0.03	0.01	0.10	0.07	0.09	0.00
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	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	0.00
Skate	-	-	-	-	-	0.01	0.02	0.01	0.00	0.00	0.02	0.01	0.00	0.01	0.01	0.00
Squid	0.07	0.02	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
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	0.07	0.24
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	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	0.00
Octopus	-	-	-	-	-	0.14	0.16	0.00	0.00	0.02	0.04	0.01	0.00	0.01	0.00	0.00
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	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	0.09	0.08
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	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	0.03
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	0.58	0.01	0.03
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	0.00
Sculpin	-	-	-	-	-	0.05	0.06	0.04	0.02	0.01	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	0.00
SC/NR Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SR/RE Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shortraker/Rougheye/Sharpchin/Northern Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Slope Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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	0.00

Table 30: 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, 1993-2021 (2022 data current through October 30). Note: RE=rougheye, NR=northern, SR=shortraker, SC=sharpchin.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Other Flatfish	-	-	-	-	0.00	0.01	0.22	0.06	0.06	0.13	0.29	0.01	0.00	0.32	0.00
RE Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	0.14	0.02
SR Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.09
Skate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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 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	0.00	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	0.00	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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	-	-
Shortraker/Rougheye/Sharpchin/Northern Rockfish	0.21	0.01	0.00	-	0.00	-	0.00	-	-	-	-	-	-	-	-
Slope Rockfish	-	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-
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	2021
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	0.01	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	0.34	0.12	0.06	0.12	0.09
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	0.04	0.12
Skate	-	-	-	-	-	0.12	0.29	0.17	0.03	0.24	0.16	0.23	0.22	0.22	0.36	0.44
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	0.12	0.12
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	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	0.01	0.00
Octopus	-	-	-	-	-	0.79	0.50	0.43	0.37	0.78	0.45	0.20	0.04	0.15	0.06	0.18
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	0.05	0.07
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	0.25	0.19
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	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	0.02	0.01
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	0.01	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	0.01	0.02
Sculpin	-	-	-	-	-	0.17	0.39	0.38	0.12	0.40	0.14	0.32	0.23	0.26	0.32	-
Shark	-	-	-	-	-	0.02	0.12	0.01	0.01	0.24	0.00	0.06	0.03	0.01	0.02	0.01
SC/NR Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SR/RE Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shortraker/Rougheye/Sharpchin/Northern Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Slope Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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	0.00

Table 31: Incidental catch of selected "Other Species" complex species taken in the AI Pacific cod trawl fisheries, 1991-2021 (2022 data current through October 30), expressed as a ratio of bycatch in all fisheries and gears.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
octopus, North Pacific	-	-	-	-	-	-	-	-	1.00	1.00	1.00	0.76	0.30	0.31	0.65
Pacific sleeper shark	-	-	-	-	-	-	-	-	-	0.06	-	1.00	0.00	0.30	0.62
shark, other	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	-
shark, salmon	-	-	-	-	-	-	-	-	-	1.00	-	-	0.00	-	0.00
shark, spiny dogfish	-	-	-	-	-	-	-	-	-	-	-	0.00	0.26	0.00	0.00
skate, Alaskan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
skate, Aleutian	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
skate, big	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	1.00
skate, longnose	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.49
skate, other	-	-	-	-	-	-	-	-	0.98	1.00	1.00	0.29	0.14	0.10	0.10
skate, Whiteblotched	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
squid, majestic	0	0.01	0.02	0	0	0	0.01	0.03	0.01	0.05	0.33	0.05	0.10	0.11	0.07

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
octopus, North Pacific	0.07	0.14	0.18	0.07	0.02	0.14	0.16	0.00	0.00	0.02	0.04	0.01	0.00	0.01	0.00	0
Pacific sleeper shark	0.00	0.01	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0
shark, other	-	-	-	0.00	-	-	-	-	-	-	-	-	0.00	-	-	0
shark, salmon	0.00	0.00	-	0.29	0.00	0.39	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0
shark, spiny dogfish	0.09	0.00	0.00	0.00	0.02	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0
skate, Alaskan	-	-	-	-	0.06	0.11	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0
skate, Aleutian	-	-	-	-	-	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
skate, big	0.22	0.02	0.25	0.01	0.00	-	1.00	-	-	0.00	-	-	-	1.00	0.00	-
skate, longnose	0.00	-	0.00	0.76	0.00	-	0.00	-	-	0.00	-	-	-	-	0.00	-
skate, other	0.10	0.10	0.03	0.04	0.01	0.01	0.03	0.02	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0
skate, Whiteblotched	-	-	-	-	-	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0
squid, majestic	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-

Table 32: Incidental catch of selected “Other Species” complex species taken in the AI Pacific cod longline fisheries, 1991-2021 (2022 data current through October 30), expressed as a ratio of bycatch in all fisheries and gears.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
octopus, North Pacific	-	-	-	-	-	-	-	-	0	0	0	0.14	0.43	0.42	0.32
Pacific sleeper shark	-	-	-	-	-	-	-	-	-	0	-	0.00	0.00	0.00	0.02
shark, other	-	-	-	-	-	-	-	-	-	-	-	-	0.00	1.00	-
shark, salmon	-	-	-	-	-	-	-	-	-	0	-	-	0.00	-	0.00
shark, spiny dogfish	-	-	-	-	-	-	-	-	-	-	-	0.00	0.45	0.96	1.00
skate, Alaskan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
skate, Aleutian	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
skate, big	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00
skate, longnose	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	0.51
skate, other	-	-	-	-	-	-	-	-	0	0	0	0.04	0.16	0.46	0.48
skate, Whiteblotched	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
squid, majestic	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
octopus, North Pacific	0.27	0.45	0.23	0.50	0.47	0.79	0.50	0.43	0.37	0.78	0.45	0.20	0.04	0.15	0.07	0.19
Pacific sleeper shark	0.38	0.01	0.04	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	-
shark, other	-	-	-	0.00	-	-	-	-	-	-	-	-	0.00	-	-	-
shark, salmon	0.00	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.00	0.00	0.00	0.00	0.00	-
shark, spiny dogfish	0.66	0.87	0.55	0.84	0.92	0.43	0.66	0.21	0.05	0.86	0.03	0.17	0.79	0.35	1.00	1.00
skate, Alaskan	-	-	-	-	0.52	0.11	0.08	0.10	0.07	0.17	0.03	0.07	0.19	0.29	1.00	1.00
skate, Aleutian	-	-	-	-	-	0.23	0.24	0.07	0.04	0.13	0.01	0.03	0.04	0.13	0.98	1.00
skate, big	0.11	0.00	0.00	0.00	0.55	-	0.00	-	-	0.59	-	-	-	0.00	1.00	-
skate, longnose	1.00	-	1.00	0.24	1.00	-	0.00	-	-	1.00	-	-	-	-	1.00	-
skate, other	0.34	0.54	0.38	0.58	0.58	0.12	0.41	0.22	0.03	0.32	0.27	0.34	0.30	0.30	0.97	1.00
skate, Whiteblotched	-	-	-	-	-	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.01	1.00	1.00
squid, majestic	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	-	-	-

Table 33: Incidental catch (herring and halibut in tons, 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	2001	2002	2003	2004	2005
Bairdi Tanner Crab	0.30	0.57	0.70	0.96	0.87	0.91	0.94	1.00	1.00	1.00	0.86	0.99	0.95	1.00	0.98
Blue King Crab	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-	0.30
Chinook Salmon	0.01	0.02	0.15	0.03	0.23	0.17	0.46	0.71	0.90	1.00	0.46	0.68	0.80	0.73	0.80
Golden (Brown) King Crab	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.01
Halibut	0.52	0.81	0.42	0.44	0.46	0.57	0.53	0.82	0.57	0.48	0.74	0.28	0.16	-	-
Herring	0.00	0.00	1.00	0.00	0.00	-	0.00	-	-	1.00	-	-	0.01	-	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	0.22	0.76	0.18	0.44	0.12
Opilio Tanner (Snow) Crab	0.40	0.30	0.51	0.02	0.01	0.19	0.25	0.52	0.30	0.26	0.34	0.69	0.82	1.00	0.85
Other King Crab	0.08	0.24	0.04	0.05	0.04	0.10	0.00	0.06	0.23	0.07	0.13	0.03	-	-	-
Red King Crab	0.21	0.08	0.33	0.14	0.11	0.05	0.89	0.83	0.98	0.43	0.94	0.97	0.84	0.97	0.84

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Bairdi Tanner Crab	1.00	1.00	1.00	1.00	0.94	0.45	1.00	0.98	0.98	0.00	0.00	0.97	0.99	0.99	1.00	0.99
Blue King Crab	1.00	1.00	0.78	0.92	1.00	1.00	1.00	1.00	-	0.00	0.00	0.99	0.98	0.99	0.00	0.12
Chinook Salmon	0.87	0.72	0.83	0.82	0.75	0.55	0.65	0.94	0.62	0.41	0.57	0.21	0.05	0.04	0.00	0.00
Golden (Brown) King Crab	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.24	0.06	0.05	0.08	0.22
Halibut	-	-	-	-	0.19	0.04	0.28	0.16	0.18	0.41	0.26	0.36	0.30	0.41	0.39	0.65
Herring	0.05	0.19	0.25	0.07	0.00	-	0.00	1.00	1.00	-	-	0.00	0.00	0.01	0.98	0.00
Non-Chinook Salmon	0.34	0.56	0.21	0.17	0.02	0.38	0.00	0.02	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00
Opilio Tanner (Snow) Crab	0.99	1.00	1.00	1.00	0.99	0.98	0.99	0.91	0.81	0.00	0.00	0.99	0.98	0.95	0.99	0.99
Other King Crab	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red King Crab	0.06	0.84	0.77	0.34	0.22	0.32	0.20	0.91	0.16	0.00	0.00	0.61	0.97	0.69	0.92	0.99

Table 34: 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 1993-2021, and current through October 30 of the final year. Continued on 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	-	-
Corals Bryozoans - Corals Bryozoans Unidentified	0.41	0.38	0.24	0.33	0.47	0.29	0.38	0.27	0.08
Bryozoan Corals	0.72	0.01	0.49	0.01	0.91	0.14	0.88	0.00	0.00
Bryozoan Red Tree Coral	-	-	-	-	-	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	0.40	0.00
Grenadier - Rattail Grenadier Unidentified	0.02	0.01	0.00	0.03	0.21	0.01	0.01	0.10	0.00
Rattail Grenadier Unid.	-	-	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	-	-
Large Sculpins - Myoxocephalus Unidentified	-	-	-	-	-	0.88	1.00	-	-
Lg. Sculpins - Myoxocephalus Unid.	-	-	-	-	-	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	0.98
Saffron Cod	-	-	-	-	-	-	-	-	-
Sculpin	-	-	-	-	-	-	-	-	-
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
Squid	-	-	-	-	-	-	-	-	-
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	2021	NA
Benthic urochordata	0.04	0.15	0.01	0.01	0.04	0.00	0.03	0.00	1	1	1
Bivalves	0.76	0.14	0.11	0.32	0.33	0.04	0.21	0.05	1	1	1
Brittle star unidentified	0.00	0.04	0.01	0.00	0.00	0.12	0.00	0.00	1	1	1
Capelin	1.00	0.11	1.00	-	-	-	-	-	-	-	-
Corals Bryozoans - Corals Bryozoans Unidentified	0.09	0.08	0.02	0.10	0.08	0.13	0.25	0.05	1	1	1
Bryozoan Corals	0.00	0.00	0.00	-	-	-	0.00	-	-	-	-
Bryozoan Red Tree Coral	-	-	-	-	-	-	-	-	-	-	-
Eelpouts	0.01	0.00	0.00	0.00	0.00	0.05	0.01	0.02	1	1	-
Eulachon	1.00	-	-	-	-	-	-	-	-	-	-
Giant Grenadier	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	1	1	1
Greenlings	0.46	1.00	0.68	1.00	0.67	0.48	0.47	0.20	1	1	1
Grenadier - Pacific Grenadier	-	-	-	-	-	-	-	-	-	-	-
Grenadier - Rattail Grenadier Unidentified	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	1	1	-
Rattail Grenadier Unid.	-	0.00	-	0.00	-	0.00	-	-	1	-	-
Hermit crab unidentified	0.54	0.38	0.10	0.00	0.15	0.78	0.54	0.78	1	1	1
Invertebrate unidentified	0.00	0.00	0.01	0.76	0.00	0.51	0.00	0.01	1	1	1
Large Sculpins	-	-	-	-	-	-	-	-	-	-	-
Large Sculpins - Bigmouth Sculpin	-	-	-	-	-	-	-	-	-	-	-
Large Sculpins - Great Sculpin	-	-	-	-	-	-	-	-	-	-	-
Large Sculpins - Hemilepidotus Unidentified	-	-	-	-	-	-	-	-	-	-	-
Large Sculpins - Myoxocephalus Unidentified	-	-	-	-	-	-	-	-	-	-	-
Lg. Sculpins - Myoxocephalus Unid.	-	-	-	-	-	-	-	-	-	-	-
Large Sculpins - Red Irish Lord	-	-	-	-	-	-	-	-	-	-	-
Large Sculpins - Warty Sculpin	-	-	-	-	-	-	-	-	-	-	-
Large Sculpins - Yellow Irish Lord	-	-	-	-	-	-	-	-	-	-	-
Misc crabs	0.10	0.57	0.19	0.00	0.04	0.59	0.61	0.45	1	1	1
Misc crustaceans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	-	-
Misc fish	0.04	0.05	0.04	0.01	0.01	0.01	0.01	0.01	1	1	1
Misc inverts (worms etc)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	-	1
Other osmerids	1.00	1.00	-	-	-	-	0.00	0.00	-	-	-
Other Sculpins	-	-	-	-	-	-	-	-	-	-	-
Pacific Sand lance	-	-	-	1.00	-	-	-	-	-	-	-
Pacific Sandfish	-	-	1.00	-	-	-	-	-	-	-	-
Pandalid shrimp	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	1	-	-
Polychaete unidentified	0.26	1.00	0.00	-	0.00	0.00	0.00	0.00	1	-	-
Saffron Cod	1.00	1.00	-	-	-	-	-	0.00	-	-	1
Sculpin	-	-	-	-	-	-	-	-	-	1	1
Scypho jellies	0.83	0.97	0.65	0.00	0.05	0.85	0.70	0.30	1	1	1
Sea anemone unidentified	0.14	0.03	0.01	0.03	0.08	0.05	0.15	0.02	1	1	1
Sea pens whips	1.00	0.03	0.00	0.34	0.01	0.55	0.30	0.20	1	1	1
Sea star	0.33	0.22	0.23	0.15	0.10	0.33	0.19	0.26	1	1	1
Snails	0.28	0.29	0.16	0.06	0.10	0.67	0.52	0.43	1	1	1
Sponge unidentified	0.05	0.01	0.00	0.02	0.10	0.03	0.06	0.01	1	1	1
Squid	-	-	-	-	-	-	-	0.00	1	1	1
State-managed Rockfish	0.09	0.21	0.01	0.18	0.00	0.15	0.49	0.02	1	1	1
Stichaeidae	0.00	0.00	0.00	0.00	0.00	0.00	0.06	-	-	-	-
urchins dollars cucumbers	0.04	0.02	0.03	0.02	0.07	0.06	0.04	0.02	1	1	1

Table 35: 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 the longline, trawl, and pot gear FMP AI fisheries 2003-2021 (through October 30).

	Longline																		
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Auklet	0.00	-	-	-	-	-	-	-	-	1.00	-	0	-	-	0.00	0.00	-	-	-
Black-footed Albatross	1.00	-	-	0.00	-	-	-	1.00	0.00	-	0.00	0	0.00	-	-	-	-	-	-
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	1.00	1.00	1
Kittiwake	1.00	-	1.00	-	-	-	-	-	1.00	1.00	1.00	-	-	-	-	1.00	-	1.00	-
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	-	-	-
Murre	1.00	-	0.36	-	-	-	-	-	-	1.00	-	-	-	-	-	-	-	1.00	-
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	0.07	0.01	0.00	0.04	1
Other	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-
Other Alcid	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	-
Puffin	-	-	-	-	-	-	-	1.00	-	-	-	-	-	-	-	-	-	-	-
Shearwaters	0.10	1.00	0.89	0.00	0.07	1.00	0.21	0.08	0.26	0.26	1.00	0	0.00	0	0.11	0.00	0.14	1.00	1
Short-tailed Albatross	-	-	-	-	-	-	-	1.00	1.00	-	-	-	-	-	-	-	-	1.00	-
Storm Petrels	1.00	-	-	0.00	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	-	-
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	-	1.00	1

	Non Pelagic Trawl																		
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Auklet	-	-	-	-	-	-	-	-	0	-	0	-	-	0	0	-	-	-	-
Gull	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0	0	0	-	0	0.00	-	0	0	0	0	0
Laysan Albatross	0.00	0.43	0.00	0.00	0.00	0.26	0.00	0	0	0	0	0	0.00	0	0	-	-	-	-
Northern Fulmar	0.04	0.63	0.10	0.00	0.49	0.05	0.37	0	0	0	0	0	0.81	0	0	0	0	0	0
Unidentified	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0	0	0	-	-	-	0	0	-	0	0	0
Unidentified Albatross	-	-	1.00	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-

	Pot Gear																		
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Auklet	0	-	-	-	-	-	-	-	-	0.00	-	1.51	-	-	3.27	0.00	-	-	-
Gull	0	0	0	0.00	0.00	0.00	0.00	0.00	0	0.00	0.0	-	0	0	-	0.00	0.00	0.00	0
Northern Fulmar	0	0	0	0.00	0.63	0.43	0.58	0.12	0	0.00	0.2	0.07	0	0	0.39	0.32	0.03	1.58	0
Other	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-
Shearwaters	0	0	0	0.01	0.00	0.00	0.00	0.00	0	0.00	0.0	0.00	0	0	0.00	0.00	0.00	0.00	0
Storm Petrels	0	-	-	1.26	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	-	-
Unidentified	0	0	0	0.00	0.00	0.00	0.00	0.00	0	4.88	0.0	-	-	-	0.00	0.00	-	0.00	0

Figures

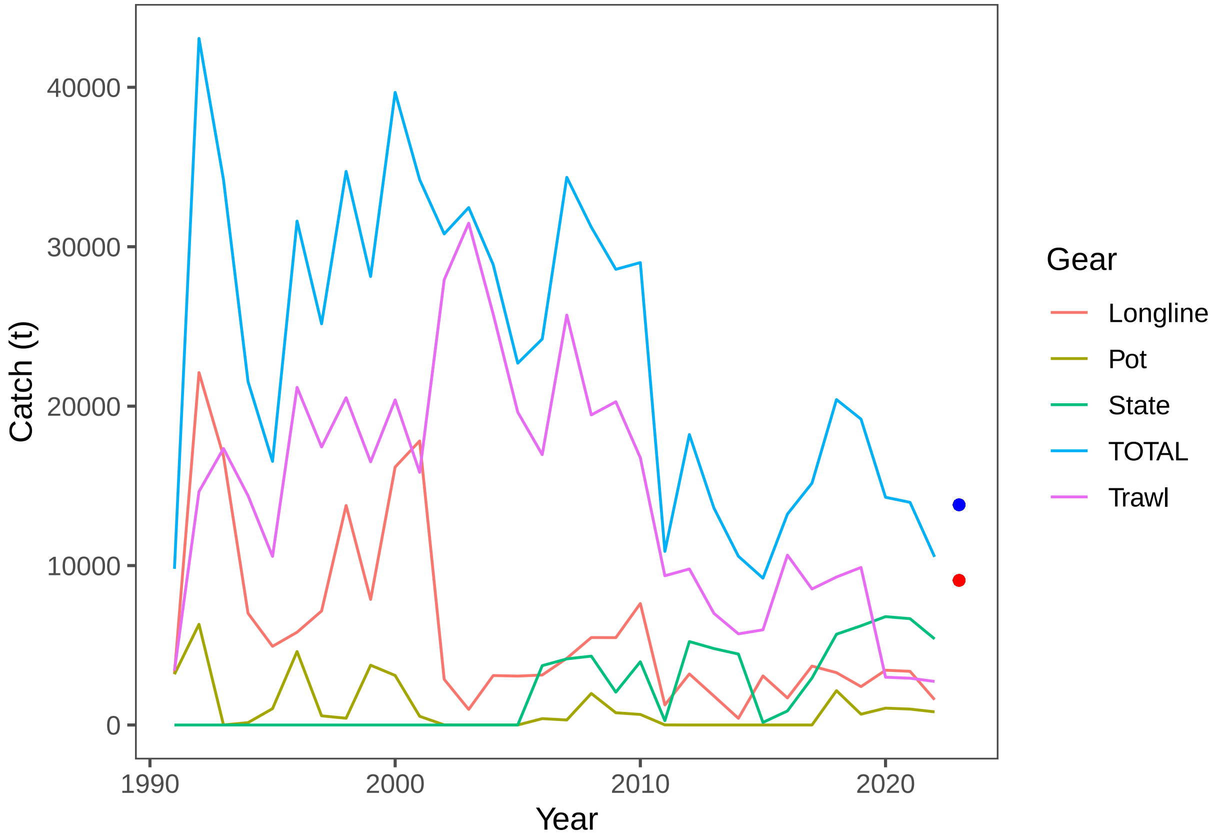


Figure 1: Aleutian Islands Pacific cod catch history, with federal catches by gear type, from 1991-2022 (through October 31). The blue dot represents the ABC for 2023 based on the Tier 5 Model, and the red dot represents the ABC for 2023 based on Model 22.0.

Figure 2: Aleutian Islands Pacific cod catch in tons by area, from 1993-2022 (through October 31).

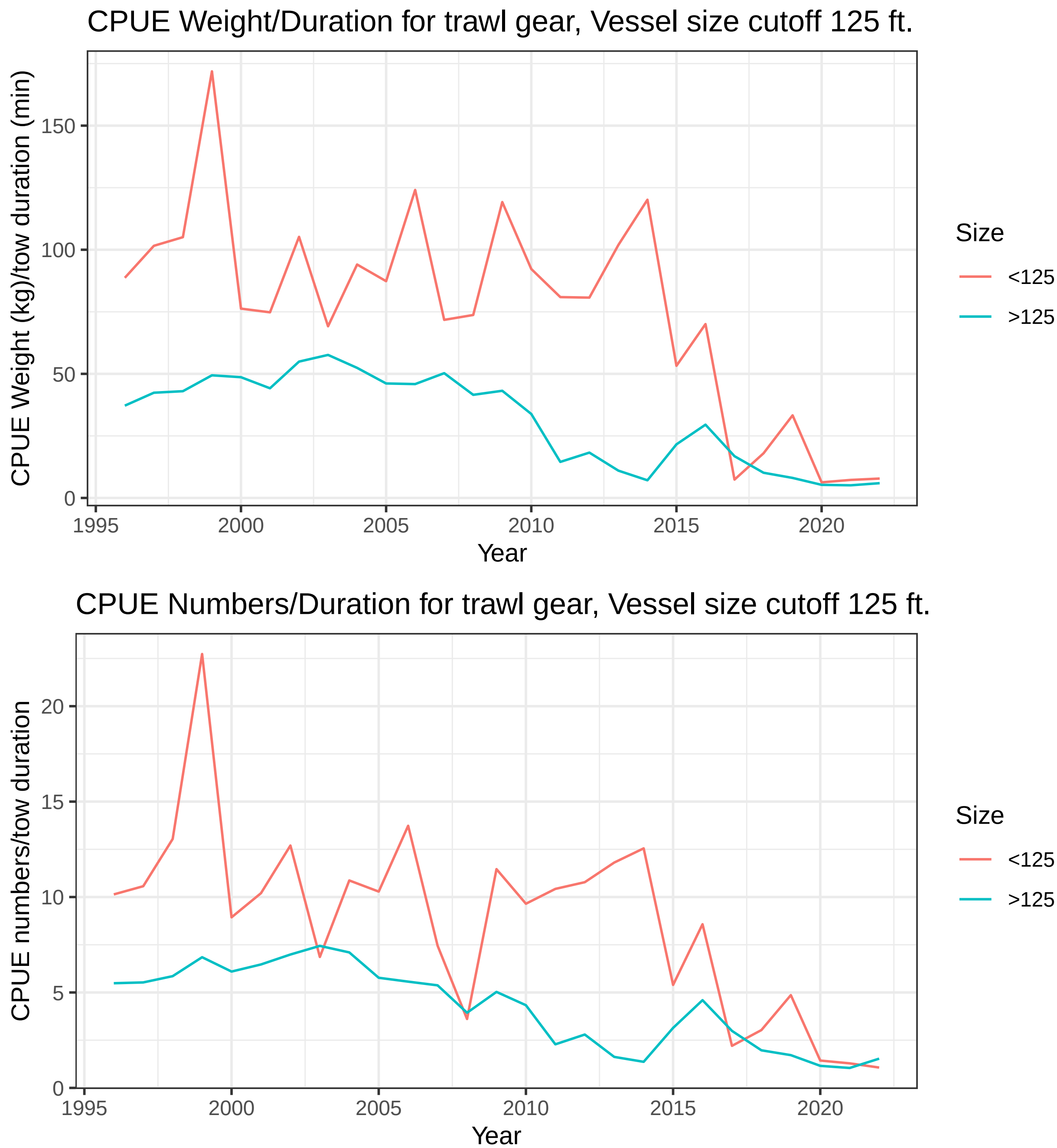
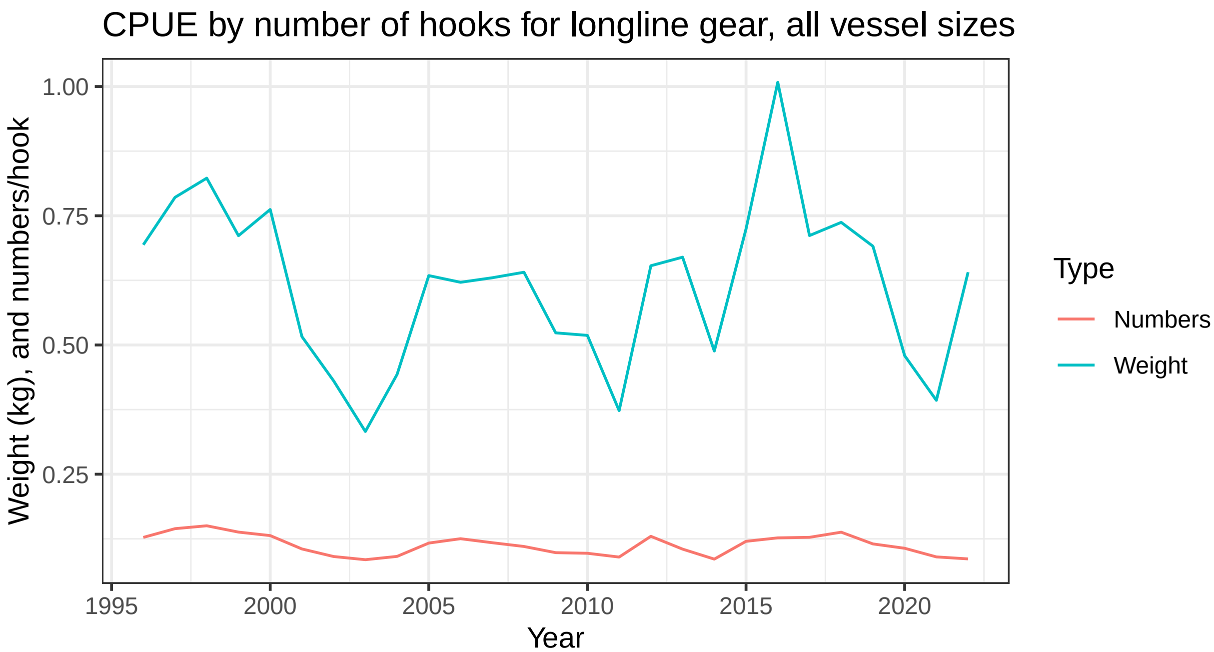


Figure 3: Catch per unit effort for AI cod fisheries, 1996-2022. The upper plot represents CPUE weight (kg)/trawl duration (min) for vessels greater and less than 125 ft. The lower panel represents CPUE numbers/trawl duration for the same vessel sizes. Only tows with duration > 0 and $<$ the 90th percentile of tow duration (909 minutes) are included. Estimates of relative CPUE are complete through October 31, 2022.



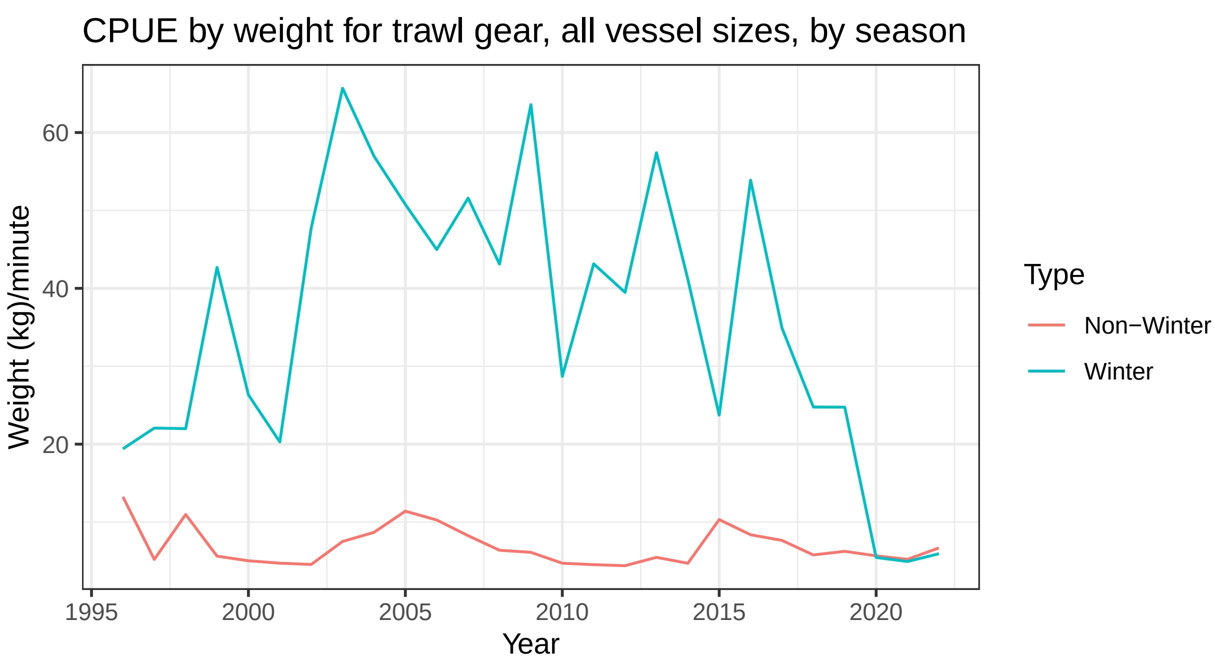
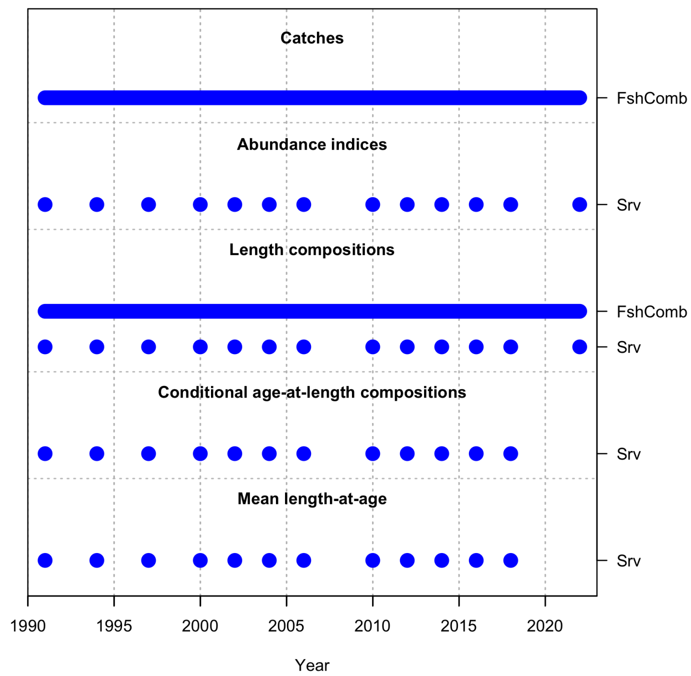


Figure 4: Catch per unit effort for AI cod fisheries, 1996-2022. The upper plot represents longline CPUE weight (kg)/number of hooks for vessels of all sizes. The lower panel represents CPUE weight/trawl duration (kg/min) for trawl vessels by season (winter and non-winter). Only tows with duration > 0 and < the 90th percentile of tow duration (909 minutes) are included. Estimates of relative CPUE were complete through October 31, 2022.



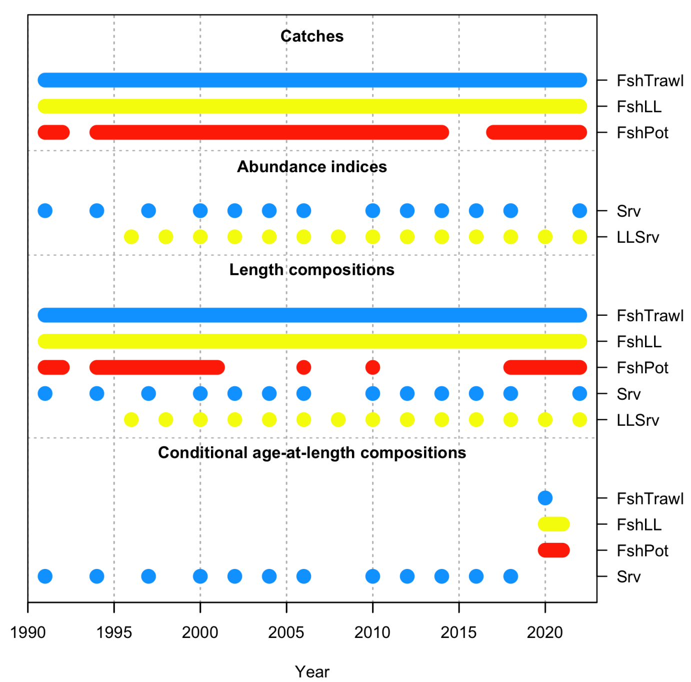


Figure 5: Data used in the models, Model 22.0 (upper panel) and Model 22.1 (lower panel).

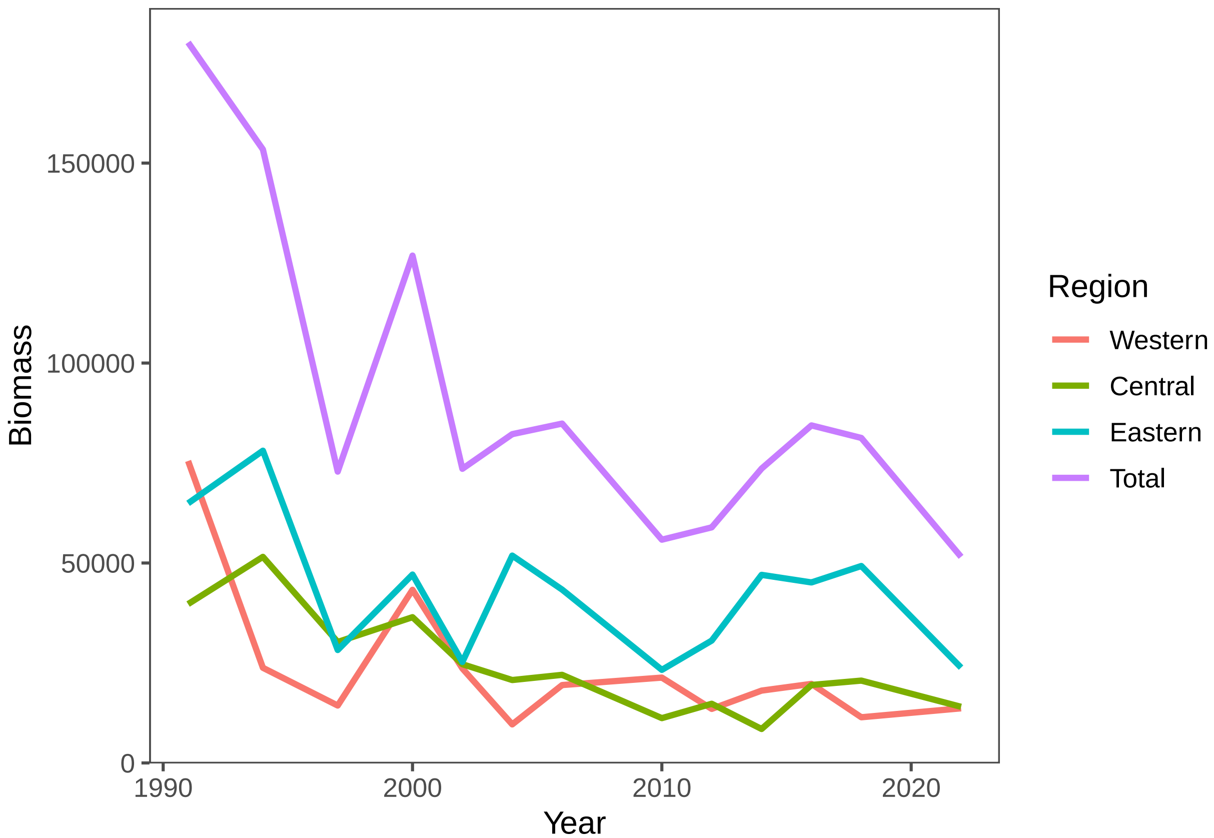


Figure 6: Aleutian Islands Pacific cod trawl survey estimates by NMFS area, 541 (eastern Aleutians), 542 (central Aleutians), and 543 (western Aleutians), 1991 - 2022, as well as the total estimate.

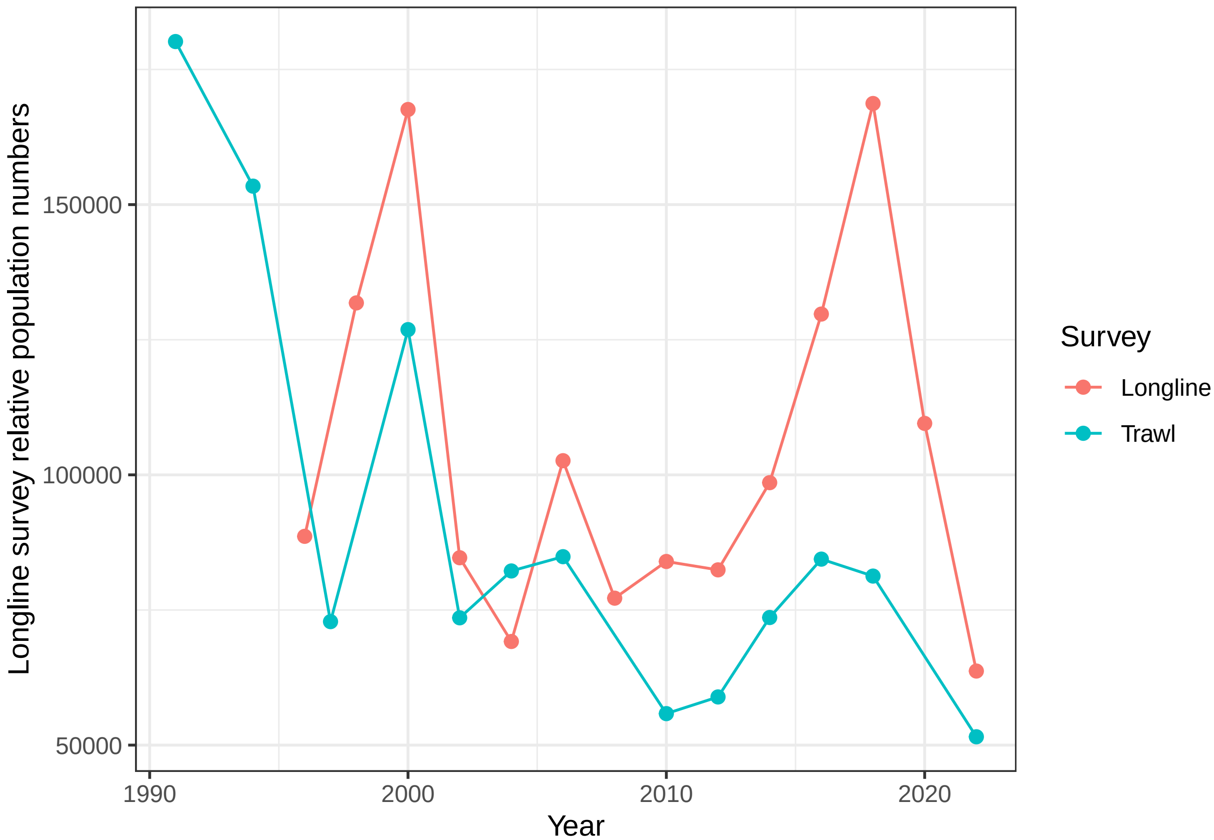


Figure 7: Aleutian Islands longline survey estimates of Pacific cod relative population numbers and trawl survey biomass estimates 1991 - 2022.

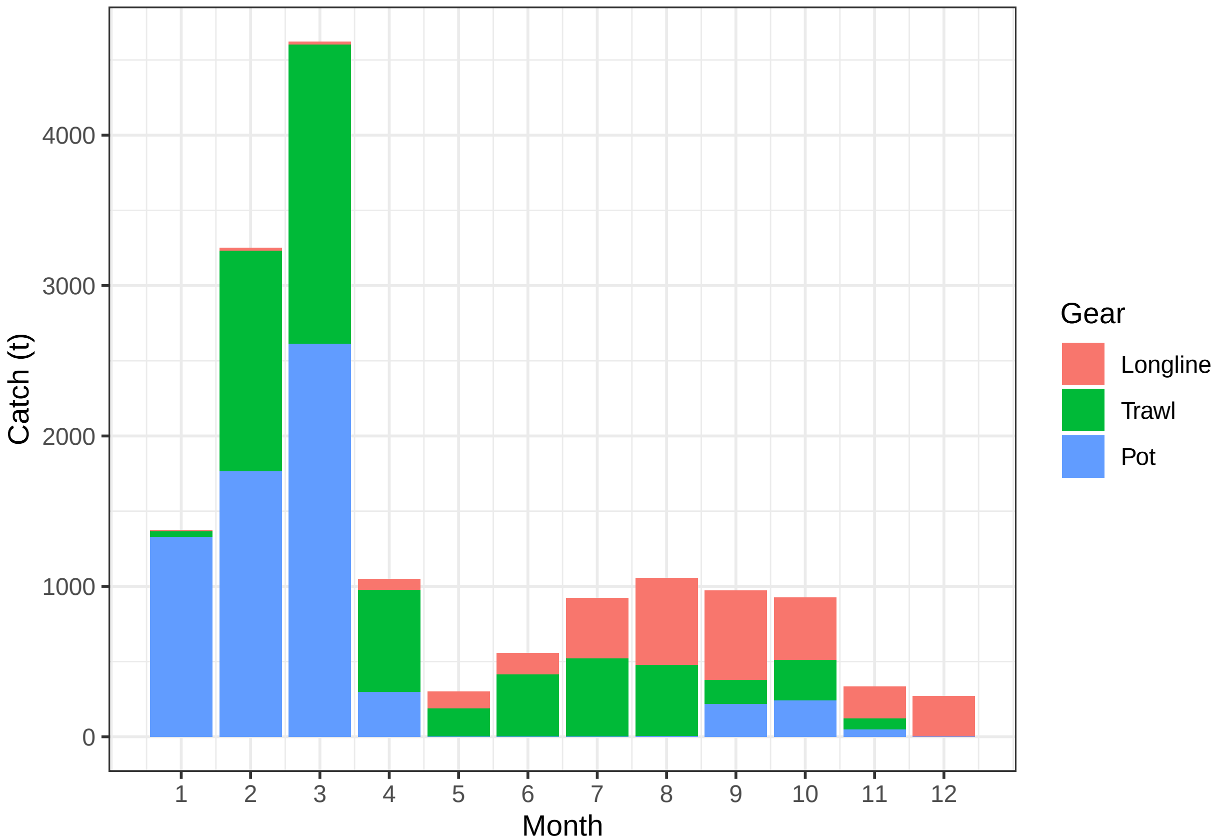


Figure 8: Aleutian Islands Pacific cod average catch (t) by month per year and gear from 2017 - October 31, 2022.

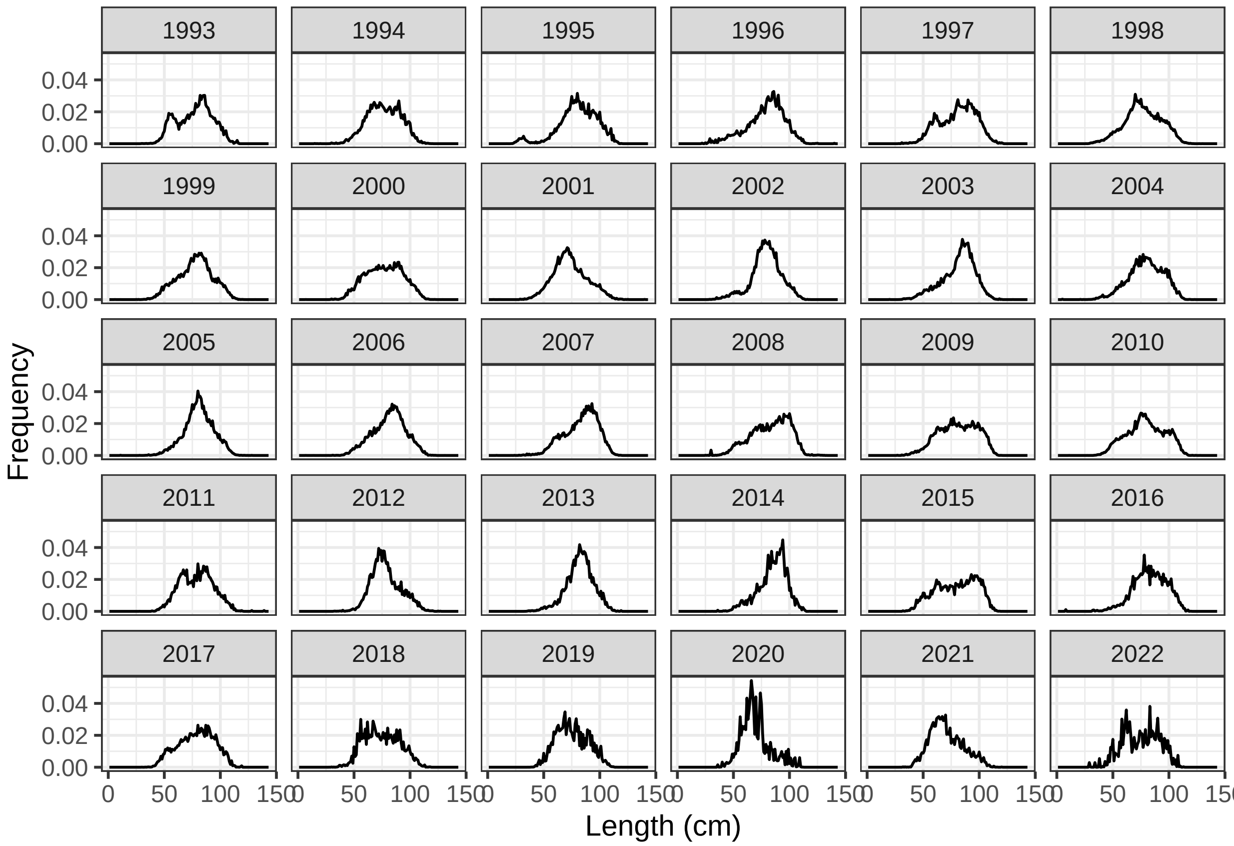


Figure 9: Fishery length compositions over all fisheries combined. Fishery length frequencies were weighted by the relative catch by year, area (NMFS areas 541, 542, and 543), gear, and quarter and only samples with a minimum of 70 observations were used. The combined fishery length compositions were used in Model 22.0.

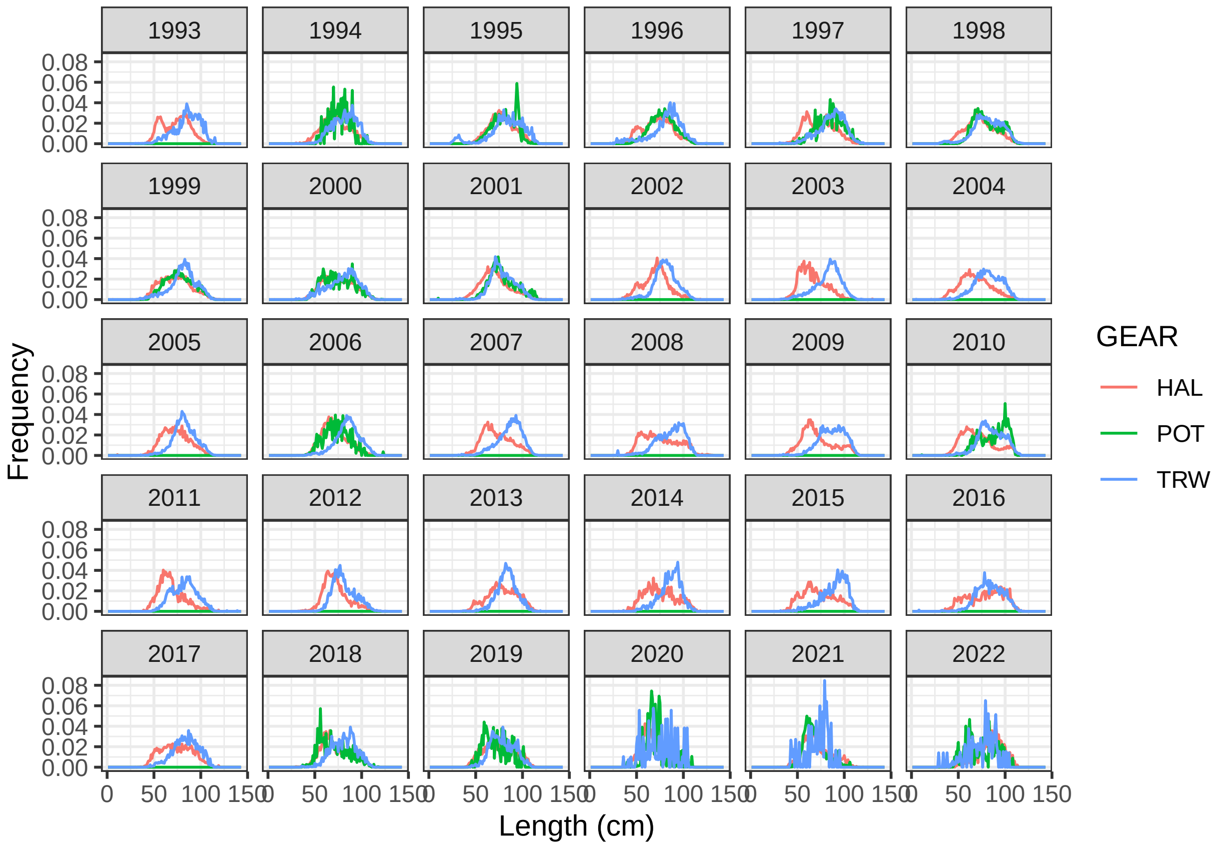


Figure 10: Fishery length compositions for Aleutian Islands Pacific cod by longline (HAL), pot (POT), and trawl (TRW) gear, 1993-2022. Fishery length frequencies were weighted by the relative catch by year, area (NMFS areas 541, 542, and 543), gear, and quarter and only samples with a minimum of 70 observations were used. These fishery length compositions were used in Model 22.1.

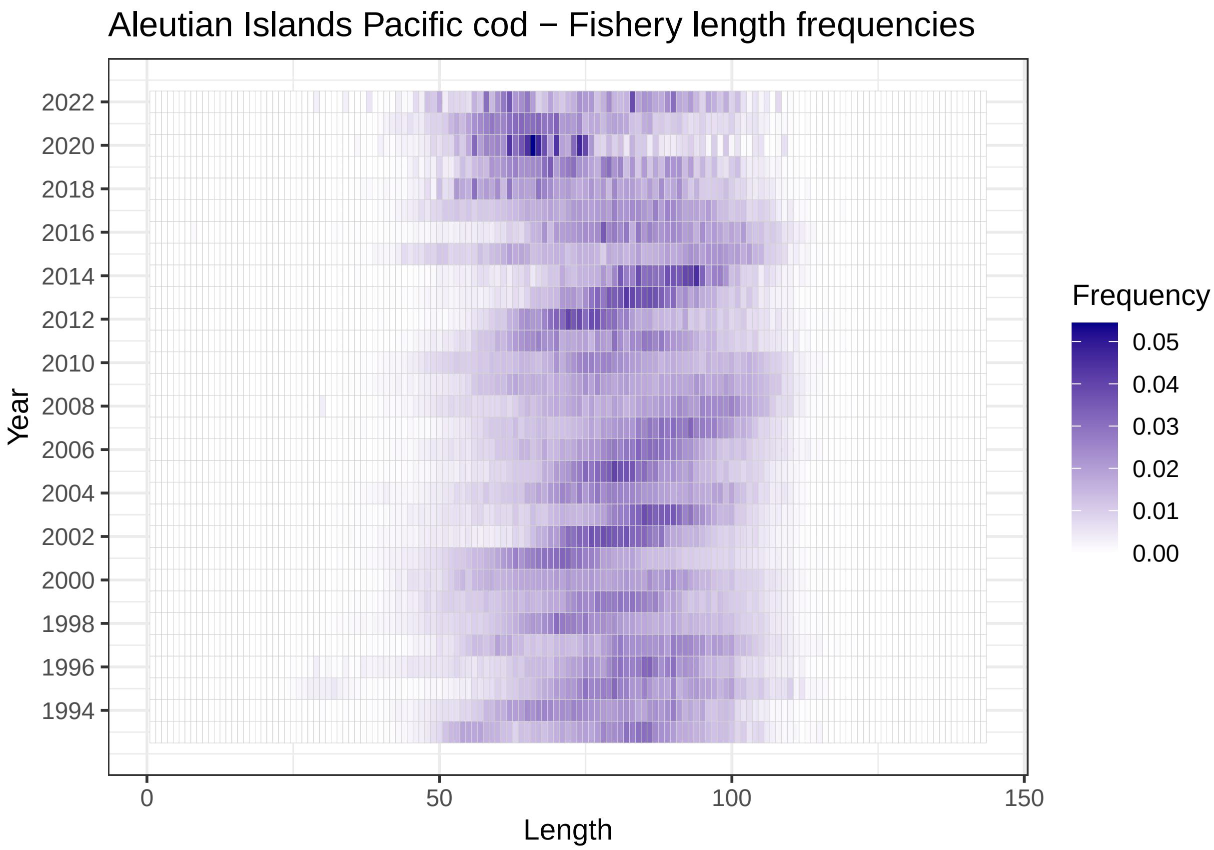


Figure 11: Fishery length compositions over all fisheries combined.

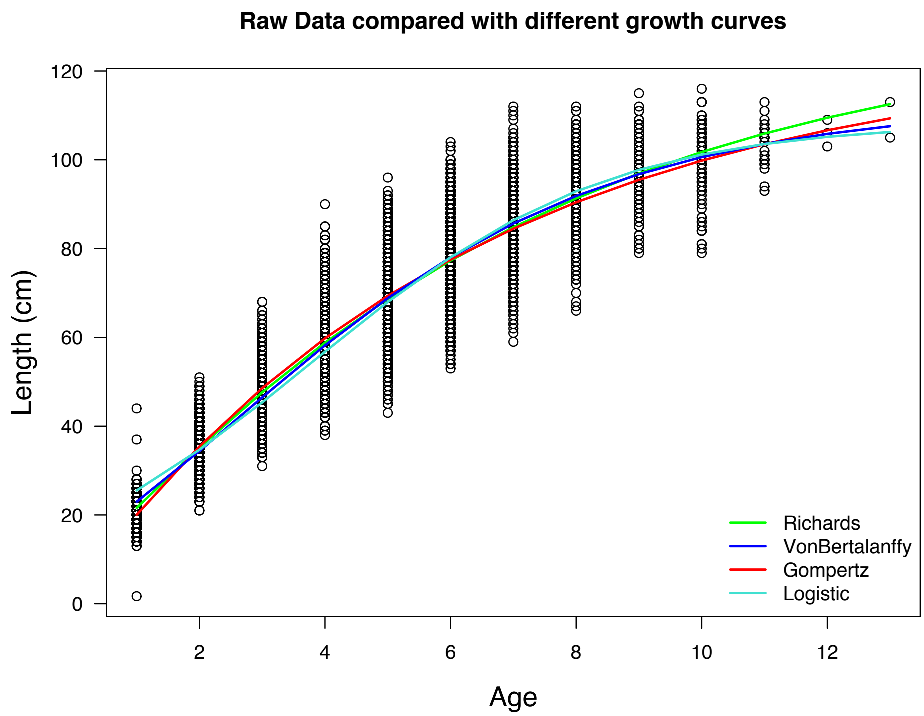


Figure 12: Four models fit to length at age data for Aleutian Islands Pacific cod, Richards, Von Bertalanffy, Gompertz, and Logistic.

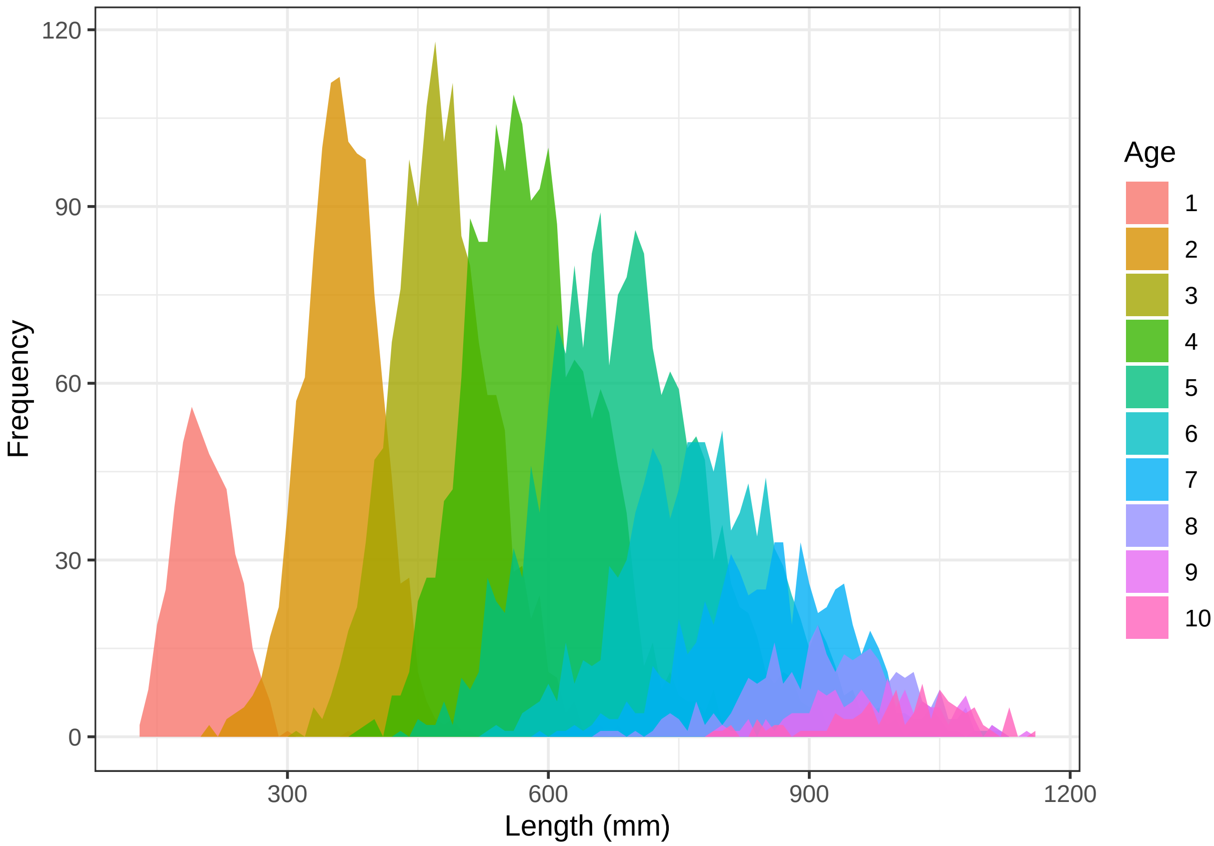


Figure 13: Length frequency by age of cod collected from surveys from 1991-2018.

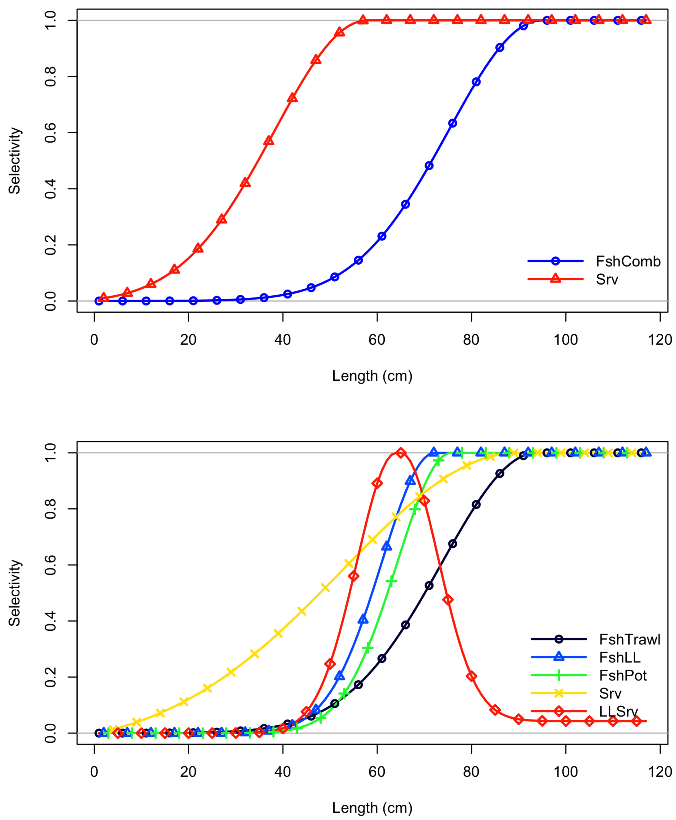


Figure 14: Fishery and survey selectivity for Model 22.0 (upper panel) and Model 22.1 (lower panel).

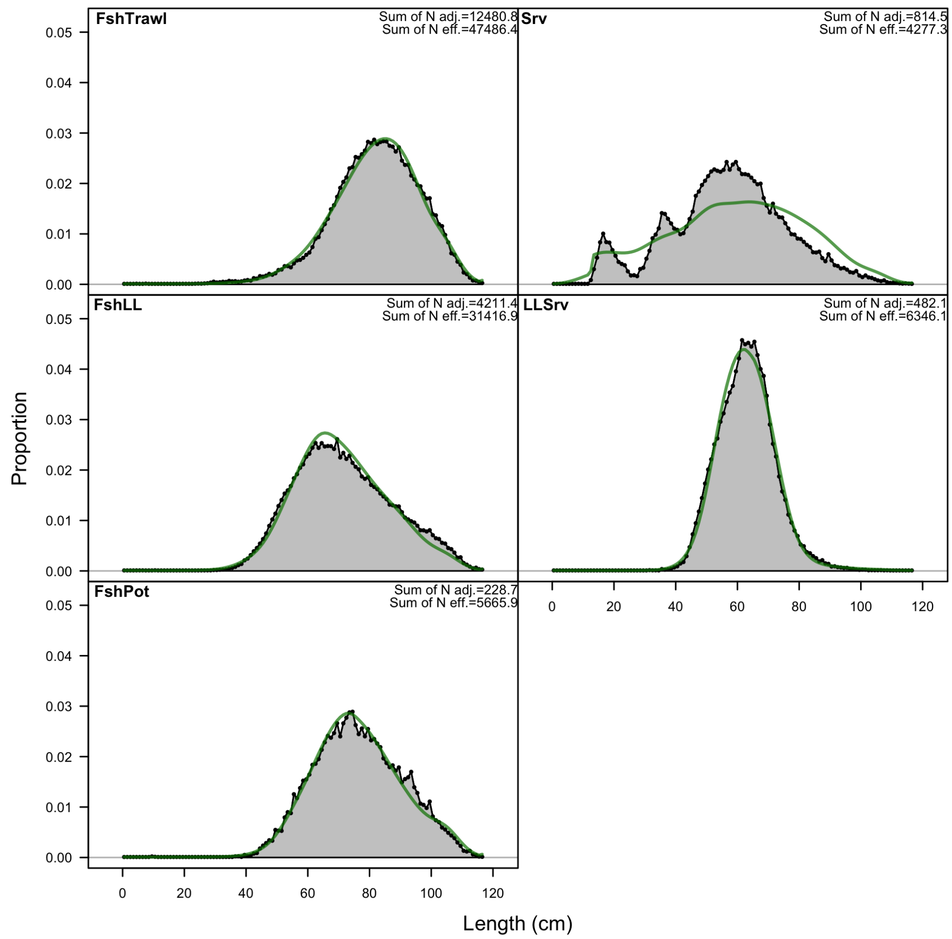


Figure 15: Length compositions aggregated over all data for the trawl and longline surveys, trawl, pot, and longline fisheries. These data were used as length compositions in Model 22.1

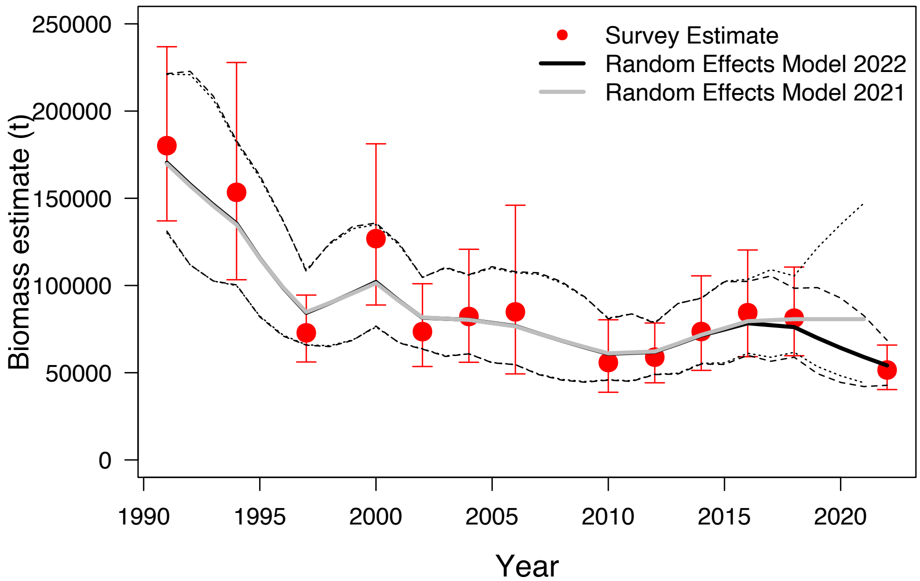


Figure 16: Tier 5 random effects estimate of Aleutian Islands Pacific cod biomass from the NMFS Trawl Survey, 1991 - 2022, with 95% confidence intervals for survey estimates (red bars) and 90% confidence intervals from the random effects model (dotted black lines). The Tier 5 random effects estimate from 2021 is included for comparison.

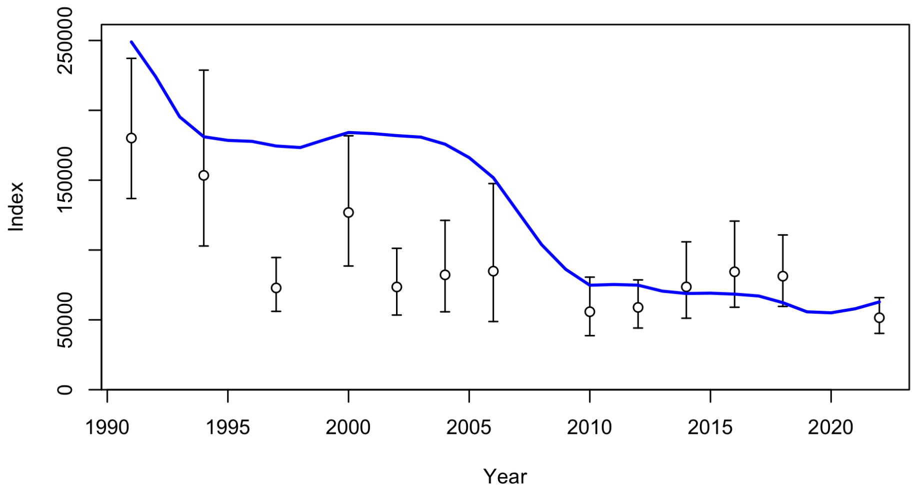
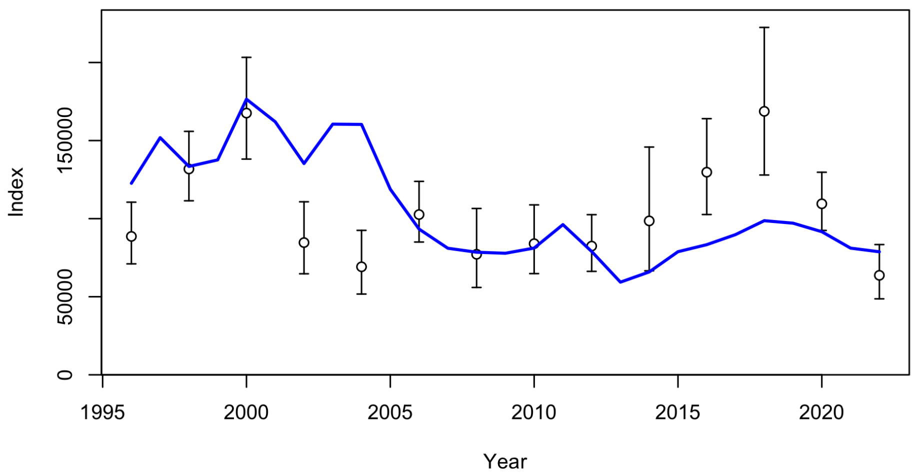


Figure 17: Fit to AFSC trawl survey biomass for Aleutian Islands Pacific cod, Model 22.0.



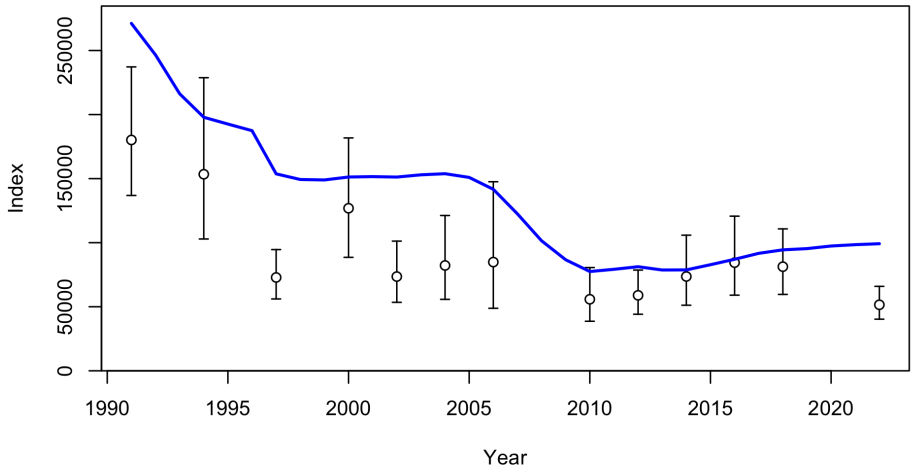


Figure 18: Fit to survey indices for Aleutian Islands Pacific cod for Model 22.1. Upper panel: fit to Aleutian Islands longline survey, bottom panel: fit to Aleutian Islands trawl survey.

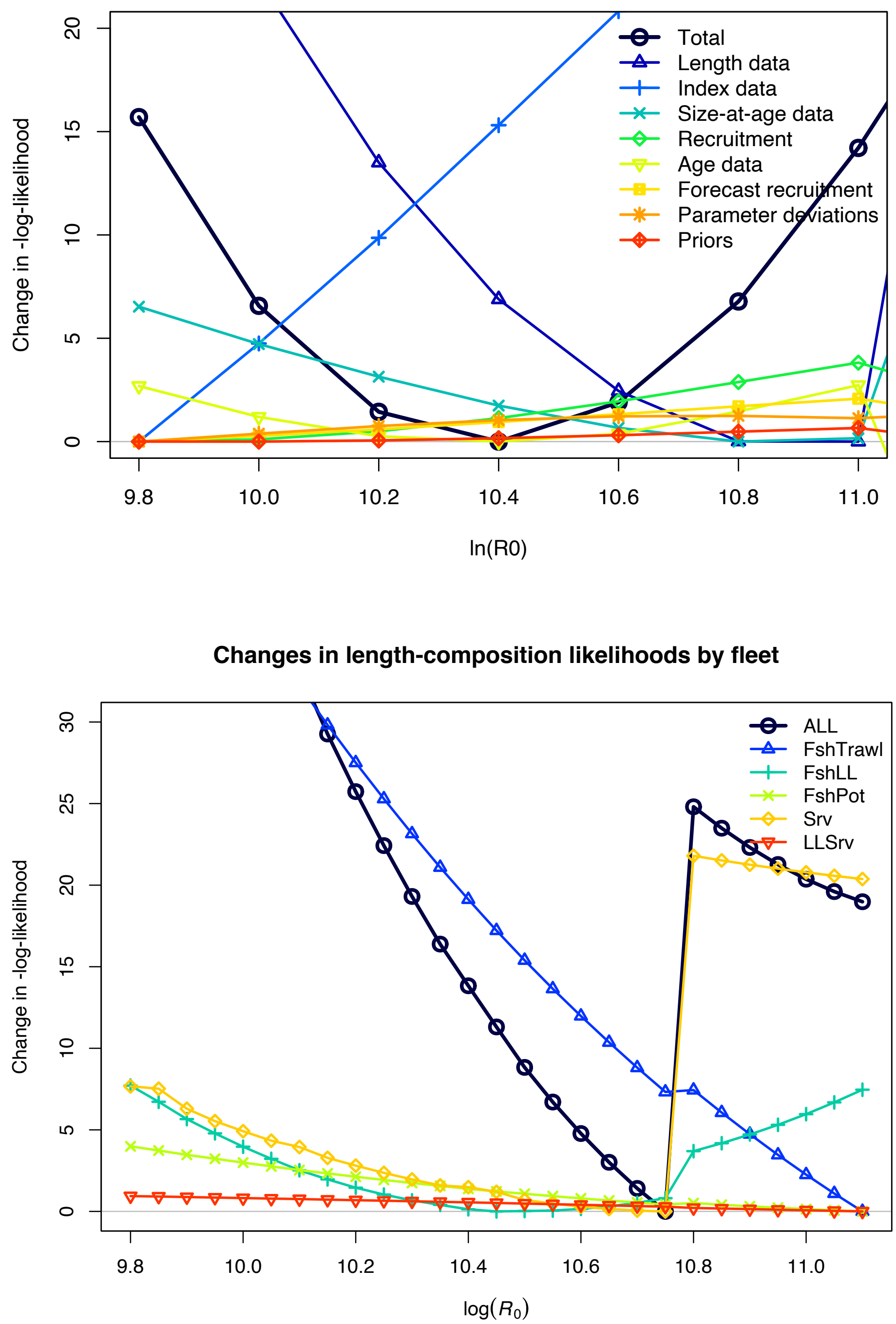


Figure 19: Piner plot showing fleet-specific contributions to the likelihood profile over log(R0), where R0 is mean recruitment in the population, Model 22.0 (upper panel) and 22.1 (lower panel).

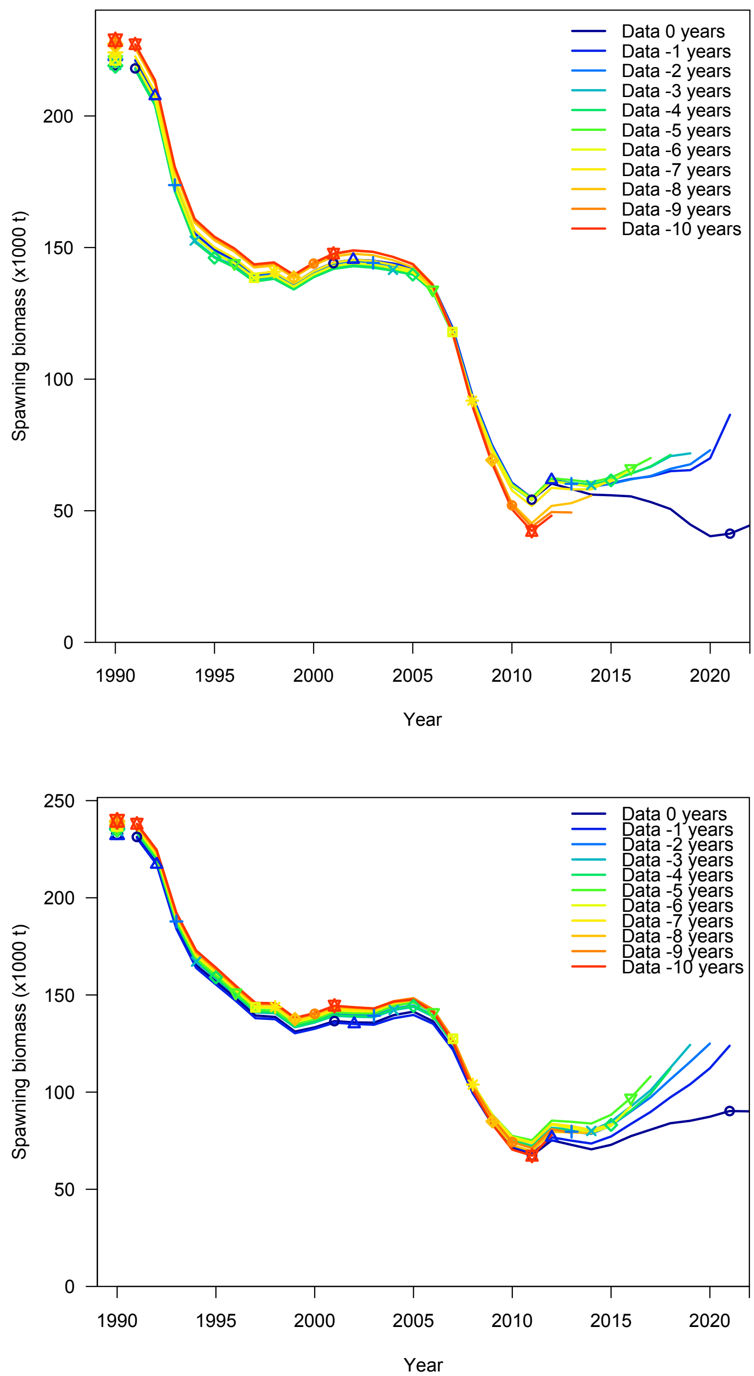


Figure 20: Retrospective pattern of spawning stock biomass, Model 22.0 (upper panel) and Model 22.1 (lower panel).

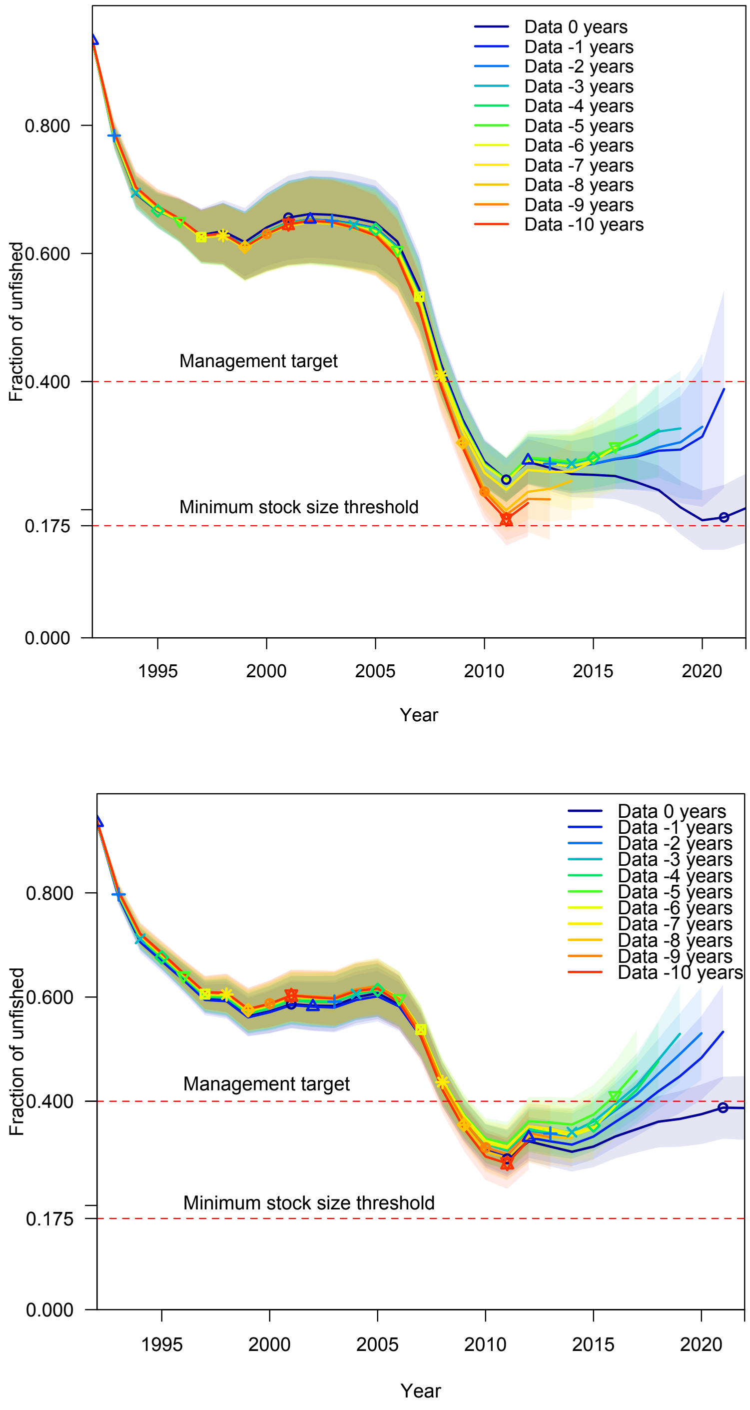


Figure 21: Retrospective pattern of spawning stock biomass with respect to unfished (B/B_0), Model 22.0 (upper panel) and Model 22.1 (lower panel).

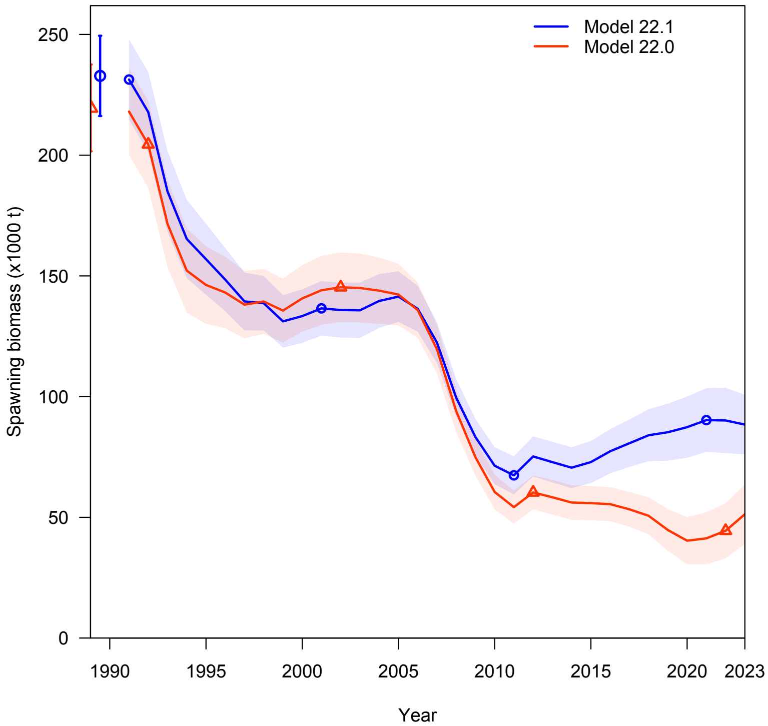


Figure 22: Spawning stock biomass estimated from 1991 through 2022, Model 22.0 (upper panel) and Model 22.1 (lower panel).

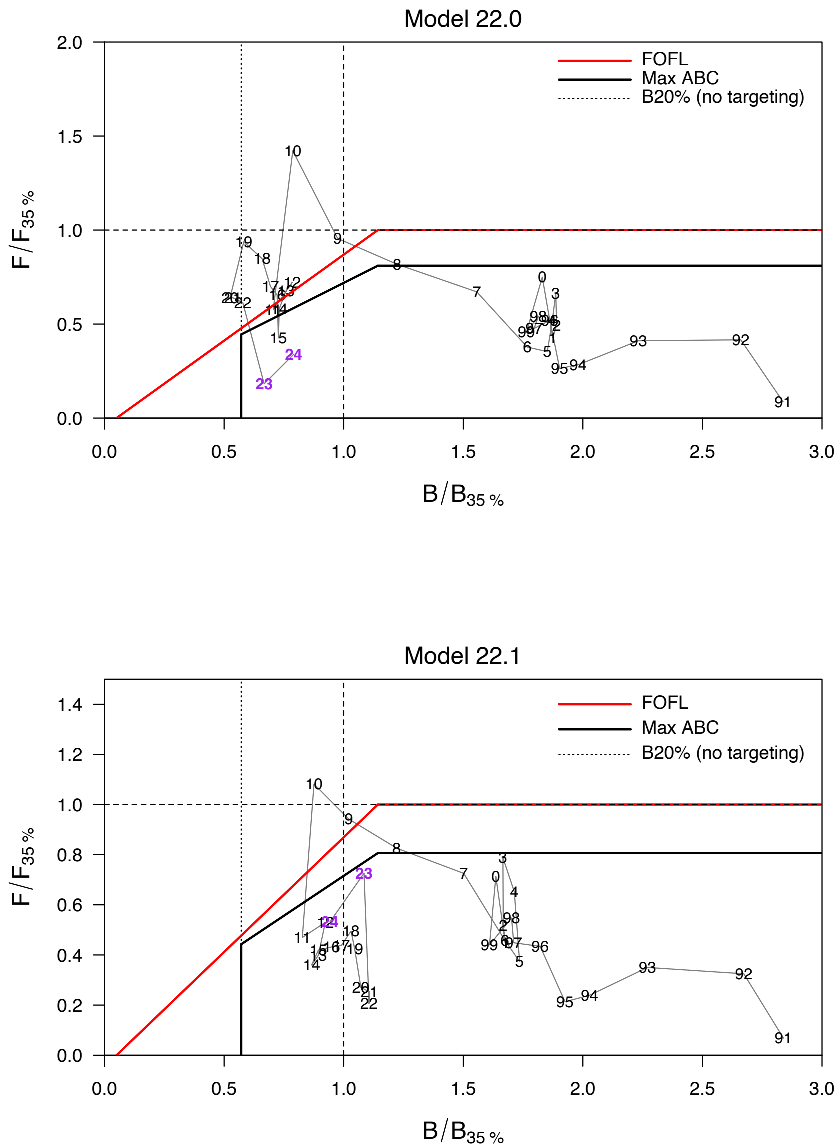


Figure 23: Relative spawning output (B/B_35) with respect to fishing intensity (F/F_35) for Model 22.0 (upper panel) and Model 22.1 (lower panel).

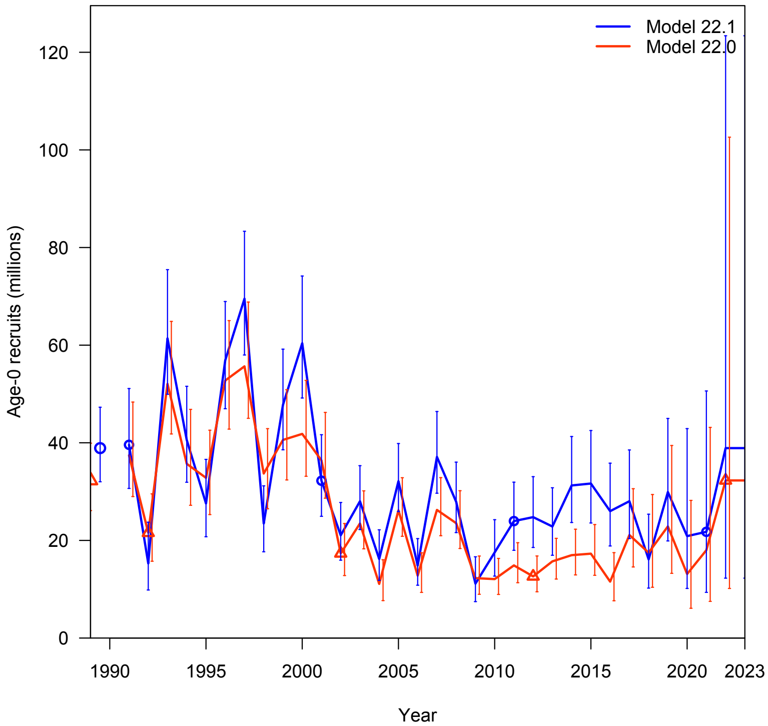


Figure 24: Recruitment estimated from 1991 through 2022, Model 22.0 (upper panel) and Model 22.1 (lower panel).

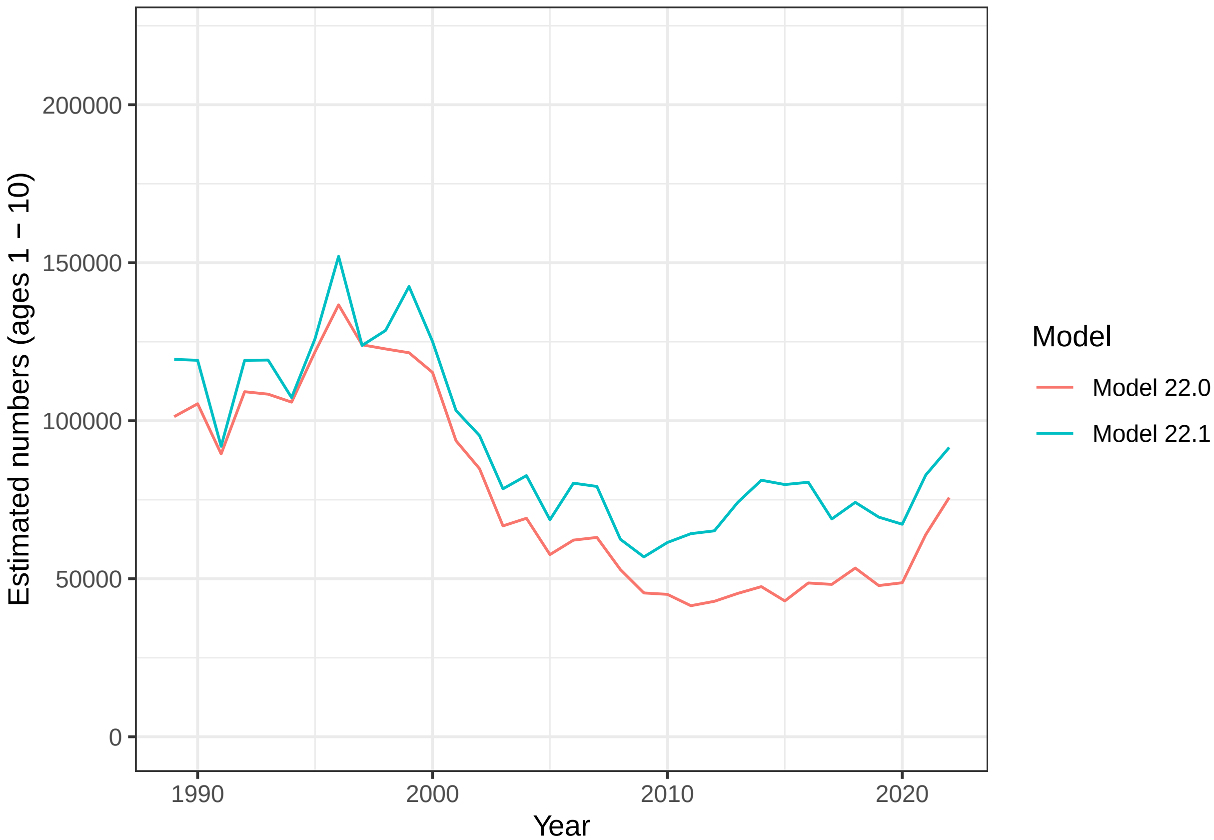


Figure 25: Estimated total numbers at age of Aleutian Islands Pacific cod from 1991 through 2022, Model 22.0 (upper panel) and Model 22.1 (lower panel).

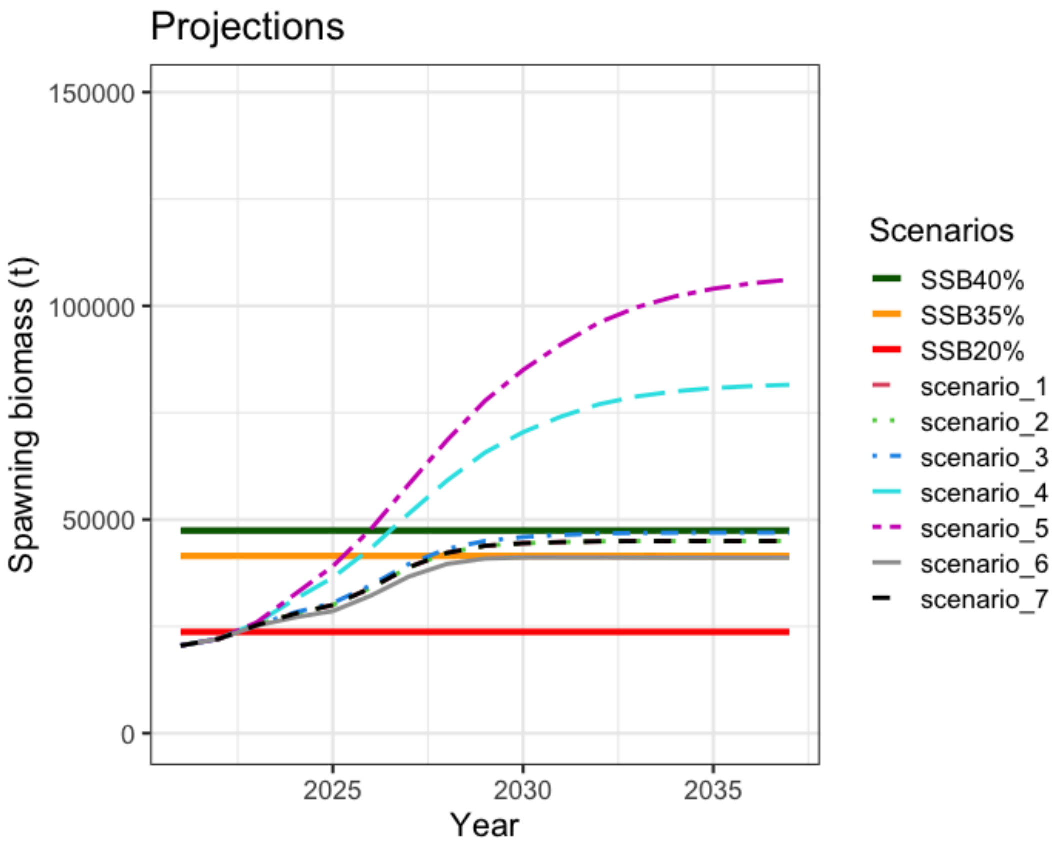


Figure 26: Model 22.0 projection of spawning stock biomass for Aleutian Islands Pacific cod 2023 through 2035 based on all seven harvest scenarios from Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

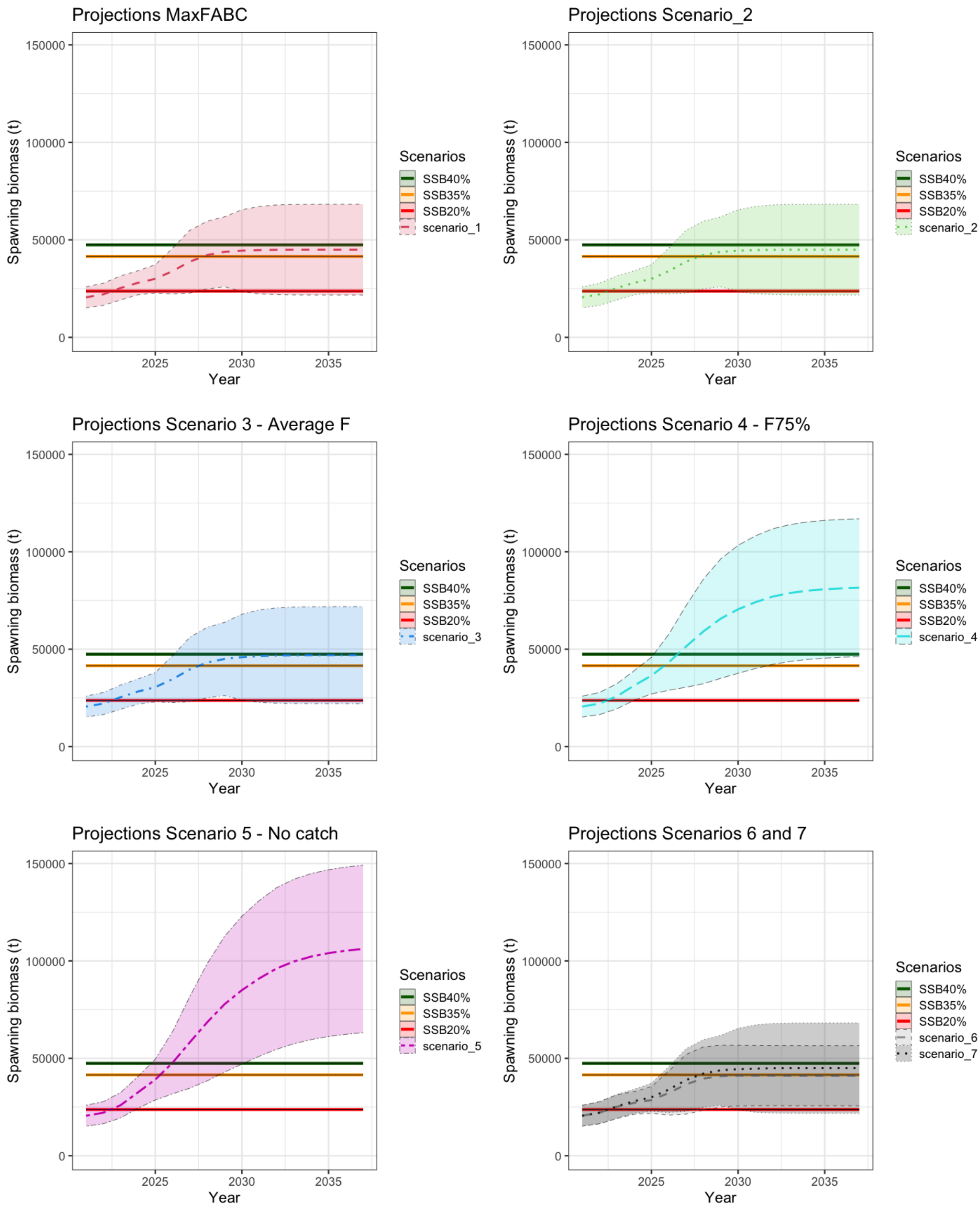


Figure 27: Model 22.0 projections of spawning stock biomass for Aleutian Islands Pacific cod 2023 through 2035 based on seven harvest scenarios from Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

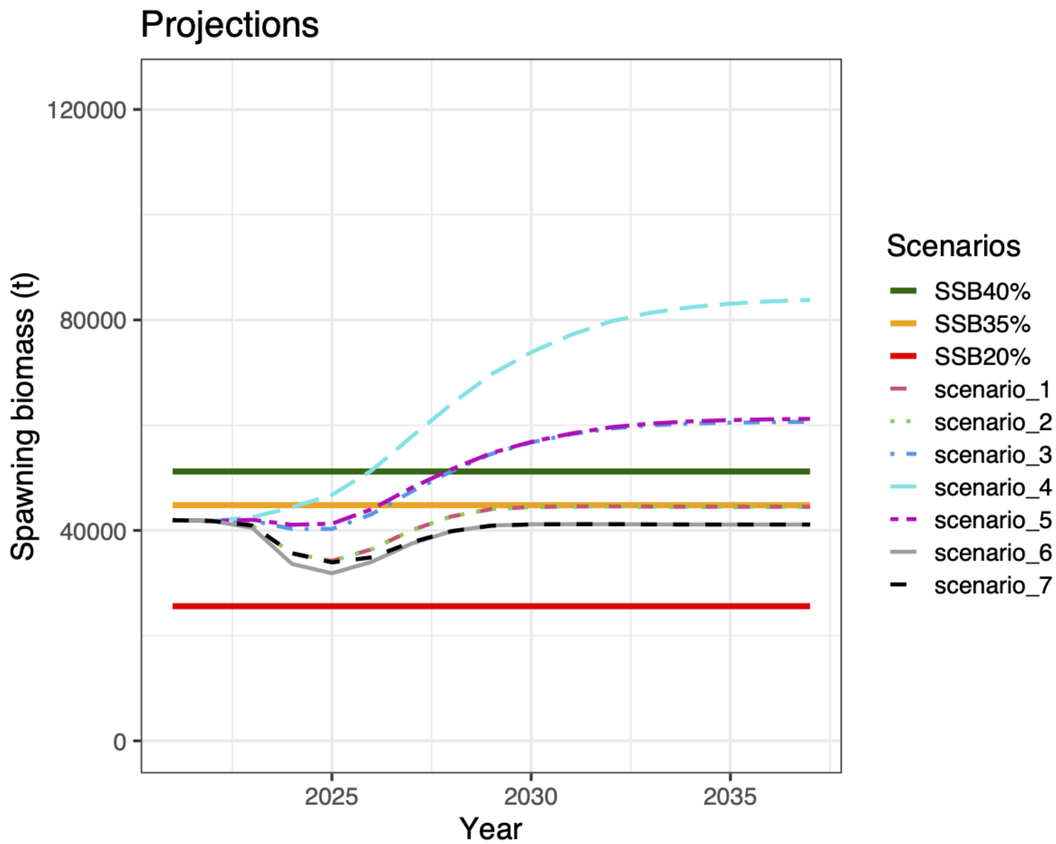


Figure 28: Model 22.1 projections of spawning stock biomass for Aleutian Islands Pacific cod 2023 through 2035 based on all seven harvest scenarios from Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

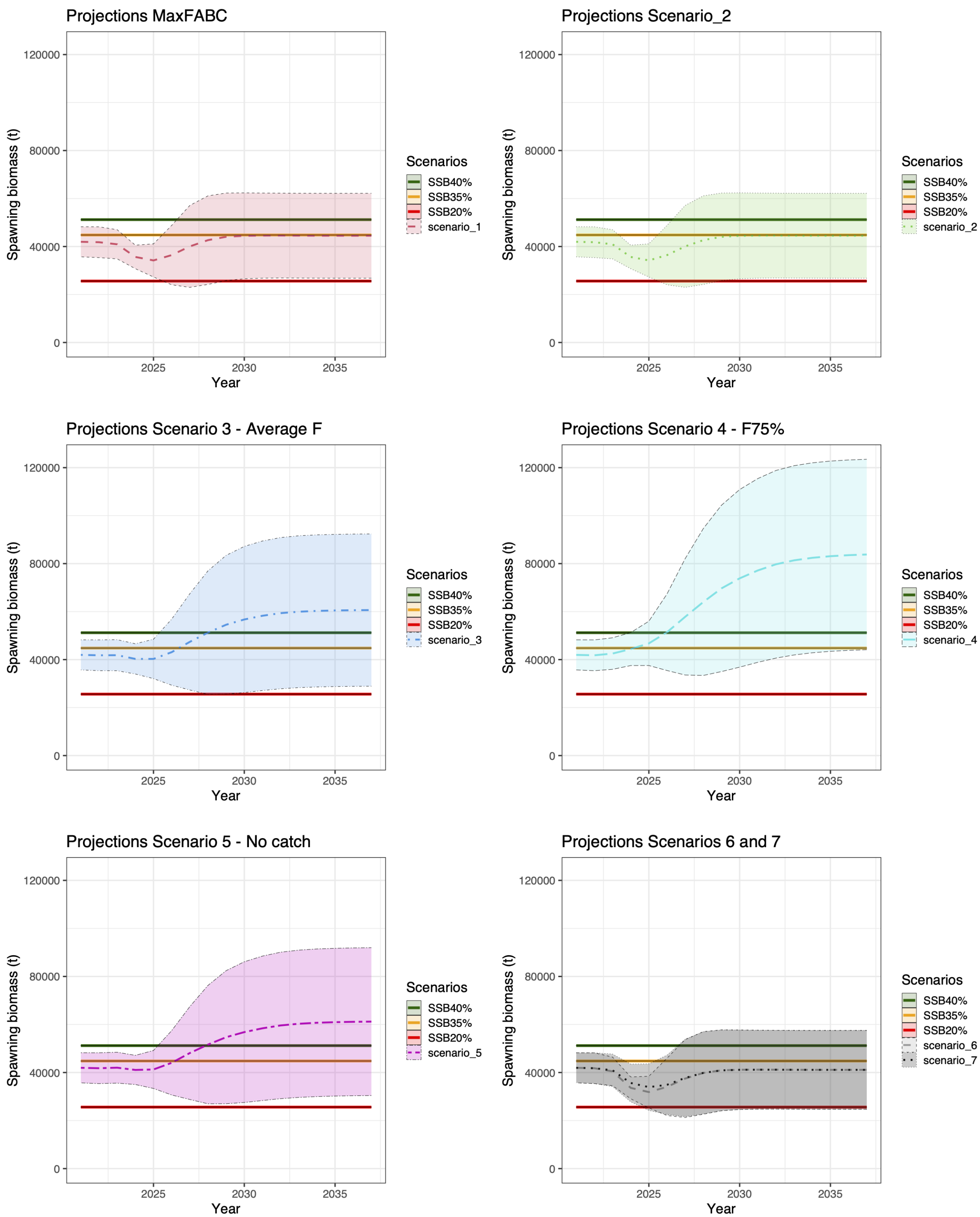


Figure 29: Model 22.1 projections of spawning stock biomass for Aleutian Islands Pacific cod 2023 through 2035 based on seven harvest scenarios from Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

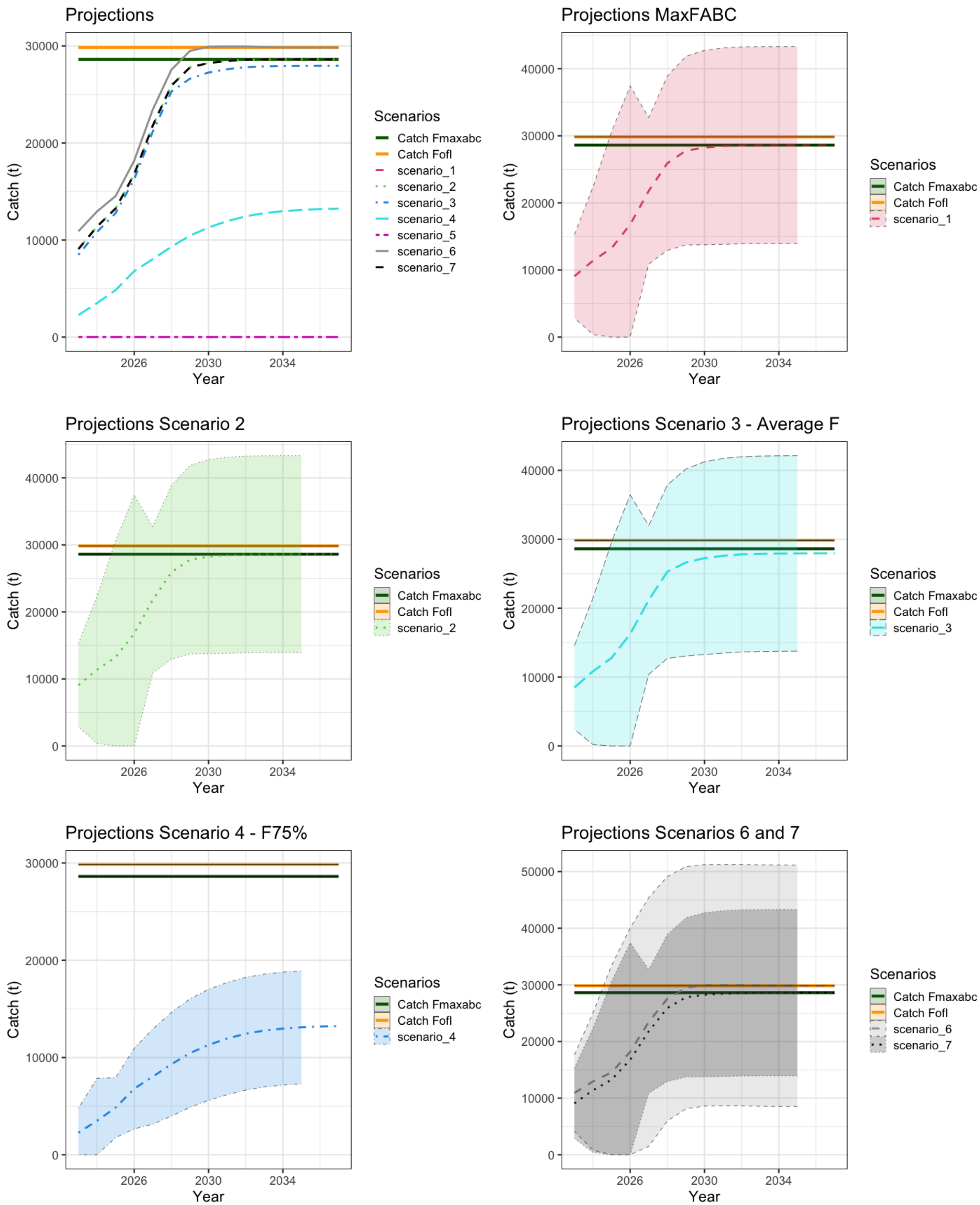


Figure 30: Model 22.0 projections of catch for Aleutian Islands Pacific cod 2023 through 2035 based on seven harvest scenarios from Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

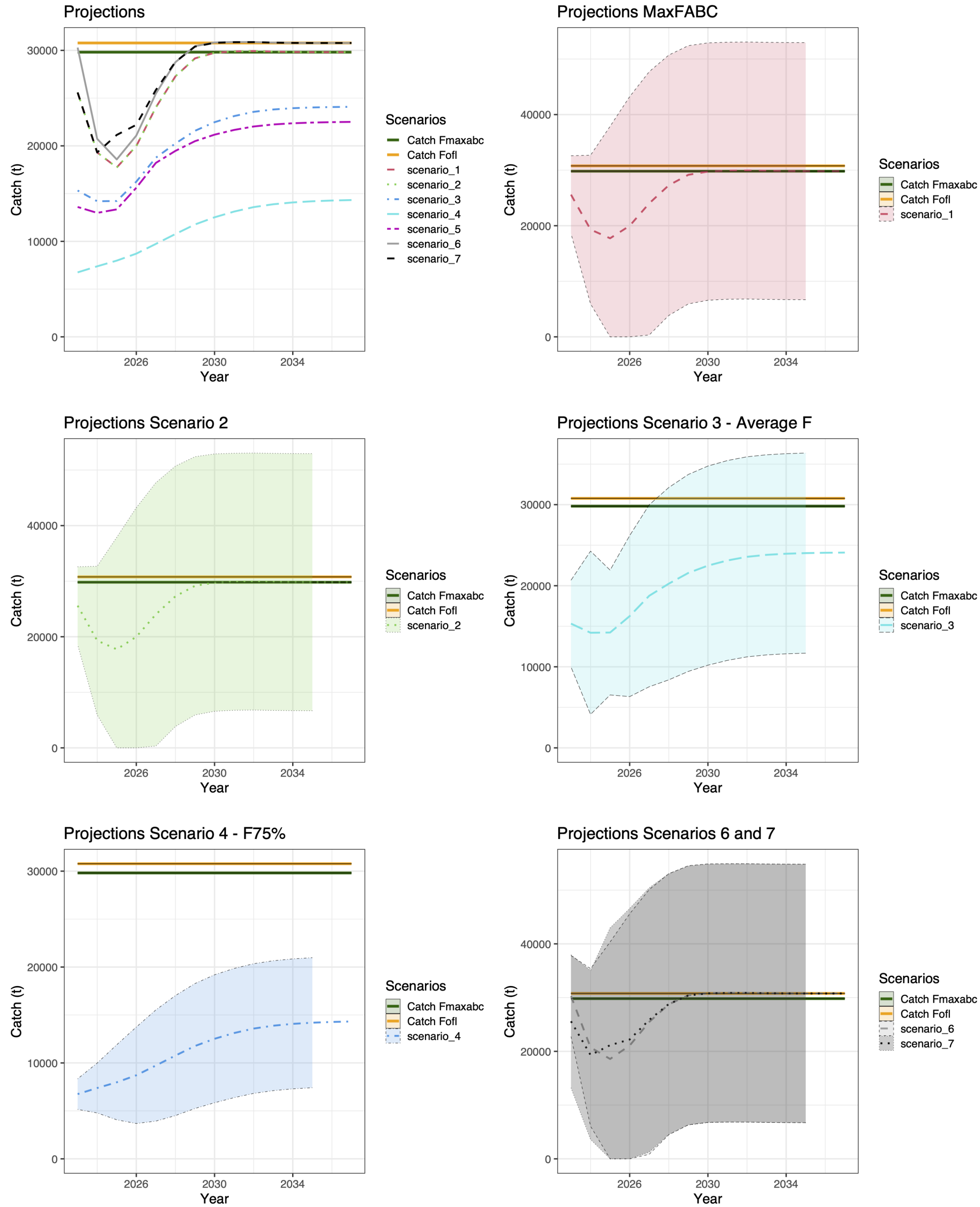


Figure 31: Model 22.1 projections of catch for Aleutian Islands Pacific cod 2023 through 2035 based on seven harvest scenarios from Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

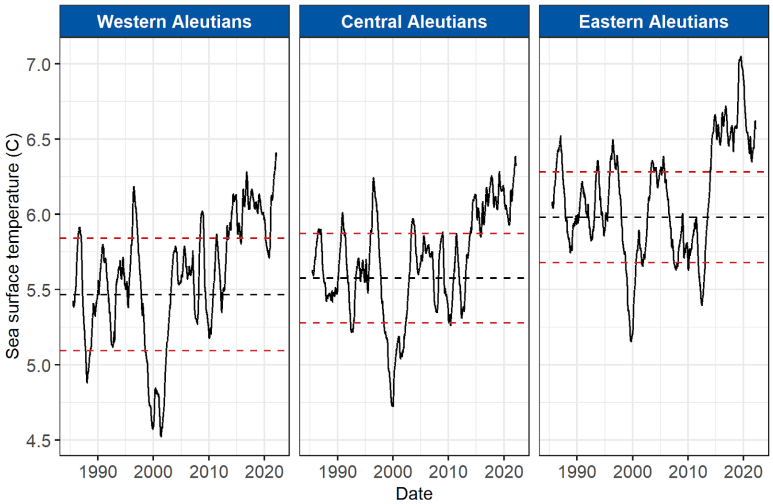


Figure 32: Satellite-derived mean sea surface temperature for the western, central, and eastern Aleutian Islands 1985 - 2022.