2A. Assessment of the Pacific cod stock in the Aleutian Islands

Ingrid Spies, Steve Barbeaux, Pete Hulson, Ivonne Ortiz
Alaska Fisheries Science Center, National Marine Fisheries Service
National Oceanic and Atmospheric Administration
7600 Sand Point Way NE., Seattle, WA 98115-6349
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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 that time. This document presents three age structured models for the Aleutian Islands Pacific cod stock using data from 1991 through 2023 (Model 23.0, 23.1, and 23.2) as well as a Tier 5 harvest specification model. A version of these models was presented to the BSAI Plan Team in September, 2023 and to the SSC in October, 2023.

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 2022 assessment.

Changes in the input data (age structured models) A version of this model was presented in 2022, with the following data used in the 2022 model and updated for the most recent year.

- Realized catches for 1991 - 2022 were used (through October 20, 2023), as well as a preliminary catch estimate through December 31, 2023.
- Commercial fishery size compositions for 1991 - 2022, as well as preliminary size composition from the 2023 commercial fisheries.
- Aleutian Islands trawl survey biomass index and size compositions from the 1991 - 2022 (there was no survey in 2023).
- Aleutian Islands trawl survey age composition from the 1991 - 2022.

Changes in the input data (Tier 5 model)

- There has been no change to the input data for Tier 5 model; it uses existing biomass estimates from 1991 - 2022 and the natural mortality estimate used in past models is retained for 2023.

Changes in the assessment methodology

- Model 13.4: is the Tier 5 random effects model implemented using the REMA package (Sullivan et al. 2022).

The age structured models presented here incorporate fishery data as a single fishery from 1991 - 2023. The single fishery combined catch data over trawl, pot, and longline gear. Survey age and length data were input as conditional age-at-length. Survey and fishery selectivity were modeled as constant over time and logistic, except in Model 23.1, which incorporated time blocks on fishery selectivity. More details on model specifications are given in the Model Structure and Parameter Estimation sections.

- Model 23.0: This model incorporates three time blocks on the growth parameter K, with breakpoints at 2003 and 2017. The first breakpoint accounts for a shift in growth determined using the methodology of Kapur et al. (2020). The second breakpoint was implemented to account for a shift to warmer temparatures during the past decade (Xiao and Ren 2022).
- Model 23.1: This model is similar to Model 23.0, except it incorporates five timeblocks on the fishery selectivity parameter for ascending width, corresponding with shifts in the gear targeting Pacific cod. Selectivity breakpoints were set at 2002, 2012, 2016, and 2019.
- Model 23.2: This model is similar to Model 23.0, except there are two timeblocks on the growth parameter K with a breakpoint at 2003. There are also two timeblocks on natural mortality with a breakpoint in 2015 corresponding to the shift to warmer temperatures during the past decade (Xiao and Ren 2022).

Summary of Results

All three age structured models presented here (Model 23.0, 23.1, and 23.2) fit the survey index and length composition data well, achieved acceptable retrospective patterns, and improved upon the models presented in September 2023 and November 2022. All models provided similar estimates of biomass, natural mortality, and reference points (Table 2A.1, Table 2A.2, and Table 2A.3). In addition, the three models had similar AIC values, with the lowest AIC in Model 23.2, followed by Model 23.1. Model 23.0 produced an acceptable Mohn's rho, 0.17; Model 23.1 produced a smaller retrospective pattern, 0.14, and Model 23.2 produced the best Mohn's rho = 0.06. Of the two models recommended by the September, 2023 Plan Team meeting, Model 23.0 and 23.1, Model 23.1 would be the preferred model, due to a lower AIC value and acceptable retrospective pattern. However, Model 23.2 provides the best fit to the data, produced the lowest AIC of all models, and the best retrospective pattern and lowest absolute value Mohn's rho. In addition, the assumption that increased natural mortality due to higher temperatures is supported by evidence, whereas there is no evidence for a shift in growth during the past decade (as assumed by Models 23.0 and 23.1). Model 23.2 retains two time blocks on growth with a break at 2003, reflecting a documented change in growth. Model 23.2 also implements a time block on natural mortality with a break in 2015, roughly corresponding with the thermal regime shift in 2013/2014 (Xiao and Ren 2022). This model estimated a total biomass of 54,611 t for 2024. Model 23.2 ABCs were 10,660 t and 10,214 t for 2024 and 2025. Model 23.2 OFLs were 12,732 t and 17,304 t for 2024 and 2025. The Tier 5 ABCs and OFLs for 2024 and 2025 are the same as estimated in 2022, due to no new survey data. The 2022 (and 2023) random effect estimates of biomass represent a 37% decline from the estimate based on the 2018 Aleutian Islands survey. Model 13.4 incorporates this biomass estimate directly in the calculation of reference points; therefore, the random effects model estimated an exploitable biomass of 54,166 t, which resulted in OFLs (18,416 t) and ABCs (13,812 t) for 2024 and 2025.

Catch of Pacific cod as of October 20, 2023 was 7,311 t. Over the past 5 years (2018 - 2022), 92.6% of the catch has taken place by this date. Therefore, the full year's estimate of catch in 2023 was extrapolated to be 7,898 t. This is lower than the average catch over the past five years of 15,936 t.

All models and detailed results are publicly available and can be found at https://github.com/afsc-assessments/AI_PCOD.

We recommend the Tier 3b assessment Model 23.2 for management quantities and no additional reduction in ABC due to Risk Table concerns. If a different model is accepted, we recommend a comparable reduction in management quantities.

Summary table for Model 13.4.

	As estimated or *specified* *last* year for:		As estimated or *recommended* *this* year for:	
Quantity	2023	2024	2024	2025
M (natural mortality rate)	0.34	0.34	0.34	0.34
Tier	5	5	5	5
Biomass (t)	54,165	54,165	54,166	54,166
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	18,416	18,416	18,416	18,416
$maxABC$	13,812	13,812	13,812	13,812
ABC	13,812	13,812	13,812	13,812
Status	2021	2022	2022	2023
Overfishing	No	n/a	No	n/a

Summary table for Model 23.2. Natural mortality is provided for two time blocks, 1991-2015, followed by 2015-2023.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2023	2024	2024	2025
M (natural mortality rate)	0.34	0.34	0.32, 0.49	0.32, 0.49
Tier	5	5	3b	3b
Projected total (age 1+) biomass (t)	54,165	54,165	54,611	61,611
Projected female spawning biomass (t)	-	-	18,687	18,302
$B_{100\%}$	-	-	56,572	56,572
$B_{40\%}$	-	-	22,628	22,628
$B_{35\%}$	-	-	19,800	19,800
F_{OFL}	0.34	0.34	0.544	0.666
$maxF_{ABC}$	0.255	0.255	0.445	0.422
F_{ABC}	0.255	0.255	0.445	0.422
OFL	18,416	18,416	12,732	17,304
$maxABC$	13,812	13,812	10,660	10,214
ABC	13,812	13,812	10,660	10,214
Status	2021	2022	2022	2023
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Responses to SSC and Plan Team comments on Assessments in General

SSC December 2022

The SSC appreciates the innovative work being done by the assessment authors through random effects (RE) modeling, by treating area-specific process variation as a random effect to properly weight and, where appropriate, consistently weight, the variation across areas. If not currently included in assessments, the SSC requests full documentation of the justification for the weighting schemes applied.

Authors' response

While this model used REMA, this comment does not apply.

SSC December 2022

The SSC reminds authors and PTs to please bring forward and respond to SSC comments from previous assessments, particularly where updates with minimal change to the assessment have been conducted in the intervening year(s).

Authors' response

Noted.

Responses to SSC and Plan Team comments specific to this assessmemt

SSC December 2022

The SSC supports the PT recommendation for continued efforts to develop a viable age-structured assessment model framework for this stock and retaining the annual assessment cycle at this time. However, the SSC encourages the authors and PT to consider whether this stock might be a viable candidate for reduced assessment frequency given the timing of available survey information and the opportunity for more model development in off-cycle years.

Authors' response

The authors agree that reduced assessment frequency would be appropriate for a tier 3 model.

SSC December 2022

The SSC notes that the majority (65.8%) of harvest is taken during the January-April spawning season while fish are aggregated, during which the majority of harvest comes from trawl (40.5%) and pot (58.3%) gears. However, the fishery length composition data are collected primarily from the longline and trawl fleets. The SSC encourages the authors to work with the observer program to identify whether it is possible to collect additional length composition data from the pot fleet to ensure representative composition samples are available to inform continued development of fleet-disaggregated models such as 22.1. Otherwise, the data may not support a fleet-specific model.

Authors' response

The authors have worked with the observer program and ADFG to obtain additional length samples. As of 2023, length composition data from the pot fleet is still low.

SSC December 2022

The SSC is encouraged by the authors' progress in developing age-structured models for this stock and offers the following suggestions for future development:

If the fleet disaggregated model 22.1 is pursued in the future, the SSC encourages consideration of dome-shaped selectivity for the HAL fleet, given the observed differences in size compositions among fleets.

Authors' response The fleet aggregated was pursued in the 2023 assessment.

SSC December 2022 If the fleet-aggregated model 22.0 is pursued in the future, the SSC encourages the authors to explore the potential for time-varying fishery selectivity as one option for addressing the retrospective pattern, and changes in fishing behavior and gear use over time.

Authors' response Time-varying fishery selectivity was incorporated into Model 23.1.

SSC December 2022 Given the uncertainty of the AI bottom trawl survey, a version of 22.0 that includes the AFSC longline survey and/or IPHC survey data could be a viable alternative.

Authors' response The longline survey was incorporated into September models and deemed a poor proxy for Pacific cod abundance in the Aleutian Islands. Therefore, it is not included in the proposed models for 2023.

SSC December 2022 With respect to future use of the Tier 5 assessment method, the SSC supports the PT recommendation to consider a hybrid approach where the natural mortality estimated by a Tier 3 age-structured model is used for Tier 5 harvest specification.

Authors' response The age structured models provide a consistent estimate of natural mortality. 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. We recommend moving this assessment to a Tier 3 approach.

Plan Team November 2023 The Plan Team recommended two age structured models for November, 1. A model with time varying growth and 2. A model with time varying growth as well as time varying selectivity.

Authors' response Model 23.0 and 23.1 incorporate time varying growth. Model 23.1 also incorporates time varying fishery selectivity. It became apparent during the model building process that previous retrospective patterns are the result of retrospective peels poorly fitting a downaward trend in spawning biomass. A time block on growth in Models 23.0 and 23.1 allowed the model to accomodate survey indices during the past 5-10 years, but there was not evidence for a change in growth patterns during that time. Therefore, a third model is presented here, Model 23.2, which retains two time blocks on growth with a break at 2003, reflecting a documented change in growth. Model 23.2 also implements a time block on natural mortality roughly corresponding with the thermal regime shift in 2013/2014 (Xiao and Ren 2022). All three Aleutian regions experienced a warm 2023 with waters in or near moderate MHW status beginning in winter, fewer heatwaves but temperatures still above average during spring and early summer, and a return to heatwave conditions in late summer. Generally, all three regions have trended towards anomalously warm (>1 standard deviation from the long term mean) conditions over the last 10 years, as well as a marked increase in heatwave days (Figure 2A.1, Satellite SST and MHW, AI ESR 2023).

As presented in the Ecosystems Considerations section, 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. 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. Pacific cod are known to be highly sensitive to temperatures outside their preferred range (2-8 C) and have been shown to experience higher natural mortality under higher than optimal temperatures (Barbeaux et al. 2018, Barbeaux et al. 2020). Therefore, there is evidence to expect that natural mortality would increase in Aleutian Islands cod during the recent periods of higher temperatures (~2015).

SSC December 2022

The SSC encourages consistency with EBS and AI cod assessments in approaches to these and other issues, where possible.

Authors' response The Aleutian Islands assessment has moved towards greater consistency with the EBS cod assessment in multiple ways, including use of the SS3 modeling platform, the same code for pulling data, code for running harvest scenarios. Whenever possible, the AI cod model adopts parameterizations that are similar for the EBS unless it is clearly different. This year the three fisheries were combined into a single fishery.

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, and until recently its northern limit was approximately 65°N latitude (Stevenson and Lauth 2019). However, in recent years Pacific cod has been observed in the Chukchi sea (Cooper et al. 2023). 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). Pacific cod likely return to their natal origin to spawn during winter months (January - April) but perform feeding migrations during other months. Genetic research indicates the existence of discrete spawning stocks in the EBS and AI, and the genetic distinctiveness of the Aleutian Islands stock (Cunningham et al. 2009, Canino et al. 2010, Spies 2012, Spies et al. 2022). 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), between February and 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, Hurst et al. 2009). 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). After hatching, Pacific cod larvae move quickly to surface waters (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 2A.4). Joint venture fisheries began operations in the AI in 1981, and peaked in 1987, with catches totaling over 10,000 t. Foreign fishing for AI Pacific cod ended in 1986, followed by an end to joint venture fishing in 1990 (Table 2A.5). Domestic fishing for AI Pacific cod began in 1981, with a peak catch of over 43,000 t in 1992 (Table 2A.6).

Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including pot, trawl and longline components (Figure 2A.2). 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 2023, 61% of the catch was taken in the state fishery (Figure 2A.2). In 2023 (as of October 20, 2023), the federal fishery consisted of 6% pot gear, 2% longline gear, and 92% trawl gear. The state fishery consisted of 87% pot gear, 0% longline gear, and 13% trawl gear.

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 2019-2023 (through October 20, 2023) was 61% from the eastern Aleutian Islands (NMFS area 541), 29% from the central Aleutian Islands (NMFS area 542), and 10% from the western Aleutian Islands (NMFS area 543).

Catches of Pacific cod taken in the AI for the periods 1964-1980, 1981-1990, and 1991-2023 are shown in Table 2A.4, Table 2A.5, and Table 2A.6, respectively. The catches in Table 2A.4 and Table 2A.5 are broken down by fleet sector (foreign, joint venture, domestic annual processing). The catches in Table 2A.5 are also broken down by gear to the extent possible. The catches in Table 2A.6 are broken down by gear. Table 2A.7 breaks down catches from 1994-2023 by statistical area (area breakdowns not available prior to 1994), both in absolute terms and as proportions of the yearly totals.

An average of 13% of the total Pacific cod catch in the Aleutian Islands has taken place in non-target fisheries from 1993-2023. Over the past 5 years, the non-target fishery catch of Pacific cod has averaged 2,753 t and the targeted fishery has averaged 10,583 t, out of a total average of 13,336 t (Table 2A.8).

Effort and CPUE

CPUE aggregated over gear types for the number and weight of fish show similar trends, indicating that there has been no large shifts in the weight of individual fish (Figure 2A.3). CPUE has decreased by all metrics since approximately 2015, including seasonally by trawl gear and for longline gear (Figure 2A.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. Recent declines in CPUE may also be due to less effort in targeted Pacific cod fishing. The amount of targeted Pacific cod fishing has decreased since 2018, but the catch in the atka mackerel and rockfish fisheries has remained the same or increased (Figure 2A.5, Table 2A.8).

Discards

The catches shown in Table 2A.5 and Table 2A.6 include estimated discards. Discard amounts and rates of Pacific cod in the AI Pacific cod fisheries are shown for each year 1993-2023 in Table 2A.9. 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 implemented amendments to the BSAI Groundfish FMP that reference Pacific cod explicitly.

History with Respect to the EBS Stock

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

The history of acceptable biological catch (ABC), overfishing level (OFL), and total allowable catch (TAC) levels is summarized and compared with the time series of aggregate (i.e., all-gear, combined area) commercial catches in Table 2A.10. Note that, prior to 2014, this time series pertains to the combined BSAI region, so the catch time series differs from that shown in Table 2A.4, Table 2A.5, and Table 2A.6, which pertain to the AI only. Total catch has been less than the OFL in every year since 1993. Instances where catch exceeds TAC can typically be attributed to the fact that the catches listed in Table 2A.10 are total catches (i.e., Federal plus State), whereas the TAC applies only to the Federal catch.

In the 10 years that AI Pacific cod have been managed separately from EBS Pacific cod, the ratio of Federal catch to TAC has ranged from 0.35 to 0.96. The catch/TAC ratio in 2023 (complete through October 26) was 0.35, 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

(Thompson et al. 2019). During the period of separate AI and EBS management, the assessment of the AI stock has been based on a simple, random effects (Tier 5) model.

History with Respect to the State Fishery

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

Year	Formula
2014	0.03*(EBS ABC + AI ABC)
2015	0.03*(EBS ABC + AI ABC)
2016	0.27*AI ABC
2017	0.27*AI ABC
2018	0.27*AI ABC
2019	0.31*AI ABC
2020	0.35*AI ABC or 6,804 t, whichever is less
2021	0.39*AI ABC or 6,804 t, whichever is less
2022	0.39*AI ABC or 6,804 t, whichever is less
2023	0.39*AI ABC or 6,804 t, whichever is less

If 90% of the Aleutian Islands GHL is harvested by November 15 of the preceding year, the GHL increases by 4%. However, the GHL cannot exceed 39% or 6,804 t. If the 2024 ABC remains at the value that was specified last year (13,812 t), the above formula would result in a GHL of 5,386 t in 2024, which is the maximum allowed (39%) of the ABC. The total caught in the state fishery by October 20, 2023 was 4,511 t (Table 2A.6). 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 2A.11 and Figure 2A.6). Partial catch information for 2023 was available and was extrapolated to estimate the catch for the full year. On average, 92.6 % of the annual catch occurs by this date, as estimated by catch statistics in 2018 - 2022. The full year's estimate of catch of Pacific cod in the Aleutian Islands for 2023, was 7,898 t.

The data used in the Tier 5 Model included biomass estimates and associated error for the NMFS Aleutian Island research surveys, 1991-2022 (Table 2A.12).

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 2A.13). 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. The number of cod aged from the survey has ranged between 500 and 1,200 and the number of hauls ranges from 76-173 (Table 2A.14). Length composition data from the fishery and surveys was also used in the model (Figure 2A.6).

The time series of NMFS bottom trawl survey biomass is shown for Areas 541-543 (Eastern, Central, and Western AI, respectively), together with their respective coefficients of variation, in Table 2A.12. 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 trawl 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 2A.7 and Table 2A.12).

The most recent longline survey estimate was also the lowest in the time series, but the longline survey data was not incorporated into the Tier 5 model or the age stuctured models (Table 2A.13). 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 2A.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, 2019 - October 20, 2023), pot and trawl gear were primarily used (1.3% longline, 33.8% trawl, 64.8% pot). After spawning, Pacific cod tend to disperse for feeding; during May through December, cod were primarily caught with longline gear, followed by trawl and pot gear (51.5% longline, 45.1% trawl, 3.4% pot). While the spawning season is approximately half the time of non-spawning (4 vs. 8 months), the majority, 67.1%, of the annual catch (January 1, 2019 - October 31, 2023) 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 2A.10).

Length frequencies from the fishery

Fishery lengths are taken throughout the year by observers during commercial fishing operations (Figure 2A.8). The length frequency composition ranges from approximately 40-120 cm and varies over time (Figure 2A.9, Figure 2A.10). Length frequency 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 2A.15. Most lengths by fisheries observers have been collected on longline and trawl vessels (Table 2A.15).

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 through 2023 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, 2022, 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 23.0, Model 23.1, and Model 23.2 are presented, which were built using Stock Synthesis version 3.30.21 (Methot and Wetzel 2013). The Stock Synthesis user manual is available at: https://nmfs-stock-synthesis.github.io/doc/).

Models 23.0, 23.1, 23.2 fit survey abundance estimates, survey and fishery age data, survey length data, fishery catch, and fishery length composition data. Survey age and length data were 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. This differs from the EBS model, which has a plus group of 20 in the 2023 model (Barbeaux et al. 2023), but is similar to the Gulf of Alaska assessment, which also has a plus group of 10 (Hulson et al. 2022). A plus group of 10 was selected due to very few individuals aged over 10 years; out of the 10,224 fish aged, only 28 were age 11 or older, and the oldest fish was age 13. The model also incorporated lengths from 1 to 117 cm (bin size =1) as compositional data from the fisheries and surveys (Figure 2A.6). Length frequencies for Models 23.0 and 23.1 combined all fisheries into a single length composition (Figure 2A.9).

Survey age and length data were incorporated as conditional age-at length, which increases the number of age composition observations. This method avoids double counting age and length information and provides more detailed information about the relationship between size and age. It is preferable for estimating growth parameters, and accommodates stratified and random age collections.

Model features:

- Single sex model, 1:1 male female ratio.

- A Von Bertalanffy growth curve was estimated within the model.
- Ageing error was applied to ages 2-10+.
- All parameters were constant over time except for the von Bertalanffy growth parameter K (Models 23.0 and 23.1) and the fishery selectivity parameter for ascending width (Model 23.1).
- Internal estimation of fishing mortality, catchability, and selectivity parameters.
- Recruitment estimated as a mean with lognormally distributed deviations.
- Natural mortality was freely estimated within the model.
- Trawl survey catchability was estimated within the model in log space, with a normally-distributed prior of 0, standard deviation = 0.01.
- Maturity-at-age was estimated externally using observer data, then input into the model, as recommended by the September 2022 Plan Team meeting.
- This is a single-fleet model that combines trawl, longline, and pot fishery data.

In addition

- Models 23.0, 23.1, and 23.2 incorporate time blocks on the growth parameter K, with breakpoints at 2003 and 2017 in Models 23.0, 23.1. Model 23.2 incorporates only two time blocks, with a breakpoint at 2003.
- Model 23.1 incorporates five timeblocks on the fishery selectivity parameter for ascending width, with breakpoints at 2002, 2012, 2016, and 2019.
- Model 23.2 incorporates two timeblocks for natural mortality, with the breakpoint corresponding to a thermal shift in the Aleutian Islands.

Parameter Estimation

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, most parameters did not have informative priors, which allowed the model to fit values freely. For two parameters, normally distributed prior distributions were used for estimation, with bounds set at values sufficiently extreme that they were non-constraining. An informative prior was used on catchability and the peak parameter for fishery selectivity. Information on these priors is available in r4ss outputs (https://github.com/afsc-assessments/AI_PCOD).

Growth Timeblock Analysis

Timeblocks on growth were supported by research based on the work of Kapur et al. (2020). We looked at whether there was a biological reason for annually varying growth differences in Pacific cod from the Aleutian Islands. There were 10,134 records of aged and lengthed Pacific cod taken from NMFS research surveys between 1991 and 2022 (1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018, 2022). These records were analyzed using methodology of Kapur et al. (2020) using a generalized additive model. The vector of observed lengths of fish of a given age serve as a response variable.

Results indicated a shift in growth in 2002. To further investigate, the age data was split into two sets. The first, pre-2004, consisted of all fish collected prior to 2004. There was no survey in 2003, and fish collected in 2004 were <2 years old, because fish are not observed in the survey until age two. The rationale was that all Pre-2004 fish would have experienced Pre-2004 growth conditions. For the older set, we sequentially selected fish that were collected in 2004 at at least age 2, fish collected in 2006 and at least age 4, . . . through fish collected in 2010 and at least age 8, and all fish collected in 2012 and subsequently. Since cod live generally not longer than 10 years, this would include only cod that experienced the growth experience of years 2003 and later. A plot of the length frenquencies confirmed a shift in growth (Figure 2A.11). A series of nested von Bertalanffy growth models was applied to the pre- and post-2004 datasets to determine which parameters changed. The results indicated that the initial length and K changed among the two datasets. Because the survey and fishery do not regularly sample smaller fish, we only applied a change in growth to the K parameter, but there is a cohort effect that is detected in later ages.

Sampling design in the surveys was likely not a factor in the results observed. Sampling procedure changed from stratified to random in 2018, indicating that the shift in growth observed in 2002 was not related to sampling design.

Time varying natural mortality

Annual mean sea surface temperature in the North Pacific has been in an above average anomaly since 2013 (Xiao and Ren 2022), (Figure 2A.12). While this has not been documented as an ecological regime shift, it is significant and should be considered as a potential factor for changes in abundance or distribution. All age-structured models accounted for changing conditions due to the shift in temperature. Model 23.0 and Model 23.1 used time-varying growth with a breakpoint at 2017. The lag was due to the time required for cod to grow to a size/age that is incorporated into the model. The Kapur analysis did not identify a shift in growth after the shift described previously in 2002; however, the decline in biomass in the last few years in the time series is not otherwise accounted for by the model.

Without incorporating a shift in growth or natural mortality, the model cannot fit recent declines documented by the Aleutian Islands survey and the retrospective patterns are outside of acceptable bounds (e.g. Mohn's rho >0.4, Figure 2A.13). Models that do not fit the survey index well were presented at the September 2023 Plan Team meeting and in the 2022 Aleutian Islands cod stock assessment, but are not documented in this assessment due to poor fits to data and retrospective patterns. Model 23.0 and 23.1 reconciled the thermal shift using growth and Model 23.2 incorporated a time block on natural mortality in 2015. This slight lag in time since 2013-2014 was incorporated due to the effect of cumulative stress that increased temperatures can incur (e.g. Barbeaux et al. 2018, Laurel and Rogers 2020). Pacific cod are known to respond poorly to temperatures that exceed their preferred thermal range; therefore, increased natural mortality due to the thermal shift may be the optimal model configuration.

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 of visual maturity data 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 2A.16). This method was approved by the Plan Team (September 2022) and SSC (October 2022).

Ageing error 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. Ageing error was applied to ages 2-10+. The standard deviation at the first age was 0.57 and 1.16 at the maximum age.

- Age at which the estimated pattern begins (just linear below this age), this is the start age. *The pattern begins at age 3, linear before this.*
- Bias at start age (as additive offset from unbiased age). *None.*
- Bias at maximum (as additive offset from unbiased age). *None.*
- Power function coefficient for interpolating between those 2 values (value of 0.0 produces linear interpolation in the bias). *Zero.*
- Standard deviation at start age. *0.57*
- Standard deviation at max age. *1.16*
- Power function coefficient for interpolating between those 2 values. *Zero.*

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 2A.17).

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 Richards because the fourth parameter increases the AIC significantly and does not make up for the improvement to the fit. We ruled out the Gompertz equation because of its unrealistic inflection point. The logistic model has symmetrical growth at early and maximum ages, which is also not the case for Pacific cod. The von Bertalanffy growth curve was closest to the point of inflection for Pacific cod. In addition, it had a similarly low AIC as the Gompertz and Logistic curves and the second lowest sum of squared residuals, after the Gompertz. Therefore, the von Bertalanffy growth was selected as the best choice.

Data weighting

Survey length and age input sample sizes generated by bootstrapping the number of hauls from which length and age data were taken using the methodology of Hulson et al. (2023). Fishery length composition input sample sizes were generated from the number of hauls, and scaled to the mean survey input sample size (so that the mean fishery length comp input sample size was the same as the survey mean input sample size). This did not result in a change in likelihood, but is preferred over a constant sample size approach to weighting compositional data because it considers the number of hauls in each year and therefore the varying informational content in each year. This approach is consistent among the Aleutian Islands, EBS, and GOA Pacific cod assessment models.

Model-based age and length composition data from survey and fishery were weighted using the methodology of Francis (2011).

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 2A.18). 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 2023 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 2A.14) 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 age structured models as a constant multiplier on the survey selectivity, but with an initial value close to 1 and a small standard deviation (0.01). The effect of the prior was evaluated by comparing the 'float' option in Stock Synthesis. The float option calculates an analytical solution for q, rather than estimating a parameter for q. The results were similar to the standard model (Table 2A.19).

The estimate of q without the prior made a small difference in the overall model; the negative log-likelihood between models were similar. The largest difference came from a lower estimate of virgin SSB and natural mortality. The estimated trajectory of spawning biomass was slightly lower in reacent years for the float q option (Figure 2A.15.

Selectivity

For Models 23.0, 23.1, and 23.2, selectivity for the fishery and the survey were fit (separately) using monotonically increasing asymptotic logistic curve (Figure 2A.16). All selectivity curves were implemented as double normal, which contains six parameters, but only two were estimated (selectivity parameters 1 and 3). This allows for monotonically increasing asymptotic selectivity, and was configured so that the second double normal defining the descending slope was at the upper bound and only the first upward sloping normal was used to model selectivity.

Natural mortality

For Models 23.0, 23.1, and 23.2, natural mortality was freely estimated within the model. Estimation within the model framework provides a maximum likelihood estimate that incorporates all data sources. Model 23.2 estimated natural mortality over the two time blocks (Table 2A.20). The time block at 2015 was selected because this was two years after the beginning of the documented thermal shift (Xiao and Ren 2022), and also corresponded with the rise in temperatures in the Aleutian Islands. The time block did not start earlier because it incorporated a ~two year lag for effects of higher temperatures to be observed.

Other parameters

The total likelihood and the number of parameters estimated for each model is shown in Table 2A.20.

Results

Tier 5 Model Evaluation

Model 13.4 estimated the 2023 biomass estimate to be 54,166 t, with a 95% confidence interval of 42,783 - 68,578.

The time series of biomass estimated by Model 13.4, with 95% confidence intervals, is shown in Table 2A.21, 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 2A.7, as well as the fit to the data used from 2018 through 2023.

Age structured model evaluation

Three age structured models were presented in this assessment. We list the unique features of these models below.

- Model 23.0: This model incorporates three time blocks on the growth parameter K, with breakpoints at 2003 and 2017.
- Model 23.1: This model is similar to Model 23.0, except it incorporates five timeblocks on the fishery selectivity parameter for ascending width, corresponding with shifts in the gear targeting Pacific cod. Selectivity breakpoints were set at 2002, 2012, 2016, and 2019 (Figure 2A.2.
- Model 23.2: This model is similar to Model 23.0, except there are two timeblocks on growth with a breakpoint at 2003. There are also two timeblocks on natural mortality with a breakpoint 2017 corresponding with warmer temperatures in the Aleutian Islands.

The three models fit the survey and fishery length compositions well (Figure 2A.17, Figure 2A.18). Survey and fishery selectivity were similar to previous models in past assessments (Figure 2A.16). Research surveys are known to select for smaller fish that are not selected for in the fishery, and are typically less desirable as catch. The three models also fit the survey biomass index relatively well (Figure 2A.19), although Model 23.2 fits the last four survey biomass estimates more closely than the other two models. Models 23.0 and 23.1 underestimate survey biomass in 2014, 2016, and 2018 and overestimate the 2022 biomass estimate, but remain within the confidence intervals.

Likelihood components, number of parameters, and AIC for the three age structured models are shown in Table 2A.20 for recruitment, survey age, survey biomass, catch, fishery length, and total likelihood. The likelihoods are comparable because they are configured with the same datasets. The model with the lowest AIC, considered the best fit, was Model 23.2 (AIC=1677.556), followed by Model 23.1 (AIC=1696.212), and Model 23.0 (AIC=1697.624). There was statistically very little difference between the AIC for models 23.1 and 23.0.

A likelihood profile over the unfished recruitment shows that the estimate is somewhat between what the survey and the fishery data would indicate (Figure 2A.20).

Retrospective analysis

A retrospective analysis was performed on Models 23.0, 23.1, and 23.2 extending back 10 years to evaluate the model, with data from 2013-2023. The retrospective pattern has been a challenging aspect of Aleutian Islands Pacific cod age structured models for the past several years. Retrospective changes have resulted from a downward shift in the population size that is not accounted for by the model. Thus, the issue that results in a poor retrospective pattern is likely an extraneous factor that has occurred over the past 5-10 years.

Retrospective plots for the three age structured models indicate an improved pattern, although there is an extreme increase followed by a drop in spawning biomass estimated by the first several retrospective years for

Models 23.0 and 23.1 (Figure 2A.21, Figure 2A.22). In Model 23.2, the retrospective pattern is mixed, with the first year somewhat lower than the terminal year, followed by several years of small overestimates, but no extreme shifts (Figure 2A.23).

Hurtado-Ferro (2015) provides some guidance on the range of acceptable values for Mohn's rho. 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 = 0.34, the lower and upper bounds were given to be -0.22 and 0.3. If Mohn's rho 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 $Rho_{upperbound} = 0.10 + 0.50 * M$. Using these guidelines, and noting that Model 23.0 and 23.1 estimated M=0.34 and Model 23.2 estimated M=0.4 (on average), lower and upper bounds can be computed. For Models 23.0 and 23.1, lower and upper bounds are -0.2 and 0.27. For Model 23.2, lower and upper bounds are -0.22 and 0.3. Given these guidelines, the Mohn's rho is not outside the acceptable bounds for any of the three age structured models presented here.

Time Series Results

Based on Model 23.1, total biomass declined from approximately 173,570 t in 1992 to a timeseries low of 60,274 t in 2014 (Table 2A.22). Similarly, Model 23.2 indicates that total biomass declined from approximately 163,079 t in 1992 to a timeseries low of 54,611 t in NA (Table 2A.22). Total biomass estimates according to Model 23.1 have since increased to an estimate of 67,312 t in 2023, and 55,767 t based on Model 23.2. 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 all models (Table 2A.23 and Figure 2A.24), with the peak spawning biomass occurring in 1991 for both models. For Model 23.1, spawning biomass reached its lowest point of 40,541 t in 2021, and spawning biomass reached its lowest point of 35,068 t in 2022 for Model 23.2.

Phase plane plots for all models are presented (Figure 2A.25, Figure 2A.26, and Figure 2A.27) show that spawning biomass has been below $B_{35\%}$ since approximately 2009. For Model 23.2, spawning biomass was at $B_{22\%}$ during 2020 and 2021 but increased to $B_{23\%}$ in 2023. None of the models indicate that spawning biomass has fallen below $B_{20\%}$ during the timeseries (Table 2A.24). However, given the variance estimated by Model 23.2, there is an 18% chance that the stock is below $B_{20\%}$ in 2023.

Recruitment estimates indicate similar recruitment among models, but overall higher recruitment in Model 23.2 during 2013-2020, Figure 2A.28, and Table 2A.25. The three models track similar trajectories with higher numbers in the population through approximately the year 2000, and then a decline through 2020, followed by an increase starting in 2020. Recent increases in numbers at age may be due to favorable recruitment in 2019 and earlier (Figure 2A.28).

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 2024 and 2025 for the Tier 5 reference points. Note that the 95% confidence intervals for the Tier 5 estimates of biomass are shown in Table 2A.21.

Quantity	2024	2025
Biomass (t)	54,166	54,166
M	0.34	0.34
F_{OFL}	0.34	0.34
maxF_{ABC}	0.255	0.255
OFL (t)	18,416	18,416
maxABC (t)	13,812	13,812

Tier 5

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).

Because the Tier 3 models were conducted using the Stock Synthesis program, projections for those models were made within Stock Synthesis. For Models 23.0 and 23.1, point estimates of all time-varying parameters used in the projections are set at their respective time series means, except for annual deviations governing length at age of year classes currently in the population, as these propagate into the future. Due to time-varying growth and natural mortality in Model 23.2, projections changed depending on the time block selected for projections. For Model 23.2, results of projections using different years in the SS3 forecast.ss file (Bmark_years) for biology (e.g. growth, natural mortality, maturity, fecundity) were examined in a sensitivity analysis (Table 2A.26). Forecasts were performed using the second biological parameter time block (2004-2023), which used the later time block growth parameter, K. For all models, the year-end catch for 2023 was estimated to be 7,898 t, as described above. In the event that catch is likely to be less than the recommended ABC in either of the first two projection years, Scenario 2 must be conducted, using the best estimates of catch in those two years (otherwise, Scenario 2 can be omitted if the author's recommended ABCs for the next two years are equal to the maximum permissible ABCs).

Five of the seven standard scenarios support the alternative harvest strategies analyzed in the Alaska Groundfish Harvest Specifications Final Environmental Impact Statement. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2024, are as follows (max F_{ABC} refers to the maximum permissible value of F_{ABC} under Amendment 56):

- Scenario 1: In all future years, F is set equal to max F_{ABC} . (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
- Scenario 2: In all future years, F is set equal to a constant fraction of max F_{ABC} , where this fraction is equal to the ratio of the F_{ABC} value for 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, 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 4: In all future years, the upper bound on F_{ABC} is set at $F_{75\%}$. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
- Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.) Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether 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 2023 or 2) above 1/2 of its MSY level in 2023 and expected to be above its MSY level in 2033 under this scenario, then the stock is not overfished.)

- Scenario 7: In 2024 , 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 2025 or 2) above 1/2 of its MSY level in 2025 and expected to be above its MSY level in 2035 under this scenario, then the stock is not approaching an overfished condition.)

ABC and OFL for 2024 and 2025

Due to time-varying growth and natural mortality in Model 23.2, parameters for projections could change depending on the time block selected for projections. Forecasts were performed using the second biological parameter time block (2004-2023), which used the second growth parameter, K. This projection used average natural mortality 0.4, but different blocks of years provide different results (Table 2A.26.)

Models 23.0, 23.1, and 23.2 indicate that the Aleutian Islands Pacific cod stock is 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 $B_{35\%}$ by 2028 (Table 2A.27, Table 2A.28, Table 2A.29). Projections of catch for Aleutian Islands Pacific cod 2024 through 2036 based on the seven harvest scenarios are shown as figures for Models 23.0, 23.1, and 23.2 (Figure 2A.29, Figure 2A.30, Figure 2A.31). Projections of spawning stock biomass for Aleutian Islands Pacific cod 2024 through 2036 based on all seven harvest scenarios for the three models are presented as a single figure (Figure 2A.32, Figure 2A.33, Figure 2A.34), and separately (Figure 2A.35, Figure 2A.36, Figure 2A.37).

For stocks in Tiers 4-6, no determination can be made of overfished status or approaching an overfished condition as information is insufficient to estimate the MSY stock level. Under Model 13.4, ABC and OFL for 2024 and 2025 are 13,812 t and 18,416 t.

Under Model 23.2 ABCs for 2024 and 2025 are 10,660 t and 10,214 t, and OFLs are 12,732 t and 17,304 t.

Risk Table

Assessment Considerations

This stock been assessed using Tier 5 methodology since 2013. The standard Tier 5 random effects model does not account for population dynamics or ecosystem effects. 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. A trawl survey was conducted in 2022 for the first time since 2018.

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

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 (Figure 2A.7). In addition, Model 23.2 indicates that the spawning biomass was $B_{22\%}$ and $B_{23\%}$ in 2022 and 2023, with an 18% chance of being below $B_{20\%}$, based on the standard deviation of the biomass estimate.

How well the longline survey targets Pacific cod is 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, the longline survey is unlikely to provide an accurate index of Pacific cod biomass in the Aleutian islands.

Fishery CPUE indicates a decline in CPUE in the past several years (Figure 2A.3, Figure 2A.4). Interpretation of population dynamics using fishery CPUE can be complicated, and there is not necessarily a clear relationship between the two. Low CPUE may also be an indication of low fishing effort. Fishery length frequencies provide information on the relative size of fish encountered. In 2022 the fish appeared to be smaller than average over the past four years.

Population dynamics considerations were rated as level 2.

Environmental/Ecosystem Considerations

Environment: Annual mean sea surface temperature in the North Pacific shifted to warmer temperatures in 2013-2014, this includes all Alaskan waters - the eastern Bering Sea, Gulf of Alaska and the Aleutian Islands (Xiao and Ren 2022). Mid-depth (100-300m) and water column temperature (surface to bottom) from the longline survey (164°W to 170°W) show slightly warmer temperatures from 150-250 m depth compared to 2022. Note however temperatures have been higher in general throughout the water column starting 2014. Sea surface temperature in 2023 shows one of the warmest winters on record both on the Extended Reconstructed Sea Surface Temperature (ERSST) dataset (Thoman, 2023) and satellite data. Temperatures cooled in late spring and early summer but remained above average, and increased again in August (Lemagie and Callahan, 2023). While marine heat waves were less intense and extensive in the western and central Aleutians, winter saw an increase in extension and intensity of MHW in the eastern Aleutian islands. The average bottom temperature from the Aleutian Islands bottom trawl survey (AIBTS, (165°W – 172°E, 30-500 m) in 2022 was ~4.4°C, similar to 2018 and cooler than the highest observed in 2016 but still above the long term mean (1984-2022), as have the last four surveys (2014 onwards). So far, mean bottom and midwater temperatures seem to have remained within the optimal thermal envelope for egg hatch success of 3-6°C during January through May (spawning season).

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. Prey consumption may have increased at depths between 150-250 m in the eastern Aleutians this year. Sustained warmer temperatures above the long term average throughout the water column and during both winter and summer is considered to have a 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: The reproductive success of planktivorous seabirds such as auklets in Buldir in the Aleutian Islands declined across all species from above average last year to average in 2023. Pacific cod stomachs collected in the bottom trawl survey in the western and central Aleutians (areas 543, 542) have shown significant 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 (O'Leary and Rohan 2022), potentially providing lower quality prey for Pacific cod. Squid and shrimp have increased in relevance across the board, as have invertebrates in general. Across the Western, Central and Eastern Aleutian, diets seem to now be dominated by invertebrates, as opposed to fish. However, this is not necessarily in increase in their availability as the total amount of prey consumed as a proportion of predator weight has declined overall. 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). Due to increased temperature, Pacific cod has likely increased its consumption to offset the higher bioenergetic costs due to the higher temperature. It appears that the only place where prey as percent or predator weight increased enough to improve condition was in the Southern Bering Sea. 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 invertebrates may be partially due to the dominance of rockfish (POP and Northern Rockfish) within the pelagic foragers, as opposed to 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) but most other species (piscivorous and planktivorous had average or below average reproductive success, with red-leged kittiwakes having complete reproductive failure. In contrast, in Aiktak (eastern Aleutians) most seabirds had above average reproductive success, indicating that forage fish to support chick-rearing were available this year in the region. Seabird success suggests broad availability of prey in the eastern Aleutians where at least half the Pacific cod stock is typically distributed; the primary prey (>80% by weight) for tufted puffins was capelin. (Rojek et al 2022). Potentially less prey is available in the western Aleutian Islands compared to last year, where the dominant prey were squids and Pacific saury for tufted puffins (above average reproduction success) and squids and Atka mackerel for horned puffins (average reproductive success). However kittiwakes and fork-tailed storm petrels (mixed diets and surface feeders) had either below average reproductive success or complete failure (red-legged kittiwakes)

Taken together, the mix of cooler summer temperatures with high winter temperatures during the spawning season, as well as seabird data suggest that 2023 conditions are potentially improving for Pacific cod in the eastern Aleutians but are not as favorable in the western Aleutians as last year. 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's and past trends in indicators suggests there still remain several 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). Pacific halibut continues at lower abundances since its peak in the 2000s (Stewart and Hicks, 2022). As of 2022, Steller sea lions were declining in the western Aleutians, as were harbor seals in 2018 (London et al. 2021). 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 2023, and consistently indicate a downward trend (Figure 2A.3, Figure 2A.4). However, a single report from the Aleutian Islands state GHL fishery indicated good fishing in 2022.

However, the fishery reports that lack of catcher-vessel (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 2023, and is unlikely to open for the 2024 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:

Assessment consideration	Population dynamics	Environmental ecosystem	Fishery performance
Level 1: No concern	Level 2: Major concern	Level 2: Major concern	Level 1: No concern

Because the Population dynamics and Environmental/ecosystem components of the Risk Table are greater than level 1, ABC may need to be reduced from the maximum permissible value. If the Tier 3b assessment Model 23.2 is accepted, we recommend no additional reduction in ABC. If a different model is accepted, we recommend a reduction in management quantities comparable to the management quantities based on Model 23.2.

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% was used between 2018 and 2022. The proportion allocated to the western Aleutian Islands region 543 would remain 25% after the State GHL is subtracted from the overall AI ABC whether a Tier 5 or Tier 3b harvest strategy is adopted.

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 (2022) is 11,851 t. This is less than the 2021 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 2023 in each of these tables are incomplete, through the end of October 2023. The Pacific cod fishery using trawl gear Table 2A.30 and fixed gear Table 2A.31 take a small proportion of the incidental catch of FMP species (1991-2023). FMP species are more commonly caught in the Pacific cod trawl fishery than with longline gear (Table 2A.30, Table 2A.31). In the Pacific cod trawl fishery, flatfish are most commonly caught FMP species, followed by Atka mackerel and occasionally sharks and skates. During some years from 1991-2023, the proportional catch of octopus and longnose skate was high in the Pacific cod trawl (Table 2A.32) and longline (Table 2A.33) fisheries, although incidental catch of squid and members of the former "other species" complex taken by trawl gear was lower. Similarly, the Pacific cod fishery accounts for a large proportion of several crab species bycatch (Table 2A.34). Discard mortality of halibut taken in the Pacific cod fishery from 1991-2023, aggregated across gear types, has declined during this time period. The proportion of incidental catch of non-target species groups taken from 2003-2023, excluding bird species, aggregated across gear types Table 2A.35 varies from very little to almost all of the bycatch in a given year.

Steller Sea Lions

Pacific cod is one of the four most important prey items of Steller sea lions in terms of frequency of occurrence averaged over years, seasons, and sites, and is especially important in winter in the GOA and BSAI (Pitcher 1981, Calkins 1998, Sinclair and Zeppelin 2002). The size ranges of Pacific cod harvested by the fisheries and consumed by Steller sea lions overlap, and the fishery operates to some extent in the same geographic areas used by Steller sea lion as foraging grounds (Livingston (ed.), 2002). A study conducted in 2002-2005 using pot fishing gear demonstrated that the local concentration of cod in the Unimak Pass area is very dynamic, so that fishery removals did not create a measurable decline in fish abundance (Conners and Munro 2008). A preliminary tagging study in 2003–2004 showed some cod remaining in the vicinity of the release area in the southeast Bering Sea for several months, while other fish moved distances of 150 km or more north-northwest along the shelf, some within two weeks (Rand et al. 2015).

Seabirds

In the BSAI and GOA, the northern fulmar (*Fulmarus glacialis*) comprises the majority of seabird bycatch, primarily in the longline fisheries, including the fixed gear fishery for Pacific cod (Livingston (ed.) 2002). Shearwater (*Puffinus* spp.) distribution overlaps with the Pacific cod longline fishery in the Bering Sea, and with trawl fisheries in general in both the Bering Sea and GOA. Black-footed albatross (*Phoebastria nigripes*) is taken in much greater numbers in the GOA longline fisheries than the Bering Sea longline fisheries, but is not taken in the trawl fisheries. The distribution of Laysan albatross (*Phoebastria immutabilis*) appears to overlap with the longline fisheries in the central and western Aleutians. The distribution of short-tailed albatross (*Phoebastria albatrus*) also overlaps with the Pacific cod longline fishery along the Aleutian chain, although the majority of the bycatch has taken place along the northern portion of the Bering Sea shelf edge; in contrast, only two have been recorded in the GOA. Some success has been obtained in devising measures to mitigate fishery-seabird interactions. For example, on vessels larger than 60 ft. LOA, paired streamer lines of specified performance and material standards have been found to significantly reduce seabird incidental take. Typically bycatch of bird species in the Pacific cod trawl and longline fisheries is low, although in some years a large proportion of certain species were taken in the Pacific cod fisheries (Table 2A.36.

Data Gaps and Research Priorities

Longer-term research needs include improved understanding of Aleutian Islands Pacific cod, including: 1) the spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment, 2) ecology of species that interact with Pacific cod, including estimation of interaction strengths, biomass, carrying capacity, and resilience, and 3) understanding the physiological response of cod to thermal stress using gene expression studies in an experimental setting.

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Tables

Table 2A.1: Summary table for Model 23.0. Last year's assessment incorporated a Tier 5 model. Projections were based on annual catches of 7,898 t for 2023 and the ABC for 2024.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2023	2024	2024	2025
M (natural mortality rate)	0.34	0.34	0.34	0.34
Tier	5	5	3b	3b
Projected total (age 1+) biomass (t)	54,165	54,165	75,238	80,120
Projected female spawning biomass (t)	-	-	26,602	27,728
$B_{100\%}$	-	-	79,980	79,980
$B_{40\%}$	-	-	31,992	31,992
$B_{35\%}$	-	-	27,993	27,993
F_{OFL}	0.34	0.34	0.445	0.487
$maxF_{ABC}$	0.255	0.255	0.363	0.398
F_{ABC}	0.255	0.255	0.363	0.398
OFL	18,416	18,416	15,311	17,880
$maxABC$	13,812	13,812	12,757	14,955
ABC	13,812	13,812	12,757	14,955
Status	2021	2022	2022	2023
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Table 2A.2: Summary table for Model 23.1. Last year's assessment incorporated a Tier 5 model. Projections were based on annual catches of 7,898 t for 2023 and the ABC for 2024.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2023	2024	2024	2025
M (natural mortality rate)	0.34	0.34	0.34	0.34
Tier	5	5	3b	3b
Projected total (age 1+) biomass (t)	54,165	54,165	73,073	77,602
Projected female spawning biomass (t)	-	-	25,887	26,654
$B_{100\%}$	-	-	78,973	78,973
$B_{40\%}$	-	-	31,589	31,589
$B_{35\%}$	-	-	27,640	27,640
F_{OFL}	0.34	0.34	0.452	0.482
$maxF_{ABC}$	0.255	0.255	0.368	0.393
F_{ABC}	0.255	0.255	0.368	0.393
OFL	18,416	18,416	14,762	16,517
$maxABC$	13,812	13,812	12,300	13,799
ABC	13,812	13,812	12,300	13,799
Status	2021	2022	2022	2023
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 was a Tier 5 model. Projections were based on annual catches of 7,898 t for 2023 and the ABC for 2024.

Table 2A.3: Summary table for Model 23.2. Last year's assessment was a Tier 5 model. Projections were based on annual catches of 7,898 t for 2023 and the ABC for 2024. Natural mortality is provided for both time blocks, in order.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2023	2024	2024	2025
M (natural mortality rate)	0.34	0.34	0.32, 0.49	0.32, 0.49
Tier	5	5	3b	3b
Projected total (age 1+) biomass (t)	54,165	54,165	54,611	61,611
Projected female spawning biomass (t)	-	-	18,687	18,302
$B_{100\%}$	-	-	56,572	56,572
$B_{40\%}$	-	-	22,628	22,628
$B_{35\%}$	-	-	19,800	19,800
F_{OFL}	0.34	0.34	0.544	0.666
$maxF_{ABC}$	0.255	0.255	0.445	0.422
F_{ABC}	0.255	0.255	0.445	0.422
OFL	18,416	18,416	12,732	17,304
$maxABC$	13,812	13,812	10,660	10,214
ABC	13,812	13,812	10,660	10,214
Status	2021	2022	2022	2023
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Table 2A.4: 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 2A.5: Summary of catches of Pacific cod (t) in the Aleutian Islands by gear type. All catches include discards. Domestic annual catch by gear is not available prior to 1988.

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

Table 2A.6: Federal and state fishery Pacific cod catch in metric tons by year, 1991-2023. To avoid confidentiality problems, federal longline and pot catches have been combined. "Other" gear types include gill net and jig. Catches for 2023 are through October 20. The state fishery catch is included in the total, and broken out as a separate column from 2006 onward.

Year	Trawl	Longline+Pot	Other	Total	State
1991	3,414	6,383	0	9,797	0
1992	14,558	28,425	83	43,067	0
1993	17,311	16,860	32	34,204	0
1994	14,382	7,156	0	21,539	0
1995	10,574	5,959	0	16,534	0
1996	21,178	10,429	0	31,609	0
1997	17,349	7,725	88	25,164	0
1998	20,530	14,195	0	34,726	0
1999	16,437	11,624	68	28,130	0
2000	20,361	19,289	32	39,684	0
2001	15,826	18,361	19	34,207	0
2002	27,929	2,871	0	30,800	0
2003	31,478	978	0	32,456	0
2004	25,770	3,102	0	28,873	0
2005	19,613	3,067	12	22,693	0
2006	20,062	4,141	7	24,211	3,720
2007	28,631	5,716	6	34,354	4,140
2008	21,826	9,193	208	31,228	4,266
2009	20,821	7,739	20	28,581	2,039
2010	18,872	10,133	0	29,006	3,966
2011	9,382	1,506	0	10,888	265
2012	12,138	6,059	21	18,219	5,209
2013	8,122	5,489	0	13,612	4,793
2014	6,765	3,817	0	10,583	4,450
2015	6,129	3,080	0	9,209	161
2016	11,535	1,696	0	13,231	882
2017	8,536	6,633	0	15,170	2,946
2018	10,118	10,239	55	20,414	5,695
2019	10,293	8,710	140	19,144	6,168
2020	4,319	9,939	5	14,264	6,777
2021	3,463	10,544	0	14,007	6,710
2022	3,649	8,202	0	11,851	5,402
2023	3,165	4,146	0	7,311	4,511

Table 2A.7: Summary of 1994-2023 catches (t) of Pacific cod in the AI, by NMFS statistical area (area breakdowns not available prior to 1994). Catches for 2023 are through October 20.

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	2,694	4,065	13,655	0.132	0.199	0.669
2019	1,340	5,298	12,507	0.070	0.277	0.653
2020	1,972	5,131	7,161	0.138	0.360	0.502
2021	1,715	3,791	8,502	0.122	0.271	0.607
2022	1,237	3,016	7,599	0.104	0.254	0.641
2023	582	1,992	4,737	0.080	0.272	0.648

Table 2A.8: Catch of Pacific cod from 1993-2023 in non-target and targeted fisheries, as of October 26, 2023.

Year	Non-target							Target	Overall
	Atka mackerel	Flatfish	Halibut	Pollock	Rockfish	Other	Total non-target	Pacific cod	Total
1993	2,634	0	0	2	218	0	2,854	1,353	4,207
1994	6,855	3	0	11	358	0	7,244	14,295	21,539
1995	4,456	25	0	47	207	37	5,713	10,822	16,535
1996	8,675	0	0	10	394	10	9,173	22,436	31,609
1997	1,988	0	0	216	110	0	2,359	22,804	25,163
1998	3,709	19	0	1	114	33	3,891	30,836	34,727
1999	2,415	16	0	0	173	2	2,660	25,471	28,131
2000	2,088	66	0	0	115	24	2,377	37,308	39,685
2001	2,018	3	0	0	194	6	2,287	31,920	34,207
2002	1,265	2	0	0	70	4	1,433	29,369	30,802
2003	1,895	9	91	0	264	5	2,275	30,182	32,457
2004	2,109	0	91	0	132	0	2,335	26,538	28,873
2005	2,154	0	236	0	83	1	2,479	20,215	22,694
2006	1,526	29	88	0	83	2	1,741	22,470	24,211
2007	1,785	34	19	1	85	1	1,933	32,422	34,355
2008	1,005	0	86	1	220	8	1,327	29,901	31,228
2009	2,022	0	14	0	84	5	2,145	26,437	28,582
2010	1,616	13	15	377	84	0	2,116	26,890	29,006
2011	1,488	94	65	0	136	5	1,795	9,093	10,888
2012	1,265	21	26	0	115	0	1,432	16,786	18,218
2013	853	230	174	9	390	0	1,659	11,951	13,610
2014	908	141	94	0	225	0	1,369	9,233	10,602
2015	2,253	27	43	0	580	0	2,903	6,313	9,216
2016	2,495	63	61	1	544	0	3,164	10,080	13,244
2017	3,913	1	78	0	673	2	4,667	10,510	15,177
2018	3,308	5	59	2	509	0	3,901	16,514	20,415
2019	2,197	33	78	0	928	0	3,249	15,896	19,145
2020	2,176	45	74	0	770	0	3,067	11,196	14,263
2021	1,951	16	77	0	526	0	2,590	11,417	14,007
2022	2,239	15	25	1	361	0	2,642	9,209	11,851
2023	1,792	26	51	0	352	0	2,221	5,197	7,418

Table 2A.9: Discards (t) and discard rates for Pacific cod caught in the Aleutian Islands, for the period 1993-October 26, 2023. 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	151	19,145	0.008
2020	142	14,264	0.010
2021	179	14,008	0.013
2022	156	11,852	0.013
2023	138	7,418	0.019

Table 2A.10: Pacific cod catch in metric tons by year, total allowable catch (TAC), acceptable biological catch (ABC), and overfishing limit (OFL), 1991-2023. 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 2023 is through October 23. ABC and OFL for 2023 are based on this year's model output. TAC from 2023 is based on harvest specifications from 2022.

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
2023	7,312	13,812	8,425	18,416

Table 2A.11: Sources of data used in the age structured models, Model 23.0 and 23.1. **Longline survey data was not used in age structured models presented here, but was considered in prelinary models

Source	Type	Years
Fishery (Trawl, Pot, LL)	Catch biomass	1991-2023*
Fishery (Trawl, Pot, LL)	Length composition	1991-2023
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

Table 2A.12: 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 2A.13: 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 models.

	Trawl Survey		Longline Survey	
Year	Biomass (t)	S.E.	Index	S.E.
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 2A.14: Survey age composition sample size data, by year, including the number of individual fish, number of hauls, and effective sample size for each year. Effective sample sizes were generated using the methodology of Hulson et al (2023).

Year	Number of aged fish	Number of hauls	Effective sample size
1991	919	121	39
1994	1174	150	25
1997	845	99	67
2000	828	111	153
2002	1270	173	162
2004	775	107	169
2006	754	105	105
2010	673	94	156
2012	599	83	126
2014	557	76	153
2016	681	95	142
2018	575	80	197
2022	765	192	253

Table 2A.15: The number of hauls in which length observations were taken for the fishery length composition data, by year.

Year	Trawl	Longline	Pot
1991	172	355	-
1992	306	-	-
1993	453	-	-
1994	455	136	-
1995	517	-	-
1996	759	-	-
1997	364	575	-
1998	1289	-	-
1999	1420	-	-
2000	2207	664	-
2001	2590	-	-
2002	1016	819	-
2003	1067	-	-
2004	1100	1030	-
2005	881	-	-
2006	901	538	-
2007	1233	-	-
2008	1015	-	-
2009	1062	-	-
2010	1550	851	-
2011	396	-	-
2012	537	733	-
2013	442	-	-
2014	214	1067	-
2015	422	-	-
2016	357	1158	-
2017	528	-	-
2018	603	1009	-
2019	340	-	-
2020	371	-	-
2021	357	-	-
2022	156	953	-
2023	14	-	-

Table 2A.16: Maturity at age ogives based on histological data (Stark 2007) and observer maturity at length data (visual observation) from 2008-2021. Observer-based maturity curves were used in age structured models.

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 2A.17: 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 2A.18: 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 2A.19: Likelihood component values and estimates of catchability (Q) for Model 23.2 and the same model with a floating Q.

	Likelihood component	M23.2	M23.2 Float Q
1	TOTAL_like	769.8720000	765.6540000
2	Survey_like	-8.2146300	-8.1439500
3	Length_comp_like	141.5530000	136.2400000
4	Age_comp_like	639.6350000	639.7600000
5	Parm_priors_like	0.6553500	0.6020350
6	Recr_Virgin_millions	24.3493000	23.0922000
7	SR_LN(R0)	10.1003000	10.0473000
8	SR_BH_steep	1.0000000	1.0000000
9	NatM_uniform_Fem_GP_1	0.4035090	0.3841560
10	NatM_uniform_Fem_GP_1_BLK2add_1991	-0.0838666	-0.0594516
11	NatM_uniform_Fem_GP_1_BLK2add_2016	0.0838670	0.0594519
12	L_at_Amax_Fem_GP_1	117.2590000	116.9630000
13	VonBert_K_Fem_GP_1	0.1936940	0.1944010
14	VonBert_K_Fem_GP_1_BLK1add_1991	0.0011298	0.0014311
15	VonBert_K_Fem_GP_1_BLK1add_2004	-0.0011296	-0.0014309
16	SSB_Virgin_thousand_mt	194.5960000	177.1000000
17	Bratio_2021	0.1832930	0.1645110
18	SPRratio_2020	0.4878260	0.5782880
NA	-	-	-

Table 2A.20: Likelihood component values for Models presented in this assessment.

Likelihood component	M23.0	M23.1	M23.2
TOTAL_like	777.812	772.106	769.872
Survey_like	-1.979	-4.268	-8.215
Length_comp_like	141.080	138.871	141.553
Age_comp_like	641.532	640.580	639.635
Parm_priors_like	0.622	0.693	0.655
Recr_Virgin_millions	23.633	24.457	24.349
SR_LN(R0)	10.070	10.105	10.100
SR_BH_steep	1.000	1.000	1.000
NatM_uniform_Fem_GP_1	0.340	0.340	0.400
NatM_uniform_Fem_GP_1_BLK2add_1991	-	-	-0.084
NatM_uniform_Fem_GP_1_BLK2add_2016	-	-	0.084
L_at_Amax_Fem_GP_1	117.212	117.631	117.259
VonBert_K_Fem_GP_1	0.191	0.190	0.194
VonBert_K_Fem_GP_1_BLK1add_1991	0.004	0.004	0.001
VonBert_K_Fem_GP_1_BLK1add_2004	0.003	0.002	-0.001
VonBert_K_Fem_GP_1_BLK1add_2018	-0.007	-0.006	-
SSB_Virgin_thousand_mt	163.374	161.961	194.596
Bratio_2021	0.231	0.250	0.183
SPRratio_2020	0.611	0.598	0.488
npar	71.000	76.000	72.000
AIC	1697.624	1696.212	1677.556
Rho	0.170	0.140	0.058

Table 2A.21: Biomass (t) estimated by Model 13.4, 1991 - 2023, with lower (UCI) and upper (UCI) 95% confidence bounds.

Year	Biomass	LCI	UCI
1991	170,408	131,159	221,403
1992	157,867	111,870	222,777
1993	146,249	102,571	208,525
1994	135,486	100,336	182,950
1995	115,673	82,021	163,132
1996	98,758	71,033	137,305
1997	84,316	65,811	108,025
1998	89,857	64,975	124,266
1999	95,761	68,542	133,788
2000	102,054	76,704	135,781
2001	91,214	67,032	124,119
2002	81,525	63,533	104,613
2003	80,944	59,321	110,447
2004	80,366	60,815	106,202
2005	78,538	55,680	110,780
2006	76,752	54,613	107,866
2007	72,423	48,903	107,257
2008	68,339	45,740	102,103
2009	64,485	44,547	93,345
2010	60,848	45,776	80,882
2011	61,383	45,021	83,692
2012	61,923	48,937	78,356
2013	66,480	49,261	89,718
2014	71,373	54,984	92,646
2015	74,777	54,756	102,119
2016	78,344	59,956	102,373
2017	77,232	56,559	105,462
2018	76,136	58,904	98,408
2019	69,923	49,488	98,797
2020	64,218	44,432	92,816
2021	58,978	42,054	82,714
2022	54,166	42,783	68,578
2023	54,166	42,783	68,578

Table 2A.22: Estimates of total biomass for Models 23.0, 23.1, and 23.2.

Year	Model 23.0	Model 23.1	Model 23.2
	Biomass (t)	Biomass (t)	Biomass (t)
1989	196,693	195,777	231,130
1990	196,693	195,777	231,130
1991	156,080	160,386	150,890
1992	168,838	173,570	163,079
1993	148,241	152,924	142,474
1994	132,603	136,938	127,361
1995	129,834	133,910	124,879
1996	133,510	137,426	128,690
1997	125,034	128,717	120,345
1998	126,729	129,979	121,949
1999	127,015	129,331	121,781
2000	134,132	134,758	128,579
2001	129,934	128,407	124,407
2002	133,118	129,677	127,385
2003	140,171	135,327	134,248
2004	140,354	135,222	134,857
2005	135,595	130,590	130,842
2006	128,760	124,193	125,226
2007	117,366	113,365	115,034
2008	97,214	93,925	95,806
2009	82,650	80,156	81,987
2010	73,372	71,766	73,661
2011	63,572	62,861	65,232
2012	66,910	66,724	70,668
2013	61,362	61,760	67,868
2014	59,177	60,274	69,608
2015	60,429	62,273	76,389
2016	65,310	67,992	90,073
2017	68,189	71,730	87,855
2018	69,018	72,873	82,311
2019	62,561	66,584	71,154
2020	57,797	61,344	62,434
2021	59,872	62,173	60,472
2022	63,652	64,352	58,732
2023	68,195	67,312	55,767

Table 2A.23: Estimates of female spawning biomass for Models 23.0, 23.1, and 23.2, with upper and lower 95% confidence intervals.

Year	Model 23.0			Model 23.1			Model 23.2		
	Biomass (t)	LCI	UCI	Biomass	LCI	UCI	Biomass	LCI	UCI
1989	163,374	127,092	199,655	161,961	126,048	197,873	194,596	147,900	241,291
1990	163,374	127,092	199,655	161,961	126,048	197,873	194,596	147,900	241,291
1991	117,303	94,784	139,821	120,062	96,738	143,385	115,206	93,287	137,124
1992	121,287	101,630	140,943	124,427	103,921	144,932	118,639	99,538	137,739
1993	109,666	91,311	128,020	113,145	93,869	132,420	106,264	88,524	124,003
1994	102,222	84,604	119,839	105,588	87,065	124,110	98,853	81,876	115,830
1995	97,676	81,462	113,889	100,677	83,653	117,700	94,919	79,261	110,577
1996	95,285	80,751	109,820	98,097	82,818	113,376	92,899	78,812	106,987
1997	89,393	76,593	102,194	92,103	78,591	105,616	86,846	74,416	99,276
1998	86,093	74,462	97,724	88,566	76,303	100,829	83,581	72,293	94,869
1999	82,879	71,502	94,255	85,014	73,152	96,876	80,311	69,274	91,348
2000	87,425	75,665	99,186	88,597	76,682	100,512	84,516	73,124	95,908
2001	88,232	75,917	100,547	87,657	75,531	99,784	85,006	73,076	96,936
2002	89,231	76,378	102,084	86,697	74,138	99,257	86,089	73,627	98,550
2003	92,428	78,977	105,880	88,204	74,894	101,513	89,300	76,229	102,371
2004	99,249	84,954	113,544	94,341	80,074	108,608	95,955	82,069	109,841
2005	102,729	88,820	116,637	97,760	83,850	111,671	99,601	86,030	113,172
2006	100,320	87,623	113,016	95,707	83,022	108,392	98,019	85,589	110,449
2007	88,581	77,516	99,645	84,511	73,501	95,521	87,320	76,448	98,192
2008	69,231	59,903	78,559	65,832	56,620	75,044	68,745	59,492	77,998
2009	55,807	47,895	63,719	53,023	45,231	60,815	55,720	47,748	63,691
2010	46,805	39,545	54,064	44,770	37,597	51,942	47,152	39,694	54,609
2011	43,048	35,973	50,124	41,881	34,792	48,969	44,135	36,649	51,621
2012	47,651	40,486	54,816	47,018	39,650	54,387	50,206	42,264	58,148
2013	44,761	37,707	51,815	44,632	37,202	52,061	49,255	40,887	57,622
2014	42,877	35,997	49,756	43,220	35,892	50,547	49,872	40,866	58,877
2015	42,779	36,005	49,552	43,626	36,349	50,903	53,198	42,984	63,412
2016	44,488	37,606	51,369	45,949	38,457	53,441	58,373	46,599	70,148
2017	45,600	38,301	52,899	47,850	39,803	55,898	55,766	45,519	66,012
2018	46,898	38,707	55,089	49,747	40,760	58,734	53,294	43,797	62,791
2019	42,692	34,284	51,100	45,988	36,740	55,236	46,173	37,106	55,239
2020	38,527	29,772	47,281	41,845	32,223	51,467	39,111	30,306	47,916
2021	37,746	28,626	46,866	40,541	30,697	50,385	35,668	27,184	44,151
2022	40,125	30,266	49,984	41,706	31,476	51,937	35,068	26,531	43,605
2023	46,590	34,457	58,723	46,608	34,438	58,779	36,603	26,269	46,936

Table 2A.24: Estimates of spawning biomass relative to unfished for Models 23.0, 23.1, and 23.2.

Year	Model 23.0	Model 23.1	Model 23.2
1991	0.73	0.76	0.73
1992	0.76	0.79	0.75
1993	0.69	0.72	0.67
1994	0.64	0.67	0.62
1995	0.61	0.64	0.60
1996	0.60	0.62	0.58
1997	0.56	0.58	0.55
1998	0.54	0.56	0.53
1999	0.52	0.54	0.51
2000	0.55	0.56	0.53
2001	0.55	0.55	0.54
2002	0.56	0.55	0.54
2003	0.58	0.56	0.56
2004	0.62	0.60	0.60
2005	0.64	0.62	0.63
2006	0.63	0.61	0.62
2007	0.55	0.54	0.55
2008	0.43	0.42	0.43
2009	0.35	0.34	0.35
2010	0.29	0.28	0.30
2011	0.27	0.27	0.28
2012	0.30	0.30	0.32
2013	0.28	0.28	0.31
2014	0.27	0.27	0.31
2015	0.27	0.28	0.33
2016	0.28	0.29	0.37
2017	0.29	0.30	0.35
2018	0.29	0.31	0.34
2019	0.27	0.29	0.29
2020	0.24	0.26	0.25
2021	0.24	0.26	0.22
2022	0.25	0.26	0.22
2023	0.29	0.30	0.23
2024	0.33	0.33	0.24
2025	0.35	0.34	0.27

Table 2A.25: Estimates of recruitment for Models 23.0, 23.1, and 23.2 with upper and lower 95% confidence intervals.

Year	Model 23.0			Model 23.1			Model 23.2		
	Recruitment	LCI	UCI	Recruitment	LCI	UCI	Recruitment	LCI	UCI
1989	23,633	16,770	33,303	24,456	17,351	34,471	24,349	17,350	34,172
1990	23,633	16,770	33,303	24,456	17,351	34,471	24,349	17,350	34,172
1991	16,355	8,903	30,044	17,163	9,328	31,580	14,547	7,972	26,542
1992	22,233	12,506	39,523	23,382	13,135	41,622	19,936	11,298	35,180
1993	42,515	27,889	64,809	44,593	29,219	68,056	37,243	24,376	56,900
1994	16,832	8,565	33,080	17,617	8,957	34,648	15,140	7,787	29,436
1995	33,917	21,431	53,676	35,336	22,346	55,876	30,703	19,484	48,381
1996	44,389	29,831	66,051	44,939	30,249	66,761	39,641	26,625	59,019
1997	40,396	26,378	61,864	39,620	25,837	60,755	35,849	23,353	55,030
1998	29,026	18,235	46,201	28,357	17,839	45,077	26,266	16,555	41,675
1999	29,453	19,051	45,535	28,928	18,732	44,673	26,453	17,097	40,929
2000	59,696	41,136	86,629	60,624	41,910	87,696	53,443	36,812	77,587
2001	21,854	13,235	36,087	22,282	13,529	36,699	19,467	11,779	32,171
2002	19,246	11,182	33,126	19,920	11,588	34,243	17,629	10,313	30,136
2003	17,711	10,652	29,450	18,251	10,999	30,284	16,042	9,662	26,634
2004	13,160	6,782	25,537	13,533	6,977	26,251	12,145	6,314	23,358
2005	25,914	16,966	39,582	26,275	17,198	40,143	23,746	15,548	36,265
2006	15,932	9,056	28,029	16,499	9,387	29,000	14,965	8,542	26,216
2007	23,854	15,766	36,089	24,802	16,337	37,653	22,880	15,121	34,621
2008	19,110	12,155	30,044	19,802	12,552	31,239	19,391	12,403	30,316
2009	8,665	4,945	15,185	8,968	5,101	15,767	9,002	5,126	15,810
2010	13,728	8,608	21,892	14,570	9,092	23,347	15,909	9,975	25,371
2011	10,295	6,370	16,640	10,903	6,705	17,729	12,307	7,538	20,092
2012	17,599	11,511	26,906	19,159	12,445	29,496	24,216	15,512	37,803
2013	15,146	9,994	22,954	16,176	10,608	24,668	21,501	13,750	33,620
2014	24,424	16,283	36,636	26,311	17,437	39,701	41,634	25,910	66,900
2015	13,830	8,690	22,010	14,614	9,134	23,381	24,101	14,098	41,200
2016	14,208	8,148	24,772	14,931	8,553	26,065	25,707	13,662	48,370
2017	15,440	9,206	25,895	15,517	9,248	26,033	25,035	14,132	44,350
2018	20,545	12,051	35,025	19,650	11,477	33,643	32,719	18,262	58,620
2019	26,023	15,701	43,128	25,105	15,148	41,607	33,874	20,124	57,016
2020	15,268	7,316	31,863	15,458	7,502	31,848	19,610	9,620	39,973
2021	13,162	6,131	28,256	12,971	6,076	27,691	13,250	6,215	28,246
2022	23,319	7,176	75,772	24,043	7,409	78,017	24,024	7,400	77,995
2023	23,633	7,272	76,800	24,456	7,525	79,479	24,349	7,499	79,059

Table 2A.26: Results of projections using different years in the SS3 forecast.ss file (Bmark_years) for biology (e.g. growth, natural mortality, maturity, fecundity). These projections were applied to Model 23.2, which had time blocks on natural mortality and growth.

Benchmark forecast years 1991-2023									
Yr	SSB	SSB_PER	SB100	SB40	SB35	F40	F35	C_ABC	C_OFL
2024	19,027	0.274	69,521	27,808	24,332	0.237	0.288	5,991	7,174
2025	20,161	0.290	69,521	27,808	24,332	0.280	0.376	7,717	10,560

Benchmark forecast years 2004-2023									
Yr	SSB	SSB_PER	SB100	SB40	SB35	F40	F35	C_ABC	C_OFL
2024	18,687	0.330	56,572	22,628	19,800	0.445	0.544	10,660	12,732
2025	18,302	0.324	56,572	22,628	19,800	0.422	0.666	10,214	17,304

Benchmark forecast years 2017-2023									
Yr	SSB	SSB_PER	SB100	SB40	SB35	F40	F35	C_ABC	C_OFL
2024	17,821	0.613	29,082	11,632	10,178	0.993	1.269	20,915	25,133
2025	14,164	0.487	29,082	11,632	10,178	0.993	1.269	16,712	27,244

Table 2A.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 23.0. Estimates of SSB and catch are in metric tons (t).

Year	Scenarios						
Catch	1	2	3	4	5	6	7
2023	7898.0	7898.0	7898.0	7898.00	7898	7898.0	7898.0
2024	12757.0	12757.0	14265.4	3144.87	0	15311.3	12757.0
2025	14955.3	14955.3	15752.3	5260.21	0	16207.0	14955.3
2026	16345.2	16345.2	16827.5	6052.19	0	17091.3	19524.4
2027	18429.0	18429.0	18935.7	6815.98	0	19244.9	19798.7
2028	20331.6	20331.6	20868.4	7569.71	0	21203.2	21216.5
2029	21367.9	21367.9	21852.8	8252.68	0	22148.6	22078.4
2030	21678.4	21678.4	22097.6	8813.08	0	22348.9	22310.8
2031	21682.6	21682.6	22070.0	9239.98	0	22302.8	22293.3
2032	21632.5	21632.5	22015.3	9549.74	0	22247.1	22247.7
2033	21603.7	21603.7	21990.6	9765.75	0	22225.8	22227.5
2034	21595.1	21595.1	21985.6	9913.16	0	22223.1	22223.8
2035	21594.7	21594.7	21986.6	10012.20	0	22224.7	22224.9
2036	21595.8	21595.8	21987.9	10077.90	0	22226.0	22225.9

Year	Scenarios						
F	1	2	3	4	5	6	7
2023	0.265116	0.265116	0.265116	0.2651160	0.265116	0.265116	0.265116
2024	0.362991	0.362991	0.410951	0.0831015	0.000000	0.444931	0.362990
2025	0.397747	0.397747	0.432130	0.1132650	0.000000	0.454102	0.397748
2026	0.425526	0.425526	0.455843	0.1132650	0.000000	0.475225	0.521826
2027	0.468727	0.468727	0.502664	0.1132650	0.000000	0.525153	0.535022
2028	0.503875	0.503875	0.540655	0.1132650	0.000000	0.565215	0.565097
2029	0.520952	0.520952	0.557857	0.1132650	0.000000	0.582366	0.580991
2030	0.525485	0.525485	0.561527	0.1132650	0.000000	0.585372	0.584692
2031	0.525269	0.525269	0.560763	0.1132650	0.000000	0.584254	0.584103
2032	0.524367	0.524367	0.559738	0.1132650	0.000000	0.583180	0.583201
2033	0.523908	0.523908	0.559326	0.1132650	0.000000	0.582815	0.582848
2034	0.523786	0.523786	0.559258	0.1132650	0.000000	0.582783	0.582797
2035	0.523787	0.523787	0.559282	0.1132650	0.000000	0.582819	0.582821
2036	0.523807	0.523807	0.559305	0.1132650	0.000000	0.582842	0.582841

Year	Scenarios						
SSB	1	2	3	4	5	6	7
2023	23295.30	23295.30	23295.30	23295.30	23295.30	23295.30	23295.30
2024	26602.25	26602.25	26489.45	27272.25	27475.10	26409.90	26602.30
2025	27728.15	27728.15	27099.15	32086.45	33650.20	26671.20	27728.15
2026	28597.10	28597.10	27738.05	36421.65	39991.30	27185.95	28338.25
2027	29936.30	29936.30	28990.15	40991.05	46621.65	28398.00	28642.95
2028	31024.40	31024.40	30007.15	45270.95	52926.00	29373.50	29371.50
2029	31551.75	31551.75	30467.60	48882.30	58489.00	29791.90	29758.60
2030	31691.50	31691.50	30566.15	51729.50	63181.50	29865.90	29849.40
2031	31684.90	31684.90	30546.05	53852.00	66983.00	29839.15	29835.45
2032	31657.15	31657.15	30518.80	55368.00	69963.00	29813.15	29813.65
2033	31643.05	31643.05	30507.80	56433.00	72278.00	29804.25	29805.05
2034	31639.30	31639.30	30505.95	57163.50	74039.50	29803.45	29803.80
2035	31639.30	31639.30	30506.60	57656.00	75361.50	29804.30	29804.35
2036	31639.95	31639.95	30507.20	57984.00	76342.50	29804.90	29804.85

Table 2A.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 23.1. Estimates of SSB and catch are in metric tons (t).

Year	Scenarios						
Catch	1	2	3	4	5	6	7
2023	7898.0	7898.0	7898.0	7898.00	7898	7898.0	7898.0
2024	12300.5	12300.5	11458.6	3020.98	0	14762.5	12300.5
2025	13799.5	13799.5	13306.5	4879.70	0	14932.0	13799.5
2026	15460.5	15460.5	15106.1	5840.06	0	16255.8	18498.6
2027	18105.2	18105.2	17727.1	6596.18	0	19045.6	19552.8
2028	20516.4	20516.4	20122.7	7390.92	0	21510.4	21515.2
2029	21820.4	21820.4	20817.9	8136.25	0	22678.3	22611.7
2030	22122.6	22122.6	21188.5	8757.27	0	22906.4	22873.3
2031	22153.8	22153.8	21382.7	9232.63	0	22842.4	22835.3
2032	22139.8	22139.8	21471.1	9577.31	0	22776.9	22778.0
2033	22119.4	22119.4	21508.1	9816.40	0	22754.3	22755.8
2034	22105.5	22105.5	21523.5	9978.43	0	22752.5	22753.1
2035	22097.9	22097.9	21529.9	10086.40	0	22754.8	22754.8
2036	22093.7	22093.7	21532.6	10157.40	0	22756.1	22756.0

Year	Scenarios						
F	1	2	3	4	5	6	7
2023	0.207051	0.207051	0.207051	0.207051	0.207051	0.207051	0.207051
2024	0.368361	0.368361	0.340653	0.083793	0.000000	0.451828	0.368362
2025	0.393460	0.393460	0.372498	0.112431	0.000000	0.448724	0.393459
2026	0.431560	0.431560	0.411658	0.117685	0.000000	0.484425	0.530211
2027	0.490383	0.490383	0.467594	0.117685	0.000000	0.553494	0.562927
2028	0.537255	0.537255	0.512406	0.117685	0.000000	0.606571	0.606273
2029	0.559577	0.559577	0.515956	0.117685	0.000000	0.628586	0.627226
2030	0.563015	0.563015	0.515956	0.117685	0.000000	0.632007	0.631396
2031	0.563015	0.563015	0.515956	0.117685	0.000000	0.630427	0.630317
2032	0.563015	0.563015	0.515956	0.117685	0.000000	0.629122	0.629153
2033	0.563015	0.563015	0.515956	0.117685	0.000000	0.628726	0.628756
2034	0.563015	0.563015	0.515956	0.117685	0.000000	0.628714	0.628725
2035	0.563015	0.563015	0.515956	0.117685	0.000000	0.628763	0.628764
2036	0.563000	0.563000	0.515956	0.117685	0.000000	0.628788	0.628787

Year	Scenarios						
SSB	1	2	3	4	5	6	7
2023	23304.40	23304.40	23304.40	23304.40	23304.40	23304.40	23304.40
2024	25887.80	25887.80	25951.55	26551.80	26751.25	25696.95	25887.80
2025	26654.20	26654.20	27007.35	30811.70	32298.75	25647.55	26654.15
2026	27769.75	27769.75	28265.60	35020.10	38343.15	26457.95	27521.95
2027	29482.40	29482.40	30050.95	39679.20	44944.05	28028.25	28247.80
2028	30844.20	30844.20	31476.75	44191.15	51372.50	29237.25	29231.25
2029	31490.15	31490.15	32232.60	48058.10	57118.00	29738.90	29708.15
2030	31656.80	31656.80	32672.80	51122.00	61993.50	29817.60	29803.70
2031	31667.50	31667.50	32896.95	53408.00	65956.50	29782.20	29779.65
2032	31641.80	31641.80	32998.00	55036.00	69067.50	29752.65	29753.35
2033	31617.20	31617.20	33041.95	56173.50	71481.00	29743.65	29744.30
2034	31601.50	31601.50	33060.70	56948.00	73314.00	29743.35	29743.60
2035	31593.05	31593.05	33068.60	57466.50	74684.50	29744.45	29744.45
2036	31588.95	31588.95	33071.95	57808.50	75697.50	29745.00	29745.00

Table 2A.29: 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 23.2. Estimates of SSB and catch are in metric tons (t).

Year	Scenarios						
Catch	1	2	3	4	5	6	7
2023	7311.63	7311.63	7311.63	7311.63	7311.63	7311.63	7311.63
2024	10660.30	10660.30	10121.90	2633.78	0.00	12732.00	3655.20
2025	10214.20	10214.20	10005.70	3895.11	0.00	10768.90	5894.46
2026	10934.10	10934.10	10776.10	4692.86	0.00	11410.90	21048.20
2027	13240.30	13240.30	13016.90	5204.31	0.00	14021.50	14914.50
2028	15484.40	15484.40	15232.60	5789.37	0.00	16351.10	16061.30
2029	16626.90	16626.90	16407.30	6353.18	0.00	17345.50	17105.70
2030	16889.20	16889.20	16707.50	6817.61	0.00	17471.50	17407.90
2031	16852.10	16852.10	16685.60	7160.38	0.00	17393.50	17396.50
2032	16798.20	16798.20	16632.30	7396.23	0.00	17345.10	17354.00
2033	16778.00	16778.00	16609.50	7550.36	0.00	17335.10	17338.40
2034	16775.80	16775.80	16605.80	7648.07	0.00	17337.00	17337.30
2035	16777.50	16777.50	16607.10	7708.74	0.00	17339.10	17338.70
2036	16778.50	16778.50	16608.20	7745.86	0.00	17339.60	17339.50

Year	Scenarios						
F	1	2	3	4	5	6	7
2023	0.327310	0.327310	0.327310	0.327310	0.32731	0.327310	0.327310
2024	0.444860	0.444860	0.419785	0.100738	0.00000	0.544400	0.141283
2025	0.421717	0.421717	0.407050	0.127130	0.00000	0.469938	0.200104
2026	0.449513	0.449513	0.435277	0.137973	0.00000	0.499372	0.774473
2027	0.526869	0.526869	0.508461	0.137973	0.00000	0.595351	0.618552
2028	0.592355	0.592355	0.571401	0.137973	0.00000	0.670210	0.660289
2029	0.621877	0.621877	0.600951	0.137973	0.00000	0.698457	0.691471
2030	0.627667	0.627667	0.607511	0.137973	0.00000	0.701034	0.699384
2031	0.626318	0.626318	0.606558	0.137973	0.00000	0.698455	0.698632
2032	0.624870	0.624870	0.605156	0.137973	0.00000	0.697050	0.697323
2033	0.624382	0.624382	0.604616	0.137973	0.00000	0.696802	0.696892
2034	0.624348	0.624348	0.604547	0.137973	0.00000	0.696876	0.696879
2035	0.624397	0.624397	0.604586	0.137973	0.00000	0.696936	0.696926
2036	0.624424	0.624424	0.604614	0.137973	0.00000	0.696951	0.696947

Year	Scenarios						
SSB	1	2	3	4	5	6	7
2023	18301.65	18301.65	18301.65	18301.65	18301.65	18301.65	18301.65
2024	18687.35	18687.35	18728.10	19255.85	19426.20	18526.65	19187.80
2025	18302.85	18302.85	18510.40	21651.15	22876.95	17526.15	21137.95
2026	18779.65	18779.65	19032.30	24032.15	26627.90	17908.65	21639.95
2027	20119.60	20119.60	20392.10	26955.95	30949.60	19201.05	19530.75
2028	21254.85	21254.85	21561.25	29975.95	35276.95	20214.15	20082.40
2029	21765.05	21765.05	22107.95	32587.30	39135.85	20597.40	20503.25
2030	21865.25	21865.25	22229.10	34603.50	42334.40	20633.55	20611.05
2031	21842.25	21842.25	22211.70	36044.70	44850.75	20599.25	20601.50
2032	21817.40	21817.40	22185.90	37017.55	46749.30	20580.30	20583.95
2033	21809.00	21809.00	22175.95	37655.05	48154.95	20576.95	20578.15
2034	21808.40	21808.40	22174.70	38061.45	49172.80	20577.90	20577.95
2035	21809.25	21809.25	22175.40	38315.05	49896.40	20578.70	20578.55
2036	21809.70	21809.70	22175.90	38470.80	50404.00	20578.90	20578.85

Table 2A.30: 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, 1991-2023 (2023 data current through October 31). Note: RE=rougheye, NR=northern, SR=shortraker, SC=sharpchin.

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Atka Mackerel	0.06	0.05	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
Kamchatka Fl.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rougheye Rockfish	-	-	-	-	-	-	-	-	-	-	-	0.00	0.01	0.04	0.00	0.00	0.00
Shortraker Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.02	0.01	0.00	0.00
Skate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Squid	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	0.07	0.02	0.00
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	0.86	0.76	0.55
Flounder	0.59	0.45	0.35	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greenland Turbot	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	0.00	0.01	0.00
Non TAC Species	-	-	-	-	-	-	-	0.02	0.00	0.02	0.01	-	-	-	-	-	-
Northern Rockfish	-	-	-	-	-	-	-	-	-	-	0.03	0.04	0.03	0.05	0.05	0.02	0.02
Octopus	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-
Other	0.12	0.09	0.05	0.04	0.07	0.10	0.13	0.13	0.12	0.04	0.16	-	-	-	-	-	-
Other Flatfish	-	-	-	0.00	0.01	0.03	0.80	0.47	0.48	0.19	0.53	0.29	0.29	0.25	0.29	0.37	0.28
Other Rockfish	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	0.02	0.02	0.02
Other Species	-	-	-	-	-	-	-	-	-	-	-	0.23	0.16	0.13	0.14	0.16	0.06
Pacific Cod	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	0.76	0.78	0.66
Pacific Ocean Perch	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	0.01	0.01	0.01
Pollock	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	0.18	0.16	0.04
Rock Sole	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	0.78	0.77	0.75
Sablefish	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	0.00	0.00	0.00
Sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shallow Water Flatfish	0.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shark	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SR/NR Rockfish	0.13	0.07	0.03	0.01	0.02	0.04	0.04	0.03	0.05	0.03	-	-	-	-	-	-	-
SR/RE Rockfish	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.02	-	-	-	-	-
SR/RE/SC/NR	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	0.79	0.05	0.23

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Atka Mackerel	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kamchatka Fl.	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rougheye Rockfish	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	0.00	0.00
Shortraker Rockfish	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	0.00	0.02
Squid	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	0.61	0.58	0.46	0.73	0.49	0.26	0.31	0.53	0.23	0.19	0.45	0.07	0.19	0.07	0.19
Flounder	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greenland Turbot	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
Non TAC Species	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Rockfish	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	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	0.00	0.02
Other	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other Flatfish	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	0.03	0.08
Other Rockfish	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	0.00	0.00
Other Species	0.07	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-
Pacific Cod	0.65	0.58	0.70	0.59	0.49	0.52	0.35	0.64	0.26	0.31	0.37	0.09	0.07	0.09	0.14
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	0.03	0.01	0.05	0.08	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.02	0.01	0.00
Rock Sole	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	0.07	0.20
Sablefish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sculpin	-	-	0.05	0.06	0.04	0.02	0.01	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	0.00	0.00
SR/NR Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SR/RE Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SR/RE/SC/NR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Slope Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellowfin Sole	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	0.03	0.00

Table 2A.31: 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, 1993-2023 (2023 data current through October 31). Note: RE=rougheye, NR=northern, SR=shortraker, SC=sharpchin.

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Atka Mackerel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kamchatka Fl.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rougheye Rockfish	-	-	-	-	-	-	-	-	-	-	-	0.00	0.14	0.02	0.01	0.18	0.27
Shortraker Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.09	0.05	0.06	0.06
Skate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Squid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Demersal Shelf Rockfish	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flathead Sole	0.00	-	-	0.03	0.08	0.06	0.10	0.01	0.06	0.14	0.01	0.00	0.01	0.01	0.02	0.08	0.13
Flounder	0.08	0.07	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greenland Turbot	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	0.02	0.03	0.00
Non TAC Species	-	-	-	-	-	-	-	0.04	0.06	0.08	0.00	-	-	-	-	-	-
Northern Rockfish	-	-	-	-	-	-	-	-	-	-	0.01	0.00	0.01	0.00	0.00	0.01	0.02
Octopus	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-
Other	0.33	0.54	0.30	0.27	0.22	0.43	0.57	0.44	0.61	0.75	0.25	-	-	-	-	-	-
Other Flatfish	-	-	-	0.00	0.01	0.22	0.06	0.06	0.13	0.29	0.01	0.00	0.32	0.00	0.01	0.00	0.01
Other Rockfish	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	0.05	0.12	0.12
Other Species	-	-	-	-	-	-	-	-	-	-	-	0.13	0.33	0.37	0.26	0.36	0.34
Pacific Cod	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	0.14	0.14	0.18
Pacific Ocean Perch	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	0.00
Pollock	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	0.00	0.00	0.01
Rock Sole	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	0.01	0.00	0.01
Sablefish	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	0.03	0.02	0.03
Sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shallow Water Flatfish	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shark	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SR/NR Rockfish	0.03	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	-	-	-	-	-	-	-
SR/RE Rockfish	0.31	0.17	0.11	0.02	0.12	0.06	0.30	0.21	0.31	0.23	0.08	0.04	-	-	-	-	-
SR/RE/SC/NR	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	0.00	0.00	0.23

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Atka Mackerel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Kamchatka Fl.	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0
Rougheye Rockfish	0.12	0.14	0.01	0.16	0.05	0.01	0.11	0.04	0.34	0.12	0.06	0.14	0.10	0.10	0
Shortraker Rockfish	0.05	0.17	0.01	0.03	0.04	0.00	0.04	0.00	0.05	0.08	0.32	0.05	0.20	0.01	0
Skate	-	-	0.12	0.29	0.17	0.03	0.24	0.16	0.23	0.22	0.22	0.35	0.39	0.36	0
Squid	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	0.14	0.09	0.01	0.09	0.00	0.00	0.01	0.01	0.06	0.20	0.01	0.12	0.17	0.06	0
Flounder	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greenland Turbot	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0
Non TAC Species	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northern Rockfish	0.02	0.03	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0
Octopus	-	-	0.79	0.50	0.43	0.37	0.78	0.45	0.20	0.04	0.15	0.06	0.18	0.10	0
Other	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other Flatfish	0.35	0.05	0.05	0.13	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.11	0
Other Rockfish	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	0.07	0
Other Species	0.43	0.50	-	-	-	-	-	-	-	-	-	-	-	-	-
Pacific Cod	0.20	0.27	0.11	0.18	0.12	0.03	0.33	0.12	0.24	0.16	0.12	0.25	0.23	0.20	0
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
Pollock	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	0.01	0
Rock Sole	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0
Sablefish	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.01	0
Sculpin	-	-	0.17	0.39	0.38	0.12	0.40	0.14	0.32	0.23	0.26	0.32	-	-	-
Shallow Water Flatfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shark	-	-	0.02	0.12	0.01	0.01	0.24	0.00	0.06	0.03	0.01	0.02	0.02	0.02	0
SR/NR Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SR/RE Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SR/RE/SC/NR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Slope Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellowfin Sole	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	0.00	0

Table 2A.32: Incidental catch of selected "Other Species" complex species taken in the AI Pacific cod trawl fisheries, 1991-2023 (2023 data current through October 31), 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	2022	2023
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	0.00	0.03
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	1.00	-	-	-
shark, other	-	-	-	0.00	-	-	-	-	-	-	-	-	0.00	-	-	-	0.00	-
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	1.00	-	-	-
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	0.00	-
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	0.00	-
skate, Aleutian	-	-	-	-	-	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0	0.00	-
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	0.03	0	0.02	1.00
skate, Whiteblotched	-	-	-	-	-	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0	0.00	-
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 2A.33: Incidental catch of selected “Other Species” complex species taken in the AI Pacific cod longline fisheries, 1991-2023 (2023 data current through October 31), 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	2006
octopus, North Pacific	-	-	-	-	-	-	-	-	0	0	0	0.14	0.43	0.42	0.32	0.27
Pacific sleeper shark	-	-	-	-	-	-	-	-	-	0	-	0.00	0.00	0.00	0.02	0.38
shark, other	-	-	-	-	-	-	-	-	-	-	-	-	0.00	1.00	-	-
shark, salmon	-	-	-	-	-	-	-	-	-	0	-	-	0.00	-	0.00	0.00
shark, spiny dogfish	-	-	-	-	-	-	-	-	-	-	-	0.00	0.45	0.96	1.00	0.66
skate, Alaskan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
skate, Aleutian	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
skate, big	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.11
skate, longnose	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	0.51	1.00
skate, other	-	-	-	-	-	-	-	-	0	0	0	0.04	0.16	0.46	0.48	0.34
skate, Whiteblotched	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
squid, majestic	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
octopus, North Pacific	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	0.10	0
Pacific sleeper shark	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	-	-	-	1.00	-
shark, salmon	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	0.87	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	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	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	1.00	-
skate, big	0.00	0.00	0.00	0.55	-	0.00	-	-	0.59	-	-	-	0.00	1.00	-	-	-
skate, longnose	-	1.00	0.24	1.00	-	0.00	-	-	1.00	-	-	-	-	1.00	-	-	-
skate, other	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	0.98	0
skate, Whiteblotched	-	-	-	-	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.01	1.00	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	-	-	-	-	-

Table 2A.34: 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, 1991-2023 (through October 31).

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
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	1.00
Blue King Crab	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-	0.30	1.00
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	0.87
Golden (Brown) King Crab	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.01	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	0.05
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	0.34
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	0.99
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	0.06

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Bairdi Tanner Crab	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	0.99	1.00
Blue King Crab	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	0.06	0.00	0.00
Chinook Salmon	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	0.00	0.07
Golden (Brown) King Crab	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	0.07	0.20	0.08	0.02
Halibut	-	-	-	0.19	0.04	0.28	0.16	0.18	0.41	0.26	0.36	0.30	0.41	0.39	0.66	0.41	0.07
Herring	0.19	0.25	0.07	0.00	-	0.00	1.00	1.00	-	-	0.00	0.00	0.01	0.99	0.00	0.83	0.00
Non-Chinook Salmon	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	0.01	0.00
Opilio Tanner (Snow) Crab	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	0.98	0.96
Other King Crab	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red King Crab	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	1.00	0.97

Table 2A.35: 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 1993-2023, and current through October 31 of the final year. Continued on next page.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Benthic urochordata	0.14	0.16	0.42	0.13	0.06	0.03	0.05	0.06	0.01	0.04
Bivalves	0.99	0.94	0.99	0.99	0.97	0.96	0.78	0.64	0.53	0.76
Brittle star unidentified	0.00	0.06	0.03	0.39	0.64	0.20	0.01	0.01	0.00	0.00
Capelin	0.00	-	-	0.00	0.00	1.00	0.00	-	-	1.00
Bryozoan Corals	0.41	0.38	0.24	0.33	0.47	0.29	0.38	0.27	0.08	0.09
Bryozoan Red Tree Coral	0.72	0.01	0.49	0.01	0.91	0.14	0.88	0.00	0.00	0.00
Dark Rockfish	-	-	-	-	-	0.65	0.53	-	-	-
Eelpouts	0.09	0.51	0.14	0.04	0.15	0.02	0.02	0.02	0.00	0.01
Eulachon	-	-	0.68	0.01	0.00	0.05	0.00	0.00	-	1.00
Giant Grenadier	0.30	0.00	0.00	0.08	0.02	0.01	0.00	0.06	0.00	0.01
Greenlings	0.74	0.20	0.04	0.88	0.24	0.64	0.39	0.50	0.75	0.46
Rattail Grenadier Unid.	-	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	0.00
Gunnels	-	-	0.01	-	-	0.00	-	-	-	-
Hermit crab unidentified	0.80	0.98	0.11	0.68	0.81	0.86	0.85	0.42	0.24	0.54
Invertebrate unidentified	0.09	0.13	0.05	0.62	0.18	0.09	0.01	0.22	0.04	0.00
Large Sculpins	0.51	0.40	0.39	0.45	0.44	-	-	-	-	-
Large Sculpins - Bigmouth Sculpin	-	-	-	-	-	0.12	0.14	-	-	-
Large Sculpins - Great Sculpin	-	-	-	-	-	0.94	0.95	-	-	-
Large Sculpins - Hemilepidotus Unidentified	-	-	-	-	-	0.96	0.98	-	-	-
Lg. Sculpins - Myoxocephalus Unid.	-	-	-	-	-	0.88	1.00	-	-	-
Large Sculpins - Plain Sculpin	-	-	-	-	-	1.00	0.97	-	-	-
Large Sculpins - Red Irish Lord	-	-	-	-	-	0.12	0.32	-	-	-
Large Sculpins - Warty Sculpin	-	-	-	-	-	1.00	1.00	-	-	-
Large Sculpins - Yellow Irish Lord	-	-	-	-	-	0.34	0.20	-	-	-
Misc crabs	0.73	0.56	0.52	0.50	0.65	0.48	0.47	0.38	0.01	0.10
Misc crustaceans	0.99	0.29	0.98	0.93	0.33	0.88	0.13	0.38	0.06	0.00
Misc fish	0.23	0.11	0.12	0.06	0.09	0.06	0.08	0.09	0.05	0.04
Misc inverts (worms etc)	0.00	0.28	1.00	1.00	0.00	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	1.00
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	0.00
Polychaete unidentified	1.00	0.13	1.00	-	0.15	0.76	0.11	0.00	0.98	0.26
Saffron Cod	-	-	-	-	-	-	-	-	-	1.00
Sculpin	-	-	-	-	-	-	-	-	-	-
Scypho jellies	0.17	0.48	0.45	0.19	0.06	0.22	0.11	0.21	0.25	0.83
Sea anemone unidentified	0.85	0.53	0.93	0.78	0.37	0.32	0.47	0.38	0.08	0.14
Sea pens whips	0.80	1.00	0.96	0.96	0.73	0.36	0.64	0.94	0.94	1.00
Sea star	0.59	0.73	0.49	0.57	0.57	0.61	0.52	0.63	0.11	0.33
Snails	0.53	0.52	0.25	0.60	0.48	0.62	0.74	0.35	0.45	0.28
Sponge unidentified	0.32	0.16	0.33	0.22	0.09	0.03	0.12	0.09	0.03	0.05
State-managed Rockfish	-	-	-	-	-	-	-	0.61	0.13	0.09
Stichaeidae	0.00	0.00	0.00	0.08	0.00	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	0.04

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Benthic urochordata	0.15	0.01	0.01	0.04	0.00	0.03	0.00	0.00	0.07	0.00	0.01
Bivalves	0.14	0.11	0.32	0.33	0.04	0.21	0.05	0.67	0.47	0.77	0.02
Brittle star unidentified	0.04	0.01	0.00	0.00	0.12	0.00	0.00	0.10	0.01	0.01	0.00
Capelin	0.11	1.00	-	-	-	-	-	0.00	-	-	-
Bryozoan Corals	0.08	0.02	0.10	0.08	0.13	0.25	0.05	0.40	0.48	0.13	0.00
Bryozoan Red Tree Coral	0.00	0.00	-	-	-	0.00	-	-	-	-	-
Dark Rockfish	-	-	-	-	-	-	-	-	-	-	-
Eelpouts	0.00	0.00	0.00	0.00	0.05	0.01	0.02	0.00	0.01	0.00	0.00
Eulachon	-	-	-	-	-	-	-	0.00	-	-	-
Giant Grenadier	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
Greenlings	1.00	0.68	1.00	0.67	0.48	0.47	0.20	0.10	0.26	0.19	0.00
Rattail Grenadier Unid.	-	-	-	-	-	-	-	-	-	0.00	-
Grenadier - Rattail Grenadier Unidentified	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.02	0.00	0.00
Gunnels	0.00	-	0.00	-	0.00	-	-	1.00	0.00	-	-
Hermit crab unidentified	0.38	0.10	0.00	0.15	0.78	0.54	0.78	0.71	0.96	0.51	0.60
Invertebrate unidentified	0.00	0.01	0.76	0.00	0.51	0.00	0.01	0.02	0.00	0.11	0.00
Large Sculpins	-	-	-	-	-	-	-	-	-	-	-
Large Sculpins - Bigmouth Sculpin	-	-	-	-	-	-	-	-	-	-	-
Large Sculpins - Great Sculpin	-	-	-	-	-	-	-	-	-	-	-
Large Sculpins - Hemilepidotus Unidentified	-	-	-	-	-	-	-	-	-	-	-
Lg. Sculpins - Myoxocephalus Unid.	-	-	-	-	-	-	-	-	-	-	-
Large Sculpins - Plain Sculpin	-	-	-	-	-	-	-	-	-	-	-
Large Sculpins - Red Irish Lord	-	-	-	-	-	-	-	-	-	-	-
Large Sculpins - Warty Sculpin	-	-	-	-	-	-	-	-	-	-	-
Large Sculpins - Yellow Irish Lord	-	-	-	-	-	-	-	-	-	-	-
Misc crabs	0.57	0.19	0.00	0.04	0.59	0.61	0.45	0.72	0.40	0.75	0.61
Misc crustaceans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Misc fish	0.05	0.04	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01
Misc inverts (worms etc)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
Other osmerids	1.00	-	-	-	-	0.00	0.00	0.00	0.00	0.00	-
Other Sculpins	-	-	-	-	-	-	-	-	-	-	-
Pacific Sand lance	-	-	1.00	-	-	-	-	0.00	-	0.00	0.00
Pacific Sandfish	-	1.00	-	-	-	-	-	0.00	-	-	-
Pandalid shrimp	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Polychaete unidentified	1.00	0.00	-	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Saffron Cod	1.00	-	-	-	-	-	0.00	0.00	-	1.00	1.00
Sculpin	-	-	-	-	-	-	-	-	0.43	0.39	0.03
Scypho jellies	0.97	0.65	0.00	0.05	0.85	0.70	0.30	0.31	0.39	0.44	0.14
Sea anemone unidentified	0.03	0.01	0.03	0.08	0.05	0.15	0.02	0.28	0.10	0.10	0.04
Sea pens whips	0.03	0.00	0.34	0.01	0.55	0.30	0.20	0.28	0.46	0.99	0.04
Sea star	0.22	0.23	0.15	0.10	0.33	0.19	0.26	0.41	0.59	0.54	0.23
Snails	0.29	0.16	0.06	0.10	0.67	0.52	0.43	0.56	0.91	0.69	0.11
Sponge unidentified	0.01	0.00	0.02	0.10	0.03	0.06	0.01	0.06	0.04	0.06	0.00
State-managed Rockfish	0.21	0.01	0.18	0.00	0.15	0.49	0.02	0.29	0.33	0.07	0.00
Stichaeidae	0.00	0.00	0.00	0.00	0.00	0.05	-	0.00	0.00	0.00	0.00
urchins dollars cucumbers	0.02	0.03	0.02	0.07	0.06	0.04	0.02	0.11	0.08	0.05	0.00

Table 2A.36: 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 2003-2023 (through October 31).

Longline																					
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
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	-	-	-	-	-	-	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	0.43	0.66	0
Kittiwake	1.00	-	1.00	-	-	-	-	-	1.00	1.00	1.00	-	-	-	-	1.00	-	0.89	-	-	-
Laysan Albatross	0.04	0.00	0.17	0.45	0.23	0.40	0.12	0.30	0.00	0.00	0.00	0	0.22	0	0.00	0.00	-	0.00	-	-	-
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	0.01	0.60	0.08	0
Other	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	0.00	-
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	0.00	0.12	0.05	0
Short-tailed Albatross	-	-	-	-	-	-	-	1.00	1.00	-	-	-	-	-	-	-	-	1.00	-	-	-
Storm Petrels	1.00	-	-	0.00	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	-	-	0.00	0
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	0.30	1.00	0

Non Pelagic Trawl																					
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Auklet	1.00	-	-	-	-	-	-	-	-	0	-	0	-	-	0	0	-	-	-	-	-
Gull	0.99	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0	0	0	-	0	0.00	-	0	0	0	0	0	0
Laysan Albatross	0.35	0.00	0.43	0.00	0.00	0.00	0.26	0.00	0	0	0	0	0	0.00	0	0	-	0	-	-	-
Northern Fulmar	0.00	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	0
Unidentified	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0	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	2022	2023
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	2.36	0.00
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	0.86	0	0.16	0.62
Other	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	2.66	-
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	0.00	0.00
Storm Petrels	0	-	-	1.26	-	0.00	-	-	-	-	-	-	-	-	-	0.00	-	-	-	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	0.00	5.15

Figures

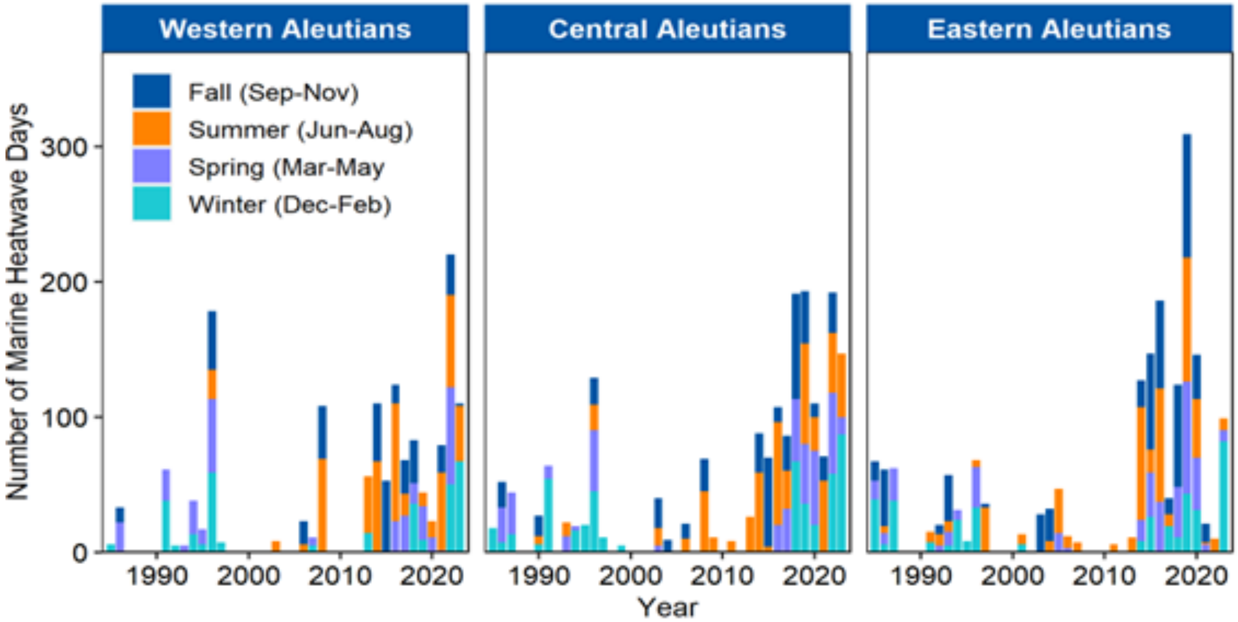


Figure 2A.1: The number of days under heatwave conditions for the western, central, and eastern Aleutian Islands, 1982 - 2023).

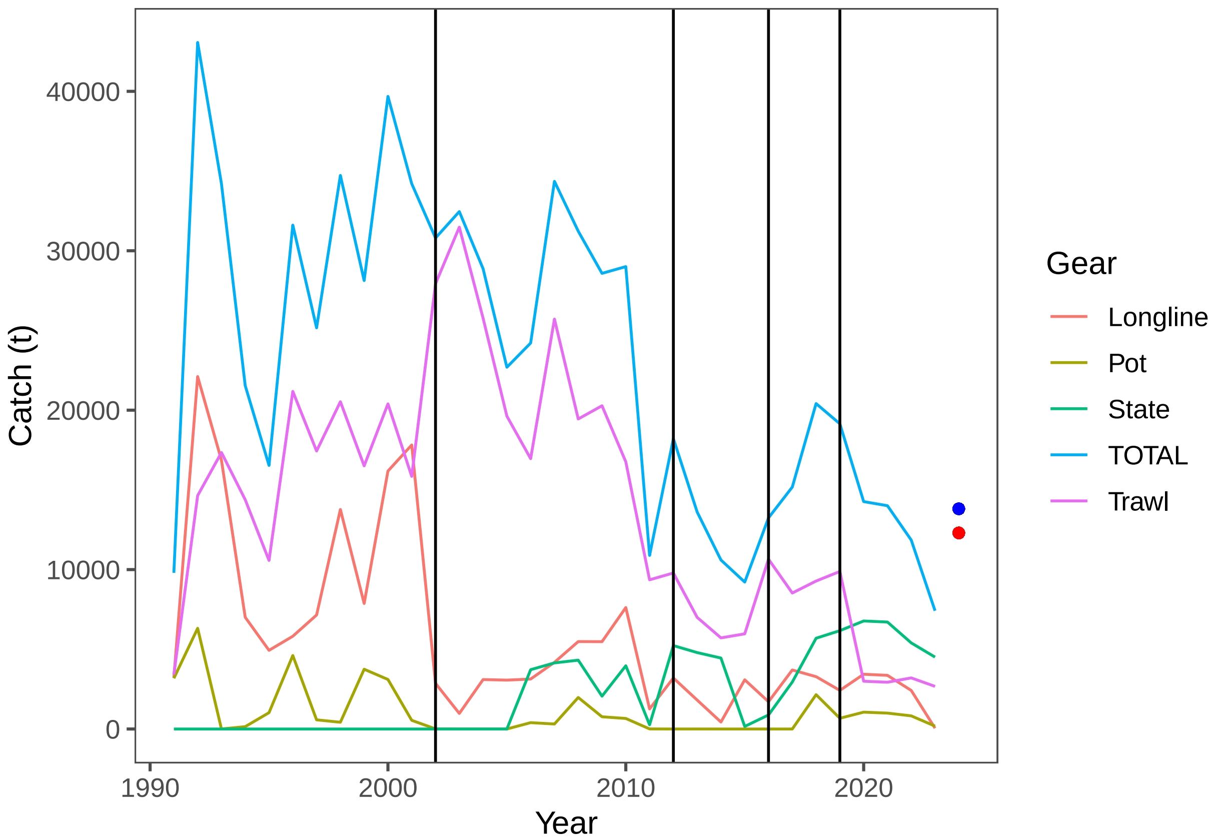


Figure 2A.2: Aleutian Islands Pacific cod catch history, with federal catches by gear type, from 1991-2023 (through October 20). The blue dot represents the ABC for 2024 based on the Tier 5 Model, and the red dot represents the ABC for 2024 based on Model 23.1. Vertical lines indicate timeblocks for fishery selectivity.

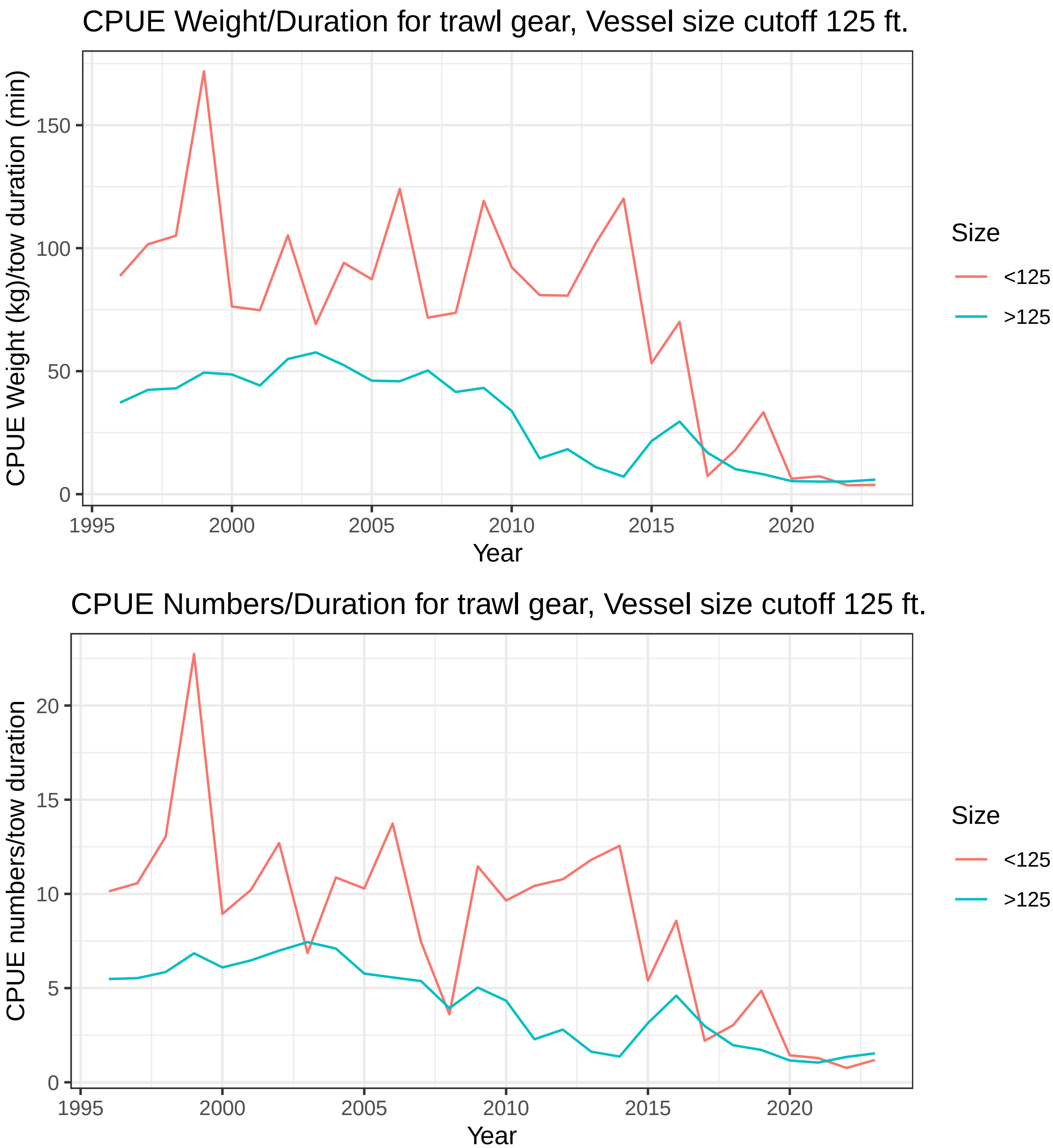
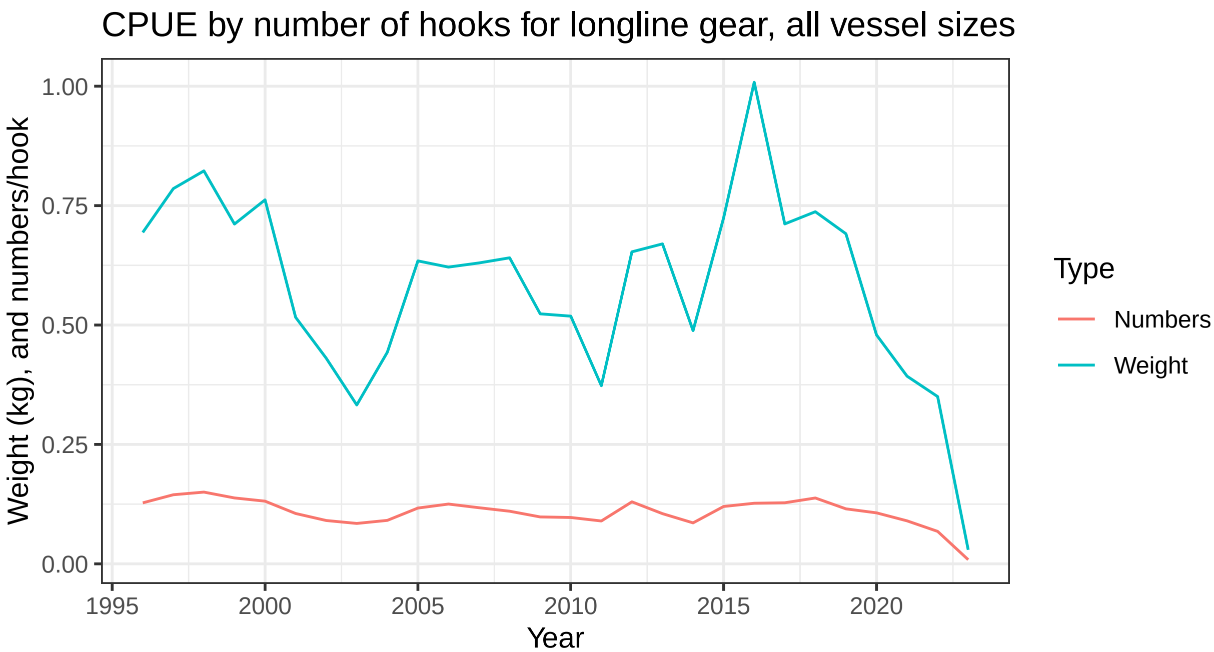


Figure 2A.3: Catch per unit effort for AI cod fisheries, 1996-2023. The upper plot represents CPUE weight (kg)/trawl duration (min) for vessels greater and less than 125 ft. The lower panel represents CPUE numbers/trawl duration for the same vessel sizes. Only tows with duration > 0 and < the 90th percentile of tow duration (909 minutes) are included. Estimates of relative CPUE are complete through October 20, 2023.



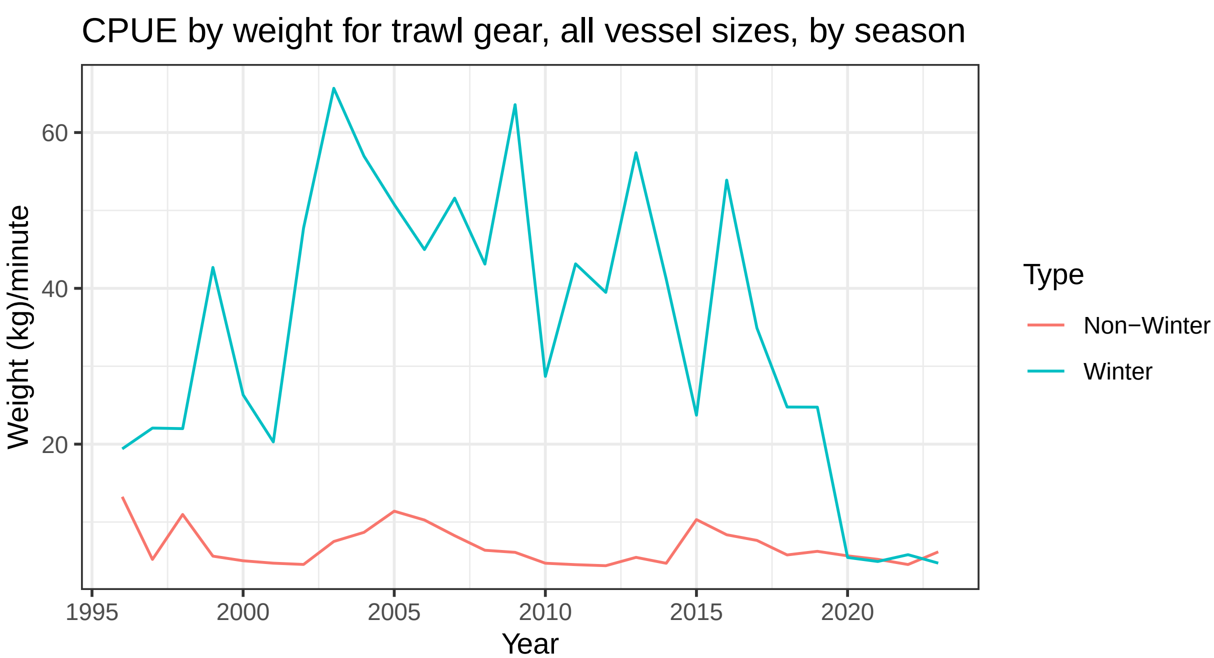


Figure 2A.4: Catch per unit effort for AI cod fisheries, 1996-2023. The upper plot represents longline CPUE weight (kg)/number of hooks for vessels of all sizes. The lower panel represents CPUE weight/trawl duration (kg/min) for trawl vessels by season (winter and non-winter). Only tows with duration > 0 and < the 90th percentile of tow duration (909 minutes) are included. Estimates of relative CPUE were complete through October 20, 2023.

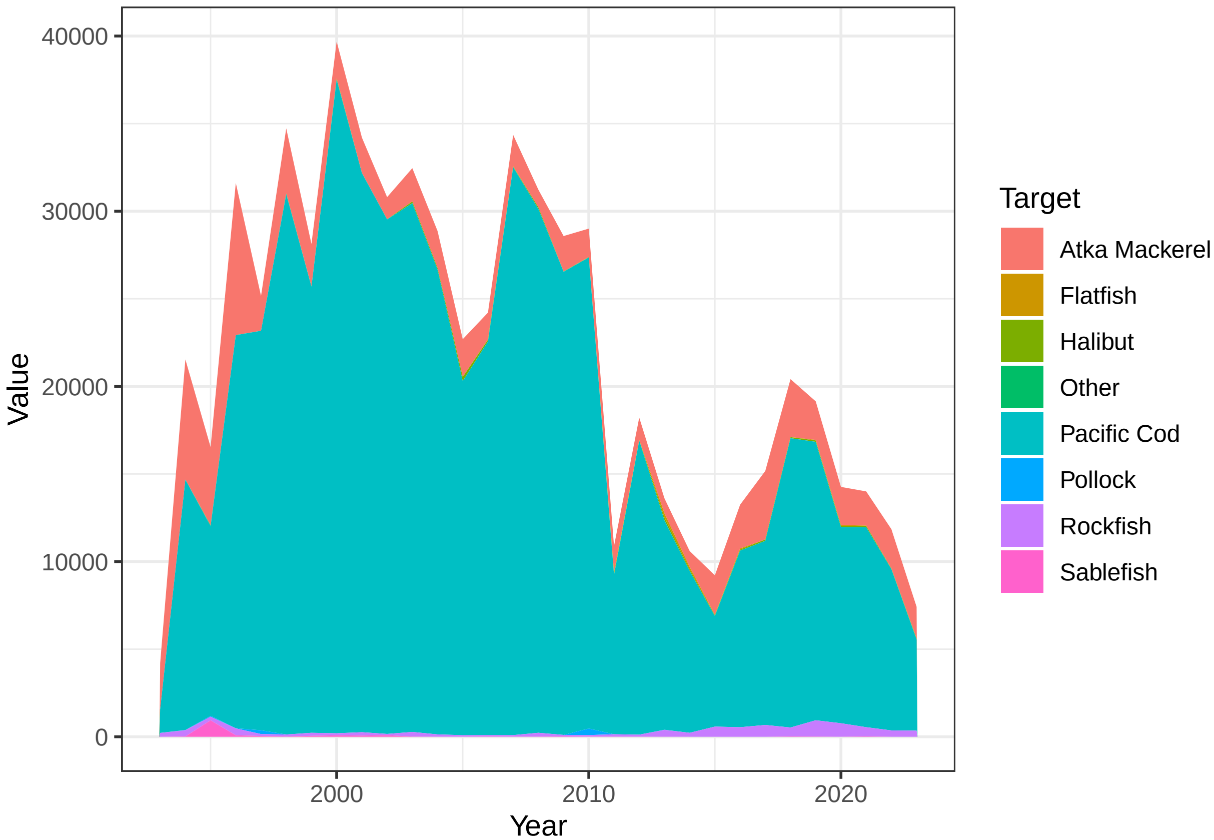


Figure 2A.5: Proportion of Pacific cod caught in targeted fisheries in the Aleutian Islands (541, 542, and 543) from 1991 through October 26, 2023.

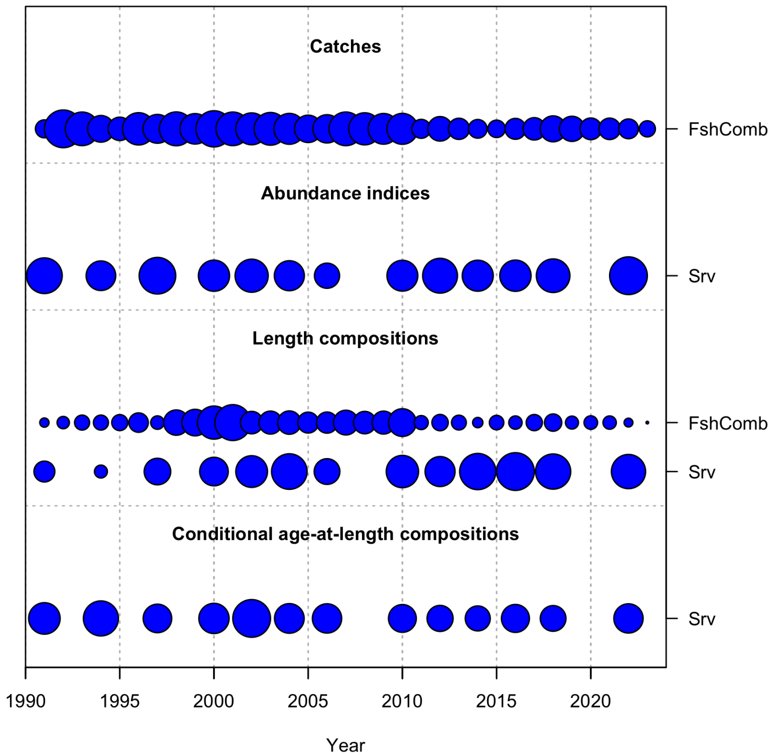


Figure 2A.6: Data sources and relative weight used in Models 23.0, Model 23.1, and Model 23.2.

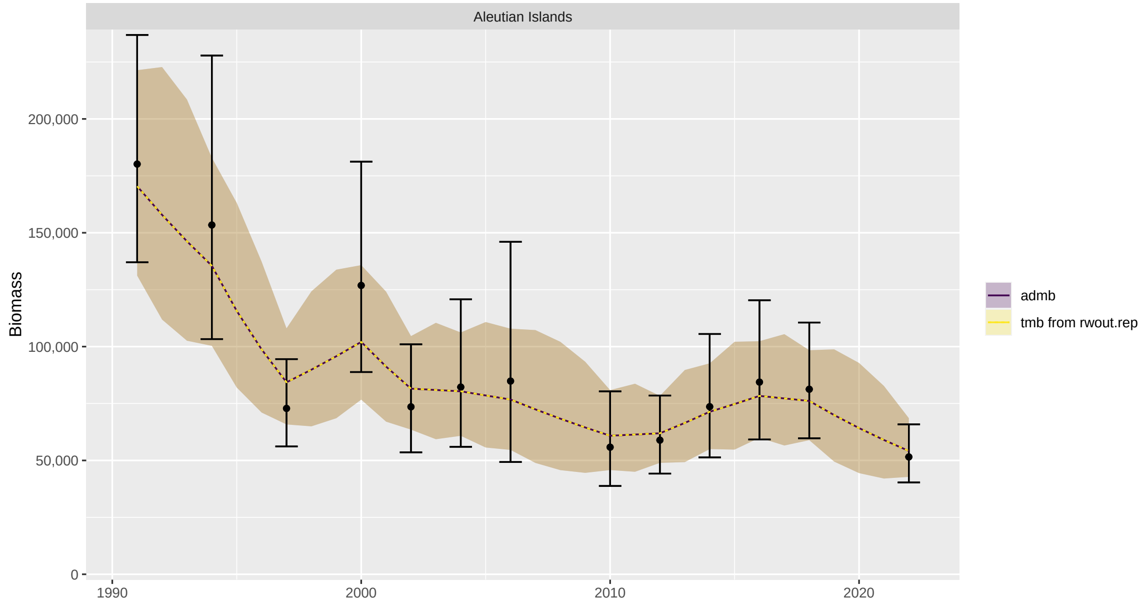


Figure 2A.7: Survey index of biomass and Tier 5 fit using a random effects model.

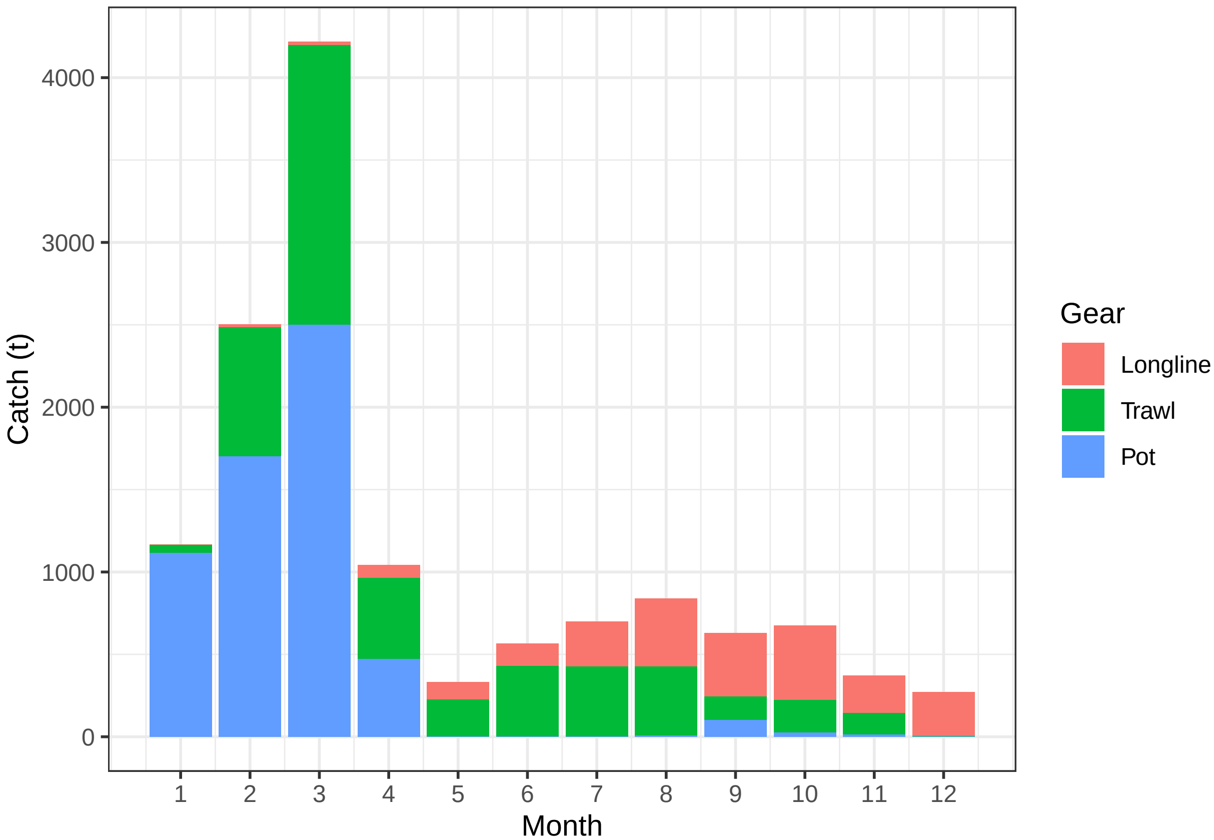


Figure 2A.8: Aleutian Islands Pacific cod average catch (t) by month per year and gear from January 1, 2019 - October 20, 2023.

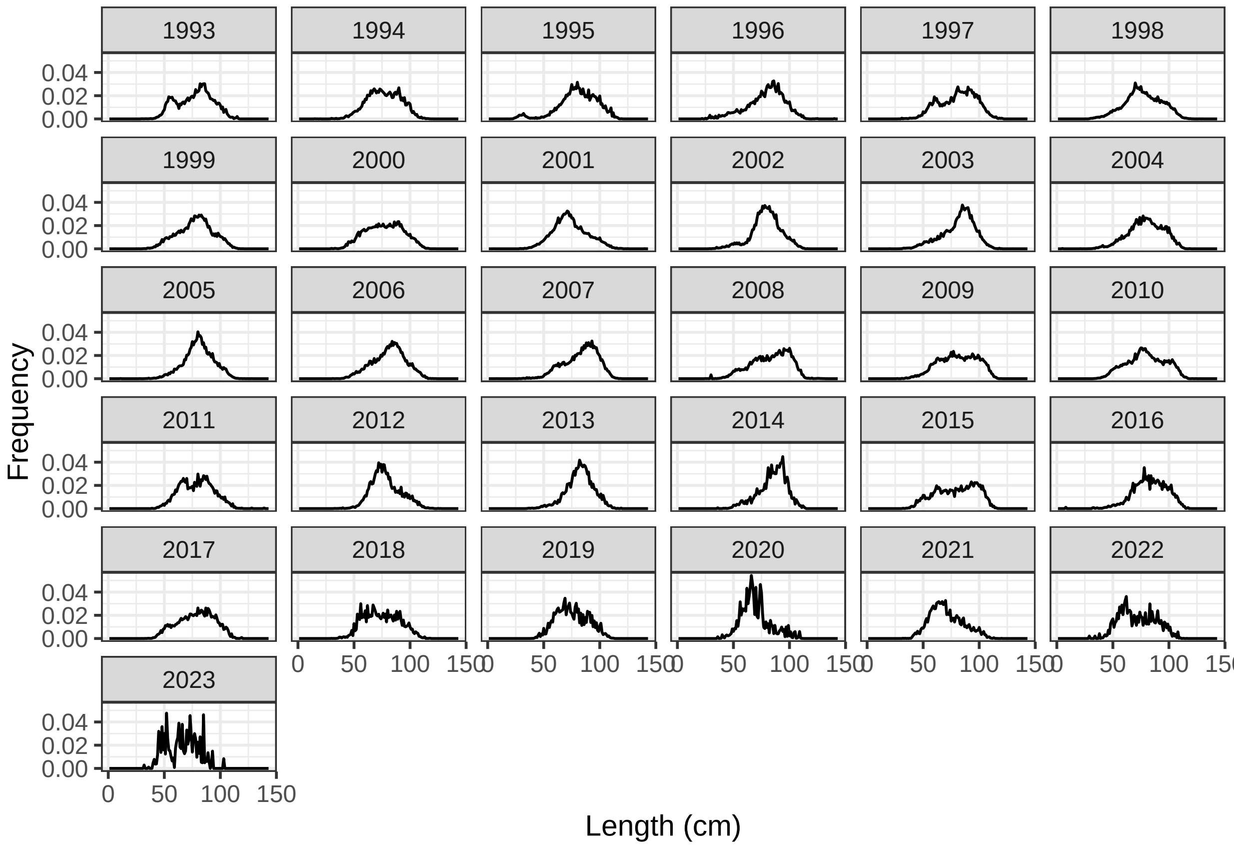


Figure 2A.9: Fishery length compositions over all fisheries combined. Fishery length frequencies were weighted by the relative catch by year, area (NMFS areas 541, 542, and 543), gear, and quarter and only samples with a minimum of 70 observations were used. The combined fishery length compositions were used in Model 23.0, Model 23.1, and Model 23.2.

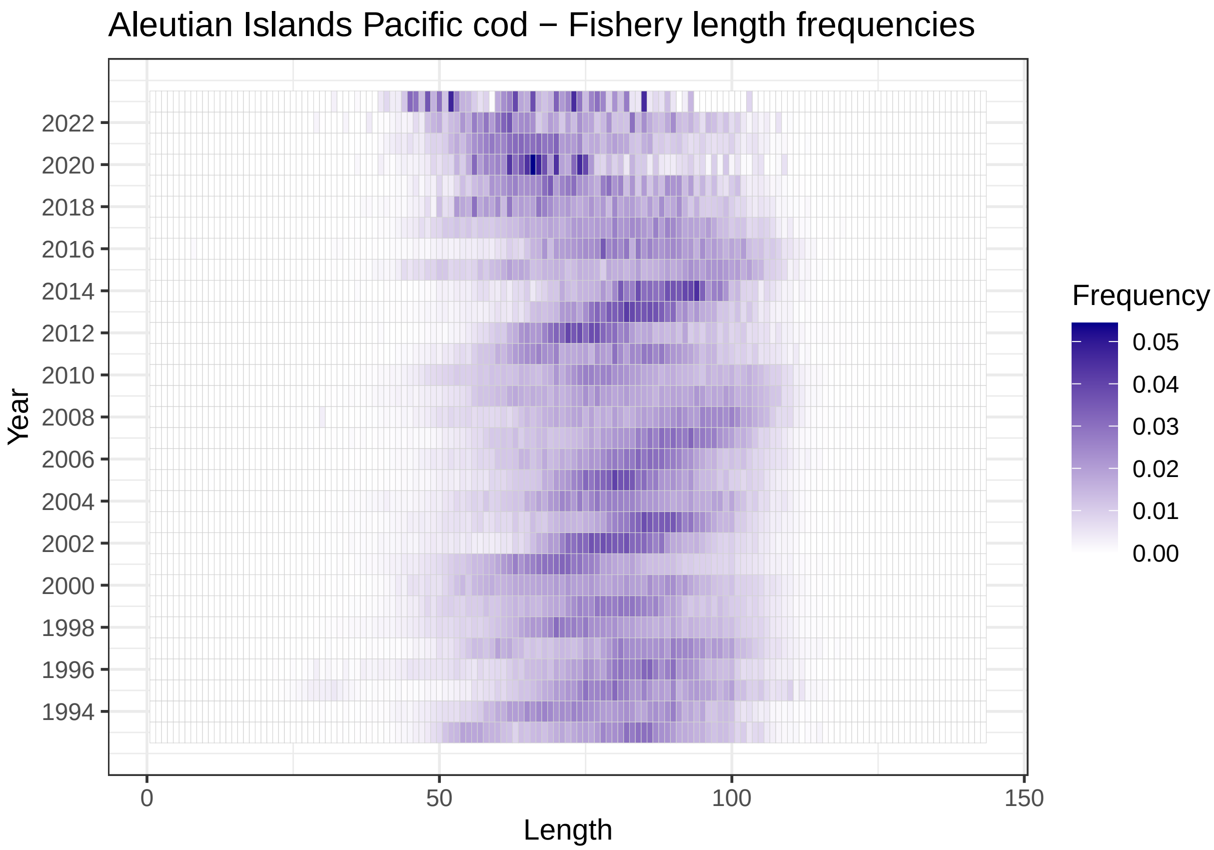


Figure 2A.10: Fishery length compositions over all fisheries combined.

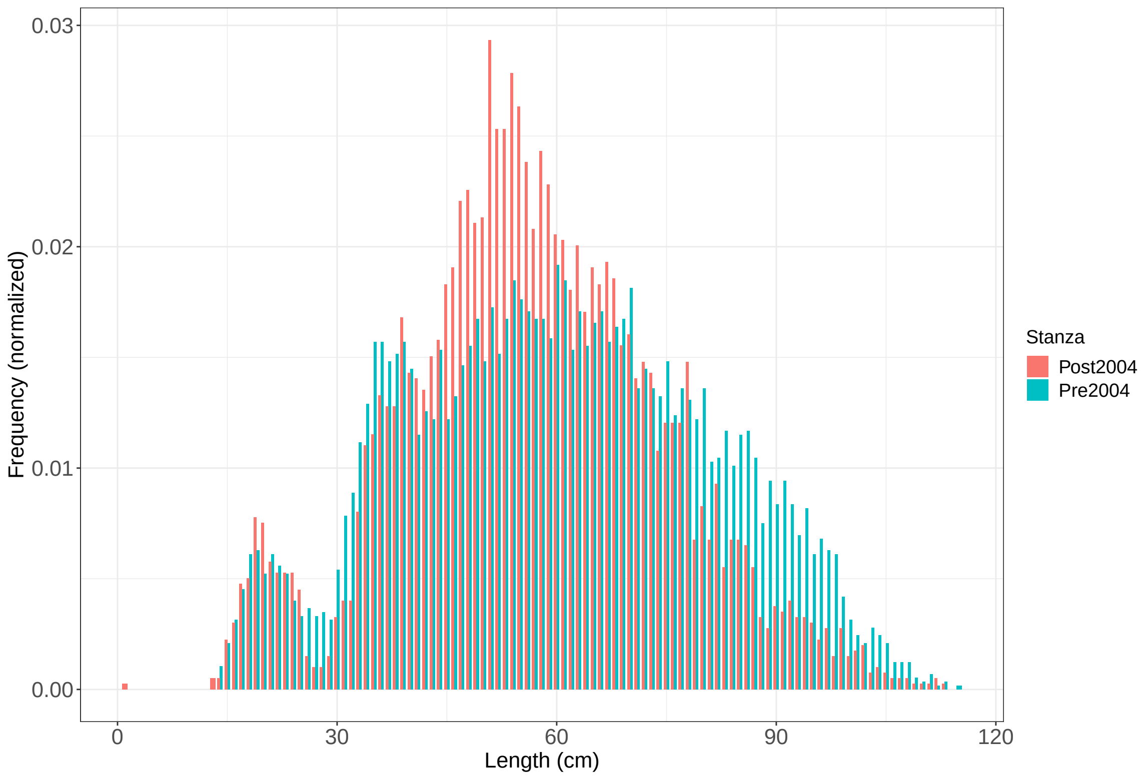


Figure 2A.11: Normalized length frequency for Aleutian Islands Pacific cod aged before and after 2004.

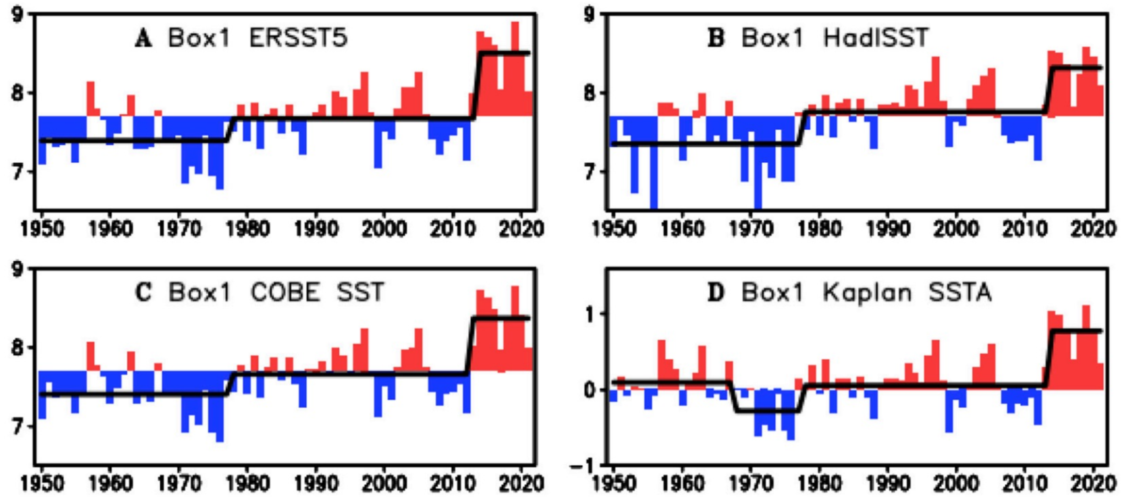


Figure 2A.12: Time series (colored bar) and epoch average (black thickened solid line) of annual mean SST in four data sets during 1950–2021 (Figure 2 from Xiao and Ren (2022).

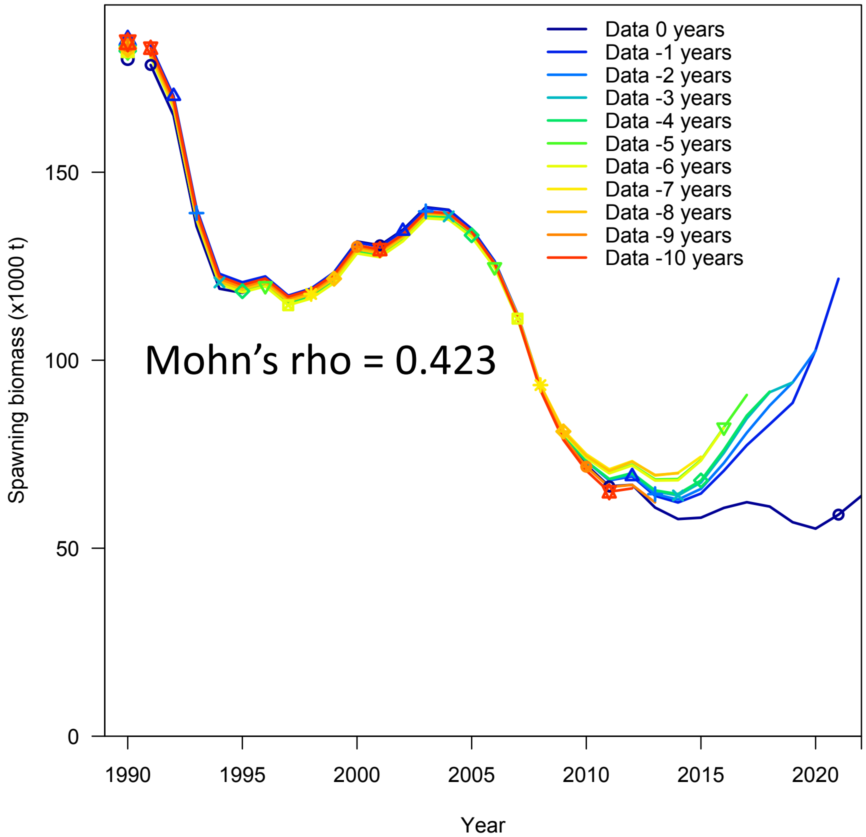


Figure 2A.13: Retrospective pattern of spawning stock biomass for Model 23.0a, presented in September 2023, as an example of a poor retrospective fit, and Mohn's rho.

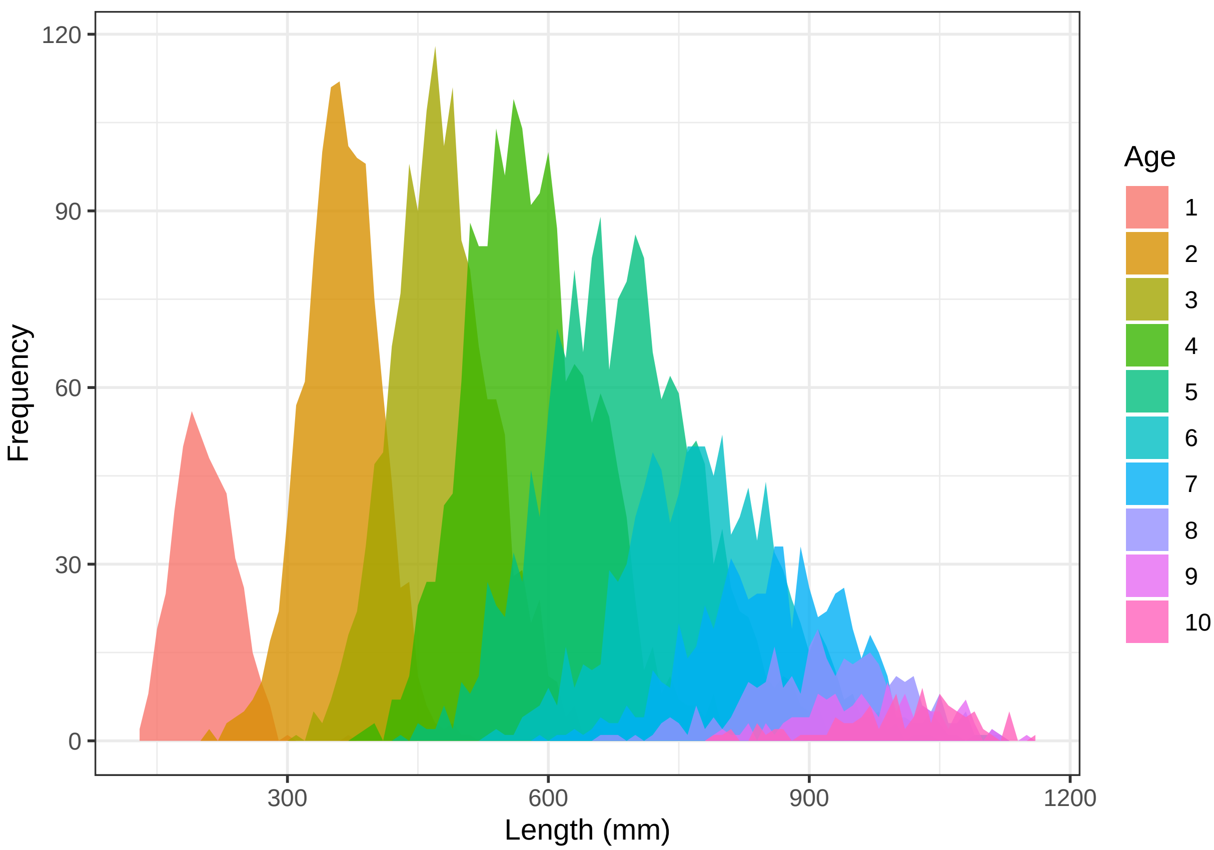


Figure 2A.14: Length frequency by age of cod collected from surveys from 1991-2018.

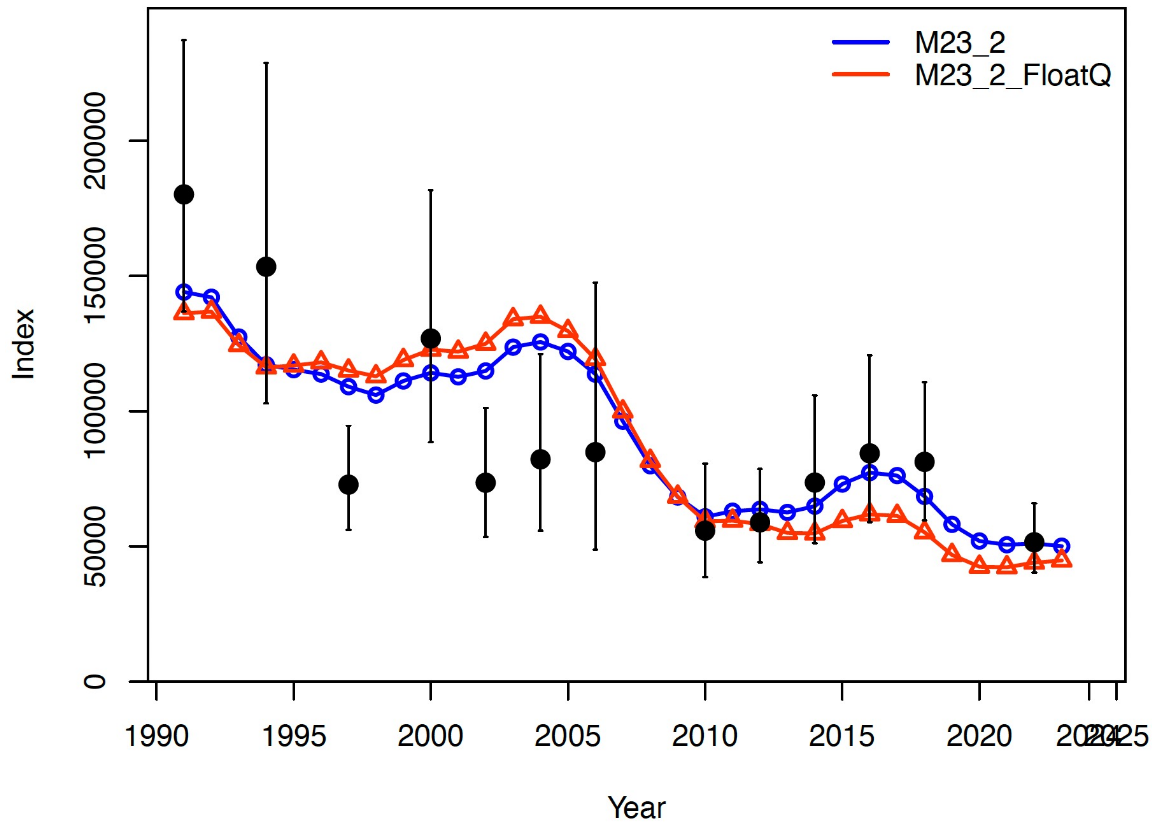


Figure 2A.15: Model 23.2 estimate of spawning biomass using the standard model with estimated catchability (Q) vs. Model 23.2 with an analytical solution for catchability (Model 23.2FQ).

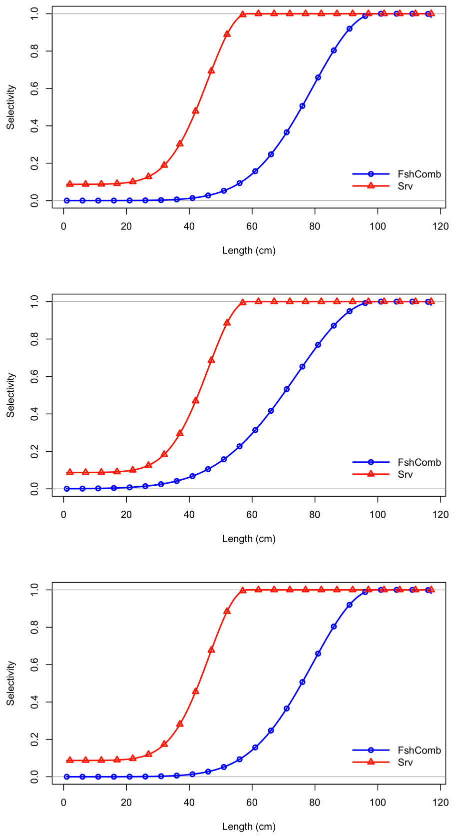


Figure 2A.16: Fishery and survey selectivity for Model 23.0 (upper panel), Model 23.1, and Model 23.2 (lower panel). For Model 23.1, this represents a mean over the 5 selectivity timeblocks.

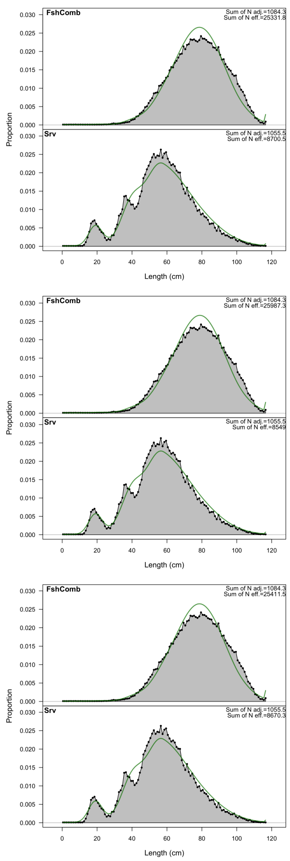


Figure 2A.17: Fit to survey and fishery length compositions, aggregated over time for Model 23.0 (upper panel), Model 23.1 (middle panel), and Model 23.2 (lower panel).

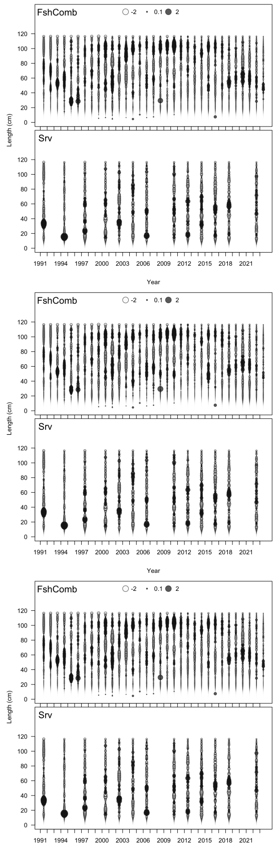


Figure 2A.18: Pearson residuals for survey and fishery length compositions. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected), Model 23.0 (upper panel), Model 23.1 (middle panel), and Model 23.2 (lower panel).

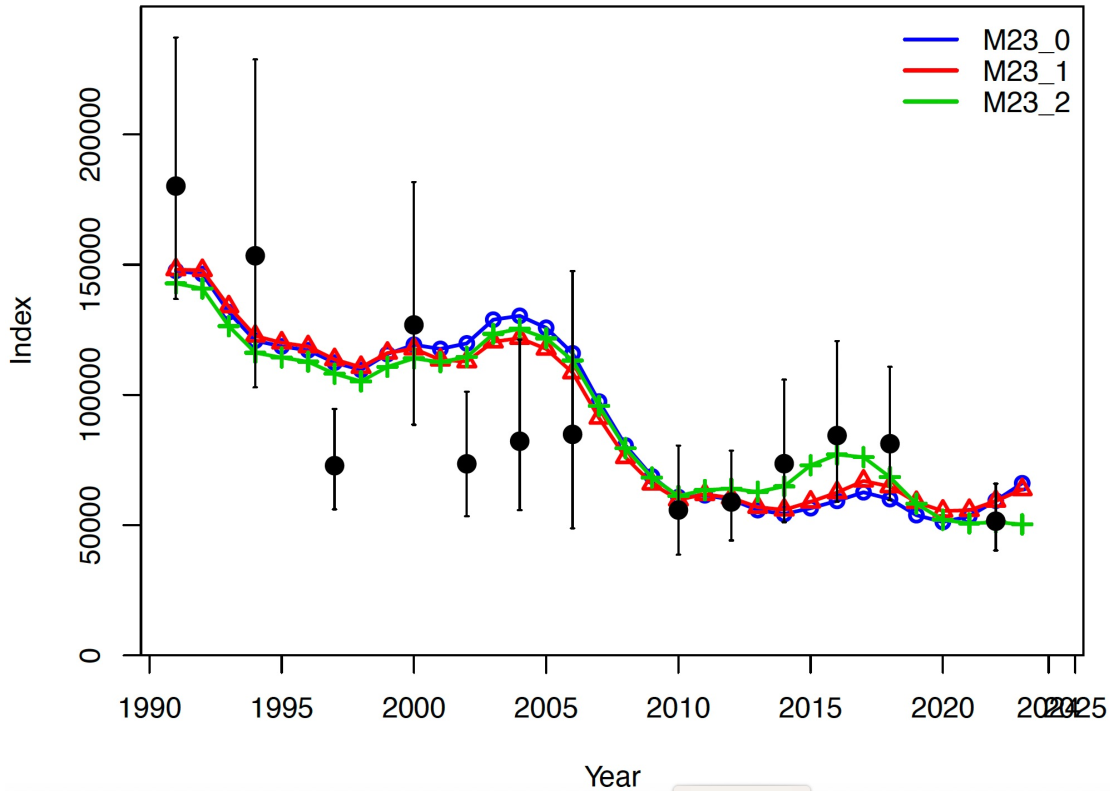


Figure 2A.19: Fit to the survey index for Models 23.0, 23.1, and 23.2.

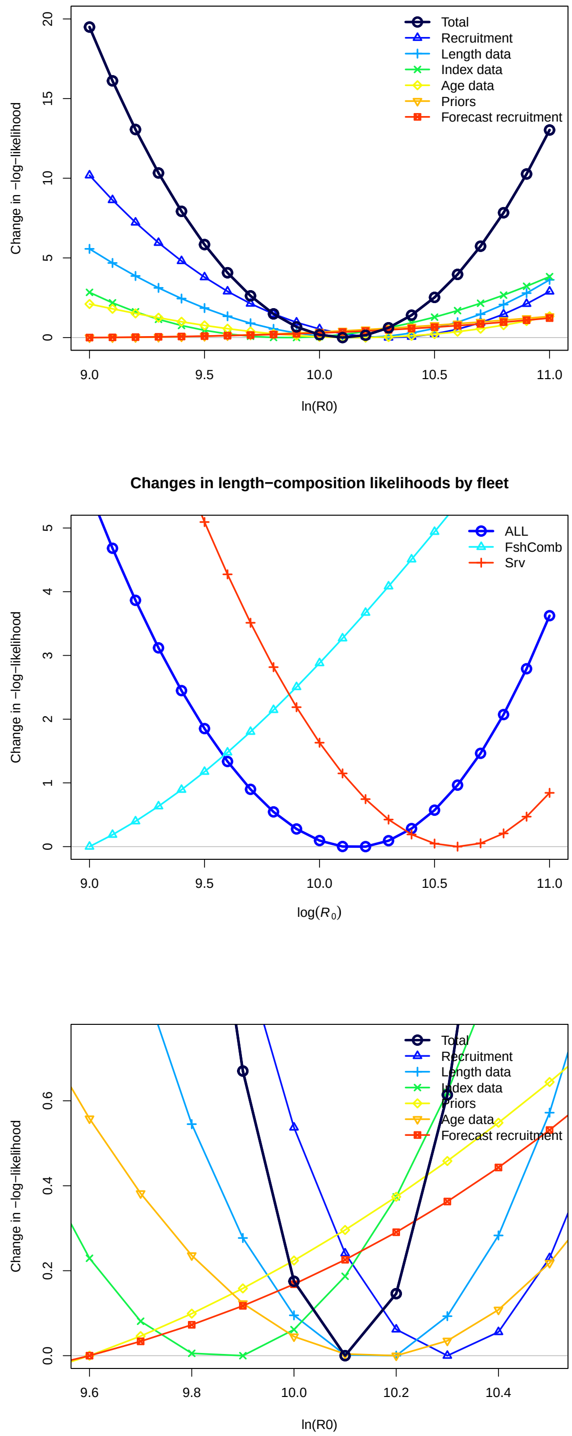


Figure 2A.20: Likelihood profile over unfished recruitment, R0. Three types of plots are shown, a likelihood profile over the components used in the model (upper panel), a Piner plot (middle panel), and a profile summary (lower panel).

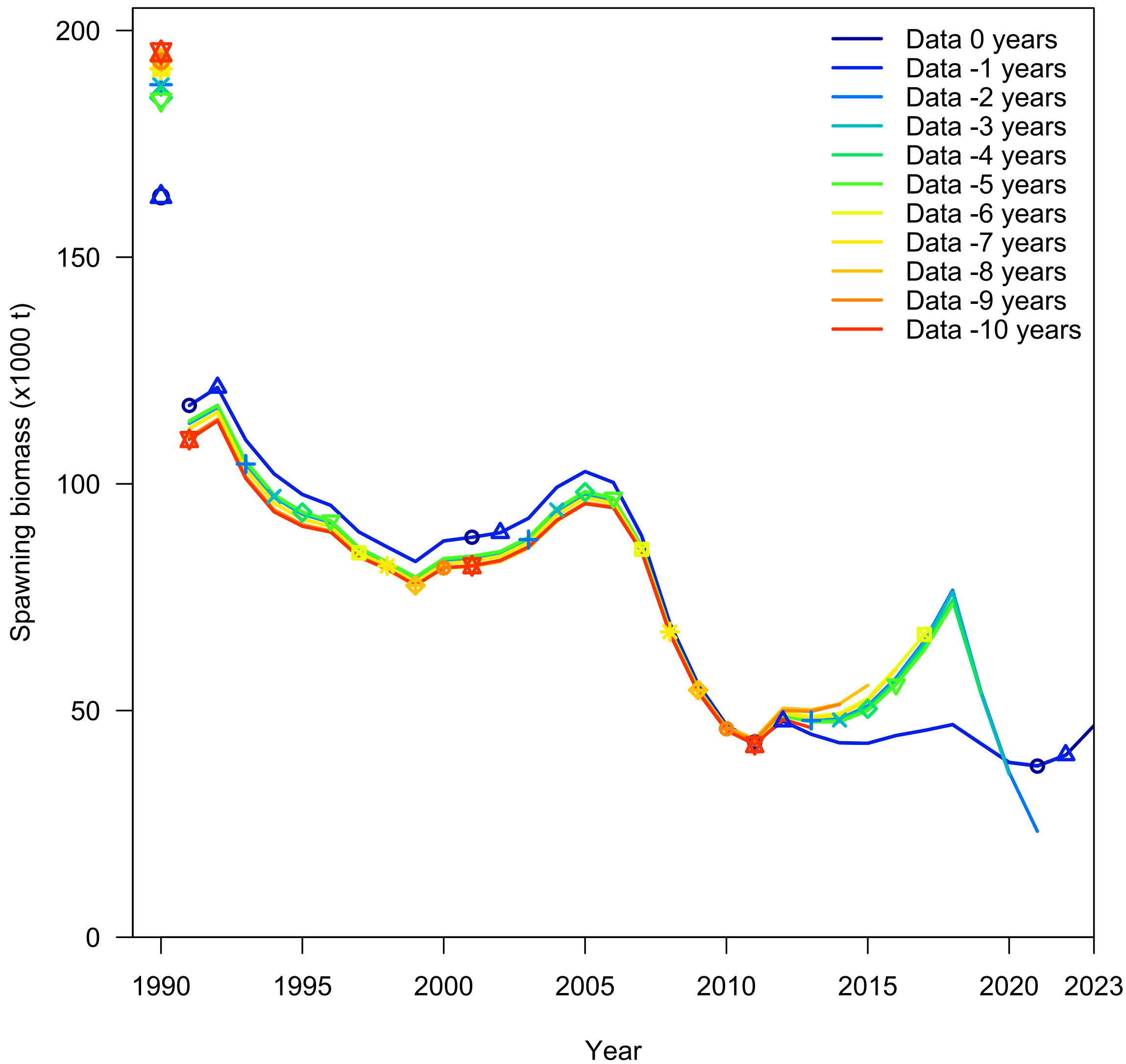


Figure 2A.21: Ten year retrospective plot of spawning biomass for Model. 23.0.

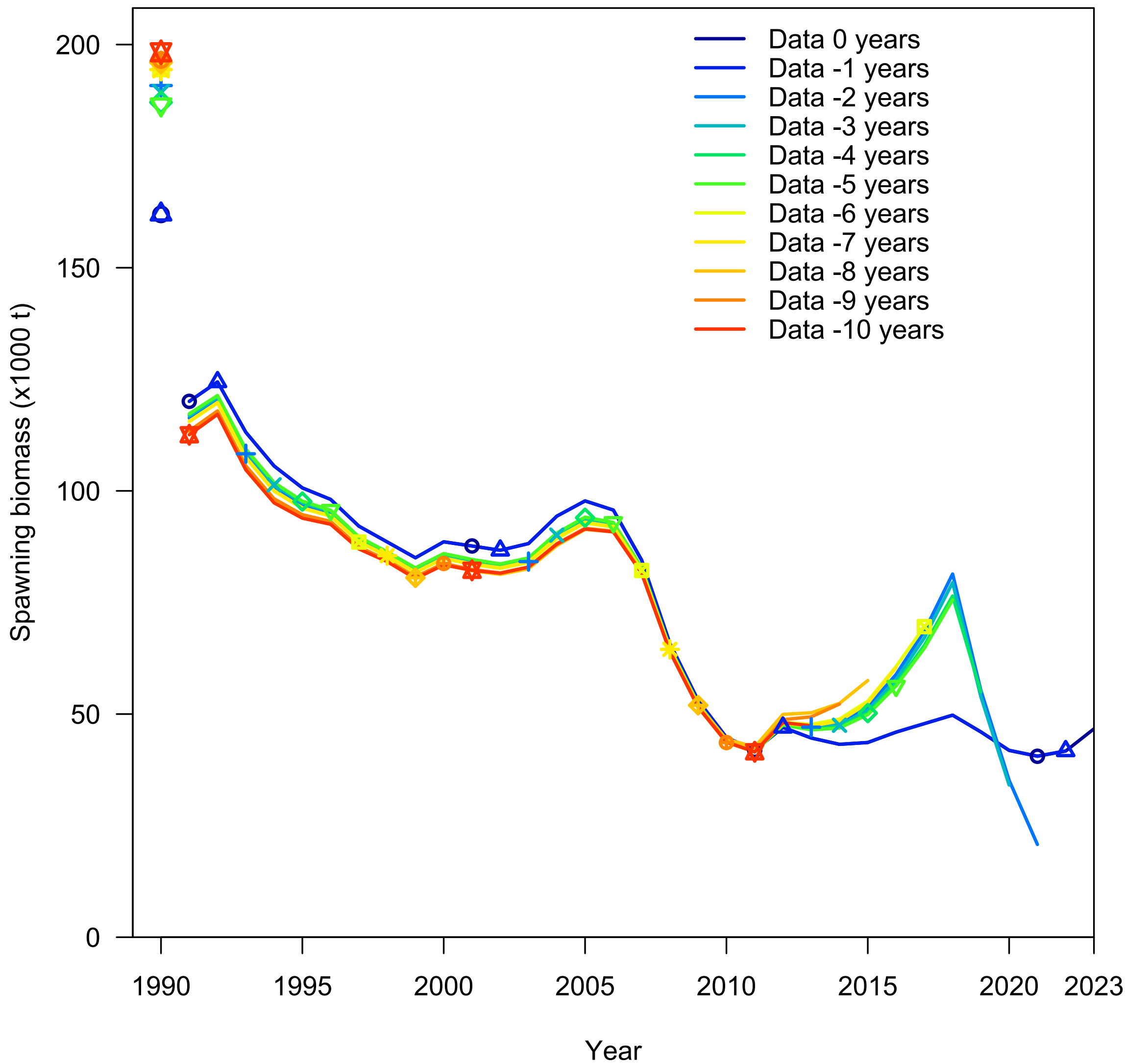


Figure 2A.22: Ten year retrospective plot of spawning biomass for Model. 23.1.

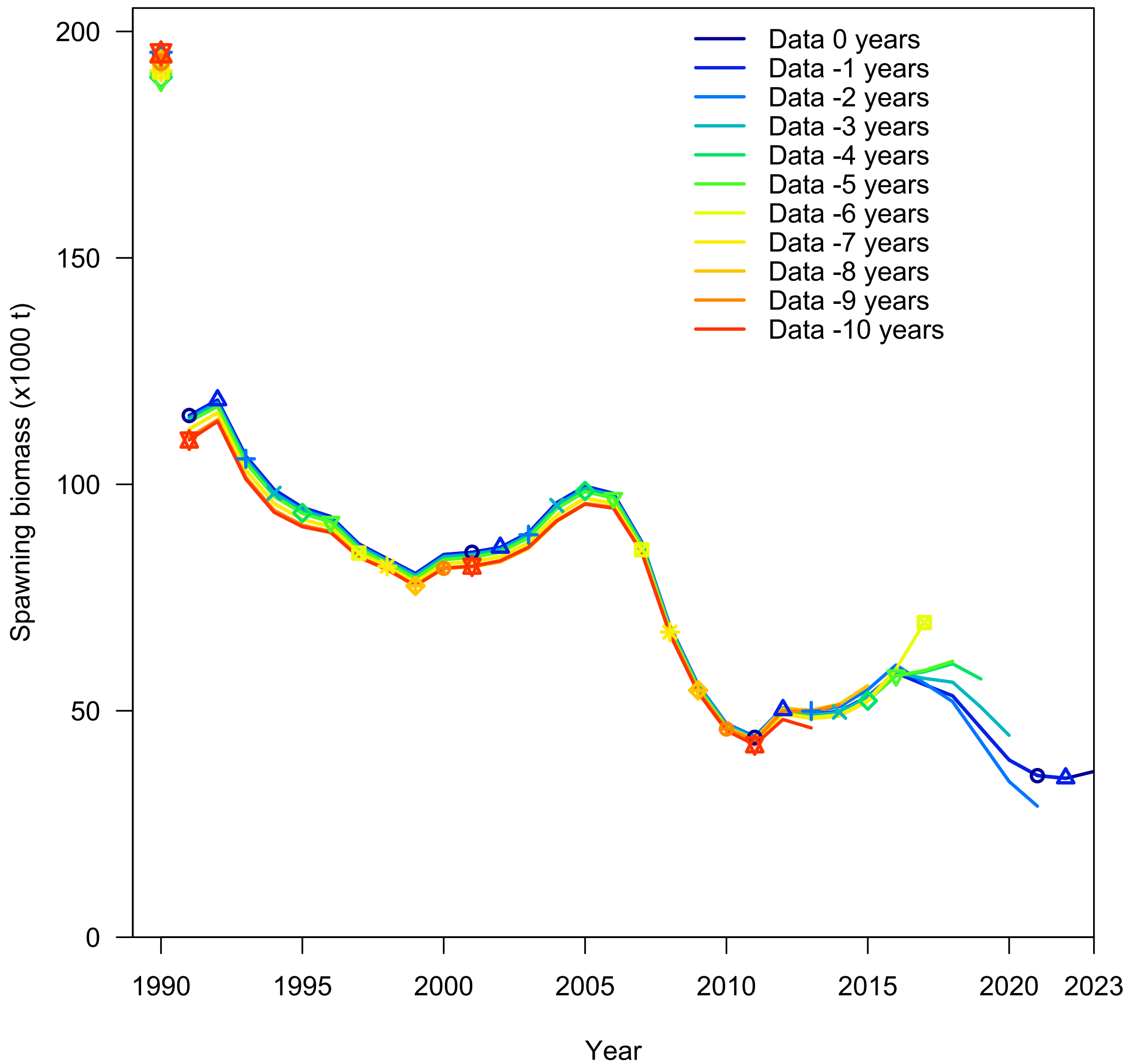


Figure 2A.23: Ten year retrospective plot of spawning biomass for Model. 23.2.

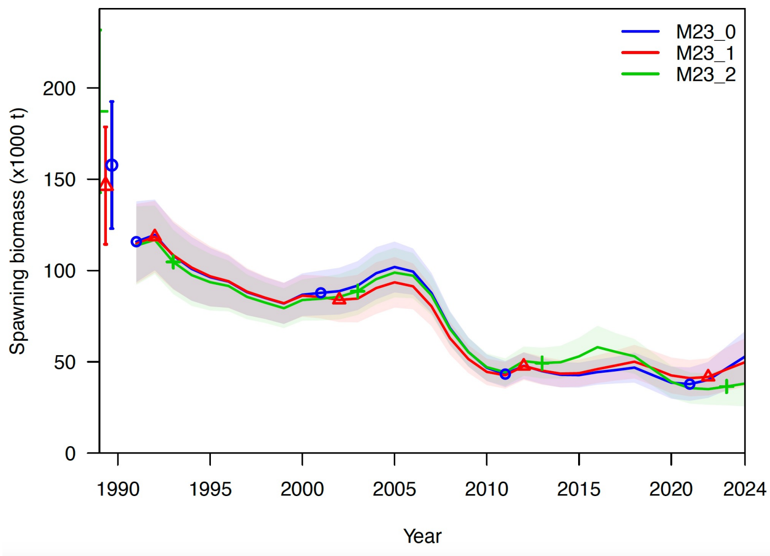


Figure 2A.24: Spawning stock biomass estimated from 1991 through 2023, Model 23.0, 23.1, and 23.2.

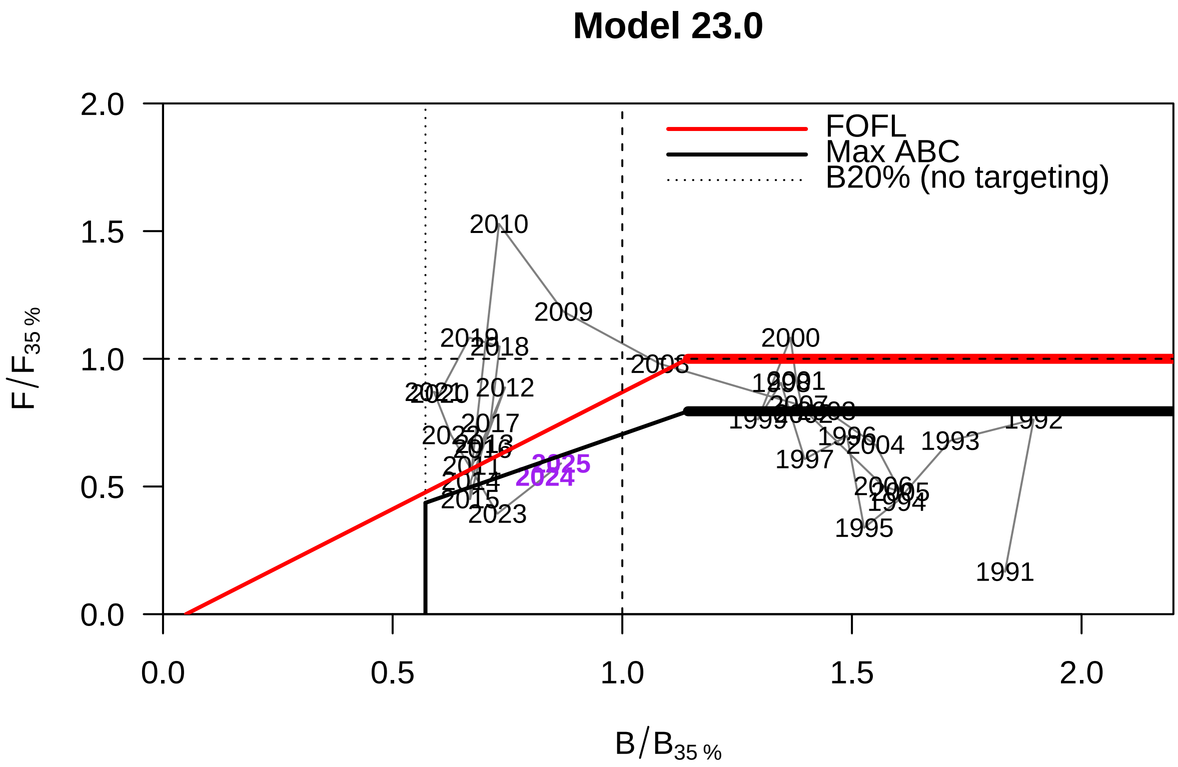


Figure 2A.25: Phaseplane plot for Model 23.0.

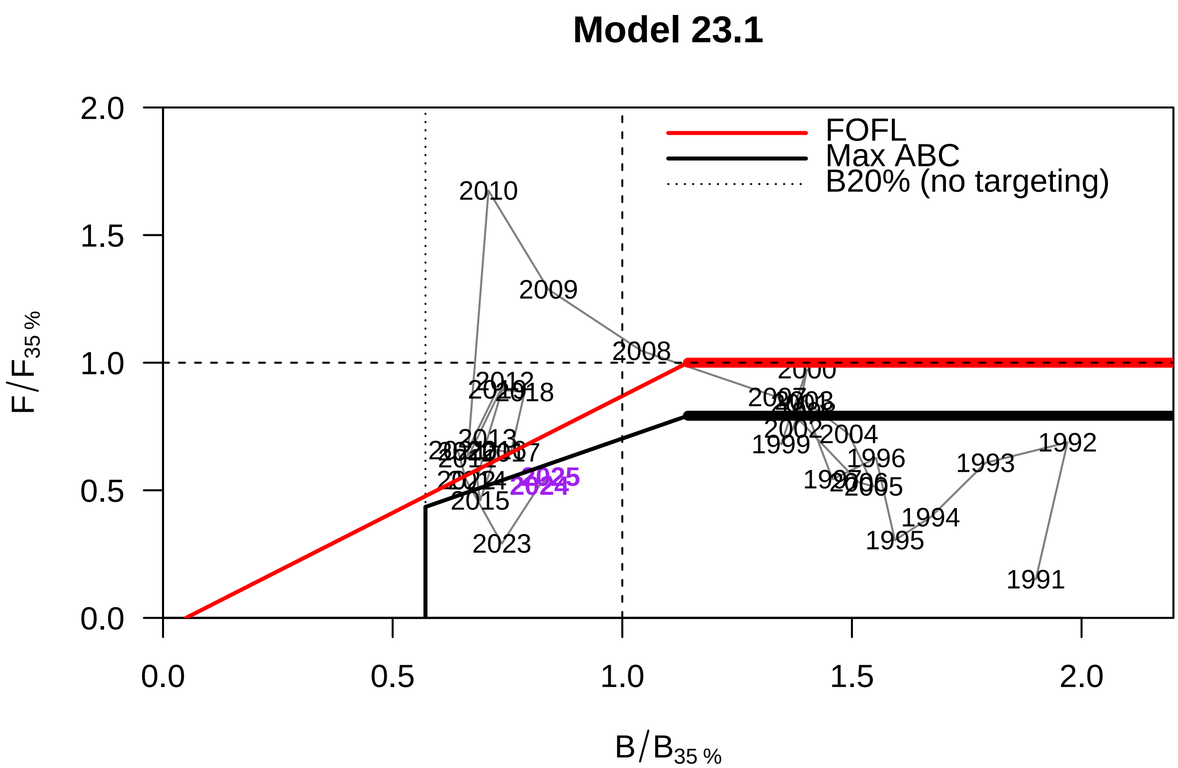


Figure 2A.26: Phaseplane plot for Model 23.1.

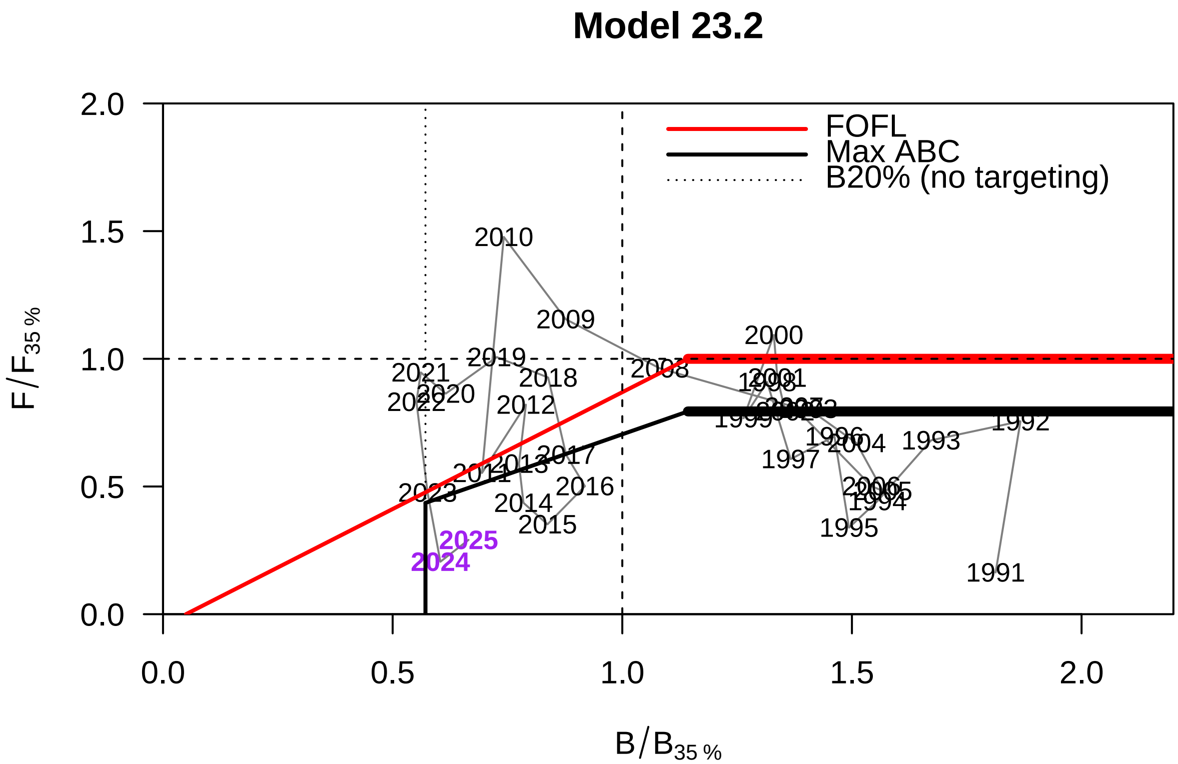


Figure 2A.27: Phaseplane plot for Model 23.2.

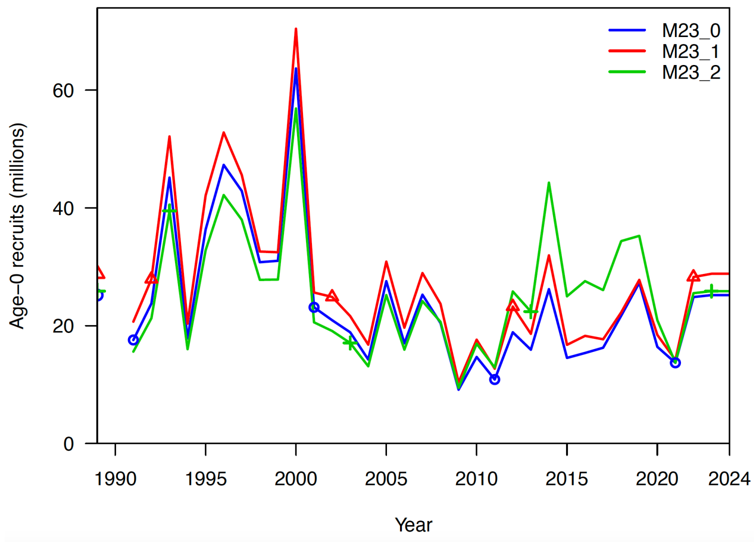


Figure 2A.28: Recruitment estimated from 1991 through 2023, Model 23.0, 23.1, and 23.2.

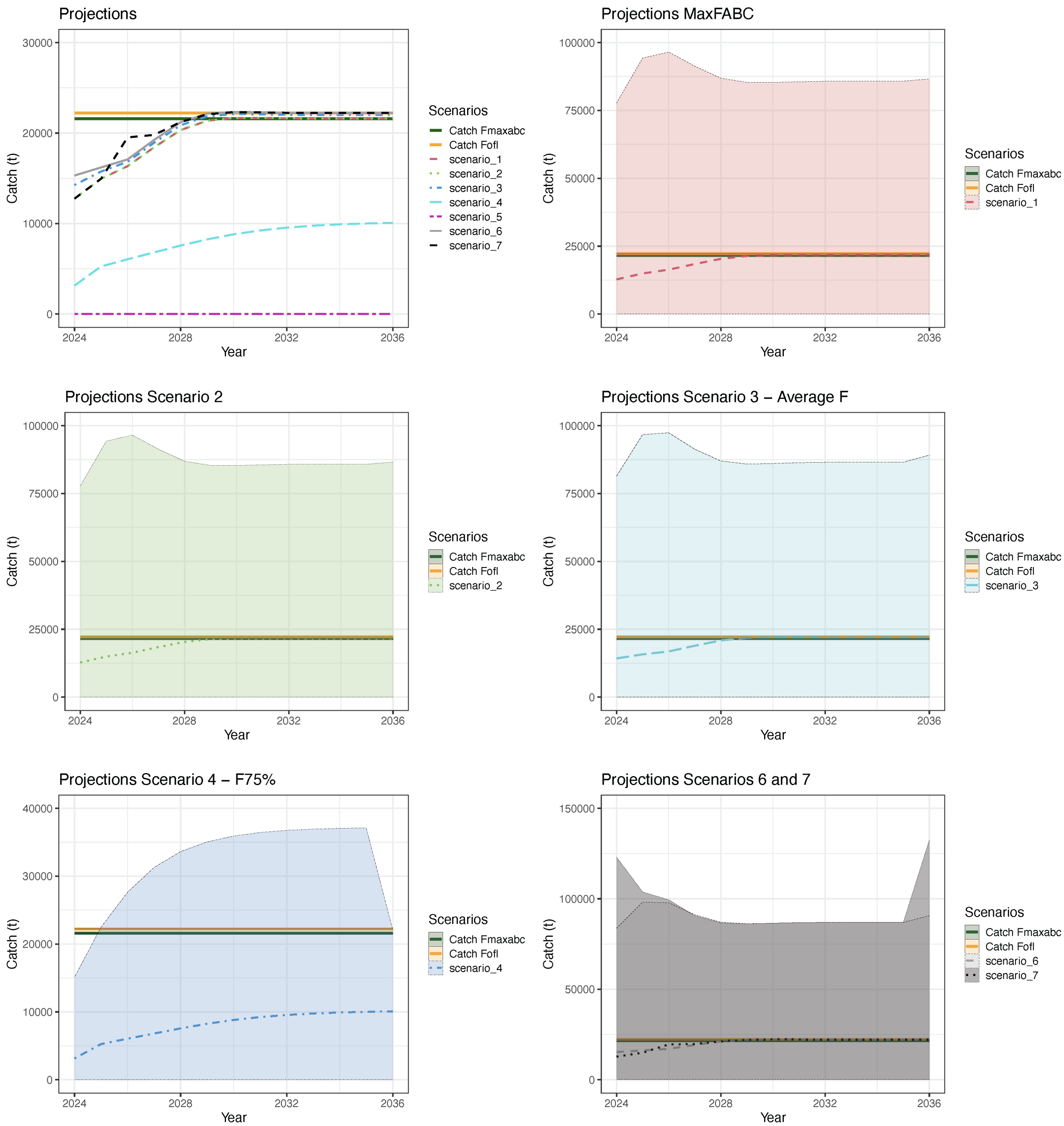


Figure 2A.29: Model 23.0 projections of catch for Aleutian Islands Pacific cod 2024 through 2036 based on seven harvest scenarios from Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

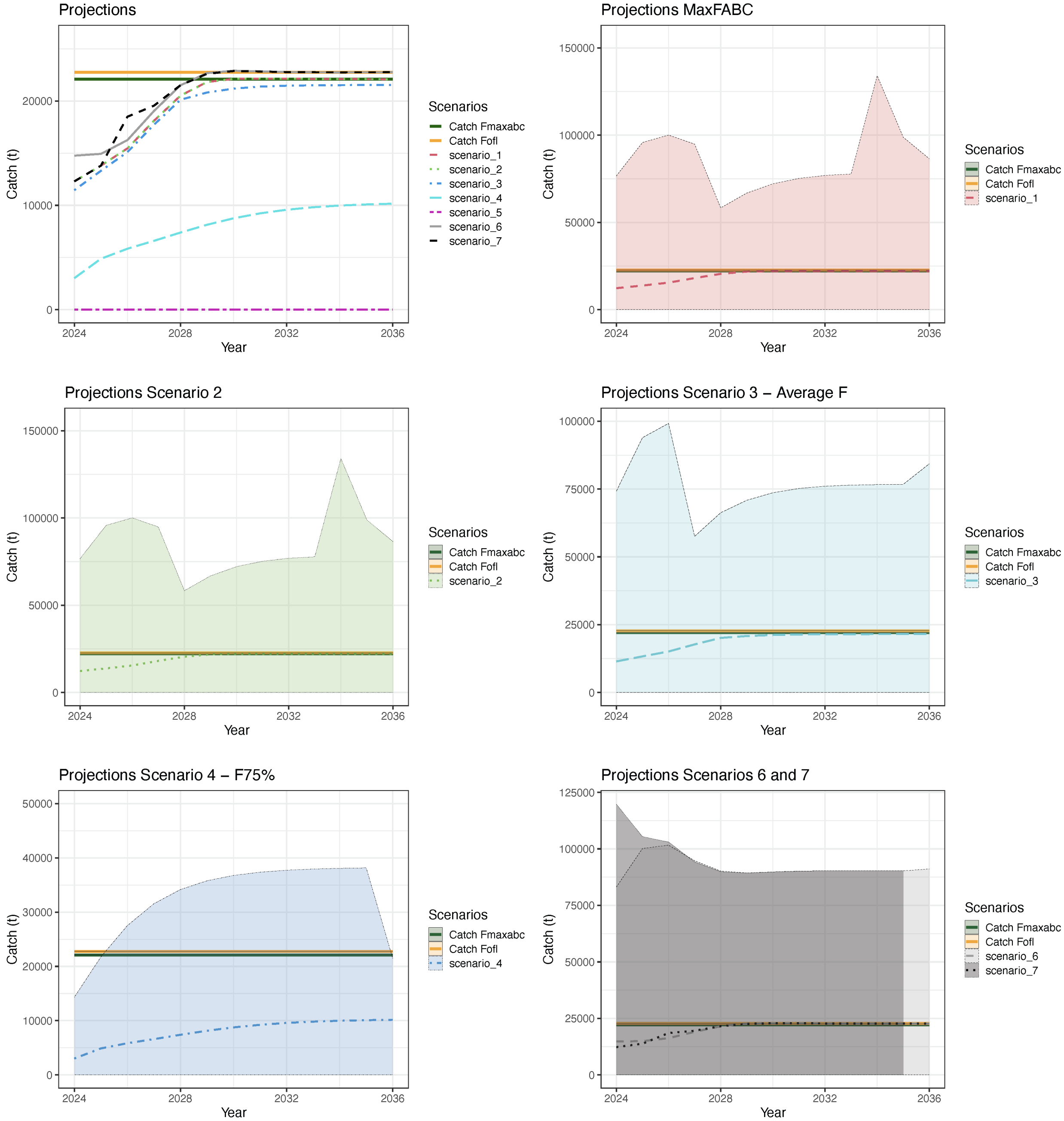


Figure 2A.30: Model 23.1 projections of catch for Aleutian Islands Pacific cod 2024 through 2036 based on seven harvest scenarios from Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

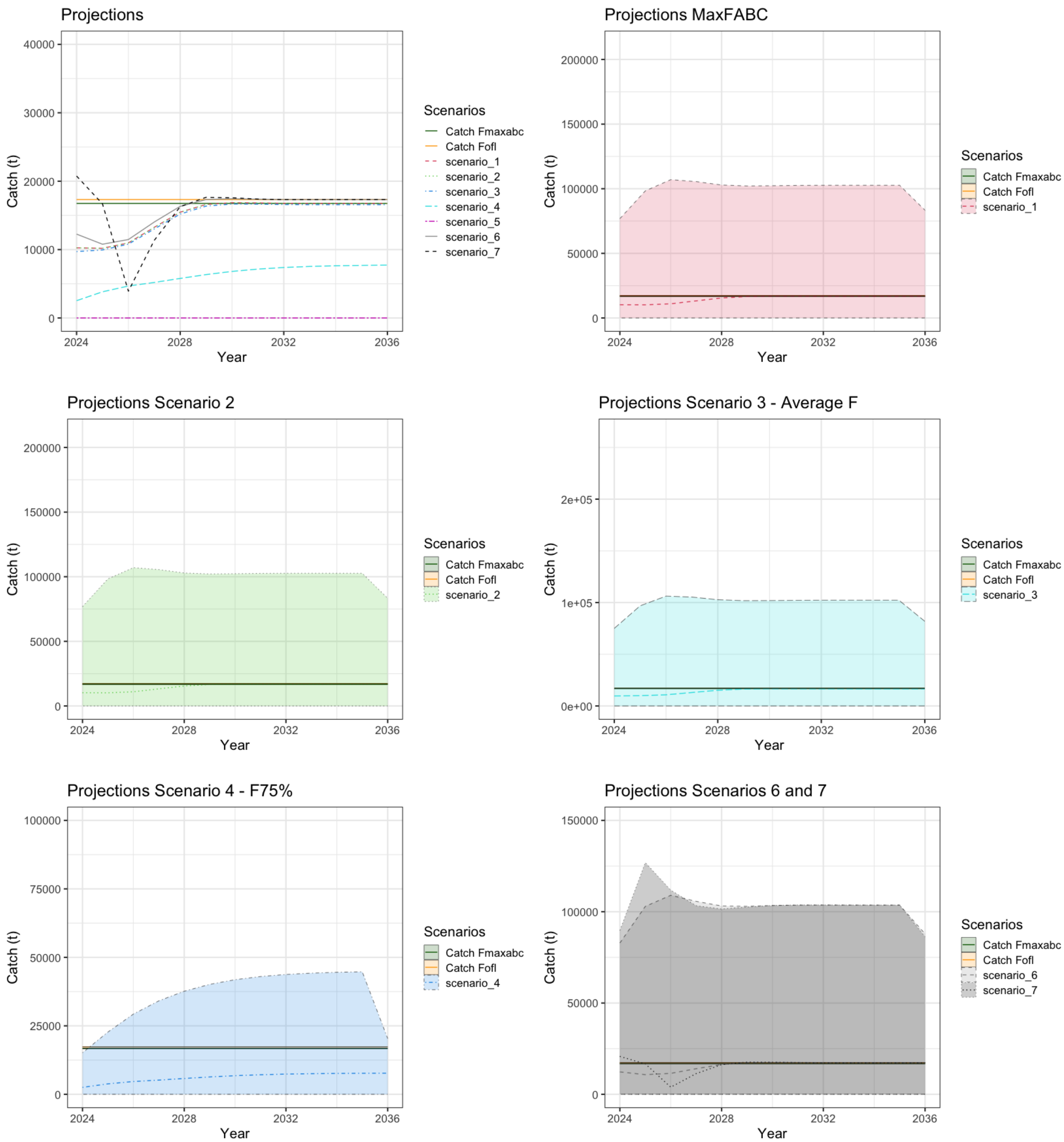


Figure 2A.31: Model 23.2 projections of catch for Aleutian Islands Pacific cod 2024 through 2036 based on seven harvest scenarios from Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

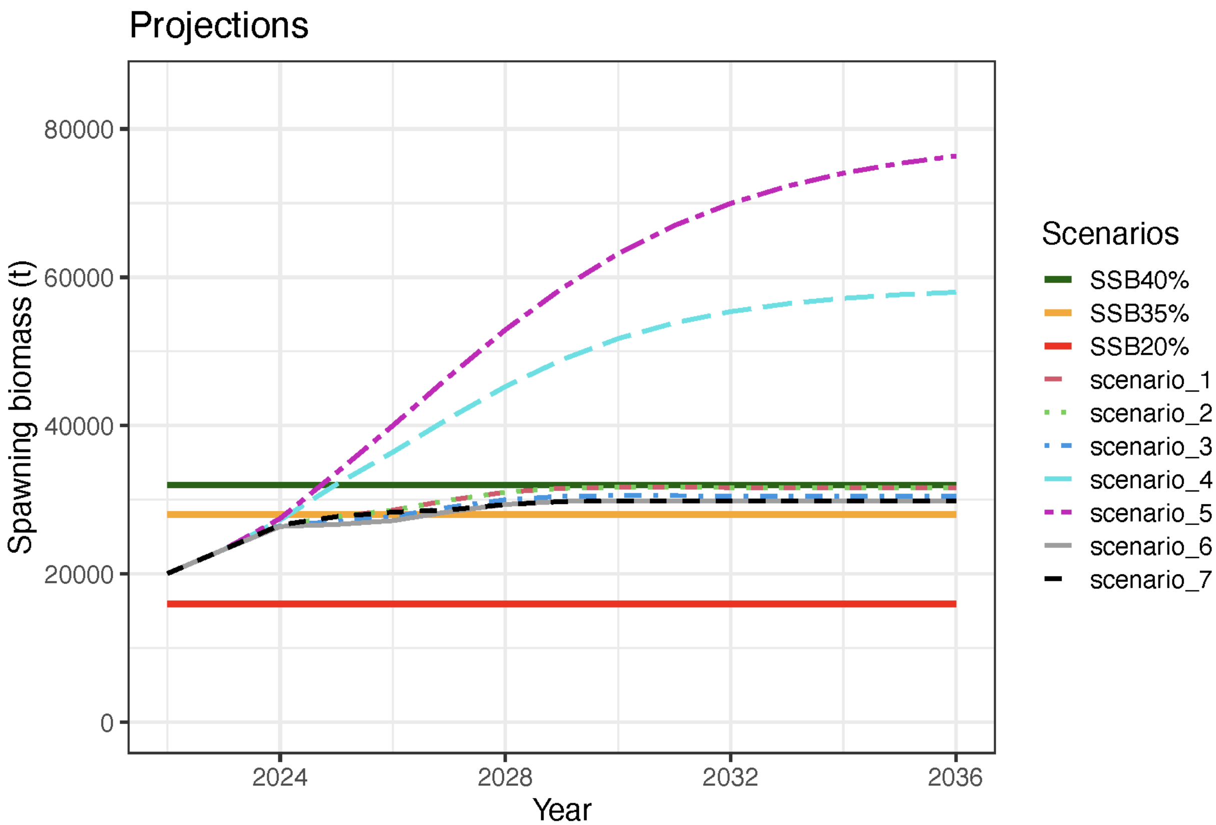


Figure 2A.32: Model 23.0 projection of spawning stock biomass for Aleutian Islands Pacific cod 2024 through 2036 based on all seven harvest scenarios from Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

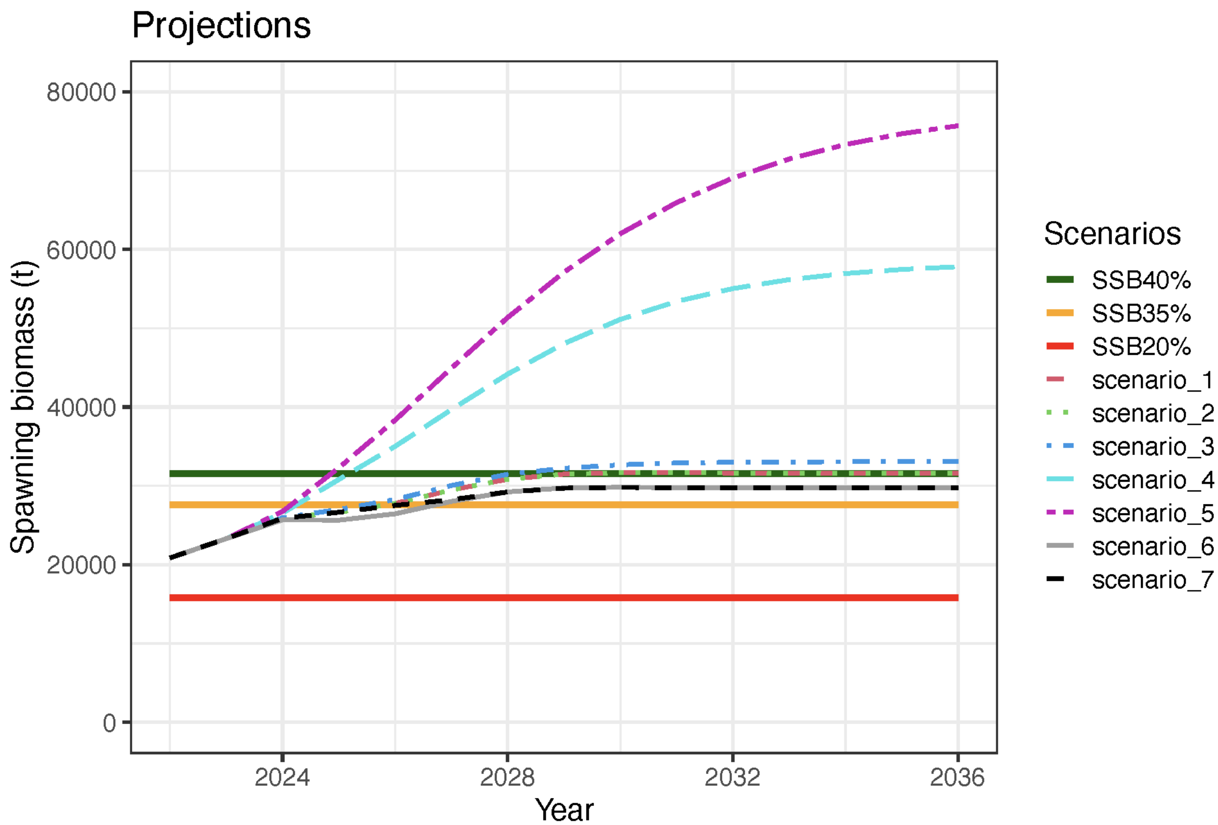


Figure 2A.33: Model 23.1 projection of spawning stock biomass for Aleutian Islands Pacific cod 2024 through 2036 based on all seven harvest scenarios from Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

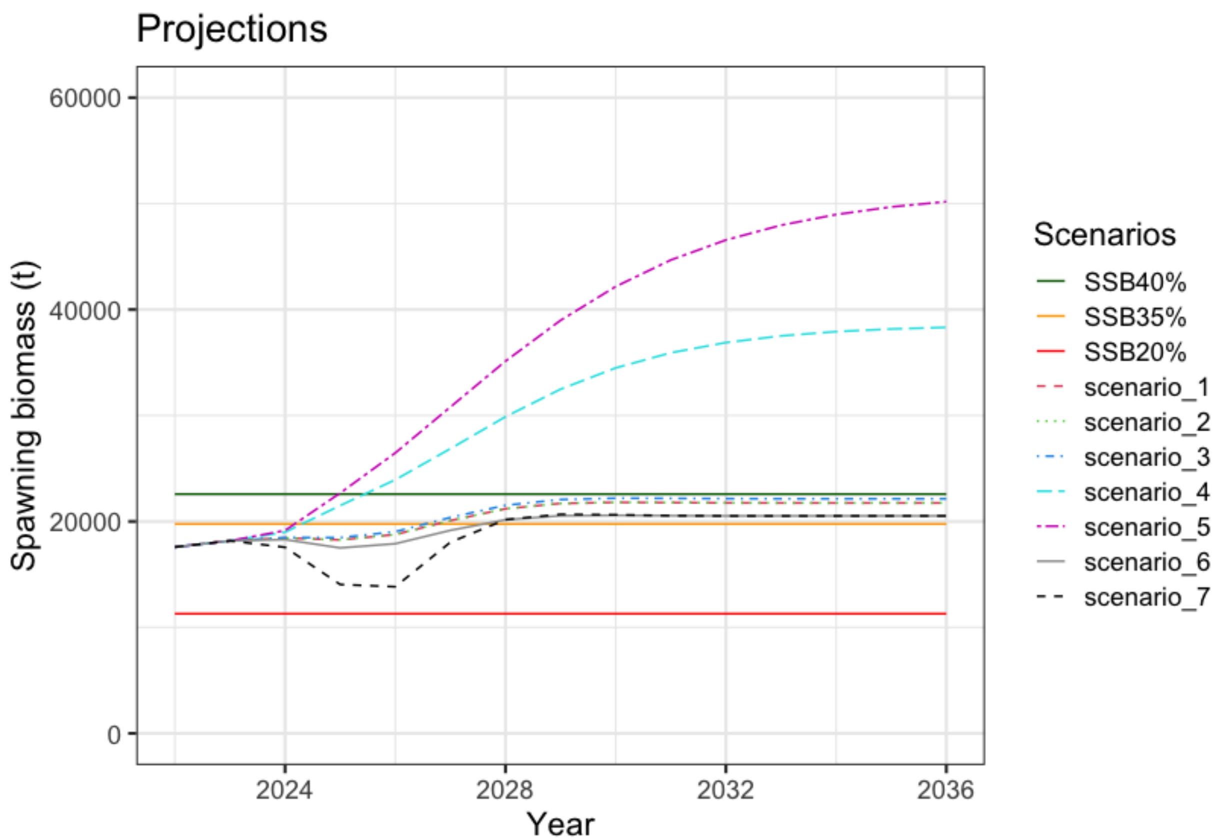


Figure 2A.34: Model 23.2 projection of spawning stock biomass for Aleutian Islands Pacific cod 2024 through 2036 based on all seven harvest scenarios from Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

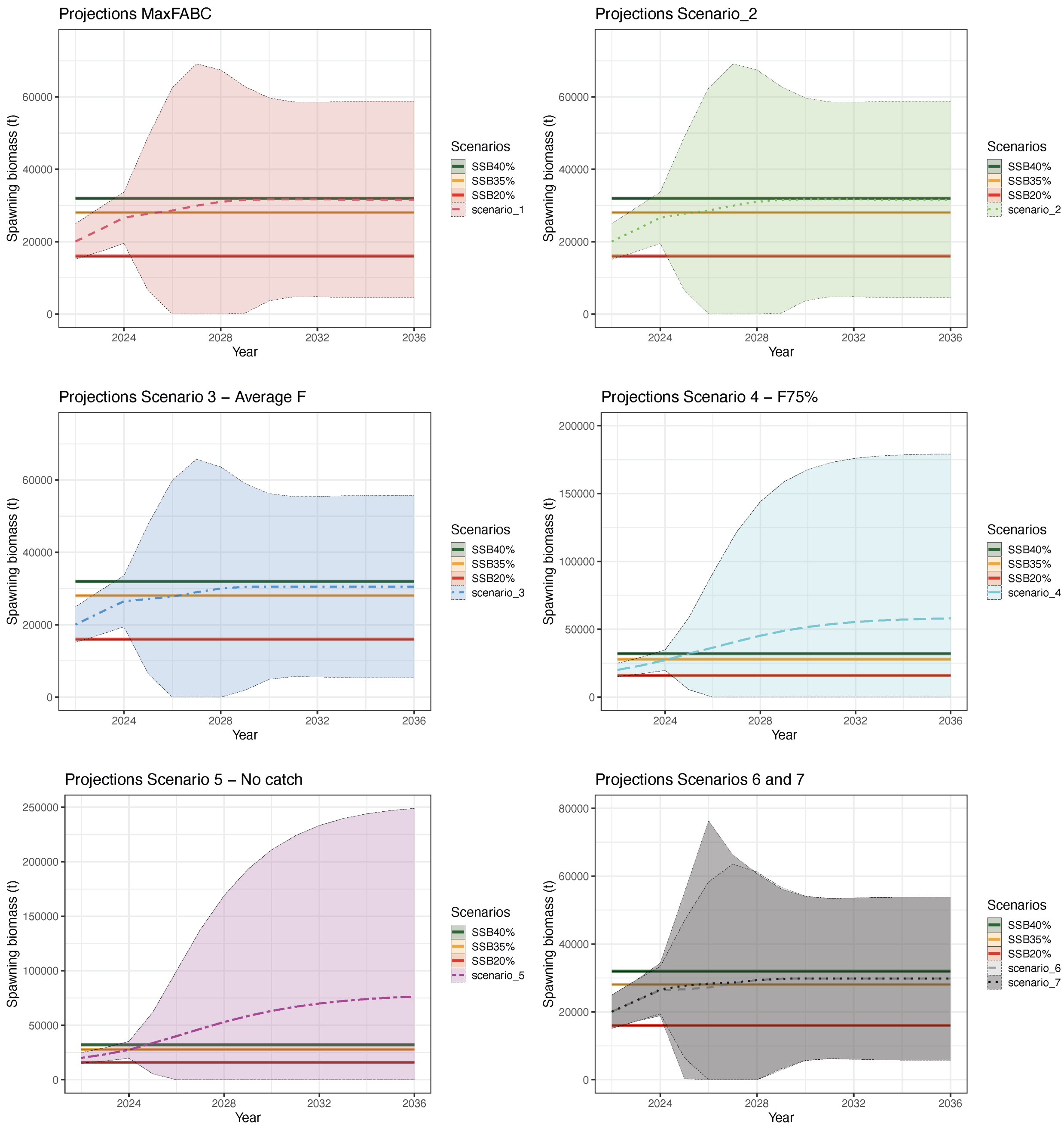


Figure 2A.35: Model 23.0 projections of spawning stock biomass for Aleutian Islands Pacific cod 2024 through 2036 based on seven harvest scenarios from Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

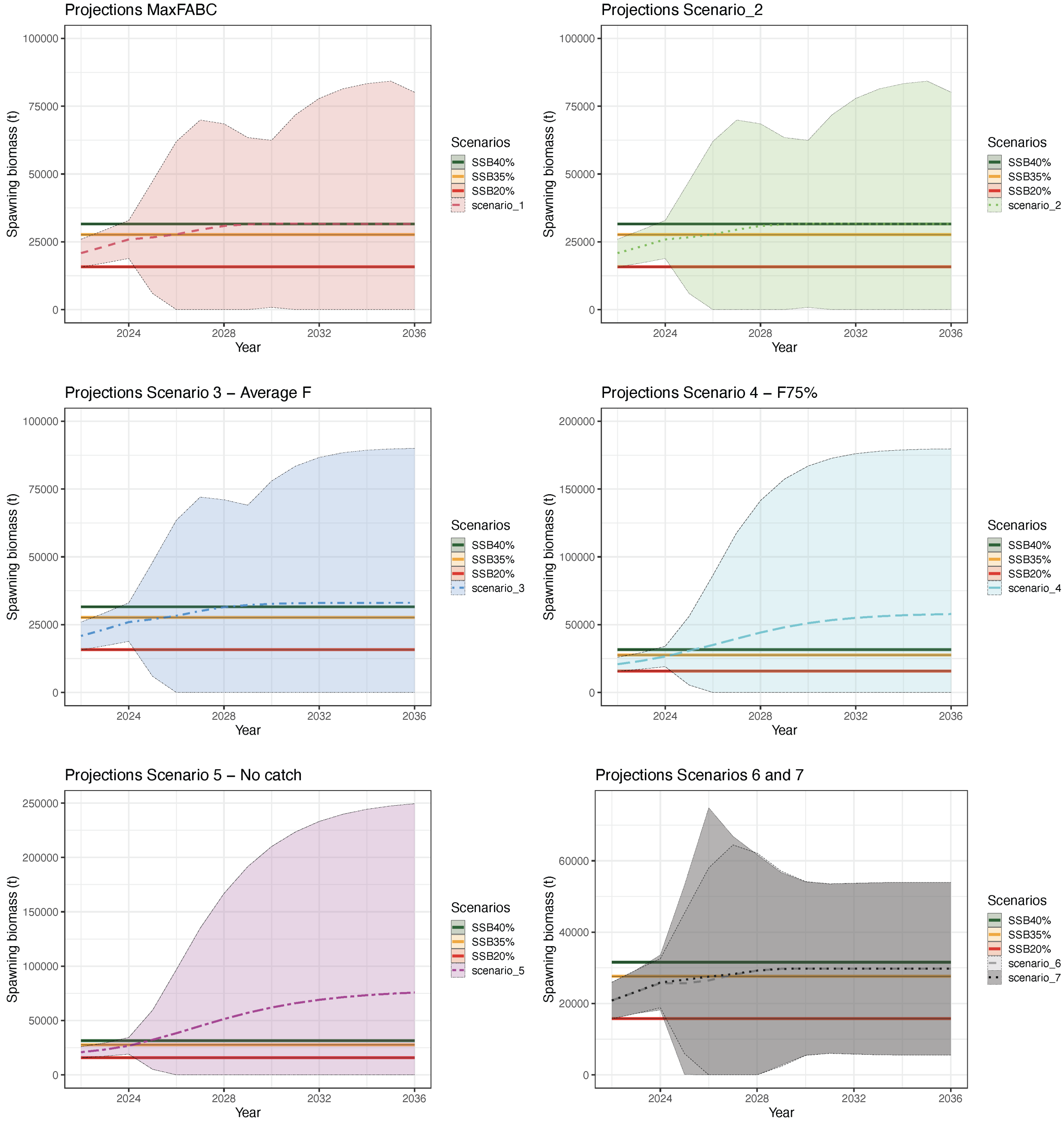


Figure 2A.36: Model 23.1 projections of spawning stock biomass for Aleutian Islands Pacific cod 2024 through 2036 based on seven harvest scenarios from Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

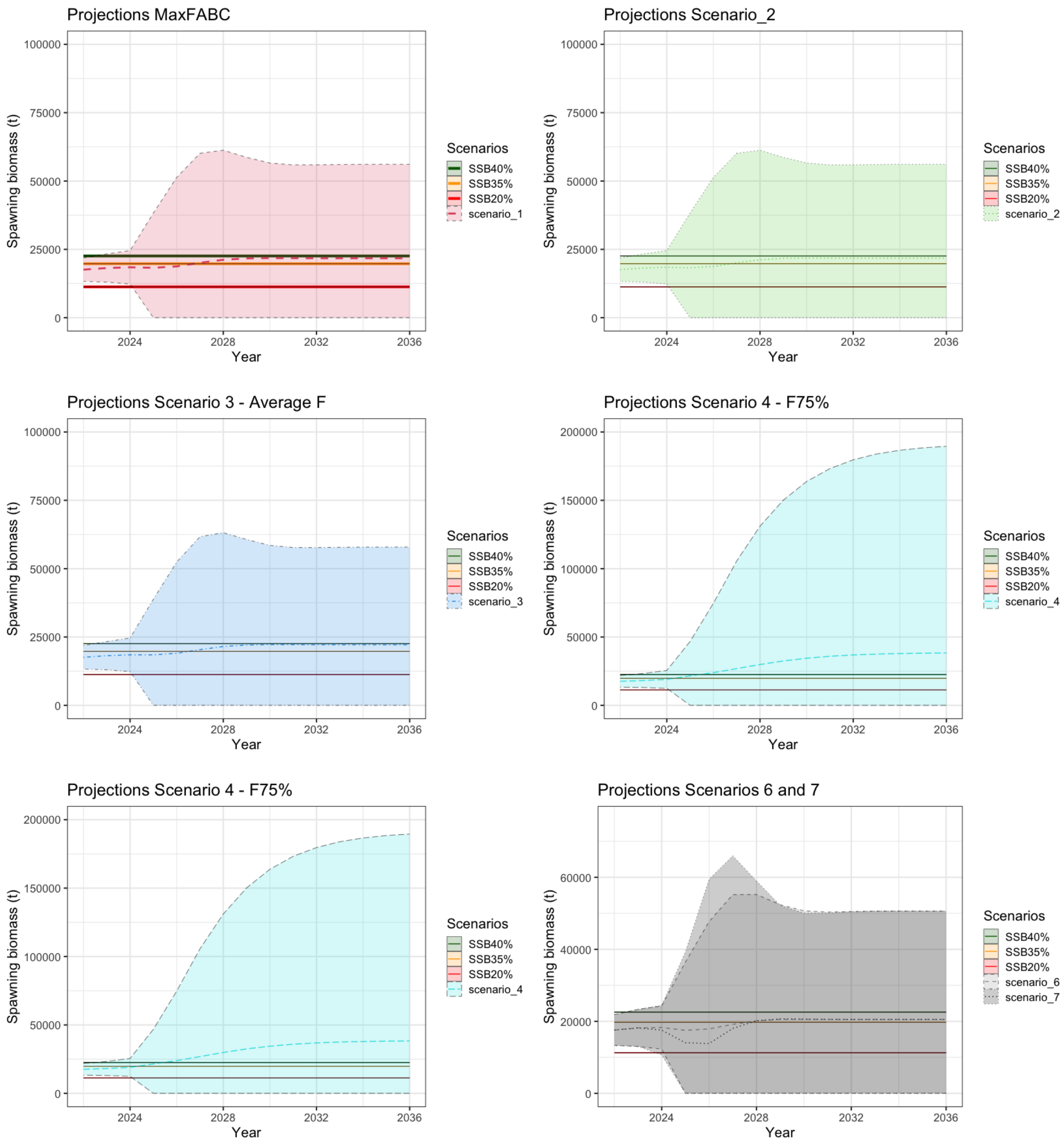


Figure 2A.37: Model 23.2 projections of spawning stock biomass for Aleutian Islands Pacific cod 2024 through 2036 based on seven harvest scenarios from Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).