2. Assessment of the Pacific Cod Stock in the Eastern Bering Sea

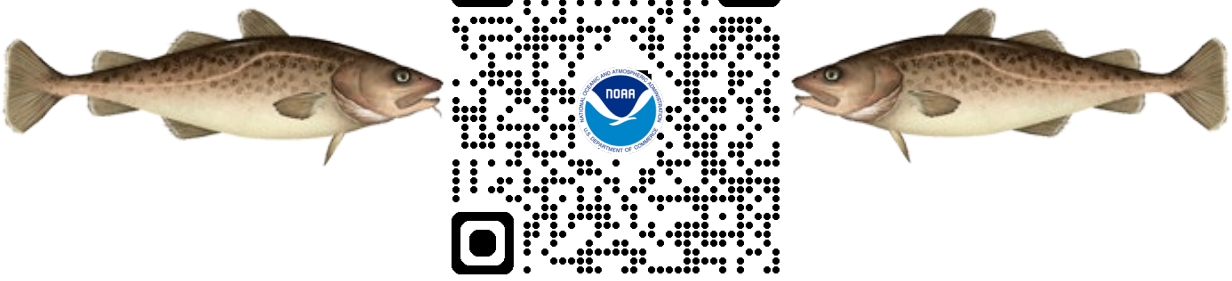
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Additional content links:

- 2026 EBS Pacific Cod Page (.html)
- Appendix 2.1: September Documentation (.pdf)
- Appendix 2.2: Eastern Bering Sea Pacific Cod ESP Report Card (.pdf)
- Appendix 2.3: 2026 Models Stock Synthesis Files (.zip)
- Appendix 2.4: All Models Data and Results (.xlsx)

EXECUTIVE SUMMARY

Summary of Changes in Assessment Inputs

Relative to the November edition of the 2024 BSAI SAFE report, the following substantive changes have been made in the eastern Bering Sea (EBS) Pacific cod stock assessment.

Changes in the Input Data

- Catches for 1991-2025 were updated, and a preliminary total catch estimate for 2026 was incorporated. All fishery data used in the models were retrieved on September 18, 2026.
- Commercial fishery size compositions for 1991–2026 were updated, including a preliminary size composition from the 2026 commercial fishery.
- The AFSC Eastern and Northern Bering Sea (EBS+NBS) bottom trawl survey abundance index was re-estimated using sdmTMB and updated through 2026.
- The size composition from the 2025 and 2026 EBS+NBS survey was incorporated
- The tinyVAST approach was used to estimate the age compositions from the combined EBS+NBS bottom trawl survey time series through 2025.

Changes in the Assessment Methodology

The model accepted for use in the 2024 assessment (Model 24.1) was re-run with the updated data while retaining the model structure and parameterization used in 2024. In addition, one alternative model, Model 26.1, was developed as described in the September update (Appendix 2.1). Model 26.1 is identical to Model 24.1 except that the maximum modeled age reduced from age 20 to age 14, resulting in an age-14 plus group.

Summary of Results

Model 24.1 and Model 26.1 produced very similar fits to the data and nearly identical estimates of stock status and derived management quantities. The total objective function values were 266.34 for Model 24.1 and 266.52 for Model 26.1, and differences among the individual likelihood components were small. Reference points were also very similar between the two models. Estimated unfished female spawning biomass (B_0) was 539,445 t for Model 24.1 and 546,405 t for Model 26.1, a difference of less than 1.3%. Estimated $F_{40\%}$ decreased slightly from approximately 0.360 for Model 24.1 to 0.354 for Model 26.1, a difference of about 1.7%. These results indicate that reducing the plus-group age from 20 to 14 had little effect on estimated stock status or biological reference points.

The primary difference between the models is the treatment of older ages. Reducing the maximum modeled age from 20 to 14 in Model 26.1 eliminates six initial-age deviation parameters associated with ages 15–20, reducing the number of estimated parameters from 184 to 178 without materially affecting model fit or management quantities. Given the comparable performance of the two models, the greater parsimony of Model 26.1 supports its selection as the preferred model for the 2026 assessment.

Although the change in plus-group age had little effect on model results, incorporating the 2025 and 2026 observations resulted in substantial revisions to recent recruitment estimates and lower projected spawning biomass relative to the 2024 assessment. The largest downward revisions in recruitment were associated with the 2018-, 2023-, and 2025-year classes, partially offset by higher estimated recruitment for the 2022-year class. Projected female spawning biomass in 2027 declined from 204,037 t in the 2024 assessment to 192,115 t in Model 26.1, a decrease of

5.8%, while maximum acceptable biological catch (maxABC) declined from 140,135 t to 123,787 t, a decrease of 11.7%. These changes primarily reflect revisions to estimated year-class strength and population abundance rather than differences in model configuration.

In consideration of the similar model performance, greater parsimony of Model 26.1, and limited sensitivity of management quantities to the plus-group specification, the authors recommend Model 26.1 for developing harvest advice for 2027 and 2028. Results from Model 24.1 are also presented to allow the Plan Team and SSC to evaluate the effects of changing the plus-group age.

The principal results from **Model 26.1** are listed in the table below (biomass and catch quantities are in units of tons (t)) and compared with the corresponding quantities specified by the SSC in 2024.

Quantity	As estimated or *specified in 2024** for: 2025	2026	As estimated or *recommended this* year for: 2027**	2028**
M (natural mortality rate)	0.386	0.386	0.386	0.386
Tier	3b	3b	3b	3b
Projected total (age 0+) biomass (t)	769,813	762,206	676,864	661,234
Projected female spawning biomass	215,747	206,498	192,115	187,929
$B_{100\%}$	561,915		546,405	
$B_{40\%}$	224,767		218,562	
$B_{35\%}$	196,670		191,242	
F_{OFL}	0.43	0.41	0.38	0.37
$maxF_{ABC}$	0.35	0.33	0.31	0.30
F_{ABC}	0.35	0.33	0.31	0.30
OFL (t)	183,509	169,243	148,179	141,676
maxABC (t)	153,617	141,520	123,787	118,299
ABC (t)	153,617	141,520	123,787	118,299
Status	As determined in 2024 for: 2023	2024	2025	2026
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*There was no stock assessment produced in 2025, therefore 2025 and 2026 projections were from the 2024 assessment.

**Projections for 2027 and 2028 are based on assumed catches of 133,475 t and 123,787 t in 2026 and 2027, respectively. The 2026 catch was projected based on the 5-year average proportion of the ABC harvested.

Note that the recommended 2027 and 2028 F_{ABC} and ABC values listed above may be subject to modification following consideration by the Plan Team and SSC. The summarized results of the risk analysis (see subsection in the "Harvest Recommendations" section) are shown below:

Assessment-related considerations	*Population dynamics considerations*	*Ecosystem considerations*	*Fishery-informed stock considerations*
Level 1: No Concern	Level 1: No Concern	Level 1: No Concern	Level 1: No Concern

Under the author's recommended model, a specific reduction from maximum ABC was not considered. In the event that the 2027 F_{ABC} or ABC values are changed from those shown above, projected 2028 values of other non-constant quantities would need to change in response and would be reflected in the harvest specification tables.

Responses to SSC and Plan Team Comments

September 2024 Plan Team

The Team recommended the author consider the effect of the increase in length bins on spawning biomass and derived management quantities and pointed to Monnahan et al. (2016) as a helpful reference on the topic.

The authors consider the current 5-cm length bins adequate for characterizing growth and key length-based processes such as selectivity and maturity. Pacific cod generally grow more than 5 cm per year across the age range most influential to the assessment, resulting in multiple length bins represented within each year class. Therefore, the authors do not expect finer binning near selectivity or maturity inflection points to provide substantial additional information to the model at this time.

Team recommended continued development of models using conditional age-at-length and suggested the author consider an empirical weight-at-age approach or a time-varying length-weight relationship in future years.

The authors have considered an empirical weight-at-age approach. A primary challenge for Pacific cod is accounting for known aging bias and aging error in the observed age data. Implementing an empirical weight-at-age approach is therefore not straightforward because the current Stock Synthesis framework does not provide a mechanism to incorporate aging error or bias directly into empirical weight-at-age inputs. One possible alternative would be to use weight-at-age estimates derived from a previous model; however, these would be model-derived quantities rather than strictly empirical observations. As new modeling frameworks are developed, the authors will continue to consider approaches for addressing this issue.

October 2024 SSC

The SSC recommends that stock assessment authors spotlight their need for updated maturity data in the "Data gaps and research priorities" of their upcoming SAFEs if warranted.

The SSC concurs with this (the September 2024 Plan Team recommendation) and recommends that the authors explore finer bin structure closer to inflection points of key processes such as

selectivity and maturity, and areas of the growth curve where cod are growing quickly, rather than using 5 cm uniformly across the length range.

Because the assessment reference points are based on female spawning biomass, accurately characterizing maturity is particularly important. For Pacific cod, maturity appears to vary among years and/or cohorts and is likely influenced by environmental conditions. The authors therefore consider continued investigation of temporal and environmental variation in maturity to be an important area of research. Improving our understanding of these relationships should strengthen the biological basis of the assessment and inform future model development and management of the stock.

At the authors' discretion, the SSC recommends a model similar to 23.1.0.d with static survey selectivity, linear aging error and an attempt to fit marginal fishery ages rather than conditional length-at-age.

The authors continue to evaluate alternative approaches for characterizing aging error, including linear aging-error models. The authors also continue to investigate appropriate methods for incorporating marginal fishery age compositions into the assessment, including consideration of how these data should be constructed and weighted.

November 2024 Plan Team

The Team recommended the authors clarify this section of text in the stock assessment, specifically justifying the choice of maximum age assumptions in the natural mortality analysis.

The authors revised this section to clarify the rationale for the maximum-age assumptions used in the natural mortality analysis and to more clearly describe how those assumptions affect the resulting estimates of natural mortality.

The Team recommended a likelihood profile on the parameter for the survey selectivity ascending limb in Model 24.3 in order to diagnose the estimate of that selectivity parameter and relative influence of the data components on its estimate.

Model 24.3 was not carried forward for 2026.

December 2024 SSC

The SSC … recommends that the authors explore finer bin structure closer to inflection points of key processes such as selectivity and maturity, and areas of the growth curve where cod are growing quickly, rather than using 5 cm uniformly across the length range.

The authors consider the current 5-cm length bins adequate for characterizing growth and key length-based processes such as selectivity and maturity. Pacific cod generally grow more than 5 cm per year across the age range most influential to the assessment, resulting in multiple length bins represented within each year class. Therefore, the authors do not expect finer binning near selectivity or maturity inflection points to provide substantial additional information to the model at this time.

At the authors' discretion, the SSC recommends a model similar to 23.1.0.d with static survey selectivity, linear aging error and an attempt to fit marginal fishery ages rather than conditional length-at-age.

The authors are awaiting further development and maturation of the work that was conducted by Dr. Brent Stacey to improve methods for constructing fishery composition data and quantifying appropriate input sample sizes. This work was delayed due to the federal furlough in the Fall 2025 and SSCs request for the full GOA Pacific cod assessment.

September 2025 Plan Team

No recommendations specific for Pacific cod.

October 2025 SSC

No recommendations specific for Pacific cod.

November Plan Team 2025

No recommendations specific for Pacific cod.

December 2025 SSC

No recommendations specific for Pacific cod.

INTRODUCTION

Pacific cod (*Gadus macrocephalus*) is a transoceanic species, ranging from Santa Monica Bay, California, northward along the North American coast; across the Gulf of Alaska and Bering Sea north to Norton Sound; and southward along the Asian coast from the Gulf of Anadyr to the northern Yellow Sea. The species occurs from nearshore waters to depths of approximately 500 m (Ketchen 1961, Bakkala et al. 1984). The southern limit of its distribution is approximately 34° N latitude, and the northern limit is approximately 65° N latitude (Lauth 2011). Pacific cod are widely distributed throughout the eastern Bering Sea (EBS) and Aleutian Islands (AI). Recent genetic and tagging studies indicate that this broad distribution includes substantial connectivity among some regions, particularly between the EBS and western Gulf of Alaska, while also providing evidence of genetically differentiated groups within the broader species range.

Recent genetic research on Pacific cod has significantly advanced our understanding of the species' genomic diversity, environmental resilience, and sex-determination systems (Spencer et al, In Review; Spies et al., In Review A; Spies et al. In Review B). By leveraging whole-genome sequencing technologies alongside morphological and behavioral datasets, we have made significant progress toward providing new insights that are beneficial for management and conservation of this commercially important fish species.

One key finding highlights the discovery of unexpected genomic complexity within populations spanning from the eastern Bering Sea to the western Gulf of Alaska (Spies et al. In Review A). Integrating genomic data with morphological metrics and satellite tagging data revealed a distinct separation of concurrently sampled fish into two distinct groups. This divergence is driven by a genomic structural variant, likely a segmental duplication, that correlates with physical condition. Individuals displaying the higher copy number structural variant weighed approximately 4.5% more at a given length than those matching the reference genome, highlighting a direct genetic link to growth and body size.

Complementary research evaluated how Pacific cod populations respond to extreme environmental stressors, specifically the recent marine heatwaves in the Gulf of Alaska (Spies et al., In Review B). By analyzing age-0 cohorts from 2018 through 2021 using low-coverage whole-genome sequencing and otolith analysis, researchers at AFSC observed surprising genomic stability. Despite marine heatwave conditions and record low recruitment, the genetic diversity and composition of the spawning cohorts remained relatively unchanged, demonstrating short-term resilience consistent with population genetic theory. However, this study also revealed localized variation in spawning phenology and increased genetic variation in the Shumagin region, indicating subtle, unresolved regional differences across spawning components.

Finally, researchers have successfully mapped the genetic architecture of sex determination in Pacific cod, paving the way for non-lethal and early life-stage sex assignment (Spencer et al., In Review). A genome-wide association analysis identified 138 sex-associated single nucleotide polymorphisms (SNPs), primarily on a 150-kb region of Chromosome 11. The data support a conserved XX/XY sex-determination system, where males exhibit heterogametic haplotypes. Using these genomic markers, a highly reliable classification tool capable of predicting phenotypic sex with over 99% accuracy was developed, providing a new tool for fisheries research.

Building on these breakthroughs, Laura Timm in 2026 secured two years of funding from the Pacific Cod Disaster Fund to expand the scope of the research on the genomic structural variant. Research will 1. investigate the geographic extent of each group across the large marine ecosystems of Alaska to describe presence and prevalence and 2. characterize the phenotypic features and environmental habitats of each group to elucidate adaptive genomic diversity. Furthermore, we received a one-year NPRB Flex Grant to continue analysis of unprocessed pop-up archival tag data for Pacific cod. This project will allow for the release of depth and temperature data from approximately 200 satellite tags successfully deployed on Pacific cod in Alaskan waters, in collaboration with genetic analysis of each new tagged fish.

Six years of satellite tagging research on Pacific cod has revealed important insights into seasonal connectivity between management regions in Alaska. Pacific cod tagging research was initiated in 2019 and consists of an inter-agency collaboration between NOAA scientists and the Aleutians East Borough (AEB), the Freezer Longline Coalition (FLC), the Native Village of Savoonga, Norton Sound Economic Development Corporation (NSEDC), and Pacific Cod Harvesters. Satellite tags are programmed to "pop up" from the fish at a pre-programmed time, providing a fishery-independent recovery location when they reach the surface and start transmitting data to a satellite network. Transmitted depth, temperature, and light data from satellite tags can be used to reconstruct movement paths between the release and pop-up locations using a hidden Markov model for geolocation (Nielsen et al. 2023B). Thus, satellite tags are a valuable source of information about movement, environment, and behavior of tagged fish. In general, tags are deployed during the winter to gain information about movement from winter spawning to summer foraging areas or during the summer to understand movement from summer foraging to winter spawning areas and annual movement patterns.

Satellite tags were first deployed in the Aleutian Islands in 2019 to demonstrate the feasibility of geolocation and establish tagging methods for Pacific cod (Bryan et al., 2021, Nielsen et al. 2023A). To date, 395 satellite tags have been deployed on Pacific cod in Alaskan waters (Figure 2.1). From 2019 – 2024, satellite tags were released in the EBS and NBS from the annual Bering Sea summer trawl survey. Tags were also released from the Native Village of Savoonga in 2019, 2023, and 2024. In 2024 and 2025, tags were released from the EBS in collaboration with the FLC aboard a FLC vessel. However, the majority of the tags were released in the Gulf of Alaska in the winter in collaboration with the AEB during the years 2021 – 2025 as part of a multi-year study to understand seasonal movement within the GOA and between the GOA and BS. Detailed information on release and pop-up locations as well as all reconstructed movement pathways for fish tagged in the GOA between 2021 and 2024 are available in NOAA technical memos (Rand et al. 2026A, Rand et al. 2026B, Rand et al. 2026C, Rand et al. 2026D).

Results from tag pop-up locations and reconstructed movement paths obtained to date suggest that substantial seasonal connectivity exists between the western GOA and regions in the Bering Sea (EBS, NBS, and Russian waters). Across five years of winter releases in the western GOA (2021 – 2025), approximately 50% of satellite-tagged fish moved to summer foraging locations in the Bering Sea each year. When viewed together with seasonal movement from summer foraging to winter spawning areas of fish tagged in the EBS and NBS, it seems likely that a large proportion of the fish in the WGOA join the larger BS population of fish that move north in the summer and south in the winter (Figure 2.2A). Winter sea ice likely influences the timing and extent of seasonal movements in the NBS, as tagged fish leave the region prior to sea ice coverage and increased occupation of NBS, Russia, and Chukchi sea during the summer months

is likely in years with warmer temperatures and reduced sea ice extent (Nielsen et al., 2025). No tagged fish have been observed to remain alive in ice-covered areas of the NBS through the winter. In general, within-season movement is smaller than between-season movement (Figure 2.2B). Little movement between the western and central GOA or between the AI and other regions has been observed. Partial migration (i.e., only part of the population migrates) is apparent in our data, as some tagged fish in the AI, GOA, and EBS do not undertake large seasonal movements. Research is underway to evaluate whether genetic, physical, or environmental factors are related to migration characteristics and the proportion of fish that undertake migrations each year. In addition, results from a recent NPRB-funded acoustic telemetry pilot study indicate that an acoustic array in Unimak Pass could provide complementary information on timing of movement between the GOA and BS and would allow increased sample sizes as well as multi-year observations of Pacific cod seasonal movement between management areas.

Additional information on the biology of Pacific cod, including early life history, can be found in the Appendix 2.2 Eastern Bering Sea Pacific Cod Ecosystem and Socioeconomic Profile (Shotwell et al. 2026).

FISHERY

Description of the modern directed fishery

During the early 1960s, a Japanese longline fishery harvested EBS Pacific cod for the frozen fish market. Beginning in 1964, the Japanese trawl fishery for walleye pollock (*Gadus chalcogrammus*) expanded, and Pacific cod became an important bycatch species and an occasional target when high concentrations were encountered during pollock fishing operations. By the time the Magnuson Fishery Conservation and Management Act went into effect in 1977, annual foreign catches of Pacific cod had consistently ranged from approximately 30,000 to 70,000 t for a decade. In 1981, a U.S. domestic trawl fishery and several joint-venture fisheries began operating in the EBS. Foreign and joint-venture sectors dominated catches through 1988, but the domestic sector became dominant by 1989, and by 1991 foreign and joint-venture fisheries had been displaced entirely.

Currently, EBS Pacific cod are harvested by a multi-gear fishery that includes trawl, longline, pot, and jig gear. Catch by jig gear remains small relative to the other three major gear types, averaging less than 200 t annually since 1991. During the most recent complete five-year period (2021–2025), longline gear accounted for an average of 47% of the catch, trawl gear for 30%, and pot gear for 23%.

Pacific cod are caught throughout much of the EBS continental shelf. During 2021–2025, NMFS statistical areas 509, 513, 517, 519, 521, and 524 each accounted for at least 5% of total EBS Pacific cod catch. Statistical areas 521 and 509 accounted for 27% and 26% of the catch, respectively, together comprising more than half of the total EBS catch.

Catches of Pacific cod taken in the EBS for the periods 1964-1980, 1981-1990, and 1991-2026 are shown in Table 2.1, Table 2.2, and Table 2.3. The time series for 1964-2026 and catch by gear type for 1988-2026 are shown in Figure 2.3. Total EBS Pacific cod catch generally increased from the early 1980s through the late 1980s and subsequently fluctuated considerably, with several periods of annual catches exceeding 200,000 t. Catch reached its most recent peak in 2016 and declined substantially thereafter. Following a low in 2021, total catch increased in

2022 before declining through 2025. Longline gear has accounted for the largest share of catch in most years since the late 1990s, while trawl and pot fisheries have contributed smaller but substantial portions of the total catch.

Annual cumulative catches for 2016-2026 are shown in Figure 2.4. Through late September, the 2026 trawl fishery accumulated catch relatively rapidly during the first several weeks of the year and continued to increase gradually through the summer similar to previous years. Early in the winter cumulative trawl catch was below that observed at the same point in several of the more recent years, however catch increase in the late winter to above all but the highest catches observed in 2016 and 2017. The 2026 longline fishery accumulated catch more gradually and remained below all years back to 2016 through late September. The pot fishery accumulated most of its catch during the first part of the year, was relatively stable through much of the summer, and increased again later in the season. Overall pot catch remained low for 2026 compared to most recent years. There was no jig catch registered as of October 9th for 2026.

Maps of fishing effort for 2024 through 2026 by fishing sector are shown in Figure 2.5 and for all gear types shown in Figure 2.6. Previous assessments documented a pronounced southward shift in fishing activity following the northward expansion observed during the warm period of the late 2010s and early 2020s (Barbeaux et al. 2023). Fishing remained concentrated in the south with no fishing north of St. Lawrence Island recorded by observers.

In 2021 through 2026 there were few longline sets north of St. Lawrence Island and in 2022 through 2026 there were few longline sets north of St. Mathews Island. So far in 2025 and 2026 observed and reportable pot cod fishery was restricted to along the north side of the Alaska Peninsula and Aleutian Islands and in the southern side of St. George Island in the Pribilof Islands.

Figure 2.7 summarizes the distribution of observed hauls by latitude and bottom depth for each major gear type. Historically, the greatest latitudinal variability has occurred in the longline fishery, which shifted somewhat southward during 2008–2013, northward through approximately 2019–2021, and southward again beginning in 2022. Spatial shifts in the trawl and pot fisheries have generally been less pronounced. The largest latitudinal shift in fishing distribution is observed in the longline fishery. Here we see a slight southward shift in 2008-2013, then a shift northward peaking in 2019 through 2021, then a southward shift in the 2022 through 2026 observations.

The raw CPUE indices, calculated using the methods described by Thompson et al. (2021), show that CPUE by number increased sharply from 2016 to 2017, remained relatively stable through 2019, and subsequently declined in 2020 (Figure 2.8). Since 2020, CPUE by number has fluctuated, with relatively low values in 2023 and 2025 and increases in 2024 and 2026. CPUE by weight followed a somewhat different pattern, increasing from 2016 to a peak in 2019, followed by a general decline through 2025, with a modest increase in 2026. Gear-specific monthly CPUE indices indicate that longline CPUE in March 2026 was relatively high compared to most recent years, followed by a sharp decline during the spring and summer and a partial recovery in August (Figure 2.9). Longline CPUE in September 2026 was lower than in several recent years. Similarly, pot and trawl CPUE in 2026 were relatively high during the early months of the year but declined sharply during the spring and remained low through the summer and early fall. Unlike several previous years, neither the pot nor trawl fisheries exhibited a substantial increase in CPUE during August and September 2026.

Catches of Pacific cod from the portion of the western Bering Sea (WBS) under Russian jurisdiction during 1977–2025 are summarized in Table 2.4. Catch data for 2001–2008 were obtained from Lajus et al. (2019), while data for 2009–2025 were obtained from annual reports of the Russian Ministry of Fisheries, Российская Федерация: Сведения об улове рыбы и добыче других водных биоресурсов (Russian Federation: Information on the Catch of Fish and Harvest of Other Aquatic Biological Resources). Western Bering Sea Pacific cod catches were relatively stable during 2001–2010, generally ranging from approximately 15,000 to 25,000 t annually (Figure 2.10). Catches increased gradually during 2011–2016, followed by a substantial increase beginning in 2017, reaching a peak of approximately 106,000 t in 2020. During this period, WBS catches increased considerably relative to those in the eastern Bering Sea (EBS). Following the 2020 peak, WBS catches declined sharply, falling to approximately 35,000 t in 2024 before increasing slightly to approximately 40,000 t in 2025. Despite this recent decline, WBS catches remain above the levels observed during much of the 2000s and early 2010s.

Discards

The catches shown in Table 2.1 and Table 2.2 include estimated discards. Proportion retained of Pacific cod in the EBS Pacific cod fisheries are shown for each year 1991-2024 in Table 2.3. Amendment 49, which mandated increased retention and utilization of Pacific cod, was implemented in 1998. From 1991-1997, discard rates in the Pacific cod fishery averaged about 14%. Since then, they have averaged about 2% overall. There was an increase in 2021 in the discard of Pacific cod in the trawl fisheries up to 5% from 1% in 2019. However, discard rates in the trawl fisheries have once again dropped to 2% in 2022 and then to 1% between 2023 through 2026.

Management History

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 2.5. 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 2.3 which pertains to the EBS only.

From 1980 through 2026 TAC has averaged about 85% of ABC (ABC was not specified prior to 1980), and from 1980 through 2026, commercial catch averaged about 95% of TAC. In 8 of these 45 years, TAC equaled ABC exactly, and in 17 of these 45 years, catch exceeded TAC. However, in 10 of those overages TAC was reduced by various proportions to account for the state-managed fishery inside state of Alaska waters (such reductions have been made in all years since 2006; see text table below for recent formulae); thus, while the combined Federal and State catch exceeded the Federal TAC in 2006-2010 and 2016-2026 by up to 13%, the overall target catch (Federal TAC plus State Guideline Harves Levels (GHLs)) was *not* exceeded. An OFL has been specified since 1992 and has never been exceeded.

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. Assessments conducted prior to 1985 consisted of simple projections of current survey numbers at age. In 1985, the assessment was expanded to consider all survey numbers at age from 1979-1985. From 1985-1991, the assessment was conducted using a bespoke separable age-structured model. In 1992, the assessment was conducted using the Stock Synthesis modeling software

(Methot 1986, 1990) with age-based data. All assessments from 1993 through 2003 continued to use the Stock Synthesis modeling software, but with length-based data. Age data based on a revised ageing protocol were added to the model in the 2004 assessment. At about that time, a major upgrade in the Stock Synthesis architecture resulted in a substantially new product, at that time labeled "SS2" (Methot 2005). The assessment was migrated to SS2 in 2005. Changes to model structure were made annually through 2011, then the base model remained constant through 2015, and new base models were adopted in 2016, 2018, 2019, and 2020 (see Appendix 2.3 of Thompson et al. 2021). In 2021 a model ensemble approach was adopted and used through 2022 (Barbeaux et al. 2022). The model ensemble approach was discarded in 2023 and a new base model accepted (Barbeaux et al. 2023).

Beginning with the 2014 fishery, the Board of Fisheries for the State of Alaska has established GHLs in State waters between 164° and 167° west longitude in the EBS subarea (these have supplemented GHLs that had been set aside for the Aleutian Islands subarea since 2006). The table below shows the formulas that have been used to set the State GHL for the EBS, including the formula anticipated for setting the 2027 GHL. The 2027 GHL depends on state fishery performance, if the 2026 state-waters harvest hits the 90% threshold by the end of the year, the 2027 formula will step up to 14%; if not, it remains anchored at 13%.

Year	Formula	Year	Formula
2014	0.03 × (EBS ABC +AI ABC)	2022	0.11 × EBS ABC
2015	0.03 × (EBS ABC +AI ABC)	2023	0.12 × EBS ABC
2016	0.064 × EBS ABC	2024	0.12 × EBS ABC
2017	0.064 × EBS ABC	2025	0.13 × EBS ABC
2018	0.064 × EBS ABC	2026	0.13 × EBS ABC
2019	0.08 × EBS ABC	2027	0.13 or 0.14 × EBS ABC
2020	0.09 × EBS ABC		
2021	0.10 × EBS ABC		

For 2020 through 2026 the Board of Fisheries established an additional GHL of 100,000 lbs. (45.4 t) for vessels using jig gear within State waters (https://www.adfg.alaska.gov/FedAidPDFs/RIR.4K.2023.12.pdf).

Table 2.6 lists all implemented amendments to the BSAI Groundfish FMP that reference Pacific cod explicitly.

In addition to those, the following rulemaking became effective for 2021 on permit requirements:

https://www.federalregister.gov/documents/2020/12/03/2020-26593/fisheries-of-the-exclusive-economic-zone-off-alaska-pacific-cod-in-the-bering-sea-and-aleutian. In this rule, NMFS modified Federal permit conditions and imposed participation requirements for certain federally permitted vessels when fishing for Pacific cod in State of Alaska waters (state waters) adjacent to the Exclusive Economic Zone (EEZ) of the Bering Sea and Aleutian Islands (BSAI). The state waters portion of the Pacific cod fishery that runs concurrent with the Federal Pacific cod fishery is commonly known as the State's parallel fishery. The "parallel fisheries" in this preamble refer

to the State waters Pacific cod parallel fisheries in the State of Alaska Bering Sea-Aleutian Islands Area, which presently is in the Dutch Harbor Subdistrict of the Bering Sea and within the Aleutian Islands Subdistrict of the Aleutian Islands, respectively. This rule prohibits (1) a hook-and-line, pot, or trawl gear vessel named on a Federal Fisheries Permit (FFP) or License Limitation Program (LLP) license from being used to catch and retain BSAI Pacific cod in State of Alaska (State) waters adjacent to the BSAI during the State's parallel Pacific cod fishery unless the vessel is named on an FFP and LLP license that have the required endorsements; (2) a hook-and-line, pot, or trawl gear vessel named on an FFP or LLP license from catching and retaining Pacific cod in state waters adjacent to the BSAI EEZ during the State's parallel fishery when NMFS has closed the EEZ to directed fishing for Pacific cod by the sector to which the vessel belongs; (3) the holder of an FFP with certain endorsements from modifying those endorsements during the effective period of the FFP; and (4) the reissuance of a surrendered FFP with certain endorsements for the remainder of the three-year term, or cycle, of FFPs.

In four consecutive year 2020-2023 the Bering Sea non-CDQ Pacific cod directed fishing closed for all non-CDQ sectors. The non-CDQ sectors have BSAI allocations and there was less fishing in the Aleutian Islands until after the Bering Sea non-CDQ sectors closed. Directed fishing for the Pacific cod non-CDQ sectors closed in 2020 on November 18th, in 2021 on September 17th, in 2022 on October 7th, and in 2023 on October 16th. The closures were to prevent exceeding the non-CDQ allocation of the total allowable catch of Pacific cod in the Bering Sea subarea of the BSAI. After the closures there was still fishing by the CDQ groups and incidental catch of Pacific cod in other targets. The fisheries remained open in 2024 and 2025, and in 2026 to have remained open through at least October 15th.

DATA

The first two subsections below describe fishery and survey data that are used in the current stock assessment models. The third subsection describes data that are not used in the current stock assessment models, but that may help to provide some context for the data that are used.

The following table summarizes the sources, types, and years of data included in the data file for at least one of the stock assessment models:

Source	Type	Years
Fishery	Catch biomass	1977-2026
Fishery	Catch size composition	1977-2026
Fishery	Catch per unit effort (VAST)	1996-2026
EBS+NBS trawl survey	Survey numerical abundance (VAST)	1982-2019, 2021-2026
EBS+NBS trawl survey	Survey age composition (VAST)	2000-2019, 2021-2025
EBS and GOA trawl survey	Aging bias 2004 and 2018 reads	2003
EBS and GOA trawl survey	Aging error – in year rereads	2000-2019, 2021-2023

All data used in the 2026 models are provided in zip files in the following appendices:

- Appendix 2.3 2026 Models Stock Synthesis files.zip (0.3MB)
  - https://afsc-assessments.github.io/EBS_PCOD/2026_ASSESSMENT/NOVEMBER_MODELS/APPENDICES/APPENDIX_2.3_2026_MODELS.zip
- Appendix 2.4 Data and results for all models.xlsx (2.6 MB)
  - https://afsc-assessments.github.io/EBS_PCOD/2026_ASSESSMENT/NOVEMBER_MODELS/APPENDICES/Appendix_2.4_Data_and_results.xlsx

Fishery Data Used in the Models

Catch Biomass

Catch estimates for the period 1977-2026 are shown in Table 2.1, Table 2.2, Table 2.3, and Table 2.5. However, the estimate for 2026 used in the model is complete only through September 28th. The 2026 year-end catch in the model was set at the 5-year average proportion of the ABC that was harvested (94% or 133,475 t).

The catches shown in Table 2.1, Table 2.2, Table 2.3, and Table 2.5 consist of "official" data from the NMFS Alaska Region. However, other removals of Pacific cod are known to have occurred over the years, including removals due to subsistence fishing, sport fishing, scientific research, and fisheries managed under other FMPs. Estimates of such other removals are shown in Table 2.7 .

The catch estimates for the years 1977-1980 shown in Table 2.1 may or may not include discards.

Size Composition

Figure 2.11 presents the fishery length compositions from 1977 through September 28th, 2026, aggregated into 5-cm length bins for use in the stock assessment models. Annual length compositions were calculated using catch-weighted proportions stratified by haul, vessel, month, gear, and area, as described in Appendix 2.1 of Barbeaux et al. (2023). A minimum sample size of 30 fish was required for each month/gear/area combination. The annual numbers of Pacific cod measured in the fishery from 1977 through 2026 are provided in Table 2.8.

Fishery length distributions were generally unimodal, although bimodal distributions occurred in some years, potentially reflecting the presence of relatively strong year classes (Figure 2.11). Modal lengths typically ranged from approximately 50 to 70 cm. Although the overall size composition of the fishery has remained relatively stable over time, changes in mean length appear to reflect, at least in part, variation in recruitment and subsequent growth of fish entering the fishery (Figure 2.12). Mean length generally increased from 1977 through 1991, reaching the highest value in the time series in 1990. However, relatively limited sampling during the early years resulted in substantially greater uncertainty in estimated mean lengths. Beginning in 1992, expansion of the domestic fishery observer program and increased sampling substantially reduced this uncertainty.

From the early 1990s through 2026, mean fishery length fluctuated between approximately 55 and 66 cm. Mean length declined during the late 2000s, reaching a low around 2010–2011, before increasing steadily through 2021. The relatively large mean lengths observed during

2018–2021 may have been associated with low recruitment during 2014–2017. Mean length subsequently declined from 2021 through 2024, potentially reflecting increased contributions of the 2018-year class to fishery catches. Since 2024, mean length has remained relatively stable at approximately 62 cm. It should be noted that the aggregate fishery length compositions combine observations from trawl, longline, and pot fisheries, which may differ in their size selectivity (Table 2.3 and Figure 2.3). Consequently, changes in the relative contributions of these gear types may also influence observed trends in fishery length composition and mean length.

The nominal sample sizes (number of sampled hauls) for the size compositions and input sample sizes are shown in Table 2.9.

Survey Data Used in the Models

Overview of Survey Areas and Frequency

The areas covered by the eastern Bering Sea (EBS) shelf and northern Bering Sea (NBS) bottom trawl surveys are shown in Figure 2.13. Prior to 2020, in the EBS, strata 10-62 had been surveyed annually since 1982 and strata 82 and 90 had been surveyed annually since 1987. However, the EBS bottom trawl survey was cancelled in 2020 due to the COVID-19 pandemic. In the NBS, strata 70, 71, and 81 in the NBS were surveyed fully in 2010, 2017, 2019, 2021, 2022, 2023, and 2025. Less extensive surveys of the NBS were conducted in 1982, 1985, 1988, 1991, and 2018. The 2020 NBS survey was cancelled due to the COVID-19 pandemic. The NBS was not surveyed in 2024 or 2026.

Updated EBS Shelf and NBS Bottom Trawl Survey Net Spread Measurement

The Groundfish Assessment Program's (GAP) transition from Netmind to Marport net spread sensors (2009–2012) included the development and application of a Marport-to-Netmind (M2N) correction factor (Lauth and Kotwicki, 2014), applied in 2013 and all subsequent surveys to maintain consistency with historical survey data. GAP subsequently upgraded to new-generation digital Marport sensors in 2024. Since 2024, comparative data and field experiments have demonstrated that the new digital sensors align more closely with legacy Netmind data, rendering the M2N correction factor unnecessary, and its application in 2024–2025 has likely led to an underestimation of net spread relative to historical data. Consequently, the M2N correction factor was discontinued for datasets from 2024 onward, prompting the recalculation of uncorrected net spread values for all hauls from the 2024–2026 EBS and 2025 NBS surveys. This methodological adjustment resulted in ~4% higher calculated effort and a corresponding ~3–4% downward adjustment in previously released design-based biomass and abundance indices for all species. The discontinuation of the M2N correction factor aligns recent survey data more closely with historical data, so the correction will not be applied to future surveys. Specific to the Bering Sea Pacific cod assessment this correction led to a 3.9% downward adjustment to the 2024 design-based abundance estimate and a 5.0% downward adjustment in the 2024 model-based abundance estimate from the values used in the 2024 assessment (Table 2.11).

Model-based Estimates of Abundance from the EBS Shelf and NBS Bottom Trawl Surveys

For model-based indices in the Bering Sea, we fitted observations of numerical abundance per unit area from all sampling locations in the 83-112 bottom trawl survey of the EBS, 1982-2026, including exploratory northern extension samples in 2001, 2005, and 2006, as well as the 83-112

samples available in the NBS in 1982, 1985, 1988, 1991, 2010, 2017-2019, 2021-2023, and 2025. NBS samples collected prior to 2010 and in 2018 did not follow the 20 nautical mile sampling grid that was used in other survey years. Assimilating these unbalanced data requires extrapolating into unsampled areas, facilitated by including a spatially varying response to cold-pool extent (Thorson 2019b). This spatially varying coefficient term was estimated for both linear predictors of a delta-model, and detailed comparison of results has shown that it has a small but notable effect on indices and resulting stock assessment outputs for Pacific cod (O'Leary et al. 2020, 2022). Models were fitted in the sdmTMB R package (https://pbs-assess.github.io/sdmTMB; Anderson et al., 2025). The cold-pool extent data used as covariates were computed within the coldpool R package (https://github.com/afsc-gap-products/coldpool; Rohan et al., 2022a).

We used a spatiotemporal Poisson-link delta-model (Thorson 2018), using a Bernoulli distribution (with a log link) for encounter probability and a gamma distribution (with a log link) to model positive catch rates. We predicted population density across the entire EBS and NBS in each year, using a prediction grid including 2,250 cells of 10nm^2 resolution. Spatial and spatiotemporal fields were estimated using a spatial mesh including 750 "knots" whose locations were determined using a K-means algorithm to place the knots evenly over space, in proportion to the dimensions of the prediction grid.

We estimated geometric anisotropy (how spatial autocorrelation declines with differing rates over distance in some cardinal directions than others) and included a spatial and spatiotemporal term for both linear predictors. To facilitate prediction of density in regions with unsampled years, we specified that the spatiotemporal fields were structured over time as an AR(1) process (where the magnitude of autocorrelation was estimated as a fixed effect for each linear predictor). We did not include any temporal correlation for intercepts, which we treated as fixed effects for each linear predictor and year. Finally, we used epsilon bias-correction to correct for retransformation bias (Thorson and Kristensen 2016).

We checked model fits for convergence by confirming that the derivative of the marginal likelihood with respect to each fixed effect was sufficiently small (less than ~ 0.001) and that the Hessian matrix was positive definite, along with other model checks produced by the function sdmTMB::sanity(). We then checked goodness of model fit by computing randomized quantile residuals (Dunn and Smyth 1996) from simulation using the DHARMa R package (Hartig 2021) and inspecting a quantile-quantile plot given a single draw of the random effects from the joint precision matrix (Waagepetersen 2006). We also evaluated the distribution of residuals over space in each year, and inspected them for evidence of residual spatiotemporal patterns.

750 vs 250 knot mesh analysis

We evaluated the sensitivity of model-based bottom trawl survey abundance indices to spatial mesh resolution by comparing sdmTMB models fitted using 250 and 750 knots. In the prior assessment year (2024) the abundance index was estimated in VAST using a 750-knot mesh. We revisited this specification to determine whether a coarser mesh could provide comparable abundance estimates and statistical performance while reducing computational demands.

The previous selection of 750 knots was based largely on model-fitting experience and evidence that increasing mesh resolution generally improved likelihood-based measures of fit to within-sample data (Commander et al. 2022), rather than on a comprehensive evaluation of out-of-sample predictive performance. Thorson et al. (2021) evaluated mesh-resolution sensitivity for

20 Alaska groundfish stocks using 100-, 250-, and 500-knot meshes. For delta-gamma models, they found that 250- and 500-knot configurations generally produced similar performance, as measured by agreement between model- and design-based estimates and root-mean-squared error (RMSE).

In our sensitivity analyses across multiple species, models fitted using 250–750 knots, in increments of 50 knots, generally produced similar abundance estimates, while coarser meshes substantially reduced computational requirements. However, Pacific cod abundance estimates in the Bering Sea exhibited sufficient sensitivity to mesh resolution to warrant further evaluation before changing the established 750-knot configuration (Figure 2.14).

The abundance indices generated using 250- and 750-knot meshes were highly correlated ($r = 0.997$), indicating that both configurations produced nearly identical temporal trends. Nevertheless, the 250-knot mesh produced abundance estimates averaging approximately 3.1% higher than those from the 750-knot mesh, with reported log-scale standard errors approximately 10.4% higher. These differences indicate that, although temporal patterns were largely insensitive to mesh resolution, the absolute scale and estimated uncertainty of the indices were affected.

When incorporated into Stock Synthesis, the alternative indices produced similar overall model fits and estimates of population dynamics. Differences in total likelihood were primarily associated with the survey abundance index component, whereas fishery length and survey age composition likelihoods changed relatively little. Standardized survey residuals were nearly identical, with an RMSE of 0.992 for both configurations.

The most notable parameter difference was in estimated survey catchability (q). The 250-knot index resulted in an estimated catchability of 1.044, compared with 1.014 for the 750-knot index, representing an increase of approximately 3.0%. This difference closely matched the relative increase in survey index magnitude associated with the coarser mesh. The higher estimated catchability largely compensated for the increase in survey index magnitude associated with the coarser mesh, limiting its influence on estimated population biomass. Although the 250-knot configuration produced an abundance index approximately 3.1% higher on average, estimated catchability was also approximately 3.0% higher. Consequently, differences in estimated population biomass were relatively small, with the 250-knot configuration producing an estimate of 2026 female spawning biomass that was 2.0% lower than that estimated by the 750-knot model.

Other estimated population parameters were relatively insensitive to mesh resolution. Unfished recruitment differed by approximately 0.2%, and the estimated F35% reference fishing mortality was essentially identical between configurations (0.434). Nevertheless, relatively small differences in estimated biomass propagated into management quantities. The 250-knot configuration produced a 2027 maximum acceptable biological catch (ABC) of 118,932 t, compared with 123,787 t for the 750-knot configuration, representing a 3.9% reduction. Corresponding 2027 overfishing level (OFL) estimates were 142,440 t and 148,179 t, respectively, also representing a reduction of approximately 3.9%.

Ward and Anderson (2026) demonstrate that increasing spatial mesh resolution generally improves in-sample model fit but does not necessarily improve out-of-sample predictive performance, which frequently peaks at intermediate mesh resolutions. For area-weighted biomass indices, they found that mesh resolution had relatively little effect on temporal trends

for most species, although differences in resolution affected the absolute scale of biomass estimates and, for some species, their uncertainty. They concluded that relatively fine meshes are generally appropriate for abundance-index estimation but emphasized the importance of evaluating mesh sensitivity, particularly when differences in index scale or uncertainty may influence stock assessment results. Their findings are consistent with our Pacific cod analysis, in which temporal trends were largely insensitive to mesh resolution, but differences in index magnitude and uncertainty propagated into estimates of survey catchability and management quantities. Future evaluations should therefore consider a broader range of mesh resolutions, cross-validation to assess out-of-sample predictive performance, stability of abundance estimates and their uncertainty, and sensitivity of estimated spatial covariance parameters.

Overall, these results indicate that mesh resolution has relatively little influence on estimated temporal trends in Pacific cod abundance but affects the absolute scale and uncertainty of the survey index, with subsequent effects on assessment parameters and management quantities. Although the results do not establish that the 750-knot mesh provides the optimal balance between predictive performance and computational efficiency, they demonstrate that changing mesh resolution can affect assessment results despite producing nearly identical temporal abundance trends. Given these differences, the absence of a comprehensive evaluation of out-of-sample predictive performance, and the value of maintaining consistency with previous assessments, we retained the established 750-knot mesh for the 2026 Pacific cod assessment. Additional evaluation of mesh resolution, including intermediate mesh configurations and predictive-performance diagnostics, will be considered during the next assessment cycle.

750 knot mesh results

The resulting set of estimates for the 750-knot mesh model is shown in Table 2.11, together with their respective log-scale standard deviations (“Sigma”), and compared with those used in the 2024 assessment in Figure 2.16 ($R^2 = 0.999$). The model-based population abundance estimates closely resemble the design-based estimates (Table 2.11 and Figure 2.17 ; $R^2 = 0.871$), however the variances of the model-based estimates are on average 40% lower than the design-based estimates.

The model-based estimates of abundance show that population numbers were at an all-time high in 2014 at $1{,}221 \times 10^6$ fish. Abundance dropped rapidly through 2017 before rebounding again in 2019 (Figure 2.16). Abundance once again dropped in 2021 and again in 2022. Since 2022 the survey estimate has been oscillating downward from 2023 to 2026. The 2026 value is the lowest abundance in the time series since 1989 and a drop of 27% since 2025 and 65% since the 2014 high. Maps of log population density are shown in Figure 2.18 and in Figure 2.19 model-derived estimates of centers of gravity of abundance, abundance by region (NBS and EBS) and Figure 2.20 shows effective area occupied. The most apparent shift in these distributional metrics is the move northward in the center of gravity between 2010 and 2017 and a shifting southward after 2019. With this change we observed a larger proportion of the stock residing in the NBS and a reversal of that trend starting in 2021 and continuing through 2026. These distributional trends are consistent with the observed warming trend and decreasing cold pool extent through the 2010s and a return to near average conditions since 2021.

Size Composition

Design-based estimates of length compositions (in 5-cm bins) from the combined eastern Bering Sea (EBS) and northern Bering Sea (NBS) bottom trawl surveys for 1982–2026 are shown in

Figure 2.21. Because tinyVAST estimates of length composition are not available, design-based estimates were used in all assessment models. The numbers of fish measured for length and otoliths collected and aged are provided in Table 2.8, while sample sizes for the survey length and age compositions, expressed as numbers of sampled hauls, are provided in Table 2.9. Annual mean lengths calculated from the survey length compositions are presented in Figure 2.21.

Unlike fishery length compositions, survey length distributions are frequently multimodal, reflecting the capture of smaller fish (less than 40 cm) and the progression of individual cohorts through the population (Figure 2.21). Relatively strong year classes (e.g., 2006, 2008, 2013, and 2018) are associated with reductions in mean length as smaller fish enter the survey population, whereas periods of poor recruitment, such as 2014–2017, are associated with subsequent increases in mean length as existing cohorts grow (Figure 2.21). The 2012–2014 length compositions show distinct modes associated with incoming year classes, while the 2015–2017 distributions indicate relatively weak recruitment. The strong 2018-year class is evident in the 2019 and 2021–2024 surveys, with a prominent mode at approximately 40–50 cm in 2021 that progressed to approximately 50–60 cm during 2022–2024. In 2023, additional modes appeared at approximately 30–40 cm and 15–20 cm, likely corresponding to the 2021- and 2022-year classes, respectively. These cohorts remained evident in 2024, along with a smaller mode at approximately 15–20 cm potentially associated with the 2023-year class.

The 2025 and 2026 survey length compositions show a prominent mode of smaller fish, likely associated with the 2024-year class. In 2025, the distribution was multimodal, with a relatively strong mode at approximately 20–30 cm and additional modes representing larger fish. By 2026, the dominant mode had shifted to approximately 35–45 cm, consistent with growth of the 2024-year class. The continued presence of larger fish in both years indicates contributions from older cohorts, although their relative representation has declined compared with earlier years. Mean survey length remained relatively low in 2025, increased in 2026, and was below the relatively high values observed during 2016–2018. These recent changes in the length distributions suggest that the 2024-year class may be contributing substantially to the surveyed population, although its relative abundance and contribution to recruitment should be evaluated using the corresponding survey age composition data.

Model-based age composition

For model-based estimation of age compositions in the Bering Sea, we fitted observations of numerical abundance-at-age per unit area at each sampling location. This was made possible by applying a year-specific, region-specific (EBS and NBS) age-length key to records of numerical abundance and length composition and dividing by the area swept. In subcategories (combinations of year, length, age, sex) that contained insufficient data, age composition was computed from length composition given a globally pooled age-length key. We computed these estimates in the tinyVAST R package (https://vast-lib.github.io/tinyVAST; Thorson et al., 2025), assuming a Poisson-link delta-model (Thorson 2018), using a Bernoulli distribution (with a log link) for encounter probability and a gamma distribution (with a log link) to model positive catch rates. We did not include any density covariates in estimation of age composition for consistency with models used in the previous assessments and due to computational limitations. We estimated the spatial range assuming geometric isotropy (i.e. spatial autocorrelation declines with equal rates over distance in all cardinal directions). We used the same prediction grid as implemented for abundance indices, but here we modeled spatial and spatiotemporal fields with a coarser spatial mesh than the index model, here using 50 “knots”. This reduction in the spatial

resolution of the model, relative to that used for the abundance indices, was necessary due to the increased computational load of fitting multiple age categories. The estimates of abundance at age were bias-corrected with the same method as the abundance index. We implemented the same diagnostics to check convergence and model fit as those used for the abundance index.

Both the model-based bottom trawl index and age composition estimates were calculated using code in the AFSC GAP model-based indices GitHub repository (https://github.com/afsc-gap-products/model-based-indices).

Updated tinyVAST age compositions from the combined eastern Bering Sea (EBS) and northern Bering Sea (NBS) bottom trawl surveys for 1994–2025 are shown in Figure 2.23. The age-length keys used to produce these estimates incorporate newly read otolith samples from the 2024 and 2025 surveys. Sample sizes for the survey age composition data, expressed as numbers of otoliths read, are provided in Table 2.8. The number of hauls and the input sample sizes for the length and age composition are provided in Table 2.9. Annual mean ages calculated from the survey age compositions are shown in Figure 2.22.

The survey age compositions generally reflect the patterns observed in the corresponding length compositions, with substantial interannual variation associated with the emergence and progression of individual year classes. The relatively strong 2018-year class was prominent in the 2019 survey as age-1 fish and continued to contribute substantially to the survey age compositions through 2022. However, the 2023 survey age composition showed increased contributions from ages 1–3 (the 2020- and 2022-year classes), resulting in a broader distribution of younger age classes and a reduced relative contribution from the 2018-year class. This pattern continued in 2024, when ages 1–3 dominated the survey age composition, with relatively few fish older than age 5.

The 2025 survey age composition was dominated by age-1 fish (the 2024-year class), which accounted for approximately 38% of the observed age composition, with additional contributions from ages 2 and 3 (the 2023- and 2022-year classes, respectively). The prominence of the 2024-year class is consistent with the distinct mode of smaller fish observed in the 2025 survey length composition. Mean survey age declined from approximately 3.1 years in 2021 to 2.4 years in 2025, reflecting the increasing proportion of younger fish in the surveyed population. The recent age compositions indicate a shift toward younger age classes, with the 2024-year class potentially representing an important source of recruitment to the population. However, the relative strength of this cohort will require further evaluation as additional survey observations become available.

Aging bias and aging error

The aging error used in the 2023 accepted model (Model 23.1.0.d) was based on a linear vector from age 1 to age 20 for data collected from 1990 – 2018 using the method devised by Punt et al. (2008). For 2026 the data were updated to include only data aged 2000 to 2023 (Figure 2.24). In addition, discussions with the AFSC Age and Growth Laboratory indicate that ages read prior to 2000 were likely not consistent with those read using current best practices and should not be used (Beth Matta, pers. comm.). From 2000 to 2023 the Age and Growth Laboratory at the AFSC conducted a total of 17,477 paired otolith readings for Pacific cod. Meaning the otoliths from each of these Pacific cod were assessed by two different age readers allowing an assessment of reader agreement. Using these paired tests two different aging error matrixes were

estimated using the AgeingError R library 2.0.2 (Punt et al. 2025, https://pfmc-assessments.github.io/AgeingError/); a linear model and a nonlinear spline model. The linear model fit a single coefficient of variation parameter for all ages for the nonlinear aging error model a spline (option 5) with five knots at 2, 4, 6, 8, and 10 was used. For both configurations because there were few ages older than 12 in the database, 12 was used as a plus group and aging error for ages 12-20 were set at the age 12 value. In both configurations the estimated standard deviation at age increased for all ages compared to the aging error vector applied last year (Figure 2.24 and Table 2.10).

Between 2008 and 2012 the age and growth laboratory changed aging criteria in response to stable oxygen isotope chronologies (Kastelle et al. 2017) showing an overall over-aging of Pacific cod at the AFSC. To compare pre-2008 and current aging practices otoliths from 2,057 Pacific cod that had been read initially in 2004 were reread in 2018 (Figure 2.25). AgeingError R library 2.0.2 was used to estimate an aging bias between these two reads. In the analysis the 2018 reads were assumed to be unbiased and it was assumed that the expected age was a linear function of the its true age having a constant coefficient of variation. The bias observed in the 2004 reads was higher than what had been previously estimated within the stock assessment model (Table 2.10).

Data Provided for Context Only

Design-Based Index Estimates from the EBS Shelf and NBS Bottom Trawl Surveys

The design-based area-swept estimates for population abundance (numbers of fish) are given in Table 2.11 and the biomass in Table 2.12. The population numbers for 2026 (428×10^6) decreased from 2025 (585×10^6) after an uptick from 2024 (485×10^6), continuing the overall decline since 2019 (770×10^6) and landing at less than 1/3 of the number observed in 2014 ($1{,}294\times10^6$). The biomass in the Eastern Bering Sea has been fluctuating between 663×10^3 t and 507×10^3 t since 2017. The latest 2026 survey indicated an increase to 621×10^3 t from the 2025 value of 548×10^3 t despite the drop in numbers. There has been an overall decline in biomass Bering Sea-wide (Table 2.12) as biomass in the NBS dropped from 365×10^3 t in 2014 to 67×10^3 t in 2025, an overall drop of 298×10^3 t or -80%. The distribution of cod on the EBS shelf for 2024 through 2026 from the survey are provided in Figure 2.14 and population numbers with confidence intervals in Figure 2.17. The distribution of the survey shows a continued shift southward and towards the shelf edge. For 2016-2026 the inshore distribution of Pacific cod south of Nunivak Islands observed in 2010-2015 was at much lower abundance. This shift from the NBS is a continuation of a trend since 2019 when the overall proportion of the Bering Sea Pacific cod biomass in the NBS was 41% now down to only 11% in 2025.

AFSC Longline Survey

The AFSC longline survey was resumed in 2026 after not being conducted in 2024 and 2025. The domestic longline survey began biennial sampling of the eastern BS in 1997 (Rutecki *et al.* 1997). Figure 2.26 shows the locations of the Bering Sea stations sampled by the AFSC longline survey. A Relative Population Number (RPN) index of Pacific cod abundance for the 1997 through 2026 Eastern Bering Sea survey area is available from this survey (Table 2.12 and Figure 2.27). Details about these data and a description of the methods for the AFSC sablefish longline survey can be found in Hanselman *et al.* (2016) and Echave *et al.* (2012). The 2026 estimate of 98,112 was a 33% increase from the 2023 estimate at 73,821 which was a 31%

decrease from the 2021 estimate of 108,312. The 2026 estimate remained the third lowest in the series and below the series mean of 118,411. The index has been below the long-term average since 2017.

ADFG port sampling

Beginning in 2023, the Alaska Department of Fish and Game (ADF&G) initiated biological sampling of Pacific cod landed from the Dutch Harbor Subdistrict (DHS) state-waters Pacific cod fishery. As of October 15th, 2026, the fishery had harvested approximately 73% of its guideline harvest level (GHL) of 18,443 t. In comparison, the DHS fishery harvested approximately 98%, 91%, and 95% of its GHL in 2023, 2024, and 2025, respectively.

During February–April 2023, ADF&G port samplers measured 1,099 Pacific cod for length and recorded individual weights for 790 fish from 11 deliveries by five pot fishing vessels. During the same period in 2024, samplers measured 1,314 fish for length and recorded individual weights for 755 fish from 13 deliveries by seven vessels. Sampling continued during February–April 2025, with 1,206 fish measured for length and 658 weighed, and during February–April 2026, with 1,025 fish measured for length and 565 weighed.

Comparisons of length compositions from the ADF&G state-waters pot fishery and the federally observed pot fishery during corresponding periods indicate differences in the sizes of fish encountered by the two fisheries (Figure 2.28 and Figure 2.29). In 2023 and 2024, the DHS fishery generally harvested smaller Pacific cod than the federally observed pot fishery, with a greater proportion of fish less than approximately 70 cm and a smaller proportion of fish greater than 75 cm. These differences were particularly apparent in 2023, when the federally observed length composition exhibited a broader distribution extending toward larger fish. In contrast, the length compositions from the two fisheries were more similar in 2025 and 2026 (Figure 2.30 and Figure 2.31), with substantial overlap in their distributions and modal lengths generally between 60 and 70 cm.

Comparisons of individual fish measurements also revealed differences between the fisheries in length and weight distributions and weight-at-length relationships. In 2023 and 2024, the estimated weight-at-length relationships were relatively similar between the two data sources over much of the observed length range, although some differences were evident among larger fish. In 2025 and 2026, the estimated relationships diverged more noticeably, with federally observed fish generally exhibiting greater weights at a given length, particularly among larger individuals. These differences suggest potential variation in fish condition, sampling characteristics, or the spatial and temporal distribution of sampled fish between the two fisheries. However, additional investigation is needed to determine the underlying causes.

The increasing similarity in length compositions between the ADF&G and federally observed pot fisheries during 2025–2026 suggests that the two fisheries may be sampling more similar components of the Pacific cod population than in earlier years. Nevertheless, differences in weight-at-length relationships indicate that the biological characteristics of fish sampled by the two programs are not necessarily equivalent. Although the ADF&G biological data are not included in the current stock assessment model, their potential incorporation into future assessments is being evaluated. These additional observations could improve the spatial and

temporal coverage of fishery biological sampling and provide information on differences in fish size and condition between state-waters and federal fisheries.

ANALYTIC APPROACH

General Model Structure

Although Pacific cod in the EBS and AI were managed on a BSAI-wide basis through 2013, the stock assessment model has always been configured for the EBS stock only. Since 1992, the assessment model has always been developed under some version of the Stock Synthesis modeling framework (technical details given in Methot and Wetzel 2013). Beginning with the 2005 assessment, the EBS Pacific cod models have all used versions of Stock Synthesis based on the ADMB software package (Fournier et al. 2012). A history of previous model structures, including all Stock Synthesis-based models that have been fully vetted since 2005, is given in Appendix 2.3 of Thompson et al. (2021). Female spawning stock biomass from the accepted models from 1999 to present is provided in Figure 2.32.

Stock Synthesis V3.30.25.1 was used to run all of the models in this final assessment. The user manual is available at https://nmfs-ost.github.io/ss3-doc/SS330_User_Manual_release.html.

Parameter Estimation

Stock Synthesis requires that prior distributions be associated with all internally estimated time-invariant parameters and the base values of all internally estimated time-varying parameters. For the models presented in this assessment, uniform prior distributions were used for estimation of all such parameters, with bounds set at values sufficiently extreme that they were non-constraining. To simplify terminology, such parameters will be referred to here as being "freely estimated."

On the other hand, for each parameter that varies randomly on an annual basis, Stock Synthesis estimates a vector of annual deviations that are either added to, or multiplied by, the base value of the parameter. In the case of log recruitment, the deviations are constrained by a $N(0,\sigma^2)$ distribution. The deviations in every other vector are constrained by a $N(0,1)$ distribution, and then the vector is multiplied by a σ term specific to that vector. In 2026 each σ was tuned iteratively as follows:

- For the vector of deviations associated with log-scale recruitment, σ was tuned to match the square root of the variance of the estimates plus the sum of the estimates' variances (Methot and Taylor 2011).
- For all other vectors of deviations, σ was tuned to set the variance of the estimates plus the sum of the estimates' variances equal to unity.

For 2026 Model 26.1 were retuned as described above for σ_R and the σ terms on the annual deviates for growth and selectivity parameters.

Both models were run using the "-hess_step" option in ADMB. As an additional check on convergence, the final versions of both of the 2026 models successfully passed a "jitter" test of 50 runs with the jitter rate set at 0.1. The models performed well with Model 24.1 and Model 26.1 converging at the MLE 88% and 90% of the runs and no runs converging at a negative log likelihood lower than the accepted MLE.

Description of Models

Names of Models

Beginning with the final 2015 assessment (Thompson 2015), model numbering has followed the protocol given by Option A in the SAFE chapter guidelines. Names of all final models adopted between the 2005 assessment (when an ADMB-based version of Stock Synthesis was first used) and the 2015 assessment were translated according to that protocol in Table 2.11 of the 2015 assessment. The goal of the protocol is to make it easy to distinguish between major and minor changes in models and to identify the years in which major model changes were introduced. Names of models constituting *minor* changes from the original form of the current base model get linked to the name of that model (e.g., Model 19.12a, is a minor modification of Model 19.12, which was the base model adopted at the conclusion of the 2019 assessment cycle), while names of models constituting *major* changes get linked to the year that they are introduced (e.g., when Model 19.12 was adopted at the conclusion of the 2019 assessment cycle, it constituted a major change from the previous base model (Model 16.6i).

There are two models presented this year, Model 24.1 which is the same as that presented in 2024 and Model 26.1 which is the same as Model 24.1 except with the plus age group reduced to 14. (Appendix 2.1).

Model description

The Model 24.1 is the model used for management in 2024 (Barbeaux et al. 2024) with 5 cm size bins, random walks on $L_{1.5}$ and Richard's K, splined aging error and survey selectivity with annually varying ascending width parameter. For the fishery data there are two active selectivity parameters fit separately for early and late fishery data with 1977-1989 and 1990-2026 time blocks. The only difference between this model and the alternate proposed Model 26.1 is the reduction in the plus age group from age 20 to age 14.

It has been long understood that environment, particularly temperature, is influential in the growth of Gadus species (Taylor 1958) and annual variability in growth should be expected. Growth in Pacific cod specifically has been found to be rather elastic and dependent on environmental conditions, particularly for young fish (Laurel et al. 2008). To consider this elasticity, we included annually varying growth in both of our models. Both models have a random walk on the $L_{1.5}$ growth parameter and a random walk on the Richard's K parameter. Both models use a splined aging error.

For the annually varying parameters (e.g. σ_R, $\sigma L_{1.5}$,σ_K, and survey selectivity σ) in our models the σ's were tuned iteratively to set the variance of the estimates plus the sum of the estimates' variances equal to unity. Table 2.14 provides a list of the σ values for each set of annually varying parameters. The size and age composition data sets were fit as simple multinomial distributions and data weights iteratively adjusted with a Francis reweighting scheme TA1.8 (Francis, 2011) using variance adjustment factors to tune the input sample sizes as implemented in the r4ss R library (Taylor et al. 2021). Model 24.1 and Model 26.1 were tuned to the same variance adjustment factors.

Parameters Estimated Outside the Assessment Model

Weight at Length

Using the functional form weight = $\alpha \times \text{length}^{\beta}$, where weight is measured in kg and length is measured in cm, the long-term base values for the parameters were estimated this year (using fishery data from 1974 through 2021) as α = 5.40706E-06 (mean-unbiased) and β = 3.19601.

Maturity

A detailed history and evaluation of parameter values used to describe the maturity schedule for BSAI Pacific cod was presented in the 2005 assessment (Thompson and Dorn 2005). A length-based maturity schedule was used for many years. The parameter values used for the length-based maturity schedule in the 2005 and 2006 assessments were set on the basis of a study by Stark (2007) at the following values: length at 50% maturity = 58 cm and slope of linearized logistic equation = –0.132. However, in 2007, changes in Stock Synthesis allowed for use of either a length-based or an age-based maturity schedule. Beginning with the 2007 assessment, the accepted model has used an age-based schedule with intercept = 4.88 years and slope = –0.965 (Stark 2007). The use of an age-based rather than a length-based schedule followed a recommendation from the maturity study's author (James Stark, AFSC, *pers. commun.*), and the age-based parameters were retained through the 2018 assessment. However, because all assessments since 2009 have estimated some amount of ageing bias, all models beginning with the 2019 assessment have returned to using the length-based schedule.

Stock-Recruitment "Steepness"

Following the standard Tier 3 approach, all models assume that there is no relationship between stock and recruitment, so the "steepness" parameter is set at 1.0 in each.

Natural Mortality

The parameter M representing adult natural mortality is difficult to estimate in many stock assessment models. When total removals are fitted and information exists to estimate the fishing mortality rate, estimates of M are typically correlated with estimates of survey catchability, q, such that including a Bayesian prior on M can provide information about population scale and resulting catch limits.

Substantial empirical and theoretical evidence suggests that natural mortality is lower for large bodied individuals (Andersen, 2019). Asymptotic body length L_inf is negatively correlated with the von Bertalanffy growth parameter k, such that these two growth parameters are sometimes used to predict M (Hoenig, 1983). In fact, the ratio M/k has erroneously been called a "life-history invariant" (Roff, 1984), despite theory suggesting that higher M/k is associated with lower L_mat/L_inf (Beverton & Holt, 1959). In particular, some taxa evolve behavioral and morphological defenses against predators (e.g., spines) that which likely contribute to a lower M/k than otherwise expected (Thorson et al., 2014). These antipredator defenses may in some cases be evolutionarily conserved, such that a lower-than-expected M/k for a related taxa will be informative when predicting the value of M from k for a given species. This intuition gives rise to taxonomic-nested linear mixed models or phylogenetic trait imputation, which have been used

to impute missing values for natural mortality (Thorson et al., 2017), recruitment density dependence (Thorson, 2020), or other behavioral and ecological traits (Thorson et al., 2023, Thorson 2024).

As an alternative to estimating natural mortality from growth parameters, researchers have also compiled estimates of longevity from aged specimens, and research suggests that longevity-based predictions of natural mortality rate are more precise than growth-based estimates (Hamel & Cope, 2022; Then et al., 2015). Longevity can be recorded either as the maximum aged specimen, or the average of the five maximum ages (Sullivan et al., 2022). However, developing separate estimators using longevity and growth parameters then results in multiple estimators for a given species (Sullivan et al., 2022), which presents a challenge in either selecting a single estimator or weighting alternative estimators within an ensemble (Cope & Hamel, 2022).

As alternative to developing separate models using growth or longevity information, recent research has developed phylogenetic structural equation models, which can explicitly represent the dependency among multivariate trait data (Thorson et al., 2023; van der Bijl, 2018; von Hardenberg & Gonzalez-Voyer, 2013). In particular, a user-friendly R-package phylosem can impute missing trait values jointly with estimating complex dependencies among traits (Thorson & van der Bijl, 2023). Research confirms that phylosem exactly replicates results from simpler models including structural equation models, phylogenetic linear models, and phylogenetic trait imputation (Thorson & van der Bijl, 2023).

For this assessment a phylogenetic structural equation model (PSEM) was fit to a high-quality database of independent estimates of natural mortality (Then et al., 2015). A PSEM was specifically used that specifies three linear associations log(L_inf)→log(t_max), log(k)→log(t_max), and t_max→log(M). A jackknife experiment confirms that this PSEM can explain nearly 50% additional variance relative to a conventional linear model when using growth parameters to predict natural mortality rate, while also providing a simple method to include both growth and longevity information in a single natural mortality estimator (Thorson, 2024). We then use either the maximum specimen age, or the average of the maximum ages to predict natural mortality rate for Pacific cod in the eastern Bering Sea since 2008. Both longevity metrics result in the same value t_max=14 years, and this results in a predicted value M=0.3866 and log standard deviation of 0.4. A natural mortality of M=0.3866 was specified in all Models.

Parameters Estimated Inside the Assessment Models

Except for the addition of some annual deviations necessitated by extending the terminal year through 2026 the parameters estimated by the assessment models are enumerated in Table 2.13. For all parameters estimated within individual Stock Synthesis runs, the estimator used was the minimum negative log likelihood.

In addition to the above, the full set of fishing mortality rates was also estimated internally, but not in the same sense as the above parameters. The fishing mortality rates are determined (almost) exactly as functions of other model parameters, because Stock Synthesis assumes that the input total catch data are true values rather than estimates, so the fishing mortality rates can be computed algebraically given the other parameter values and the input catch data. An option does exist in Stock Synthesis for treating the fishing mortality rates as full parameters, but

previous explorations have indicated that adding these parameters has almost no effect on other model output (Methot and Wetzel 2013).

Objective Function Components

Both models in this assessment include likelihood components for catch, initial (equilibrium) catch, trawl survey relative abundance, fishery and survey size composition, survey age composition, recruitment, initial recruitment, "softbounds" (analogous to a very weak prior distribution designed to keep parameters from hitting bounds), and parameter deviations.

In Stock Synthesis, emphasis factors are specified to determine which likelihood components receive the greatest attention during the parameter estimation process. As in previous assessments, all likelihood components were given an emphasis of 1.0 here.

Use of Size Composition Data in Parameter Estimation

Size composition data are assumed to be drawn from a multinomial distribution specific to a particular year and fleet (fishery or survey). In the parameter estimation process, Stock Synthesis weights a given size composition observation according to the emphasis associated with the respective likelihood component and the sample size specified (and perhaps adjusted by a multiplier) for the multinomial distribution from which the data are assumed to be drawn. In developing the model upon which Stock Synthesis was originally based, Fournier and Archibald (1982) suggested truncating the multinomial sample size at a value of 400 in order to compensate for contingencies which cause the sampling process to depart from the process that gives rise to the multinomial distribution. Over the years, assessments of EBS Pacific cod have used a variety of approaches to specify multinomial sample sizes that are roughly consistent with this recommendation (summarized most recently by Thompson and Thorson 2019).

Model input sample size

Hulson et al. (2023) found that there was not a consistent approach to setting input sample sizes for composition data in assessment models at the Alaska Fisheries Science Center. They proposed a unifying bootstrap approach that would evaluate the variance and autocorrelation within the survey composition data collections to appropriately calculate annual input sample sizes. Using a bootstrap approach (Hulson et al. 2023) for calculating input sample size for the survey length and age composition data resulted in an on average smaller age composition sample size of 157 and a much larger on average input sample size of for the size composition data of 710 (Table 2.9). A bootstrap approach is not yet available for the fishery composition data and therefore for the fishery size composition data input sample size the annual number of hauls sampled standardized to the mean survey size composition input sample size were used so that both means were equal for the two size composition data sets. As in previous years it was assumed that the raw numbers of hauls were far too high as they numbered in the tens of thousands for some year, far higher than the survey input sample size.

The 2026 models were iteratively tuned using method TA1.8 proposed by Francis (2011). This method evaluates the variability in the size and age composition data through the annual mean length or age and adjusts the input sample size so that the fit of the mean size or age is meant to fit within the uncertainty intervals at a rate consistent with the variability expected based on the adjusted sample sizes. In all models, this resulted in reductions in the input sample sizes (Table 2.14). The Francis TA1.8 input sample size adjustments for the fishery length compositions,

survey length compositions, and survey age compositions are shown in Figure 2.32, Figure 2.33, and Figure 2.34, respectively.

Use of Survey Relative Abundance Data in Parameter Estimation

For each index, each year's abundance estimate was assumed to be drawn from a lognormal distribution specific to that year. The point estimates and lognormal "sigma" terms are shown in Table 2.11.

Use of Recruitment Deviation "Data" in Parameter Estimation

The likelihood component for recruitment is different from traditional likelihoods because it does not involve "data" in the same sense that traditional likelihoods do. Instead, the log-scale recruitment deviation plays the role of the datum in a normal distribution with mean zero and specified standard deviation; but, of course, the deviations are parameters, not data. The standard deviations associated with recruitment deviations and other vectors of annual random deviations are summarized in Table 2.14.

Use of Generative Artificial Intelligence

OpenAI was used to assist with editorial review, language refinement, document organization, and the preparation and formatting of selected figures and tables. AI-assisted activities included improving clarity and consistency of technical descriptions, identifying potential inconsistencies in text and references, and supporting the development of graphical presentations of assessment results.

Scientific analyses, stock assessment model development, interpretation of results, and management recommendations remain the responsibility of the authors. AI-generated or AI-modified material was subject to author review and verification prior to inclusion in this report.

RESULTS

Model Evaluation

Sensitivity to updated data inputs

A series of sensitivity analyses was conducted to evaluate the effects of updating the population length bins, input sample sizes (ISS), age composition data, length composition data, and eastern Bering Sea (EBS) bottom trawl survey biomass index relative to the 2024 base Model 24.1.

Overall, the model was relatively insensitive to the updated data inputs, although some differences were evident in historical recruitment and spawning biomass estimates. Changes to the population length bins had negligible effects on model parameters and derived quantities. Updating the input sample sizes resulted in relatively small changes in recent spawning biomass, while incorporating updated age and length composition data produced modest changes in growth, selectivity, recruitment, and spawning biomass estimates. The updated age composition data had a somewhat greater effect on estimated survey catchability than the updated length composition data.

Differences in estimated female spawning stock biomass relative to the 2024 base model were generally small throughout the assessment period (Figure 2.36). The greatest differences

occurred during the early 1980s, particularly in the models incorporating the updated survey index and age composition data, when estimated spawning biomass increased by as much as approximately 5,800 t. In recent years, the updated composition data generally produced relatively small changes in spawning biomass, whereas models incorporating the revised survey index exhibited progressively larger reductions in estimated biomass after approximately 2017. By 2025, the greatest reduction in spawning biomass occurred in the model incorporating the updated ISS, age and length compositions, and survey index, with estimated spawning biomass approximately 4,000 t lower than the 2024 base model in the revised sensitivity comparison (Figure 2.37).

Changes in estimated age-0 recruitment were more variable among years but generally remained small relative to the base model (Figure 2.38). The largest differences occurred in the earliest assessment years and for several recent recruitment estimates. Models incorporating the updated survey index exhibited the greatest changes, including reductions in estimated recruitment of approximately 10–13 million age-0 fish for some recent year classes. In contrast, models incorporating only updated composition data generally showed smaller changes in recruitment estimates. The revised survey index therefore appears to have a greater influence on the estimated strength of some recent year classes than the composition data alone.

Despite these changes in historical recruitment and spawning biomass trajectories, the effects on overall stock status and management quantities were relatively modest. In the original sensitivity comparison, estimated spawning biomass in 2025 decreased from 431,493 t in the 2024 base model to 423,176 t in the fully updated model (1.9%). Estimated spawning biomass in 2026 decreased by 1.5%, while reported forecast maximum ABC for 2025 and 2026 decreased by 3.8% and 2.9%, respectively. Estimated survey catchability decreased from 0.987 to 0.980, while growth parameters and unfished spawning biomass remained relatively stable.

Collectively, these analyses indicate that the updated EBS bottom trawl survey index has the greatest influence within the model and on recent population estimates, particularly spawning biomass, recruitment, and management-related quantities. The largest influence was the change in the 2024 abundance estimate due to net measurement corrections. The updated composition data and input sample sizes generally produce smaller changes, although some differences are apparent in historical recruitment and spawning biomass trajectories. The relatively small changes in overall stock status suggest that the principal conclusions of the 2024 assessment are robust to the data revisions we examined.

Effects of incorporating 2025 and 2026 data

Following the evaluation of revisions to the input sample sizes, composition data, and bottom trawl survey biomass index, additional analyses were conducted to examine the effects of incorporating the 2025 and 2026 data into the assessment. These analyses compared the 2024 base Model 24.1 with the fully updated data sensitivity model, 2026 Model 24.1, and Model 26.1. The comparisons were intended to evaluate the influence of the additional years of data on estimated model parameters, historical and projected population trajectories, recruitment, and stock status.

Incorporating the additional data resulted in substantially greater changes in estimated spawning biomass than those observed in the preceding data sensitivity analyses (Figure 2.37). Both updated models estimated lower female spawning biomass throughout most of the assessment

period, with the differences becoming particularly pronounced after approximately 2017. The largest reductions occurred in 2024, when estimated female spawning biomass was approximately 40,000 t lower than the 2024 base model. Differences became smaller in the subsequent projection years, although spawning biomass in 2027 remained approximately 12,000–15,000 t lower than the base model. In contrast, the model incorporating only the revised ISS, composition data, and survey index produced relatively small changes in spawning biomass. The similarity of the trajectories from 2026 Model 24.1 and Model 26.1 indicates that the primary differences relative to the 2024 assessment were associated with the updated assessment information shared by both models rather than differences between their configurations.

The reduction in estimated spawning biomass was accompanied by substantial changes in estimated recruitment, particularly for recent year classes (Figure 2.38). Although estimates for some historical cohorts also changed, the largest differences were associated with the 2018 and 2023–2025-year classes. Both updated models estimated substantially lower recruitment for the 2018-, 2023-, and 2025-year classes, with reductions approaching 180 million age-0 fish for 2018 and approximately 300 million age-0 fish for each of the 2023 and 2025 cohorts. These reductions were partly offset by higher estimated recruitment for the 2022-year class. In contrast, the revised-data sensitivity model without the additional observations produced relatively small recruitment changes. These results indicate that the incorporation of the 2025 and 2026 observations was the principal driver of the revised estimates of recent year-class strength.

The sensitivity of recent recruitment estimates to additional observations is particularly important because the abundance of younger cohorts is generally informed by fewer years of survey and fishery observations than that of older cohorts. As additional observations become available, estimates of recruitment can be revised through changes in the inferred abundance and survival of individual year classes. The magnitude of the revisions observed here indicates that estimates of recent year-class strength remain sensitive to the information available at the time of assessment. Although the sensitivity analyses identify the addition of recent observations as the primary source of these changes, they do not isolate the relative influence of individual data components within those additional years. Consequently, the results should not be interpreted as evidence that a particular data source or model process is responsible for the recruitment revisions.

Changes in recruitment were also reflected in estimates of unfished recruitment (R_0) and survey catchability (Figure 2.38). The two updated models estimated lower R_0 than the 2024 base model, with the mode of the estimated distribution shifting from approximately 625 million to 585 million age-0 fish. Estimated survey catchability increased from approximately 0.98 in the 2024 base and revised-data sensitivity models to approximately 1.02 in the updated 2026 models. The uncertainty distributions for both parameters overlapped substantially among models, although shifts in their central estimates were evident. The simultaneous decrease in estimated unfished recruitment and increase in survey catchability is consistent with the reduced estimates of population abundance in the updated models.

In contrast to the changes in recruitment and population scale, estimates of growth and selectivity were relatively stable (Figure 2.39 and Figure 2.40). Estimated annual deviations in the Richards growth coefficient (K) and length at age 1.5 years (L_{min}) were nearly identical among models, indicating that the additional observations had relatively little influence on estimated historical growth patterns. The updated models extended the estimated growth deviations through 2026, with relatively large positive deviations in K in the most recent year.

Similarly, estimated base fishery and survey selectivity curves showed little difference among models. These results suggest that changes in stock status were driven primarily by revisions to recruitment and population scale rather than substantial changes in estimated growth or selectivity relationships.

The updated models also produced lower estimates of projected spawning biomass and greater uncertainty in stock status (Figure 2.41). The distributions of projected female spawning biomass in 2027 shifted from approximately 200,000 t in the 2024 base model to approximately 190,000 t in the updated 2026 models. The updated models also exhibited broader uncertainty distributions, reflecting greater estimated uncertainty in projected biomass. Despite the reduction in absolute spawning biomass, the central estimates of spawning biomass relative to unfished biomass (Bratio) remained similar among models, near 0.35–0.36. However, the distribution of Bratio was considerably wider in the updated models, indicating greater estimated uncertainty in stock status relative to the unfished condition. This distinction is important because similar central estimates of relative stock status can obscure differences in the uncertainty surrounding those estimates, particularly when projected biomass is near a management reference point.

Examination of projected biomass by recruitment cohort provides additional insight into the causes of the differences among models (Figure 2.42). The greatest reductions in projected total biomass in 2027 were associated with the 2023- and 2025-year classes. In particular, the estimated contribution of the 2023-year class to total biomass was approximately 70,000 t lower in Model 26.1 than in the 2024 base model, partly offset by an increase of approximately 16,000 t in the contribution of the 2022-year class. Differences in projected female spawning biomass were distributed somewhat differently among cohorts. Although the 2023-year class exhibited the largest reduction in spawning biomass (approximately 10,000 t), the estimated contribution of the 2018-year class also declined substantially, by approximately 6,000 t. The 2018-year class is particularly important because these fish will be age 9 in 2027 and are expected to be largely mature, making their reduced abundance directly relevant to spawning biomass. In contrast, the 2023-year class will be age 4 in 2027, when a smaller proportion of females are expected to be mature. The reduced contribution of the 2018-year class, together with downward revisions to more recent cohorts, indicates that lower projected spawning biomass reflects changes in the estimated abundance of both established spawning cohorts and younger cohorts entering the spawning population.

These cohort-specific revisions also help explain why relatively modest changes in projected spawning biomass can be accompanied by larger changes in management quantities. Projected catch depends not only on spawning biomass but also on the estimated age structure, selectivity, growth, and expected survival of fish entering the fishery. The revised abundance of individual year classes therefore affects both the spawning biomass available to support future recruitment and the numbers and sizes of fish expected to contribute to future catches. Consistent with these changes, projected 2027 female spawning biomass declined from 204,037 t in the 2024 assessment to 192,115 t in Model 26.1, while the corresponding maximum ABC declined from 140,135 t to 123,787 t.

Overall, incorporating the 2025 and 2026 observations resulted in a substantial downward revision to recent population abundance and spawning biomass, primarily associated with lower estimated recruitment for several recent year classes. The updated models also estimated higher survey catchability and lower unfished recruitment, while growth and selectivity estimates

remained relatively stable. Although the central estimates of relative spawning biomass were similar among models, the updated models indicated greater uncertainty in projected stock status.

The substantial revisions to recent recruitment estimates highlight an important limitation of relying solely on conventional goodness-of-fit and retrospective diagnostics when evaluating assessment uncertainty. Although these diagnostics provide information on model performance, they do not fully characterize the potential for estimates of recent year-class strength to change as additional observations become available. The similarity of the updated Models 24.1 and 26.1 demonstrates that the revised population trajectories are largely insensitive to the plus-group specification, but does not independently evaluate uncertainties shared by both model configurations. Thus, while the additional observations improve the information available for estimating recent population dynamics, the sensitivity of recruitment estimates to newly incorporated data remains an important consideration when interpreting short-term projections and associated harvest recommendations.

Individual Model Goodness of Fit for 2026 Model 24.1 and Model 26.1

Table 2.15 , Table 2.16, and Table 2.17 show the objective function value for each data component in each model along with the number of parameters in each model. The 2026 Model 24.1 and Model 26.1, data and tuning remain the same and therefore direct comparisons of likelihood fits can be made across models. For the most part model fits for all components were indistinguishable by eye and therefore only fits to Model 26.1 are going to be provided in this document. Links to the r4ss library plots have been provided for examination of fits to Model 24.1.

The fit to the bottom trawl survey abundance data for Model 26.1 are shown in Figure 2.43. Individual model diagnostics and residuals for the index fits can be found in the r4ss library (Taylor et al. 2021) output provided on the AFSC-assessments public GitHub repository:

- Model 24.1
- Model 26.1

Effective sample sizes implied by the models' fits to the size composition and age composition data are compared with the corresponding input sample sizes in Table 2.18.

Individual figures for selectivities for each model can be found here:

- Model 24.1 Selectivity
- Model 26.1 Selectivity

The two models have fishery and survey selectivities that are indistinguishable (Figure 2.44, Figure 2.45, and Figure 2.46).

Size composition: Fits to the mean length are shown for Model 26.1 in Figure 2.47. One-step-ahead (OSA) residual diagnostics indicate generally good fits to both the fishery and survey length composition data (Table 2.15 and Figure 2.48). Aggregated predicted length compositions closely match the observed proportions for both fleets, although some discrepancies are evident in the survey length compositions, particularly between 25 and 35 cm. The Q-Q plots show approximately normal residual distributions, with SDNR values of 0.85 for the fishery and 1.00 for the survey. The fishery residuals exhibit slightly less dispersion than expected, whereas the survey residuals closely follow the theoretical normal distribution, with a few deviations in the tails. Examination of residuals by year and length reveals some localized patterns, including

clusters of positive and negative residuals at particular lengths and periods, but no strong, persistent systematic bias across the full time series. Overall, the OSA diagnostics suggest that the model adequately represents the principal features of both fishery and survey length composition data.

Model fits to the size composition data and Pearson residuals can be found in the r4ss library (Taylor et al. 2021) output provided on the AFSC-assessments public github repository:

- Model 24.1 size composition fits
- Model 26.1 size composition fits

Age composition: Fits to the mean age are shown for Model 26.1 in Figure 2.49. As with the length composition data, the OSA residual diagnostics indicate generally satisfactory fits to the survey age composition data (Table 2.15 and Figure 2.50). Aggregated predicted age compositions closely match the observed proportions, although the model slightly underestimates the proportion of age-1 fish and overestimates the proportion of age-2 fish. The Q-Q plot indicates an approximately normal residual distribution, with an SDNR of 0.90, suggesting slightly less dispersion than expected. Some deviations from the theoretical normal distribution are evident in both tails, particularly among the largest positive residuals. Examination of residuals by year and age reveals systematic age-specific patterns, with positive residuals occurring more frequently at younger ages and negative residuals predominating at older ages. These patterns suggest a tendency for the model to underestimate the proportions of younger fish and overestimate those of older fish. However, the residuals show no pronounced temporal trends, indicating that the model generally captures the principal features of the survey age composition data. Nevertheless, the remaining age-specific residual structure indicates some systematic lack of fit that is not fully reflected in the aggregate diagnostics. These discrepancies warrant consideration when interpreting estimates of year-class strength, particularly for recent cohorts whose estimated abundances are informed by relatively few years of observations.

Model fits to the age composition data and residuals can be found in the r4ss library (Taylor et al. 2021) output provided on the AFSC-assessments public github repository:

- Model 24.1 age composition fits
- Model 26.1 age composition fits

Carvalho et al. (2021) Model Diagnostics from ss3diags R Library (Winker et al. 2022)

Retrospective Performance

Retrospective analyses were conducted for all models. Mohn's ρ values (Mohn 1999) for both models are provided in Table 2.19 and shown for Model 26.1 in Figure 2.51. For both models the spawning stock biomass retrospective analysis have small values of ρ within their respective acceptable ranges as suggested by Hurtado-Ferro et al. (2015). Values fishing mortality are also provided. However acceptable ranges for these have yet to be determined.

Parameter Estimates

A select number of parameters estimates with their standard deviations for the 2024 Model 24.1, the 2026 Model 24.1 and Model 26.1 are provided in Table 2.13. From the 2024 Model 24.1 to

the 2026 Model 24.1 and 26.1 the largest change was in the 2024 survey ascending selectivity deviation from -1.85 in the 2024 model to 0.13 in both the 2026 models following the change in the survey length and age compositions. There was a less than 7% change between the 2024 and 2026 models for the remainder of active parameters. Between the 2026 models the largest change was in the Lmax which changed from 112.15 cm to 110.75 cm and in the growth coefficient (K) which changed from 0.116 to 0.121 from Model 24.1 to 26.1. This change is consistent with the change in the plus group from age 20 to age 14.

Estimated length and weight at ages 2, 6, and 10 are shown in Figure 2.52, providing additional context for the model estimates of growth and the relative contributions of different age classes to population biomass.

All parameter estimates with their standard deviations are provided in an Excel file as Appendix 2.4.

Likelihood profiles

Likelihood profiles were run for survey catchability (q), natural mortality (m), L_{max}, and Sigma R.

Catchability

The likelihood profile for EBS bottom trawl survey catchability in Model 26.1 indicates a well-defined minimum in the total negative log-likelihood (Figure 2.53), with no evidence of multiple local minima over the evaluated range. However, individual likelihood components exhibit substantially different responses to changes in catchability. The length composition likelihood favors lower values of catchability, whereas the survey index and age composition likelihoods favor higher values. Consequently, the estimated catchability represents a compromise among competing data components, with the length composition data providing a substantial constraint on the upper range of catchability values. These results suggest that the estimate is reasonably well identified within the current model structure, although additional investigation is warranted to determine how changes in catchability affect estimated population scale, selectivity, recruitment, and fits to individual data sources.

Natural Mortality

The likelihood profile for natural mortality (M) in Model 26.1 (Figure 2.54) indicates a well-defined minimum near M = 0.38–0.39, consistent with the natural mortality rate of 0.3866 used in the assessment. The profile is asymmetric, with a steep increase in negative log-likelihood at lower values of M and a more gradual increase at higher values. Values below approximately 0.35 and above approximately 0.42 result in noticeably poorer model fits, indicating that the available data provide information about both the lower and upper ranges of plausible natural mortality. The deterioration in fit at lower values of M is distributed among several likelihood components, including the survey index, length compositions, age compositions, and initial equilibrium recruitment. In contrast, the deterioration in fit at higher values is driven primarily by the age composition likelihood, with additional contributions from the survey index and recruitment deviations. The length composition likelihood remains relatively flat near the optimum but increases at both extremes of the evaluated range.

The likelihood profile indicates that lower natural mortality rates are inconsistent with several components of the available data, whereas higher natural mortality rates are increasingly constrained by the observed age compositions. The opposing responses of individual likelihood

components at higher values of M suggest that the estimated natural mortality represents a compromise among the data sources. The total likelihood profile crosses the nominal 95% profile-likelihood threshold (ΔNLL = 1.92) on both sides of the optimum, suggesting that natural mortality is reasonably well identified within the current model configuration. Overall, the profile provides support for the natural mortality rate used in Model 26.1, while indicating asymmetric uncertainty around the estimated value.

L_{max}

The likelihood profile for maximum length (L_{max}) in Model 26.1 (Figure 2.55) indicates a relatively well-defined minimum near 110.5–111 cm, with increasing negative log-likelihood at both lower and higher values. However, individual likelihood components exhibit contrasting responses. The age composition likelihood improves consistently with increasing L_{max} whereas the length composition likelihood reaches a minimum near 109.5–110 cm and deteriorates substantially at higher values. Consequently, the estimated maximum length represents a compromise between the growth relationships favored by these data components. The total likelihood profile is relatively smooth and exhibits no evidence of multiple local minima within the evaluated range, although the evaluated parameter range does not extend sufficiently to establish the full nominal 95% profile-likelihood confidence interval. Further evaluation of predicted mean length-at-age, selectivity, and composition residuals across the profile may help identify the sources of disagreement between age and length composition data.

Sigma R

The likelihood profile for recruitment variability (sigma R) in Model 26.1 (Figure 2.56) indicates a minimum in the total negative log-likelihood near (sigma_R = 0.67), with a pronounced increase in negative log-likelihood at lower values and a relatively flat likelihood surface at higher values. The deterioration in model fit at lower values of sigma R is driven primarily by the length composition likelihood, with additional contributions from the parameter deviation and age composition likelihoods. Increasing sigma R allows greater flexibility in estimated recruitment deviations, improving the model's ability to reproduce the observed length composition data. However, this improvement is partially offset by increasing contributions from the recruitment likelihood and survey index components at higher values of sigma R. The age composition likelihood changes relatively little across the evaluated range, suggesting that these data provide comparatively limited information about recruitment variability. The resulting profile is strongly asymmetric, indicating that lower values of sigma R are poorly supported by the available data, whereas higher values are less strongly constrained. Although the total likelihood has a minimum near 0.67, the shallow likelihood surface at higher values suggests that the upper confidence limit for sigma R is not well defined within the evaluated range. Overall, the profile indicates that recruitment variability is informed primarily by the length composition data and that relatively high recruitment variability is favored within the current model configuration.

Derived Quantities

Table 2.20 contain selected management reference points for the models explored this year. Static quantities include $B_{100\%}$, $B_{40\%}$, $B_{35\%}$, $F_{40\%}$, and $F_{35\%}$. Quantities shown for each of the first two projection years (2027 and 2028) consist of female spawning biomass, relative spawning biomass, the probability that the ratio of spawning biomass to $B_{100\%}$ will fall below 0.2, maxFABC, maxABC, catch, FOFL, OFL, and the probability that maxABC exceeds the true-

but-unknown OFL. A more complete listing of derived quantities for all the models considered this year is provided in an excel worksheet as Appendix 2.4.

The projected 2027 female spawning biomass, relative spawning biomass, maximum fishing mortality (maxFABC), and maximum allowable biological catch (maxABC) differ between the 2026 models and the 2024 Model 24.1 (Table 2.15, Table 2.20, Figure 2.57). Both 2026 models project lower spawning biomass and recommend reductions in maxFABC and maxABC relative to the 2024 assessment. These reductions are primarily attributed to the downward revision of the 2024 bottom trawl survey biomass index and the low 2026 survey biomass estimate. Additionally, whereas the 2024 assessment assumed average recruitment for the 2023- and 2024-year classes, the updated models estimate below-average recruitment for both cohorts, contributing to lower projected spawning biomass in 2027. Relative to the 2024 Model 24.1, Model 26.1 estimates a 5.8% reduction in 2027 female spawning biomass, from 204,037 t to 192,115 t, and a decline in relative spawning biomass from 36.3% to 35.2% of unfished levels. Consequently, the 2027 maxFABC decreases by 5.7%, from 0.328 to 0.309, and the maxABC decreases by 11.7%, from 140,135 t to 123,787 t. The reduction in maxABC is proportionally larger than the decline in spawning biomass because the stock is projected to remain below B40%, on the declining portion of the Tier 3 harvest control rule. Differences between the two 2026 models are comparatively small, with Model 26.1 projecting 1.3% higher female spawning biomass but a 0.4% lower maxABC than the updated Model 24.1.

Difference between the 2024 Model 24.1, this year's Model 24.1, and 26.1 are shown below:

Year	Quantity	2024 Model 24.1	2026 Model 24.1	Change	Model 26.1	Change	2026 Model 24.1 vs. 26.1
Unfished female spawning biomass		561,915	539,445	−4.0%	546,405	−2.8%	+1.3%
2027	Female spawning biomass	204,037	189,735	−7.0%	192,115	−5.8%	+1.3%
2027	Relative spawning biomass	0.363	0.352	−3.1%	0.352	−3.1%	−0.04%
2027	$maxF_{ABC}$	0.328	0.314	−4.1%	0.309	−5.7%	−1.7%
2027	maxABC	140,135	124,251	−11.3%	123,787	−11.7%	−0.4%

The distributions of projected spawning biomass relative to unfished spawning biomass for 2027 and 2028 are compared among models in Figure 2.58. These distributions provide a measure of uncertainty in projected stock status and allow comparison of the probabilities of alternative spawning biomass ratios among the assessment models.

Choice of model

The two models considered for the 2026 assessment produced similar results, with negligible differences in model fit, diagnostic performance, and estimated management quantities. Model 24.1 had a slightly lower negative log-likelihood than Model 26.1, with a difference of 0.182 units, primarily attributable to a difference of approximately 0.202 units in the survey age

composition likelihood (Table 2.15). These differences are small relative to the total objective function values, indicating that reducing the plus-group age from 20 to 14 had little effect on the models' overall fits to the data. Both models exhibited similar retrospective performance, including Mohn's ρ and predictive retrospective diagnostics for spawning stock biomass and fishing mortality (Table 2.19), as well as nearly identical SDNR values for the survey index, length compositions, and age compositions (Table 2.15). Jitter analyses also indicated satisfactory convergence, with most runs converging to the maximum likelihood estimate (MLE) and no runs achieving a lower negative log-likelihood than the final MLE.

The models produced nearly identical estimates of stock status and management quantities, with Model 26.1 estimating 1.3% higher projected female spawning biomass in 2027 and a 0.4% lower maximum acceptable biological catch (maxABC) than Model 24.1. As demonstrated by the preceding data sensitivity analyses, the larger revisions to recent recruitment, spawning biomass, and projected management quantities relative to the 2024 assessment were primarily associated with incorporating the additional 2025 and 2026 observations rather than differences in model structure (Figure 2.37, Figure 2.38, Figure 2.39, Figure 2.40, Figure 2.41,and Figure 2.42). Thus, the comparison between Models 24.1 and 26.1 supports the conclusion that reducing the plus-group age has little influence on estimated stock status or harvest recommendations.

Given their comparable fits, diagnostic performance, and management implications, model selection was primarily informed by parsimony. Model 26.1 reduced the number of estimated parameters from 184 to 178 by eliminating six initial-age deviation parameters associated with ages 15–20, without materially changing model performance or management quantities. This reduction in model complexity, together with the limited sensitivity of estimated stock dynamics and management quantities to the plus-group specification, supports adopting Model 26.1 as the preferred model for the 2026 assessment and for developing harvest recommendations for 2027 and 2028.

Time Series Results

The biomass estimates presented here will be defined in two ways: 1) age 0+ biomass, consisting of the biomass of all fish aged 0 years or greater in January of a given year; and 2) spawning biomass, consisting of the biomass of all spawning females in January of a given year. The recruitment estimates presented here will be defined as numbers of age 0 fish in a given year.

Result tables including estimated time series, numbers-at-age and -length, and selectivity from all models and ensembles are provided in Excel tables in Appendix 2.4.

For all of the following values the results are from Model 26.1.

Female spawning biomass

Table 2.21 compares female spawning biomass estimates from the 2024 Model 24.1 and 2026 Model 26.1, with uncertainty distributions generated using point estimates and standard deviations derived from the inverted Hessian. Figure 2.57 shows the time series of female spawning biomass for 2024 Model 24.1 and 2026 Model 26.1 with distributions generated from the inverted hessian point estimates. Figure 2.59 presents the corresponding time series of relative spawning biomass (B/B_0) for these two models. Both models indicate that spawning biomass increased rapidly during the early 1980s, reaching a historical maximum in the mid-1980s, before declining through the late 1980s and early 1990s. Spawning biomass remained relatively low throughout much of the 1990s and 2000s, reaching its minimum in 2009 at

approximately 19% of unfished spawning biomass ($B_{19\%}$). Subsequently, strong recruitment from the 2006-, 2008-, 2010-, 2011-, and 2013-year classes contributed to a substantial recovery, with spawning biomass reaching approximately 320 kt ($B_{58\%}$) in 2018. Since 2018, spawning biomass has declined, with Model 26.1 estimating female spawning biomass of approximately 186 kt ($B_{34\%}$) in 2026 and projecting a slight increase to 192 kt ($B_{35.2}$%) in 2027.

The 2024 Model 24.1 and 2026 Model 26.1 produce very similar historical trends in spawning biomass and relative stock status, with nearly overlapping estimates throughout most of the time series. However, the estimates begin to diverge after 2020, with Model 26.1 indicating a more pronounced decline in spawning biomass and lower stock status in recent years. Whereas the 2024 Model 24.1 projects female spawning biomass of 204,037 t ($B_{36.3\%}$) in 2027, Model 26.1 projects 192,115 t ($B_{35.2\%}$), a reduction of 5.8% in spawning biomass. The differences are particularly apparent in the projected trajectories, with the 2024 model indicating a more gradual decline and Model 26.1 suggesting that spawning biomass will remain relatively stable near $B_{35\%}$ through 2028. Despite these differences in recent estimates and projections, the uncertainty distributions overlap substantially, indicating that the differences are relatively small compared with the uncertainty in estimated spawning biomass.

Total Biomass

Table 2.22 and Figure 2.60 provides the estimated time series of age-0+ biomass since 1977 for the 2024 Model 24.1, the updated 2026 Model 24.1, and Model 26.1. Age-0+ biomass generally follows trends similar to spawning biomass, increasing rapidly during the early 1980s and reaching a historical maximum of 1,383 kt in 1983 under Model 26.1. Following this peak, biomass declined substantially through the late 1980s and early 1990s, with occasional periods of recovery, reaching a minimum of 472 kt in 2008, a 66% decline from the 1983 peak. Biomass subsequently increased, reaching a second peak of 1,195 kt in 2016, approximately 86% of the historical maximum. Since 2016, age-0+ biomass has generally declined, falling to 679 kt in 2024 and 662 kt in 2026, a 45% reduction from the 2016 peak. Biomass is projected to increase slightly to 677 kt in 2027 before declining to 661 kt in 2028. The continued low biomass estimates in recent years are consistent with the relatively weak recruitment observed since 2018 and the declining contribution of earlier strong year classes to the population.

The 2024 Model 24.1 and 2026 Model 26.1 produce similar historical trends in age-0+ biomass, with both models identifying the same periods of high and low biomass. However, Model 26.1 generally estimates slightly lower biomass throughout the historical time series, with differences becoming more pronounced after 2016. The 2024 Model 24.1 estimated a historical maximum of 1,423 kt in 1983, compared with 1,383 kt for Model 26.1, a reduction of 2.8%. Similarly, the 2016 biomass peak decreased from 1,250 kt to 1,195 kt, a reduction of 4.4%. Differences between the models have increased in recent years, with Model 26.1 estimating 679 kt in 2024 compared with 795 kt in the 2024 Model 24.1, a reduction of 14.6%. These differences persist into the forecast period, with Model 26.1 projecting age-0+ biomass of 677 kt in 2027 compared with 784 kt from the 2024 Model 24.1, a reduction of 13.7%. The projected trajectories also differ, with the 2024 model indicating increasing biomass between 2026 and 2028, whereas Model 26.1 projects relatively stable biomass near 660–680 kt. These results indicate that the updated assessment estimates a lower recent population biomass and a weaker short-term recovery than projected by the 2024 assessment.

Age-0 recruitment

Table 2.23 and Figure 2.61 provides the estimated time series of age-0 recruitment (numbers of fish) since 1977 for the 2024 Model 24.1, the updated 2026 Model 24.1, and Model 26.1, along with their associated standard deviations. Recruitment estimates from Model 26.1 indicate considerable interannual variability, with the highest estimated recruitment occurring in 1977 at approximately 1.68 billion fish. Other strong year classes occurred in 1982 (1.29 billion), 1984 (1.16 billion), and 1992 (1.10 billion). Recruitment was generally lower during the late 1990s and early 2000s, followed by a period of relatively strong recruitment associated with the 2006-, 2008-, 2010-, 2011-, and 2013-year classes. The 2008-year class was particularly strong, with estimated recruitment of 1.49 billion fish, followed by 1.28 billion in 2011 and 1.42 billion in 2013. Since 2013, recruitment has generally been below the long-term mean, except for the relatively strong 2018-year class (858 million fish). Recruitment declined to 246 million fish in 2019 before increasing to 418 million in 2020 and 533 million in 2021. More recently, Model 26.1 estimates recruitment of 423 million fish in 2022, 329 million in 2023, 536 million in 2024, and 334 million in 2025. Recruitment for 2026 is estimated at 548 million fish, while recruitment in subsequent forecast years is assumed to be approximately 594 million fish, consistent with the model's estimated mean recruitment.

Recruitment estimates from the 2024 Model 24.1 and 2026 Model 26.1 are generally similar throughout most of the historical time series, with both models identifying the same periods of strong and weak recruitment. However, Model 26.1 generally estimates slightly lower recruitment for several of the stronger historical year classes, including 2008, 2011, 2013, and 2018. The most notable difference occurs in 2018, when Model 26.1 estimates recruitment of 858 million fish compared with 1.04 billion fish in the 2024 Model 24.1, a reduction of approximately 17%. Differences are also evident in the recent recruitment estimates. The 2024 Model 24.1 assumed average recruitment of approximately 621 million fish for the 2023 and subsequent year classes, whereas Model 26.1 estimates recruitment of 329 million fish in 2023 and 536 million fish in 2024, approximately 47% and 14% lower, respectively. Model 26.1 also estimates recruitment of 334 million fish in 2025, substantially below the mean recruitment of approximately 594 million fish. These downward revisions to recent recruitment estimates are consistent with the lower projected spawning biomass in Model 26.1 relative to the 2024 assessment (Figure 2.41).

Fishing Mortality

Table 2.24 provides the estimated time series of instantaneous apical fishing mortality (F) since 1977 for the 2024 Model 24.1, the updated 2026 Model 24.1, and Model 26.1, along with their associated standard deviations. Figure 2.62 compares the estimated time series of instantaneous apical fishing mortality for the 2024 Model 24.1 and 2026 Model 26.1, with uncertainty distributions generated using point estimates and standard deviations derived from the inverted Hessian. Fishing mortality was relatively low during the late 1970s and early 1980s, before increasing steadily through the 1980s and into the 1990s. Fishing mortality reached an initial peak of 0.559 in 1997, declined to 0.409 in 2001, and subsequently increased to 0.687 in 2009 and a historical maximum of 0.688 in 2011. Following this peak, fishing mortality declined substantially, reaching 0.283 in 2021. Fishing mortality subsequently increased to 0.364 in 2022 and remained relatively stable through 2024 (0.368), before declining slightly to 0.354 in 2025. Model 26.1 estimates fishing mortality of 0.334 in 2026, with projected values declining to 0.309 in 2027 and 0.302 in 2028. Using an F35% reference value of approximately 0.44, estimated

fishing mortality exceeded this level in 1992, 1995–2000, and 2002–2014, but has remained below this level since 2015.

The 2024 Model 24.1 and 2026 Model 26.1 produce very similar historical trends in instantaneous apical fishing mortality, with both models identifying the same periods of relatively high and low fishing pressure. However, Model 26.1 generally estimates slightly higher fishing mortality throughout much of the historical time series, with differences becoming more apparent after 2007. For example, the 2024 Model 24.1 estimated fishing mortality of 0.672 in 2009 and 0.667 in 2011, compared with 0.687 and 0.688, respectively, for Model 26.1. Differences are also evident in recent years, with Model 26.1 estimating fishing mortality of 0.283 in 2021 compared with 0.255 in the 2024 Model 24.1, an increase of approximately 10.8%. Similarly, the 2024 Model 24.1 estimated fishing mortality of 0.318 in 2022 and 0.306 in 2023, compared with 0.364 in both years for Model 26.1, increases of approximately 14% and 19%, respectively. Despite these differences in recent estimates, the two models produce broadly similar fishing mortality trajectories, with substantial overlap in their associated uncertainty distributions. Projected fishing mortality in 2027 is slightly lower in Model 26.1 (0.309) than in the 2024 Model 24.1 (0.328), a reduction of approximately 5.7%.

Phase Plane

Figure 2.63 illustrates the estimated and projected trajectories of relative instantaneous apical fishing mortality ($F/F_{35\%}$) and relative female spawning biomass ($B/B_{35\%}$) from 1977 through 2028, overlaid with the Tier 3 harvest control rules for the fishing mortality limit (F_{OFL}) and maximum F_{ABC}. Models developed prior to 2016 incorporated dome-shaped survey selectivity, whereas models since 2016 have assumed asymptotic survey selectivity. This change substantially altered the reconstructed historical stock trajectory, indicating that fishing mortality exceeded the retrospectively estimated F_{OFL} in several years during the 1990s and 2000s, although these estimates do not necessarily correspond to the official F_{OFL} values established at the time. The current model indicates that fishing mortality was particularly high relative to $F_{35\%}$ during the late 2000s and early 2010s, coinciding with relatively low spawning biomass. Since that period, fishing mortality has generally declined, while spawning biomass recovered above $B_{40\%}$ before subsequently declining. In recent years, the stock trajectory has shifted toward lower relative spawning biomass, with projected stock status approaching $B_{35\%}$. Fishing mortality has remained below $F_{35\%}$ in recent years, and the projected 2027 and 2028 values remain below the maximum FABC harvest control rule.

The uncertainty ellipses shown for 2022–2028 illustrate the joint uncertainty in relative spawning biomass and fishing mortality, including the correlation between these quantities. The ellipses are generally elongated along a negative slope, indicating that lower estimates of spawning biomass are associated with higher estimates of fishing mortality. This relationship is consistent with the inverse relationship between estimated population biomass and the fishing mortality required to account for observed catches. The ellipses also overlap substantially among adjacent years, indicating that differences in estimated stock status and fishing mortality over this period are relatively small compared with their associated uncertainty. Importantly, the uncertainty distributions for recent and projected years extend across the $B_{35\%}$ and $B_{40\%}$ biomass reference points, indicating uncertainty regarding the stock's position relative to these management thresholds. Although the point estimates for projected years remain near $B_{35\%}$ and below the maximum F_{ABC} control rule, portions of the uncertainty distributions extend into regions representing lower spawning biomass and higher relative fishing mortality. These results

emphasize the importance of accounting for uncertainty in both stock status and fishing mortality when interpreting the recent trajectory and evaluating projected management outcomes.

Figure 2.64 provides additional context for these trends by illustrating the relationship between annual catch and female spawning biomass, along with the annual proportion of total population biomass removed by the fishery. During the early to mid-1980s, relatively high catches were supported by a large spawning stock, with female spawning biomass exceeding 400,000 t in several years. As spawning biomass declined through the late 1980s and 1990s, catches remained relatively high, and the proportion of total biomass removed annually increased substantially. This proportion reached approximately 30% during portions of the late 1990s and mid-2000s, compared with less than 10% during much of the late 1970s and early 1980s. During the late 2000s, spawning biomass declined to approximately 100,000 t, while catches remained near 140,000–150,000 t in some years. Following the recovery in spawning biomass during the 2010s, catches declined from their historical highs, and the proportion of biomass removed decreased. In recent years, female spawning biomass has again approached 200,000 t, with annual catches generally between 165,000 and 210,000 t and the proportion of total biomass removed remaining near 18–21%. Together, these figures illustrate that the stock has experienced substantial changes in biomass and fishing pressure over its history. Although recent fishing mortality estimates remain below the maximum F_{ABC} control rule, the combination of declining spawning biomass, relatively high catch relative to total biomass, and uncertainty surrounding the $B_{35\%}$ threshold highlights the importance of continued evaluation of stock status and harvest levels.

Recent Cohorts

Figure 2.65 illustrates the estimated numbers at age by cohort from Model 26.1 for 2012 through 2027. The influence of several strong year classes is evident throughout the time series, particularly the 2008, 2011, 2013, and 2018 cohorts. During 2012–2015, the population was dominated numerically by the relatively strong 2011- and 2013-year classes, which subsequently declined in abundance as they aged. The 2018-year class became particularly prominent beginning in 2019, when it entered the population at age 1, and remained an important component of the population through the early 2020s. By 2024–2027, the numerical contribution of the 2018 cohort had declined substantially, with younger cohorts increasingly dominating population abundance. The projected age structure in 2027 consists primarily of younger fish, with relatively low numbers of fish older than age 6.

Figure 2.66 illustrates the corresponding biomass at age by cohort from Model 26.1. Unlike numbers at age, which are generally dominated by younger fish, biomass is concentrated among intermediate-aged fish because of increases in individual weight with age. The strong 2008-, 2011-, and 2013-year classes contributed substantially to population biomass during the early and middle portions of the time series. The 2013 cohort became particularly prominent during 2016–2019, while the 2018-year class emerged as a major contributor to population biomass beginning in 2020. Its contribution was greatest during 2021–2023, when the cohort was approximately ages 3–5, before declining as the cohort aged. By 2025, the biomass contribution of the 2018-year class at age 7 remained substantial, but was smaller than that of several younger cohorts, particularly the 2021-year class at age 4. In the 2026 and 2027 projections, biomass is increasingly distributed among the 2021–2024-year classes, with the contribution of the 2018 cohort continuing to diminish. These changes reflect the declining influence of the historically strong 2018-year class and the increasing importance of more recent recruitment to future population biomass.

Figure 2.67 illustrates the estimated catch biomass at age by cohort from Model 26.1 for 2012 through 2027. The contribution of individual cohorts to the catch generally follows their contribution to population biomass, although differences arise from the age- and size-specific selectivity of the fishery. The strong 2011- and 2013-year classes contributed substantially to catches during the middle of the time series, followed by the 2018-year class, which became a major contributor beginning in 2021. The 2018 cohort remained prominent in the catch through 2023, but its contribution declined substantially by 2025 as younger cohorts became increasingly important. By 2026–2027, catches are distributed primarily among fish aged approximately 3–6, with comparatively small contributions from fish older than age 8. As in previous assessments, the contribution of older cohorts to the catch declines more rapidly than their contribution to total population biomass, reflecting the combined effects of declining cohort abundance and fishery selectivity at older ages. Together, these figures illustrate the progression of strong year classes through the population and fishery, while highlighting the increasing dependence of future biomass and catches on recruitment from more recent cohorts.

Harvest Recommendations

Results presented in this section pertain to Model 26.1 only, however results for Model 24.1are available.

Amendment 56 Reference Points

Amendment 56 to the BSAI Groundfish Fishery Management Plan (FMP) defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, Pacific cod in the EBS have generally been managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points: $B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing. The following formulae apply under Tier 3:

3a) Stock status: $B/B_{40\%} > 1$

$F_{OFL} = F_{35\%}$

$F_{ABC} \leq F_{40\%}$

3b) Stock status: $0.05 < B/B_{40\%} \leq 1$

$F_{OFL} = F_{35\%} \times (B/B_{40\%} - 0.05) \times 1/0.95$

$F_{ABC} \leq F_{40\%} \times (B/B_{40\%} - 0.05) \times 1/0.95$

3c) Stock status: $B/B_{40\%} \leq 0.05$

$F_{OFL} = 0$

$F_{ABC} = 0$

For Model 26.1 the estimate of $F_{35\%}$ is 0.433; and the estimate of $F_{40\%}$ is 0.354 (Table 2.20). The estimate of $B_{100\%}$ from Model 26.1 is 546,405 t. The distributions of $B_{100\%}$ for each model are shown in Figure 2.68; the estimate of $B_{40\%}$ from Model 26.1 is 218,562 t; and $B_{35\%}$ is 191,242 t (Table 2.20). Means and standard deviations of the ABC and OFL distributions for 2027 and 2028 are shown for Model 26.1 in Table 2.20, and the distribution for the maxABCs are shown in Figure 2.69.

Specification of OFL and Maximum Permissible ABC

For Model 26.1 given the assumptions of Scenario 2 (below), female spawning biomass for 2027 is estimated to be 192,115 t; and female spawning biomass for 2028 is estimated to drop to 187,929 t (Table 2.25).

For Model 26.1 female spawning biomass for 2027 and 2028 is projected to be below $B_{40\%}$, thereby placing Pacific cod in Tier 3b for both 2027 and 2028. Given this, the estimates of OFL, maximum permissible ABC, and the associated fishing mortality rates for 2027 and 2028 are as follows (from Table 2.25):

Year	F_{OFL}	maxF_{ABC}	OFL (t)	maxABC (t)
2027	0.38	0.31	148,179	123,787
2028	0.37	0.30	141,676	118,299

The age 0+ biomass projections for 2027 and 2028 from Model 26.1 are 676,864 t and 661,234 t, respectively (Table 2.22).

Standard Harvest Scenarios, Projection Methodology, and Projection Results

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 Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). Projections were made within Stock Synthesis. 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. Year-end catch for 2026 was estimated to be 133,475 t, equal to the proportion of end of year catch to ABC for the previous five years times the 2026 ABC. 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). The following relationship between ABC and catch was described under "Management History" in the "Fishery" section: For ABC≥198,000 t, catch = 89,000 t + 0.55×ABC; for ABC<198,000 t, catch = ABC. Because the recommended ABCs for both of the first two projection years are less than 198,000 t, no adjustment is necessary.

In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario.

Five of the seven standard scenarios are sometimes used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide

a range of harvest alternatives that are likely to bracket the final TACs for 2027 and 2028, are as follow ("*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 ("author's F") of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2027 recommended in the assessment to the *max* F_{ABC} for 2027, and where catches for 2027 and 2028 are estimated at their most likely values given the 2027 and 2028 recommended ABCs under this scenario. (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; also, catch tends not to equal ABC exactly.)

Scenario 3: In all future years, *F* is set equal to the 2021-2025 average *F*. (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 $F_{60\%}$. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 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 follows (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 2027 or 2) above 1/2 of its MSY level in 2027 and expected to be above its MSY level in 2036 under this scenario, then the stock is not overfished.)

Scenario 7: In 2027 and 2028, *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 2028 or 2) above 1/2 of its MSY level in 2027 and expected to be above its MSY level in 2038 under this scenario, then the stock is not approaching an overfished condition.)

Projections (means and standard deviations) of female spawning biomass (B), full selection fishing mortality (F), and catch (C) corresponding to the standard scenarios are shown for the updated Model 24.1 in Table 2.26 and Model 26.1 in Table 2.25. Female spawning stock biomass trajectories for all scenarios for Model 26.1 are presented in Figure 2.70.

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2025, it does not provide the best estimate of OFL for 2026, because the mean 2026 catch under Scenario 6 is predicated on the 2025 catch being equal to the 2025 OFL, whereas the actual 2025 catch will likely be less than the 2025 OFL. Table 2.20 contains the appropriate one- and two-year ahead projections for both ABC and OFL.

Risk Table and ABC Recommendation

Development of the risk table in this assessment follows the approach described by Thompson (2021), which is an explicit attempt to view the risk table in the context of the probability that ABC exceeds the true-but-unknown OFL. The approach partitions this probability into internal and external components. The internal probability is routinely computed from the stock assessment model; for example, Table 2.20 indicates that if the 2027 catch were to equal the 2027 maxABC, the internal probability for Model 26.1 that catch exceeds the 2027 OFL is approximately 23.1% (see the line in the table labeled "Pr(maxABC>truOFL)"). The external probability cannot be computed from the stock assessment model, because it involves factors that are external to the stock assessment model, and hence is evaluated using the risk table.

Assessment-related considerations

Recognizing the SSC's recommendation that, "Risk scores should be specific to a given stock or stock complex", the assessment considerations will be limited to a comparison of the present assessment with previous assessments of the same stock. As a point of departure, the assessment considerations category was assigned a risk level of 1 in each of the five previous assessments.

The range expansion of the stock into the NBS made assessment modeling more difficult for a few years for a two main reasons: 1) the design-based methods for calculating the index did not allow for accurate or unbiased extrapolation into the newly surveyed area for historic data and 2) it was uncertain whether the expansion was a range extension or the discovery of a new population. However, with the development of the model-based methods (Thorson and Barnett 2017), it has become possible to treat the combined EBS and NBS surveys in a coherent fashion, eliminating the need to treat those surveys separately, either with or without explicit movement between areas. Spatial distribution concerns have now shifted to some extent toward movement between American and Russian jurisdictions and the western Gulf of Alaska. Although harvests in Russian waters have the potential to impact harvests in American waters if there is significant mixing between the two areas, the best available data suggest that recent harvest rates in Russian waters have continued to be above their long-term average (Table 2.4).

There is likely a need to spatially restructure the stock assessment for the Gulf of Alaska and Bering Sea and current genetics and tagging projects described in the introduction will help inform this effort.

Table 2.27 considers the possibility that stock dynamics are better represented by one model, but management advice is used from the other. The difference between the 2024 Model 24.1 and 2026 Model 26.1 in probable catch in 2027 and 2028 would be 36,847 t and 22,029 t.

If Model 26.1 represented the true dynamics of the stock and the 2024 Model 24.1 was used for management, the stock would be fished in 2027 at an F of 0.355 and in 2028 at 0.406. This fishing rate would drive the stock down to $B_{33\%}$ in 2028 instead of the expected status of $B_{35\%}$ (Figure 2.71). This mismatch would increase the probability of the stock being below B20% in 2028 and 2029 from < 0.01% to 0.05% in 2028 and 0.54% in 2029 and increase the probability

of the catch exceeding the true OFL from 23.1% in 2027 and 24.3% in 2028 to 50.7% and 83.1%.

Despite this uncertainty and slight increase in risk while managing the stock under Model 26.1, the assessment considerations were once again rated as level 1 – Normal as this concern is not considerably elevated above previous concerns.

Population dynamics considerations

Population dynamics considerations were assigned a risk level of 1 in each of the four previous assessments.

As noted above under "Time Series Results," nine out of the ten most recent (2016-2025) cohorts are estimated to have been below average. Although strings of poor recruitment are not unprecedented, they are at least somewhat concerning, as they may be harbingers of a long-term change in mean recruitment. While the time series of recruitment estimates are already part of the stock assessment model and therefore should not be considered as a reason for a risk table adjustment, the possibility of a long-term change in mean recruitment is not part of the stock assessment model.

The estimate of age 0+ biomass for 2027 is 0.63 standard deviations or -20% removed from the pre-2027 time series mean, and the estimate of female spawning biomass for 2027 is 0.41 standard deviations or -17% removed from the pre-2027 time series mean. The estimated rate of change in age 0+ biomass from 2026 to 2027 is +2%. The estimated rate of change in female spawning biomass from 2026 to 2027 is +3%. None of this suggests that abundance is "increasing or decreasing faster than has been seen recently".

Population dynamics considerations were once again rated as level 1 – Normal.

Ecosystem considerations

The following is a synthesis and interpretation of the most recent ecosystem and socioeconomic information available for EBS Pacific cod from the Eastern Bering Sea Ecosystem Status Report (ESR; Siddon 2026) and the Ecosystem and Socioeconomic Profile (ESP; Shotwell et al. 2026; Appendix 2.2). Note that the research referenced in the section below are all included in the Eastern Bering Sea ESR and not referenced independently in this document. Based on information presented in the 2026 Eastern Bering Sea ESR and the 2026 ESP, the overall ecosystem-related risk for EBS Pacific cod was assigned Level 1 – Normal .

Juvenile Pacific cod: Early life stages, recruitment, and survival

Environmental conditions during the egg, larval, and juvenile stages can influence Pacific cod recruitment through effects on egg and larval transport, prey availability, growth, and survival. Indicators for 2026 suggest generally favorable prey conditions, although cooler temperatures and changes in circulation may have affected the distribution and retention of early life stages. Direct indicators of juvenile Pacific cod abundance and survival remain limited.

Environmental processes

- Atmospheric circulation and sea ice: A weak Aleutian Low during winter 2025/2026 was associated with cooler Arctic air entering the EBS (Lemagie and Wang, 2026). Sea ice extent was above average for approximately six weeks during March–April, followed by

rapid retreat in late April (Thoman, 2026). These conditions may influence the timing of spring productivity and environmental conditions experienced by early life stages.

- Wind-driven transport: Spring winds favored northwestward and off-shelf Ekman transport (Hennon, 2026). Wind-driven circulation may affect the transport and retention of Pacific cod eggs and larvae and their subsequent distribution relative to suitable nursery habitats. However, the implications for 2026 recruitment have not been established.
- Sea surface temperatures: Spring to early summer (April–June) sea surface temperatures over the SEBS shelf were slightly below the long-term mean (Lemagie and Callahan, 2026). Cooler temperatures may affect egg development, larval growth, and the timing of prey availability, although the magnitude and direction of their effects on juvenile survival remain uncertain.

Prey availability and quality

- Primary productivity: Diatom abundance anomalies measured by the Continuous Plankton Recorder were above average during 2023–2025 (Ostle and Batten, 2026). Spring chlorophyll-a concentrations were above average across both the SEBS and NBS (Gann et al., 2026). These observations suggest favorable primary production supporting the planktonic food web, potentially benefiting prey resources for larval Pacific cod.
- Zooplankton abundance: Spring Rapid Zooplankton Assessments indicated adequate small copepod abundance and above-average large copepod abundance by late summer (Kimmel et al., 2026). Euphausiid abundance also increased relative to 2025 (Levine et al., 2026; Spear et al., 2026). These indicators suggest relatively favorable availability of potential prey for juvenile Pacific cod, although prey suitability varies with developmental stage and fish size.
- Zooplankton nutritional quality: Copepod and euphausiid lipid contents were above average in the SEBS in 2026 (Pinger et al., 2026). Higher lipid content suggests increased energy availability from these prey organisms, potentially supporting juvenile growth and condition.
- Benthic prey availability: Motile epifauna biomass remained more than one standard deviation above the long-term mean (Whitehouse, 2026). Elevated benthic prey biomass may benefit larger juveniles as their diets shift toward benthic organisms, although this indicator does not directly measure prey availability within juvenile Pacific cod habitats.

Competition and predation

- Pelagic forager competition: Pelagic forager biomass increased in 2026, primarily due to higher walleye pollock biomass (Whitehouse, 2026). Increased pollock abundance may increase competition for shared zooplankton prey, particularly during early juvenile stages. However, favorable zooplankton abundance and lipid content may have moderated potential competition.
- Sablefish: Strong recruitment from the 2020 and 2022 sablefish year classes has contributed to increased sablefish abundance. Potential overlap in the use of pelagic prey

resources could increase competition with juvenile Pacific cod, although the magnitude of this interaction remains uncertain.

- Jellyfish: Jellyfish biomass in the NBS continued a gradual decline but remained slightly above the long-term mean (Domke et al., 2026). In the SEBS, jellyfish biomass was approximately average in the bottom trawl survey (Buser 2026) and below average in BASIS observations (Domke et al., 2026). These indicators do not suggest an increase in potential jellyfish competition or predation on Pacific cod eggs and larvae.
- Predation on juvenile Pacific cod: Juvenile Pacific cod are potentially vulnerable to predation by larger fish and other predators. However, available ecosystem indicators do not provide sufficient information to quantify changes in juvenile Pacific cod predation mortality in 2026.

Juvenile ecosystem assessment

Environmental and prey indicators in 2026 suggest generally favorable conditions for juvenile Pacific cod, particularly with respect to planktonic and benthic prey availability and nutritional quality. However, cooler temperatures and changes in wind-driven transport may have altered egg and larval dispersal, retention, and early survival. Without direct estimates of juvenile Pacific cod abundance or survival, it is not possible to determine whether these conditions resulted in improved recruitment. Overall, the available indicators do not provide clear evidence of increased ecosystem-related concern for juvenile Pacific cod.

Adult Pacific cod: Distribution, condition, and survival

Adult Pacific cod are influenced by bottom temperature, the availability and distribution of fish and benthic prey, competition with other groundfish, and predation. In 2026, cooler bottom temperatures and an extensive cold pool coincided with a northwestern concentration of Pacific cod biomass, improved adult condition, decreased bottom trawl abundance, but increased bottom trawl survey biomass relative to 2025.

Distribution and environmental conditions

- Survey abundance, biomass, and distribution: Pacific cod abundance decreased but biomass increased in the 2026 standard EBS bottom trawl survey relative to 2025. Biomass was concentrated in the northwestern outer shelf domain, coincident with the expansion of the cold pool across the middle shelf. This redistribution may affect spatial availability to fisheries and surveys, complicating the interpretation of trends in abundance and fishery CPUE.
- Cold pool: The extent of the ≤2°C cold pool was approximately 150% greater than in 2025, representing the largest cold pool since 2012 (Rohan and Barnett, 2026). The extensive cold pool may have influenced Pacific cod habitat use and distribution, although the extent to which the observed spatial pattern resulted directly from cold-pool expansion remains uncertain.
- Bottom temperature: Bottom temperatures in 2026 were comparable to those observed during historically cool years, including 1986, 1992, 2006, and 2010 (Kearney, 2026). Cooler conditions may have reduced exposure to elevated temperatures experienced

during recent warm years. However, temperature effects on adult Pacific cod depend on thermal preferences, habitat availability, prey distributions, and other ecological factors.

- Ocean acidification: Bottom-water pH continued its multidecadal decline (Pilcher et al., 2026). Although direct effects on adult Pacific cod have not been established, continued acidification represents a potential longer-term concern through effects on habitat and prey communities.

Prey availability and fish condition

- Walleye pollock availability: Walleye pollock continued to be an important component of adult Pacific cod diets. In the SEBS, age-0 pollock abundance was below average, while age-1 abundance was relatively high (Andrews et al., 2026). Age-0 pollock energy density was above average (Page et al., 2026), and length-weight residuals of small pollock improved relative to previous years, although they remained slightly below the long-term mean (Prohaska and Rohan, 2026). In the NBS, age-0 pollock abundance was approximately average, but energy density was below average (Andrews et al., 2026; Page et al., 2026). These indicators suggest regional variation in both the abundance and nutritional quality of pollock prey.
- Benthic prey availability: Motile epifauna biomass remained more than one standard deviation above the long-term mean (Whitehouse, 2026). This indicates continued availability of potential benthic prey resources for Pacific cod, although biomass alone does not establish the spatial accessibility of these prey.
- Crab availability: Mature male and female Tanner crab biomass and mature female snow crab biomass were above their respective long-term means (Richar, 2026). However, consumption of snow and tanner crabs by Pacific cod remained low and was similar to 2025 (Aydin, 2026), suggesting that increased crab biomass did not translate into a substantial increase in their contribution to Pacific cod diets.
- Adult fish condition: Pacific cod length-weight residuals were above average in both 2025 and 2026, representing an improvement from below-average condition in 2024 (Prohaska and Rohan, 2026). This pattern is consistent with relatively favorable feeding or thermal conditions, although the respective contributions of prey availability, temperature, and spatial distribution cannot be distinguished.

Competition and predation

- Arrowtooth flounder and walleye pollock: Arrowtooth flounder biomass remained above the long-term mean, representing potential competition for shared benthic and demersal prey. Increased walleye pollock biomass may also affect competition for fish and invertebrate prey. However, favorable prey indicators and improved Pacific cod condition do not suggest widespread food limitation in 2026.
- Apex predator guild: Biomass of the apex predator guild increased between 2025 and 2026, primarily reflecting increased Pacific cod biomass, but remained below the long-term mean (Whitehouse, 2026). Guild-level biomass provides context for potential

ecological interactions but does not directly quantify competition or predation pressure on Pacific cod.

- Marine mammal predation: Steller sea lions and several whale species consume Pacific cod. Northern fur seal pup weights at St. Paul Island were more than one standard deviation above average, while maternal foraging trip durations were the shortest in the time series (McHuron et al., 2026). These indicators suggest favorable foraging conditions for fur seals but provide limited direct information on predation pressure on adult Pacific cod. Available data are insufficient to determine annual changes in marine mammal predation mortality on Pacific cod.

Adult ecosystem assessment

The available indicators suggest generally favorable conditions for adult Pacific cod in 2026. Increased bottom trawl survey biomass, above-average length-weight condition, and generally positive prey indicators provide little evidence of substantial food limitation or deteriorating adult condition. However, the extensive cold pool and concentration of Pacific cod biomass in the northwestern outer shelf indicate substantial spatial variability that could affect fishery and survey availability.

Although these distributional changes warrant continued monitoring, the available evidence does not indicate adverse ecosystem effects sufficient to justify an elevated risk designation for adult Pacific cod.

Overall ecosystem risk determination

Ecosystem indicators for 2026 suggest generally favorable prey conditions for juvenile Pacific cod and relatively favorable condition and prey availability for adult fish. The principal uncertainties differ among life stages. For juveniles, the effects of cooler spring temperatures, wind-driven transport, and prey conditions on recruitment and early survival remain poorly quantified. For adults, the primary concerns relate to substantial spatial redistribution, changing habitat availability, and the implications for survey abundance and fishery performance.

Despite these uncertainties, the available ecosystem indicators do not provide clear evidence of adverse conditions sufficient to warrant an elevated ecosystem risk designation. Accordingly, ecosystem considerations were assigned Level 1 – Normal .

Fishery-informed stock considerations

Fishery-informed stock considerations were assigned a risk level of 1 in each of the four previous assessments. Figure 2.8 shows simple annual averages of catch (in weight and number) per unit effort for all gears. CPUE by number has been relatively stable over the previous 7 years and CPUE by weight has been steadily declining since 2018 with small upticks in 2024 and 2026. Examining the monthly CPUE by gear shows a different pattern where although the winter fishery had relatively high CPUE, the September CPUE appears to be below the recent average (Figure 2.9).

Fishery performance considerations were once again rated as level 1 – Normal.

Summary and ABC Recommendation

The risk levels assigned to the four categories are summarized below:

Assessment-related considerations	*Population dynamics considerations*	*Ecosystem considerations*	*Fishery -informed stock considerations*
Level 1: Normal	Level 1: Normal	Level 1: Normal	Level 1: Normal

Note that normal does not mean no concern, simply that the concerns have not risen above the normal level of concern.

The authors do not have a recommendation for reduction in ABC from maximum.

Status Determination

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

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2025) is 138,925 t. This is less than the 2025 OFL of 183,509 t. Therefore, the EBS Pacific cod stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2026:

a. If spawning biomass for 2026 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2026 is estimated to be above $B_{35\%}$, the stock is above its MSST.

c. If spawning biomass for 2026 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 2.25). If the mean spawning biomass for 2036 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario 7 (Table 2.25):

a. If the mean spawning biomass for 2027 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2027 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2027 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2038. If the mean spawning biomass for 2038 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Table 2.25, the stock is not overfished and is not approaching an overfished condition.

To fulfill reporting requirements for the Species Information System, Model 26.1 was used to reverse-engineer the fishing mortality rate corresponding to the specified OFL for the last year with complete data (2025). The reverse-engineered F_{OFL} value ($RE\ F_{OFL}$) for Model 26.1 is 0.486523.

ECOSYSTEM CONSIDERATIONS

Ecosystem considerations are addressed in Appendix 2.2. Ecosystem and Socioeconomic Profile of the Pacific cod stock in the eastern Bering Sea - Report Card (Shotwell et al. 2026) and in the 2026 Ecosystem Status Report (Siddon 2026). Bycatch of prohibited species in the targeted Bering Sea Pacific cod fisheries is summarized in Table 2.28, while groundfish catch and catch of non-target species in the targeted Bering Sea Pacific cod fisheries, including seabirds, are summarized in Table 2.29 and Table 2.30.

DATA GAPS AND RESEARCH PRIORITIES

Substantial improvements in the quality and reliability of this assessment could be achieved by addressing several important data gaps and sources of uncertainty. Among the highest priorities is improving our understanding of the spatial dynamics of Pacific cod across the eastern, northern, and western Bering Sea and the western Gulf of Alaska. Recent observations suggest substantial, and potentially unprecedented, movements among these regions, raising questions about whether the spatial structure currently used for stock assessment and management adequately represents the underlying population structure. The potential mismatch between management boundaries and the biological distribution of Pacific cod may introduce bias and uncertainty into estimates of abundance, population dynamics, and stock status. Resolving these uncertainties should remain a high research priority.

Research should focus on identifying the environmental and biological factors influencing Pacific cod movement, determining how movement patterns and rates vary seasonally and interannually, quantifying the magnitude and direction of movement among regions, evaluating the extent of reciprocal exchange, and determining the contributions of fish from different regions to spawning populations and recruitment. Continued bottom trawl surveys in the northern Bering Sea are particularly important for tracking changes in distribution and abundance. Expanded genetic analyses, electronic tagging studies, and coordinated research with Russian scientists would further improve our understanding of stock connectivity and population structure. Particular emphasis should be placed on quantifying the potential effects of Pacific cod catches in Russian waters that are not explicitly represented in the current assessment. Given evidence of seasonal connectivity between the eastern and western Bering Sea, unaccounted removals of fish that contribute to the assessed population could affect estimates of abundance, survival, fishing mortality, and recruitment. The magnitude and direction of these effects remain

uncertain and depend on movement patterns, regional population structure, and the extent to which fish harvested in Russian waters contribute to the eastern Bering Sea stock. These efforts should be accompanied by continued development and evaluation of spatially explicit assessment models capable of representing movement, regional differences in population dynamics, and fishing removals across management boundaries.

Several additional biological and methodological uncertainties warrant continued investigation. Age determination remains an important concern, as assessment models consistently indicate a positive ageing bias, particularly during 2008–2013, when ageing methods were changing. Further evaluation of ageing error and potential temporal biases is needed to improve the interpretation of age composition data. Maturity is another important source of uncertainty because the assessment currently applies a static maturity-at-age relationship developed primarily from observations collected before 2007. Additional maturity data and analyses of temporal, cohort-specific, and environmentally driven variation would improve estimates of female spawning biomass and associated biological reference points. Improvements in the treatment of compositional data are also needed, particularly methods for estimating input sample sizes that account for among-sample variability. Bootstrap-based and model-based approaches should be further developed and evaluated for fishery age and length composition data.

The sensitivity of recent recruitment estimates to newly incorporated observations represents an additional research priority. The substantial revisions to several recent year classes following the addition of 2025 and 2026 data demonstrate that estimated year-class strength can change considerably as new information becomes available, with corresponding effects on projected biomass and management quantities. These revisions may reflect changes in the information available to estimate cohort abundance, but could also be influenced by unmodeled fishing removals and movement across management boundaries. In particular, catches in Russian waters may affect the apparent abundance and survival of cohorts contributing to the eastern Bering Sea stock, although their contribution to the observed recruitment revisions has not been established. Future analyses should evaluate the stability and predictive performance of recruitment estimates through retrospective cohort tracking and hindcasting, examine the relative influence of survey abundance indices and composition data, and investigate sensitivity to alternative assumptions about movement and fishing removals outside U.S. waters. Incorporating available Russian catch and biological data into spatially explicit assessment models would help evaluate these potential effects and better characterize uncertainty in short-term population projections.

Longer-term research priorities include improving our understanding of Pacific cod ecology in the eastern Bering Sea, particularly the relationships among spatial distribution, habitat use, trophic interactions, environmental conditions, and recruitment variability. Additional research is also needed on species taken as bycatch in Pacific cod fisheries and on species that interact with Pacific cod as predators, prey, or competitors. This work should include improved estimates of biomass, carrying capacity, resilience, and the strength of ecological interactions. Integrating these biological and ecological processes into future assessment frameworks would improve our ability to characterize population dynamics, evaluate uncertainty, and assess the consequences of environmental change and fishing on Pacific cod and the broader ecosystem.

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TABLES

Table 2.1. Summary of 1964-1980 catches (t) of Pacific cod in the eastern Bering Sea by fleet sector. "For." = foreign, "JV" = joint venture processing, "Dom." = domestic annual processing. Catches by gear are not available for these years. Catches may not always include discards.

Year	For.	JV	Dom.	Total
1964	13,408	0	0	13,408
1965	14,719	0	0	14,719
1966	18,200	0	0	18,200
1967	32,064	0	0	32,064
1968	57,902	0	0	57,902
1969	50,351	0	0	50,351
1970	70,094	0	0	70,094
1971	43,054	0	0	43,054
1972	42,905	0	0	42,905
1973	53,386	0	0	53,386
1974	62,462	0	0	62,462
1975	51,551	0	0	51,551
1976	50,481	0	0	50,481
1977	33,335	0	0	33,335
1978	42,512	0	31	42,543
1979	32,981	0	780	33,761
1980	35,058	8,370	2,433	45,861

Table 2.2. Summary of 1981-1990 catches (t) of Pacific cod in the eastern Bering Sea by fleet sector, and gear type. All catches include discards. "LLine" = longline, "Subt." = sector subtotal. Breakdown of domestic annual processing by gear is not available prior to 1988.

	Foreign			Joint Venture		Domestic Annual Processing				
Year	**Trawl**	**LLine**	**Subt.**	**Trawl**	**Subt.**	**Trawl**	**LLine**	**Pot**	**Subt.**	**Total**
1981	30,347	5,851	36,198	7,410	7,410	n/a	n/a	n/a	12,899	56,507
1982	23,037	3,142	26,179	9,312	9,312	n/a	n/a	n/a	25,613	61,104
1983	32,790	6,445	39,235	9,662	9,662	n/a	n/a	n/a	45,904	94,801
1984	30,592	26,642	57,234	24,382	24,382	n/a	n/a	n/a	43,487	125,103
1985	19,596	36,742	56,338	35,634	35,634	n/a	n/a	n/a	51,475	143,447
1986	13,292	26,563	39,855	57,827	57,827	n/a	n/a	n/a	37,923	135,605
1987	7,718	47,028	54,746	47,722	47,722	n/a	n/a	n/a	47,435	149,903
1988	0	0	0	106,592	106,592	93,706	2,474	299	96,479	203,071
1989	0	0	0	44,612	44,612	119,631	13,935	145	133,711	178,323
1990	0	0	0	8,078	8,078	115,493	47,114	1,382	163,989	172,067

Table 2.3. Summary of 1991-2026 catches (t) and percent retained (%) of Pacific cod in the EBS by gear type. Catches for 2026 are through October 3rd.

	Catch (t)					Percent retained (%)			
Year	Longline	Pot	Trawl	Other	Total	Longline	Pot	Trawl	Other
1991	77,506	3,342	129,394	0	210,242	98	100	88	0
1992	79,404	7,510	77,291	1	164,206	98	99	72	100
1993	49,297	2,094	81,793	2	133,186	95	99	65	100
1994	78,557	8,036	84,934	730	172,257	96	98	69	100
1995	97,664	19,277	110,954	600	228,495	96	99	68	100
1996	88,881	28,003	91,912	266	209,062	97	99	76	100
1997	117,010	21,490	93,924	171	232,595	97	100	82	96
1998	84,328	13,229	60,775	193	158,525	97	100	98	100
1999	81,470	12,397	51,897	100	145,864	98	100	97	100
2000	81,643	15,849	53,847	39	151,378	97	100	98	100
2001	90,365	16,472	35,649	53	142,539	98	100	98	100
2002	100,272	15,050	51,064	165	166,551	98	99	97	100
2003	108,670	19,936	46,673	155	175,434	98	99	98	100
2004	108,474	17,242	57,793	231	183,740	98	100	99	100
2005	113,127	17,096	52,600	104	182,927	98	100	99	100
2006	96,567	18,960	53,213	83	168,823	98	100	98	100
2007	77,136	17,237	45,672	82	140,127	98	100	99	100
2008	88,918	17,367	33,490	20	139,795	98	99	99	100
2009	96,595	13,611	36,954	12	147,172	98	100	99	100
2010	81,616	19,678	41,201	344	142,839	98	100	97	100
2011	116,762	27,995	63,926	506	209,189	98	100	99	100
2012	128,300	28,725	75,505	86	232,616	99	100	99	100
2013	124,814	30,249	81,614	14	236,691	97	100	98	100
2014	127,256	39,196	72,261	2	238,715	98	100	99	100
2015	128,191	37,937	66,665	28	232,821	98	100	99	100
2016	127,917	47,078	72,574	48	247,617	98	100	99	100
2017	122,774	46,182	68,876	13	237,845	98	100	99	100
2018	100,209	39,684	59,958	0	199,851	98	100	99	0
2019	88,780	41,056	49,018	49	178,903	98	100	99	100
2020	72,088	32,967	50,564	38	155,657	98	100	98	100
2021	57,256	25,693	38,764	20	121,733	98	100	95	100
2022	69,408	36,841	42,536	28	148,813	98	100	98	100
2023	66,819	34,915	41,780	22	143,536	98	100	99	100
2024	69,252	30,428	43,022	18	142,720	98	100	99	100
2025	62,707	35,180	41,038	0	138,925	98	100	99	0
2026*	46,222	27,241	44,552	0	118,015	99	100	99	0

Table 2.4. Pacific cod catch in the western Bering Sea Russian EEZ for 1977-2025. 1977-2001, 2001-2008 from Lajus et al. (2019). 2009-2025 catch data from the Russian Ministry of Fisheries annual reports, РОССИЙСКАЯ ФЕДЕРАЦИЯ: СВЕДЕНИЯ ОБ УЛОВЕ РЫБЫ И ДОБЫЧЕ ДРУГИХ ВОДНЫХ БИОРЕСУРСОВ (translation: RUSSIAN FEDERATION: INFORMATION ABOUT THE CATCH OF FISH AND THE EXTRACTION OF OTHER WATER BIORESOURCES).

Year	Catch (t)	Year	Catch (t)
1977	1,685	2002	18,919
1978	994	2003	20,992
1979	1,464	2004	23,988
1980	4,090	2005	17,769
1981	12,797	2006	17,631
1982	20,233	2007	16,239
1983	26,729	2008	18,312
1984	45,058	2009	13,993
1985	48,513	2010	22,423
1986	58,049	2011	24,358
1987	39,745	2012	25,360
1988	37,250	2013	25,250
1989	45,590	2014	28,530
1990	42,308	2015	28,130
1991	41,064	2016	30,240
1992	58,860	2017	40,220
1993	55,920	2018	61,450
1994	24,998	2019	92,090
1995	26,795	2020	106,200
1996	44,100	2021	94,400
1997	25,476	2022	62,700
1998	20,639	2023	55,011
1999	29,230	2024	34,190
2000	19,179	2025	40,041
2001	24,846		

Table 2.5. History of BSAI (1977-2013) and EBS (2014-2026) Pacific cod catch, TAC, Alaska State GHL (2016-2026), ABC, and OFL (t). Catch for 2026 is through October 3rd. Note that specifications through 2013 were for the combined BSAI region, so BSAI catch is shown rather than the EBS catches from Table 2.3 for the period 1977-2013. Source for historical specifications: NPFMC staff.

Year	Catch	TAC	ABC	OFL	Year	Catch	TAC	GHL	ABC	OFL
1977	35,597	58,000			2002	197,356	200,000		223,000	294,000
1978	45,838	70,500			2003	207,900	207,500		223,000	324,000
1979	39,354	70,500			2004	212,621	215,500		223,000	350,000
1980	51,649	70,500	148,000		2005	205,633	206,000		206,000	265,000
1981	63,941	78,700	160,000		2006	193,029	189,768		194,000	230,000
1982	69,501	78,700	168,000		2007	174,484	170,720		176,000	207,000
1983	103,231	120,000	298,000		2008	171,030	170,720		176,000	207,000
1984	133,084	210,000	291,000		2009	175,756	176,540		182,000	212,000
1985	150,384	220,000	347,000		2010	171,850	168,780		174,000	205,000
1986	142,511	229,000	249,000		2011	220,089	227,950		235,000	272,000
1987	163,110	280,000	400,000		2012	250,840	261,000		314,000	369,000
1988	208,236	200,000	385,300		2013	250,301	260,000		307,000	359,000
1989	182,865	230,681	370,600		2014	238,715	246,897		255,000	299,000
1990	179,608	227,000	417,000		2015	232,821	240,000		255,000	346,000
1991	220,038	229,000	229,000		2016	247,617	238,680	16,320	255,000	390,000
1992	207,278	182,000	182,000	188,000	2017	237,845	223,704	15,296	239,000	284,000
1993	167,391	164,500	164,500	192,000	2018	199,851	188,136	12,864	201,000	238,000
1994	193,802	191,000	191,000	228,000	2019	178,903	166,475	15,204	181,000	216,000
1995	245,033	250,000	328,000	390,000	2020	155,657	141,799	14,074	155,873	191,386
1996	240,676	270,000	305,000	420,000	2021	121,733	111,380	12,426	123,805	147,949
1997	257,765	270,000	306,000	418,000	2022	148,813	136,466	16,917	153,383	183,012
1998	193,256	210,000	210,000	336,000	2023	143,536	127,409	17,425	144,834	172,495
1999	173,998	177,000	177,000	264,000	2024	142,720	147,753	20,199	167,952	200,995
2000	191,060	193,000	193,000	240,000	2025	138,925	133,602	20,015	153,617	183,509
2001	176,749	188,000	188,000	248,000	2026	118,015	123,077	18,443	141,520	169,243

Table 2.6. Amendments to the BSAI Fishery Management Plan (FMP) that reference Pacific cod explicitly (excerpted from Appendix A of the FMP, except that Amendment 113, which is listed in Appendix A of the FMP, is omitted here, due to the fact that the final rule implementing that amendment was vacated by the U.S. District Court for the District of Columbia on March 21, 2019).

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

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

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

Amendment 24, implemented February 28, 1994, and effective through December 31, 1996:
1. Established the following gear allocations of BSAI Pacific cod TAC as follows: 2 percent to vessels using jig gear; 44.1 percent to vessels using hook-and-line or pot gear, and 53.9 percent to vessels using trawl gear.
2. Authorized the seasonal apportionment of the amount of Pacific cod allocated to gear groups. Criteria for seasonal apportionments and the seasons authorized to receive separate apportionments will be set forth in regulations.

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

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

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

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

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

(Continued on next page.)

Table 2.6. (Cont.) Amendments to the BSAI Fishery Management Plan (FMP) that reference Pacific cod explicitly (excerpted from Appendix A of the FMP).

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

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

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

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

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

Amendment 103, implemented November 14, 2014:

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

Amendment 109, implemented May 4, 2016:

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

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

Amendment 120, implemented December 20, 2019:

1. Limits the number of catcher/processors (C/Ps) eligible to operate as motherships receiving and processing Pacific cod from catcher vessels (CVs) directed fishing in the BSAI non-Community Development Quota Program Pacific cod trawl fishery.
2. Prohibits replaced Amendment 80 C/Ps from receiving and processing Pacific cod harvested and delivered by CVs directed fishing for Pacific cod in the BSAI and GOA.

(Continued on next page.)

Table 2.6. (Cont.) Amendments to the BSAI Fishery Management Plan (FMP) that reference Pacific cod explicitly (excerpted from Appendix A of the FMP).

Amendment 122, implemented September 7, 2023

Established the Pacific Cod Trawl Cooperative (PCTC) Program, a limited access privilege program for the BSAI Pacific cod trawl catcher vessel sector. The program:

1. Allocates Pacific cod quota share (QS) to qualifying License Limitation Program (LLP) license holders (77.5%) and processors (22.5%) based on historical participation in the fishery.
2. Requires QS holders to participate in cooperatives that receive annual allocations of Pacific cod cooperative quota (CQ) for the A and B fishing seasons, while maintaining the C season as a limited access fishery.
3. Establishes cooperative-specific halibut and crab prohibited species catch (PSC) limits and reduces PSC limits for the sector.
4. Establishes provisions for Pacific cod deliveries to Aleutian Islands shoreplants, sideboard limits for participants in other fisheries, quota transfer restrictions, ownership and use caps, and additional monitoring and reporting requirements.

Amendment 127, implemented October 30, 2024

Updated the identification and description of Essential Fish Habitat (EFH) for BSAI groundfish species, including Pacific cod, based on the 2023 five-year EFH review. The amendment:

1. Revised EFH descriptions and distribution maps using updated habitat information, species distribution models, and available life history data.
2. Updated information on the effects of fishing activities on EFH and potential adverse impacts from non-fishing activities.
3. Revised EFH conservation recommendations and identified updated habitat research and information needs.

Amendment 125, implemented May 1, 2026

Modified the BSAI Pacific cod jig sector to allow catcher vessels less than or equal to 55 feet length overall using hook-and-line or pot gear to harvest Pacific cod under the jig sector allocation during the jig gear A season (January 1 through April 30). Pacific cod harvested by these vessels during this period accrues to the jig sector allocation rather than the less than 60-foot hook-and-line or pot catcher vessel sector allocation. The amendment maintains the existing Pacific cod sector allocation percentages and reallocation provisions.

Table 2.7. Non-commercial catch of Pacific cod (kg) in the Bering Sea 2021-2024.

	2021	2022	2023	2024	Grand Total
AFSC Annual Longline Survey	26,629		16,365		42,985
Aleutian Island Bottom Trawl Survey		2,522		1,568	4,090
Bait for Crab Fishery	957,800	181,944	140,439	61,553	1,341,736
Blue King Crab Pot Survey		4,581			4,581
BSAI Trawl Salmon Excluder Device EFP 2018-03-02	2,041				2,041
Eastern Bering Sea Bottom Trawl Survey	22,500	24,334	25,464	19,812	92,110
EBS Walleye Pollock Acoustic-Trawl Survey		12		8	20
Gulf of Alaska Bottom Trawl Survey			225		225
IPHC Annual Longline Survey	26,513	32,881		17,738	77,132
Large-Mesh Trawl Survey	373	934	182	344	1,833
NBS Bottom Trawl Survey	7,616	4,987			12,603
Grand Total	1,043,473	252,195	182,666	101,022	1,579,356

Table 2.8. Number of otoliths and fish measured for length from the bottom trawl survey and fishery.

	Otoliths				Lengths	
Year	Survey Collected	Survey Aged	Fishery Collected	Fishery Aged	Survey	Fishery
1977						1,324
1978						11,683
1979						17,031
1980						17,939
1981						23,955
1982					10,863	9,658
1983					13,143	33,200
1984	782	316			12,133	45,635
1985					16,921	66,940
1986					15,872	58,257
1987					9,483	129,226
1988	639	639			6,765	111,065
1989	703	703			4,246	58,625
1990	793	793	4,500	1,073	5,428	39,698
1991	659	659	6,085	658	7,001	374,227
1992	717	717	2,333	368	10,129	344,923
1993	653	635	1,229		10,500	248,967
1994	731	715	7,050		12,931	359,147
1995	625	571	5,500	1	9,820	344,794
1996	733	711	2,087		9,348	445,217
1997	737	719	1,818		9,591	474,908
1998	694	635	1,433		9,574	438,746
1999	878	860	2,691		11,183	186,233
2000	883	860	3,797		12,170	199,708
2001	948	920	3,857		19,078	210,419
2002	889	870	3,871		11,897	230,802
2003	1,278	1,263	4,272		11,835	288,854
2004	1,017	995	3,668		10,437	237,487
2005	1,313	1,279	3,341		11,753	228,664
2006	1,316	1,300	3,714		12,530	179,782
2007	1,477	1,441	2,793	964	13,441	140,663
2008	1,229	1,213	10,243	1,324	15,064	164,860
2009	1,427	1,412	4,656	1,207	23,737	147,875
2010	1,475	1,467	5,501	1,176	20,688	131,514
2011	1,266	1,253	6,211	1,735	25,150	172,269
2012	1,307	1,301	15,182	983	29,828	192,273
2013	1,424	1,418	16,529	988	19,902	211,962
2014	1,441	1,420	17,758	987	29,204	234,476
2015	1,827	1,819	16,433	994	19,880	213,888
2016	1,634	1,624	14,100	987	19,180	182,980
2017	1,764	1,744	12,271	995	15,020	157,482
2018	1,352	1,339	9,729	985	8,806	124,004
2019	1,940	1,824	7,105		23,408	86,800
2020			5,511	414		65,301
2021	1,810	1,757	4,244	409	17,397	55,858
2022	1,806	1,781	6,024	395	16,677	72,426
2023	1,697	1,677	6,154	408	19,943	71,087
2024	1,345	1,309	7,171	393	12,950	85,645
2025	1,722	1,706	7,182		17,599	87,207
2026	1,334		3,609		12,273	49,154

Table 2.9. Number of hauls sampled and input composition sample sizes (survey includes EBS and NBS; units = hauls). * as of October 3rd, 2026

Year	Survey hauls	Survey Length Input	Survey Age Input	Fishery hauls	Fishery Length input	Year	Survey hauls	Survey Length Input	Survey Age Input	Fishery hauls	Fishery Length input
1977				92	6	2002	364	928	169	11,607	761
1978				147	10	2003	363	402	248	14,477	949
1979				181	12	2004	361	763	202	12,144	796
1980				187	12	2005	360	344	165	11,641	763
1981				212	14	2006	354	1074	454	9,078	595
1982	313	1175		106	7	2007	368	116	59	7,119	467
1983	255	334		393	26	2008	338	531	77	8,429	552
1984	264	1008		471	31	2009	360	249	145	7,465	489
1985	345	220		710	47	2010	405	369	49	6,652	436
1986	349	682		725	48	2011	368	411	53	8,739	573
1987	339	1141		1,328	87	2012	356	253	60	9,342	612
1988	339	1078		1,353	89	2013	354	237	68	11,094	727
1989	293	809		626	41	2014	373	294	143	12,129	795
1990	329	557		643	42	2015	354	808	88	11,200	734
1991	313	399		5,267	345	2016	376	1279	161	9,498	622
1992	332	256		5,195	340	2017	481	1846	156	8,317	545
1993	363	366		3,080	202	2018	364	1416	129	6,390	419
1994	364	494		4,839	317	2019	479	582	183	4,605	302
1995	347	880		5,258	345	2020		1659	191	3,526	231
1996	359	521		6,797	445	2021	476	1036	183	2,894	190
1997	369	643		7,216	473	2022	481	721	216	3,871	254
1998	362	1044		6,898	452	2023	438	1018	274	3,796	249
1999	336	861		9,171	601	2024	335	773	375	4,532	297
2000	355	507	168	9,966	653	2025	433	775	337	4,586	301
2001	366	581	232	10,581	693	2026*	337	928	169	2,555	154

Table 2.10. Aging error and aging bias with splined aging error.

Expected Age	1977-2007		2008-2026	
	Observed Age	Stdev	Observed Age	Stdev
0.5	0.595	0.180	0.5	0.180
1.5	1.786	0.180	1.5	0.180
2.5	2.977	0.301	2.5	0.301
3.5	4.167	0.381	3.5	0.381
4.5	5.358	0.439	4.5	0.439
5.5	6.549	0.492	5.5	0.492
6.5	7.739	0.563	6.5	0.563
7.5	8.930	0.670	7.5	0.670
8.5	10.121	0.815	8.5	0.815
9.5	11.312	0.993	9.5	0.993
10.5	12.502	1.204	10.5	1.204
11.5	13.693	1.325	11.5	1.325
12.5	14.884	1.445	12.5	1.445
13.5	16.074	1.565	13.5	1.565
14.5	17.265	1.686	14.5	1.686
15.5	18.456	1.806	15.5	1.806
16.5	19.646	1.927	16.5	1.927
17.5	20.837	2.047	17.5	2.047
18.5	22.028	2.168	18.5	2.168
19.5	23.218	2.288	19.5	2.288
20.5	24.409	2.408	20.5	2.408

Table 2.11. Model-based estimates of bottom trawl survey population estimates including estimates from 2026 and designed-based bottom trawl survey population abundance estimates in number of fish. Note that the design-based estimates are not used in the assessment models presented.

Year	Model-based				Design-based	
	2024 Survey Population	Survey sigma	2026 Survey population	Survey sigma	Survey population	Survey sigma
1982	715,517,329	0.057	732,944,936	0.063	584,527,764	0.065
1983	873,613,312	0.068	879,688,308	0.069	755,141,713	0.107
1984	706,333,724	0.052	706,857,454	0.051	653,144,367	0.073
1985	901,208,370	0.046	899,155,789	0.046	844,157,635	0.135
1986	885,008,114	0.048	884,883,083	0.048	840,829,831	0.100
1987	825,641,077	0.057	819,607,502	0.055	698,609,301	0.064
1988	546,100,589	0.044	544,682,850	0.044	512,360,646	0.070
1989	359,172,791	0.057	355,908,006	0.055	301,283,393	0.066
1990	472,140,589	0.051	469,760,200	0.050	439,009,229	0.084
1991	513,627,319	0.052	513,605,223	0.051	498,850,467	0.103
1992	558,055,506	0.057	555,202,214	0.057	587,304,178	0.117
1993	828,771,804	0.057	824,491,885	0.056	817,857,217	0.122
1994	1,174,742,378	0.049	1,178,403,094	0.049	1,260,690,444	0.122
1995	722,059,064	0.048	724,637,496	0.048	764,228,128	0.099
1996	613,005,030	0.060	607,110,595	0.057	615,809,467	0.143
1997	523,442,900	0.056	519,095,094	0.054	494,486,664	0.143
1998	619,556,656	0.071	611,062,122	0.067	524,149,999	0.090
1999	527,894,428	0.055	527,747,057	0.054	542,810,224	0.100
2000	518,416,637	0.056	514,241,065	0.053	489,723,432	0.090
2001	1,009,879,503	0.055	1,005,266,858	0.053	977,116,907	0.094
2002	631,717,077	0.071	623,194,136	0.067	545,304,209	0.099
2003	625,925,880	0.079	613,317,600	0.074	517,535,040	0.120
2004	492,384,586	0.081	485,251,184	0.076	405,251,778	0.085
2005	503,964,618	0.071	496,242,203	0.067	465,249,132	0.137
2006	440,786,736	0.046	439,487,628	0.046	407,949,964	0.059
2007	596,072,936	0.051	595,400,998	0.051	758,497,684	0.261
2008	483,587,514	0.051	482,495,859	0.051	494,359,349	0.101
2009	713,922,932	0.046	713,773,666	0.046	724,773,833	0.087
2010	752,482,556	0.049	753,409,284	0.049	908,910,263	0.130
2011	862,076,821	0.048	860,898,865	0.048	847,967,419	0.094
2012	1,053,714,988	0.059	1,053,236,501	0.059	996,959,219	0.092
2013	768,343,917	0.056	768,734,619	0.056	764,239,273	0.165
2014	1,230,165,174	0.068	1,220,904,785	0.067	1,134,482,396	0.127
2015	1,081,398,929	0.066	1,077,649,925	0.065	989,903,732	0.115
2016	941,485,483	0.094	928,212,916	0.090	662,074,754	0.093
2017	519,064,849	0.044	516,947,592	0.043	500,634,049	0.073
2018	527,814,198	0.063	523,774,655	0.062	249,081,430	0.071
2019	761,370,473	0.051	758,431,384	0.050	730,701,588	0.092
2021	607,307,846	0.056	602,154,082	0.053	551,453,353	0.072
2022	552,637,226	0.048	550,398,090	0.046	511,194,737	0.064
2023	620,365,123	0.046	620,583,063	0.046	607,932,837	0.073
2024	501,465,762	0.054	473,561,525	0.051	419,402,573	0.071
2025			582,761,855	0.047	537,886,704	0.068
2026			426,270,267	0.048	391,636,211	0.081

Table 2.12. Designed-based biomass estimates for the AFSC bottom trawl survey 1987-2026 and relative population number (RPN) estimates for the AFSC longline survey Bering Sea region 1997-2026. Note that these are not used in any assessment model.

	EBS		NBS		Total		AFSC Longline	
Year	Biomass (t)	CV	Biomass (t)	CV	Biomass (t)	CV	RPN	CV
1982	1,013,625	0.073			1,013,625	0.073		
1983	1,189,533	0.102			1,189,533	0.102		
1984	1,014,756	0.062			1,014,756	0.062		
1985	1,001,620	0.056			1,001,620	0.056		
1986	1,118,640	0.062			1,118,640	0.062		
1987	1,064,504	0.060			1,064,504	0.060		
1988	975,197	0.079			975,197	0.079		
1989	866,777	0.072			866,777	0.072		
1990	727,806	0.072			727,806	0.072		
1991	530,731	0.073			530,731	0.073		
1992	539,064	0.083			539,064	0.083		
1993	670,773	0.080			670,773	0.080		
1994	1,379,428	0.179			1,379,428	0.179		
1995	1,010,002	0.091			1,010,002	0.091		
1996	910,374	0.096			910,374	0.096		
1997	627,118	0.109			627,118	0.109	204,250	0.099
1998	551,408	0.078			551,408	0.078		
1999	618,730	0.091			618,730	0.091	139,390	0.105
2000	537,449	0.080			537,449	0.080		
2001	827,408	0.088			827,408	0.088	168,872	0.135
2002	597,450	0.106			597,450	0.106		
2003	625,549	0.099			625,549	0.099	203,096	0.124
2004	578,018	0.058			578,018	0.058		
2005	638,154	0.068			638,154	0.068	109,534	0.210
2006	543,533	0.053			543,533	0.053		
2007	450,305	0.078			450,305	0.078	119,105	0.139
2008	427,423	0.065			427,423	0.065		
2009	430,461	0.082			430,461	0.082	95,553	0.222
2010	872,777	0.118	29,126	0.226	901,904	0.114		
2011	913,952	0.073			913,952	0.073	143,786	0.182
2012	899,909	0.113			899,909	0.113		
2013	813,804	0.092			813,804	0.092	171,225	0.245
2014	1,098,193	0.140			1,098,193	0.140		
2015	1,111,980	0.135			1,111,980	0.135	157,996	0.193
2016	986,144	0.078			986,144	0.078		
2017	644,508	0.078	287,551	0.127	932,060	0.066	124,913	0.147
2018	507,316	0.058			507,316	0.058		
2019	517,141	0.044	365,005	0.147	882,146	0.066	94,496	0.141
2020								
2021	616,380	0.049	227,582	0.178	843,962	0.060	108,312	0.216
2022	647,400	0.065	153,735	0.130	801,135	0.058		
2023	663,075	0.056	108,346	0.146	771,421	0.053	73,822	0.181
2024	610,697	0.057			610,697	0.057		
2025	548,400	0.054	66,693	0.144	615,093	0.050		
2026	621,664	0.096			621,664	0.096	98,112	0.239

Table 2.13. Estimated parameter values and standard deviations for 2024 Model 24.1, 2026 Model 24.1 and Model 26.1 The full list of parameters and deviations can be found in Appendix 2.4.

	2024 Model 24.1		2026 Model 24.1		Model 26.1	
Label	Est.	Stdev.	Est.	Stdev.	Est.	Stdev.
$L_{1.5}$	13.851	0.323	13.342	0.397	13.356	0.390
Lmax	112.260	3.437	112.146	3.241	110.745	2.907
Richards_K	0.115	0.013	0.116	0.013	0.121	0.012
Richards ρ	1.486	0.074	1.488	0.069	1.468	0.066
LN(R_0)	13.341	0.042	13.283	0.042	13.284	0.042
SR_regime_1976	-0.647	0.235	-0.667	0.226	-0.665	0.227
Early_InitAge_20	-0.005	0.689	-0.005	0.666	—	—
Early_InitAge_19	-0.003	0.690	-0.003	0.667	—	—
Early_InitAge_18	-0.005	0.689	-0.005	0.666	—	—
Early_InitAge_17	-0.008	0.688	-0.007	0.666	—	—
Early_InitAge_16	-0.013	0.686	-0.012	0.664	—	—
Early_InitAge_15	-0.020	0.684	-0.018	0.662	—	—
Early_InitAge_14	-0.031	0.680	-0.029	0.659	-0.070	0.646
Early_InitAge_13	-0.048	0.675	-0.045	0.654	-0.044	0.654
Early_InitAge_12	-0.073	0.667	-0.068	0.647	-0.068	0.647
Early_InitAge_11	-0.109	0.657	-0.103	0.637	-0.103	0.637
Early_InitAge_10	-0.156	0.644	-0.150	0.625	-0.151	0.624
Early_InitAge_9	-0.215	0.629	-0.208	0.610	-0.214	0.609
Early_InitAge_8	-0.281	0.614	-0.274	0.595	-0.277	0.595
Early_InitAge_7	-0.341	0.600	-0.337	0.581	-0.341	0.580
Early_InitAge_6	-0.372	0.591	-0.372	0.572	-0.372	0.572
Early_InitAge_5	-0.325	0.593	-0.331	0.573	-0.332	0.572
Early_InitAge_4	-0.149	0.604	-0.160	0.583	-0.164	0.582
Early_InitAge_3	0.064	0.599	0.054	0.577	0.054	0.576
Early_InitAge_2	-0.001	0.606	-0.013	0.583	-0.011	0.583
Early_InitAge_1	0.079	0.652	0.052	0.625	0.056	0.624
InitF	0.087	0.029	0.095	0.031	0.094	0.031
Ln (Q_{BT})	-0.013	0.056	0.015	0.052	0.014	0.052
Q_{BT} extra SD	0.093	0.019	0.087	0.018	0.086	0.018
Fishery peak selectivity 1990-2026	74.624	0.938	74.465	0.888	74.382	0.885
Fishery ascending slope width 1990-2026	5.965	0.042	5.959	0.040	5.959	0.040
Fishery peak selectivity 1977-1989	74.691	5.668	74.687	5.512	74.628	5.533
Fishery ascending slope width 1977-1989	6.456	0.268	6.459	0.261	6.459	0.262
Survey peak selectivity	22.450	1.117	20.971	1.321	21.011	1.293
Survey ascending slope width	3.993	0.256	3.766	0.334	3.775	0.327

Table 2.14. "Sigma" terms for vectors of annual random deviations other than those associated with catchability. Deviations are ~normal(0,σ^2) for ln(Recruits), ~normal(0,1) for others.

	2024 Model 24.1			2026 Model 24.1			Model 26.1		
Parameter	**var_dev**	**ave_var**	**sigma**	**var_dev**	**ave_var**	**sigma**	**var_dev**	**ave_var**	**sigma**
ln(R)	0.4453	0.0359	0.6908	0.4066	0.0441	0.6679	0.4040	0.0438	0.6679
$L_{1.5}$	0.3836	0.6323	0.2903	0.3318	0.6543	0.2810	0.3316	0.6537	0.2810
Richard's K	0.2037	0.8025	0.0624	0.2775	0.7257	0.0772	0.2775	0.7263	0.0772
Sur. Sel. Asc.	0.4015	0.7315	0.2338	0.4833	0.5315	0.3973	0.4848	0.5303	0.3973

Table 2.15. Objective function values (negative log likelihood) and parameter counts as well as selected results for 2026 proposed models.

Label	2024 Model 24.1	2026 Model 24.1	Model 26.1
# parameters	174	184	178
Final gradient	0.0×10^{14}	0.0×10^{14}	0.0×10^{14}
TOTAL like	246.832	266.338	266.520
Survey like	-59.0658	-64.3449	-64.4093
Length comp like	222.633	241.900	242.046
Age comp like	57.439	61.1517	61.3539
Francis TA1.8 Variance adjustment factors			
Fishery length	0.428	0.446	0.446
Survey length	0.194	0.222	0.222
Survey age	0.454	0.486	0.486
Jitter % success	84%	88%	90%
Index RMSE	0.146	0.138	0.138
SDNR			
Survey Age	0.90	0.90	0.90
Survey Length	0.98	1.00	1.00
Fishery Length	0.84	0.85	0.85
LN(R_0)	13.3409	13.2832	13.2841
σ_R	0.6908	0.6679	0.6679
Natural mortality (M)	0.387	0.387	0.387
Lmax	112.260	112.146	110.745
$L_{1.5}$	13.851	13.342	13.356
Richards K	0.115	0.116	0.121
Bratio 2025	0.384	0.342	0.341
SPRratio 2025	0.571	0.585	0.593
Q Bottom trawl survey	0.987	1.015	1.014
Q sd ajustment	0.093	0.087	0.086
$B_{100\%}$ (t)	561,915	539,445	546,405
$F_{40\%}$	0.363	0.360	0.354
maxABC 2027	140,135	124,251	123,787
maxABC 2028	149,985	118,879	118,299

Jitter % success = percent of 50 jitter runs at 0.1 jitter that successfully converged at the MLE.
RMSSR = Root of the mean squared standardized residual (>1 = underfit, <1 overfit)
LN(R_0) = the natural log of the equilibrium virgin recruits at age-0
$B_{100\%}$ = equilibrium unfished female spawning biomass
$F_{40\%}$ = fishing mortality that reduces equilibrium spawning per recruit to 40% of unfished
maxABC = maximum permissible ABC under Tier 3

Table 2.16. Parameter counts in the models.

Model	2024 Model 24.1	2026 Model 24.1	Model 26.1
Early recruitment deviations	20	20	14
Main recruitment deviations	46	50	50
Length at age 1.5 deviations	25	27	27
K deviations	25	27	27
Selectivity (survey) deviations	43	45	45
Annual deviations	159	169	163
Growth	4	4	4
Stock-recruitment	2	2	2
Initial fishing mortality	1	1	1
Log catchability (survey)	2	2	2
Selectivity (fishery)	4	4	4
Selectivity (survey)	2	2	2
TRUE parameters	15	15	15
Total parameters	174	184	178

Table 2.17. Likelihoods by fleet for all models.

Label	All	fishery	survey	Model
Age_like	57.439	0	57.439	2024 Model 24.1
Age_like	61.152	0	61.152	2026 Model 24.1
Age_like	61.354	0	61.354	Model 26.1
Catch_like	6.862e-11	6.862e-11	0	2024 Model 24.1
Catch_like	1.196e-10	1.196e-10	0	2026 Model 24.1
Catch_like	1.052e-10	1.052e-10	0	Model 26.1
Init_equ_like	0.00017	0.00017	0	2024 Model 24.1
Init_equ_like	0.000231	0.000231	0	2026 Model 24.1
Init_equ_like	0.000225	0.000225	0	Model 26.1
Length_like	222.633	119.365	103.269	2024 Model 24.1
Length_like	241.900	128.435	113.465	2026 Model 24.1
Length_like	242.046	128.924	113.122	Model 26.1
Surv_like	-59.066	0	-59.066	2024 Model 24.1
Surv_like	-64.345	0	-64.345	2026 Model 24.1
Surv_like	-64.409	0	-64.409	Model 26.1

Table 2.18. Fits to size composition and age composition data with (Nave) adjusted average input sample size, the (Har. Mean EffN) harmonic mean of the effective sample size, and the ratio of the two.

Model	Data	Nave	Har. Mean Effn	Ratio
2024 Model 24.1	Fishery Length	154.982	157.306	1.015
2026 Model 24.1	Fishery Length	161.844	161.612	0.999
Model 26.1	Fishery Length	161.844	161.823	1.000
2024 Model 24.1	Survey Length	138.364	141.252	1.021
2026 Model 24.1	Survey Length	155.002	148.861	0.960
Model 26.1	Survey Length	155.002	149.045	0.962
2024 Model 24.1	Survey Age	70.087	52.403	0.748
2026 Model 24.1	Survey Age	82.559	62.668	0.759
Model 26.1	Survey Age	82.559	62.631	0.759

Table 2.19. Retrospective Mohn's rho values for spawning stock biomass (SSB) and full selection fishing mortality (F) for all models.

Models	2024 Model 24.1	2026 Model 24.1	Model 26.1
SSB Mohn's	-0.10	0.03	0.03
SSB Predictive	-0.15	0.01	0.02
F Mohn's	0.13	0.00	-0.01

F Predictive	0.19	0.03	0.02

Table 2.20. Management reference point for 2024 Model 24.1, 2026 Model 24.1, and Model 26.1.

	2024 Model 24.1	2026 Model 24.1		Model 26.1	
	Est.	Est.	cv	Est.	cv
$B_{100\%}$	561,915	539,445	0.033	546,405	0.033
$B_{40\%}$	224,767	215,778	0.033	218,562	0.033
$B_{35\%}$	196,670	188,805	0.033	191,242	0.033
$F_{40\%}$	0.363	0.360	0.047	0.354	0.045
$F_{35\%}$	0.444	0.441	0.050	0.433	0.048
2027 Female spawning biomass	204,037	189,735	0.126	192,115	0.126
2027 Relative spawning biomass	0.363	0.352	0.113	0.352	0.113
2027 Pr(B/B100%<0.2)		0.012%		0.012%	
2027 $maxF_{ABC}$	0.328	0.314	0.128	0.309	0.127
2027 maxABC	140,135	124,251	0.226	123,787	0.227
2027 Catch	140,135	124,251	0.226	123,787	0.227
2027 F_{OFL}	0.328	0.385	0.129	0.378	0.128
2027 OFL	140,135	148,667	0.224	148,179	0.224
2027 Pr(maxABC>truOFL)		23.2%		23.1%	
2028 Female spawning biomass	209,904	185,798	0.088	187,929	0.088
2028 Relative spawning biomass	0.374	0.344	0.073	0.344	0.073
2028 Pr(B/B100%<0.2)		<0.001		<0.001%	
2028 $maxF_{ABC}$	0.338	0.307	0.084	0.302	0.085
2028 maxABC	149,985	118,879	0.153	118,299	0.153
2028 Catch	149,985	118,879	0.153	118,299	0.153
2028 F_{OFL}	0.398	0.376	0.134	0.369	0.133
2028 OFL	160,001	142,311	0.237	141,676	0.237
2028 Pr(maxABC>truOFL)		24.3%		24.3%	

Legend:
$B_{100\%}$ = equilibrium unfished female spawning biomass
$B_{40\%}$ = 40% of B100% (the inflection point of the harvest control rules in Tier 3)
$B_{35\%}$ = 35% of B100% (the BMSY proxy for Tier 3)
$F_{40\%}$ = fishing mortality that reduces equilibrium spawning per recruit to 40% of unfished
$F_{35\%}$ = fishing mortality that reduces equilibrium spawning per recruit to 35% of unfished
Relative spawning biomass = ratio of female spawning biomass to $B_{100\%}$
Pr($B/B_{100\%}$<0.2) = probability that relative spawning biomass is less than 0.2
$maxF_{ABC}$ = maximum permissible ABC fishing mortality rate under Tier 3
maxABC = maximum permissible ABC under Tier 3
Catch = estimated catch conditional on ABC=maxABC
F_{OFL} = OFL fishing mortality rate under Tier 3
OFL = OFL under Tier 3
Pr(maxABC>truOFL) = probability that maxABC is greater than the "true" OFL

Table 2.21. Female spawning biomass (t) time series comparison for 2024 Model 24.1, 2026 Model 24.1, and Model 26.1. 2027 values based on an estimated 2026 total catch of 133,475 t.

	2024 Model 24.1	2026 Model 24.1		Model 26.1			2024 Model 24.1	2026 Model 24.1		Model 26.1	
Year	Est.	Est.	Stdev.	Est.	Stdev.	Year	Est.	Est.	Stdev.	Est.	Stdev.
1978	165,991	149,207	44,756	149,388	47,204	2003	184,756	172,801	14,083	174,317	14,223
1979	168,090	150,793	43,306	149,912	44,842	2004	193,897	187,015	13,789	188,456	13,907
1980	190,833	172,512	42,171	151,667	43,409	2005	186,819	183,035	12,903	184,352	13,001
1981	257,826	239,710	40,898	173,262	42,296	2006	163,753	162,112	12,070	163,273	12,173
1982	352,521	335,081	41,136	239,881	40,932	2007	136,737	136,053	10,932	137,023	11,023
1983	439,046	421,883	40,873	334,801	41,021	2008	115,022	112,526	9,744	113,382	9,825
1984	472,651	455,590	39,340	421,636	40,712	2009	105,534	102,043	10,232	102,806	10,308
1985	456,011	439,288	36,480	455,479	39,196	2010	116,758	113,489	10,625	114,340	10,723
1986	430,656	415,714	32,713	439,117	36,350	2011	143,535	138,475	12,992	139,396	13,083
1987	418,469	406,109	28,933	415,620	32,617	2012	170,574	161,384	14,492	162,291	14,585
1988	411,910	402,135	25,474	406,279	28,897	2013	200,427	188,539	15,755	189,699	15,863
1989	384,457	377,179	22,650	402,722	25,512	2014	220,434	202,506	18,167	203,639	18,262
1990	342,855	336,845	20,472	378,163	22,744	2015	263,139	247,299	20,572	248,506	20,665
1991	280,354	274,046	18,388	338,036	20,590	2016	305,675	288,168	24,691	289,370	24,755
1992	203,719	196,719	16,294	276,350	18,649	2017	340,486	318,456	26,377	319,673	26,441
1993	175,431	168,540	14,641	198,500	16,486	2018	346,635	318,540	25,939	319,792	26,005
1994	189,119	183,032	13,569	170,086	14,819	2019	327,393	297,984	24,118	299,152	24,191
1995	203,348	197,883	12,859	184,339	13,703	2020	285,052	257,939	21,500	259,097	21,599
1996	208,069	202,919	12,307	199,117	12,986	2021	242,603	215,331	19,402	216,246	19,489
1997	210,698	205,873	12,153	204,327	12,476	2022	231,997	201,150	18,220	202,664	18,416
1998	181,424	176,778	11,944	207,261	12,307	2023	225,886	189,206	17,693	190,663	17,865
1999	162,336	158,255	11,909	178,131	12,109	2024	224,653	183,663	18,237	185,387	18,464
2000	160,865	157,706	12,457	159,481	12,063	2025	218,076	184,256	19,753	186,337	20,055
2001	169,948	160,612	12,651	158,979	12,607	2026	—	184,260	21,229	186,171	21,504
2002	178,553	166,591	12,950	162,031	12,797	2027	—	189,735	23,864	192,115	24,225

Table 2.22. Total biomass (t) time series comparison for 2024 Model 24.1, this 2026 Model 24.1, and Model 26.1. 2027 values based on an estimated 2026 total catch of 133,475 t

Year	2024 Model 24.1 Est.	2026 Model 24.1 Est.	Model 26.1 Est.	Year	2024 Model 24.1 Est	2026 Model 24.1 Est.	Model 26.1 Est.
1978	550,282	589,753	474,780	2003	758,441	712,896	716,482
1979	655,838	839,799	493,936	2004	732,029	703,564	706,849
1980	909,972	1,119,810	590,018	2005	661,502	642,174	645,120
1981	1,192,160	1,318,230	837,073	2006	573,115	558,151	560,767
1982	1,387,590	1,383,860	1,116,420	2007	496,234	481,665	483,833
1983	1,448,190	1,370,420	1,315,880	2008	488,525	470,051	471,853
1984	1,431,710	1,355,320	1,382,790	2009	544,238	523,342	525,099
1985	1,410,450	1,328,720	1,369,540	2010	636,989	612,497	614,026
1986	1,378,320	1,338,290	1,354,550	2011	774,572	744,104	745,695
1987	1,380,590	1,290,400	1,328,340	2012	846,214	798,475	800,101
1988	1,323,240	1,121,740	1,338,900	2013	944,966	881,983	883,787
1989	1,149,090	933,019	1,292,520	2014	1,049,020	967,914	969,650
1990	958,850	788,641	1,124,710	2015	1,185,160	1,107,160	1,108,820
1991	816,098	696,454	936,010	2016	1,271,800	1,193,230	1,195,140
1992	726,438	707,272	793,312	2017	1,243,690	1,158,300	1,160,590
1993	736,082	781,296	700,035	2018	1,122,320	1,030,460	1,032,800
1994	810,303	843,924	710,658	2019	983,014	890,940	893,181
1995	871,297	806,279	784,109	2020	877,304	780,121	782,129
1996	830,130	729,092	846,757	2021	837,339	728,550	730,266
1997	749,380	630,404	809,833	2022	829,640	708,893	711,915
1998	650,029	638,083	732,652	2023	807,840	676,678	679,495
1999	656,580	653,547	633,625	2024	804,068	675,262	678,626
2000	671,559	641,750	641,221	2025	782,614	670,426	674,600
2001	680,977	680,181	657,083	2026	—	657,887	661,876
2002	729,587	589,753	645,391	2027	—	671,662	676,864

Table 2.23. Age 0 recruitment (1000x of fish) time series comparison for 2024 Model 24.1, 2026 Model 24.1, and Model 26.1.

Year	2024 Model 24.1 Est.	2026 Model 24.1 Est.	2026 Model 24.1 Stdev.	Model 26.1 Est.	Model 26.1 Stdev.	Year	2024 Model 24.1 Est	2026 Model 24.1 Est.	2026 Model 24.1 Stdev.	Model 26.1 Est.	Model 26.1 Stdev.
1978	1,005,390	934,096	409,123	940,566	404,137	2003	319,878	315,421	40,488	315,638	40,471
1979	982,446	949,226	209,107	951,760	207,293	2004	273,704	250,630	36,060	250,996	36,064
1980	249,826	236,440	64,998	238,110	64,927	2005	440,262	424,548	59,581	424,447	59,442
1981	236,934	240,359	60,077	240,716	59,985	2006	933,032	924,338	93,868	923,424	93,495
1982	1,341,750	1,290,690	126,288	1,288,420	125,782	2007	389,806	351,071	76,790	351,843	76,746
1983	303,002	319,684	96,693	319,994	96,408	2008	1,554,170	1,492,700	140,522	1,487,250	139,473
1984	1,218,170	1,162,030	111,095	1,163,250	110,975	2009	289,488	298,515	103,274	299,898	103,248
1985	478,916	502,911	64,832	505,930	64,845	2010	987,372	923,719	124,938	921,280	124,038
1986	278,068	252,661	39,336	254,485	39,435	2011	1,359,690	1,285,690	146,972	1,283,390	146,115
1987	97,798	79,201	21,860	79,705	21,950	2012	705,064	667,379	120,205	666,708	119,772
1988	342,990	351,257	51,736	351,489	51,658	2013	1,504,940	1,422,830	123,238	1,422,440	122,953
1989	815,342	759,775	90,415	758,053	89,923	2014	274,996	255,375	64,121	255,578	64,105
1990	744,006	743,442	94,090	744,211	93,782	2015	422,232	402,709	60,931	403,275	60,939
1991	463,598	453,058	80,930	453,124	80,554	2016	247,918	221,168	47,566	221,491	47,590
1992	1,142,840	1,097,990	91,427	1,097,320	91,142	2017	263,956	221,784	50,805	221,746	50,715
1993	360,670	366,707	57,921	368,837	57,789	2018	1,050,520	859,737	85,655	858,452	85,410
1994	301,424	295,991	46,226	297,747	46,197	2019	262,854	246,328	49,694	246,421	49,658
1995	263,606	276,213	44,566	276,564	44,442	2020	474,678	417,986	55,693	417,905	55,622
1996	955,230	907,612	75,082	908,151	75,075	2021	564,534	533,496	65,752	533,161	65,653
1997	424,290	435,873	52,899	437,176	52,903	2022	420,396	422,574	55,630	422,640	55,595
1998	321,116	300,322	50,016	301,086	50,062	2023	629,438	328,757	52,976	329,117	52,995
1999	745,128	705,471	69,556	705,425	69,471	2024	629,438	534,683	76,798	535,659	76,895
2000	691,694	664,132	61,733	664,424	61,673	2025	—	333,541	163,014	334,068	163,075
2001	323,094	315,954	44,275	316,212	44,249	2026	—	547,637	368,057	547,988	368,237
2002	370,938	358,725	42,454	359,022	42,448						

Table 2.24. Instantaneous apical fishing mortality comparison for 2024 Model 24.1, 2026 Model 24.1, and Model 26.1. 2026 F based on an estimated catch of 133,475 t.

Year	2024 Model 24.1 Est.	2026 Model 24.1 Est.	2026 Model 24.1 Stdev.	Model 26.1 Est.	Model 26.1 Stdev.	Year	2024 Model 24.1 Est	2026 Model 24.1 Year	2026 Model 24.1 Stdev.	Model 26.1 Est.	Model 26.1 Stdev.
1977	0.090	0.098	0.031	0.097	0.031	2002	0.465	0.474	0.043	0.468	0.043
1978	0.113	0.123	0.037	0.122	0.037	2003	0.463	0.469	0.042	0.463	0.041
1979	0.083	0.091	0.026	0.090	0.025	2004	0.463	0.465	0.039	0.460	0.038
1980	0.067	0.071	0.016	0.071	0.016	2005	0.492	0.496	0.040	0.491	0.040
1981	0.076	0.080	0.015	0.080	0.015	2006	0.529	0.535	0.046	0.529	0.045
1982	0.064	0.066	0.011	0.066	0.011	2007	0.529	0.538	0.050	0.533	0.049
1983	0.088	0.090	0.012	0.090	0.012	2008	0.632	0.650	0.068	0.643	0.067
1984	0.118	0.121	0.014	0.121	0.014	2009	0.672	0.695	0.077	0.687	0.076
1985	0.143	0.147	0.016	0.146	0.016	2010	0.547	0.566	0.061	0.559	0.060
1986	0.141	0.144	0.016	0.143	0.016	2011	0.667	0.695	0.074	0.688	0.073
1987	0.157	0.160	0.017	0.160	0.017	2012	0.615	0.642	0.065	0.635	0.064
1988	0.219	0.223	0.024	0.222	0.024	2013	0.558	0.585	0.059	0.579	0.058
1989	0.212	0.215	0.021	0.214	0.021	2014	0.497	0.520	0.052	0.515	0.051
1990	0.258	0.263	0.018	0.261	0.018	2015	0.404	0.418	0.041	0.414	0.040
1991	0.421	0.430	0.035	0.426	0.034	2016	0.373	0.388	0.037	0.385	0.037
1992	0.440	0.450	0.043	0.445	0.042	2017	0.331	0.348	0.032	0.345	0.032
1993	0.369	0.376	0.035	0.372	0.035	2018	0.281	0.299	0.026	0.297	0.026
1994	0.433	0.439	0.037	0.434	0.036	2019	0.277	0.298	0.026	0.296	0.026
1995	0.545	0.551	0.043	0.545	0.042	2020	0.287	0.312	0.029	0.310	0.028
1996	0.478	0.482	0.036	0.477	0.035	2021	0.255	0.284	0.027	0.283	0.027
1997	0.559	0.564	0.043	0.559	0.042	2022	0.318	0.367	0.037	0.364	0.036
1998	0.444	0.449	0.037	0.444	0.036	2023	0.307	0.367	0.038	0.364	0.038
1999	0.450	0.453	0.041	0.448	0.040	2024	0.360	0.372	0.041	0.368	0.040
2000	0.456	0.460	0.042	0.454	0.041	2025	—	0.358	0.042	0.354	0.041
2001	0.407	0.414	0.038	0.409	0.037	2026	—	0.338	0.042	0.334	0.042

Table 2.25. Standard harvest scenarios for Model 26.1

Female spawning biomass (t)							
Yr	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**
2027	192,115	192,115	192,115	192,115	192,115	192,115	192,115
2028	187,929	187,929	182,755	197,266	228,877	180,036	187,929
2029	183,965	183,965	174,333	198,724	261,795	172,596	183,965
2030	185,057	185,057	170,142	202,386	293,333	172,532	177,757
2031	194,892	194,892	170,496	213,379	328,478	182,041	184,011
2032	208,339	208,339	171,280	228,143	368,493	194,812	195,286
2033	217,769	217,769	170,180	240,809	404,449	203,292	203,222
2034	222,841	222,841	168,850	251,030	438,041	207,335	207,206
2035	225,696	225,696	167,791	258,206	467,711	208,521	208,454
2036	227,074	227,074	166,983	262,604	490,735	208,477	208,456
2037	227,700	227,700	166,456	265,182	507,875	208,221	208,219
2038	228,150	228,150	166,288	267,000	523,890	208,160	208,160
2039	228,226	228,226	166,079	267,760	532,600	208,030	208,029
2040	228,415	228,415	166,122	268,522	542,275	208,091	208,089
2041	228,522	228,522	166,054	268,991	549,680	208,117	208,116
Full selection F							
2027	0.3090	0.3090	0.3538	0.2317	0	0.3781	0.309
2028	0.3018	0.3018	0.3538	0.2383	0	0.3529	0.3018
2029	0.2951	0.2951	0.3538	0.2402	0	0.3373	0.3611
2030	0.2969	0.2969	0.3538	0.2449	0	0.3372	0.3481
2031	0.3137	0.3137	0.3538	0.2589	0	0.357	0.3612
2032	0.3366	0.3366	0.3538	0.2656	0	0.3837	0.3847
2033	0.3527	0.3527	0.3538	0.2656	0	0.4014	0.4012
2034	0.3541	0.3541	0.3538	0.2656	0	0.4098	0.4095
2035	0.3541	0.3541	0.3538	0.2656	0	0.4123	0.4121
2036	0.3541	0.3541	0.3538	0.2656	0	0.4122	0.4122
2037	0.3541	0.3541	0.3538	0.2656	0	0.4117	0.4117
2038	0.3541	0.3541	0.3538	0.2656	0	0.4115	0.4115
2039	0.3541	0.3541	0.3538	0.2656	0	0.4113	0.4113
2040	0.3541	0.3541	0.3538	0.2656	0	0.4114	0.4114
2041	0.3541	0.3541	0.3538	0.2656	0	0.4114	0.4114
Catch (t)							
2027	123,787	123,787	139,752	95,177	0	148,179	123,787
2028	118,299	118,299	133,045	99,591	0	130,953	118,299
2029	113,589	113,589	127,416	100,741	0	121,185	136,096
2030	116,936	116,936	126,065	105,782	0	123,662	130,272
2031	131,576	131,576	127,008	119,055	0	139,808	142,259
2032	150,333	150,333	127,196	130,635	0	159,948	160,445
2033	163,343	163,343	126,161	137,427	0	173,074	172,873
2034	166,977	166,977	125,145	142,383	0	178,994	178,764
2035	168,543	168,543	124,431	145,643	0	180,516	180,407
2036	169,266	169,266	123,947	147,577	0	180,301	180,269
2037	169,589	169,589	123,650	148,685	0	179,867	179,863
2038	169,812	169,812	123,548	149,434	0	179,752	179,753
2039	169,853	169,853	123,440	149,756	0	179,569	179,568
2040	169,944	169,944	123,455	150,057	0	179,654	179,652
2041	169,996	169,996	123,420	150,240	0	179,688	179,688

Table 2.26. Standard harvest scenarios 2026 Model 24.1.

Female Spawning Biomass							
Yr	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**
2027	189,735	189,735	189,735	189,735	189,735	189,735	189,735
2028	185,798	185,798	180,845	195,116	226,710	177,933	185,798
2029	181,711	181,711	172,508	196,404	259,462	170,422	181,711
2030	182,876	182,876	168,481	200,100	291,085	170,460	175,605
2031	192,667	192,667	168,888	211,009	326,115	179,950	181,861
2032	205,531	205,531	169,321	224,976	363,567	192,266	192,670
2033	215,251	215,251	168,465	237,934	399,859	200,985	200,889
2034	220,227	220,227	167,139	248,043	432,026	204,952	204,806
2035	222,985	222,985	166,017	254,973	458,887	206,037	205,955
2036	224,417	224,417	165,257	259,375	480,337	206,036	206,006
2037	225,131	225,131	164,796	262,046	496,962	205,834	205,829
2038	225,485	225,485	164,536	263,625	509,690	205,697	205,699
2039	225,655	225,655	164,391	264,525	519,030	205,638	205,640
2040	225,738	225,738	164,315	265,037	525,980	205,624	205,625
2041	225,779	225,779	164,275	265,325	531,125	205,625	205,625
Full selection F							
2027	0.3144	0.3144	0.3582	0.2358	0	0.3847	0.3144
2028	0.3075	0.3075	0.3582	0.2429	0	0.3593	0.3075
2029	0.3003	0.3003	0.3582	0.2446	0	0.3432	0.3674
2030	0.3024	0.3024	0.3582	0.2495	0	0.3433	0.3543
2031	0.3196	0.3196	0.3582	0.2639	0	0.3637	0.3678
2032	0.3422	0.3422	0.3582	0.2702	0	0.3901	0.391
2033	0.3593	0.3593	0.3582	0.2702	0	0.4089	0.4087
2034	0.3602	0.3602	0.3582	0.2702	0	0.4174	0.4171
2035	0.3602	0.3602	0.3582	0.2702	0	0.4197	0.4195
2036	0.3602	0.3602	0.3582	0.2702	0	0.4197	0.4197
2037	0.3602	0.3602	0.3582	0.2702	0	0.4193	0.4193
2038	0.3602	0.3602	0.3582	0.2702	0	0.419	0.419
2039	0.3602	0.3602	0.3582	0.2702	0	0.4189	0.4189
2040	0.3602	0.3602	0.3582	0.2702	0	0.4188	0.4188
2041	0.3602	0.3602	0.3582	0.2702	0	0.4188	0.4188
Catch (t)							
2027	124,251	124,251	139,606	95,559	0	148,677	124,251
2028	118,879	118,879	133,022	100,194	0	131,460	118,879
2029	113,942	113,942	127,370	101,193	0	121,438	136,465
2030	117,363	117,363	126,051	106,298	0	124,018	130,624
2031	132,130	132,130	127,025	119,662	0	140,324	142,736
2032	150,482	150,482	127,063	130,869	0	160,152	160,566
2033	164,029	164,029	126,144	137,873	0	173,787	173,552
2034	167,471	167,471	125,123	142,867	0	179,679	179,426
2035	169,018	169,018	124,374	146,089	0	181,081	180,951
2036	169,780	169,780	123,908	148,054	0	180,920	180,878
2037	170,150	170,150	123,640	149,214	0	180,550	180,545
2038	170,331	170,331	123,493	149,886	0	180,328	180,333
2039	170,418	170,418	123,414	150,264	0	180,240	180,244
2040	170,461	170,461	123,373	150,477	0	180,223	180,225
2041	170,481	170,481	123,352	150,595	0	180,227	180,228

Table 2.27. Management scenarios and probabilities derived from assuming catch using the 2024 Model 24.1 recommended values for 2027 and 2028 but using Model 26.1 model dynamics as true.

Value	2026 Model 26.1
$Catch_{2027}$	140,135
$Catch_{2028}$	149,985
$Bratio_{2028}$	0.334
F_{2027}	0.355
F_{2028}	0.406
$F_{2027}/F_{35\%}$	0.819
$F_{2028}/F_{35\%}$	0.936
$Pr(B_{2028} < B_{20\%})$	0.05%
$Pr(B_{2029} < B_{20\%})$	0.54%
$Pr(Catch_{2027}>OFL_{2027})$	50.7%
$Pr(Catch_{2028}>OFL_{2028})$	83.1%

Table 2.28. Bycatch of prohibited species in the Pacific cod target fishery 2022-2026. All values but halibut are in numbers, halibut values are in tons.

	2022	2023	2024	2025	2026
Bairdi Tanner Crab (#)	110,091	72,885	86,780	163,548	91,621
Blue King Crab (#)	4,563	1,144	1,522	11,258	1,874
Chinook Salmon (#)	269	1,202	954	758	491
Golden (Brown) King Crab (#)	2,859	2,483	122	171	2,337
Halibut (t)	348	349	318	413	357
Herring (#)	0	1	0	0	1
Non-Chinook Salmon (#)	100	77	105	351	216
Opilio Tanner (Snow) Crab (#)	67,081	54,841	61,795	83,464	71,653
Red King Crab (#)	147,538	91,807	31,143	27,362	78,148

Table 2.29. Catch of groundfish in the targeted Bering Sea Pacific cod fisheries. Catch of <0.1t is not included in table. Catch for 2026 is through October 11th, 2026.

Species	2022	2023	2024	2025	2026
cod, Pacific (gray)	129,890.6	125,128.7	125,645.6	125,138.9	101,359.9
skate, other	12,474.8	10,105.5	11,461.5	10,735.6	7,207.2
skate, Alaskan	9,768.8	9,579.8	10,524.4	7,965.4	5,645.7
pollock, walleye	6,260.5	7,182.4	6,690.3	6,427.2	6,042.4
sole, rock	661.6	1,313.9	1,651.0	2,722.1	1,557.0
flounder, arrowtooth	391.7	599.5	1,189.4	1,162.2	924.9
sole, flathead	536.7	552.9	757.3	886.8	615.8
sole, yellowfin	810.1	431.9	638.7	818.8	616.4
skate, Aleutian	485.5	1,122.4	485.1	265.3	139.8
octopus, North Pacific	149.4	101.6	226.6	292.6	156.4
sole, butter	45.1	149.3	145.4	438.9	129.7
skate, big	49.6	135.2	183.6	133.8	77.6
groundfish, general	336.7	51.6	43.7	76.3	70.6
sablefish (blackcod)	185.9	126.9	194.8	41.8	18.3
flounder, starry	33.8	186.5	111.9	179.1	41.1
skate, Whiteblotched	102.5	166.0	109.1	66.6	39.9
Kamchatka flounder	47.7	63.5	77.7	71.8	62.1
rockfish, northern	23.5	25.2	32.4	40.1	21.0
greenling, atka mackerel	67.9	9.0	17.4	29.2	6.3
sole, rex	18.2	25.1	36.2	12.7	16.6
rockfish, dusky	13.0	11.0	15.7	46.1	21.0
rockfish, other	8.5	15.2	20.3	32.8	14.3
flounder, Alaska plaice	9.7	8.6	20.5	21.0	21.5
turbot, Greenland	12.5	27.9	12.5	8.0	18.4
Pacific sleeper shark	20.0	12.6	11.6	10.2	6.2
sole, English	1.2	33.3	0.2	0.4	0.1
flounder, general	15.4	7.6	6.5		0.0
rockfish, rougheye	3.6	3.8	3.9	5.7	1.8
perch, Pacific ocean	2.8	1.7	1.6	5.3	2.7
sole, sand	0.1	1.1	6.4	5.5	0.3
rockfish, shortraker	2.0	2.7	2.2	3.6	1.6
shark, spiny dogfish	0.9	3.6	3.2	2.0	1.0
rockfish, black	0.9	1.5	0.8	2.6	2.5
shark, salmon	3.0	2.4	1.1	0.5	
rockfish, thornyhead (idiots)	0.3	0.2	1.5	3.3	0.5
skate, longnose		0.4	3.3	0.9	0.3
sole, dover	1.8	1.5	0.2	0.1	0.5
halibut, Pacific	0.6	1.8	0.0	0.0	0.0
shark, other	1.0		0.1	0.1	0.1
rockfish, yelloweye (red snapper)	0.1	0.0	0.2	0.1	0.2
rockfish, redstripe				0.3	
rockfish, yellowtail		0.2			
Bering flounder		0.0			0.2
rockfish, quillback				0.0	0.1
rockfish, silvergray			0.1		
rockfish, widow		0.1			0.0
Grand Total	162,438.2	157,194.4	160,333.9	157,653.8	124,842.3

Table 2.30. Catch of non-target species in the targeted Bering Sea Pacific cod fisheries. Catch of <0.1t is not included in table. All species except birds in tons, birds are in number and not included in the bottom total weight. Catch for 2026 is through October 11th, 2026.

Species	2022	2023	2024	2025	2026
Birds (#)	3,264	2,611	4,515	4,499	1,126
Benthic urochordata	0.6	3.6	16.4	6.0	1.6
Bivalves	5.4	4.2	6.5	9.3	11.2
Brittle star unidentified	0.1	0.4	0.2	0.6	0.2
Corals Bryozoans - Corals Bryozoans Unidentified	3.0	0.9	3.8	6.8	2.1
Eelpouts	0.3	0.5	1.4	8.2	0.2
Giant Grenadier	9.2	2.8	1.5	6.9	
Greenlings	0.4	1.3	0.6	1.0	0.1
Grenadier - Rattail Grenadier Unidentified	0.0		0.1		
Hermit crab unidentified	1.5	1.1	0.9	1.5	2.4
Invertebrate unidentified	4.8	10.3	2.4	5.1	1.9
Misc crabs	16.5	20.0	2.3	7.2	3.8
Misc crustaceans	0.0	1.5	0.9	0.1	0.0
Misc fish	25.4	45.6	46.0	58.3	32.7
Misc inverts (worms etc)	0.0	0.0	0.0	0.1	0.1
Pacific Hake	0.5				
Pacific Sandfish	0.0		0.1	0.4	0.0
Saffron Cod	0.7	0.2	0.4	0.0	
Sculpin	2477.4	2058.1	2360.2	2390.1	682.5
Scypho jellies	97.0	98.9	122.1	89.7	104.3
Sea anemone unidentified	63.6	64.0	151.1	239.9	87.1
Sea pens whips	33.8	19.4	49.9	48.3	29.6
Sea star	472.4	332.9	357.5	360.3	108.1
Snails	34.1	35.7	46.5	53.9	11.1
Sponge unidentified	1.6	0.7	2.3	2.0	0.7
Squid	3.6	0.0	0.0	2.2	0.0
State-managed Rockfish	0.1	0.1	0.0	0.0	
Stichaeidae	0.0			1.3	
urchins dollars cucumbers	1.5	2.5	4.6	2.7	1.6
Total	3253.4	2704.8	3177.6	3302.1	1081.4

FIGURES

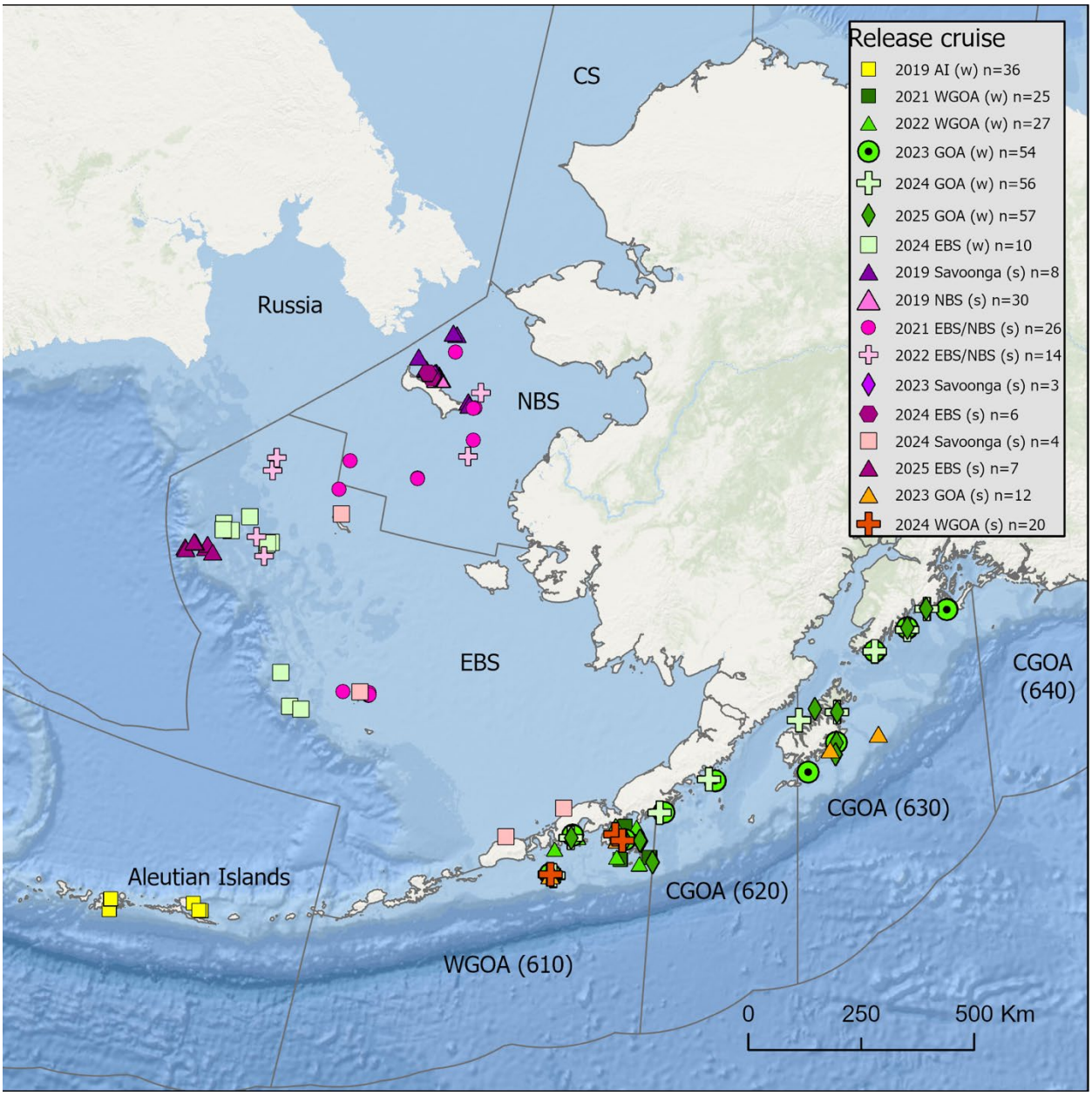


Figure 2.1. Release locations of 395 Pop-up Satellite Archival Tags (PSATs) in Alaska during 2019 - 2025. Release cruises occurred during the winter (w; color coded in green), or summer (s: color coded in purple), with sample size of PSATs deployed on Pacific cod indicated for each cruise.

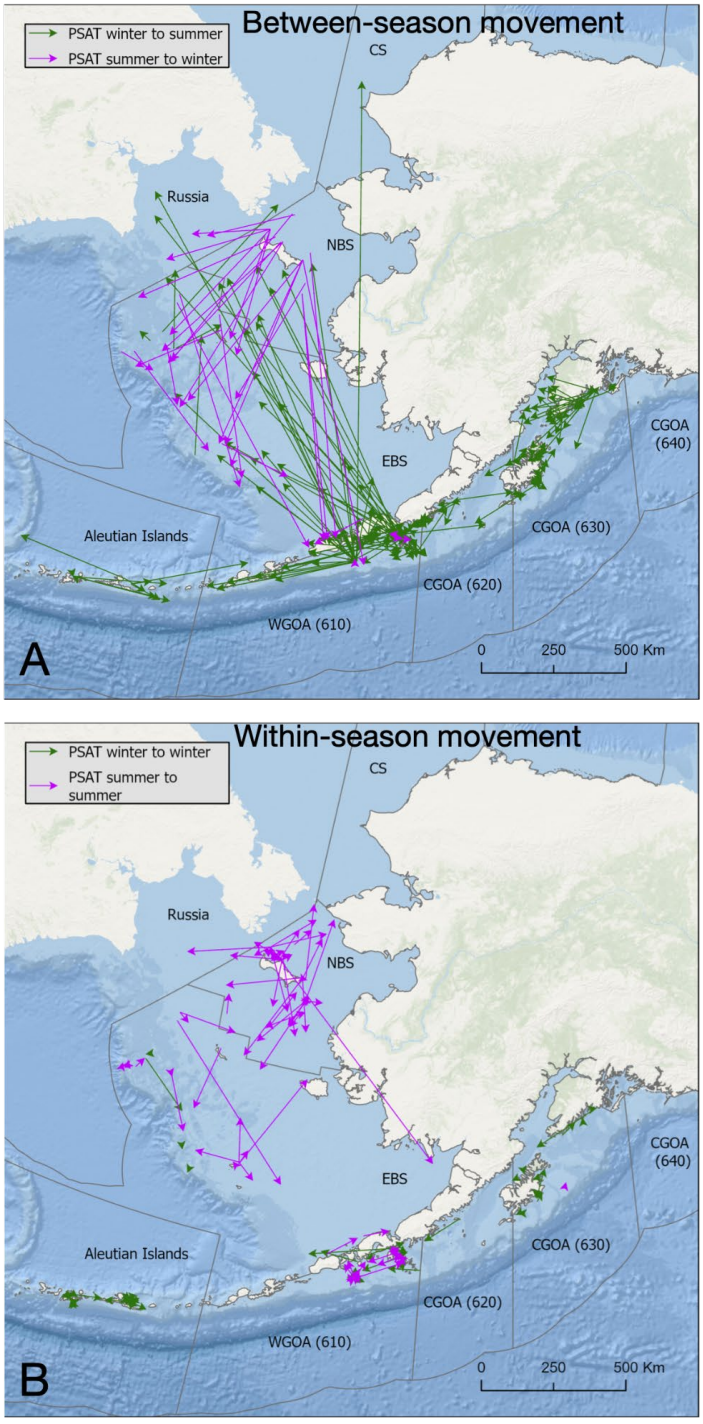


Figure 2.2. PSAT pop-up locations by A) between-season movement (winter spawning to summer foraging, green lines, and summer foraging to winter spawning, purple lines) and B) within-season movement (winter to winter, green lines, and summer to summer, purple lines). Winter is defined as January through April.

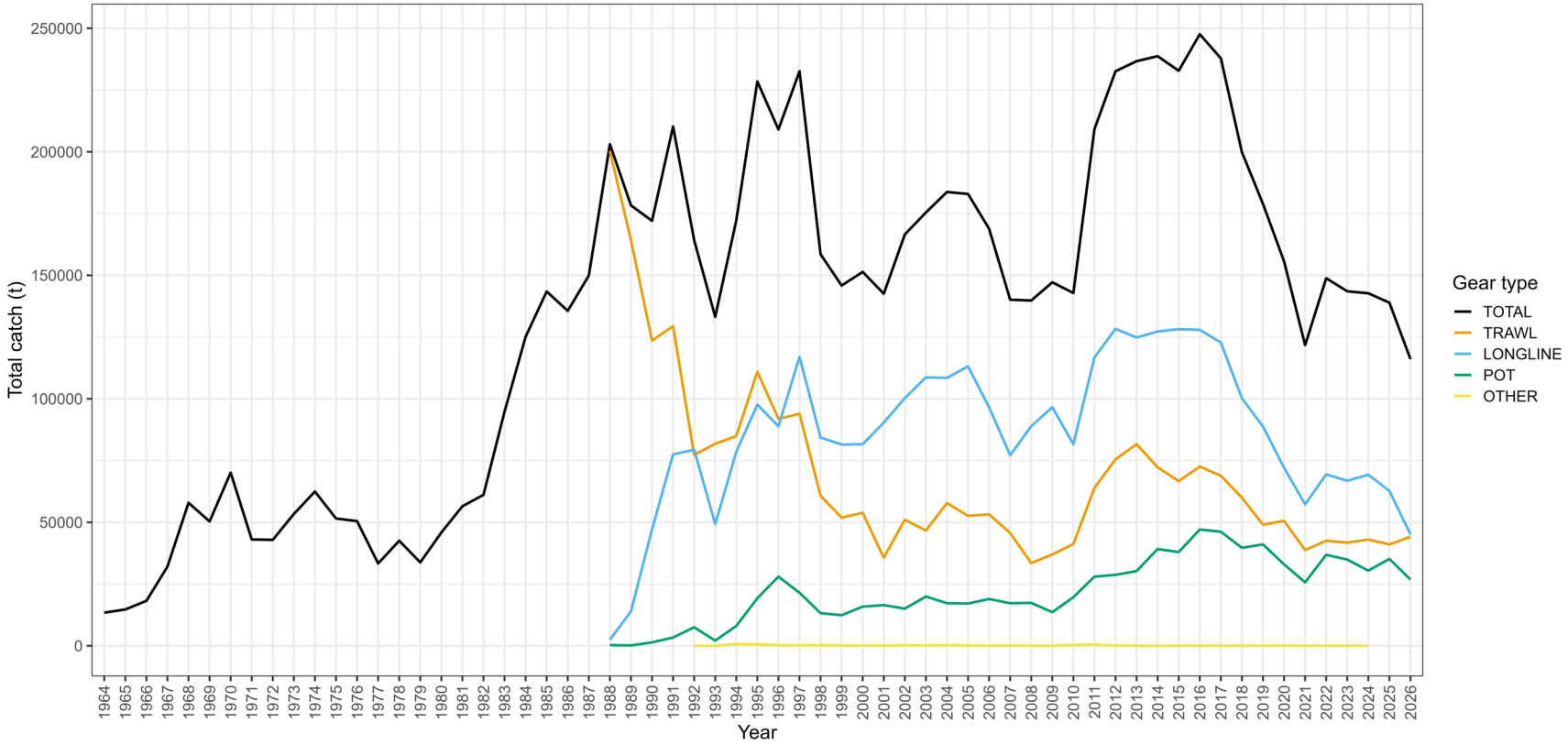


Figure 2.3. Total catch and catch by gear type. Catch for 2026 is through September 28th.

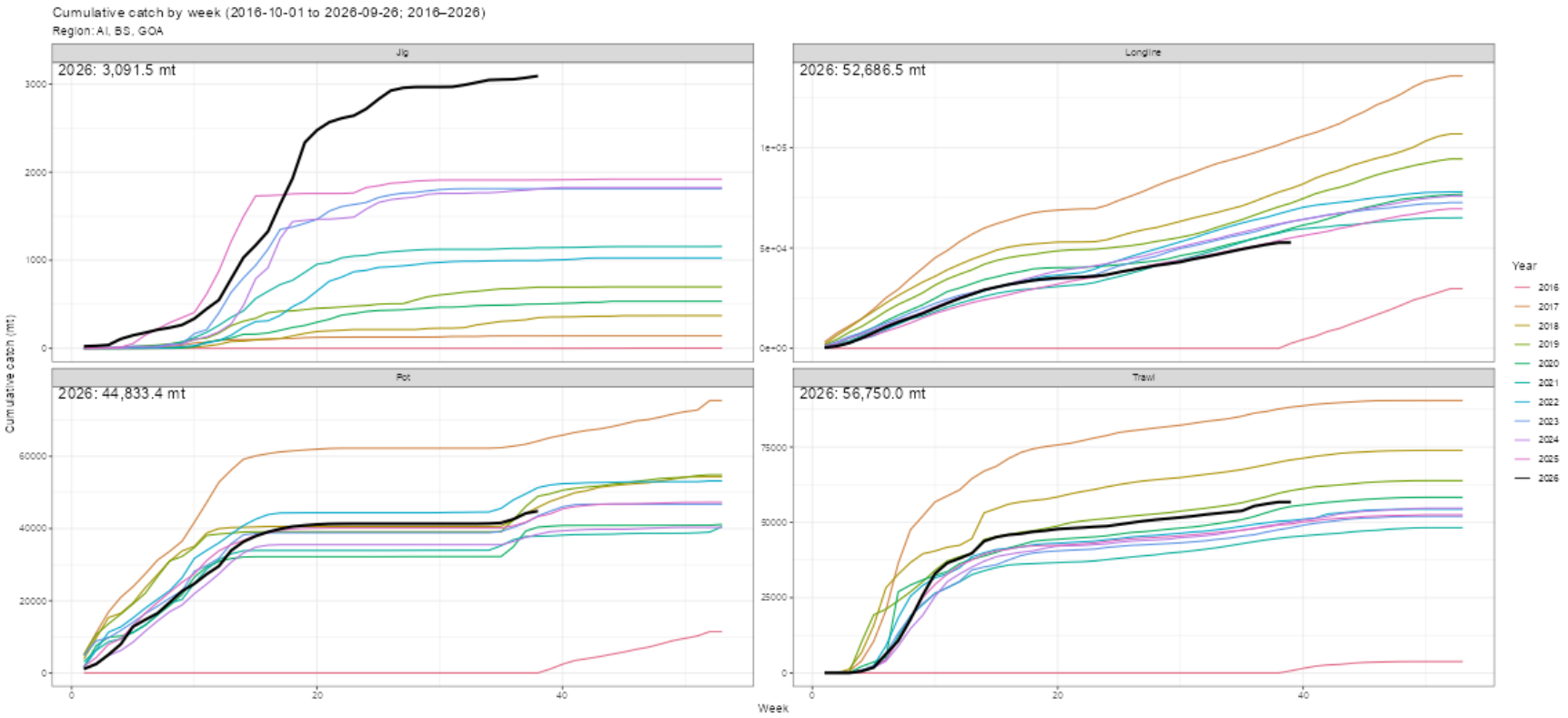


Figure 2.4. Cumulative Pacific cod catch by gear type for 2016-2026. Data for 2026 are current through September 28th.

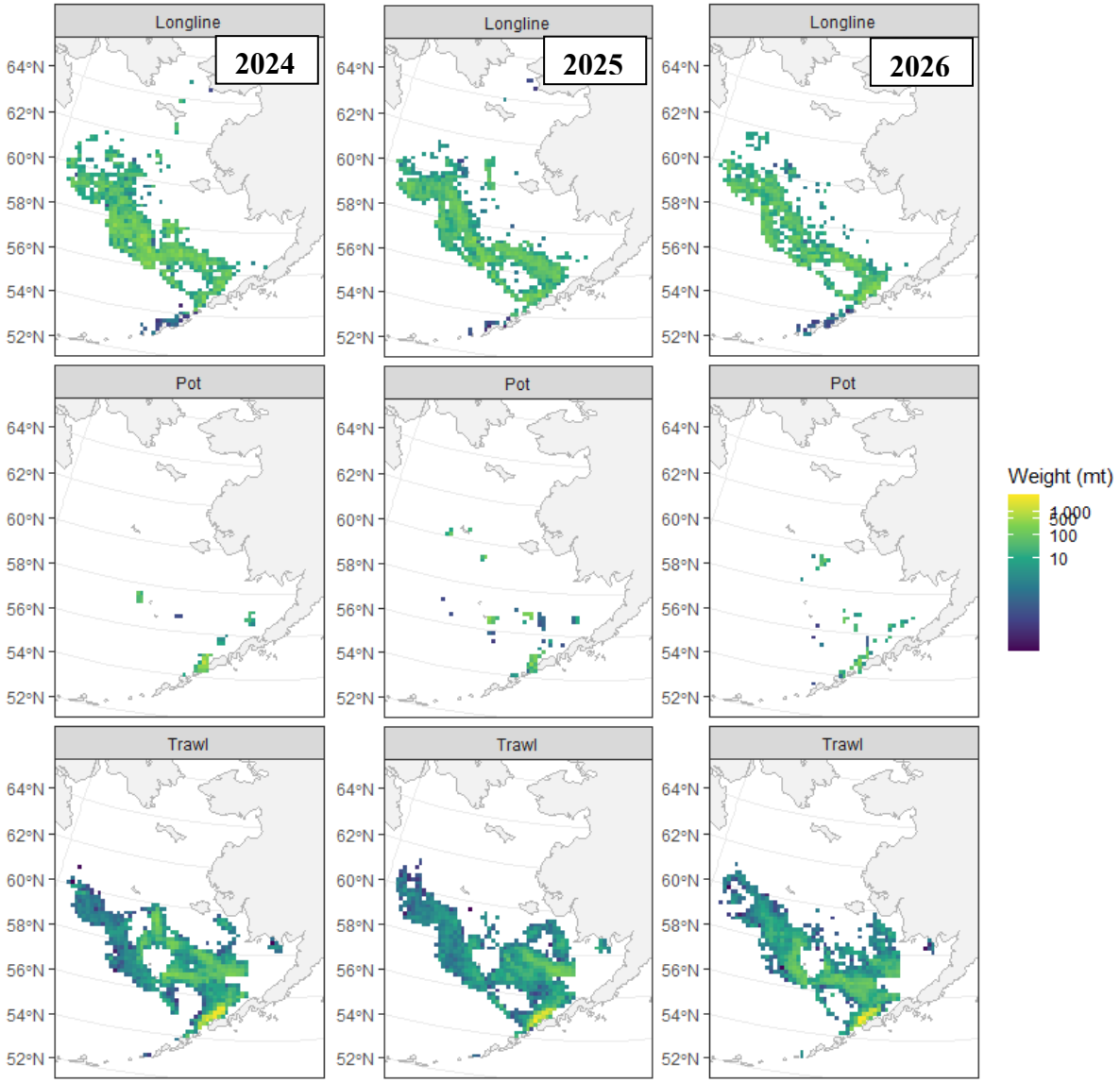


Figure 2.5. Observed catch by gear type for 2024-2026. Data are aggregated by bottom trawl survey grid cells (20nm^2). Data for 2026 are through September 30th.

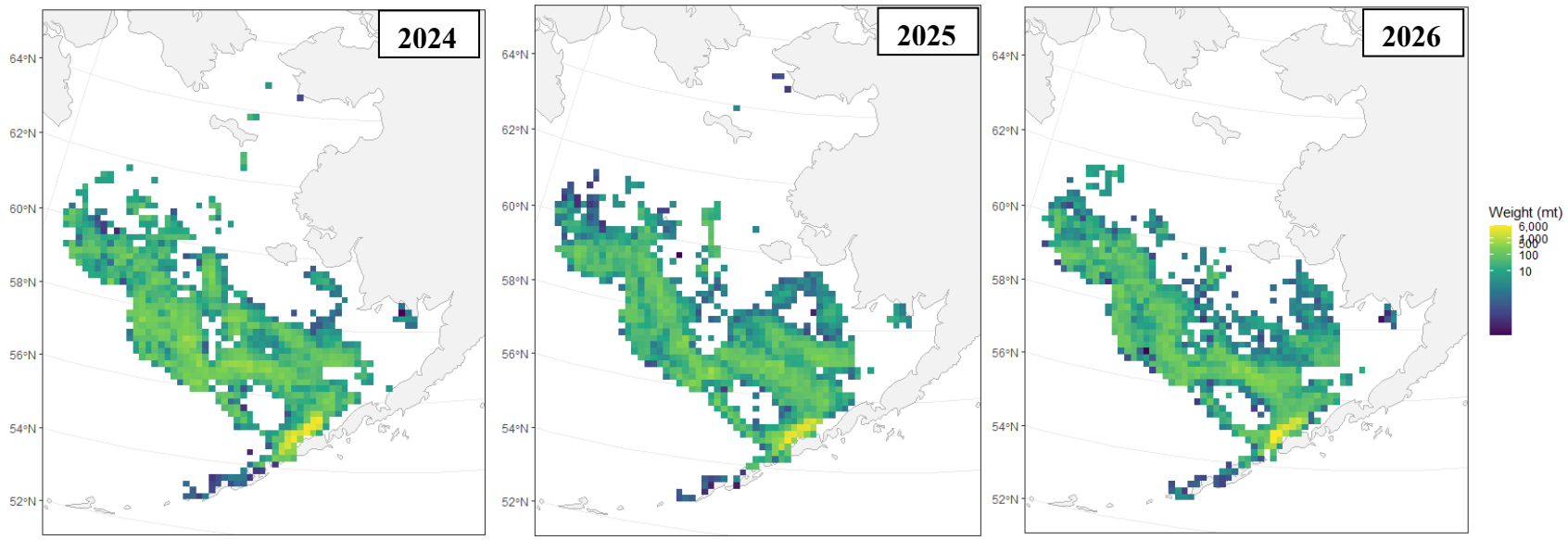


Figure 2.6. Total observed catch for 2024-2026. Data are aggregated by bottom trawl survey grid cells (20nm^2). Data for 2026 are through September 30th.

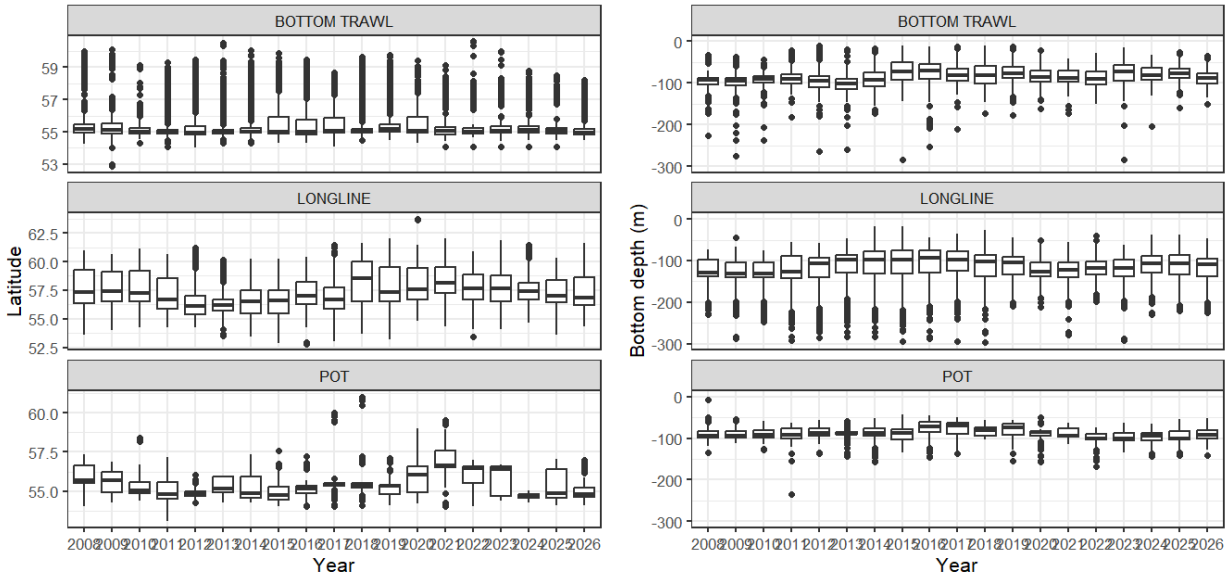


Figure 2.7. Distribution of Pacific cod hauls or sets by gear type for 2008-2026 for January-June by latitude (left) and bottom depth in meters (right). All data pulled October 9th, 2026.

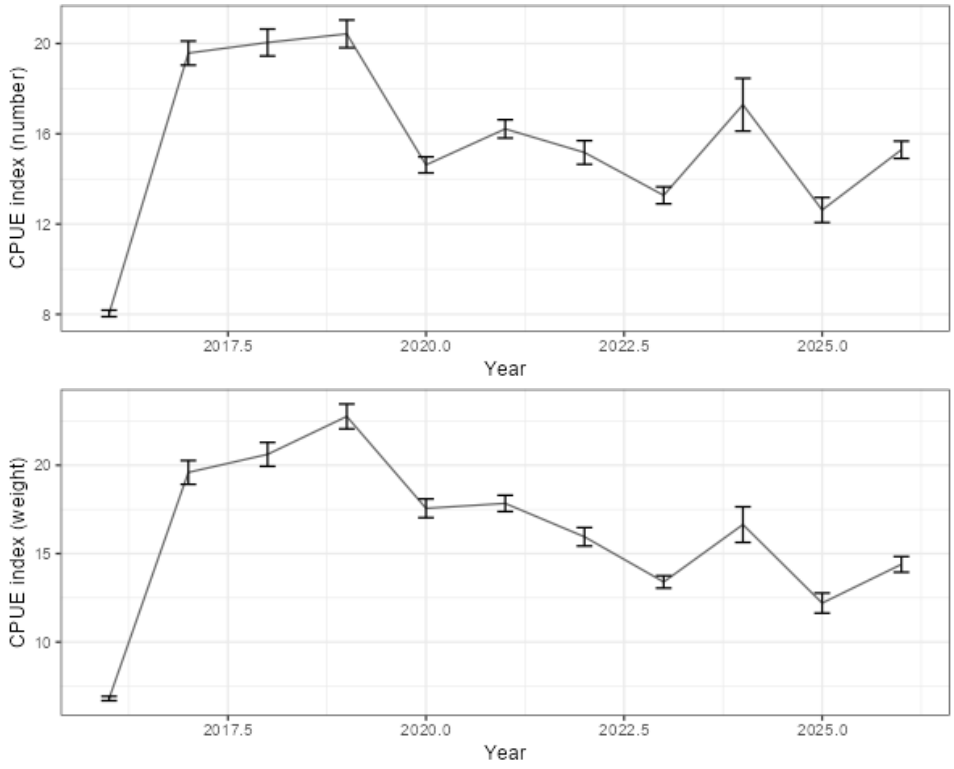


Figure 2.8. Thompson et al. (2021) combined fishery CPUE index estimates for 2016-2026 by number (top) and weight (bottom) of fish. All data pulled September 28th, 2026.

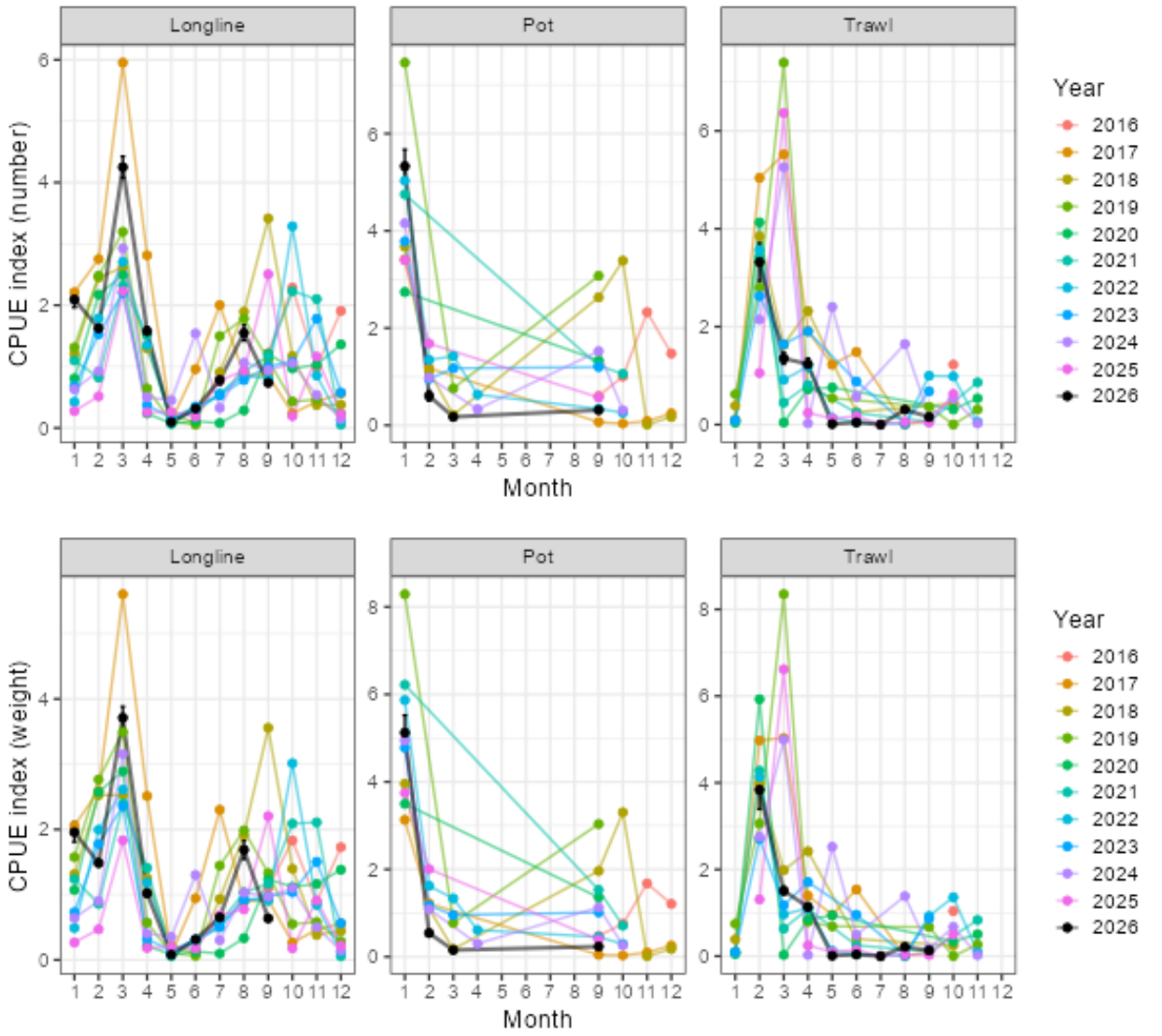


Figure 2.9. Raw and not standardized fishery catch per unit effort (CPUE) estimates by month for 2016-2026 by number (top) and weight (bottom) of fish by gear type. For numbers CPUE is log number of cod per minute, for longline it is log number of cod per hook and for pot log number of cod per pot. For weight CPUE bottom trawl is log tons per minute, longline is log kg per hook, and pot is log kg per pot. All data pulled September 28th, 2026.

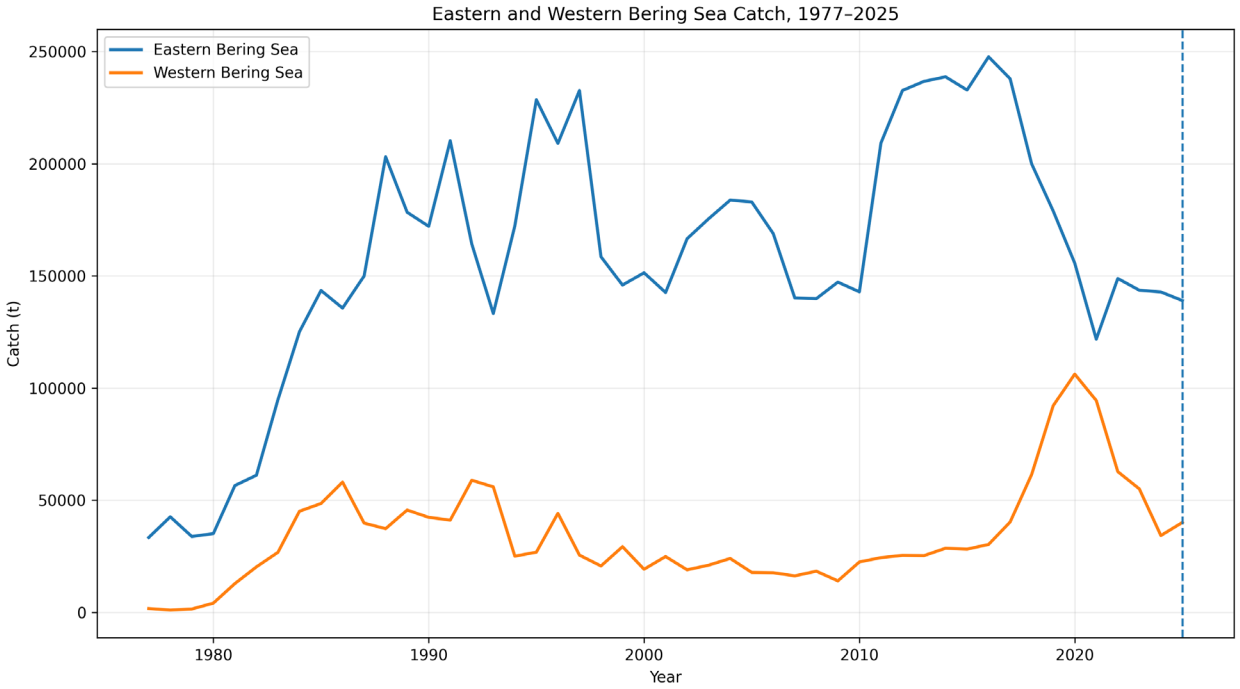


Figure 2.10. Pacific cod catch from the Eastern (US) and Western (Russian) Bering Seas for 1977-2025.

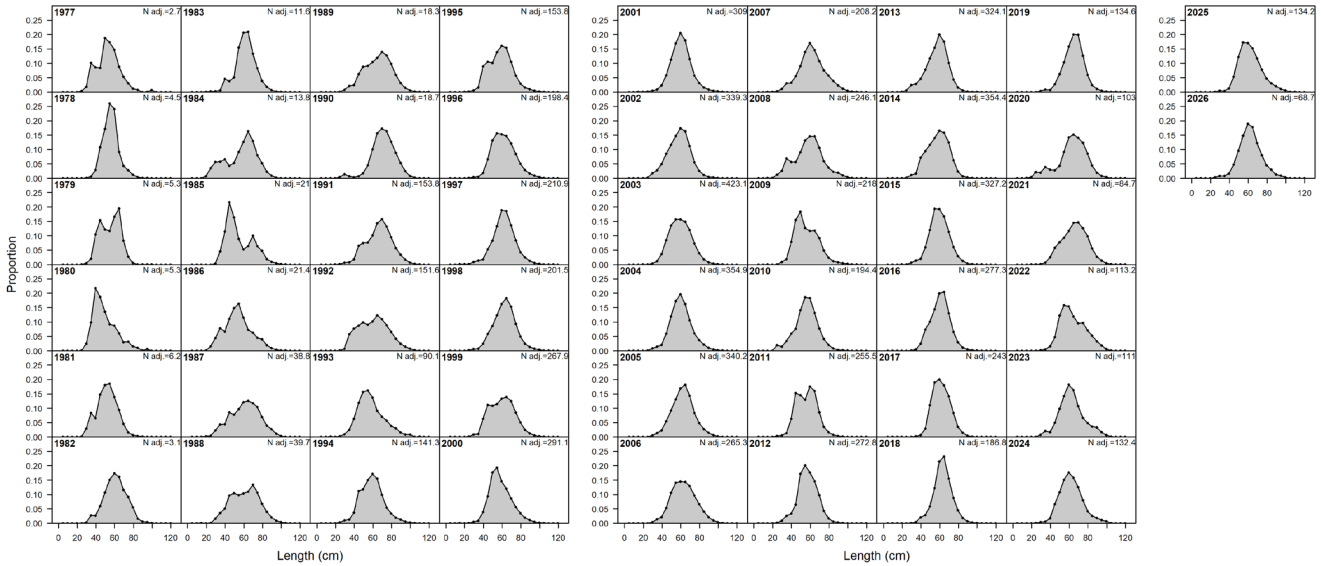


Figure 2.11. Combined fishery length composition distributions by year. Data queried September 28th, 2026.

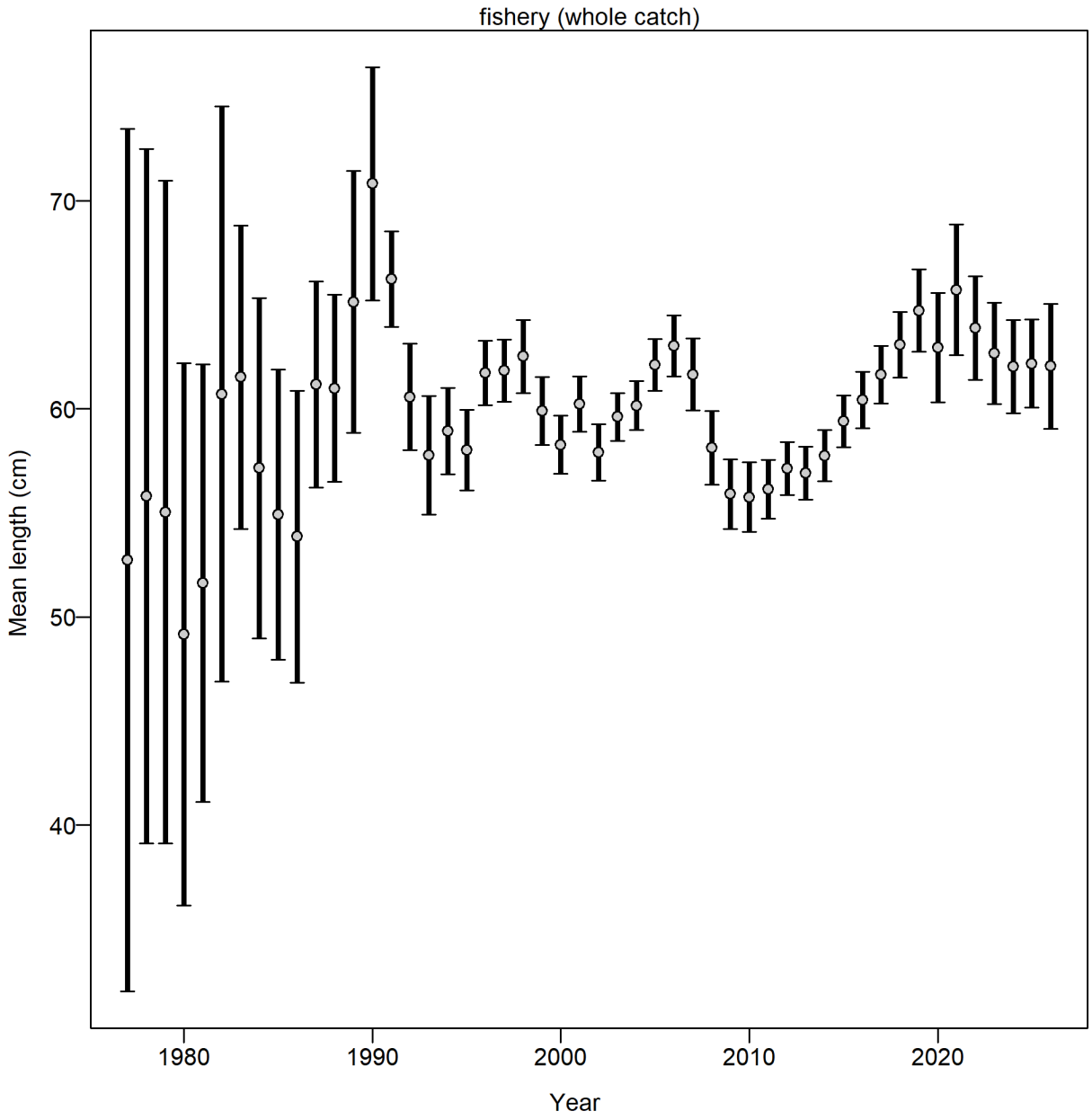


Figure 2.12. Combined fishery mean length (cm) by year.

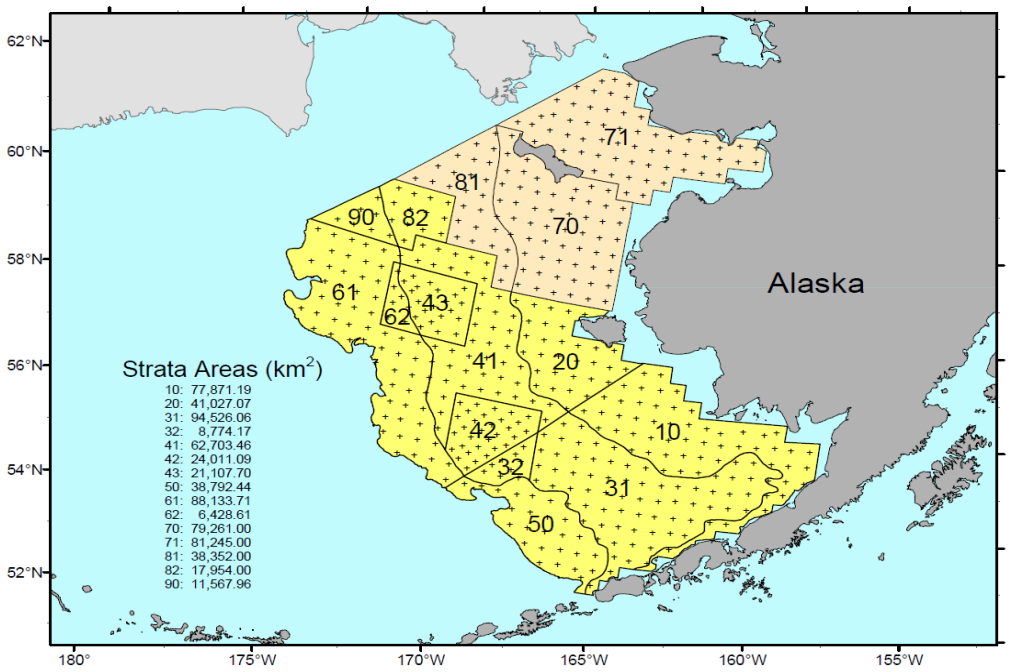


Figure 2.13. AFSC bottom trawl survey strata where crosses represent station locations.

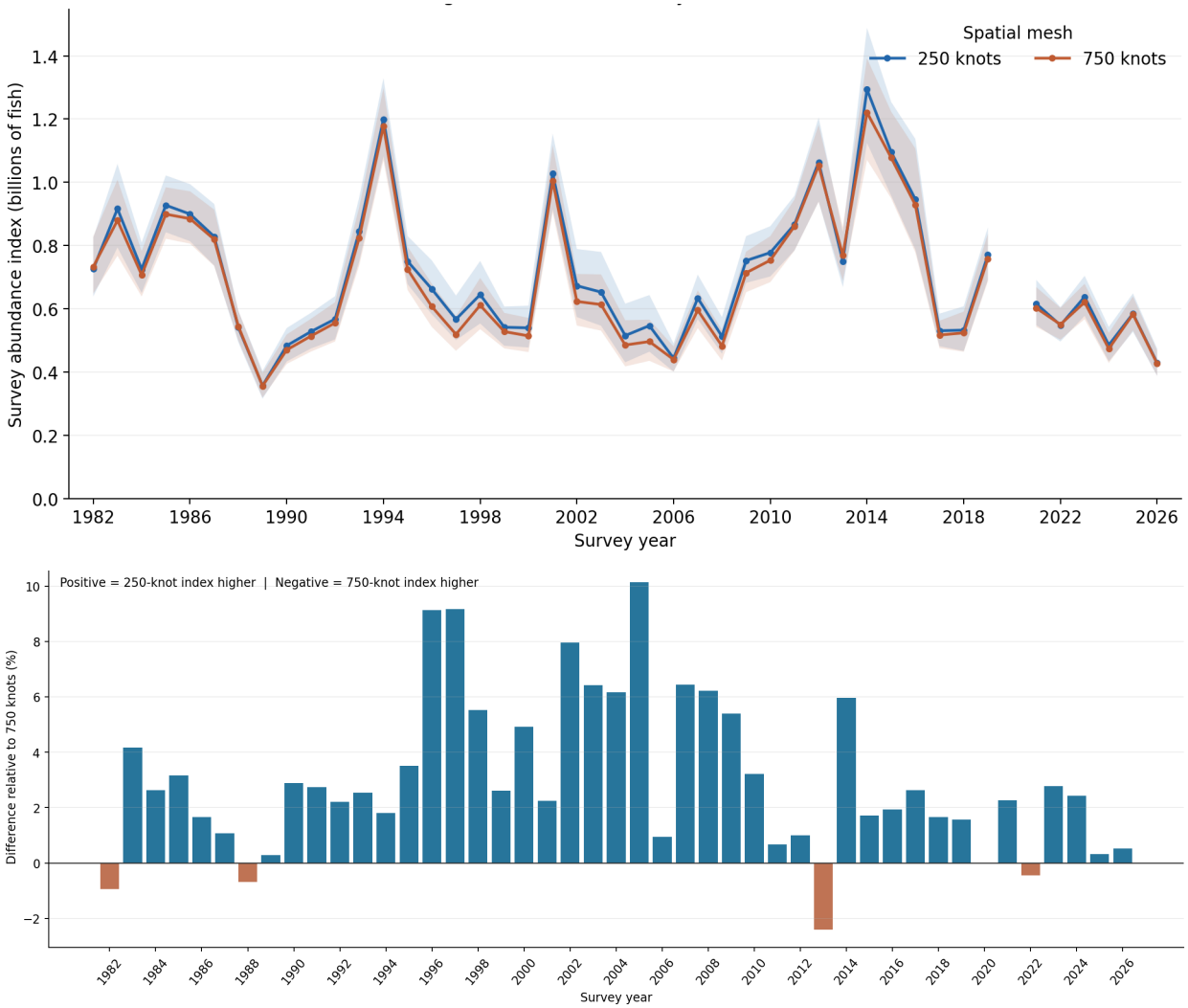


Figure 2.14. AFSC Eastern Bering Sea bottom trawl survey abundance index derived from sdmTMB models with 250 knot mesh versus 750 knot mesh with 95% confidence intervals in billions of fish (top; #×10^9) and % difference between 750 and 250 knot mesh derived indices (bottom).

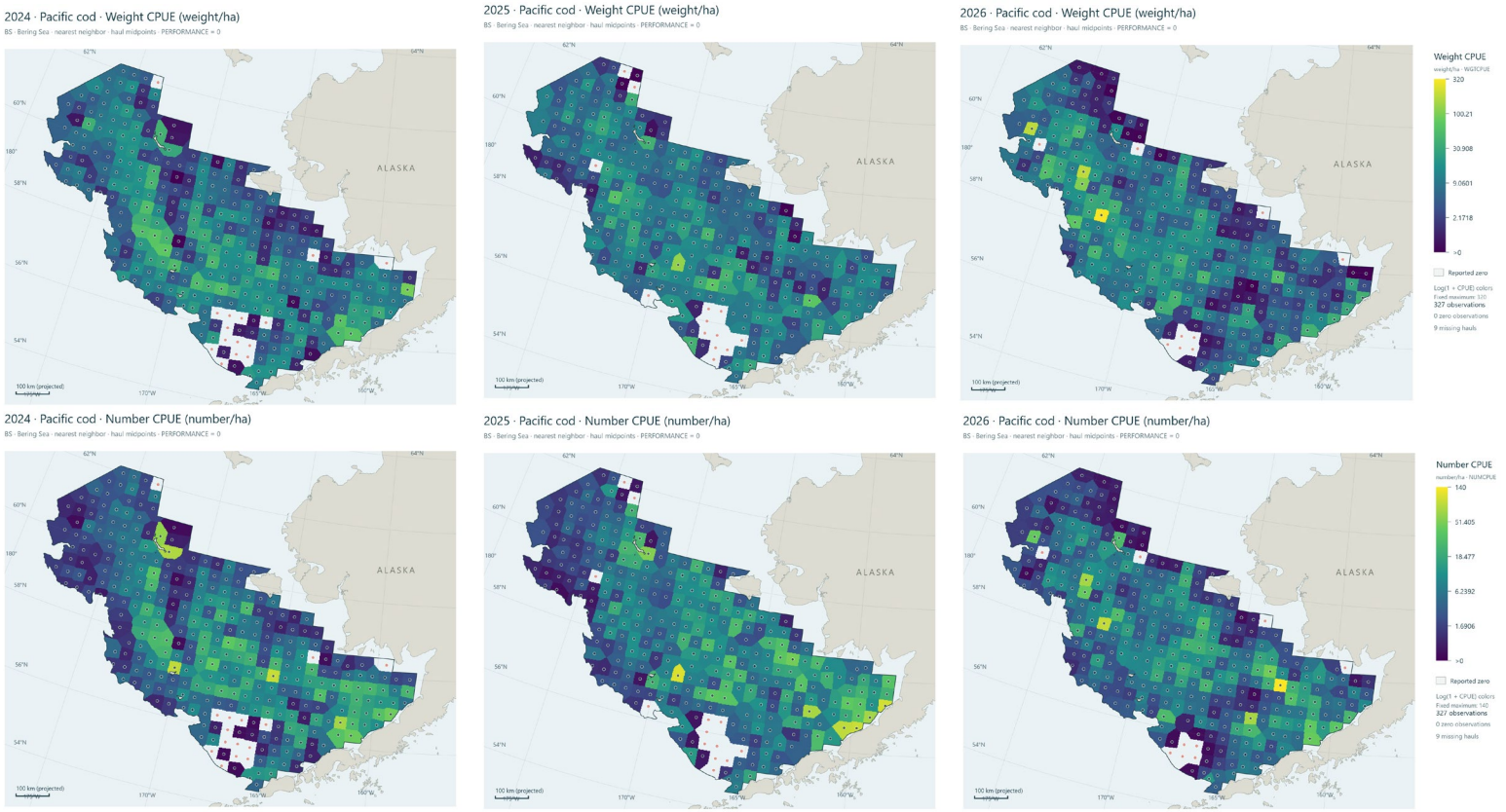


Figure 2.15. AFSC bottom trawl survey Pacific cod catch weight (top) and number (bottom) per unit effort for 2024-2026 (from left to right).

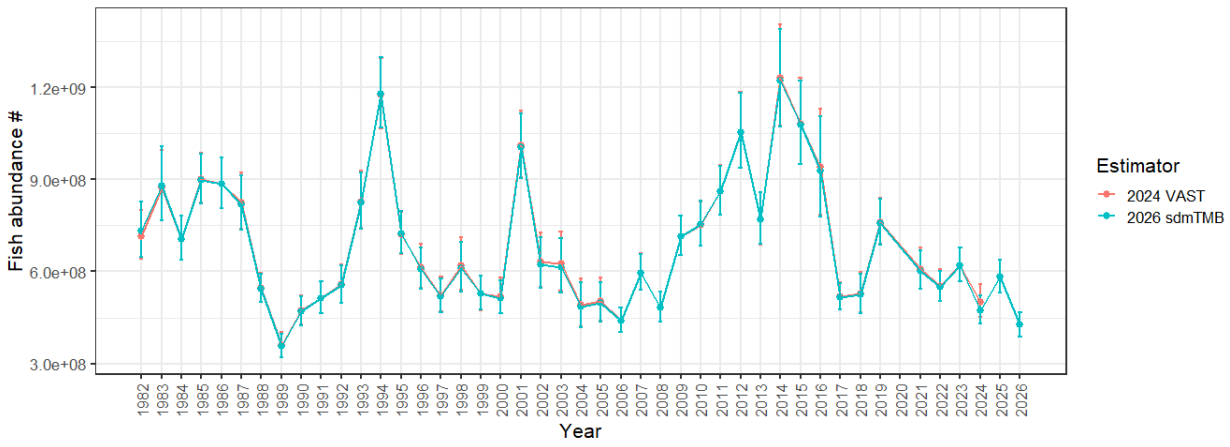


Figure 2.16. The 2024 (2024_VAST) and 2026 (2026 sdmTMB) Bering Sea bottom trawl survey Pacific cod abundance (# of fish) estimates with 95% confidence intervals.

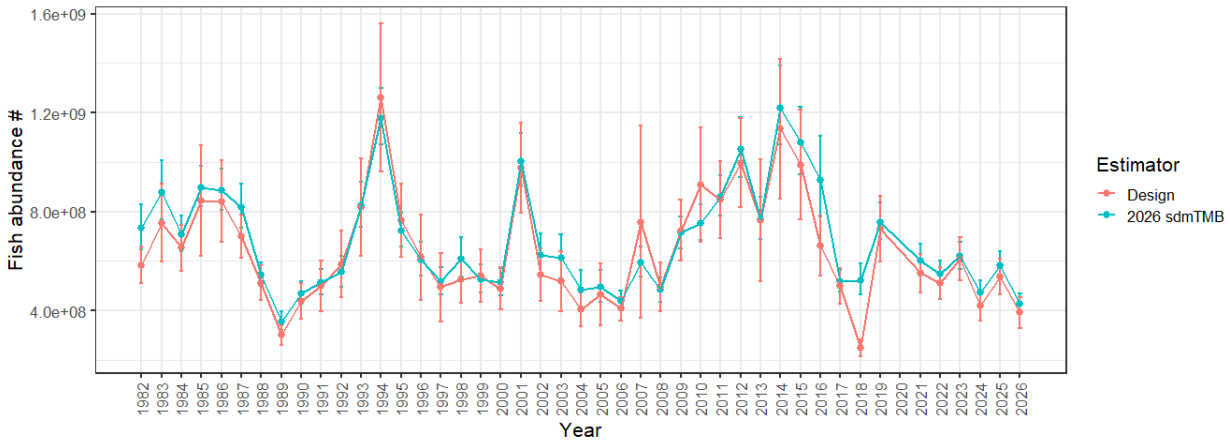


Figure 2.17. Pacific cod abundance estimates (1000s of fish) for design-based and 2026 model-based bottom trawl survey time series.

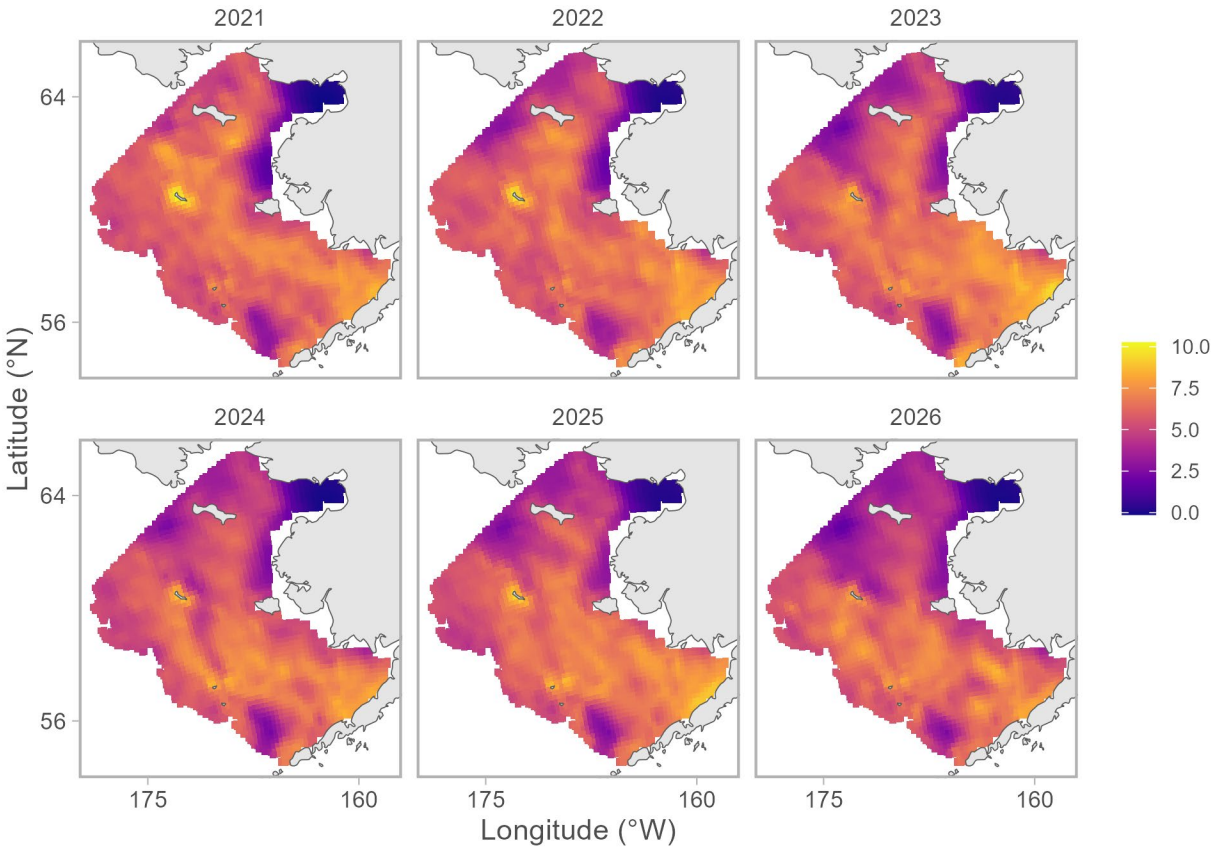


Figure 2.18. Bering Sea shelf bottom trawl survey predicted Pacific cod abundance log density (n/km^2) maps by year from 2021-2026 from the 2026 sdmTMB model run.

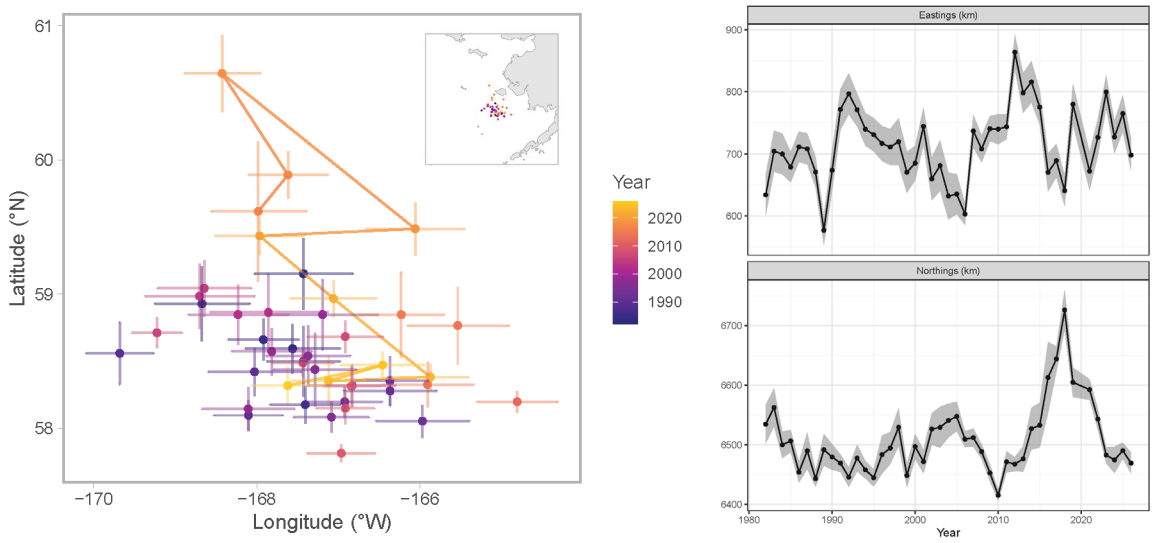


Figure 2.19. Bering Sea shelf bottom trawl survey Pacific cod index center of gravity abundance index by area for 1982-2026.

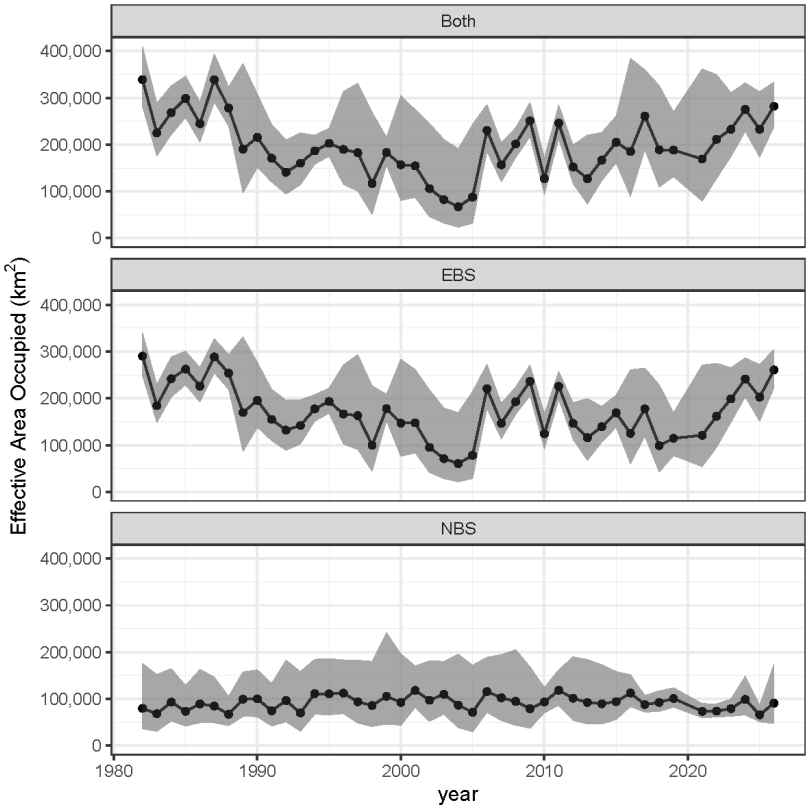


Figure 2.20. Bering Sea shelf bottom trawl survey Pacific cod index effective area occupied by area from 2026 sdmTMB for 1982-2026 for both areas (top), Eastern Bering Sea (EBS; middle), and Northern Bering Sea (NBS; bottom).

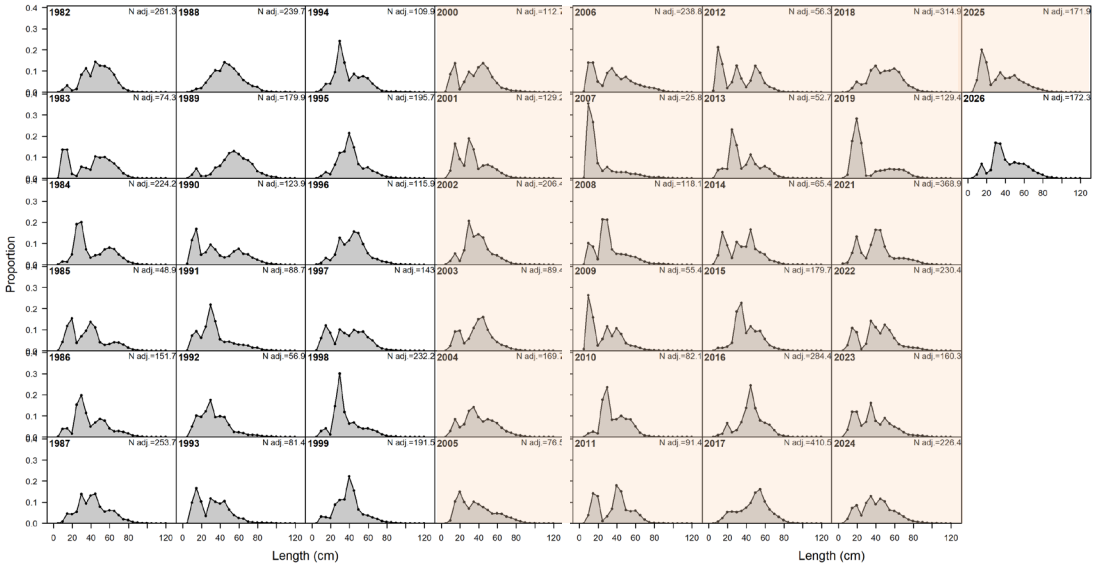


Figure 2.21. Bottom trawl survey length composition distributions by year. Colored years indicate length composition data not used in the models as age composition was available.

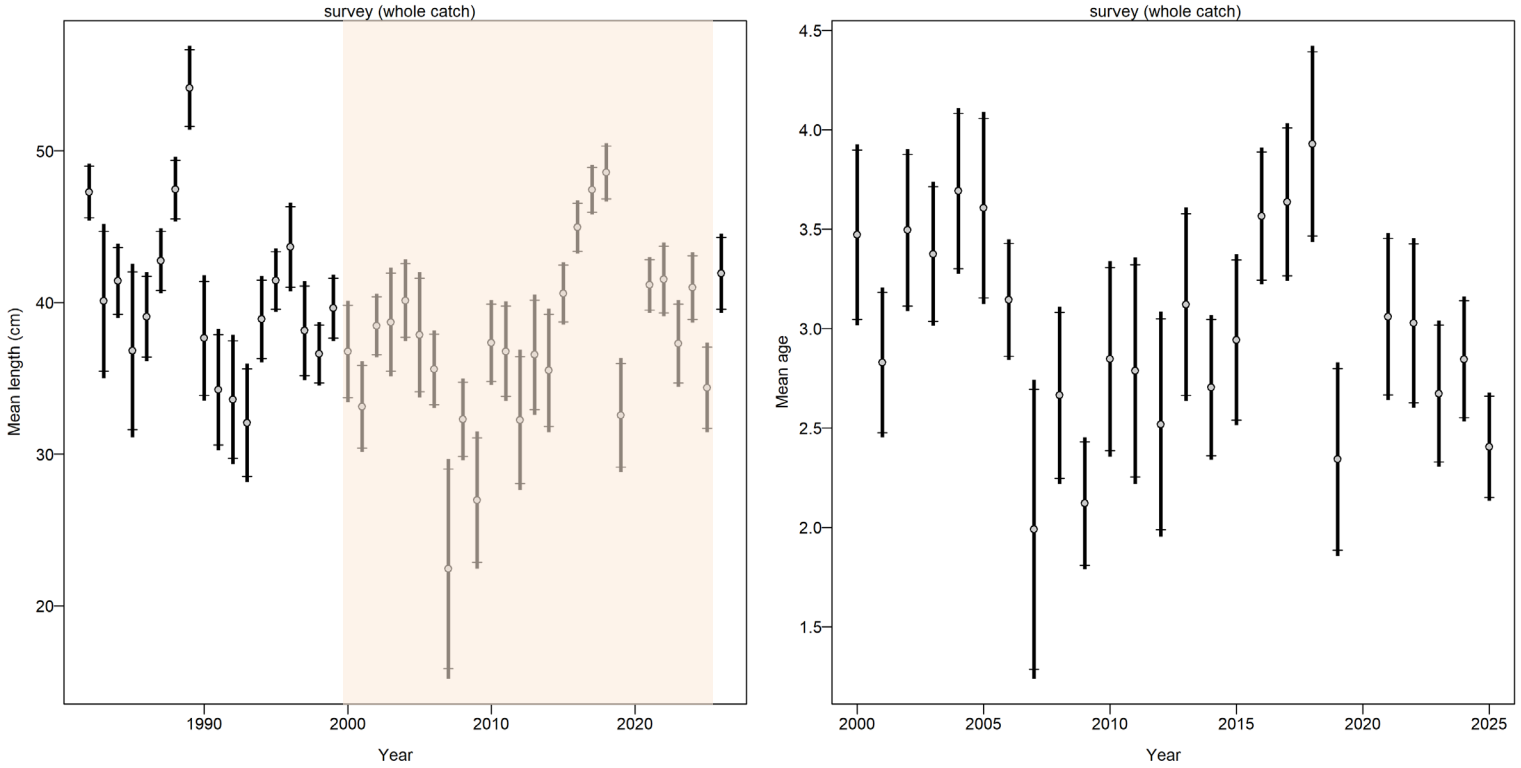


Figure 2.22. AFSC bottom trawl survey mean length (cm; left) and mean age (right) by year. Colored block in the length composition indicates times when age composition data are available.

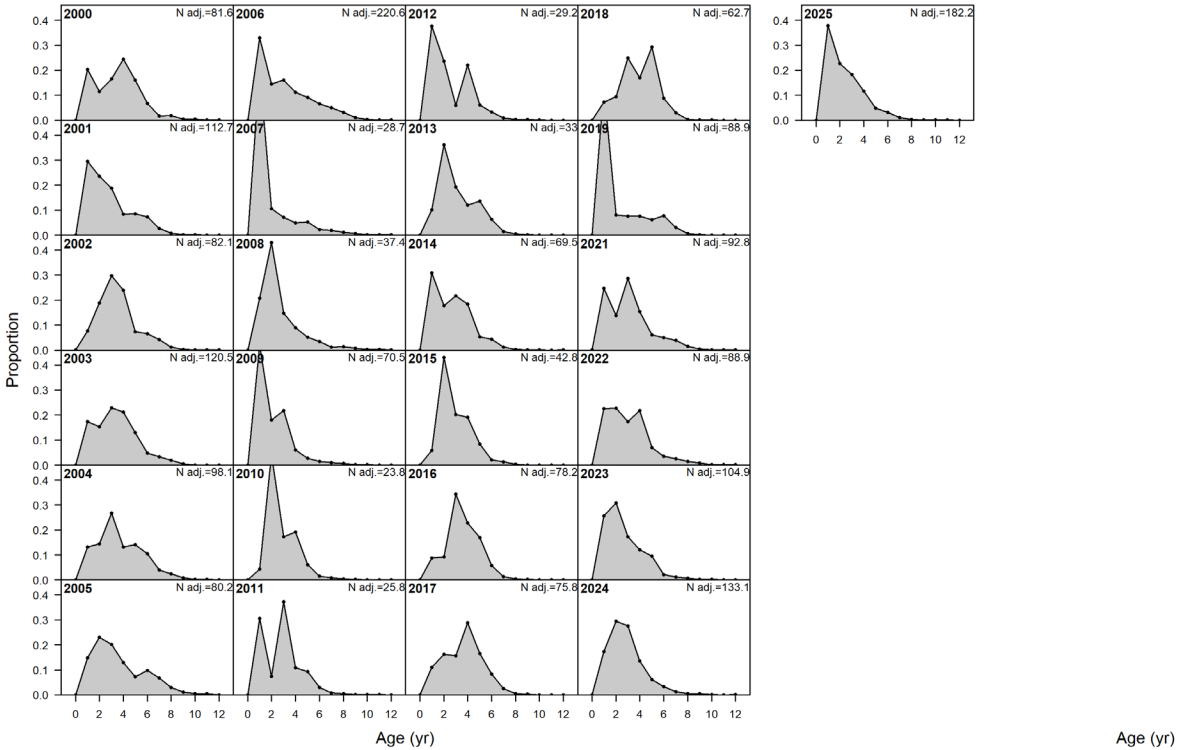


Figure 2.23. Bottom trawl survey age composition distributions by year.

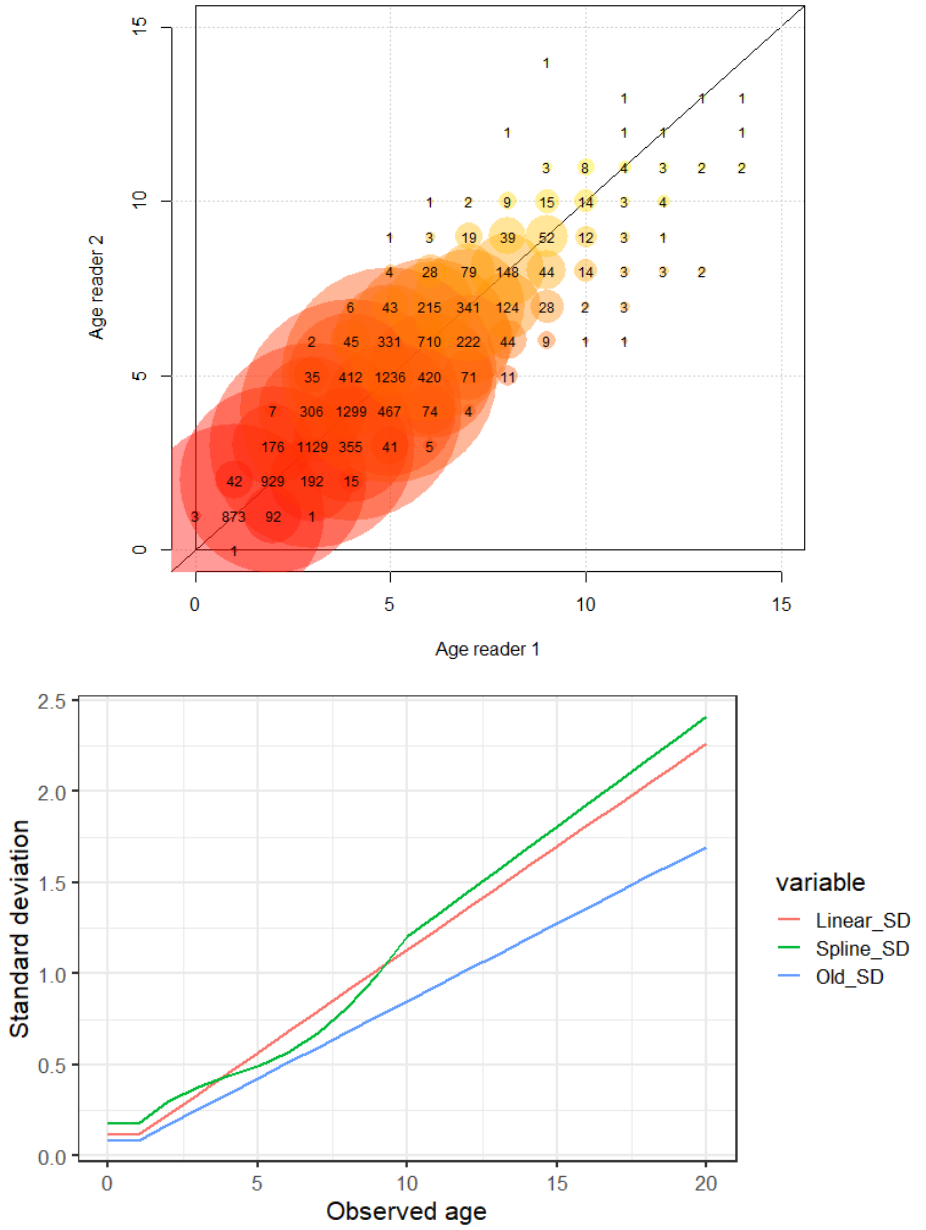


Figure 2.24. Results from paired age reader testing for Pacific cod with the number of otoliths read at each age by paired readers (top) and aging error standard deviation for (Linear_SD) linear and (Spline_SD) spline model from 2000-2023 age testing data and (old_SD) the aging error used in the 2023 model (bottom).

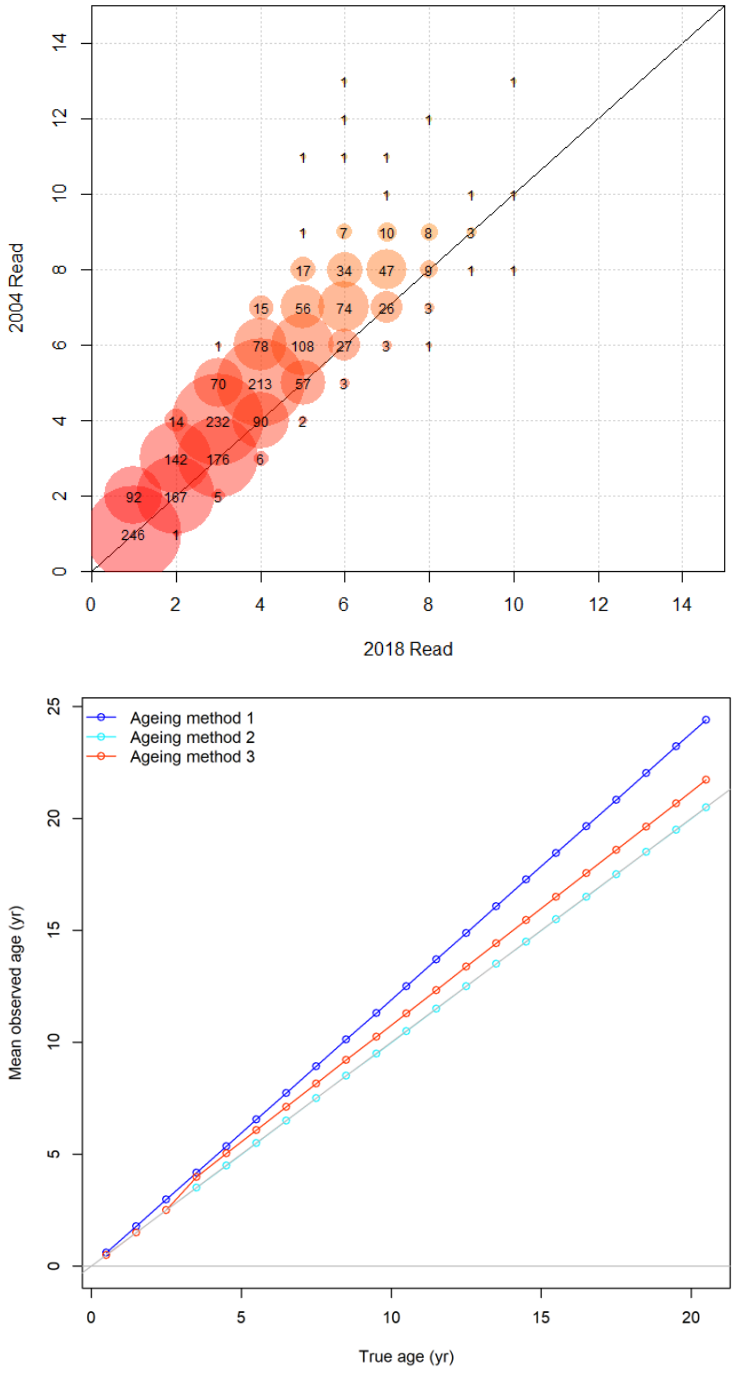


Figure 2.25. Distribution of age data read in 2004 (reader 1) and 2018 (reader 2) used to compute aging bias for pre-2008 age data (top) and aging bias (dark blue; method 1) calculated from these data, (red line; method 3) used in the 2023 model, and (light blue; method 2) no bias used for ages collected after 2008 and the 1:1 line (bottom).



Figure 2.26. Locations of AFSC longline survey stations in the EBS region.

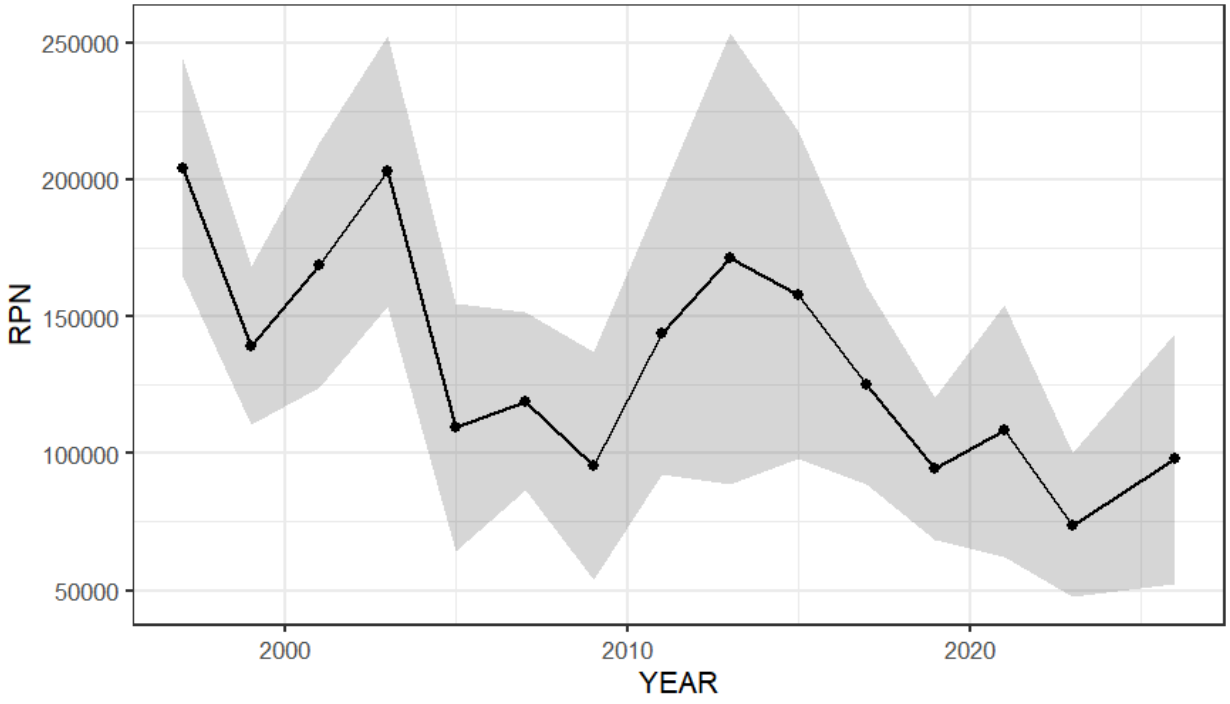


Figure 2.27. AFSC longline survey relative population numbers (RPN) for EBS region.

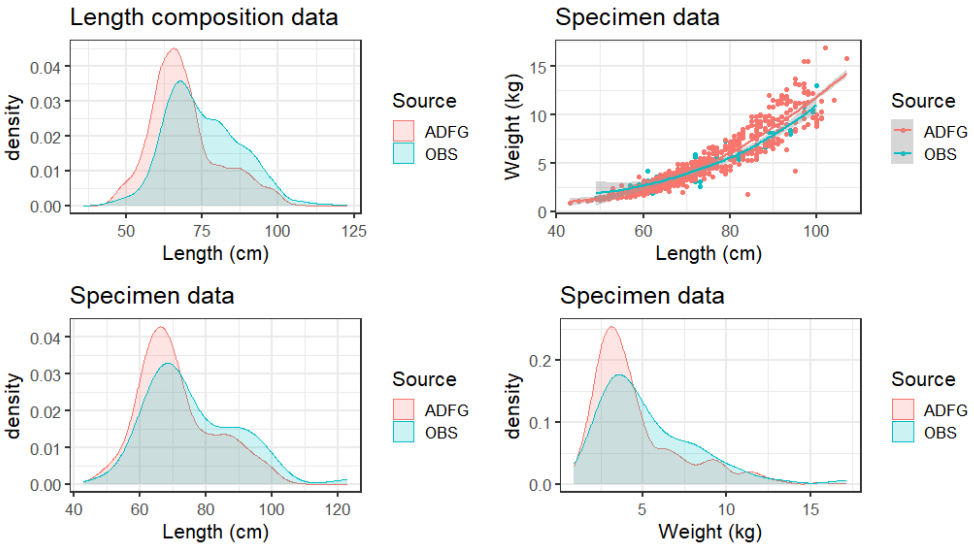


Figure 2.28. Pacific cod size and weight distribution comparisons for samples collected in the Dutch Harbor Subdistrict (DHS) pot fishery and Federal Bering Sea pot fisheries in the first trimester of 2023. All of the samples collected in the federal fishery were from NMFS Area 517. Length composition data (top left), and length and weight (top left, bottom) from individually weighed specimen collections.

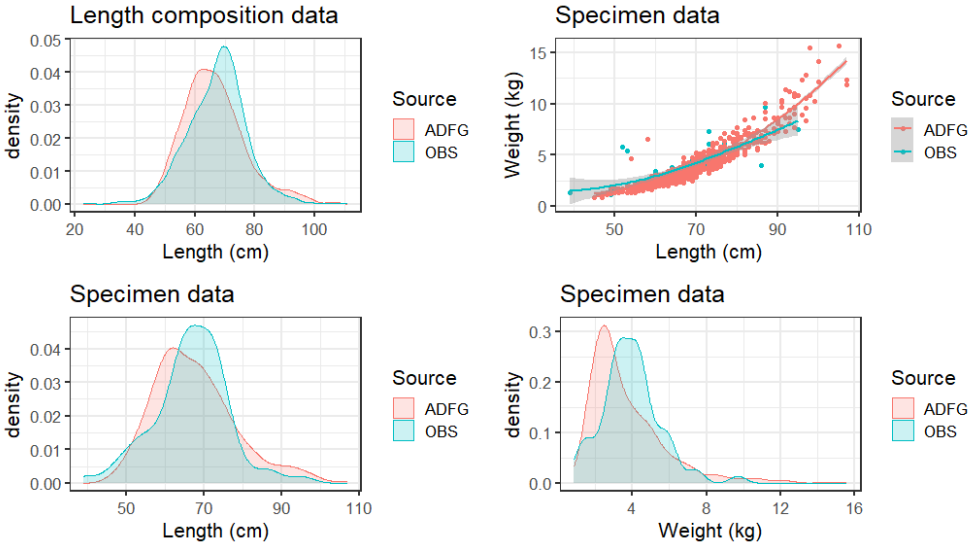


Figure 2.29. Pacific cod size and weight distribution comparisons for samples collected in the Dutch Harbor Subdistrict (DHS) pot fishery and Federal Bering Sea pot fisheries in the first trimester of 2024. All of the samples collected in the federal fishery were from NMFS Area 517. Length composition data (top left), and length and weight (top left, bottom) from individually weighed specimen collections.

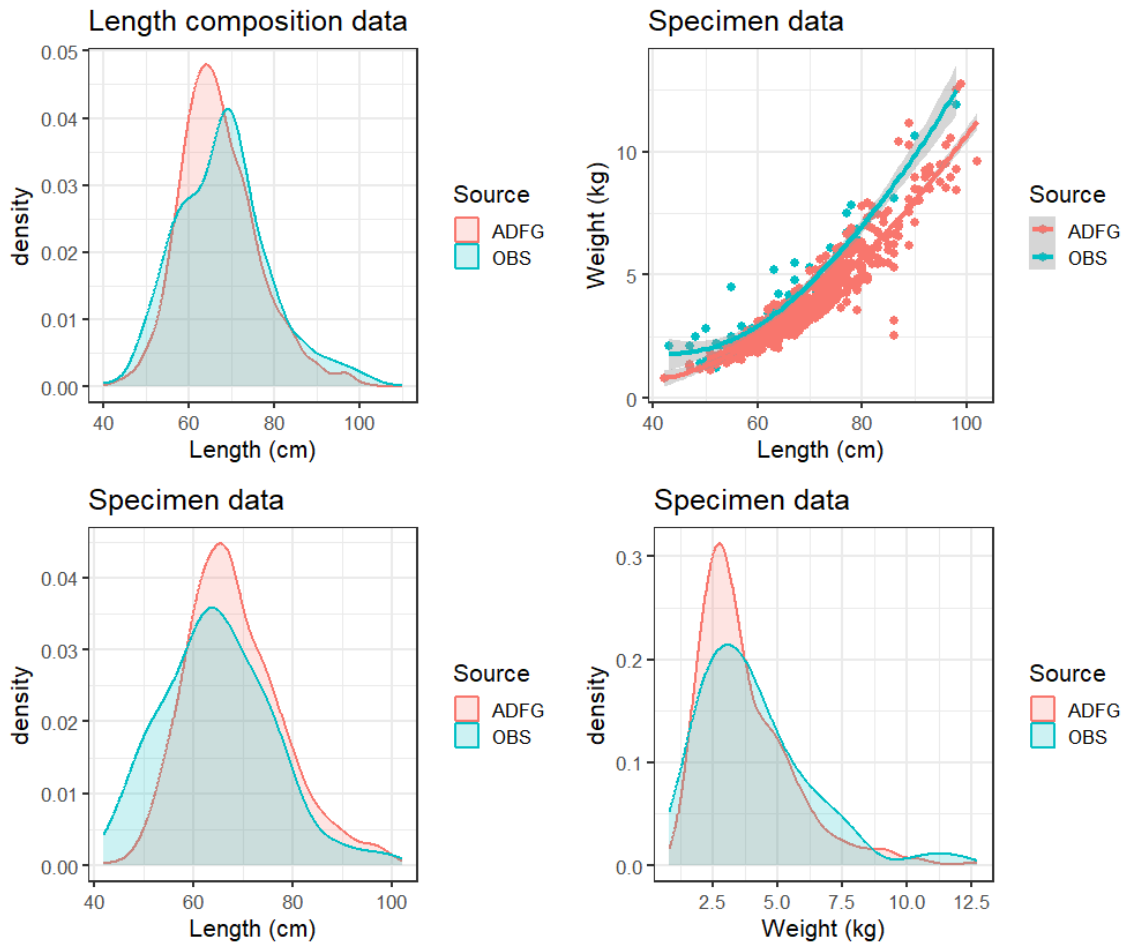


Figure 2.30. Pacific cod size and weight distribution comparisons for samples collected in the Dutch Harbor Subdistrict (DHS) pot fishery and Federal Bering Sea pot fisheries in the first trimester of 2025. All of the samples collected in the federal fishery were from NMFS Area 517. Length composition data (top left), and length and weight (top left, bottom) from individually weighed specimen collections.

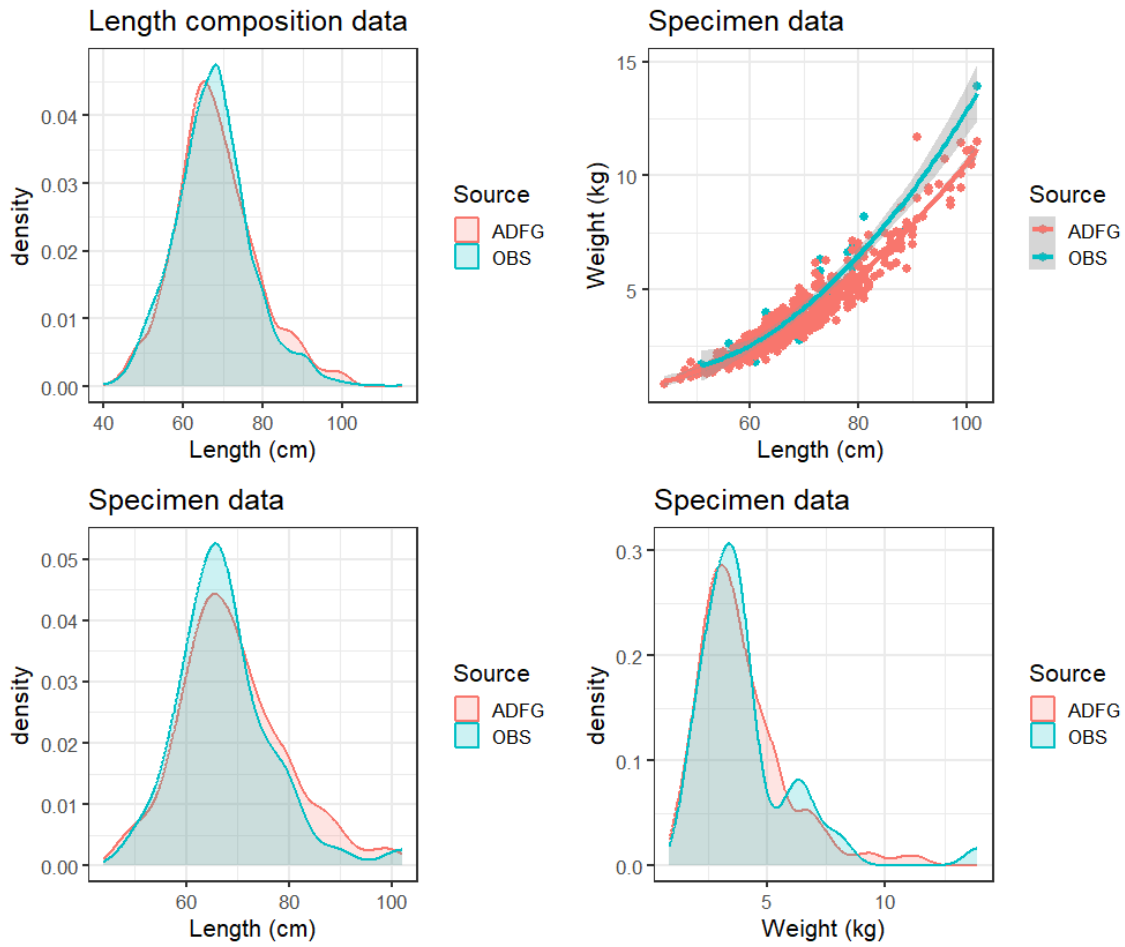


Figure 2.31. Pacific cod size and weight distribution comparisons for samples collected in the Dutch Harbor Subdistrict (DHS) pot fishery and Federal Bering Sea pot fisheries in the first trimester of 2026. All of the samples collected in the federal fishery were from NMFS Area 517. Length composition data (top left), and length and weight (top left, bottom) from individually weighed specimen collections.

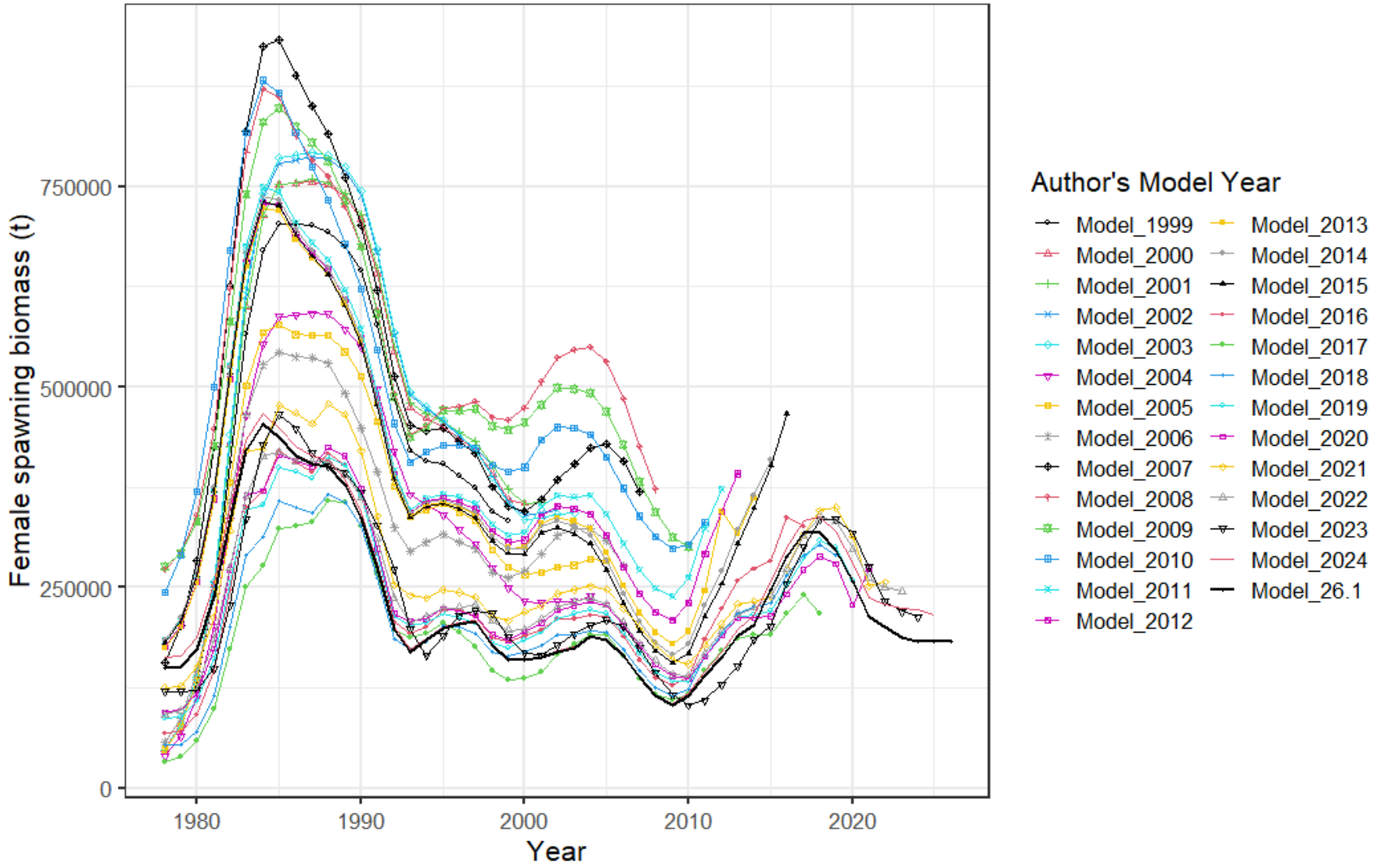


Figure 2.32. History of model estimated female spawning biomass from 1999-2026 accepted models and the 2026 Model 26.1.

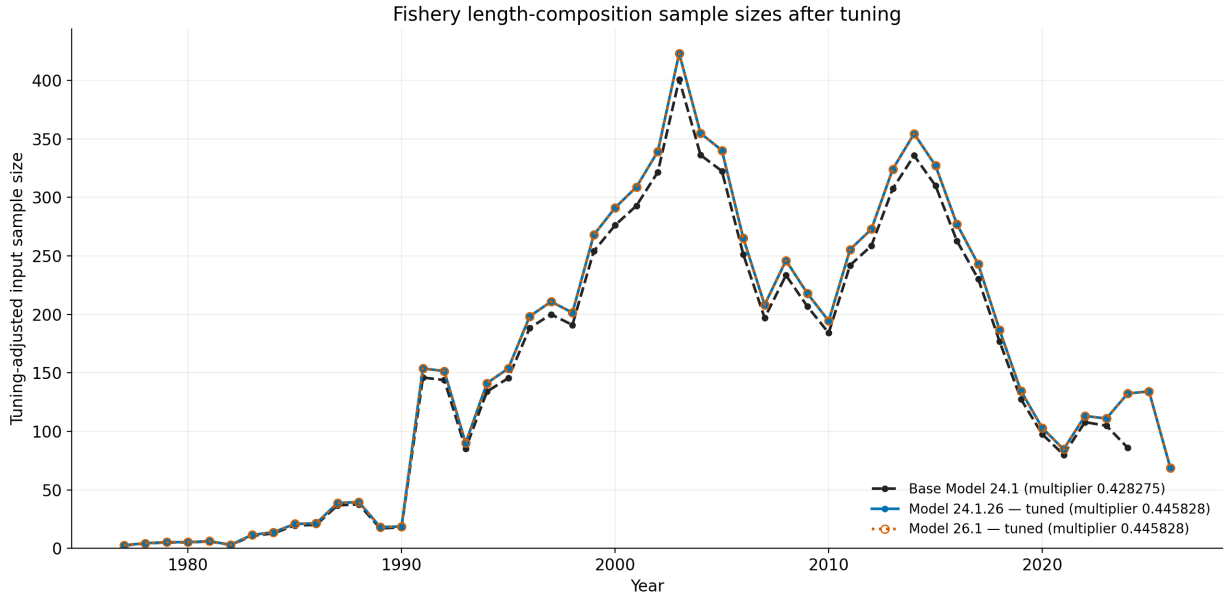


Figure 2.33. Fishery length composition Francis weighting tuned input sample size for 2024 Model 24.1 and tuned 2026 Model 24.1 and Model 26.1. The tuning adjusted fishery sample size is the input sample size (Nsamp) times the fishery length composition multiplier.

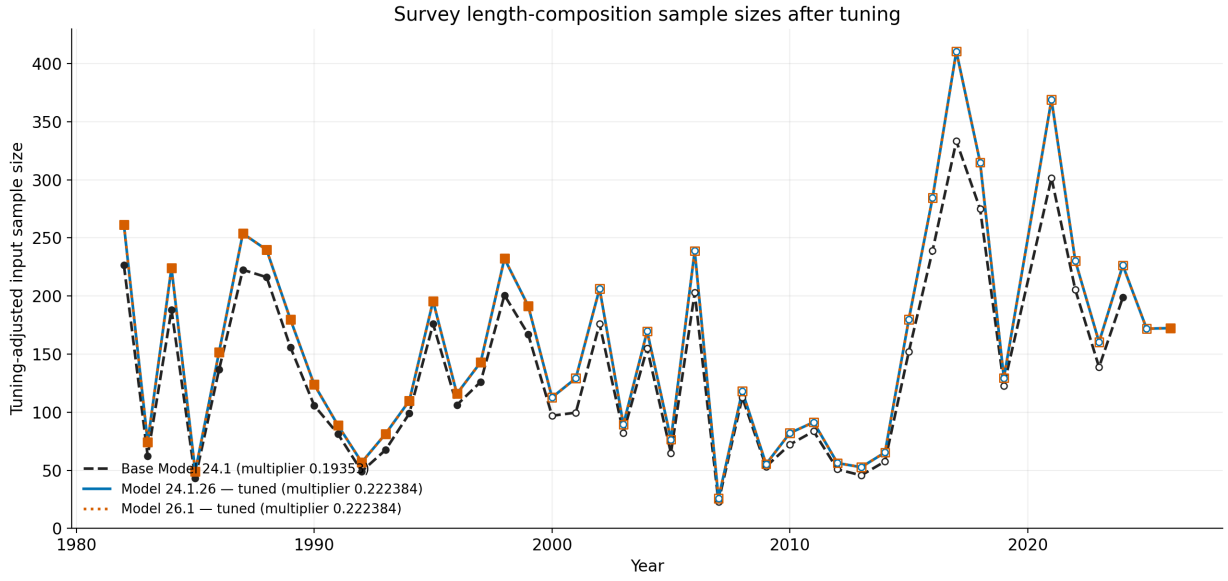


Figure 2.34. Survey length composition Francis weighting tuned input sample size for 2024 Model 24.1 and tuned 2026 Model 24.1 and Model 26.1. The tuning adjusted survey sample size is the input sample size (Nsamp) times the survey length composition multiplier. Excluded observations are shown for comparison with open points, their adjusted sample sizes do not contribute to fit.

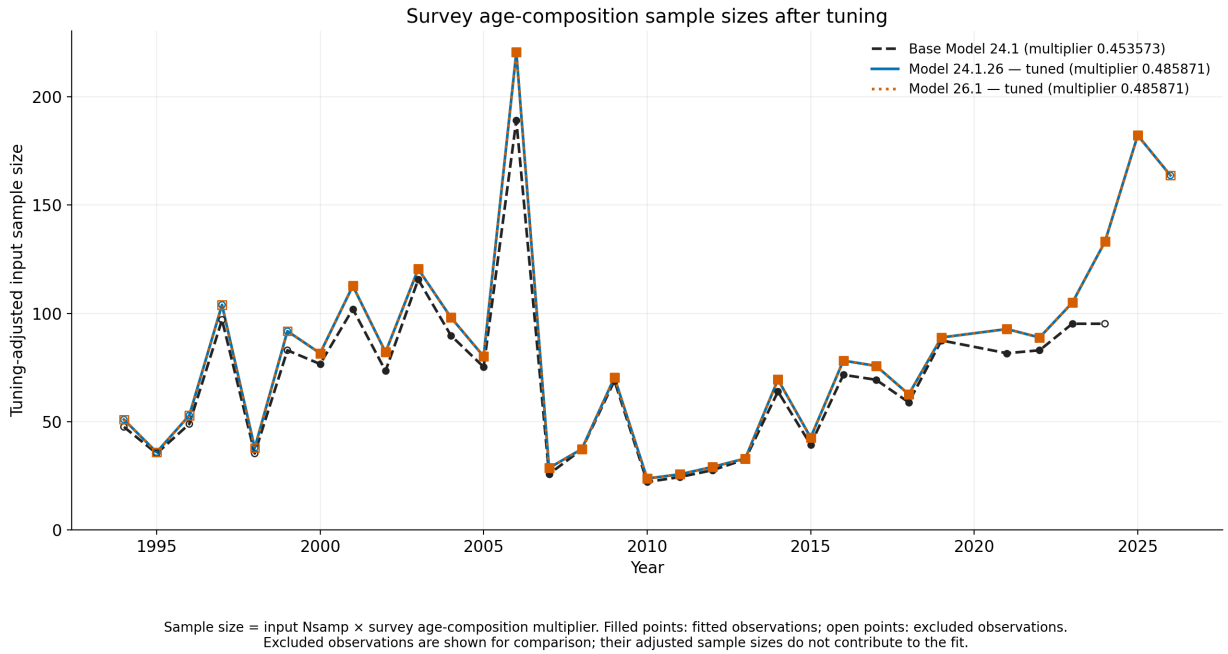


Figure 2.35. Survey age composition Francis weighting tuned input sample size for 2024 Model 24.1 and tuned 2026 Model 24.1 and Model 26.1. The tuning adjusted survey sample size is the input sample size (Nsamp) times the survey age composition multiplier. Excluded observations are shown for comparison with open points, their adjusted sample sizes do not contribute to fit.

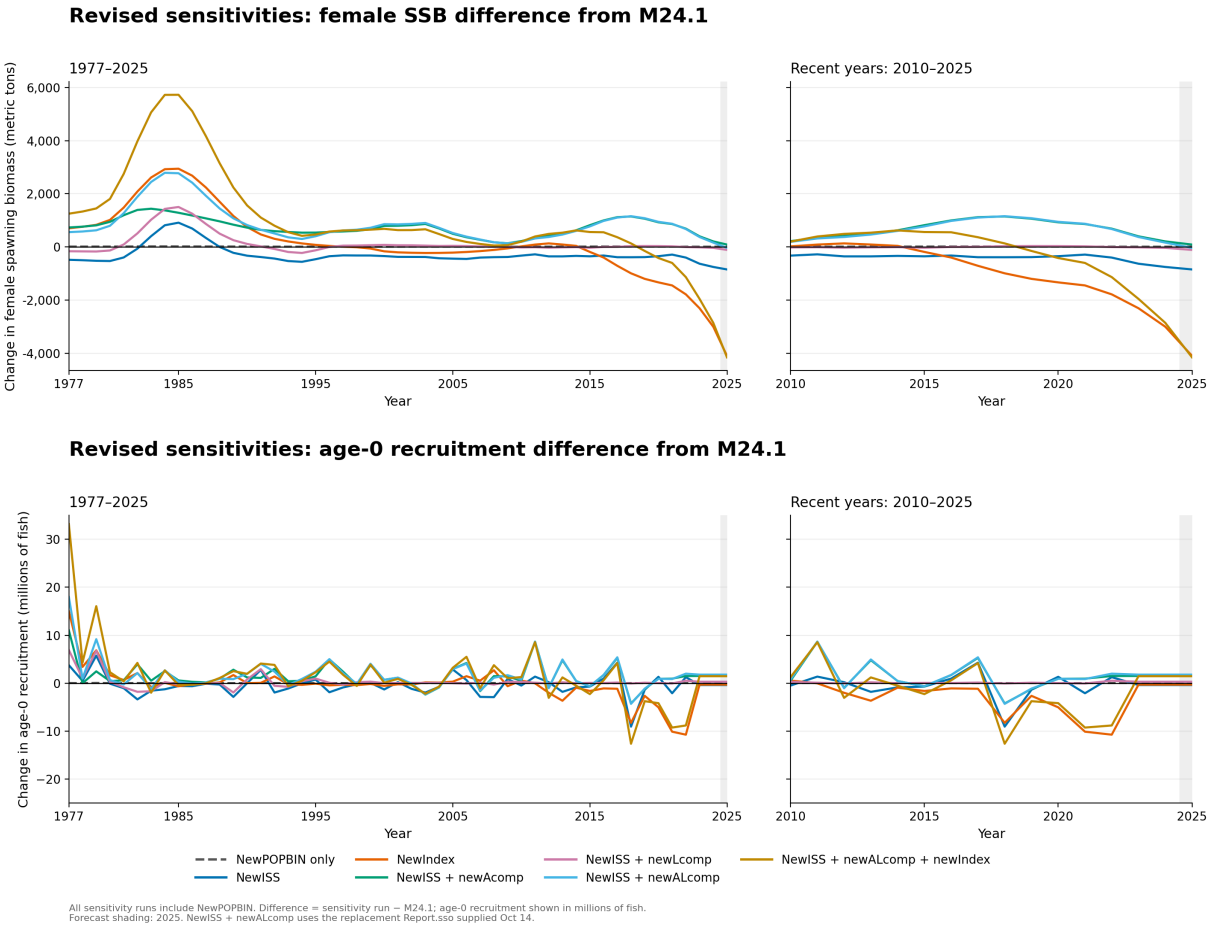


Figure 2.36. Model sensitivity to updated data components, ISS= input sample size, Acomp= Age composition, Lcomp=Length composition, AL comp is both Age and length composition, Index is the Eastern Bering Sea survey abundance index, and POPbin is a minor change in how the size bins are treated in Stock synthesis. Top figures are changes in female spawning biomass (t), and (bottom) changes in age-0 recruitment (n in millions) by year from the 2024 base Model 24.1.



Figure 2.37. Model sensitivity to updated data components, the addition of 2025–2026 data, and model tuning. Panels show differences from the 2024 base Model 24.1 in female spawning biomass (tonnes; top) and age-0 recruitment (millions of fish; bottom) by year. The gold line represents Model 24.1 with revised data through 2024. 2026 Model 24.1 and Model 26.1 incorporate updated data through 2026.

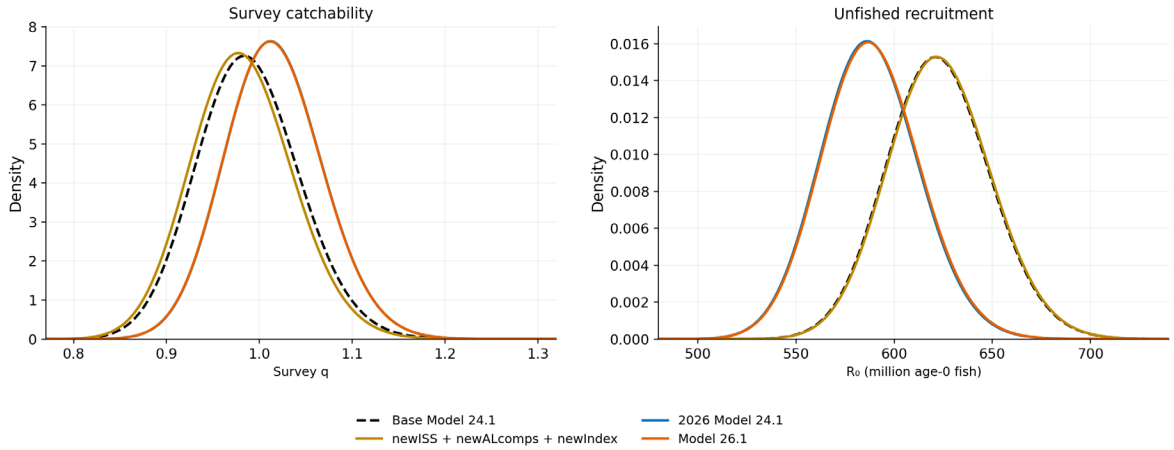


Figure 2.38. Model sensitivity to updated data components, the addition of 2025–2026 data, and model tuning. Panels show survey catchability (left) and unfished age-0 recruitment (millions of fish; right). Dashed line is 2024 Model 24.1, the gold line represents Model 24.1 with revised data through 2024. 2026 Model 24.1 and Model 26.1 incorporate updated data through 2026.

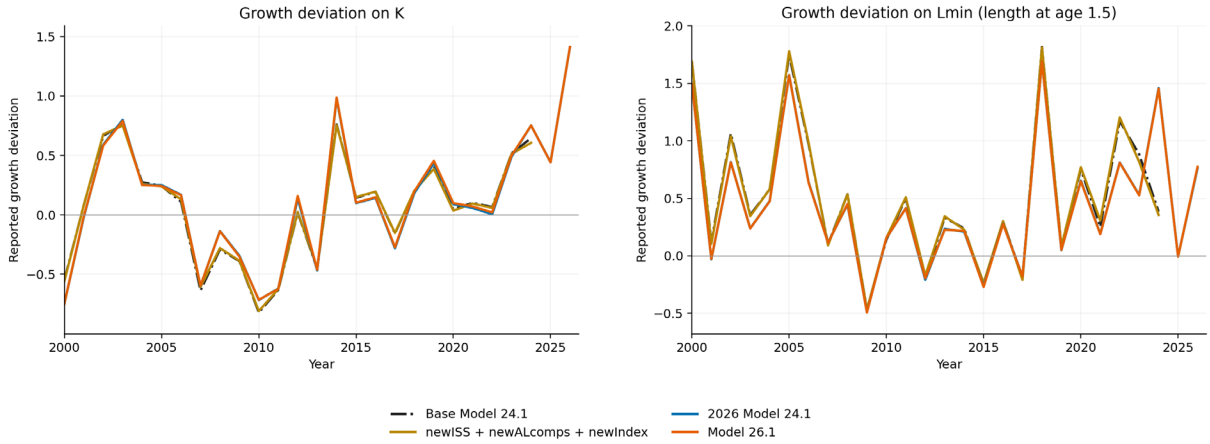


Figure 2.39. Model sensitivity to updated data components, the addition of 2025–2026 data, and model tuning. Panels show growth deviation on K (left) and growth deviation on L_{min} (right) from the Richards growth model. Dashed line is 2024 Model 24.1, the gold line represents Model 24.1 with revised data through 2024. 2026 Model 24.1 and Model 26.1 incorporate updated data through 2026.

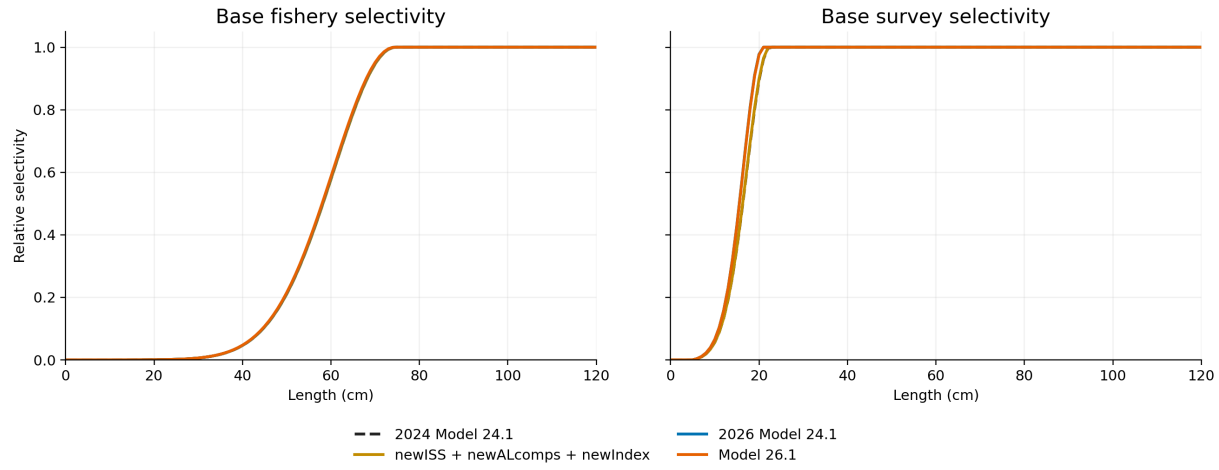


Figure 2.40. Model sensitivity to updated data components, the addition of 2025–2026 data, and model tuning. Panels show base fishery selectivity (left) and base survey selectivity (right). Dashed line is 2024 Model 24.1, the gold line represents Model 24.1 with revised data through 2024. 2026 Model 24.1 and Model 26.1 incorporate updated data through 2026.

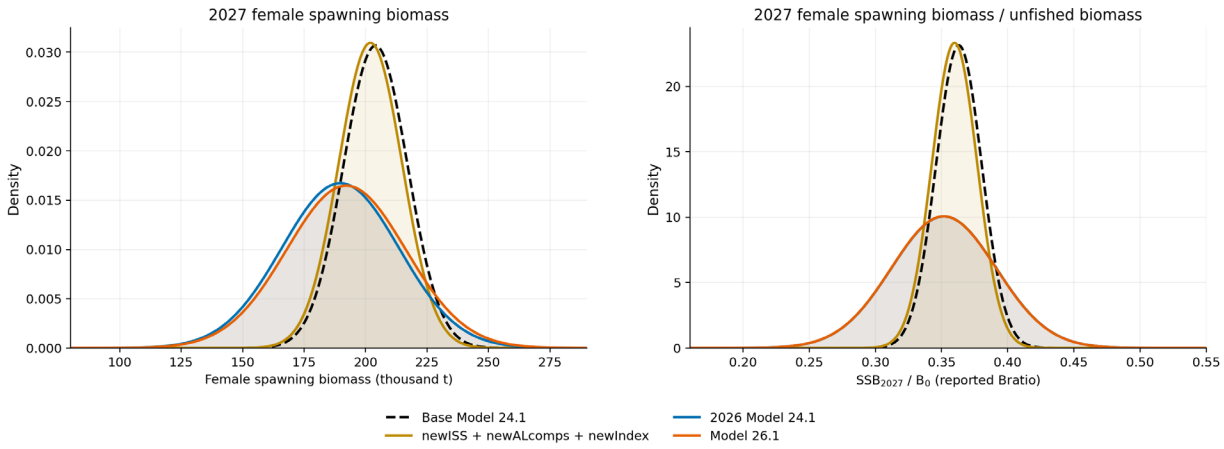


Figure 2.41. Model sensitivity to updated data components, the addition of 2025–2026 data, and model tuning. Panels show 2027 female spawning biomass (thousands of tons; left) and 2027 biomass ratio (right). Dashed line is 2024 Model 24.1, the gold line represents Model 24.1 with revised data through 2024. 2026 Model 24.1 and Model 26.1 incorporate updated data through 2026.

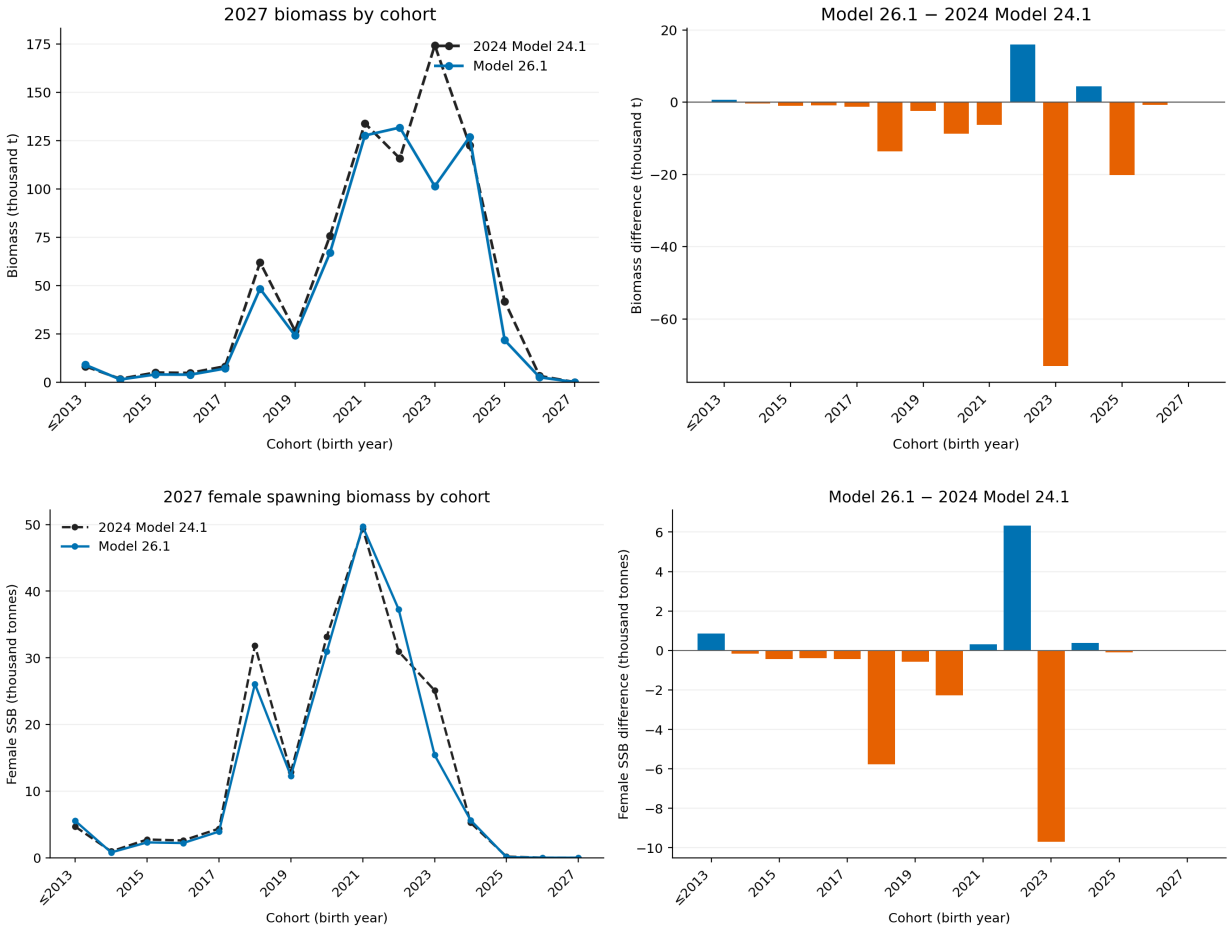


Figure 2.42. Model sensitivity to updated data components, the addition of 2025–2026 data, and model tuning. Panels show projected 2027 total biomass by individual cohort (thousands of tons; top left), difference between models by cohort (thousands of tons; top right), projected 2027 begin year female spawning biomass by individual cohort (thousands of tons; bottom left) and difference in female spawning biomass by cohort between models (thousands of tons; bottom right) for 2024 Model 24.1 and the tuned Model 26.1.

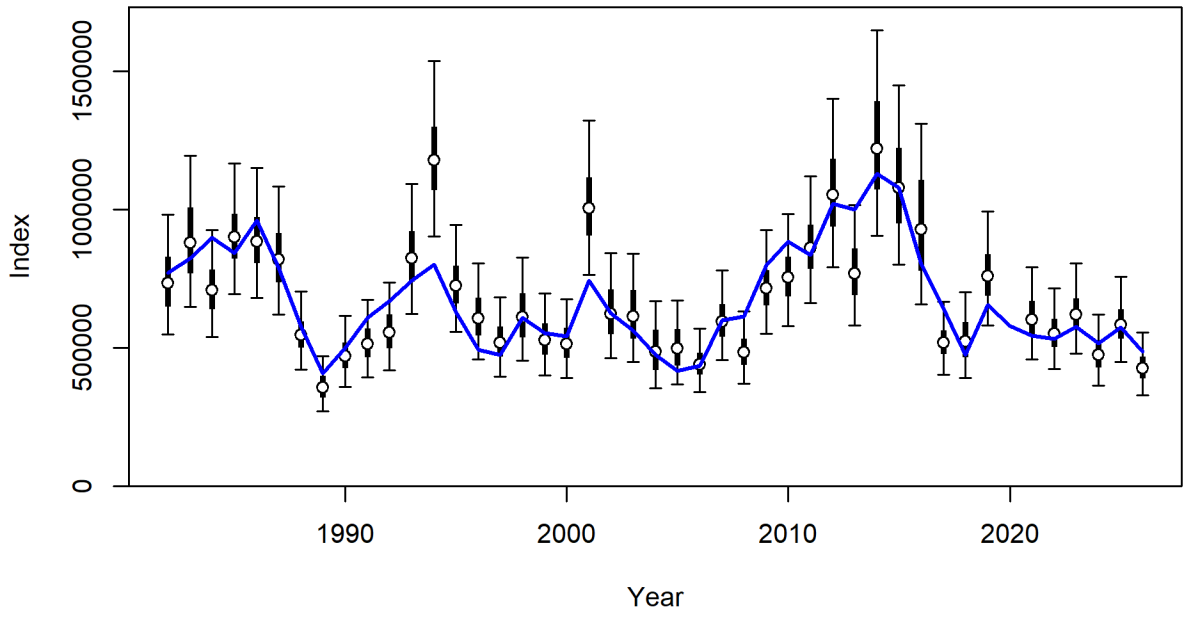


Figure 2.43. Fits to the EBS bottom trawl survey data (population numbers) for Model 26.1.

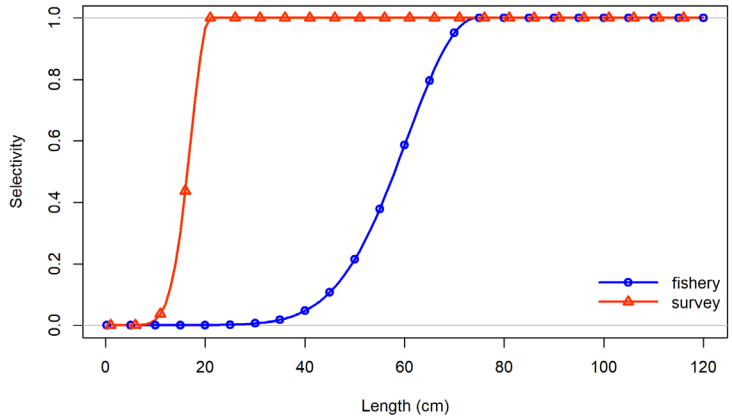


Figure 2.44. End year fishery and EBS bottom trawl survey selectivities for 2026 Model 24.1 and Model 26.1.

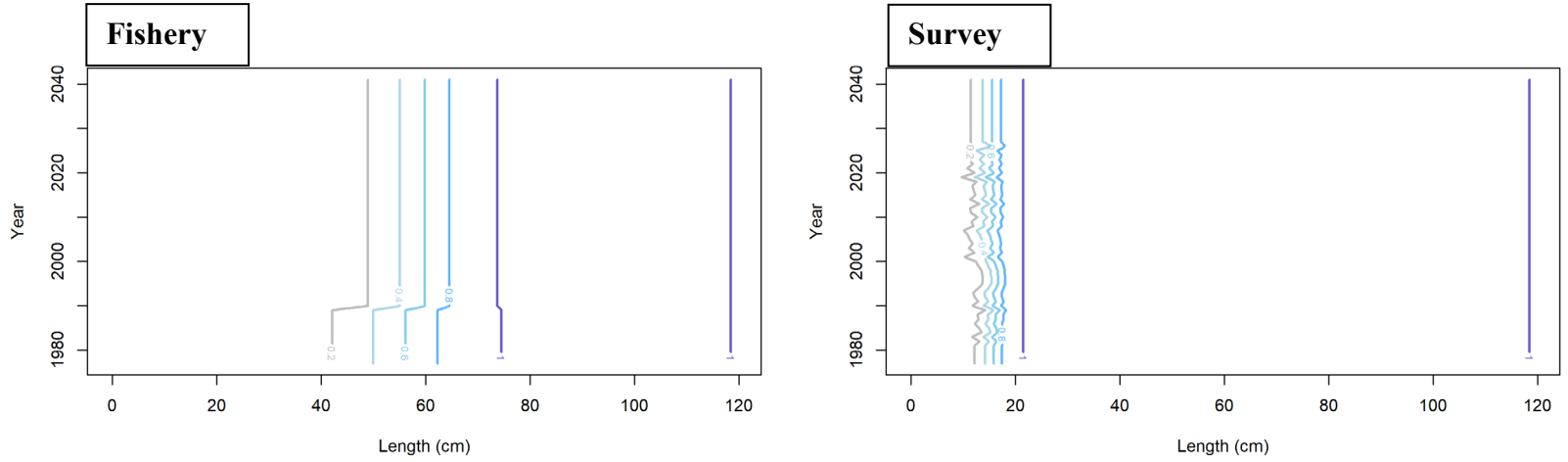


Figure 2.45. Time varying selectivity for 2026 Model 24.1 and Model 26.1 for fishery (left) and EBS bottom trawl survey (right).

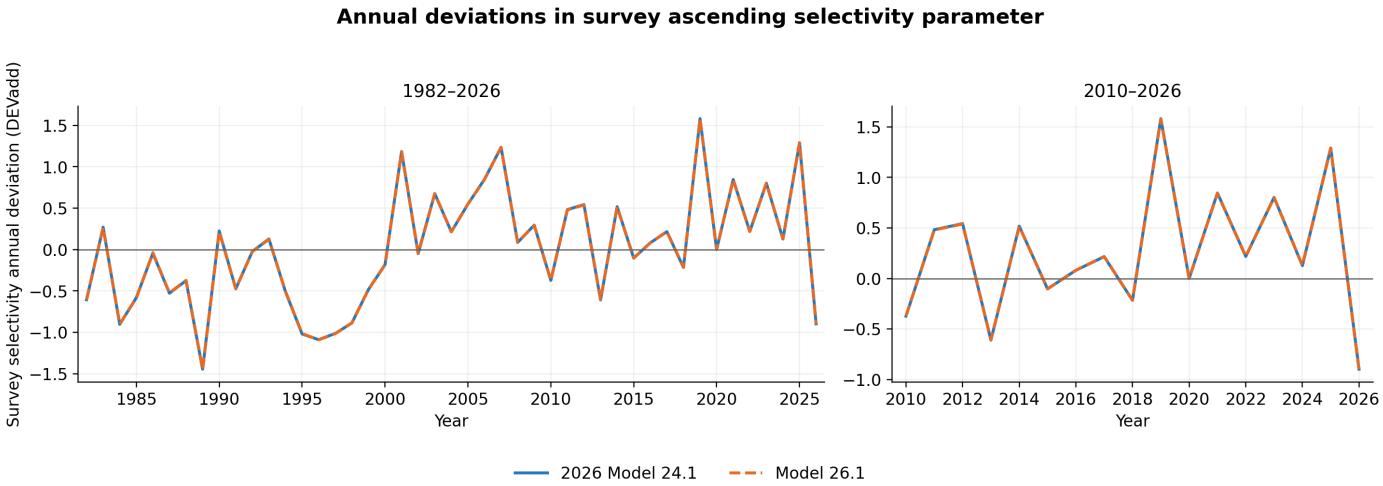


Figure 2.46. Annual deviations in EBS bottom trawl survey ascending selectivity parameter for 2026 Model 24.1 and Model 26.1.

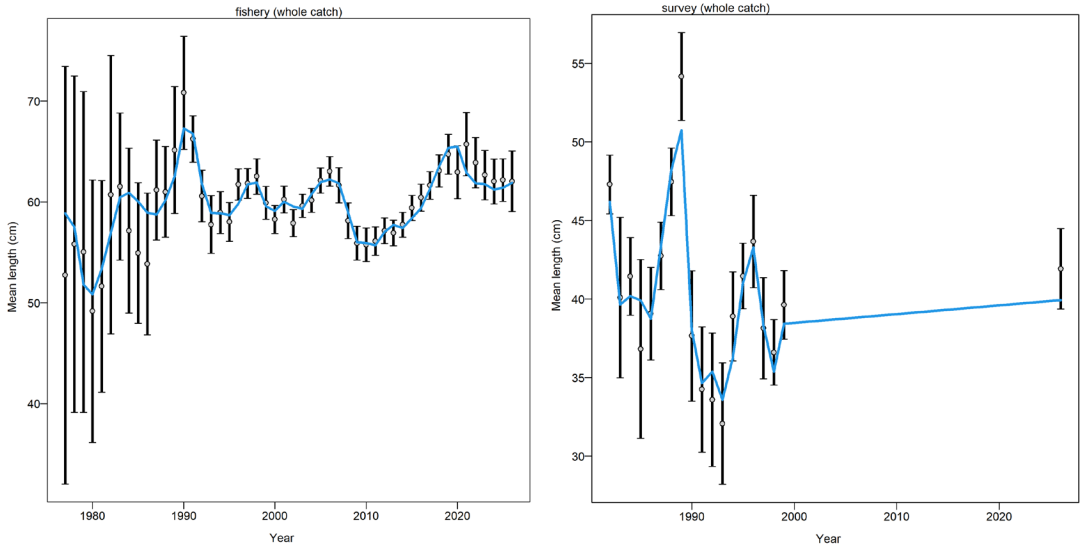


Figure 2.47. Mean length and fits to mean length for Model 26.1 for the fishery (left) and EBS bottom trawl survey (right).

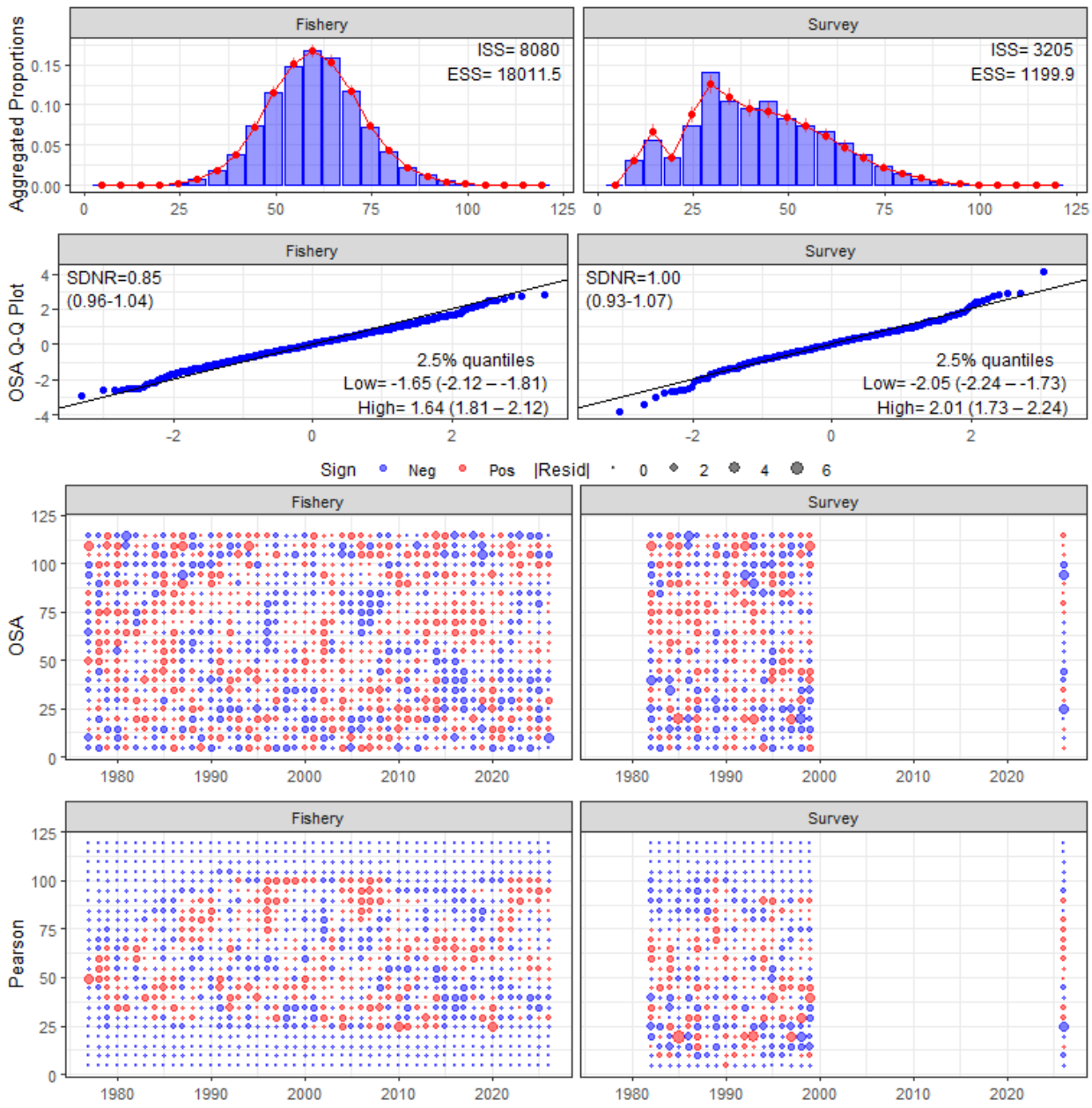


Figure 2.48. Aggregate proportions (top), OSA QQplot (2nd row), One-step-ahead (OSA) residuals (3rd row) and Pearson residuals (bottom) from fishery (left) and survey (right) length composition data for Model 26.1.

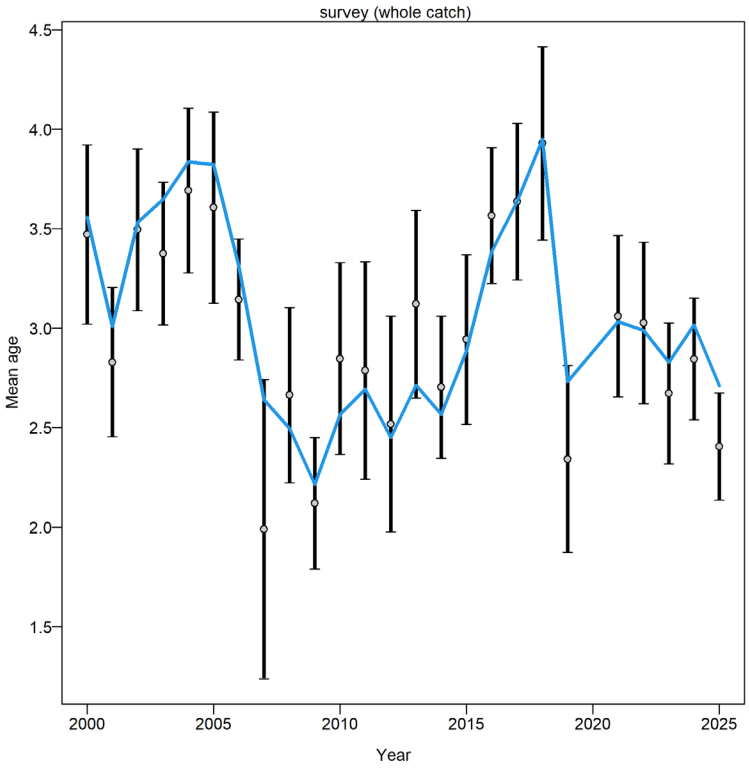


Figure 2.49. Mean age and fits to mean age for Model 26.1.

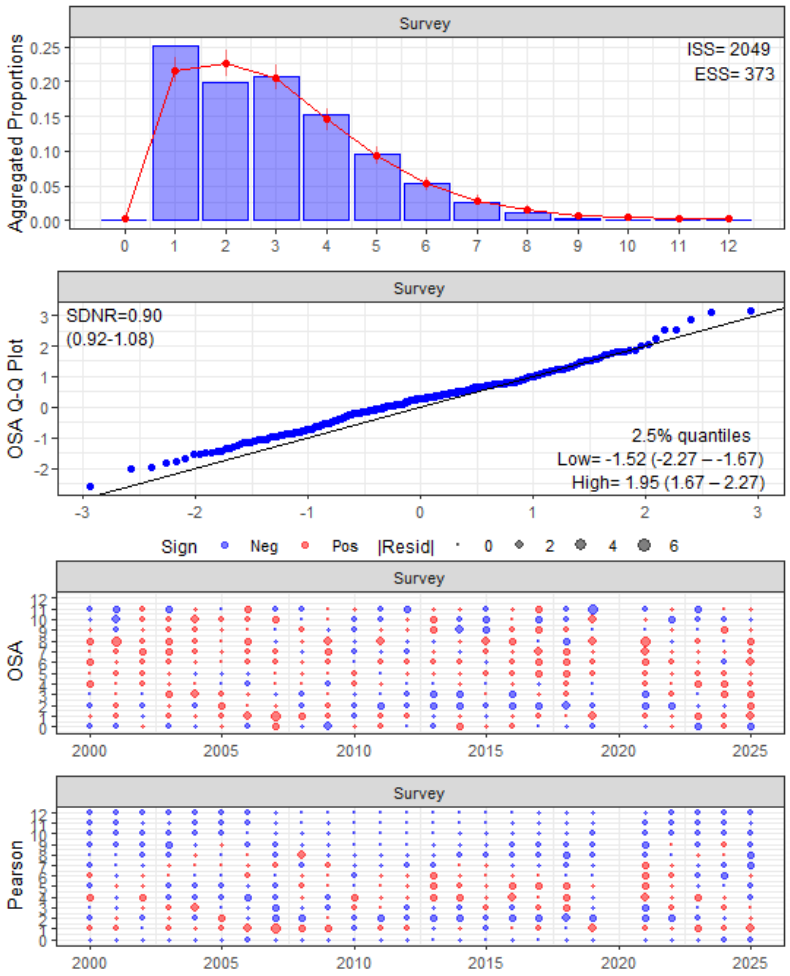


Figure 2.50. Aggregate proportions (top), OSA QQplot (2nd row), One-step-ahead (OSA) residuals (3rd row) and Pearson residuals (bottom) from survey age composition data for Model 26.1

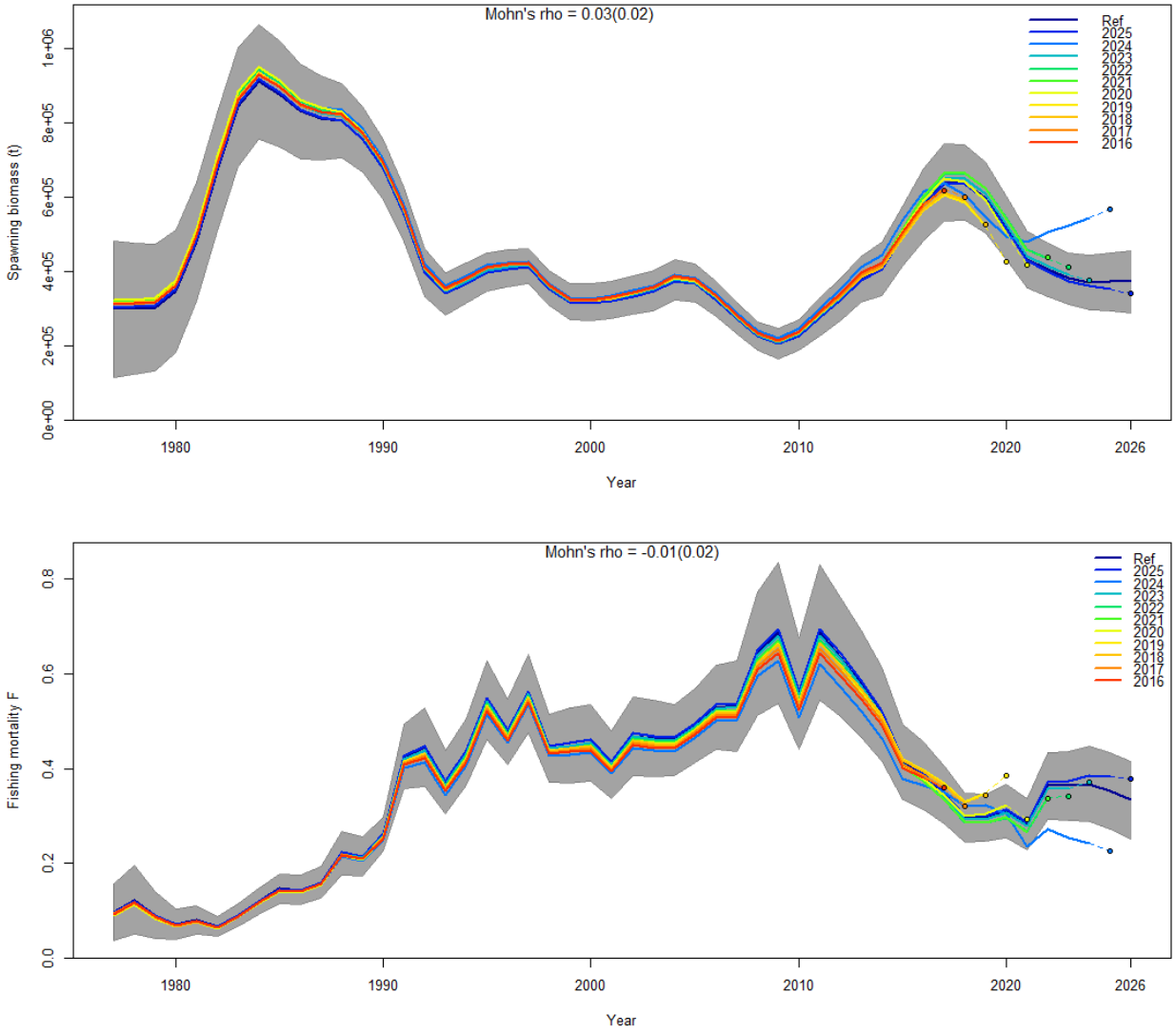


Figure 2.51. Retrospective plots of spawning stock biomass (top) and fishing mortality (bottom) including the Mohn's rho and in parenthesis the predictive rho values for Model 26.1. Plots from the ss3diags R library (Winker et al. 2022) and described in Carvalho et al. (2021).

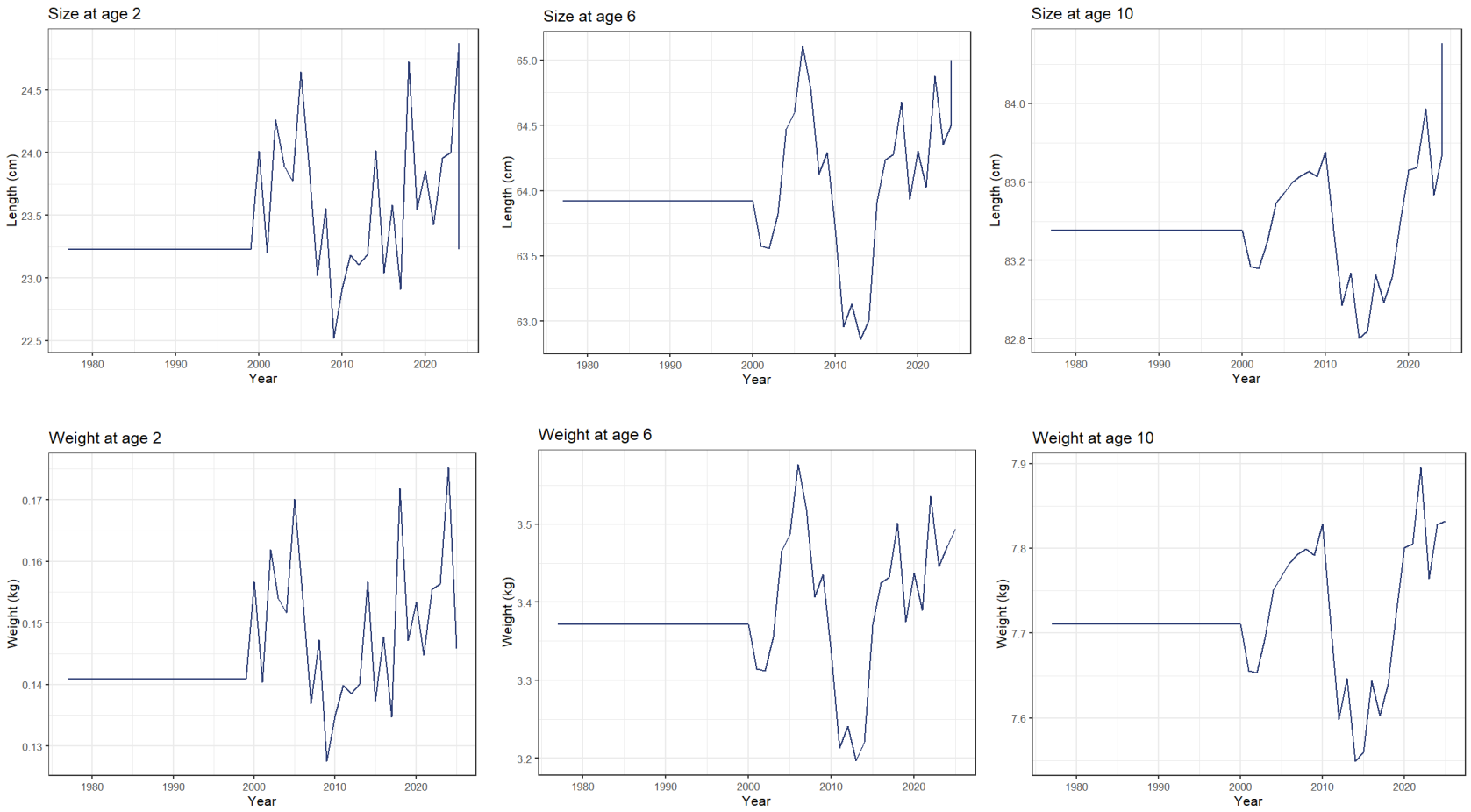


Figure 2.52 Model length (cm; top) and weight at age (kg; bottom) at age 2, age 6, and age 10.

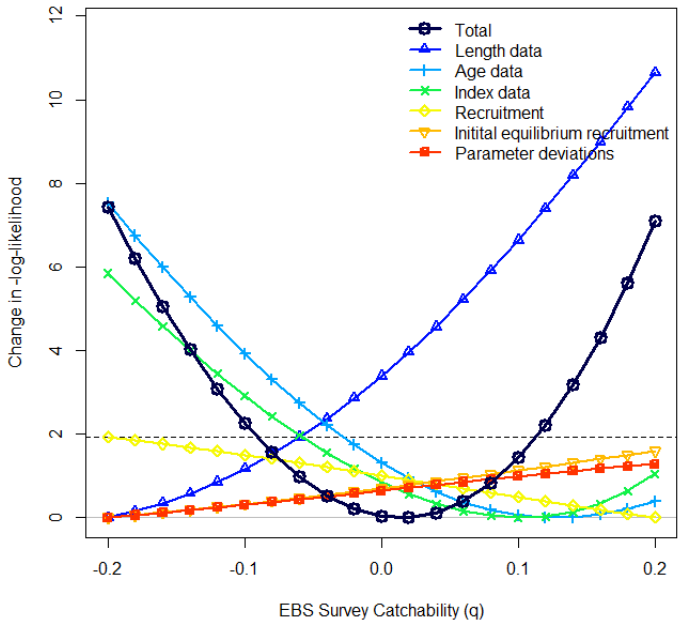


Figure 2.53. Likelihood profiles over survey catchability (q) by model component for Model 26.1.

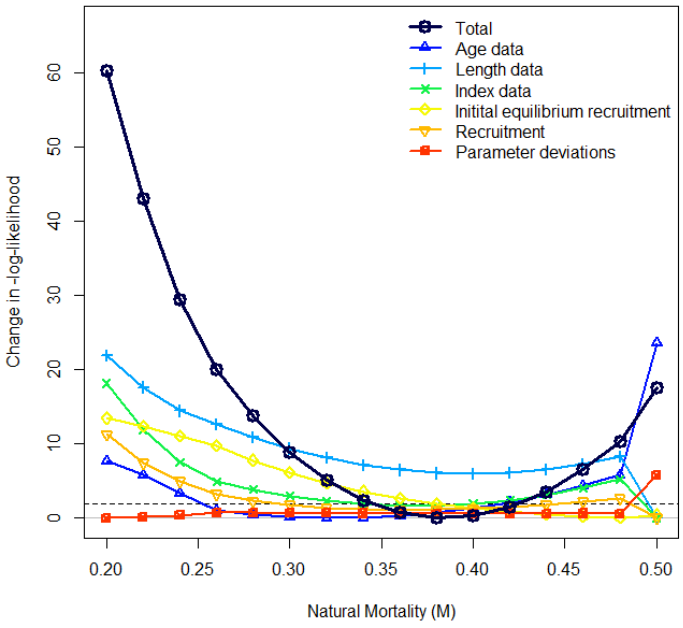


Figure 2.54. Likelihood profile over natural mortality (M) for Model 26.1.

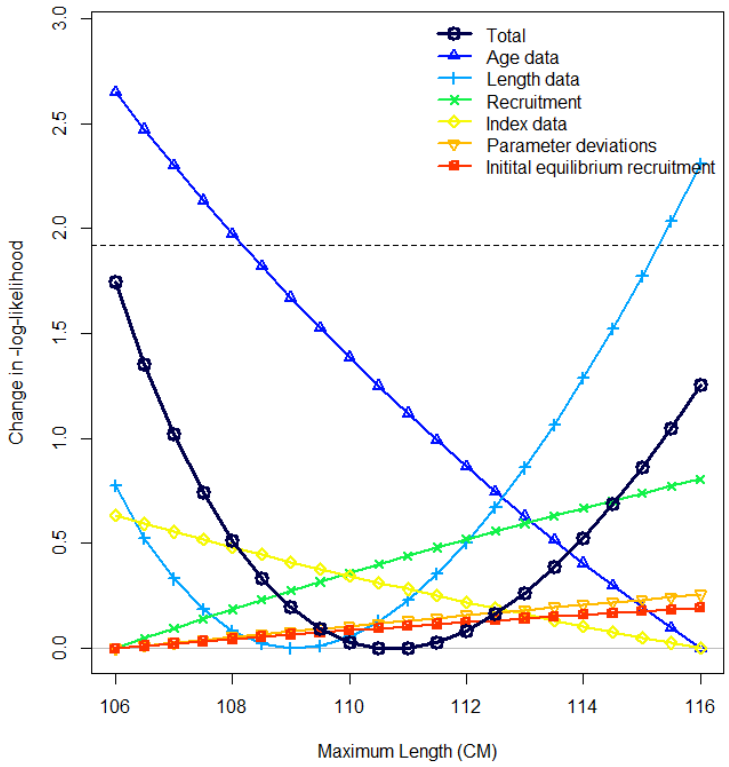


Figure 2.55. Likelihood profile over maximum length (L_{max}) for Model 26.1.

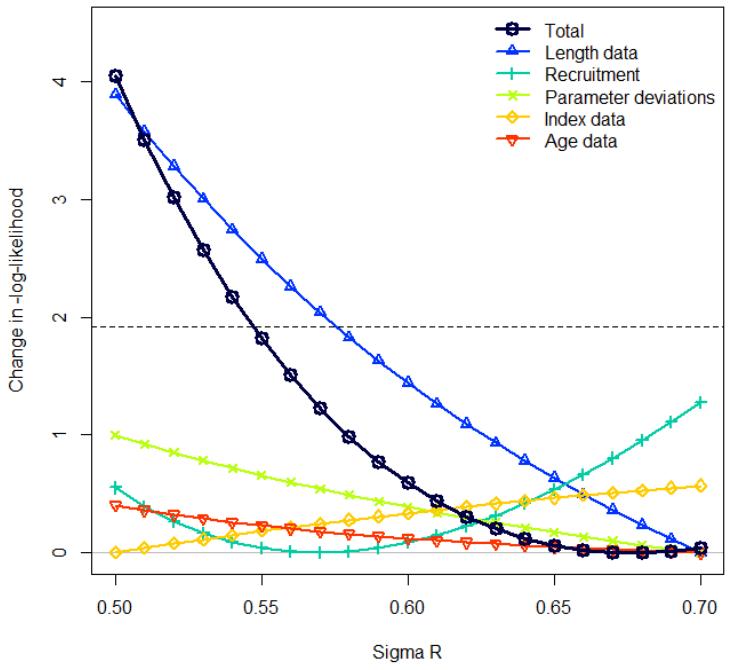


Figure 2.56. Likelihood profile over Sigma R for Model 26.1.

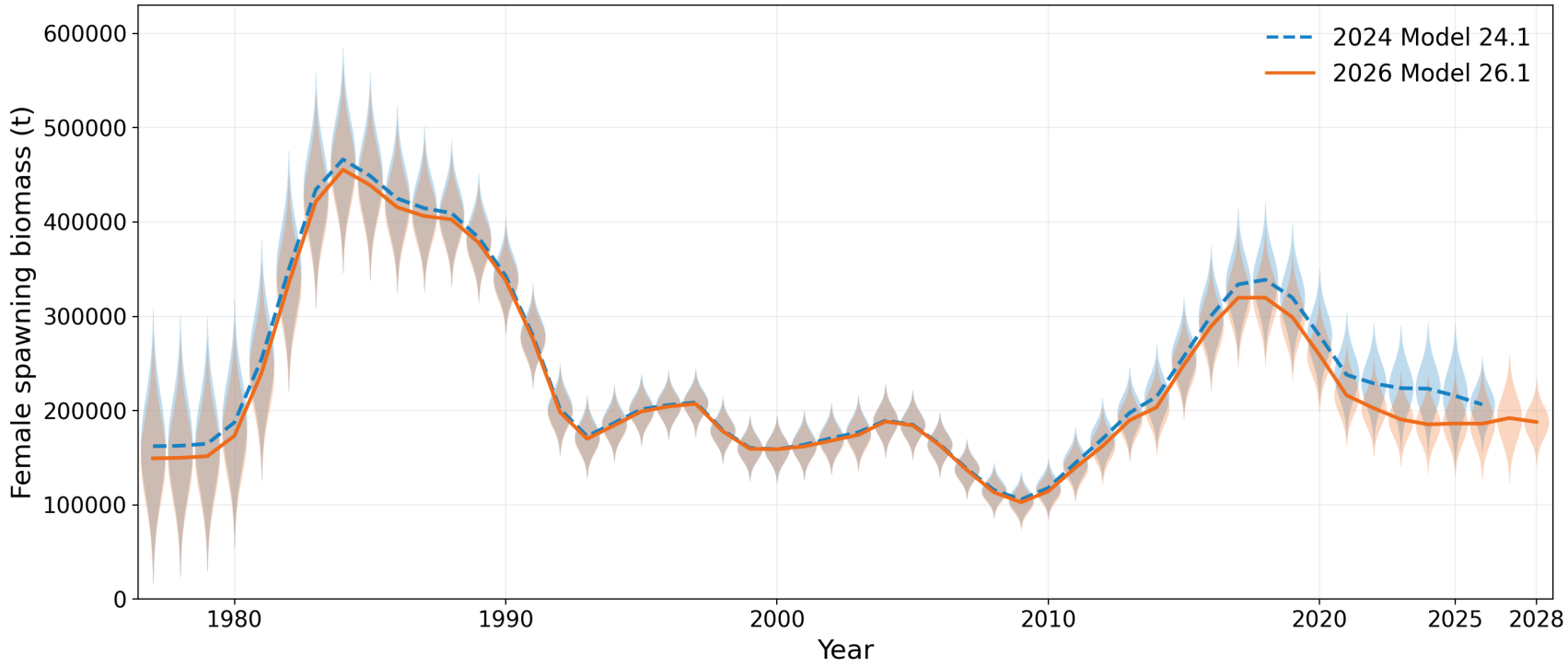


Figure 2.57. Female spawning biomass (t) for the 2024 Model 24.1 and 2026 Model 26.1.

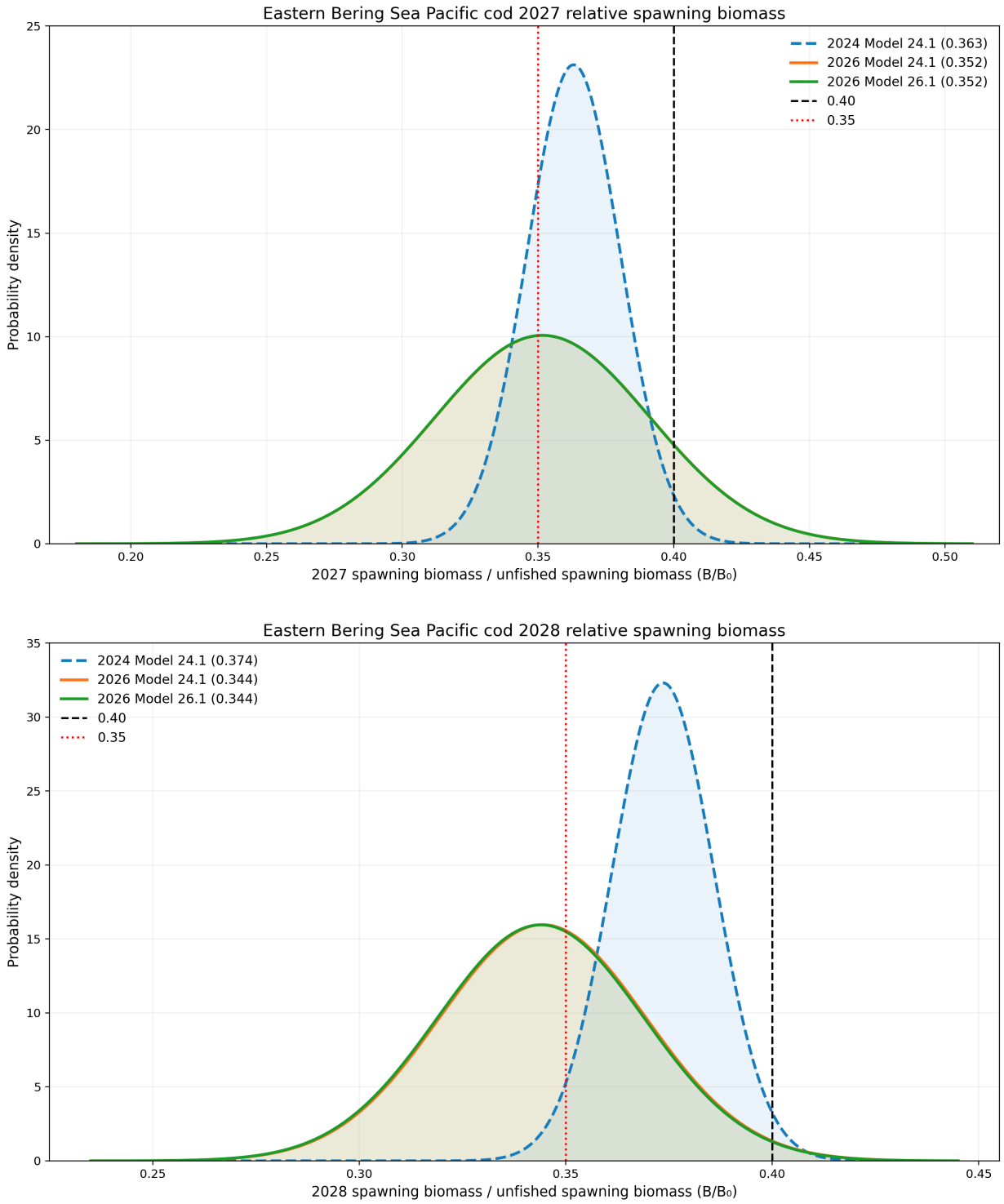


Figure 2.58. Ratio of spawning stock biomass to unfished spawning biomass distributions for 2027 (top) and 2028 (bottom) for 2024 Model 24.1, 2026 Model 24.1 and Model 26.1.

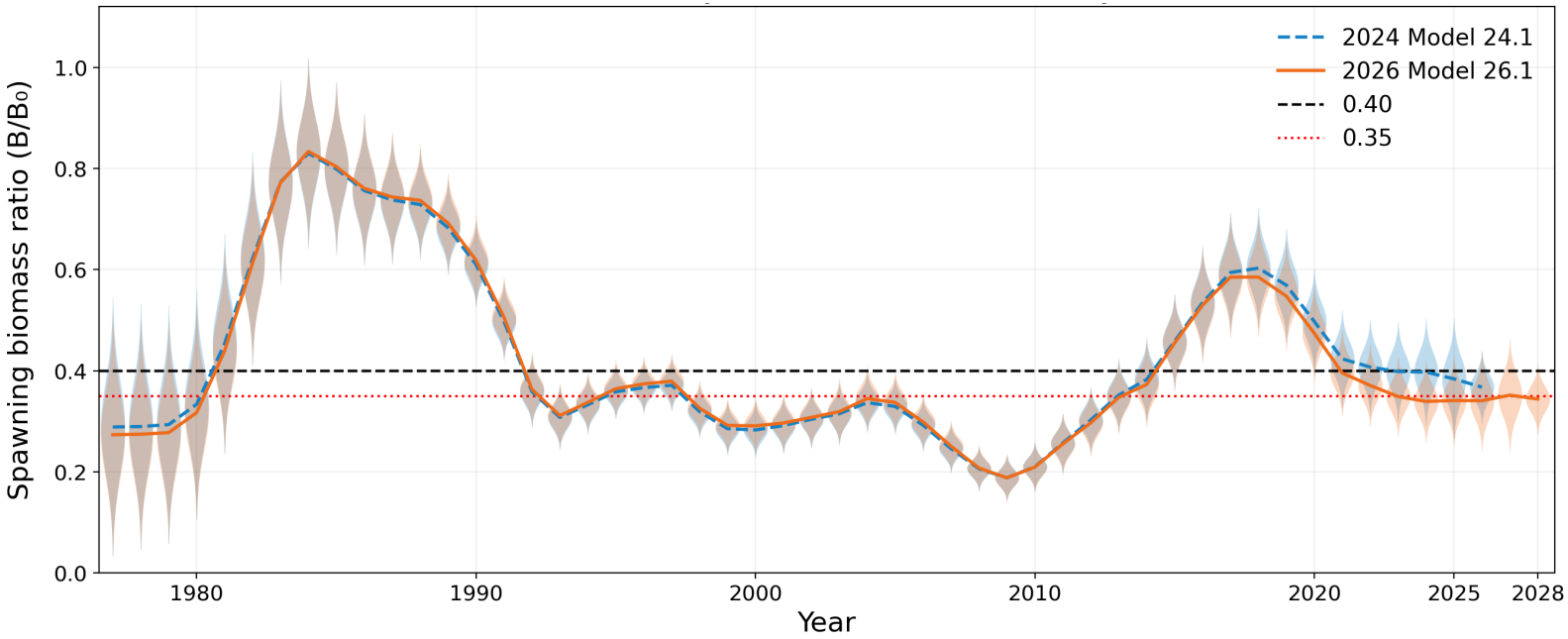


Figure 2.59. Ratio of spawning stock biomass to unfished spawning biomass (B_Y/B_0) for the 2024 Model 24.1 and 2026 Model 26.1.

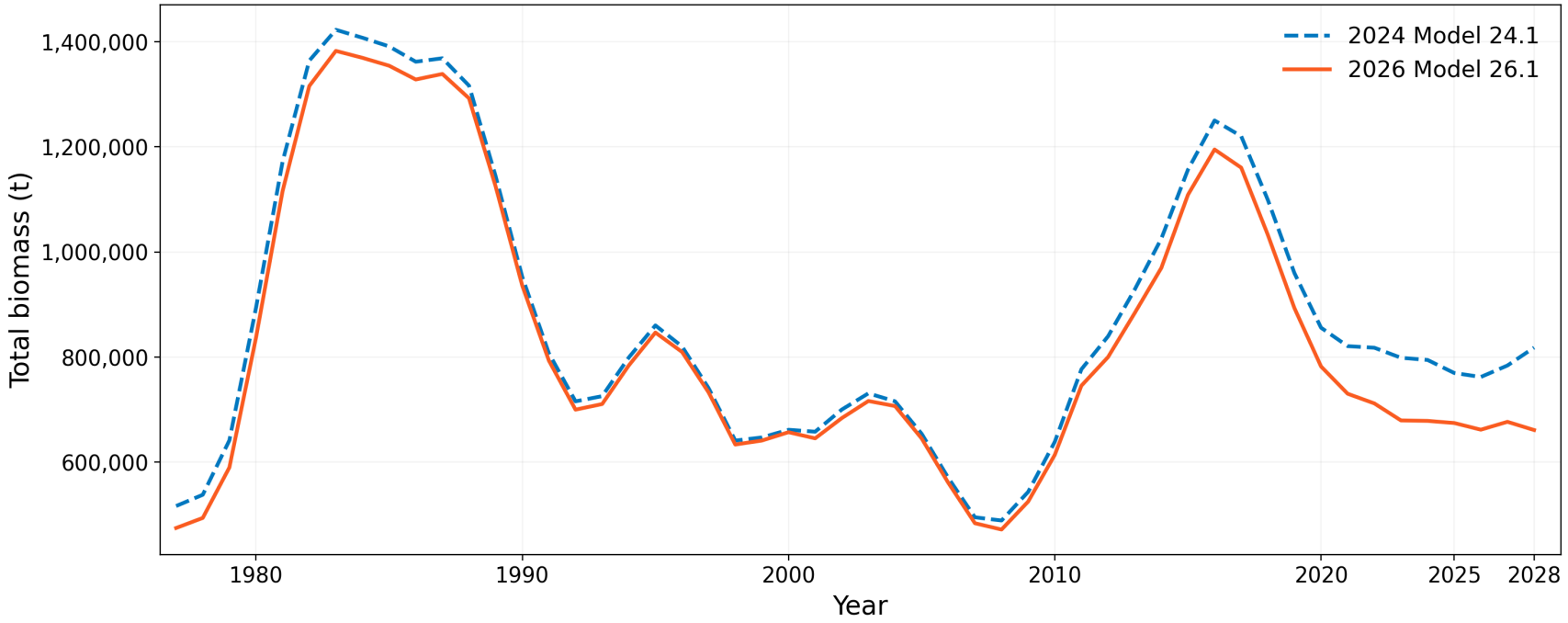


Figure 2.60. Total age-0 + biomass (t) for the 2024 Model 24.1 and 2026 Model 26.1.

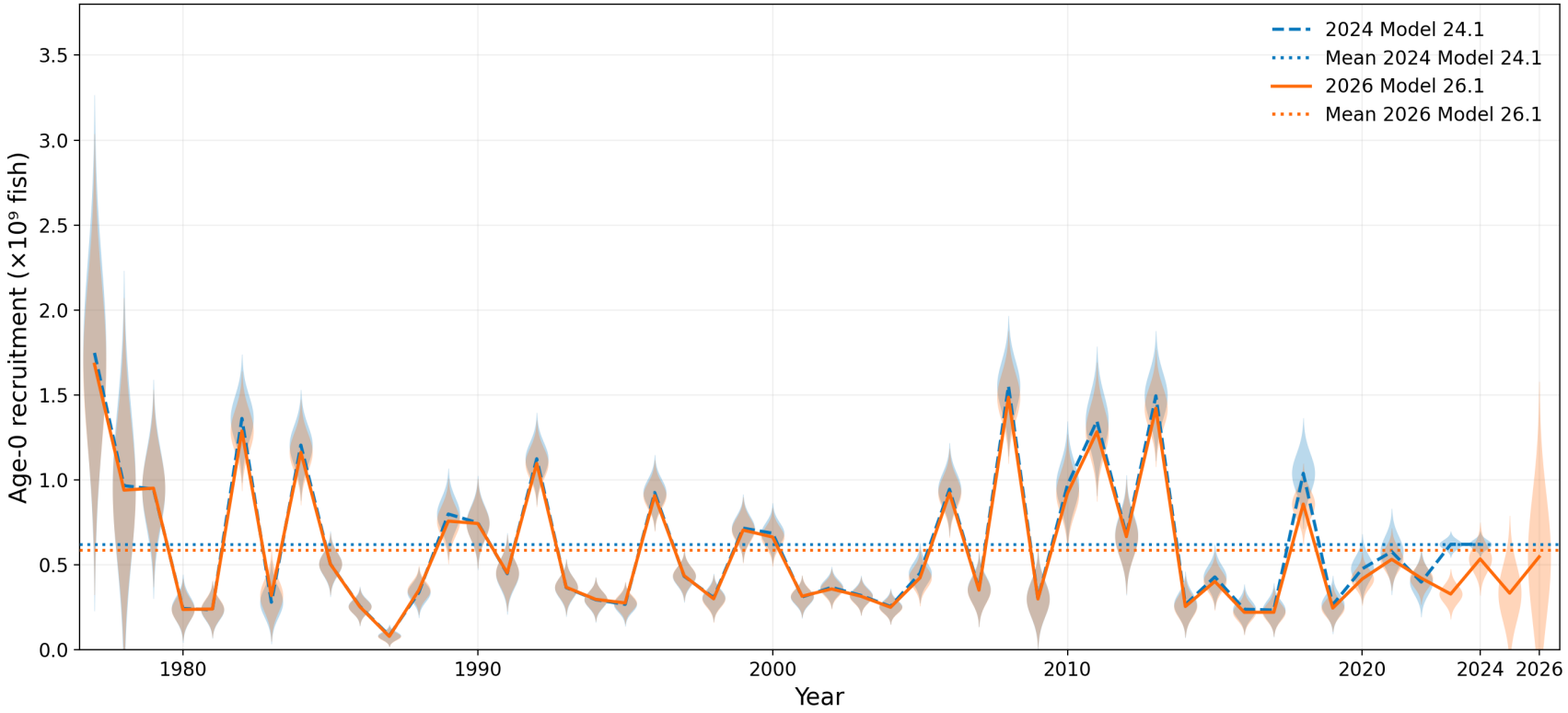


Figure 2.61. Recruitment (1,000s at age-0) for the 2024 Model 24.1 and 2026 Model 26.1.

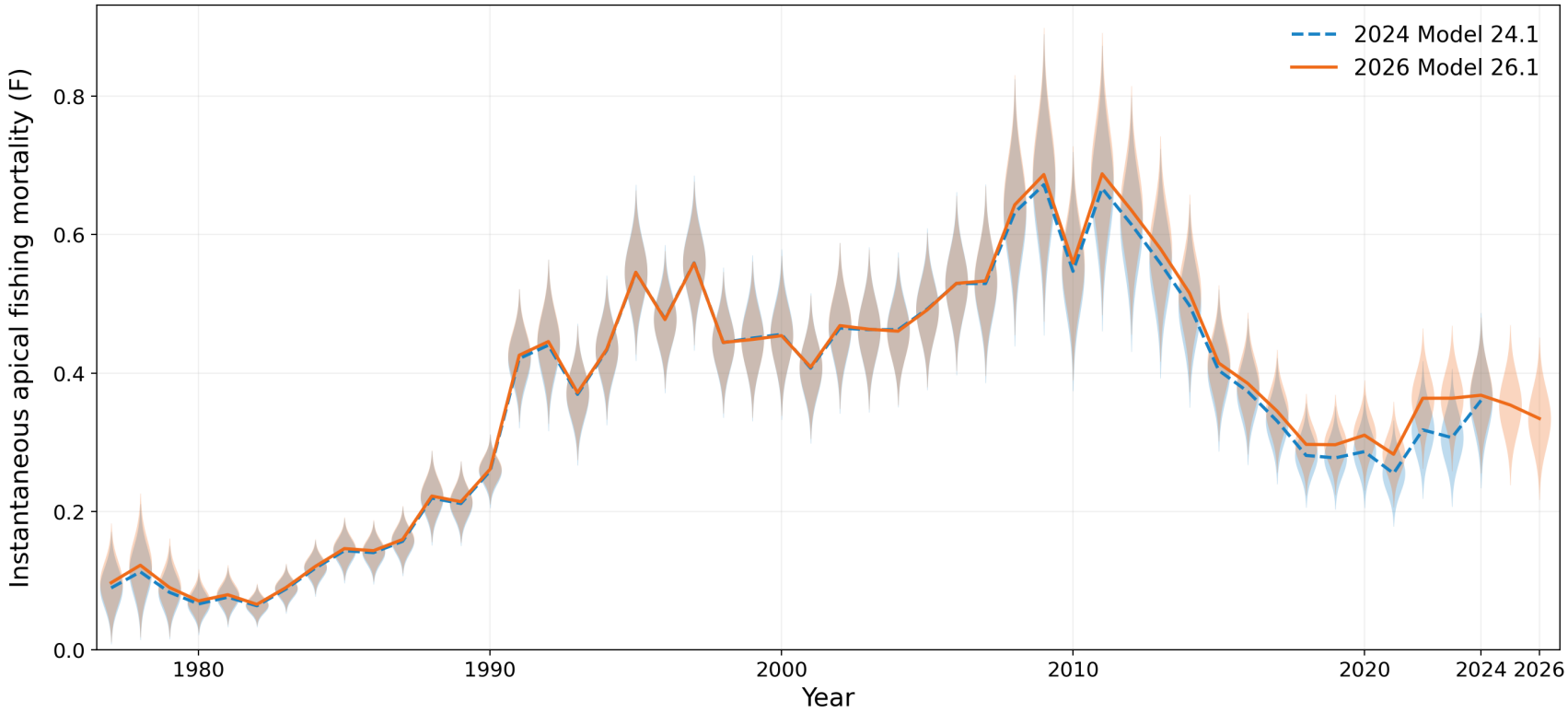


Figure 2.62. Instantaneous apical fishing mortality (F) for the 2024 Model 24.1 and 2026 Model 26.1.

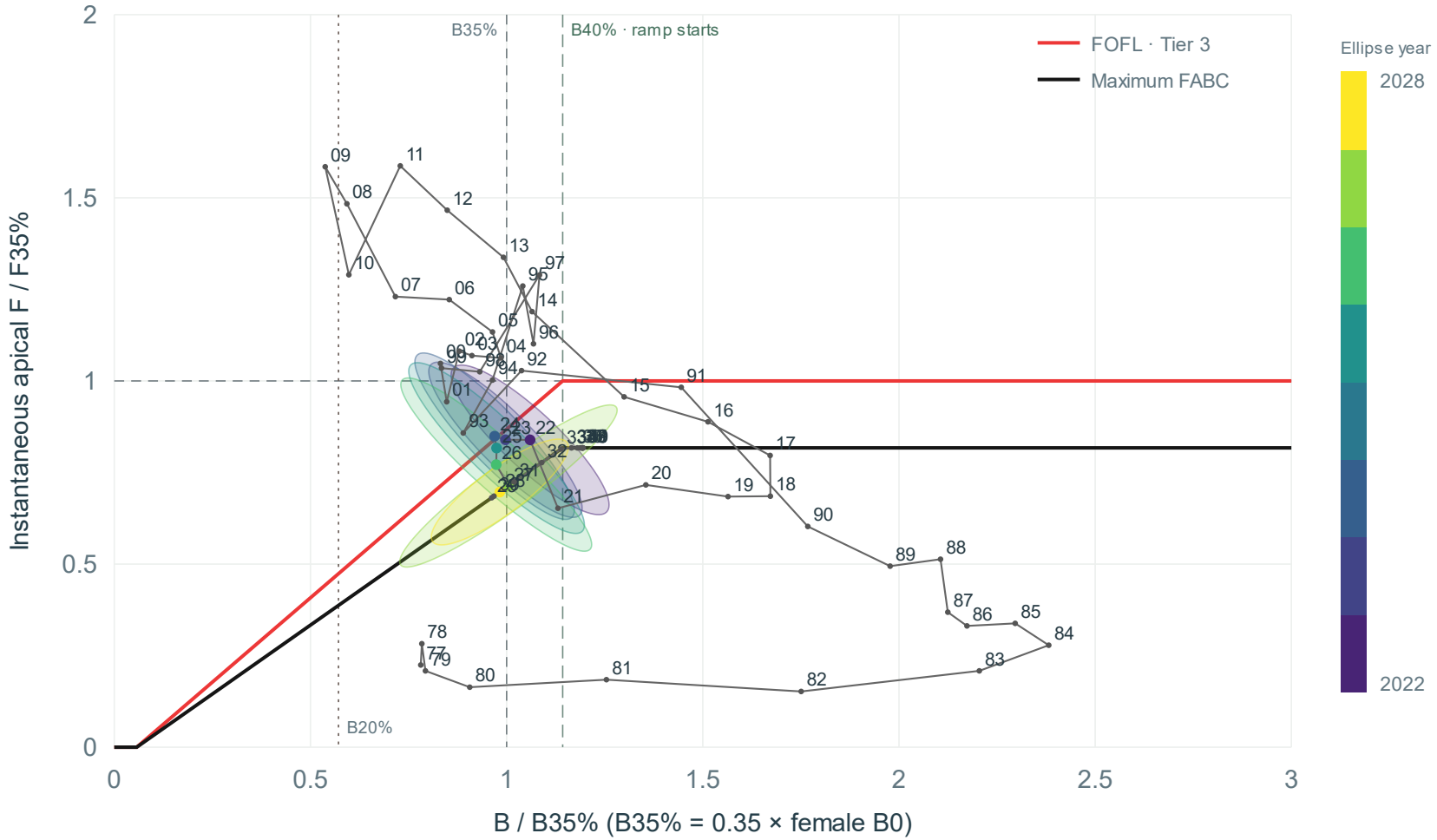


Figure 2.63. Phase plane plot for Model 26.1 with 95% joint uncertainty ellipses colored by year for 2022-2028.

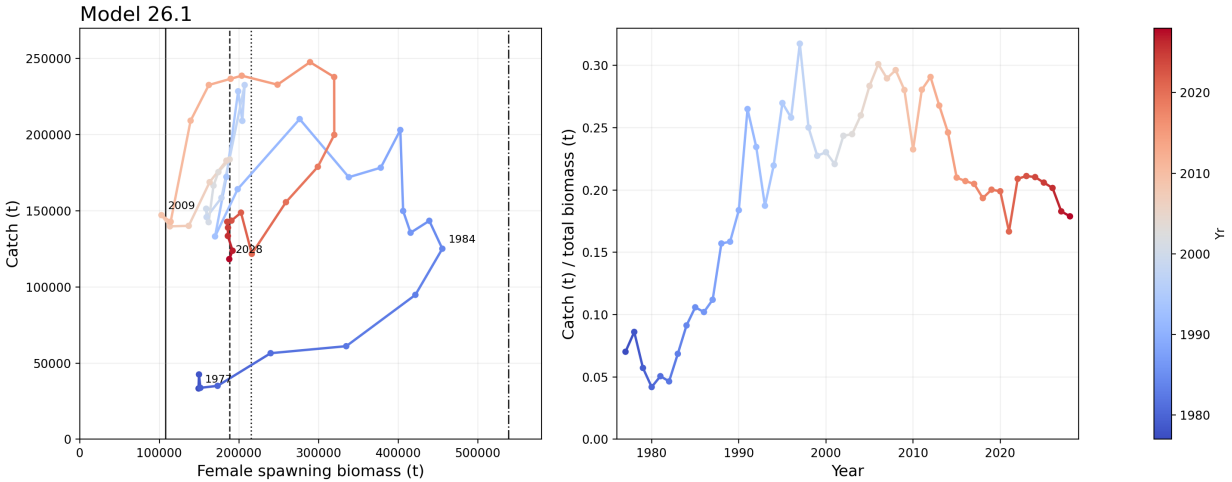


Figure 2.64. Plots of (left) catch (t) by spawning biomass (t) and (left) catch/total biomass for the Model 26.1 with (black line) $B_{20\%}$, (red dashed line) $B_{35\%}$, (orange dotted line) $B_{40\%}$, and (grey dash-dot line) $B_{100\%}$ for all years. Black triangles are projections for 2027 and 2028.

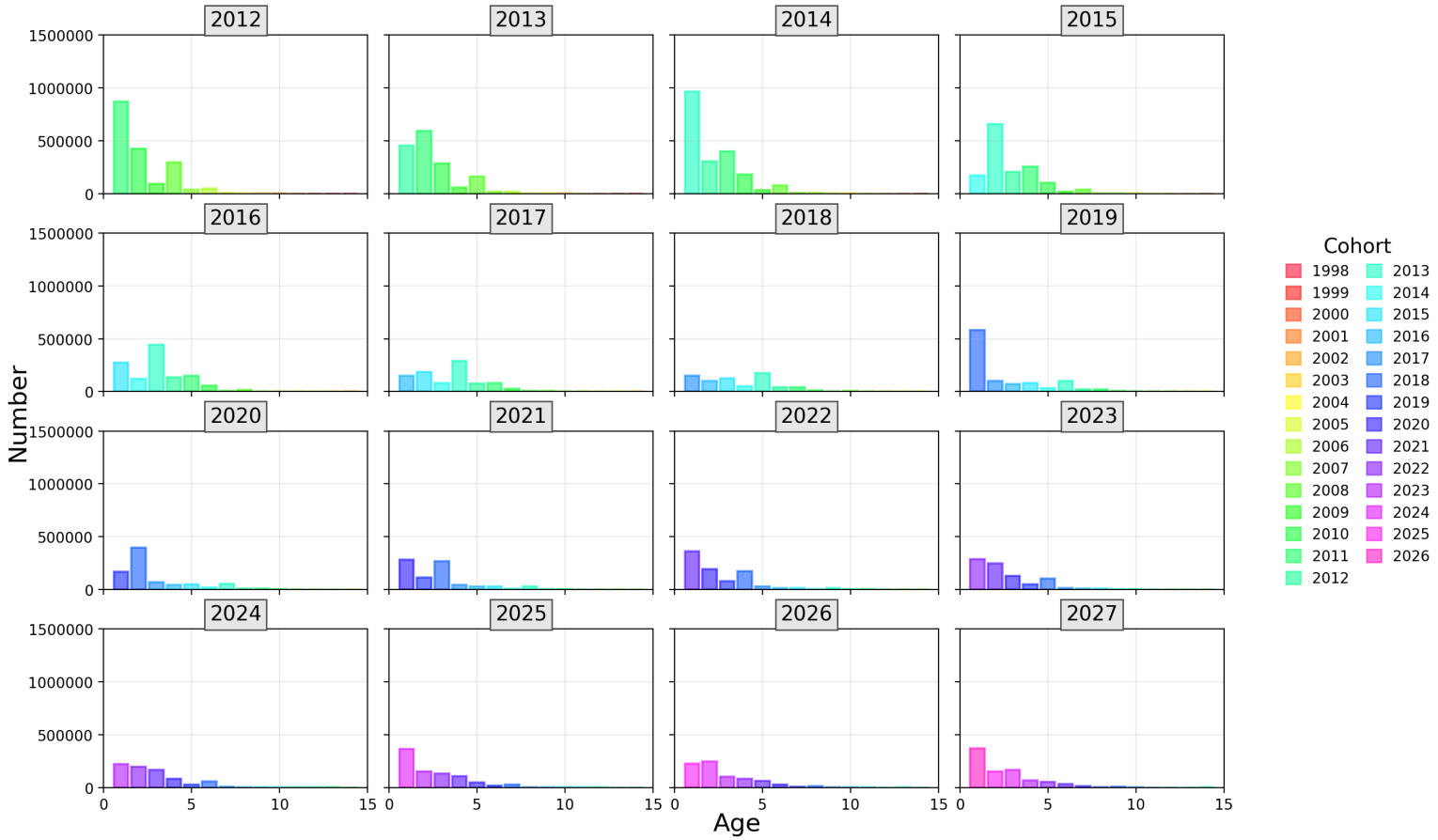


Figure 2.65. Numbers at age 2012-2027 from Model 26.1 by cohort.

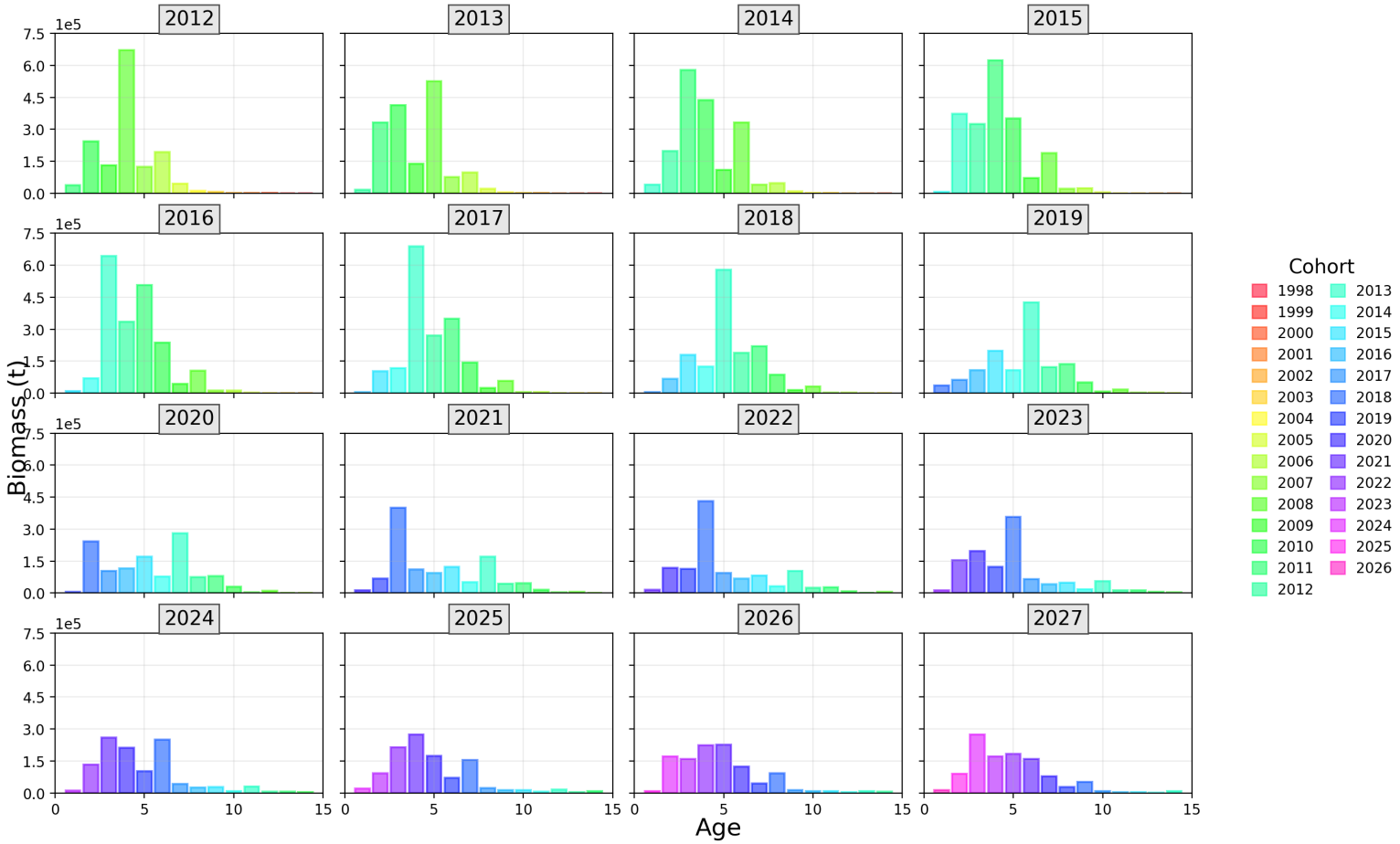


Figure 2.66. Biomass at age 2012-2027 from Model 26.1 by cohort.

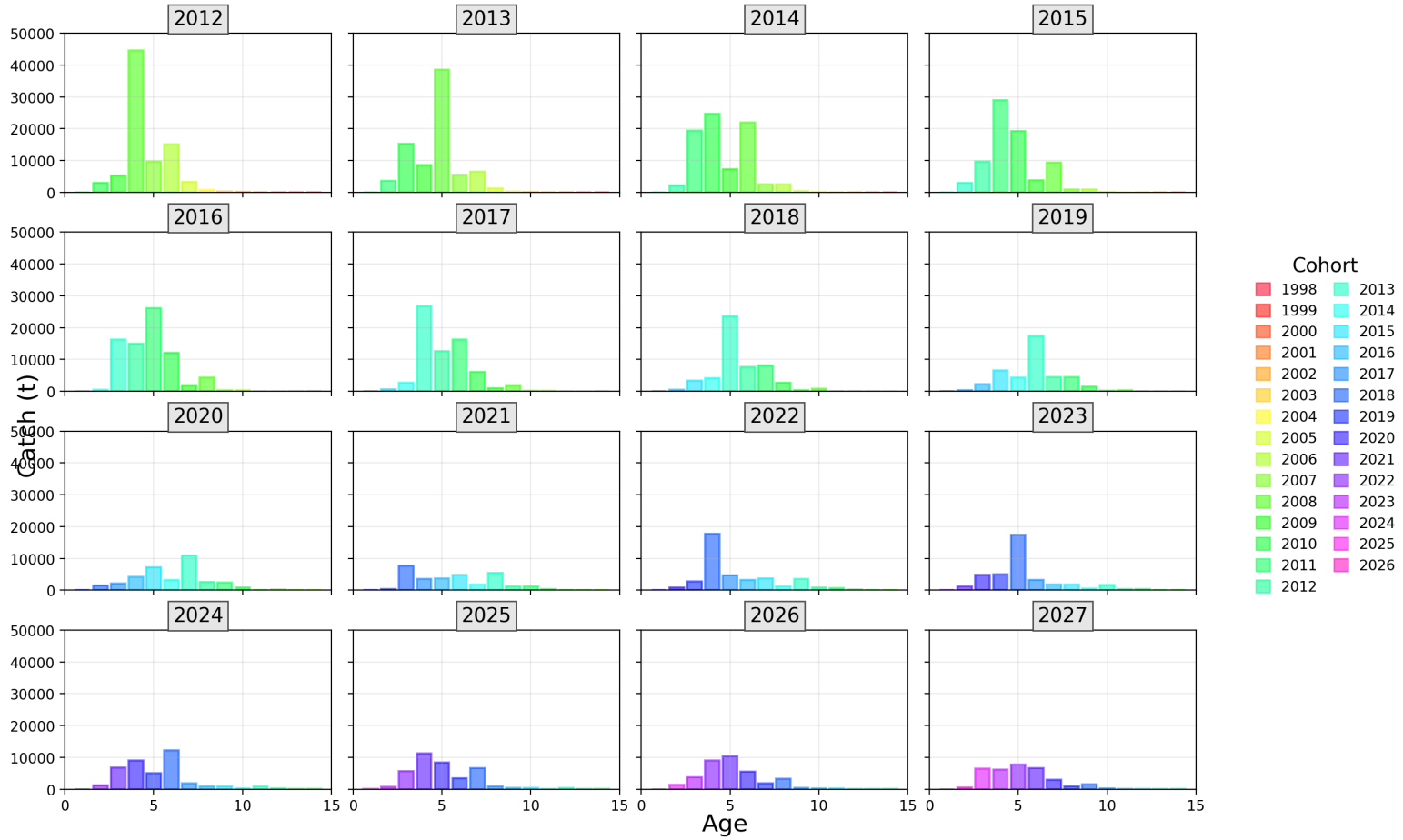


Figure 2.67. Catch in tons at age 2012-2027 from Model 26.1 by cohort.

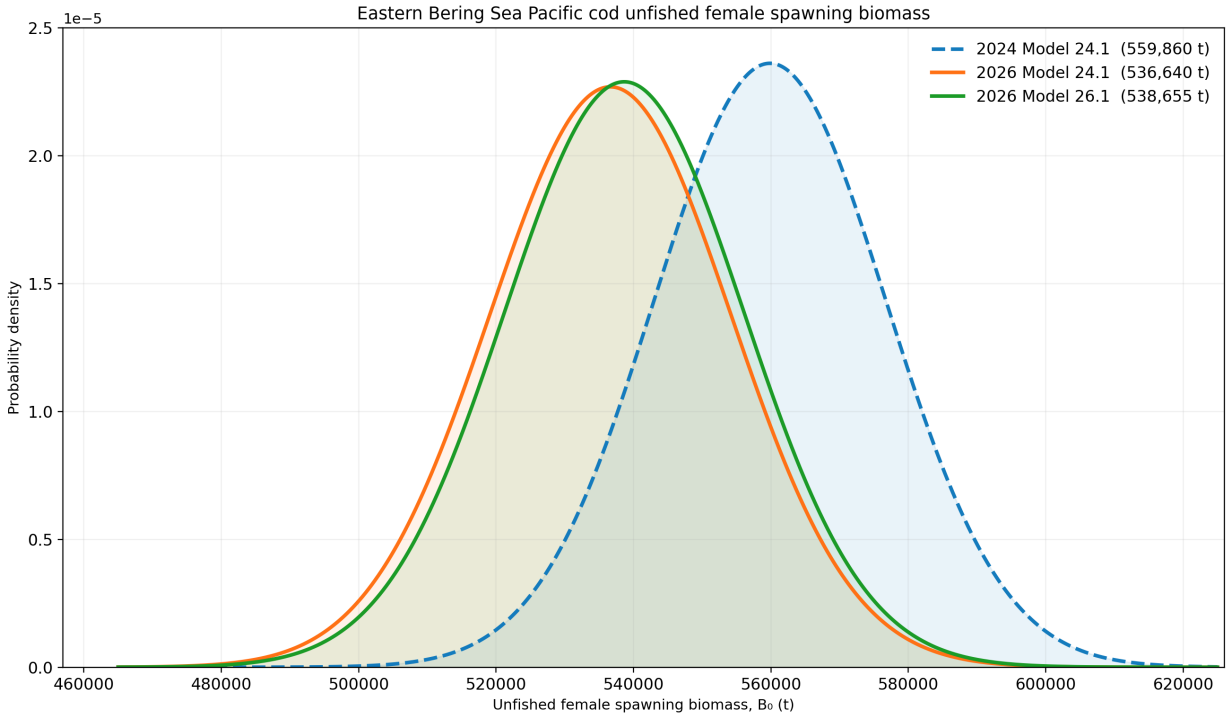


Figure 2.68. Distribution of female unfished spawning biomass ($SSB_{100\%}$) for the 2024 Model 24.1 and the 2026 Model 24.1 and Model 26.1.

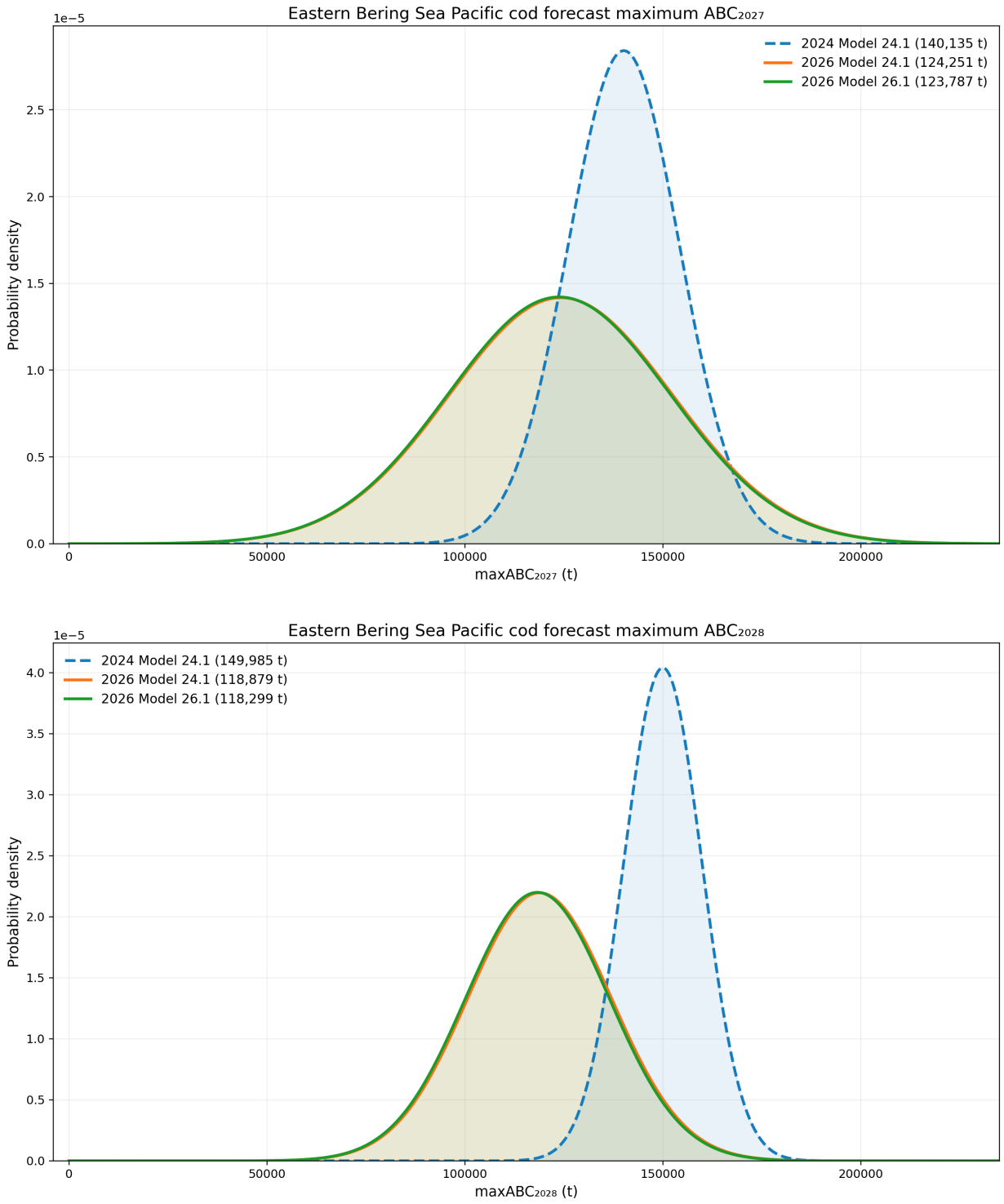


Figure 2.69. Forecasted maximum ABC for 2027 (top) and 2028 (bottom) for 2024 Model 24.1, 2026 Model 24.1 and Model 26.1.



Figure 2.70. Female spawning biomass (t; top), apical fishing mortality (middle), and projected catch (t; bottom) for the seven North Pacific projection scenarios from Model 26.1.

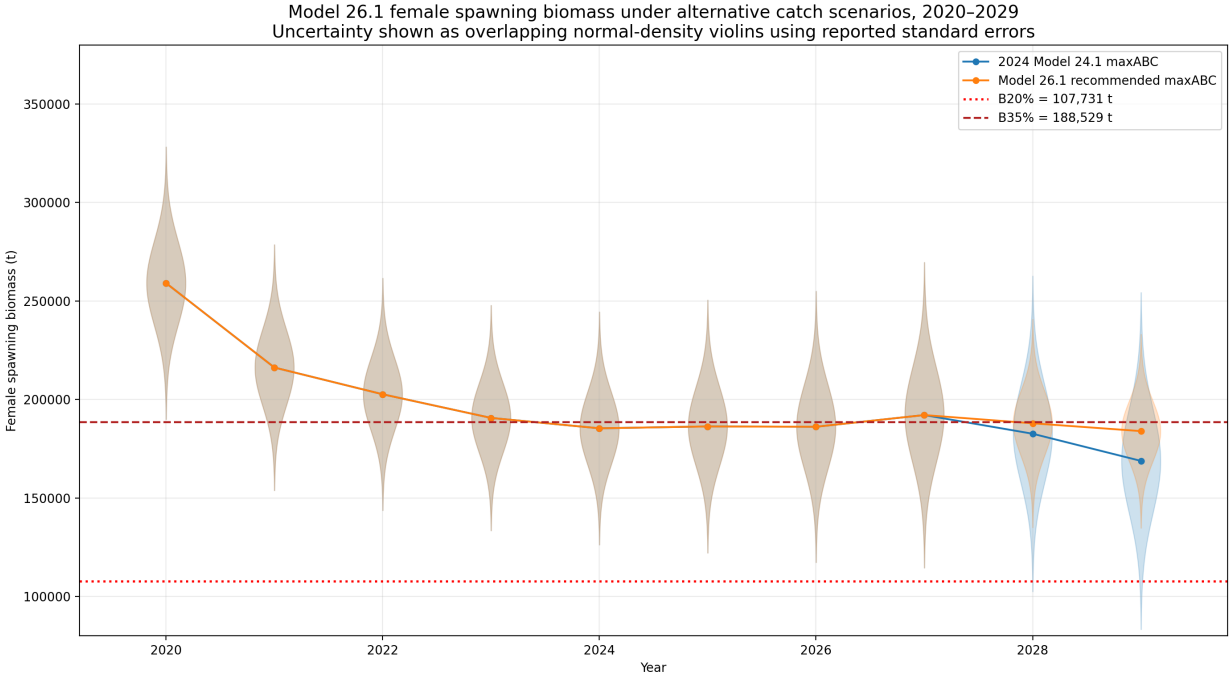


Figure 2.71. Female spawning biomass assuming Model 26.1 dynamics are true, but having 2027 and 2028 catch at 2024 Model 24.1 maximum ABC values (blue line) or the Model 26.1 maximum ABC values.

Appendix 2.1 September 2026 Eastern Bering Sea Pacific cod Alternative Assessment Model Evaluations an Explorations

Authors: Steven Barbeaux, Pete Hulson, and Ingrid Spies

- Link to Github repository Stock Synthesis model files and supporting figures

1.0 Plus-group Sensitivity Analysis

Introduction

This analysis evaluates reduction of the plus-group age for Eastern Bering Sea Pacific cod (*Gadus macrocephalus*; Barbeaux et al. 2024). The currently accepted plus-group age is 20. This analysis provides model performance results based on reducing the plus-group age from 20 to 10. Model 24.1 uses an age-20 plus group, although recent Bering Sea fishery and survey collections contained Pacific cod only through age 14. In addition, the tinyVAST-estimated bottom-trawl survey age composition used in the model applies an age-12 plus group because relatively few age-13 and age-14 fish occur in the survey data (Barbeaux et al. 2024).

The age-20 plus group in Model 24.1 is a remnant of earlier assessments, when Pacific cod were erroneously assigned substantially older ages. This analysis provides the first formal reevaluation of the retained age-20 plus group. This sensitivity analysis examines how reducing the plus-group age to better reflect the observed age structure of the population affects model fit, parameter estimates, uncertainty, and management reference points.

Methods

The data inputs for Model 24.1 were updated through 2025. The terminal plus group was then reduced from age 20 to age 10 in two-year increments, resulting in models with plus groups at ages 20, 18, 16, 14, 12, and 10 (Table 1.1). Changes in model likelihood, parameter estimates, and key derived quantities were evaluated across configurations.

Results

Model results were generally stable when the plus-group age was reduced from 20 to 14, but progressively larger changes occurred at ages 12 and 10 (Table 1.2). Total objective-function values were nearly identical for the plus-group ages 14 through 20 models, ranging from 366.31 to 366.57. The age-12 model had a slightly higher objective function of 367.55, whereas the age-10 model increased to 382.73. The deterioration in the age-10 model was primarily attributable to the length-composition likelihood, which increased by 19.08 likelihood units relative to the age-20 model, although age-composition and survey likelihood components improved slightly. The degradation in fit can mainly be attributable to the fits to the larger size bins as seen in the Pearson's residuals (Figure 1.1).

Table 1.1 Model-specific r4ss materials for the Eastern Bering Sea Pacific cod plus-group sensitivity analysis. Each link opens the model directory containing r4ss summaries generated from Stock Synthesis 3 (SS3) inputs and outputs and the associated diagnostic figures. Model names identify terminal plus-group age; 14+, for example, aggregates fish ages 14 and older.

Model	SS3/r4ss directory	Linked material	Destination
20+	MODEL26.1.20	r4ss summaries and diagnostic figures	Open MODEL26.1.20 outputs
18+	MODEL26.1.18	r4ss summaries and diagnostic figures	Open MODEL26.1.18 outputs
16+	MODEL26.1.16	r4ss summaries and diagnostic figures	Open MODEL26.1.16 outputs
14+	MODEL26.1.14	r4ss summaries and diagnostic figures	Open MODEL26.1.14 outputs
12+	MODEL26.1.12	r4ss summaries and diagnostic figures	Open MODEL26.1.12 outputs
10+	MODEL26.1.10	r4ss summaries and diagnostic figures	Open MODEL26.1.10 outputs

Table 1.2 Negative log-likelihood (NLL) results and active parameter counts for six otherwise comparable Eastern Bering Sea Pacific cod models differing in terminal plus-group age. Model names identify the terminal plus group; for example, 14+ aggregates fish ages 14 and older. Delta NLL is each model's total NLL minus the 20+ model value, so smaller values indicate lower NLL. Length-composition, age-composition, and survey columns report selected NLL components. The shaded row identifies the recommended 14+ configuration. NLL values are rounded to one decimal because finer precision does not improve interpretation.

Model	Number of estimated parameters	Total NLL	Δ NLL vs. 20+	Length comp. NLL	Age comp. NLL	Survey NLL
20+	180	366.6	—	335.1	58.5	−58.2
18+	178	366.6	0	335.1	58.5	−58.2
16+	176	366.5	−0.1	335	58.5	−58.2
14+	174	366.3	−0.3	334.8	58.5	−58.2
12+	172	367.6	1	336.7	58	−58.6
10+	170	382.7	16.2	354.2	55.8	−59.7

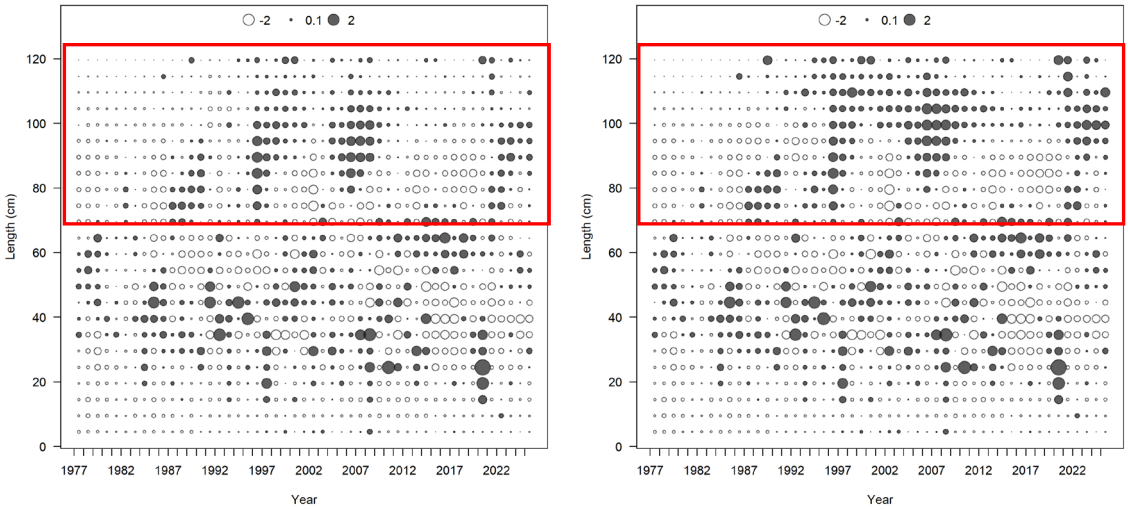


Figure 1.1 Pearson residuals for fishery length composition fits for 14+ age group (left) and 10+ age group (right) models showing higher residuals for the larger fish in the 10+ age group model. Red box indicates size bins with the greatest difference in residuals.

Estimated biological and fishery parameters were also similar among the plus-group age 14 through 20 models (Table 1.3). The age-12 model produced modest changes in recruitment scale, survey catchability, initial fishing mortality, and historical fishery selectivity. The age-10 model showed the largest departures, including an 8.7% reduction in estimated unfished recruitment, a 13.0% increase in survey catchability, and a 34.9% increase in initial fishing mortality relative to the age-20 model (Figure 1.2). The estimated 1977 fishery selectivity peak increased from 76.0 cm in the age-20 model to 79.8 cm in the age-10 model and was near its upper parameter bound. Estimated growth curves were nearly indistinguishable among the age-14 through age-20 models. For the 1977 cohort, size at age in the age-10 model was approximately 1.8% greater than the age-20 model at older ages (Figure 1.3), whereas differences for the age-12 model were approximately 0.25% and those for the age-14 through age-18 models were close to zero.

Table 1.3 Growth model parameters, catchability(q), initial F and peak fishery selectivity by plus group.

Plus group	L_{max} (cm)	von Bert. K	Richards	Ln(R_0)	R_0 Δ vs 20+	Survey Ln(q)	q Δ vs 20+	Initial F	1977 fishery peak (cm)
20+	111.04	0.118	1.462	13.331	—	0.019	—	0.1122	76.02
18+	111.01	0.118	1.462	13.331	0.01%	0.0189	−0.01%	0.1122	76.021
16+	110.97	0.118	1.462	13.331	0.08%	0.0179	−0.11%	0.1121	76.025
14+	110.83	0.119	1.461	13.331	0.05%	0.0183	−0.06%	0.1126	76.273
12+	110.92	0.12	1.451	13.314	−1.60%	0.04	2.13%	0.121	77.445
10+	110.55	0.13	1.382	13.24	−8.66%	0.1412	13.00%	0.1513	79.801

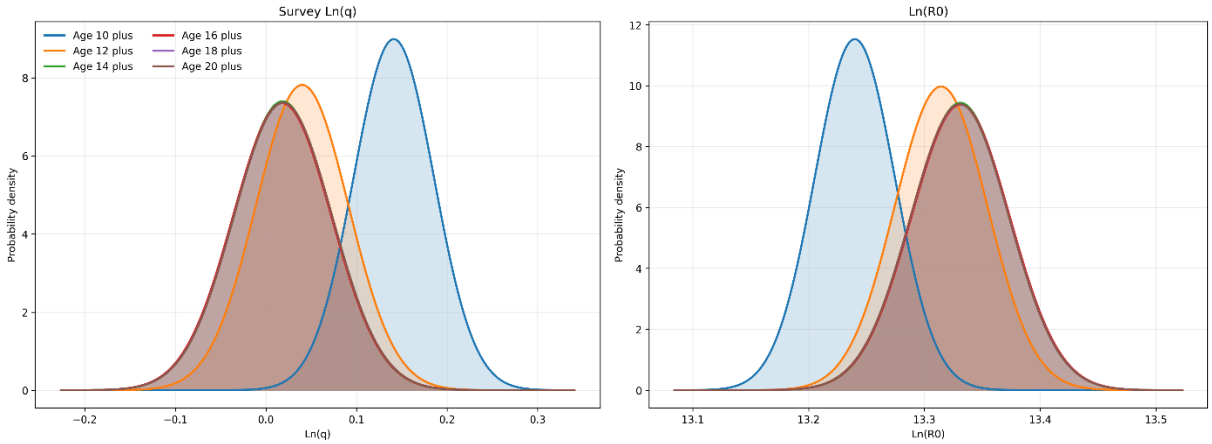


Figure 1.2 Density plots of log catchability (left) and log of virgin recruitment (R_0; right)

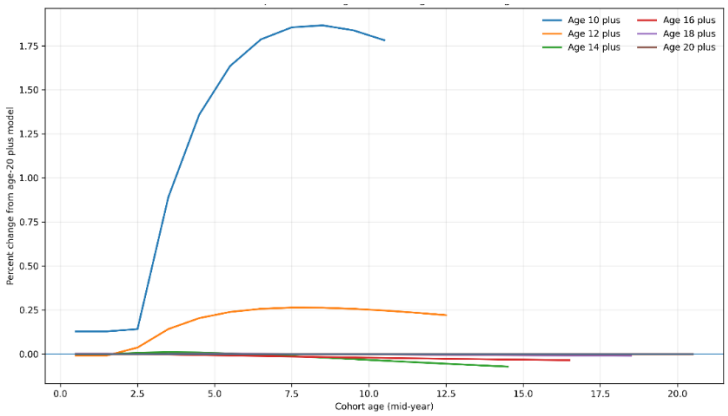


Figure 1.3 Percentage difference in size by plus group for 1977 cohort by age from the model with age 20 plus group.

Female spawning-biomass and recruitment trajectories retained the same general temporal patterns across all plus-group assumptions, but their estimated magnitudes declined as the plus-group age was reduced (Table 1.4; Figure 1.4). Approximate density distributions based on the reported estimates and standard deviations showed substantial overlap among the age-14 through age-20 models for unfished spawning biomass, 2025 spawning biomass, log survey catchability, and log unfished recruitment. In contrast, the age-10 model distributions were shifted toward lower spawning biomass and unfished recruitment and higher survey catchability, with the age-12 model generally intermediate (Figure 1.5). Overall, results indicate that plus-group ages of 14 or older produced stable model estimates, whereas use of an age-10 plus group materially affected model fit, parameter estimates, and estimated population scale.

Table 1.4 Derived quantities by plus group.

Plus group	Female unfished SSB	Female SSB_{1976}	Female SSB_{2025}	$Bratio_{2025}$	F_{2025}
20+	551.545 kt	167.712 kt	197.914 kt	0.3588	0.3516
18+	551.460 kt	167.719 kt	197.937 kt	0.3589	0.3515
16+	551.260 kt	167.906 kt	198.125 kt	0.3594	0.3512
14+	550.440 kt	167.746 kt	198.009 kt	0.3597	0.3513
12+	546.000 kt	159.351 kt	193.554 kt	0.3545	0.3596
10+	535.440 kt	133.419 kt	176.081 kt	0.3289	0.3941

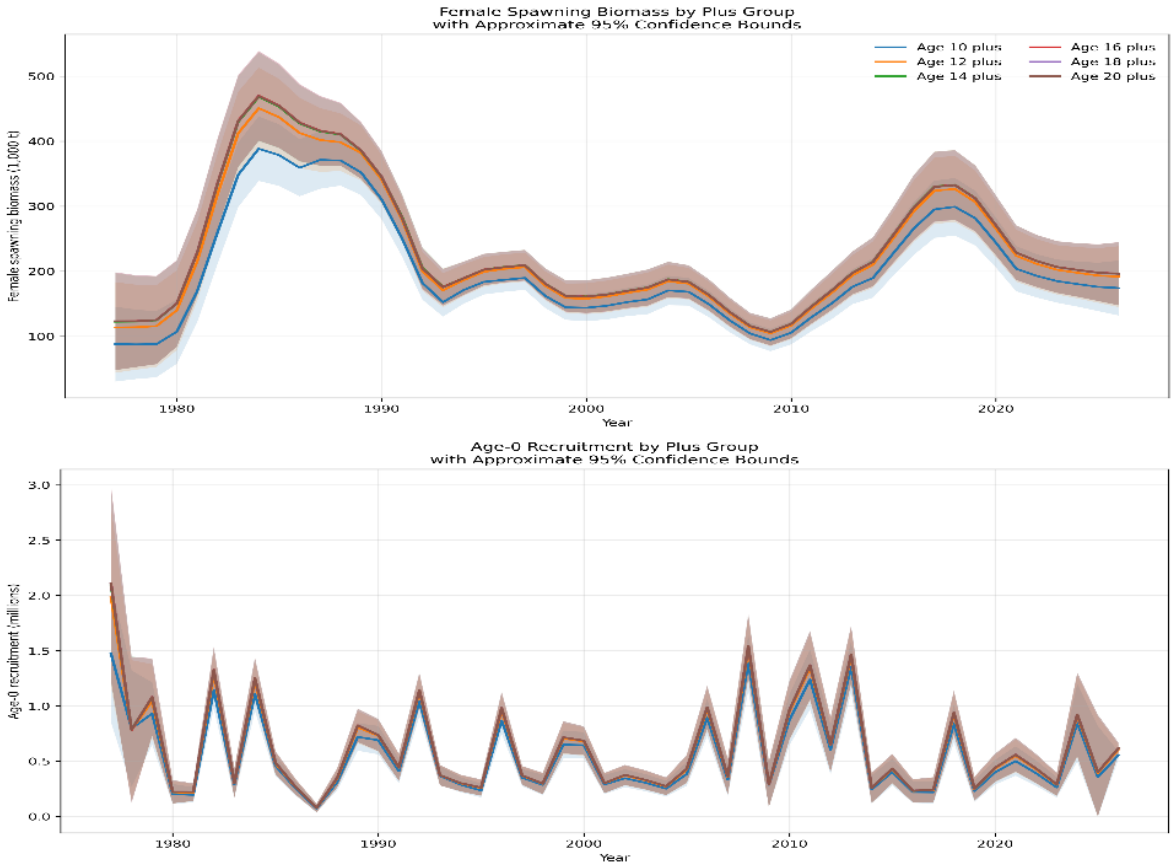


Figure 1.4 Female spawning biomass (top), and age-0 recruitment (bottom) by plus group

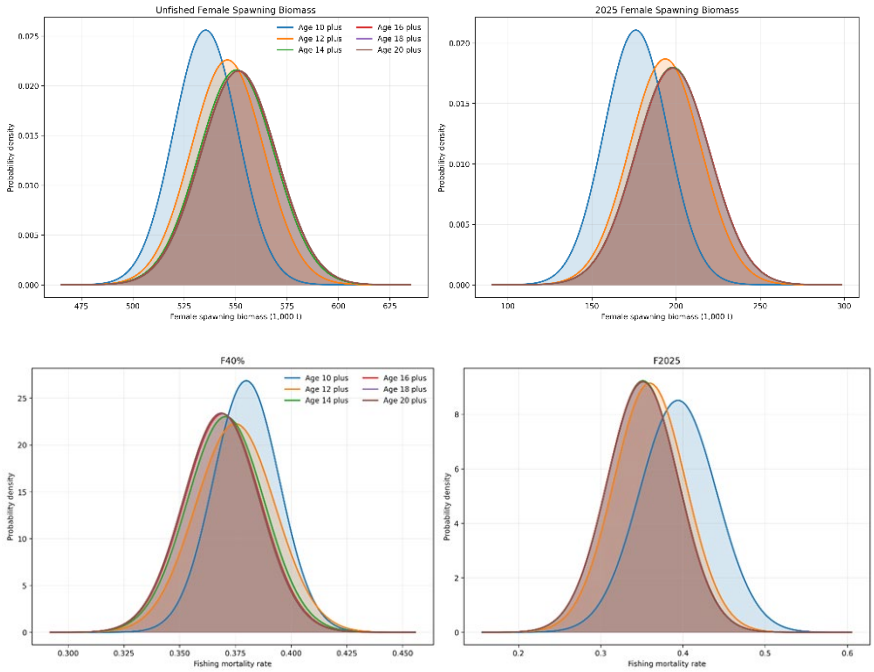


Figure 1.5 Density plot of unfished female spawning biomass (top left), 2025 female spawning biomass (top right), $F_{40\%}$ (bottom left) and fishing mortality in 2025 (bottom right) by plus group.

Models with lower plus-group ages show lower uncertainty in estimated parameters and derived quantities (Figure 1.6). The lower uncertainty in key parameters and derived quantities for models with younger plus groups likely resulted from aggregating weakly or uninformed older ages and reducing covariance among older-aged abundance, initial conditions, catchability, and recruitment scale. This increase in conditional precision should not necessarily be interpreted as improved model performance, because the youngest plus-group model showed substantial changes in parameter estimates and a poorer overall fit.

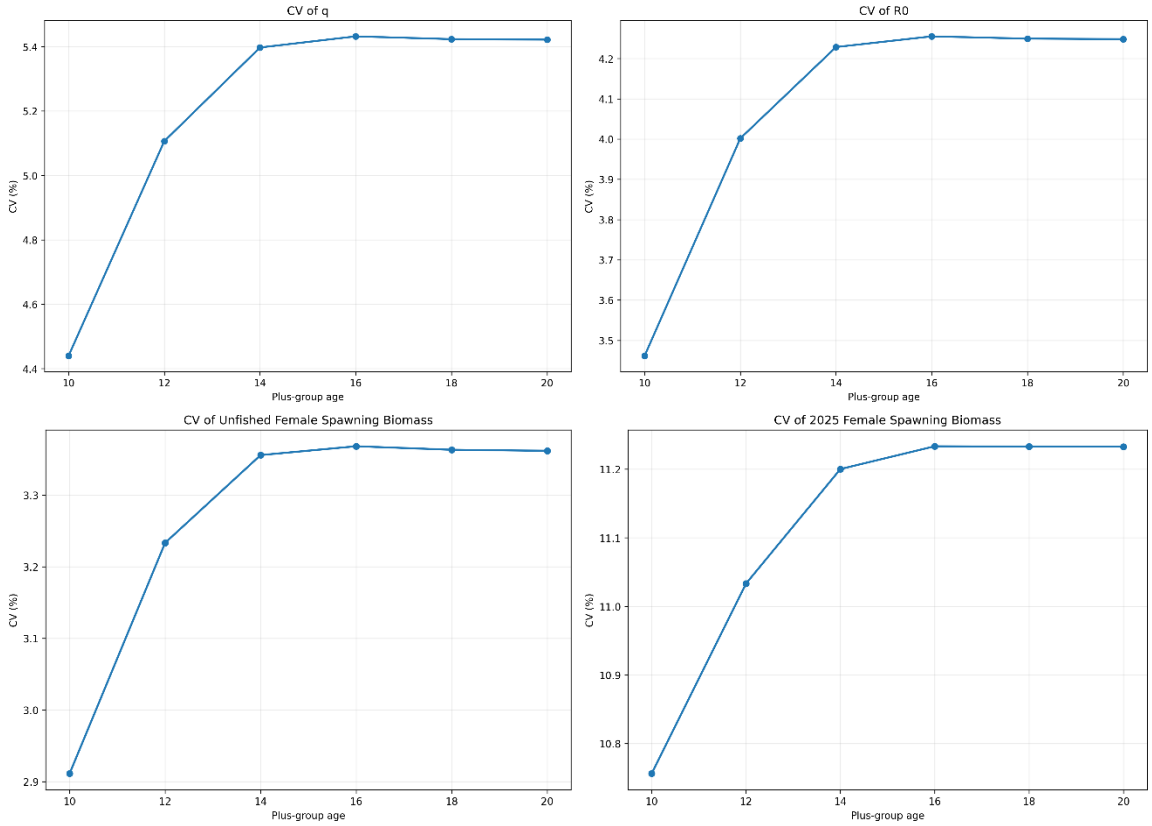


Figure 1.6 Coefficient of variation (CV) by plus-group age for catchability (q; top left), virgin recruitment (R_0; top right), female unfished spawning biomass (bottom left), and 2025 female spawning biomass (bottom right).

Recommendation

Changing the plus-group age from 20 to 14 had little effect on estimated biological and fishery parameters. Estimates of growth, recruitment, survey catchability, fishing mortality, and selectivity were nearly identical between the two models, and all differences were small relative to their estimated uncertainty. The largest changes among shared parameters were a slight decrease in maximum length, a small increase in the von Bertalanffy growth coefficient, and modest reductions in uncertainty for these growth parameters. The principal structural effect of adopting an age-14 plus group was the removal of six initial-age deviation parameters for ages 15–20 and the redistribution of less than 0.5% of the estimated initial abundance from the older age classes into the age-14 plus group. Thus, reducing the plus-group age improved model parsimony and changed the treatment of the oldest fish without materially affecting estimated population dynamics.

For the 2026 model, we recommend using an age-14 plus group because model results stabilized at plus-group ages of 14 and older. Reducing the plus-group age from 20 to 14 removed poorly informed older-age parameters while producing negligible changes in likelihood, growth, selectivity, spawning biomass, recruitment, catchability, uncertainty, and reference points. In contrast, further reductions to ages 12 and 10 produced progressively larger changes in parameter estimates and model fit. Therefore, the 2026 assessment should use an age-14 plus group.

2.0 Split-sex Model Exploration

The current Eastern Bering Sea Pacific cod assessment has historically modeled males and females as a combined population (Barbeaux et al. 2024). However, examination of sex composition data indicates that females grow faster than males and achieve higher asymptotic lengths (Figure 2.1).

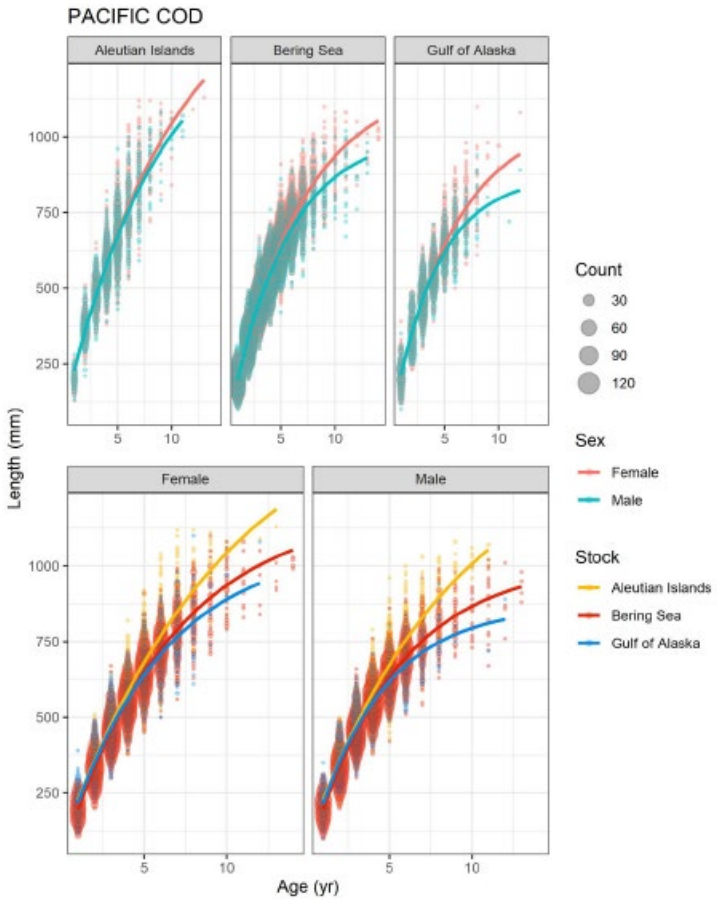


Figure 2.1 Observed length at age for samples from the Aleutian Islands, Bering Sea , and Gulf of Alaska (top) and by female on the left and males on the right (bottom) (Figure 29 from Matta et al. 2026)

In addition, the relative abundance of males and females varies with length in the bottom trawl survey (Matta et al. 2026) and the fishery, over time. In general, both the Eastern Bering Sea shelf bottom trawl survey and fishery sex composition are approximately balanced (50% male and 50% female) at lengths below 60 cm but the proportion of females in the population increases at larger sizes (Figure 2.2). Females comprise a clear majority of fish above approximately 70–80 cm, with the female proportion continuing to increase in the largest length classes.

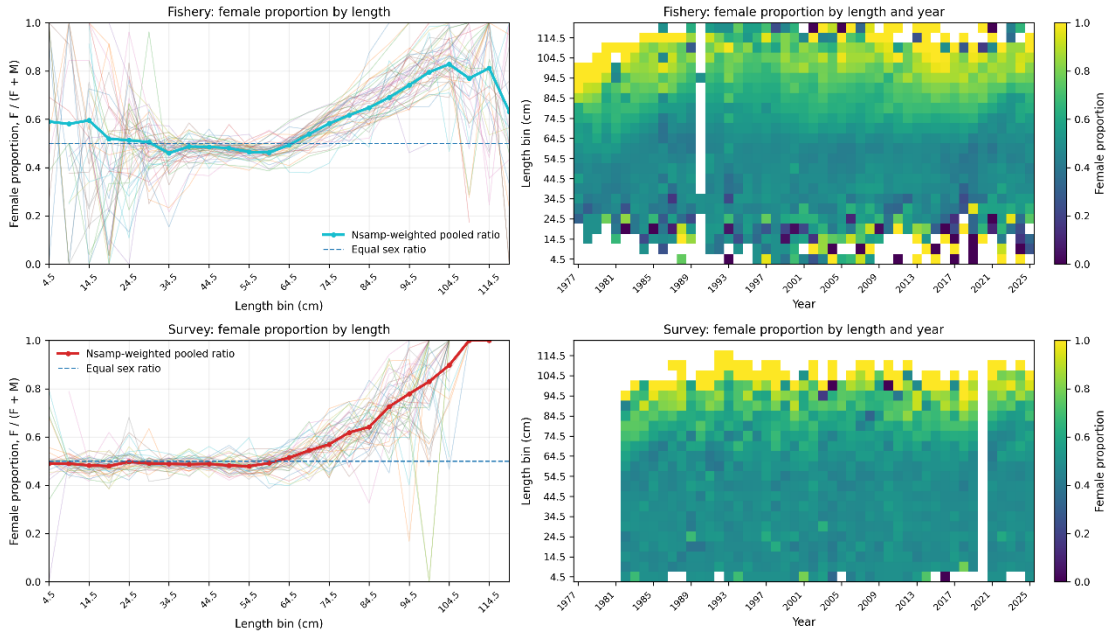


Figure 2.2 Female proportion by length (left) and length and year (right) for fishery (top) and Eastern Bering Sea shelf bottom trawl survey collections for 1977-2025 (bottom). Gray lines are annual data, colored lines are the overall weighted mean.

Survey observations also indicated age-dependent differences in sex composition (Figure 2.3). Sex ratios were approximately balanced at younger ages, whereas females generally became more prevalent among older fish. Although proportions at individual older ages were variable, the overall increase in female representation with both age and length suggests persistent differences in the population structure, growth, survival, or availability of males and females. These patterns provide additional motivation for evaluating a split-sex model in which sex-specific growth, mortality, and selectivity can be represented explicitly.

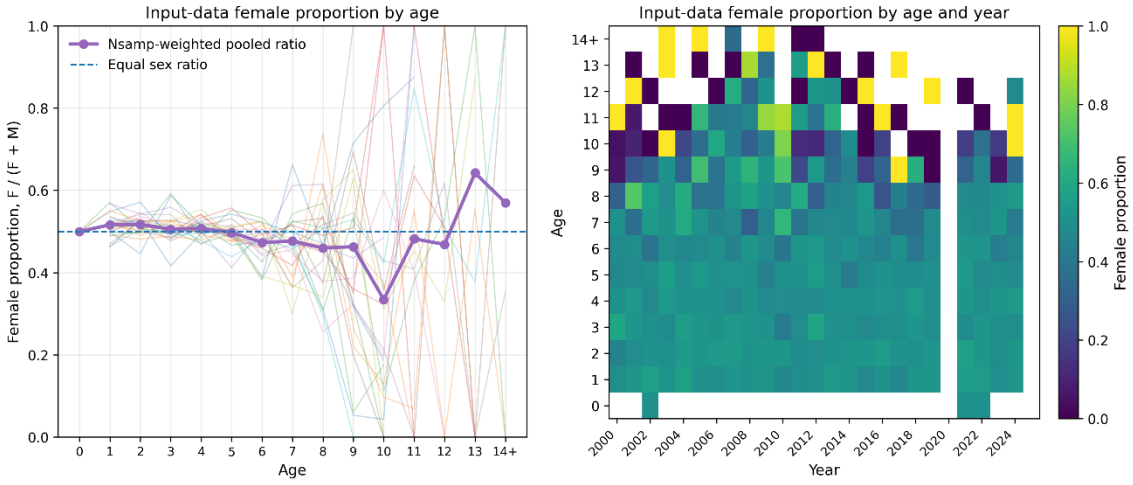


Figure 2.3 Female proportion by age (left) and age and year (right) for Eastern Bering Sea shelf bottom trawl survey collections for 2000-2024. Thin lines are annual data, the bolded line is the overall mean.

Similar length-dependent patterns are evident in both the trawl (Figure 2.4) and longline (Figure 2.5) fisheries. The proportion female is generally near 50% for fish between approximately 40 and 60 cm, a moderate increase in the proportion female at 70 cm, and a strong increase in the proportion female at 80 cm and above. The consistency of this pattern across the survey and two fisheries suggests that the predominance of females at larger sizes reflects an underlying difference in the size structure of males and females rather than an effect unique to a particular gear or sampling platform.

The data also indicate temporal variation in sex composition, particularly among the 60- and 70-cm length groups in the trawl fishery. The trawl fishery targets spawning aggregations in the winter and early spring. The variation in sex-ratios may reflect sex-specific differences in spatial distribution, availability, behavior, or vulnerability to fishing gear. Although evidence for comparable seasonal patterns in Pacific cod remains unavailable, temporal and spatial variation in spawning-season sex ratios has been documented for Atlantic cod (*Gadus morhua*). Morgan and Trippel (1996) observed both male- and female-dominated shoals off the northern Grand Bank and on the southern Scotian Shelf/Bay of Fundy. Male-dominated aggregations occurred consistently in shallower water and contained higher proportions of both males and females in spawning condition, whereas female-dominated aggregations contained a greater proportion of post-spawning (spent) females. Based on these observations, the authors hypothesized that male Atlantic cod may arrive at spawning areas before females, while females may move onto the spawning grounds to spawn and then return to deeper water after spawning is completed. Earlier arrival of males at Atlantic cod spawning grounds has also been reported in other regions, including Nova Scotia (McKenzie 1940) and the Baltic Sea (Chrzan 1950). An earlier arrival of males to the spawning grounds would explain the pattern observed in the Pacific cod trawl fishery data.

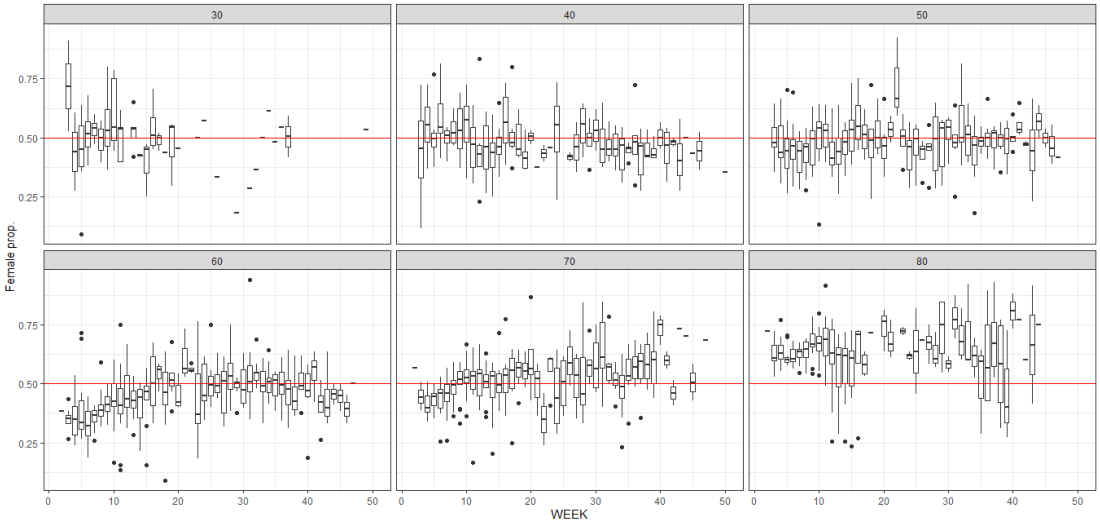


Figure 2.4 Female proportion in the Eastern Bering Sea trawl fishery by size bin (cm) and week of the year for 2010-2025. Note that the 30 cm bin includes all fish measured at 39 centimeters and below while the 80cm bin includes all fish measured at 80 cm and above.

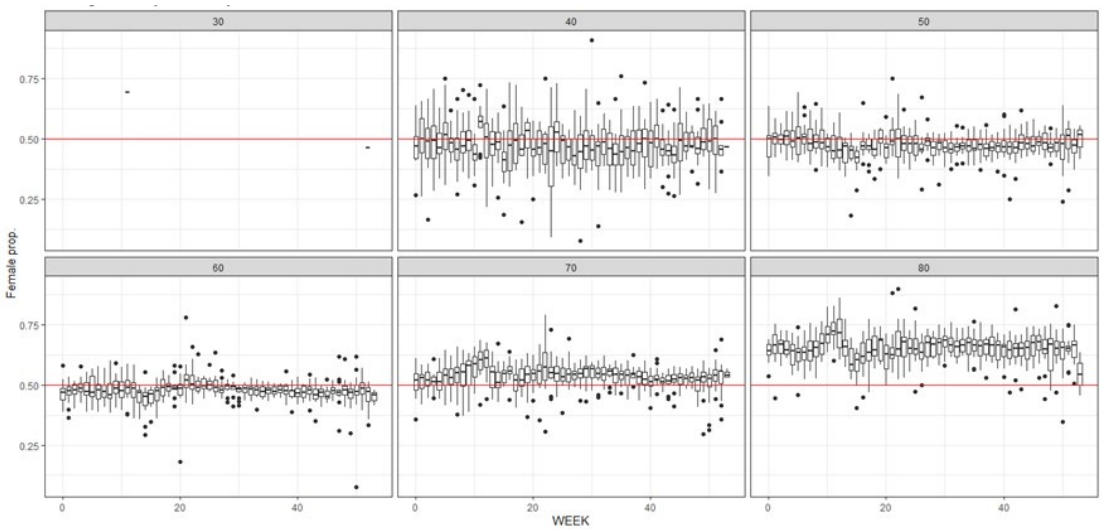


Figure 2.5 Female proportion in the Eastern Bering Sea longline fishery by size bin and week of the year for 2010-2025. Note that the 30 cm bin includes all fish measured at 39 centimeters and below while the 80cm bin includes all fish measured at 80 cm and above.

Combining sexes within a single population model may obscure these differences and require a single growth curve and selectivity pattern to represent observations generated by two potentially different components of the population. In particular, the scarcity of males in the largest length classes may be difficult to represent using a combined-sex growth model, while changes in the relative contribution of each sex could influence fitted length compositions and estimated selectivity. Because spawning biomass is determined primarily from the female component of the population, explicitly modeling females may also provide a more direct representation of the population quantity used to evaluate stock status.

Based on these observations, a split-sex Stock Synthesis model was developed and compared with the combined-sex model. The split-sex configuration estimated separate growth and selectivity relationships for males and females while retaining the same underlying data sources and general assessment structure. The evaluation focused on whether explicitly representing sex-specific population structure improved the fit to survey and fishery composition data, produced biologically reasonable parameter estimates, and materially affected estimated recruitment, spawning biomass, fishing mortality, and management reference points.

Methods

Two models were developed from the most recently accepted assessment model, Model 24.1 (Barbeaux et al. 2024). Model 24.1 uses model-based, combined-sex survey age-composition estimates produced by the Groundfish Assessment Program (GAP) of the Resource Assessment and Conservation Engineering (RACE) Division using tinyVAST (Barbeaux et al. 2024) as input. Producing these model-based estimates is time intensive, and the current analysis proceeded before split-sex model-based survey estimates became available for the current year's model exploration. Consequently, this analysis used design-based survey age-composition data in both the single-sex and split-sex models for consistency and to allow a direct comparison of results.

The single-sex model, Model 26.2, differs from Model 24.1 only in its use of design-based survey age-composition data, the inclusion of data through 2025, and the use of an age-14 plus group. The split-sex model, Model 26.3, builds on Model 26.2 by estimating sex-specific growth and fishery selectivity and by using split-sex design-based survey age compositions and split-sex fishery and survey length compositions. When the sex-specific observations in Model 26.3 were combined, the survey age compositions were effectively identical to those in Model 26.2 (Figure 2.6). Annual sample sizes, temporal coverage, age-error assignments, and combined age proportions were unchanged, with differences limited to numerical rounding. Recombined survey length compositions were also essentially unchanged, although year-specific input sample sizes differed between models. The mean age and lengths for the split sex data show older and larger females (Figure 2.7) with the single sex model means between the two sexes means.

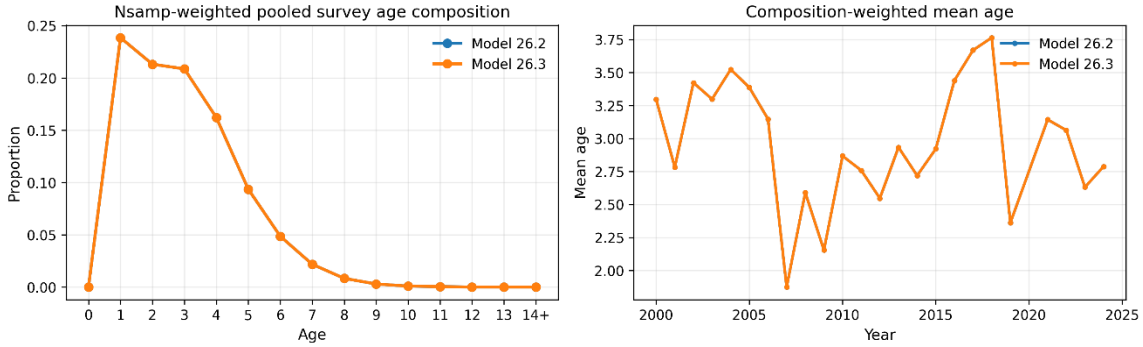


Figure 2.6 Eastern Bering Sea shelf bottom trawl survey age composition data for Model 26.2 and for pooled sexes for Model 26.3 examining sample size-weighted pooled age composition (left) and composition-weighted mean age (right).

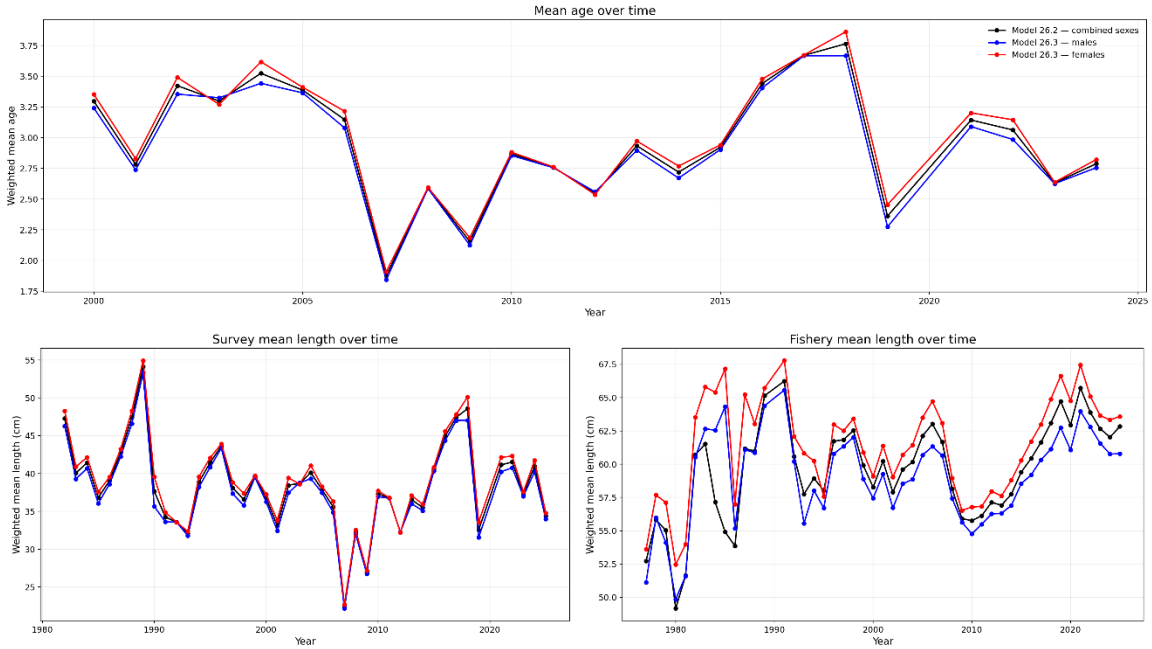


Figure 2.7 Mean age for the survey age composition data (top), mean length for survey length composition data (bottom left), and mean length for fishery age composition data (bottom right).

Both models input sample sizes for the fishery and survey age and length composition data were tuned iteratively using the *tune_comps()* function in the **r4ss** library until values remained stable for each.

Results

Because Models 26.2 and 26.3 use differently structured composition datasets, the differently structured composition datasets require comparison using common-scale residual diagnostics for evaluating overall fit. To that end we use observed-minus-expected mean length or age, coverage of the model's expected intervals, and standardized survey-index residuals (Table 2.1).

Model 26.2 fits the length and age combined-sex composition data well. Bias in the fishery mean length is essentially zero, and the typical annual discrepancy between observed and expected mean length is approximately 1.4 cm. Survey mean-length residuals are also small, although the positive mean residual indicates that observed survey fish are, on average, about 0.4 cm longer than predicted. Survey mean-age residuals are small, with the model tending to predict mean age approximately 0.15 years older than observed. The survey-index standard deviation of normalized residuals (SDNR) is 1.004, indicating that the residual variation is consistent with the assumed index uncertainty.

Model 26.3 provides a similarly good fit to the length and age split-sex composition data. Its fishery mean absolute residual is slightly lower than Model 26.2, although its fishery RMSE is slightly higher because several years have larger residuals. Model 26.3 provides a modestly better fit to the survey age compositions and a marginally lower survey-index RMSE. Its survey-index SDNR is also 1.004.

Table 2.1 Residual diagnostics for Model 26.2 and 26.3

Data component	Diagnostic	Model 26.2	Model 26.3
Fishery length	Mean residual	−0.08 cm	−0.38 cm
	Mean absolute residual	1.43 cm	1.38 cm
	RMSE	2.05	2.33
Survey length	Mean residual	+0.38 cm	+0.48 cm
	Mean absolute residual	1.18 cm	1.18 cm
	RMSE	1.62	1.69
Survey age	Mean residual	−0.151 years	−0.129 years
	Mean absolute residual	0.224 years	0.209 years
	RMSE	0.290	0.262
Survey biomass index	Log-scale RMSE	0.1518	0.1486
	SDNR	1.0044	1.0037

The common-scale diagnostics indicate comparable aggregate fit. The principal advantage of Model 26.3 is its ability to describe sex-specific length, growth, and selectivity patterns, whereas Model 26.2 has more internally consistent composition weights and achieves a comparable aggregate fit with less structural complexity. Fits were very similar with minor differences in mean age and mean length between models for most years (Figure 2.8).

The principal biological difference between models was the representation of sex-specific growth. Model 26.2 estimated a combined-sex maximum length of 111.8 cm. In Model 26.3, maximum length was estimated at 113.4 cm for females and 105.2 cm for males. The estimated von Bertalanffy K values were 0.129 for females and 0.120 for males, compared with 0.116 for the combined-sex model (Table 2.2). These differences produced increasing separation between female and male weight at age among older fish (Figure 2.9). The Model 26.2 growth curve effectively splits the difference between the male and female growth curves from Model 26.3.

Table 2.2 Growth parameters and standard error of the growth parameters (SE) for Model 26.2 and 26.3.

Growth parameter	Model 26.2 combined sex	SE	Model 26.3 female	SE	Model 26.3 male	SE
Lmin (cm)	13.95	0.32	14.03	0.32	14.30	0.31
Lmax (cm)	111.83	3.12	113.42	4.25	105.17	3.76
von Bertalanffy K	0.1158	0.0125	0.1286	0.0178	0.1197	0.0172
Richards parameter	1.4731	0.0709	1.3391	0.0937	1.5321	0.0997

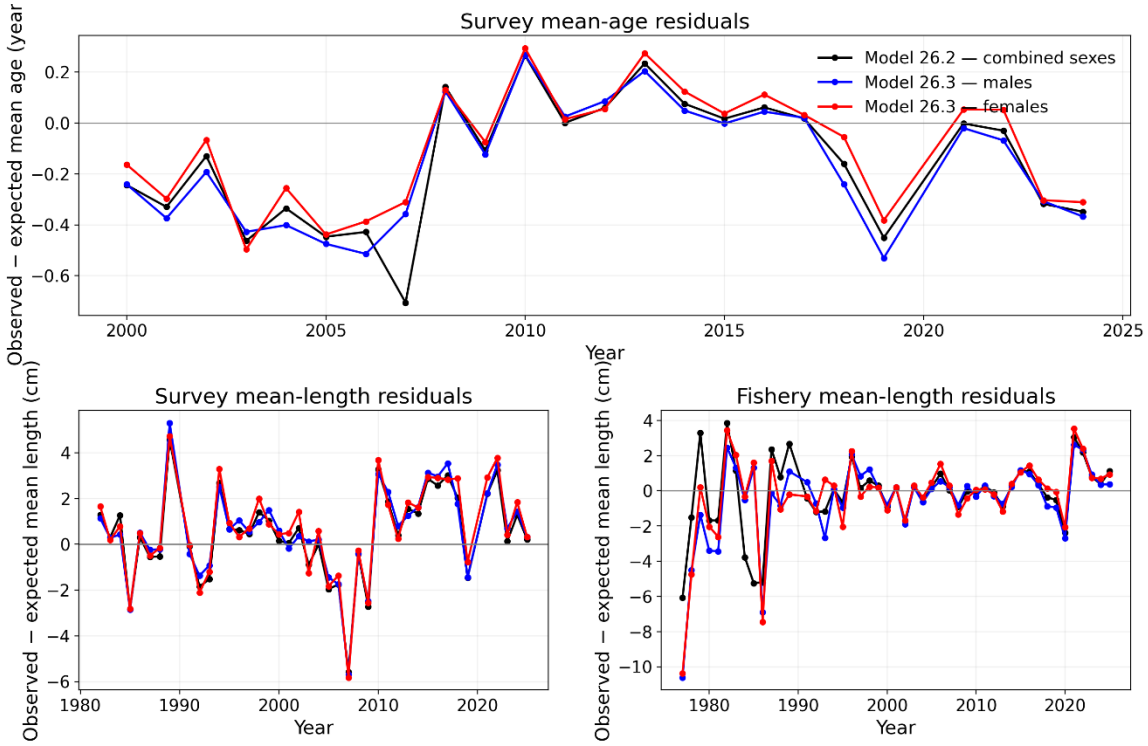


Figure 2.8 Residuals for mean age for the survey age composition fits (top), mean length for the survey length composition fits (bottom left), and mean length for the fishery length composition data fits (bottom right).

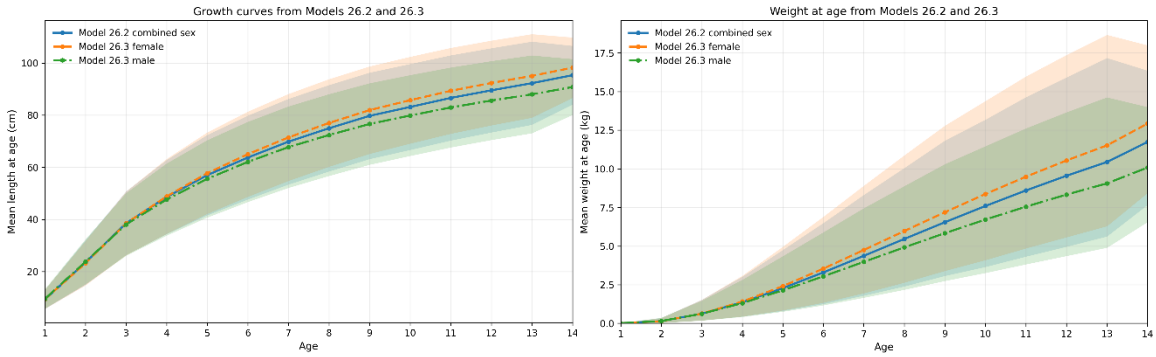


Figure 2.9 Mean length (cm; left) and weight (kg) at the beginning of the year (right) for Model 26.2 and 26.3.

Survey length selectivity was nearly identical among the combined-sex, female, and male curves. Fishery selectivity differed between sexes in Model 26.3. Male fishery selectivity approached 1.0, whereas female selectivity approached approximately 0.933. The uncertainty around the female scaling parameter included 1.0, indicating that the estimated reduction in maximum female vulnerability was not strongly distinguished from equal maximum vulnerability between sexes.

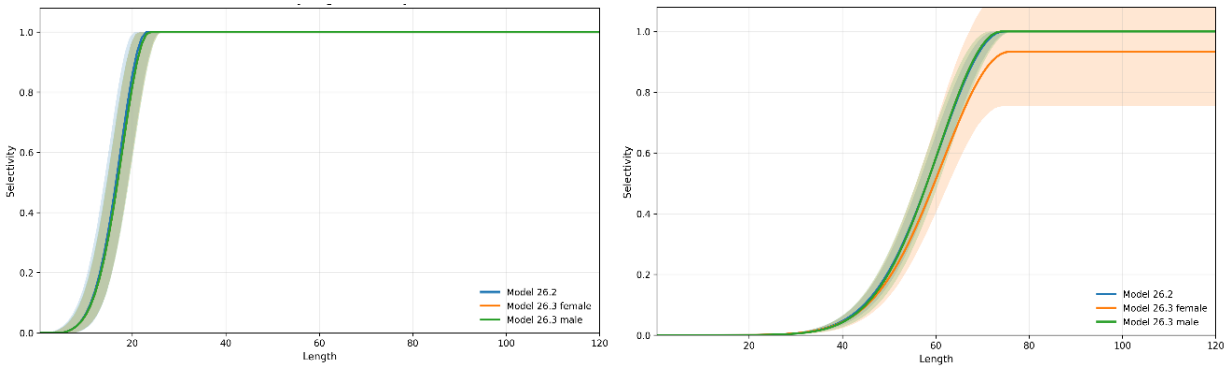


Figure 2.10 Model 26.2 combined sexes and Model 26.3 male and female survey selectivity (left), and fishery selectivity for 2025 (right)with approximate 95% confidence bounds.

Table 2.3 Key Parameters and derived quantities with standard error in parentheses for Model 26.2 and 26.3.

Quantity	Model 26.2	Model 26.3
Survey catchability, Q	1.0084 (0.0585)	1.0067 (0.0569)
Unfished recruitment, R_0	618,282 (28,344)	607,192 (26,965)
Fishery peak-selectivity parameter	74.49 cm (0.92)	♂ 74.08 cm (1.26)
		♀ 75.80 cm (1.34)
Survey peak-selectivity parameter	23.10 cm (1.32)	23.65 cm (1.19)
Unfished female spawning biomass	553.67 kt (19.95)	603.63 kt (21.78)
2025 female spawning biomass	200.76 kt (23.80)	216.66 kt (26.03)
$F_{40\%}$	0.3653 (0.0183)	0.4116 (0.0380)

Unfished recruitment (R_0) and survey catchability (q) were also similar between models (Table 2.3; Figure 2.11). Estimated unfished recruitment decreased by approximately 1.8% in Model 26.3 from

Model 26.2, and survey catchability differed by less than 0.2%. The estimated age-0 recruitment time series showed the same major year-class patterns under both model structures (Figure 2.12).

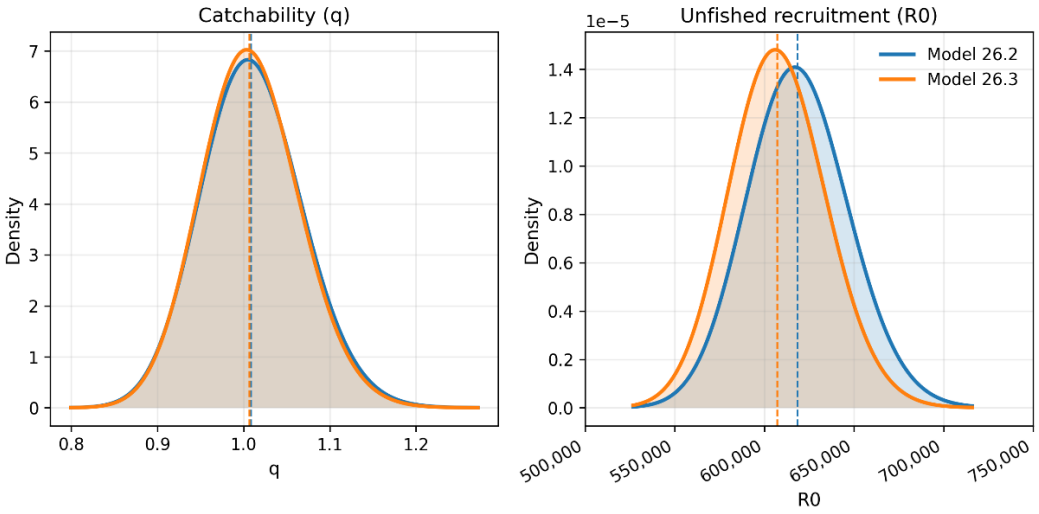


Figure 2.11 Model 26.2 and 26.3 Eastern Bering Sea shelf bottom trawl survey catchability (q; left) and unfished recruitment (R_0; right.

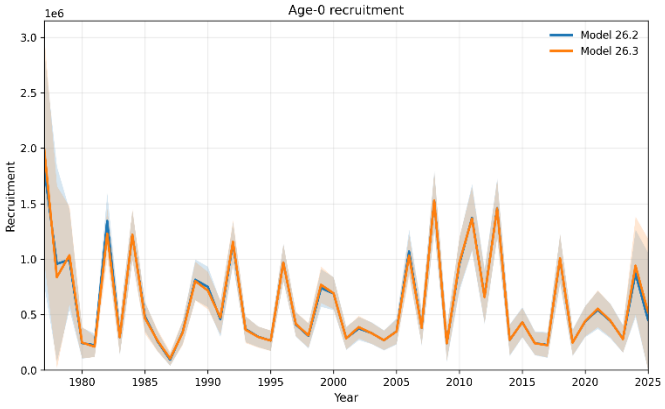


Figure 2.12 Time series of age-0 recruitment for Model 26.2 and 26.3.

Model 26.3 produced higher estimates of absolute female spawning biomass than the single-sex Model 26.2 (Figure 2.13). Unfished female spawning biomass was estimated at 603.6 kt in Model 26.3 compared with 553.7 kt in Model 26.2 (Figure 2.14), an increase of 9.0%. Female spawning biomass in 2025 was 216.7 kt in Model 26.3 and 200.8 kt in Model 26.2, while projected 2026 female spawning biomass was 210.5 and 194.9 kt, respectively.

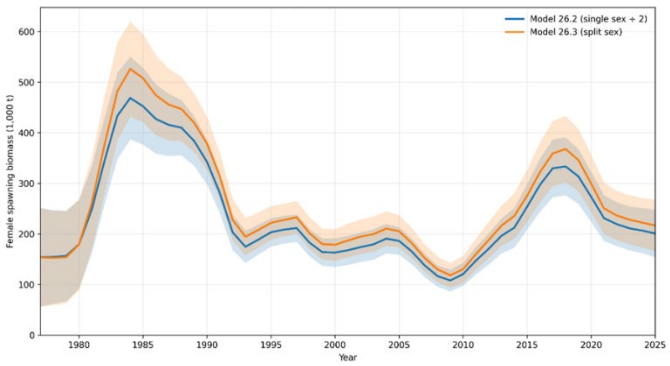


Figure 2.13 Female spawning biomass for Model 26.2 and Model 26.3.

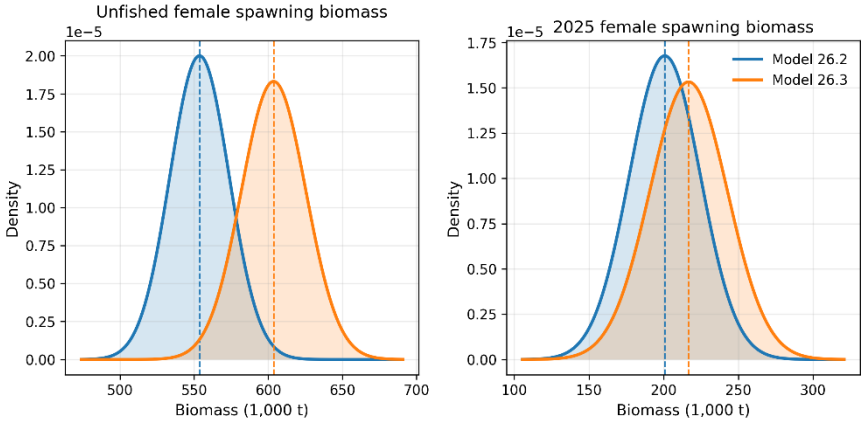


Figure 2.14 Density plots of unfished female spawning biomass (left) and 2025 female spawning biomass from Model 26.2 and 26.3.

Despite differences in absolute biomass, relative stock status was similar between models (Figure 2.15). The ratio of 2025 spawning biomass to unfished spawning biomass was 0.359 in Model 26.3 and 0.363 in Model 26.2. Similarly, $B_{2025}/B_{40\%}$ was 0.897 in Model 26.3 and 0.907 in Model 26.2. Both models therefore placed 2025 spawning biomass slightly below $B_{40\%}$.

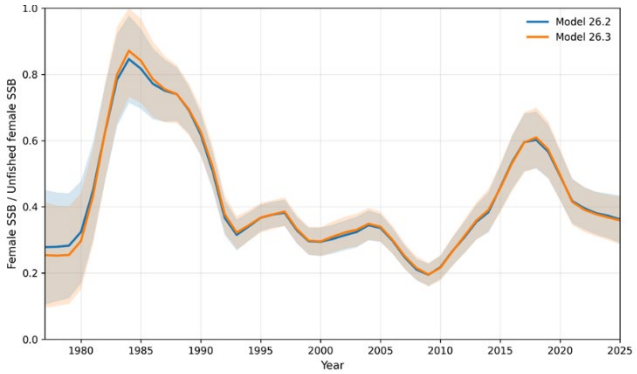


Figure 2.15 Spawning biomass ratio of annual female spawning biomass over unfished female spawning biomass for Model 26.2 and 26.3.

Fishing-mortality estimates were higher in the split-sex model (Figure 2.16 and Figure 2.17). Estimated F_{2025} increased from 0.350 in Model 26.2 to 0.382 in Model 26.3, and $F_{40\%}$ increased from 0.365 to 0.412.

However, fishing mortality relative to the model-specific reference point was slightly lower in Model 26.3: $F_{2025}/F_{40\%}$ was 0.928 compared with 0.959 in Model 26.2. Thus, both models indicated that fishing mortality in 2025 was below $F_{40\%}$.

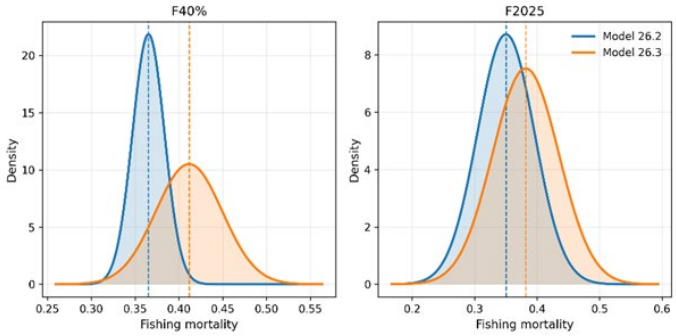


Figure 2.16 Density plots of $F_{40\%}$ (left) and F_{2025} (right)for Model 26.2 and Model 26.3.

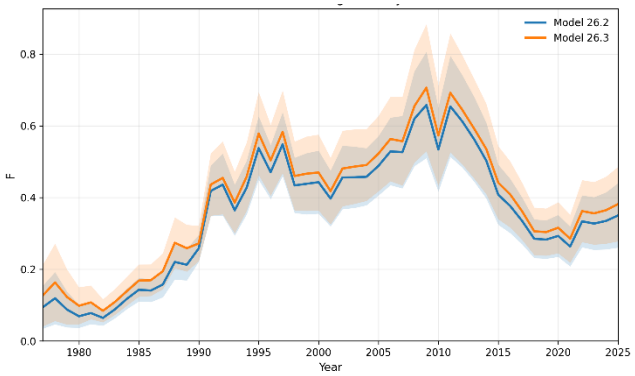


Figure 2.17 Annual fishing mortality for Model 26.2 and Model 26.3.

Management catch quantities were comparatively insensitive to model structure. Catch at $F_{40\%}$ was 175.9 kt in Model 26.2 and 174.9 kt in Model 26.3, a difference of less than 1%. The 2026 forecasted maximum ABC increased from 128.7 kt in Model 26.2 to 131.9 kt in Model 26.3 a difference of less than 2.5%. These differences were small relative to the differences in absolute biomass and fishing-mortality estimates.

Uncertainty in female spawning biomass was similar between models, but uncertainty in the fishing-mortality reference points increased under the split-sex structure. The standard error of $F_{40\%}$ increased from 0.018 in Model 26.2 to 0.038 in Model 26.3 (Table 2.3). Thus, the additional sex-specific structure changed the scale of the fishing-mortality reference points and reduced their precision without changing equilibrium yield or near-term catch advice.

The observed split-sex survey age-composition showed a weak relationship between model 26.3 derived fishing mortality and the observed female proportion among fish age 10 and older (r=0.19, p=0.39; Figure 2.19). In contrast, Model 26.3 estimated population showed a strong positive relationship (r=0.86, p<0.001; Figure 2.19 and Figure 2.20), with higher fishing mortality associated with a greater female proportion among older fish. This difference primarily reflects the limited information on older fish in the observed age compositions. The age-10+ observations from the design-based age composition data had a median implied effective sample size of less than one fish per year, resulting in

highly variable annual sex-ratio estimates with considerable uncertainty. The model-estimated numbers at age are much smoother because they integrate information from all data sources and years through the assumed population dynamics, including sex-specific growth, selectivity, mortality, and cohort survival. In particular, Model 26.3 estimates lower fishery vulnerability for larger females than for males, so periods of high fishing mortality produce a cumulative, model-implied increase in the proportion of females surviving to older ages. The observed data are therefore too sparse to independently confirm this pattern, while the strong modeled relationship partly reflects the estimated sex-specific selectivity and other structural assumptions of the model rather than a direct signal clearly present in the survey age-composition observations.

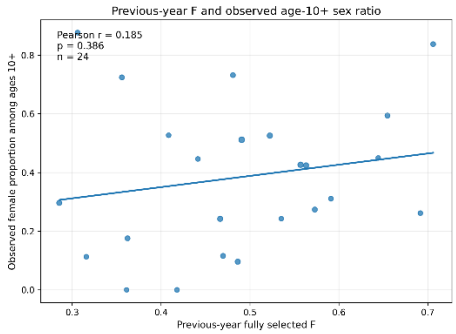


Figure 2.18 Previous-year F from Model 26.3 and observed age-10+ sex ratio from the design-based age composition data for 2000-2024.

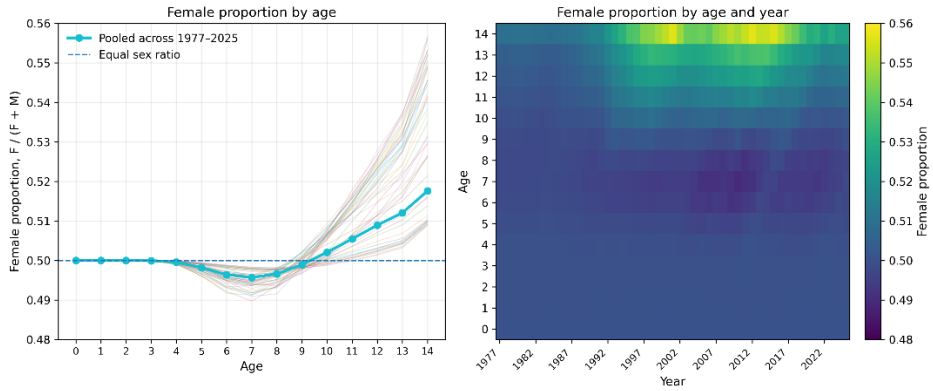


Figure 2.19 Model 26.3 modeled population sex ratios for 1977-2025.

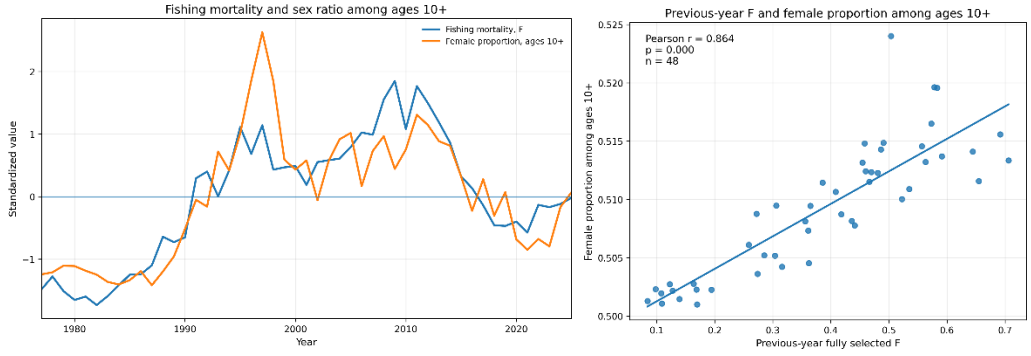


Figure 2.20 Model 26.3 standardized overall fishing mortality and sex ratio for ages 10+ (left) and ages 10+ female proportion plotted by previous-year fully selected fishing mortality.

Overall, the management conclusions were robust to the change from a single-sex to a split-sex model. Both models indicated that the stock was slightly below $B_{40\%}$, that fishing mortality was below $F_{40\%}$, and that similar catch levels were appropriate for 2026. Model 26.3 provided a more explicit representation of sex ratios over time, and sex-specific growth, weight at age, and fishery vulnerability, while Model 26.2 produced nearly the same management advice with fewer structural assumptions and a more precise estimate of $F_{40\%}$.

Recommendation

For the 2026 assessment cycle, we recommend retaining the single-sex model and continuing to use the survey age-composition estimates produced using tinyVAST. The single-sex model provides an adequate fit to the available data, is more parsimonious than the split-sex model, and produces nearly identical estimates of relative stock status and management quantities. Although the split-sex model provides a more explicit representation of sex-specific growth and fishery vulnerability, the additional complexity does not substantially change the resulting catch advice and increases uncertainty in some management reference points, particularly $F_{40\%}$.

On this basis, the available evidence supports retaining the single-sex formulation for 2026 as the primary assessment model for 2026. Nevertheless, the split-sex analysis demonstrates the potential value of explicitly accounting for sex-specific patterns in growth, selectivity, and fishery impacts. Further evaluation requires split-sex survey age compositions produced with the same model-based method. We therefore recommend requesting that the Groundfish Assessment Program produce split-sex survey age-composition estimates for the 2027 assessment cycle. Both single-sex and split-sex models should then be developed and evaluated using consistently derived survey inputs. This would allow a more direct assessment of whether the added biological realism of the split-sex model improves model performance, reduces residual patterns, or meaningfully changes estimates of stock status and management advice.

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Appendix 2.2. Ecosystem and Socioeconomic Profile of the Pacific cod stock in the Eastern Bering Sea - Update

S. Kalei Shotwell and Russel Dame (Editors)

November 2026



With Contributions from:

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ESP Data: Anna Ableman, Lewis Barnett, Matt Callahan, Russel Dame, Kirstin Holsman, Kelly Kearney, Jean Lee, Mike Levine, Beth Matta, Krista Oke, Heather Renner, Sean Rohan, Elizabeth Siddon, Katie Sweeney, Muyin Wang

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This appendix is reviewed separately from the main operational assessment document. Please refer to the 2026 assessments available from https://www.npfmc.org/library/safe-reports/ to access the full ecosystem and socioeconomic profile (ESP) document.