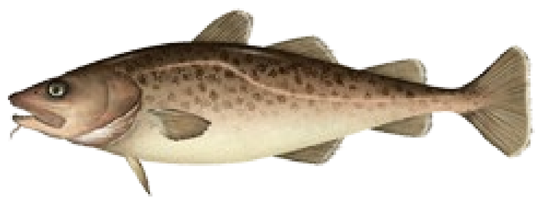
Chapter 2: Assessment of the Pacific cod stock in the Gulf of Alaska

Peter-John F. Hulson, Steven J. Barbeaux, Bridget Ferriss, Katy Echave, Julie Nielsen, Susanne McDermott, Ben Laurel, Alisa Abookire, Ingrid Spies and S. Kalei Shotwell

January 2026

This report may be cited as: Hulson, P.-J. F., S. J. Barbeaux, B. Ferriss, K. Echave, J. Nielsen, S. McDermott, B. Laurel, A. Abookire, I. Spies, and S. K. Shotwell. 2026. Assessment of the Pacific cod stock in the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK. Available from https://www.npfmc.org/library/safe-reports/.



With contributions from:
Mike Litzow, Kimberly Rand, Charlotte Levy, and Muyin Wang

Executive Summary

Pacific cod in the Gulf of Alaska are assessed on an annual stock assessment schedule to coincide with the availability of new survey data. We use a statistical age-structured model as the primary assessment tool for Gulf of Alaska Pacific cod which qualifies as a Tier 3 stock. This assessment consists of a population model, which uses survey and fishery data to generate a historical time series of population estimates, and a projection model, which uses results from the population model to predict future population estimates and recommended harvest levels. Model input files, additional plots and model diagnostics, and presentations pertaining to this assessment can be found at this link.

Summary of Changes in Assessment Inputs

Relative to last year's assessment, the following changes have been made in the current assessment:

Changes in the input data

1. Federal and state catch data for 2024 were updated and preliminary federal and state catch data for 2025 were included;
2. Commercial federal and state fishery size composition data for 2024 were updated, and preliminary commercial federal and state fishery size composition data for 2025 were included;
3. Commercial federal conditional age-at-length data for 2024 were included;
4. AFSC longline survey Pacific cod abundance index and length composition data for the GOA for 2025 were included;
5. AFSC bottom trawl survey abundance index and length composition data for 2025 were included;

Changes in the methodology

The methodology remains the same as Model 24.0 accepted in 2024.

Summary of Results

The stock appears to be recovering from low levels with the 2026 the stock estimated to be nearly equal to the B_{MSY} proxy of $B_{35\%}$ (the estimate is $B_{33.1\%}$). By the FMP, being below $B_{40\%}$ categorizes the stock status as being in sub-tier "b" of Tier 3. Under Tier 3b, the estimated maximum allowable ABC is 41,520 t. This ABC is 29% larger than the 2025 ABC of 32,141 t and 37% larger than the 2026 ABC projected in last year's assessment due to updated survey data and an increase in the estimated stock status. In Tier 3b, stock status increases along the harvest control rule ramp results in increases to the allowable fishing mortality rate and affects both the ABC and OFL. The corresponding reference values are summarized in the following table, with the recommended ABC and OFL values in bold. The stock is not subject to overfishing, is not currently overfished, nor is it approaching a condition of being overfished.

Quantity	As estimated or *specified last* year for: 2025	2026	As estimated or *specified this* year for: 2026	2027
M (natural mortality rate)	0.49*	0.49*	0.5*	0.5*
Tier	3b	3b	3b	3b
Projected total (age 0+) biomass (t)	177,497	200,521	182,156	186,118
Female spawning biomass (t)				
Projected	46,920	44,674	52,772	45,838
$B_{100\%}$	163,585	163,585	159,595	159,595
$B_{40\%}$	65,434	65,434	63,838	63,838
$B_{35\%}$	57,255	57,255	55,858	55,858
F_{OFL}	0.57	0.51	0.68	0.54
$maxF_{ABC}$	0.46	0.43	0.54	0.47
F_{ABC}	0.46	0.43	0.54	0.47
OFL (t)	38,688	33,099	**49,782**	38,812
maxABC (t)	32,141	30,193	41,520	32,209
ABC (t)	32,141	30,193	**41,520**	32,209
Status	As determined *last* year for: 2023	2024	As determined *this* year for: 2024	2025
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

**Base natural mortality M varies between 0.5 and 0.84*
*** Assumed 2025 catch to be the 2025 ABC. For 2027 projections the 2026 catch was assumed to be at the projected ABC.*

Area apportionment

Using the recommended random effects model (described in the *Area Allocation of Harvests* section as applied within the `rema` R-package, Sullivan *et al.* 2022) with the trawl survey biomass estimates through 2025, the Biologically informed Recommended Distributions (BRD) are:

	Western	Central	Eastern	Total
Area apportionment	24.80%	69.20%	6%	100%
2026 BRD	10,297	28,732	2,491	41,520
2027 BRD	7,987	22,289	1,933	32,209

Introduction

This document is an update from the 2024 assessment and includes newly available data. The model used for management recommendations is the same as the last accepted model in 2024, Model 24.0. For brevity we included the document sections in which data or model results changed; other unchanged sections are available here.

Fishery

Fishery history and management measures

For a full description of the fishery history and management measures see Hulson *et al.* 2022. Catches of Pacific cod since 1991 by gear type and jurisdiction are shown in Table 2.1; catches prior to that are listed in Thompson *et al.* (2011). Presently, the Pacific cod stock is exploited by a variety of fisheries, including trawl, longline, pot, and jig components; Figure 2.1 shows landings by gear since 1977. The history of Total Allowable Catch (TAC), Acceptable Biological Catch (ABC), Overfishing Level (OFL), and State of Alaska Guideline Harvest Levels (GHL) are summarized since 1991 and compared with the time series of aggregate commercial catches in Table 2.2 (data prior to 1991 are shown in Hulson *et al.* 2022). The complete history of allocation (in percentage terms) by regulatory area within the GOA is shown in Table 2.3. Catch reported in Tables 2.1 and 2.2 include discarded Pacific cod, estimated retained and discarded amounts are shown in Table 2.4.

Recent fishery performance

Figure 2.2 shows the distribution of observed catch for the most recent year of complete catch data (2024) for the three major gear types, as well as the distinction between observed and electronic monitored catch. Cumulative catch by week in 2025 is comparable to previous years catch across the gear types (Figure 2.3).

In 2025 the federal TAC was set at 23,670 t and state GHL set at 8,471 t (Table 2.2). As of December 8, 2025 a total of 26,947 t (84% of the ABC) has been harvested (Table 2.1); State fisheries have harvested 7,344 t (87% of the GHL) and federal fisheries 19,603 t (83% of the TAC). In 2025 41% of the Pacific cod catch was by trawl, 32% by pot gear, and 24% by longline, while jig and other gear harvested 3% (Table 2.1).

Data

This section describes updates to the data used in the current assessment. The following table and Figure 2.4 present the data included in this assessment (the years shown in bold font are those that are new to this assessment).

Data	Source	Type	Years
Federal and state fishery catch, by gear type (trawl, pot, and longline)	AKFIN	Metric tons	1977 – **2025**
Federal and state fishery catch-at-length, by gear type	AKFIN, ADF&G	Frequency observed at length (in cm)	1977 – **2025**
GOA NMFS bottom trawl survey abundance	AKFIN	Total numbers	1990 – **2025**
AFSC Sablefish Longline survey Pacific cod Relative Population Numbers	AKFIN	RPN	1990 – **2025**
GOA NMFS bottom trawl survey length composition	AKFIN	Number at length (in cm)	1990 – **2025**
GOA NMFS bottom trawl survey conditional age-at-length	AKFIN	Proportion age at length	1990 – 2023
AFSC Sablefish Longline survey Pacific Cod length composition	AKFIN	RPN at length (in cm)	1990 – **2025**
Federal fishery conditional age-at-length	AKFIN	proportion age at length	2007 – **2024**
CFSR bottom temperature indices	National Center for Atmospheric Research	temperature anomaly at mean depth for P. cod size bins	1979 – 2024

Fishery

Catch Biomass

Total catches for the period 1991-2025 are shown for the three main gear types in Table 2.1, with the 2025 values through December 8, 2025. The current year's catch within the assessment model is assumed to reach the full Total Allowable Catch (TAC) and state Guideline Harvest Level (GHL). Three fisheries were modeled (by gear categories); trawl (all trawl types), longline (longline and jig) and pot.

Length Composition

Fishery length compositions are available by fishery from 1977 through December of 2025 (Figure 2.4). Due to the selectivity of the fisheries, these length compositions are not informative about incoming year classes and primarily catch adult Pacific cod.

Age composition

Age data collected since 2007 from the commercial fishery were used to develop an annual conditional age-at-length matrix for each fishery, this data was updated to include new 2024 information (Figure 2.4).

Surveys

AFSC bottom trawl survey

In 2025, the scientists from the AFSC transitioned to a new stratified random design for this survey. The new design changed from the previous 59 strata defined by INPFC management area, depth, and general habitat type (shelf, gully, and slope) to 28 strata defined by NMFS management area and depth. We describe results of analysis comparing historical bottom trawl survey data using the restratified design in

Appendix 2.2 and noted a negligible impact on Pacific cod estimates compared to the previous design. We note that for 2025 the survey was conducted with two chartered vessels completing 431 stations and that this represented an 18% reduction compared to the number of stations sampled in 2023. The number of stations sampled in the GOA bottom trawl survey in 2025 were the fewest since 1990, including 2001 when the Eastern GOA was not sampled.

The spatial distribution of Pacific cod catch in the 2025 trawl survey was comparable to the most recent surveys (in 2023 and 2021, Figure 2.5). In general, the 2025 survey resulted in stations with higher Pacific cod catch than those from 2021 and 2023.

Indices

Since the time-series low in 2017, the Pacific cod biomass and abundance estimates from the bottom trawl survey suggest an increasing trend in the population (Table 2.5). Compared to the 2023 survey, the 2025 trawl survey biomass estimate increased by 39.2% and the abundance estimate increased by 49.6%. These increases in biomass and abundance were driven by overall increases in station density observations, rather than a few high-density stations. Nonetheless, the coefficient of variation (CV) estimate was 23% which is larger than recent CVs but within the range estimated for other years of the time-series. This increase in CV is likely influenced by the reduction in the number of stations sampled in 2025. The restratified survey design resulted in negligible differences in uncertainty (Appendix 2.2).

Length Composition

The bottom trawl survey 2025 length composition was observed to be bi-modal, with a mode at 15-20 cm (representing catches of age-1 cod, which would be the 2024 year class) and a mode at 35-70 cm (fishery and survey length composition figures can be found in the SS3 plots at the link provided for additional resources in the *Executive* Summary section, and here).

Age Composition

Otoliths for bottom trawl survey age composition estimation were collected in each survey and were used as conditional age-at-length data within the GOA Pacific cod assessment. Data from the 2025 survey were unavailable (trawl-survey age data were the same as in the 2024 assessment).

AFSC longline survey

Conducting the AFSC longline survey involves sampling the continental slope and major gullies in the GOA, providing data to calculate relative abundance in this area (Rutecki et al. 2016, Siwicke and Malecha 2024). The survey is primarily directed at sablefish, but also catches considerable numbers of Pacific cod. The survey was conducted in 2025 after missing a year in 2024.

Pacific cod catch in the longline survey primarily occur in the Western and Central GOA (Figure 2.6). There were consistent increases in catch in the Western and Central GOA in 2025 compared to 2023 for the majority of stations, with a large decrease at a single station in the Eastern GOA.

Abundance index

The AFSC longline survey index indicates a generally increasing trend since the time-series low in 2019 (Table 2.5). The 2025 estimate declined slightly (5%) compared to the most recent 2023 value. The decline was primarily due to densities observed from the Eastern GOA subregion (the Western and Central GOA subregions increased compared to 2023, for subregional RPN estimates please see slide 14 in this presentation made to the Groundfish Plan Team in September 2025). This decline was not due to the redesign of the survey by dropping several stations (see slide 8 of the linked presentation).

The AFSC longline survey RPN index is computed by multiplying the average station density (catch per hook) within a stratum by the stratum area size (where the stratum is based upon geographic region and depth). Upon further investigation, it was discovered that the magnitude of Eastern GOA RPN is driven by the area size for the 150-200m depth stratum, which is larger in the Eastern GOA than the Central or Western GOA. This has resulted in a distribution of RPN across the GOA that is inconsistent with the distribution of abundance as observed from the AFSC bottom trawl survey; Eastern GOA RPN represents an average of 33% of the total GOA RPN across the time-series of the index, whereas the AFSC bottom trawl survey has observed Eastern GOA cod abundance that is, on average, less than 5% of the total GOA abundance across the time-series. Ultimately, this has resulted in a subregion which contains the fewest stations that catch cod (Figure 2.6) having the greatest influence on the GOA-wide RPN index. Further, the decrease in the Eastern GOA RPN index in 2025 compared to 2023 was driven by reduced catch at a single station (Figure 2.6).

Upon computing the mean numbers CPUE from the AFSC longline survey we found that the GOA-wide CPUE increased by 7% in 2025 compared to 2023. Based upon the discovery of the influence of Eastern GOA RPN on the total GOA RPN index, prior to the next full assessment we will be investigating a new method to compute the AFSC longline index. Because this is an update assessment, we continue to use the AFSC longline survey RPN index in its current form.

Length composition

The observed length composition from the 2025 longline survey was unimodal and consistent with previous survey length compositions, with a peak at 60 cm.

Other indicators

There are several indicators that are monitored but not fit in the assessment model that provide auxiliary information on the GOA cod stock. We include those within the following sections.

Laurel and Litzow age-0 index

Beach seine sampling of age-0 cod was conducted in 2025. The beach seine age-0 CPUE index resulted in estimated values in 2025 that were very similar to the 2024 and 2023 estimates, all which are around 40% smaller than the time-series mean (top right panel of Figure 2.7).

Alaska Department of Fish and Game bottom trawl survey

The Alaska Department of Fish and Game (ADFG) bottom trawl survey index suggests an increasing trend in the Pacific cod population since the time-series low in 2016 (top left panel of Figure 2.7). In 2025 the ADFG bottom trawl survey CPUE of cod numbers increased by 14.7% compared to 2024.

Commercial fishery indices

Non-targeted catch of Pacific cod in other directed fisheries was examined as an indicator of population trends. We examine two disparate fisheries to evaluate trends in incidental catch of Pacific cod: the pelagic walleye pollock fishery and the bottom trawl shallow water flatfish fishery. The occurrence of Pacific cod in the pelagic pollock fishery appears to be an abundance indicator for 2-year-old Pacific cod, which are thought to be more pelagic. As an index of recruitment abundance, we tracked the incidence of occurrence as proportion of hauls with cod in the central GOA pollock A season. The shallow water flatfish fishery tracked a larger portion of the adult population of Pacific cod. As an index of the adult population abundance, we track the catch rates in tons of Pacific cod per ton of all species caught in the shallow water flatfish fishery. For the walleye pollock fishery in the central GOA, abundance of small cod in pelagic trawls has exhibited an alternating trend in the most recent 5 years, with larger catches in 2022 and 2024 and smaller catches in 2021, 2023, and 2025 (bottom right panel of Figure 2.7). The catch of Pacific cod in the shallow water flatfish fisheries has trended up since the time series low in 2017. The 2024 and 2025 values are the largest in the recent time series and only smaller than the 2014 value since 2008 (bottom right panel of Figure 2.7). It should be noted that none of these indices are controlled for gear, vessel, effort, or fishing practice changes.

Environmental indices

The Climate Forecast System Reanalysis (CFSR) temperature index has been discontinued and was not available for 2025. When an environmental index is not available in a certain year the SS3 protocol is to set that year's index value at 0, meaning that the mean parameter estimate for that year is used. An alternative environmental index will be used in the next full assessment.

Analytic Approach

We use Model 24.0 in this assessment (described in Hulson *et al.* 2024). The model for this year was run in SS3 version 3.30.22.1 (the same version as the 2024 assessment, Methot and Wetzell 2013). The SS3 control and forecast files for this year's model can be found at the link provided in the *Executive Summary* section of this document.

Results

Model Evaluation

In the 2024 assessment a full suite of model diagnostics and sensitivities were provided for Model 24.0. In the next full assessment when alternative models are explored these will be provided within this document. Model diagnostics and sensitivities that were provided in the 2024 assessment and applied to the 2025 update assessment that are not contained in this document are provided in the link in the *Executive Section*. As with the results in the 2024 assessment, the update here indicate that the likelihoods appear well defined with acceptably low final gradients (the final gradient was $6.45e^{-6}$) and asymptotic approximations of parameter variances. Convergence of Model 24.0 was further examined by "jittering" starting parameters by a factor of 5% over 50 runs to evaluate if models had converged to local minima. Jitter analysis revealed that Model 24.0 was insensitive to perturbations of parameter start values on the order of 5% with a total of 46 of the 50 jitter runs converged and 74% of the converged models resulting in estimates at the lowest MLE from the accepted models.

As in 2024, Model 24.0 configuration resulted in acceptable fits and parameter estimates (Table 2.6). Estimates of abundance and recruitment compared favorably to previous assessments and do not result in any concerning retrospective patterns (Figure 2.8 and 2.9). On the whole, Model 24.0 fits the AFSC bottom trawl and longline survey indices reasonably well (Figure 2.10). However, positive residuals have persisted in the fit to the longline survey since 2018 and the model does not fit the 2025 increase in bottom trawl survey abundance. The aggregated fit from Model 24.0 to the fishery length composition data and one-step-ahead residuals are acceptable but appeared to have a few outlier residuals in proportions at length (Figure 2.11). The fits to the survey age composition data in aggregate were also acceptable but also had some outliers present in the one-step ahead residuals (Figure 2.12). The standard SS3 plots, which contain additional results, can be found at the link provided in the *Executive Summary* section of this document.

Time Series Results

Definitions

The annual biomass estimates presented were: total biomass (the biomass at the start of the year of all fish aged 0 years or greater in a given year) and spawning biomass (the estimated biomass of mature females at the start of the year). Recruitment is defined as the number of age-0 fish by year.

Biomass

Total biomass estimates show a long decline from their peak in 1988 (Table 2.7 and Figure 2.13) to a low in 2006 and then an increase to another peak in 2014, after which there was a sharp decline through 2018 followed by a slight increase through 2024. Total biomass in 2025 is estimated to be essentially unchanged from 2024.

Spawning biomass (Table 2.7 and Figure 2.13) shows a similar trend of decline since the late 1980s with a peak in 1989 to a low in 2008. There was then a short increase in spawning biomass coincident with the maturation of the 2005-2008 year classes through 2014, after which the decline continued to lowest level in 2019 and 2020. The spawning biomass then slightly increased through 2022 and has remained steady through 2025. Compared to the most recent assessment in 2024, the current Model 24.0 results in slightly smaller spawning biomass estimates from 2015 to 2021, then larger after 2022 (Figure 2.8).

Recruitment and Numbers-at-Age

The recruitment predictions in Model 24.0 (Table 2.8 and Figure 2.14) show above average recruitment for most of the 1980s, below average recruitment from the mid-1990s to mid-2000s, above average recruitment from the mid-2000s to 2013, and below average recruitment since. Compared to the most recent assessment in 2024, the current Model 24.0 results in larger estimates of the 2020 and 2021 year classes, and smaller 2023 and 2024 year classes (Figure 2.8).

Fishing Mortality

Fishing mortality appears to have increased steadily with the decline in abundance from 1990 through a peak in 2008 with continued high fishing mortality through 2017 (Table 2.9 and Figure 2.15). 2017 had the highest total exploitation rate of the time series. The period between 1990 and 2008 saw both a decline in recruitment paired with increases in catch. The period of increasing fishing mortality was mainly attributed to the rise in the pot fishery, which also shows the largest increase in continuous F (Figure 2.15). In 2018 through 2020 there was a sharp decrease in fishing mortality coincident with the drastic cuts in ABC and closure of the federal directed fishery in 2020. In 2021 with the reopening of the federal fishery mortality once again increased, but remained lower than observed in the previous decade prior to 2017. In retrospect, the phase plane plots (Figure 2.16) show that F was estimated to have been above the ABC control rule advised levels from 2015 to 2017 and biomass has been below $B_{35\%}$ since 2017 and projected to continue to be below through 2027. It should be noted that this plot shows current model predictions, not what the past assessments had estimated.

Harvest Recommendations

Amendment 56 Reference Points

Amendment 56 to the GOA 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 GOA 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: $B/B_{40\%} \leq 0.05$

$F_{OFL} = 0$

$F_{ABC} = 0$

Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. These reference points are estimated as follows, based on this year's model, Model 24.0:

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
Spawning biomass:	55,858 t	63,838 t	159,595 t

For a stock exploited by multiple gear types, estimation of $F_{35\%}$ and $F_{40\%}$ requires an assumption regarding the apportionment of fishing mortality among those gear types. For this assessment, the apportionment was based on this year's model's estimates of fishing mortality by gear for the five most recent complete years of data.

Specification of OFL and Maximum Permissible ABC

For Model 24.0 spawning biomass for 2026 is estimated by this year's model to be 52,772 t at the start of the year. This is below the $B_{40\%}$ value of 63,838 t, thereby placing Pacific cod in sub-tier "b" of Tier 3. Given this, the model estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2026 and 2027 as follows (2027 values are predicated on the assumption of the full TAC and GHL being taken in 2025 and that the 2026 catch will be at maximum ABC in the projection):

Units	Year	Overfishing Level (OFL)	Maximum Permissible ABC
Harvest amount	2026	49,782	41,520
Harvest amount	2027	38,812	32,209
Fishing mortality rate	2026	0.68	0.54
Fishing mortality rate	2027	0.54	0.47

The age 0+ biomass projections for 2026 and 2027 from this year's model are 182,156 t and 186,118 t, respectively.

Risk Table and ABC Recommendation

Risk table summary

The risk table is included to identify considerations that introduce additional risk to the recommended ABC that are not explicitly captured within the stock assessment model for the GOA cod stock and could support a reduction in the recommended ABC. These risks are described in the following and are, in part, aided by a synthesis and interpretation of the most recent ecosystem and socioeconomic information available for GOA Pacific cod from the Ecosystem and Socioeconomic Profile (ESP, Appendix 2.1) and the GOA Ecosystem Status Report (ESR, Ferriss 2026).

These results are summarized in the table below:

Assessment-related Considerations	*Population Dynamics Considerations*	*Ecosystem Considerations*	*Fishery-informed Stock Considerations*
Level 1: Normal	**Level 1:** Normal	**Level 2:** Increased Concern	**Level 1:** Normal
Model 24.0 does not have a concerning retrospective pattern and fits the available data well	Stock continues to experience historically low spawning biomass coupled with below average recruitment	Prolonged warm ocean temperatures throughout the water column in 2025, and concerns of prey base availability, may adversely impact adult Pacific cod biological status in 2026.	Fishery performance indicators are consistent with previous years

The following sections contain further details supporting these risk levels.

Assessment-related considerations:

Risk Level 1: Normal

- The updated Model 24.0 does not show a strong retrospective pattern in recent estimates of spawning biomass, either in the data retrospective or in the model retrospective across recent assessments (Figure 2.9). The retrospective pattern in spawning biomass in the current assessment is negative, which means that as years of data were added to the model the estimates of spawning biomass increase.

- Model 24.0 is, in general, responding appropriately to observed data sources. While the model fits to the indices fall within the 2025 confidence intervals, the model underfits the trawl survey mean and overfits the longline survey mean. Given these results, the estimates of spawning and total biomass from Model 24.0 as applied with updated data though 2025 responds to and reflects the balance between the changes in the index data compared to previous assessments.
- We continue to note that the projection model uses mean recruitment from 1977 – 2023 to project biomass into future years while Model 24.0 estimates below average recruitment since 2014. Therefore, given these recent low recruitment estimates it is likely that the forecasted spawning biomass is overly optimistic. However, the effect on the two-year projections that result in ABC and OFL recommendations is not largely impacted by this recruitment assumption, as the year classes that are assumed to be at mean recruitment aren't contributing much to the overall level of spawning biomass in the short term.
- Auxiliary information on recruitment from non-target fishery sources and the beach seine survey of age-0 fish surveys suggest above average 2020- and 2022-year classes, followed by below average years classes after 2023. Within the observations of length composition (and age composition) from the AFSC bottom trawl survey these relatively stronger year classes are present, but the model estimates lower abundance of these year classes than have been observed. Therefore, we note this inconsistency between the assessment results and observations, but make the point that this inconsistency would not result in increased risk that the stock is smaller in 2026 than projected by Model 24.0, rather, that the assessment may be underestimating the magnitude of recruitment since 2014.
- A sharp decline in maximum ABC in the two-year projection (2027) compared to the one-year projection (2026) resulted from Model 24.0 after updating data through 2025. This decline is the result of declining abundance estimates of the 2020 and 2021 year-classes in the forecasted population in combination with moving down the ramp of the NPFMC Harvest Control Rule (HCR) for Tier 3b status. While this decline is notable, increases in two-year ABC in recent assessments have resulted as well. For example, the two-year projected ABC in 2022 was 61% larger than the one-year projected ABC for 2021 due to moving up the ramp of the HCR (Barbeaux et al. 2020). We make this note to highlight that this is not an additional risk to the recommended 2026 ABC but rather observe that this is a feature of the HCR ramp for Tier 3b status as applied to the population characteristics of GOA Pacific cod.
- We continue to rate the assessment considerations category at risk level 1 – typical to moderately increased concern due to 1) Model 24.0 fitting the available data reasonably well, 2) lack of a retrospective pattern, and 3) the limited impact of projected mean recruitment that is higher than the past decade of estimated recruitments on 2-year ABC and OFL recommendations.

<u>Population dynamics considerations:</u>

Risk Level 1: Normal

- Female spawning biomass is estimated to decrease over the next 3 years, then increase in the medium-term once the projected year classes (i.e., those after 2025 that are based on mean recruitment since 1977) begin contributing to the SSB. Total biomass is estimated to increase through 2030.
- The 2025 observations of population scale from both the fitted data sources (bottom trawl survey and longline survey) and the monitored data sources (ADFG trawl survey and shallow water flatfish incidental catch) continue to indicate a generally increasing trend in population size since historically low levels.

- Spawning conditions were considered below average to low in 2025. This is based on an uptick of heatwave events during the spawning period in 2025 (Appendix 2.1: S. Barbeaux) and low habitat suitability index (based on temperatures at GAK 1 of the Seward line from January to April, Appendix 2.1: L. Rogers). While these conditions are not favorable for cod recruitment, a relatively lower 2025 year class would have little impact on the recommended 2026 ABC.
- Overall, the stock has yet to recover in the GOA to historical levels and Model 24.0 continues to estimate below average recruitment of recent year-classes.
- In past assessments the low levels of spawning biomass and below average recruitment have been used to rate the population dynamics considerations category at risk level 2 – increased concern. It must be noted that these evaluations of risk are based upon the assessment model results and because these risks are obtained from evaluation of the assessment model results, they are, by definition, included within the assessment process and thus mitigated through the application of the stock status within the HCR. Therefore, in this assessment we reduce the risk level for the population dynamics considerations category to risk level 1 – typical to moderately increased concern. We make this reduction in risk level while recognizing that the GOA cod stock remains in a undesirable stock status.

<u>Ecosystem considerations:</u>

Risk Level 2: Increased Concern

- Prolonged periods of above average temperatures, including periods in moderate marine heatwave status, through the winter, early spring, late summer, and fall, throughout the water column on the shelf and offshore in the gyre (Lemagie and Bell, Lemagie and Callahan, and Ocean Temperature Synthesis, in Ferriss 2026) may lead to higher metabolic demands of adult cod (requiring increased prey base to support their energetic needs, Appendix 2.1: Adams).
- Juvenile cod (<50cm) body condition decreased slightly and remained below average while adult Pacific cod (>50cm) decreased from average to below average in 2025 (Appendix 2.1: Rohan, Prohaska and Rohan). This decrease in body condition may imply below average prey availability.
- There are mixed signals in the indicators for prey base. An adequate prey base is supported by observations of above-average euphausiid spring biomass in the northern GOA (Hopcroft, in Ferriss 2026), elevated herring ocean stocks in SE Alaska (Dressel et al., in Ferriss 2026), elevated capelin presence in seabird diets (Whelan et al., in Ferriss 2026), good reproductive success of fish-eating seabirds (Appendix 2.1: Zador, Drummond et al., in Ferriss 2026), and an increase in hermit crabs (representing benthic prey) in the western GOA (Whitehouse and Aydin, in Ferriss 2026). An inadequate prey base is supported by observations of continued low presence of P. sandlance in seabird diets in the northern GOA (Whelan et al., in Ferriss 2026), reduced biomass of brittle stars and echinoderms (representing benthic prey, Whitehouse and Aydin, in Ferriss 2026) and average to below-average pandalid shrimp (Friedman, in Ferriss 2026) in the western GOA.
- The spring phytoplankton bloom (satellite derived mean chlorophyll *a*) was slightly above average (Gann, in Ferriss 2026), while the peak timing of the spring bloom has stabilized somewhat since 2020 and is at the average for the time series (Appendix 2.1: Callahan). This may provide a buffer to increased metabolic demands in warming temperatures. However, the phytoplankton community size index observed along Seward Line was dominated by smaller-cell dominated spring bloom, comparable to recent marine heatwave years (in contrast to 2021-2024), indicating a less efficient transfer of energy up the foodweb (Hennon, in Ferriss 2026).

- Competition and predation indicators of early juvenile Pacific cod show mixed signals with low abundance of apex fish predators such as arrowtooth flounder and Pacific halibut (Whitehouse, in Ferriss 2026), slight increase in projected biomass consumed from the CEATTLE multispecies model (Appendix 2.1: Adams), and steadily increasing population of Steller sea lions in the GOA (Appendix 2.1: Sweeney).
- Overall, due to the prolonged periods of above average temperatures throughout the water column coupled with the decrease to below average body condition for adult Pacific cod as an indication of prey availability in 2025 we increase the risk level for ecosystem considerations to risk level 2 – increased concern. These conditions, while not as extreme as observed during the heatwave years, still present an increased risk to the adult population that comprises the 2026 recommended ABC.

<u>Fishery-informed stock considerations:</u>

Risk Level 1: Normal

- Where data were available, catch-per-unit effort measures in the GOA fisheries showed mixed signals that are consistent with previous years.
- It should be noted that catch levels and fishery participation have been low over the past 5 years in comparison with pre fishery closure years due to the lower population size resulting in lower catch limits than historical limits.
- Bycatch in other fisheries still remain low compared to fisheries prior to the 2014-2016 marine heatwave, with the exception of the shallow water flatfish fishery, within which we have noted that Pacific cod catch has increased.
- We continue to rate the fishery-informed stock considerations at risk level 1 – no apparent concerns.

<u>ABC recommendation</u>

While the largest score of the risk table is level 2, we recommend that the ABC be set based on the FMP HCR. The Tier 3b stock status includes an adjustment that reduces the OFL and ABC and this builds in precaution to help the stock increase to above B_{MSY} ($B_{35\%}$ in this case). Nonetheless, we acknowledge the potential increased risk from unknown factors outside of data and considerations included in the stock assessment model. Warmer than average temperatures through most of 2025 may impact population productivity even though the spawning biomass is near the B_{MSY} estimate.

In terms of the marine heatwave index, similar conditions to those in 2025 have been observed in recent years, notably in 2014 and again in 2019. After 2014, the severe marine heatwave hit in 2015 and 2016 during which the population collapsed. It must be noted that the magnitude of the population was much different in 2014 prior to the severe marine heatwave event compared to 2025; the spawning biomass in 2014 (as estimated by the 2014 assessment) was 250% larger than the spawning biomass estimated in 2025 by Model 24.0, and the adopted ABC for 2015 (the largest ABC on record) was nearly 150% larger than the recommended ABC for 2026. Rescaling the 2015 and 2026 ABCs with the total biomass estimated in these years by Model 24.0 results in an ABC that was 24% larger in 2015 compared to the recommended 2026 ABC. In other words, the 2026 ABC is buffered by an additional 24% compared to the ABC that would have resulted given the current stock status and assessment model structure as compared to that which existed in 2015. After 2019 the marine heatwave did not persist and we have since observed and estimated that the adult population trend continues to increase after 2019. However, the 2019 year class was the smallest of the time series. We suspect that it is likely that the 2025 year class will be small due to the 2025 conditions, however, it is less clear as to the impact of the conditions in 2025 on the adult population that comprises the 2026 recommended ABC. It is also unknown whether the conditions we observed in 2025 will continue into 2026, even though current conditions have cooled compared to previously in 2025. We emphasize that this is an additional risk when considering the recommended 2026 ABC.

When considering additional buffers that reduce ABC due to increased risk, it must be acknowledged that the Pacific cod stock is in Tier 3b status, or, on the ramp of the HCR. This translates to a reduction in $F_{40\%}$ of 18% to obtain the 2026 F_{ABC} and 30% to obtain the 2027 F_{ABC}. An additional point to make is that when conducting the projections, the assumption for current year catch is that the full ABC will be taken. However, since the fishery closure in 2020 an average of 82% of the ABC has been prosecuted. If the actual catch in 2025 were used in Model 24.0 instead of the full 2025 ABC this results in a 5% increase in the 2026 recommended ABC, thus, this model assumption results in an inherent reduction of roughly 5% in the recommended ABC. Finally, it should be noted that the assessment model in its current form is fundamentally the same as the model adopted in 2019. While improvements to the data and model have been adopted in the intervening years, the current model is much the same as the model that was used to recommend the fishery closure in 2020.

We have presented several aspects of the assessment process that serve to mitigate risk in the recommended 2026 ABC, including the current model structure, projection assumptions, and NPFMC Tier status. However, it remains unclear to what extent the risk we highlight due to the 2025 ecosystem conditions would be mitigated. While an additional buffer to the 2026 recommended ABC could considered, we have been provided no guidance in applying a method with clear and discernable objectives to add buffers that are in addition to the NPFMC HCR and Tier status that mitigate additional risk not explicitly considered in the assessment model. It is also unclear as to the measurable effect, or risk reduction, that previous additional buffers employed across stocks assessed by the AFSC have provided.

For 2026 the spawning stock biomass is projected to be above $B_{20\%}$, and despite a drop in spawning biomass in 2027 is projected to remain above $B_{20\%}$ in 2027.

Area Allocation of Harvests

To determine the Biologically informed Recommended Distributions (BRD) for GOA subregions, we utilize the `rema` R package. For this year's assessment, two modifications to the `rema` model configuration are recommended:

1. Process Error: Estimate a single process error parameter across all GOA subregions rather than a process error parameter for each subregion.
2. Observation Error: Estimate the parameter that defines additional observation error within the AFSC bottom trawl survey subregion biomass.

Estimates of regional trawl survey biomass from the recommended model compared to the status quo model are shown in Figure 2.17. The recommended `rema` model provides estimates of regional biomass and uncertainty that are more stable across the time-series than the status quo model. The biomass estimates from the recommended `rema` model respond to the trawl survey biomass, however, do not over-fit any given year as can be the case with the status quo `rema` model. Additionally, the estimated uncertainty in the recommended `rema` model does not have high inter-annual variability as is common in the status quo `rema` model estimates. It should be noted that the estimates of biomass from the recommended `rema` model are more reflective of the year-to-year changes in Pacific cod biomass as estimated by the recommended assessment model that integrates numerous sources of information on the Pacific cod stock in addition to the bottom trawl survey abundance index (Figure 2.13).

The stability inherent in the recommended `rema` model's biomass estimates translates directly to more consistent subregion apportionment (Figure 2.18). The recommended `rema` model adjusts to regional bottom trawl survey data and it prevents the drastic, improbable shifts in Pacific cod distribution often produced by the status quo model, shifts that are inconsistent with our understanding of the species' life history and movement patterns.

Therefore, we recommend a `rema` model configuration that reduces the number of process error parameters from regional parameters to a single parameter and estimates the extra observation error parameter to be used to estimate subregion apportionment. Beside the increased stability and biological reality that these changes produce in the recommended `rema` model, these are statistically defensible changes in that they provide parsimony by reducing the number of fixed parameters from three to two, and they have precedent in other stock assessments performed by AFSC (Echave et al. 2022, Siwicke et al. 2024).

Using the status quo and recommended `rema` model to estimate apportionment and BRDs, as well as comparison with the adopted 2025 apportionment and BRDs, resulted in the following:

	Western	Central	Eastern	Total
Previous apportionment	27.1%	63.8%	9.1%	100%
2025 BRD	8,710	20,506	2,925	32,141
Status quo apportionment	20.6%	75.1%	4.3%	100%
2026 BRD	8,553	31,182	1,785	41,520
Recommended apportionment	24.8%	69.2%	6%	100%
2026 BRD	10,297	28,732	2,491	41,520

Using the status quo `rema` model to estimate the 2026 apportionment resulted in a 24% decrease to the Western GOA, an 18% increase to the Central GOA, and a 53% decrease to the Eastern GOA as compared to the 2025 apportionment. Alternatively, in comparison with the 2025 apportionment the recommended `rema` model resulted in an 8.5% decrease in apportionment to the Western GOA, an 8.5% increase in apportionment to the Central GOA, and a 34% decrease in apportionment to the Eastern GOA.

Using the recommended `rema` model area-apportioned BRDs for the two-year projections of Model 24.0 would be:

	Western	Central	Eastern	Total
Area apportionment	24.8%	69.2%	6%	100%
2026 BRD	10,297	28,732	2,491	41,520
2027 BRD	7,987	22,289	1,933	32,209

Status Determination

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). Year-end catch for 2025 was set equal to the 2025 ABC. In each subsequent year, the fishing mortality rate is prescribed based on the spawning biomass in that year and the respective harvest scenario.

Selectivity used in the projections was the mean selectivity since 2000, recruitment was based on average recruitment from 1977-2023 and growth and mortality were as estimated in 2025.

Five of the seven standard scenarios support the alternative harvest strategies analyzed in the Alaska Groundfish Harvest Specifications Final Environmental Impact Statement. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2026, 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 the author's recommend level, max ABC.

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, F is set equal to the $F_{75\%}$. (Rationale: This scenario was developed by the NMFS Regional Office based on public feedback on alternatives.

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 expected to be above half of its B_{MSY} level in 2025 and above its B_{MSY} level in 2035 under this scenario, then the stock is not overfished.)

Scenario 7: In 2026 and 2027, 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 2027 or 2) above 1/2 of its MSY level in 2027 and expected to be above its MSY level in 2037 under this scenario, then the stock is not approaching an overfished condition.)

Scenarios 1 through 7 were projected 15 years from 2025 in Model 24.0 (Table 2.11). Scenarios 3, 4, and 5 (no fishing) project the stock to be below $B_{35\%}$ until 2029, scenarios 1, 2, 6, and 7 have the stock below $B_{35\%}$ until 2030. Fishing at the maximum permissible rate indicates that the spawning stock will be below $B_{35\%}$ in 2026 through 2029 due to poor recruitment and high mortality in 2015-2017. Under an assumption of environmental conditions at the 1977-2022 mean, the stock recovers above $B_{35\%}$ by 2030.

Our projection model run under these conditions indicates that for Scenario 6, the GOA Pacific cod stock although below $B_{35\%}$ in 2025 at 54,728 t will be above its MSY value in 2035 at 83,245 t and therefore would not be classified as overfished.

Projections 7 with fishing at the OFL after 2026 results in an expected spawning biomass of 73,648 by 2037 and would therefore not be approaching an overfished condition.

Under Scenarios 6 and 7 for Model 24.0 the GOA Pacific cod stock would not currently be considered overfished, nor would it be approaching an overfished status. The 2024 OFL given Model 24.0 would have produced a sum of apical F of 0.48 in 2024.

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Tables

Table 2.1. Catch (t) for 1991 through 2025 by jurisdiction and gear type (as of 2025-12-8, 'Other' gear type is primarily jig).

	Federal					State				
Year	Trawl	Long-line	Pot	Other	Subtotal	Long-line	Pot	Other	Subtotal	Total
1991	58,092	7,630	10,464	115	76,301	-	-	-	-	76,301
1992	54,593	15,675	10,154	325	80,747	-	-	-	-	80,747
1993	37,806	8,963	9,708	11	56,488	-	-	-	-	56,488
1994	31,447	6,778	9,161	100	47,486	-	-	-	-	47,486
1995	41,875	10,978	16,055	77	68,985	-	-	-	-	68,985
1996	45,990	10,196	12,040	53	68,279	-	-	-	-	68,279
1997	48,406	10,978	9,065	26	68,475	-	7,368	1,327	8,695	77,170
1998	41,570	10,012	10,510	29	62,121	-	9,183	1,320	10,503	72,624
1999	37,167	12,363	19,015	70	68,615	-	12,410	1,518	13,928	82,543
2000	25,443	11,660	17,351	54	54,508	-	10,399	1,644	12,043	66,551
2001	24,383	9,910	7,171	155	41,619	-	7,829	2,083	9,912	51,531
2002	19,810	14,666	7,694	176	42,346	-	10,578	1,714	12,292	54,638
2003	18,884	9,525	12,765	161	41,335	62	7,943	3,242	11,247	52,582
2004	17,513	10,326	14,966	400	43,205	51	10,602	2,765	13,418	56,623
2005	14,549	5,732	14,749	203	35,233	26	9,653	2,673	12,352	47,585
2006	13,132	10,244	14,540	118	38,034	55	9,146	662	9,863	47,897
2007	14,775	11,539	13,573	44	39,931	270	11,378	682	12,330	52,261
2008	20,293	12,106	11,229	63	43,691	317	13,438	1,568	15,323	59,014
2009	13,976	13,968	11,951	206	40,101	676	9,919	2,500	13,095	53,196
2010	22,035	16,538	20,116	429	59,118	826	14,604	4,045	19,475	78,593
2011	16,456	16,622	29,233	722	63,033	1,033	16,675	4,627	22,335	85,368
2012	20,084	14,467	21,238	722	56,511	866	15,940	4,613	21,419	77,930
2013	21,706	12,836	17,011	476	52,029	1,088	14,156	1,303	16,547	68,576
2014	26,917	14,735	19,957	1,046	62,655	1,007	18,445	2,838	22,290	84,945
2015	22,268	13,047	20,653	408	56,376	577	19,719	2,808	23,104	79,480
2016	15,217	8,123	19,248	346	42,934	803	18,609	1,708	21,120	64,054
2017	13,041	8,965	13,426	67	35,499	155	13,011	62	13,228	48,727
2018	3,818	3,033	4,013	121	10,985	310	3,660	195	4,165	15,150
2019	4,535	2,763	3,732	178	11,208	358	3,820	329	4,507	15,715
2020	3,427	586	30	-	4,043	529	1,779	491	2,799	6,842
2021	5,986	3,834	3,427	52	13,299	558	4,230	1,085	5,873	19,172
2022	8,207	5,775	4,925	3	18,910	357	5,645	994	6,996	25,906
2023	6,473	5,179	4,069	378	16,099	563	3,653	1,412	5,628	21,727
2024	8,347	5,411	5,622	319	19,699	416	4,295	1,488	6,199	25,898
2025	8,024	4,699	6,347	533	19,603	283	5,674	1,387	7,344	26,947

Table 2.2. History of Pacific cod catch (t, includes catch from State waters), Federal TAC (does not include State guideline harvest level, GHL), ABC, OFL and State of Alaska GHL (1997-Present) since 1991. Catch for 2025 is current through 2025-12-8 and includes catch from State of Alaska fisheries. See Hulson et al. 2022 (Table 2.2) for catch history prior to 1991.

Year	Catch	TAC	ABC	OFL	GHL
1991	76,301	77,900	77,900	-	-
1992	80,747	63,500	63,500	87,600	-
1993	56,488	56,700	56,700	78,100	-
1994	47,486	50,400	50,400	71,100	-
1995	68,985	69,200	69,200	126,000	-
1996	68,279	65,000	65,000	88,000	-
1997	77,170	69,115	81,500	180,000	12,385
1998	72,624	66,060	77,900	141,000	11,840
1999	82,543	67,835	84,400	134,000	16,565
2000	66,551	59,800	76,400	102,000	17,685
2001	51,531	52,110	67,800	91,200	15,690
2002	54,638	44,230	57,600	77,100	13,370
2003	52,582	40,540	52,800	70,100	12,260
2004	56,623	48,033	62,810	102,000	14,777
2005	47,585	44,433	58,100	86,200	13,667
2006	47,897	52,264	68,859	95,500	16,595
2007	52,261	52,264	68,859	97,600	16,595
2008	59,014	50,269	66,493	88,660	16,224
2009	53,196	41,807	55,300	66,600	13,493
2010	78,593	59,563	79,100	94,100	19,537
2011	85,368	65,100	86,800	102,600	21,700
2012	77,930	65,700	87,600	104,000	21,900
2013	68,576	60,600	80,800	97,200	20,200
2014	84,945	64,738	88,500	107,300	23,762
2015	79,480	75,202	102,850	140,300	27,648
2016	64,054	71,925	98,600	116,700	26,675
2017	48,727	64,442	88,342	105,378	23,900
2018	15,150	13,096	18,000	23,565	4,904
2019	15,715	12,368	17,000	23,669	4,632
2020	6,842	6,431	14,621	17,794	2,537
2021	19,172	17,321	23,627	28,977	6,306
2022	25,906	24,111	32,811	39,555	8,700
2023	21,727	18,103	24,634	29,737	6,531
2024	25,898	23,766	32,272	38,712	8,506
2025	26,947	23,670	32,141	38,688	8,471

Table 2.3. History of GOA Pacific cod allocations by regulatory area (in percent) for 1991-2025, and proposed for 2026 (in parentheses). See Barbeaux *et al.* (2018) for 1977-1990.

Year(s)	Western	Central	Eastern
1991	33	62	5
1992	37	61	2
1993-1994	33	62	5
1995-1996	29	66	5
1997-1999	35	63	2
2000-2001	36	57	7
2002	39	55	6
2002	38	56	6
2003	39	55	6
2003	38	56	6
2004	36	57	7
2004	35.3	56.5	8.2
2005	36	57	7
2005	35.3	56.5	8.2
2006	39	55	6
2006	38.54	54.35	7.11
2007	39	55	6
2007	38.54	54.35	7.11
2008	39	57	4
2008	38.69	56.55	4.76
2009	39	57	4
2009	38.69	56.55	4.76
2010	35	62	3
2010	34.86	61.75	3.39
2011	35	62	3
2011	35	62	3
2012	35	62	3
2012	32	65	3
2013	38	60	3
2014	37	60	3
2015	38	60	3
2016	41	50	9
2017	41	50	9
2018	44.9	45.1	10
2019	44.9	45.1	10
2020	33.8	57.8	8.4
2021	33.8	57.8	8.4
2022	30.3	60.2	9.5
2023	30.3	60.2	9.5
2024	27.1	63.8	9.1
2025	27.1	63.8	9.1
2026	*24.8*	*69.2*	*6*

Table 2.4. Estimated retained and discarded GOA Pacific cod (t, as of 2025-12-8)

Year	Discarded	Retained	Total
1991	1,427	74,873	76,300
1992	3,920	76,827	80,747
1993	5,886	50,602	56,488
1994	3,122	44,363	47,485
1995	3,546	65,439	68,985
1996	7,555	60,725	68,280
1997	4,828	72,342	77,170
1998	1,732	70,893	72,625
1999	1,645	80,898	82,543
2000	1,378	65,174	66,552
2001	1,904	49,627	51,531
2002	3,715	50,923	54,638
2003	2,485	50,097	52,582
2004	1,268	55,355	56,623
2005	1,043	46,541	47,584
2006	1,852	46,045	47,897
2007	1,448	50,813	52,261
2008	3,307	55,707	59,014
2009	3,944	49,252	53,196
2010	3,097	75,496	78,593
2011	2,178	83,189	85,367
2012	949	76,981	77,930
2013	4,560	64,016	68,576
2014	5,302	79,643	84,945
2015	1,723	77,758	79,481
2016	868	63,187	64,055
2017	711	48,016	48,727
2018	604	14,546	15,150
2019	1,194	14,522	15,716
2020	1,748	5,094	6,842
2021	1,404	17,769	19,173
2022	1,676	24,231	25,907
2023	1,875	19,852	21,727
2024	1,607	24,292	25,899
2025	1,881	25,065	26,946

Table 2.5. GOA AFSC Longline survey estimated Relative Population Numbers (RPNs), and bottom trawl survey estimated biomass (t) and numbers of fish ('Abundance', in 1000s) shown along with coefficients of variation (in parentheses).

Year	RPN	Biomass (t)	Abundance
1990	116,434 (13.9%)	413,281 (15.4%)	210,924 (20.9%)
1991	110,061 (14.1%)	-	-
1992	136,383 (8.7%)	-	-
1993	153,950 (11.4%)	400,054 (18.1%)	220,342 (19.5%)
1994	96,563 (9.4%)	-	-
1995	120,710 (10%)	-	-
1996	84,535 (14.1%)	529,762 (20.3%)	314,572 (21.8%)
1997	104,647 (16.9%)	-	-
1998	125,877 (11.5%)	-	-
1999	91,480 (11.3%)	301,719 (12.7%)	163,498 (11.3%)
2000	54,316 (14.5%)	-	-
2001	33,841 (18.1%)	248,745 (20.6%)	155,231 (18.2%)
2002	51,903 (17%)	-	-
2003	59,952 (15%)	295,423 (15.1%)	158,613 (13%)
2004	53,109 (11.8%)	-	-
2005	29,864 (21.4%)	302,673 (26.9%)	129,306 (21.6%)
2006	34,316 (19.7%)	-	-
2007	34,994 (14%)	230,056 (14%)	190,831 (17.6%)
2008	26,881 (22.8%)	-	-
2009	68,395 (13.8%)	741,101 (30.8%)	562,698 (29.1%)
2010	86,725 (13.8%)	-	-
2011	93,743 (14.1%)	492,596 (13.8%)	342,900 (17.9%)
2012	63,768 (14.8%)	-	-
2013	48,553 (16.2%)	502,892 (14.8%)	336,182 (15.2%)
2014	69,665 (14.3%)	-	-
2015	88,482 (15.9%)	248,178 (10.6%)	193,019 (12.1%)
2016	83,887 (17.2%)	-	-
2017	39,575 (10.1%)	103,258 (12.7%)	54,264 (11.7%)
2018	23,857 (12.1%)	-	-
2019	14,933 (18.5%)	179,860 (21.6%)	124,806 (24.7%)
2020	19,459 (21.8%)	-	-
2021	30,830 (16.2%)	172,568 (8.9%)	89,939 (8.7%)
2022	23,393 (15.9%)	-	-
2023	30,802 (20.9%)	222,473 (12.6%)	125,571 (9.9%)
2025	29,233 (18.5%)	309,761 (23.4%)	187,845 (23.3%)

Table 2.6. Key parameter estimates with standard deviations (SD) estimated from the author's recommended model.

Name	Value	SD
Biology	--	--
Beginning of year length at age-1 (cm)	17.64	0.303
Beginning of year length at age-10 (cm)	99.46	0.015
Growth rate	0.19	0.002
SD in length-at-age for age-1	4.01	0.182
SD in length-at-age for age-10	9.1	0.347
Natural mortality (2014-2016)	0.84	0.053
Natural mortality (all years)	0.5	0.023
Recruitment/Abundance	--	--
log(mean recruitment)	13.09	0.21
1976 Regime adjustment	-0.67	0.19
Survey catchability	--	--
Bottom trawl survey	1.28	0.123
Longline survey	1.17	0.108
Longline survey environmental coefficient	0.95	0.397

Table 2.7. Estimated female spawning biomass (t), standard deviation in spawning biomass (SD), and total biomass (t, age 0+) from the previous accepted assessment and the current recommended model.

Year	Previous Sp.Bio	Previous SD[Sp.Bio]	Previous Tot.Bio.	Current Sp.Bio	Current SD[Sp.Bio]	Current Tot.Bio.
1977	82,030	18,624	263,078	81,532	18,421	261,922
1978	93,526	20,289	274,934	92,738	20,019	273,698
1979	91,392	19,576	306,236	90,442	19,279	305,621
1980	86,468	18,181	367,433	85,592	17,902	366,512
1981	100,306	21,344	404,096	99,580	21,044	402,120
1982	128,098	27,305	429,094	126,933	26,868	425,811
1983	138,760	29,352	464,679	137,040	28,806	459,934
1984	140,462	29,869	506,907	138,207	29,239	500,761
1985	156,013	31,122	571,308	153,132	30,386	563,723
1986	185,062	32,452	643,066	181,474	31,604	634,589
1987	213,389	33,340	705,665	209,168	32,386	696,611
1988	228,887	32,111	733,973	224,496	31,148	724,735
1989	243,403	30,496	738,995	238,932	29,563	730,025
1990	246,430	27,784	722,469	242,038	26,936	714,093
1991	227,089	24,492	680,037	223,096	23,770	672,712
1992	207,464	21,875	646,435	203,906	21,261	640,025
1993	190,501	19,878	613,356	187,434	19,357	607,742
1994	191,073	18,675	593,657	188,231	18,204	588,353
1995	193,714	17,173	562,274	191,054	16,749	557,137
1996	176,600	14,814	500,923	174,157	14,443	496,225
1997	152,166	12,234	448,772	149,887	11,918	444,617
1998	125,266	10,174	401,629	123,258	9,913	397,910
1999	109,867	9,138	365,436	108,093	8,911	362,078
2000	96,878	8,662	324,871	95,240	8,446	322,039
2001	88,328	8,115	306,187	86,876	7,922	304,118
2002	84,006	7,558	310,405	82,753	7,388	309,067
2003	82,664	7,400	311,203	81,684	7,252	310,329
2004	88,050	7,629	302,383	87,293	7,491	301,769
2005	87,817	7,438	280,139	87,188	7,305	279,496
2006	81,816	6,620	264,404	81,328	6,503	263,509
2007	72,894	5,786	261,734	72,336	5,671	260,909
2008	65,126	5,343	282,345	64,363	5,225	281,842
2009	64,976	5,702	320,013	64,250	5,588	319,879
2010	82,099	7,028	370,972	81,442	6,910	371,394
2011	94,676	8,458	394,847	94,092	8,337	395,909
2012	103,497	9,906	399,102	103,150	9,796	401,222
2013	110,310	11,073	414,288	110,236	10,979	418,360
2014	111,288	11,831	463,262	111,680	11,770	470,503
2015	79,084	7,540	362,383	78,400	7,375	363,504
2016	62,598	5,599	255,983	61,134	5,369	252,790
2017	48,276	4,390	161,564	46,249	4,128	156,551
2018	42,448	4,549	137,613	40,443	4,306	133,276
2019	41,786	4,293	146,791	39,932	4,099	143,626
2020	41,907	4,216	159,919	40,298	4,072	158,719
2021	50,256	4,537	178,117	49,127	4,451	179,657
2022	55,452	4,940	180,403	55,225	4,901	186,049
2023	54,246	5,070	174,394	55,298	5,036	185,759
2024	52,034	5,160	174,445	54,879	5,112	188,381
2025	46,920	5,643	177,497	54,728	5,564	185,884
2026	-	-	-	52,772	6,247	182,156

Table 2.8. Age-0 recruitment (millions) and standard deviation of age-0 recruits by year from the 2024 accepted assessment (denoted as 'Previous') and the author's recommended model (denoted as 'Current'). Highlighted are the 1977 and 2012 year classes.

Year	Previous Recruitment	Previous SD[Rec]	Current Recruitment	Current SD[Rec]
1977	1.18	0.36	1.18	0.35
1978	0.39	0.14	0.39	0.14
1979	0.37	0.13	0.36	0.13
1980	0.65	0.21	0.64	0.21
1981	0.7	0.23	0.69	0.22
1982	0.94	0.3	0.93	0.3
1983	0.68	0.27	0.68	0.27
1984	0.9	0.3	0.9	0.29
1985	0.88	0.25	0.88	0.25
1986	0.61	0.17	0.62	0.17
1987	0.66	0.16	0.66	0.16
1988	0.66	0.16	0.66	0.16
1989	0.69	0.16	0.69	0.16
1990	0.78	0.17	0.78	0.17
1991	0.57	0.13	0.58	0.13
1992	0.43	0.1	0.42	0.1
1993	0.36	0.08	0.36	0.08
1994	0.42	0.09	0.42	0.09
1995	0.54	0.11	0.54	0.1
1996	0.4	0.08	0.4	0.08
1997	0.36	0.07	0.37	0.07
1998	0.34	0.07	0.34	0.07
1999	0.51	0.1	0.52	0.1
2000	0.5	0.1	0.5	0.1
2001	0.3	0.06	0.3	0.06
2002	0.26	0.05	0.26	0.05
2003	0.3	0.06	0.3	0.06
2004	0.3	0.06	0.3	0.06
2005	0.54	0.1	0.54	0.1
2006	0.74	0.13	0.74	0.13
2007	0.54	0.1	0.54	0.1
2008	0.79	0.15	0.8	0.15
2009	0.43	0.09	0.44	0.09
2010	0.52	0.11	0.53	0.11
2011	0.81	0.17	0.82	0.17
2012	1.18	0.27	1.21	0.28
2013	0.72	0.19	0.76	0.2
2014	0.24	0.07	0.25	0.07
2015	0.28	0.07	0.29	0.08
2016	0.28	0.06	0.28	0.06
2017	0.3	0.06	0.31	0.06
2018	0.21	0.04	0.23	0.05
2019	0.18	0.04	0.19	0.04
2020	0.19	0.04	0.22	0.05
2021	0.22	0.05	0.27	0.06
2022	0.21	0.07	0.2	0.05
2023	0.41	0.19	0.19	0.06
2024	0.49	0.24	0.3	0.1
2025	-	-	0.48	0.23
Mean 1977 - (Final year - 2)	0.52		0.52	

Table 2.9. Estimated fishing mortality in terms of apical F and total exploitation for the author's recommended model.

Year	Sum Apical F	SD[F]	Total Exploitation
1977	0.012	0.003	0.009
1978	0.059	0.013	0.045
1979	0.078	0.018	0.049
1980	0.194	0.046	0.096
1981	0.124	0.027	0.09
1982	0.091	0.019	0.069
1983	0.117	0.025	0.079
1984	0.076	0.017	0.048
1985	0.066	0.016	0.026
1986	0.096	0.023	0.039
1987	0.067	0.016	0.047
1988	0.064	0.009	0.047
1989	0.08	0.012	0.059
1990	0.187	0.022	0.102
1991	0.217	0.024	0.113
1992	0.253	0.028	0.126
1993	0.189	0.02	0.093
1994	0.157	0.015	0.081
1995	0.234	0.021	0.124
1996	0.255	0.022	0.138
1997	0.348	0.029	0.174
1998	0.404	0.035	0.183
1999	0.546	0.05	0.228
2000	0.488	0.047	0.207
2001	0.395	0.038	0.169
2002	0.446	0.042	0.177
2003	0.429	0.04	0.169
2004	0.439	0.039	0.188
2005	0.4	0.041	0.17
2006	0.431	0.04	0.182
2007	0.493	0.042	0.2
2008	0.613	0.055	0.209
2009	0.515	0.048	0.166
2010	0.608	0.056	0.212
2011	0.591	0.057	0.216
2012	0.477	0.048	0.194
2013	0.39	0.041	0.164
2014	0.578	0.06	0.181
2015	0.788	0.075	0.219
2016	0.815	0.073	0.253
2017	0.799	0.085	0.311
2018	0.248	0.027	0.114
2019	0.255	0.027	0.109
2020	0.101	0.01	0.043
2021	0.253	0.024	0.107
2022	0.313	0.029	0.139
2023	0.257	0.024	0.117
2024	0.311	0.03	0.137
2025	0.399	0.043	0.173

Table 2.10. Biological reference points from GOA Pacific cod SAFE documents for years 2002 – 2025, and recommended for 2026 from the author's recommended model (in italics).

Year	$SB_{100\%}$	$SB_{40\%}$	$F_{40\%}$	OFL_{y+1}	$maxABC_{y+1}$
2002	212,000	85,000	0.41	82,000	57,600
2003	226,000	90,300	0.35	88,300	52,800
2004	222,000	88,900	0.34	103,000	62,810
2005	211,000	84,400	0.31	91,700	58,100
2006	329,000	132,000	0.56	165,000	68,859
2007	259,000	103,000	0.46	136,000	68,859
2008	302,000	121,000	0.49	108,000	66,493
2009	255,500	102,200	0.52	88,000	55,300
2010	291,500	116,600	0.49	117,600	79,100
2011	256,300	102,500	0.42	124,100	86,800
2012	261,000	104,000	0.44	121,000	87,600
2013	234,800	93,900	0.49	111,000	80,800
2014	227,800	91,100	0.54	120,100	88,500
2015	316,500	126,600	0.5	155,400	102,850
2016	325,200	130,000	0.41	116,700	98,600
2017	196,776	78,711	0.53	105,378	88,342
2018	168,583	67,433	0.34	23,565	19,401
2019	172,240	68,896	0.29	23,669	19,665
2020	187,780	75,112	0.22	17,794	14,621
2021	180,111	72,045	0.33	28,977	23,627
2022	165,508	66,203	0.5	39,555	32,811
2023	167,414	66,966	0.41	29,737	24,634
2024	175,187	70,075	0.42	38,712	32,272
2025	163,585	65,434	0.46	38,688	32,141
2026	*159,595*	*63,838*	*0.54*	*49,782*	*41,520*

Table 2.11. Results for the projection scenarios from the author's recommended model. Catch in tons, fishing mortality (F), and Female spawning stock biomass (SSB) in tons for the 7 standard projection scenarios. Scenarios 1 and 2 are most similar to the current management of GOA cod.

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Catch	-	-	-	-	-	-	-
2025	32,141	32,141	32,141	32,141	32,141	32,141	32,141
2026	41,520	41,520	20,535	32,340	0	49,782	41,520
2027	32,209	32,209	20,887	28,434	0	34,424	32,209
2028	32,838	32,838	22,253	29,672	0	34,899	39,691
2029	47,592	47,592	26,758	42,138	0	51,807	53,219
2030	67,740	67,740	33,569	56,137	0	76,954	76,927
2031	75,310	75,310	39,973	64,128	0	83,998	83,896
2032	79,182	79,182	44,461	68,825	0	86,684	86,627
2033	80,798	80,798	47,200	71,138	0	87,572	87,548
2034	81,444	81,444	48,815	72,226	0	87,858	87,849
2035	81,714	81,714	49,773	72,749	0	87,963	87,959
2036	81,813	81,813	50,278	72,972	0	87,995	87,994
2037	81,845	81,845	50,526	73,060	0	88,003	88,003
2038	81,856	81,856	50,647	73,094	0	88,006	88,005
F	-	-	-	-	-	-	-
2025	0.4	0.4	0.4	0.4	0.4	0.4	0.4
2026	0.54	0.54	0.25	0.41	0	0.68	0.54
2027	0.47	0.47	0.25	0.38	0	0.54	0.47
2028	0.46	0.46	0.25	0.38	0	0.53	0.57
2029	0.56	0.56	0.25	0.45	0	0.65	0.66
2030	0.66	0.66	0.25	0.5	0	0.82	0.82
2031	0.66	0.66	0.25	0.5	0	0.83	0.83
2032	0.66	0.66	0.25	0.5	0	0.83	0.83
2033	0.66	0.66	0.25	0.5	0	0.83	0.83
2034	0.66	0.66	0.25	0.5	0	0.83	0.83
2035	0.66	0.66	0.25	0.5	0	0.83	0.83
2036	0.66	0.66	0.25	0.5	0	0.83	0.83
2037	0.66	0.66	0.25	0.5	0	0.83	0.83
2038	0.66	0.66	0.25	0.5	0	0.83	0.83
SSB	-	-	-	-	-	-	-
2025	54,728	54,728	54,728	54,728	54,728	54,728	54,728
2026	52,772	52,772	52,772	52,772	52,772	52,772	52,772
2027	45,838	45,838	53,440	49,137	61,074	42,910	45,838
2028	45,359	45,359	55,636	49,387	69,692	42,204	45,359
2029	54,298	54,298	65,974	58,499	85,168	51,177	52,016
2030	67,138	67,138	83,250	72,180	107,920	63,374	63,394
2031	75,512	75,512	100,185	83,416	131,896	69,498	69,418
2032	80,051	80,051	112,440	90,336	151,858	72,201	72,148
2033	82,043	82,043	120,216	93,903	167,166	73,152	73,128
2034	82,878	82,878	125,016	95,662	178,886	73,476	73,466
2035	83,245	83,245	127,988	96,548	187,781	73,600	73,596
2036	83,382	83,382	129,578	96,932	193,586	73,639	73,638
2037	83,426	83,426	130,359	97,082	197,123	73,649	73,648
2038	83,442	83,442	130,742	97,141	199,278	73,652	73,652

Figures

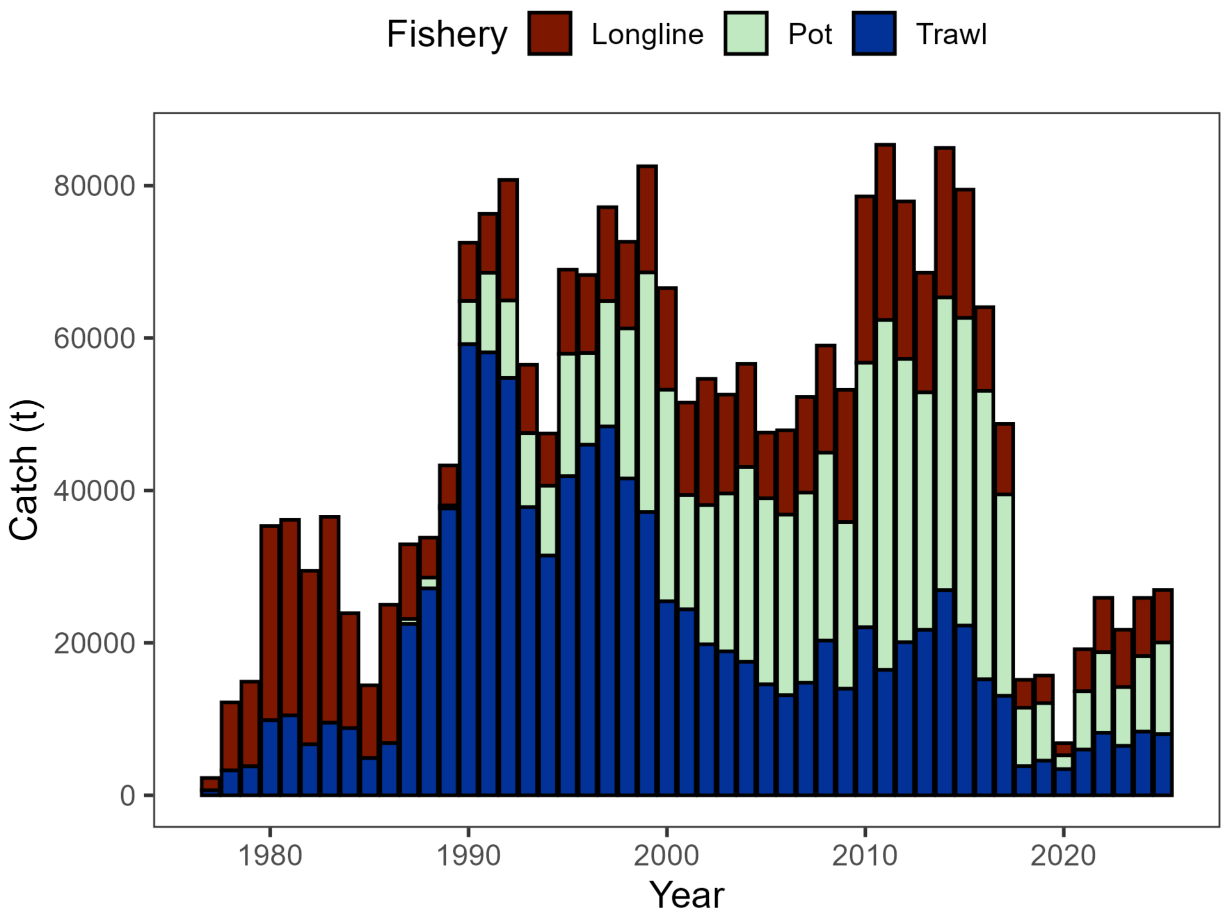

Figure 2.1. Commercial catch (mt) of Pacific cod in the GOA in trawl (FshTrawl), longline (FshLL), and pot (FshPot) gear from 1977-2025. Note that 2025 catch was through December 8.

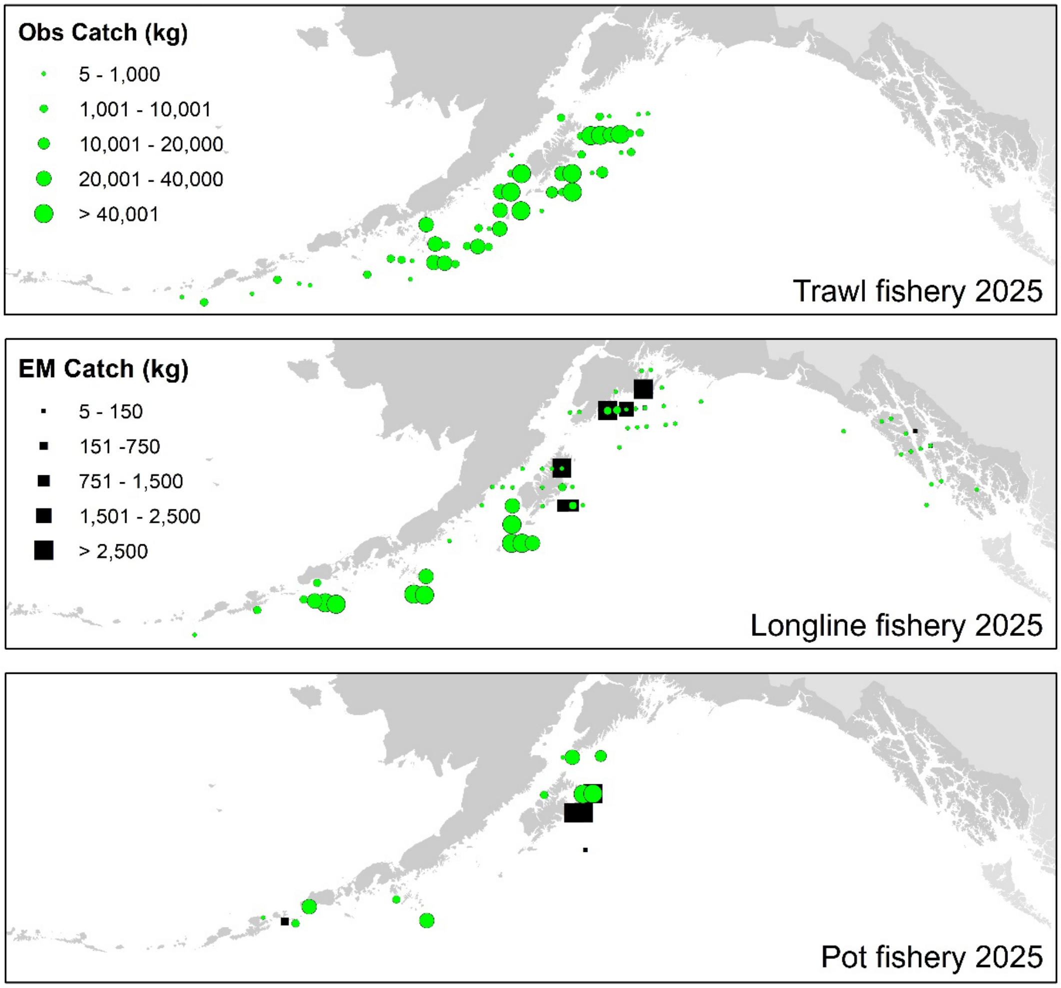

Figure 2.2. Observed (Obs) and electronic monitored (EM) commercial catch of Pacific cod in the GOA by 20 km^2 grid for 2025. These data include bycatch Pacific cod, but do not include trawl EM data as locations are not yet available.

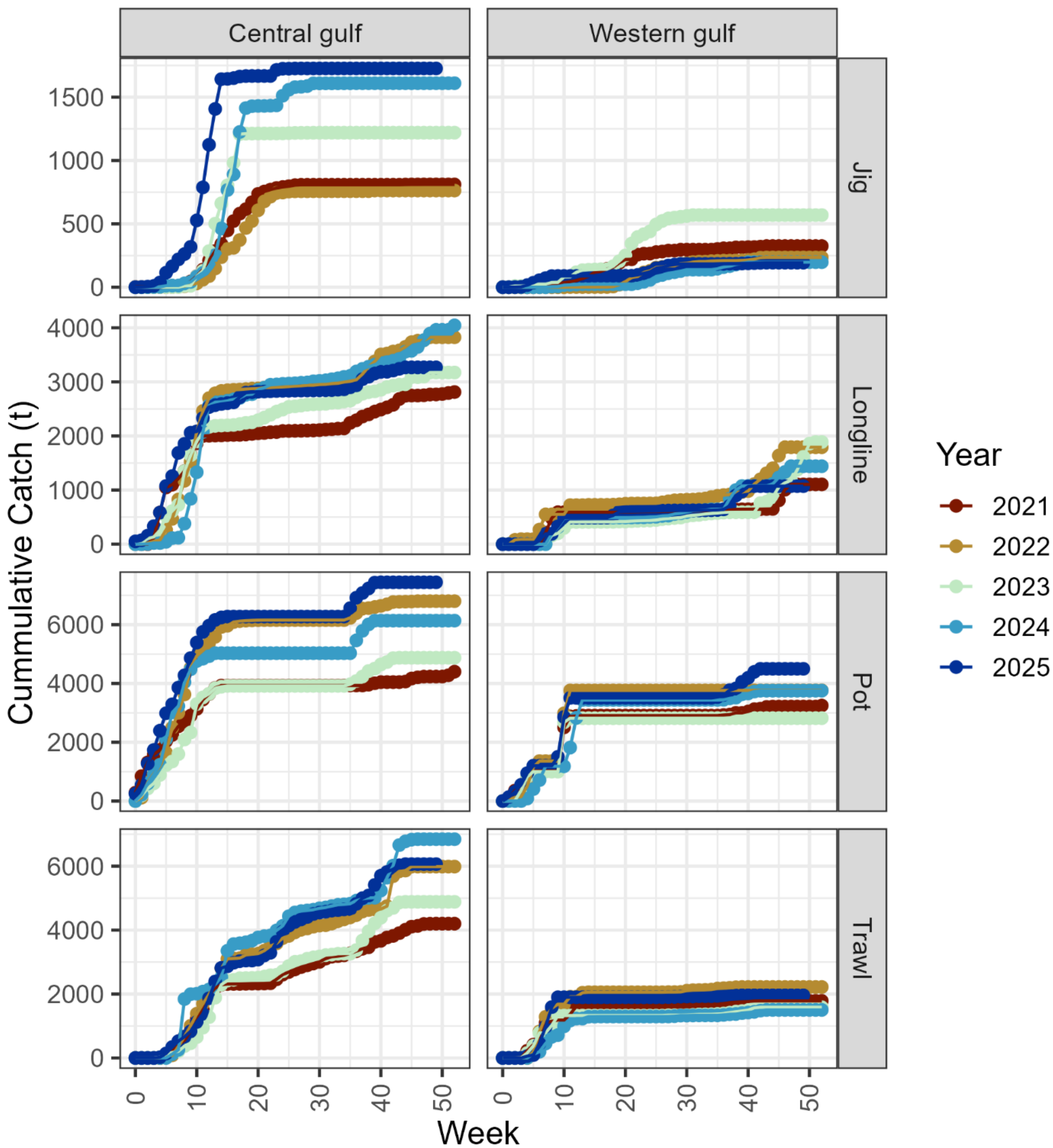

Figure 2.3. Cumulative catch week of the year for 2021-2025 by GOA sub-area and fleet (2025 catch through December 8). Note that for the assessment, data from the jig and longline gear were pooled into a distinct fishery.

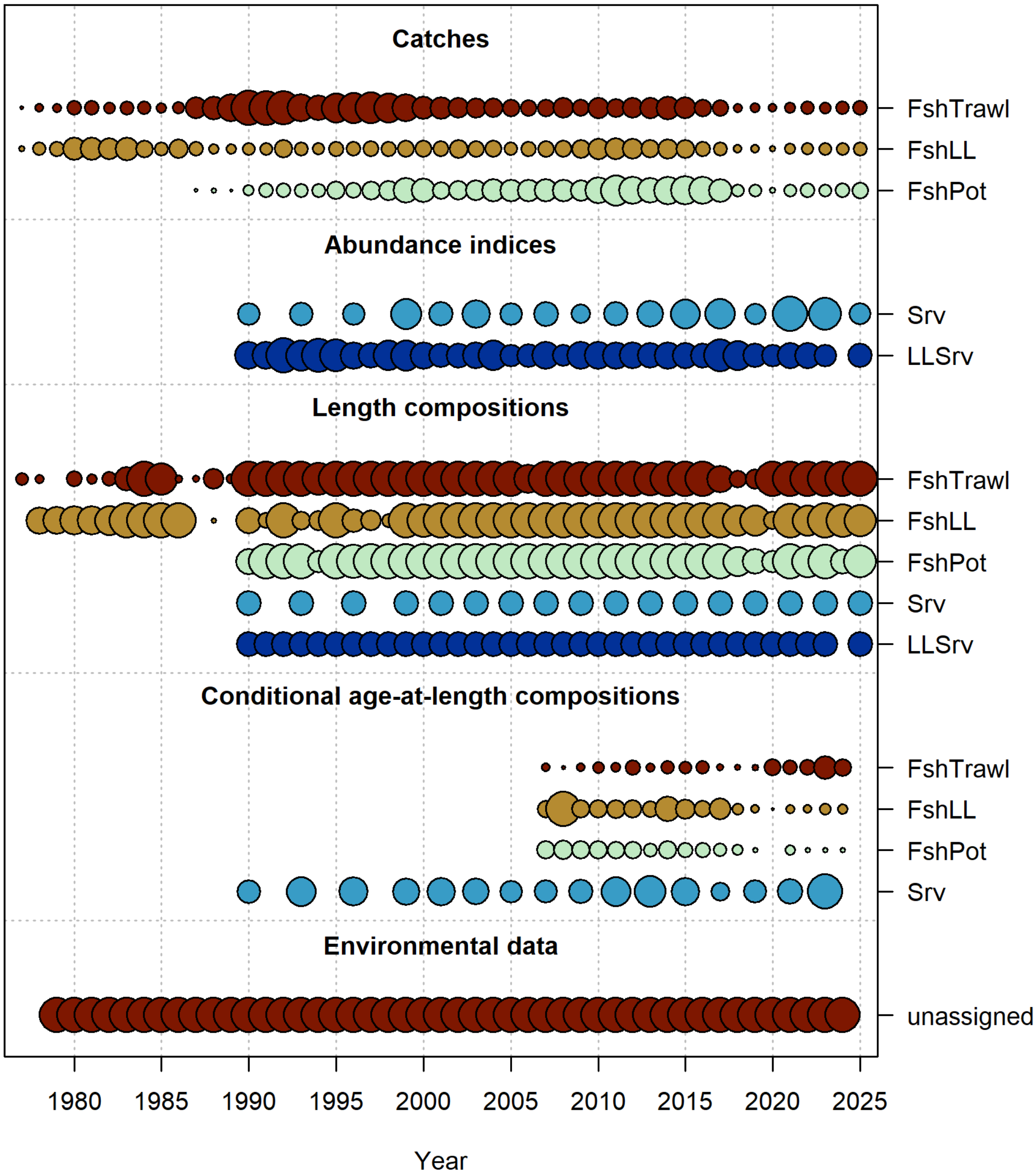

Figure 2.4. Data fit in Model 24.0. Circles are proportional to total catch for catches, precision for indices and input sample size for compositions and length-at-age observations. Data sources include fishery data from trawl (FshTrawl), longline (FshLL), and pot (FshPot) fisheries. Survey data include the AFSC longline (LLSrv) and bottom trawl (Srv) surveys. Note that since the circles are scaled relative to maximum within each type, the plots of scaling across dataset types should not be compared.

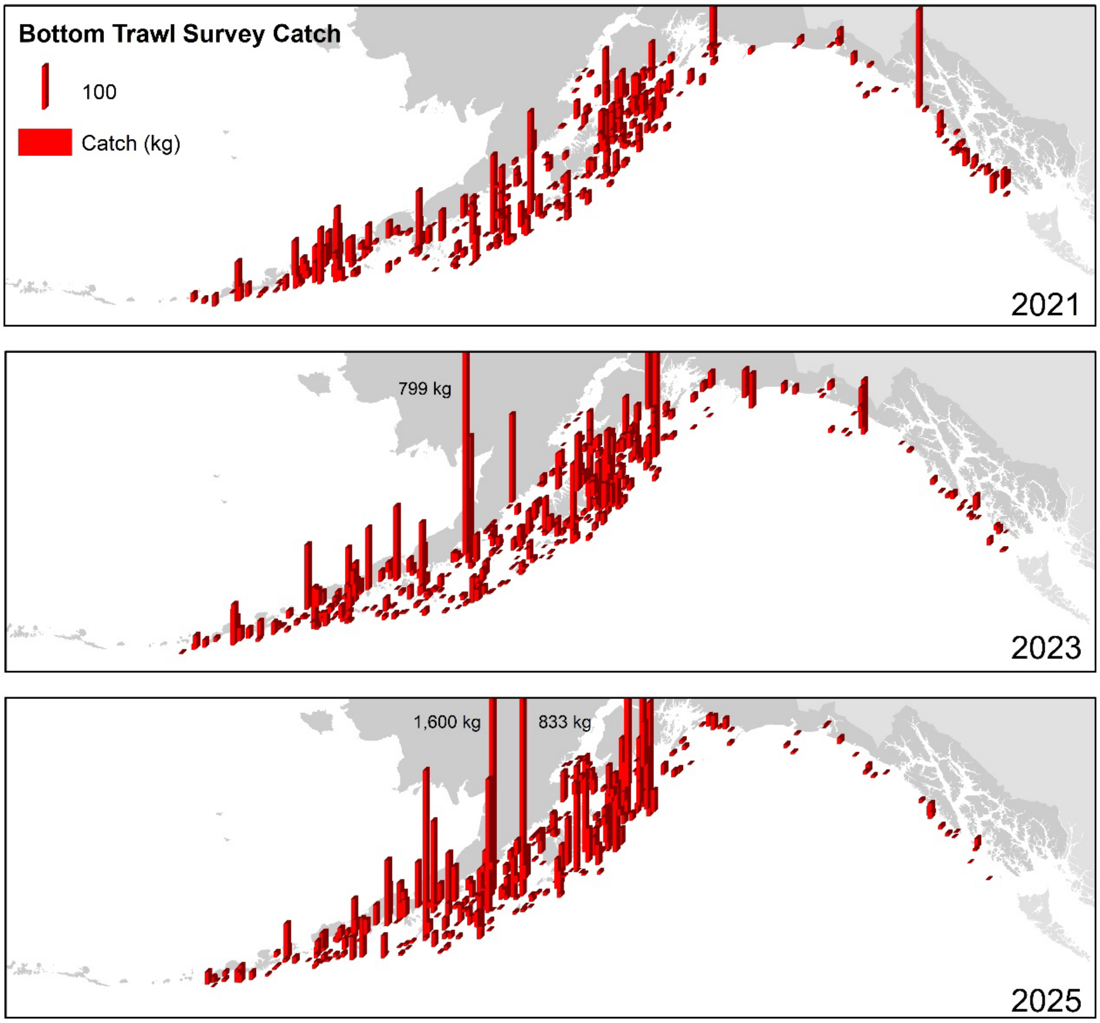

Figure 2.15. Distribution of AFSC bottom trawl survey catch (kg) of Pacific cod for 2021-2025.

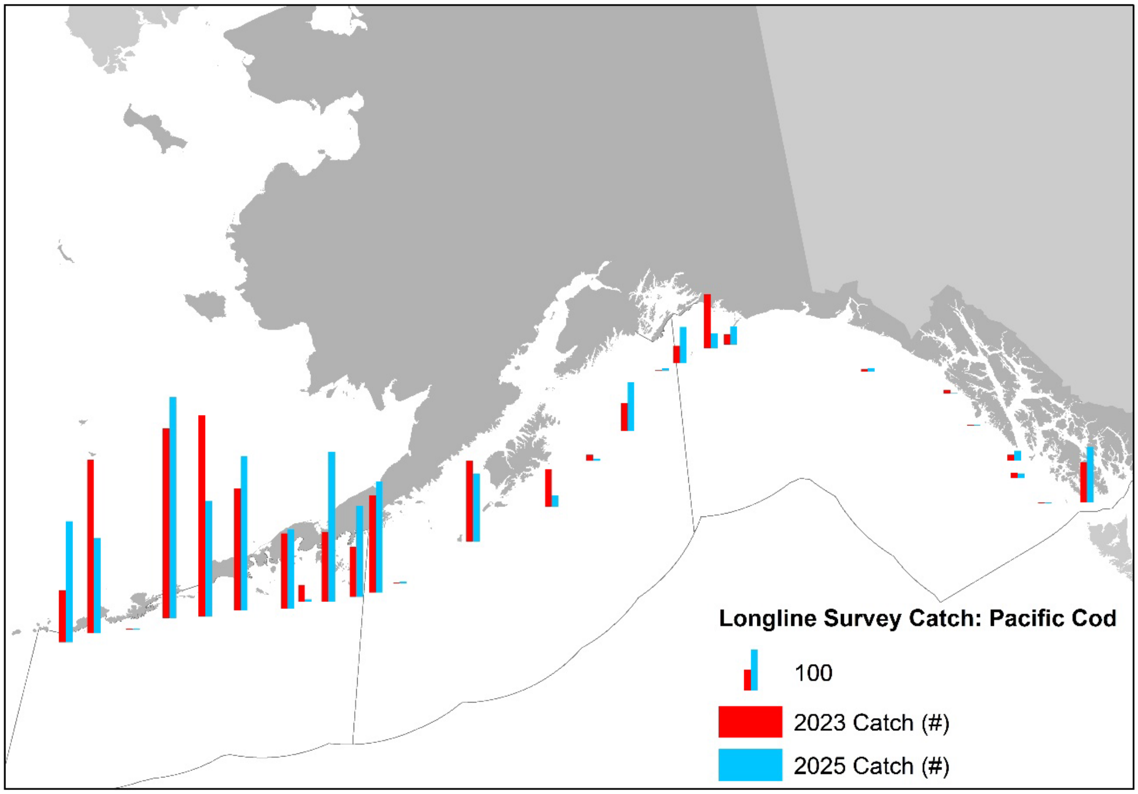

Figure 2.6. Distribution of AFSC longline survey catch (numbers) of Pacific cod in 2023 and 2025.

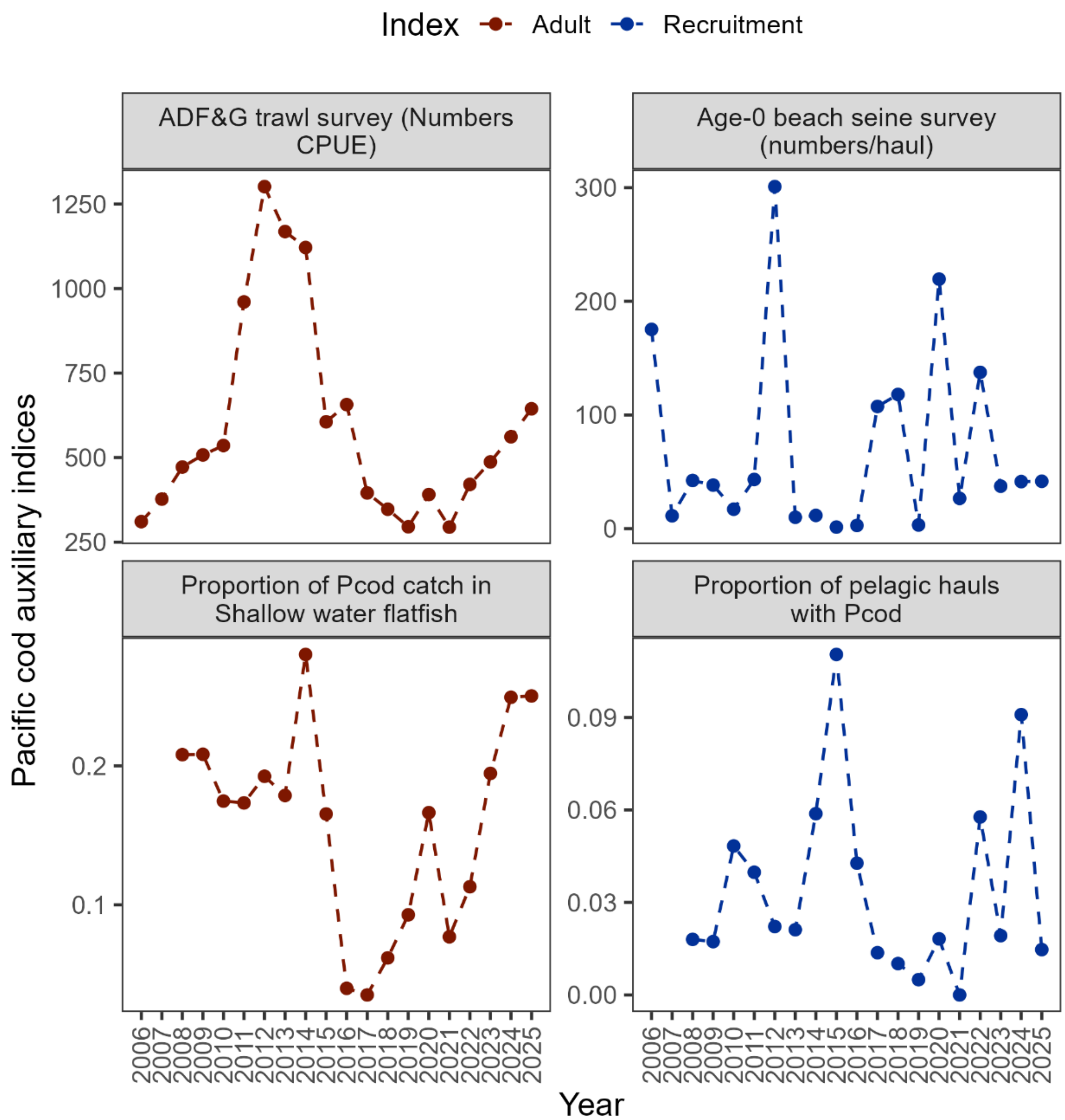

Figure 2.7. Auxiliary indices for GOA Pacific cod adult and recruitment abundance that are not used in the stock assessment model. ADFG bottom trawl survey numbers catch-per-unit-effort (top left panel) and proportion of Pacific cod bycatch in the GOA shallow water flatfish fishery (bottom left panel) representing indices for adult abundance, and age-0 beach seine survey numbers per haul (top right panel) and proportion of pelagic trawls in the Central GOA A Season (January-April) walleye pollock fishery with Pacific cod present (bottom right panel) representing indices for recruitment.

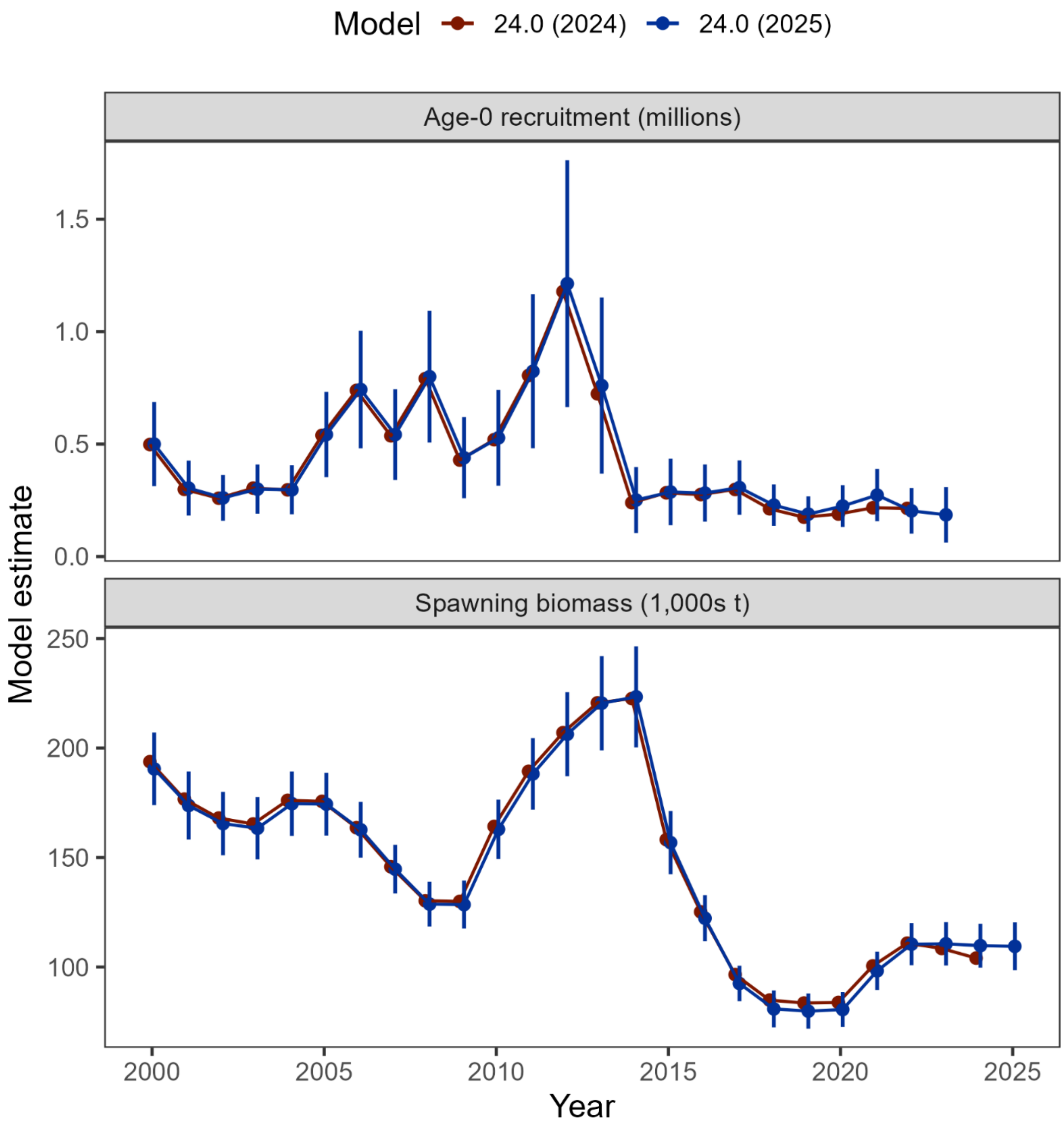

Figure 2.8. Comparison of post-2000 recruitment and spawning biomass estimated from Model 24.0 as applied in 2024 and with updated data in 2025 (including 95% confidence intervals).

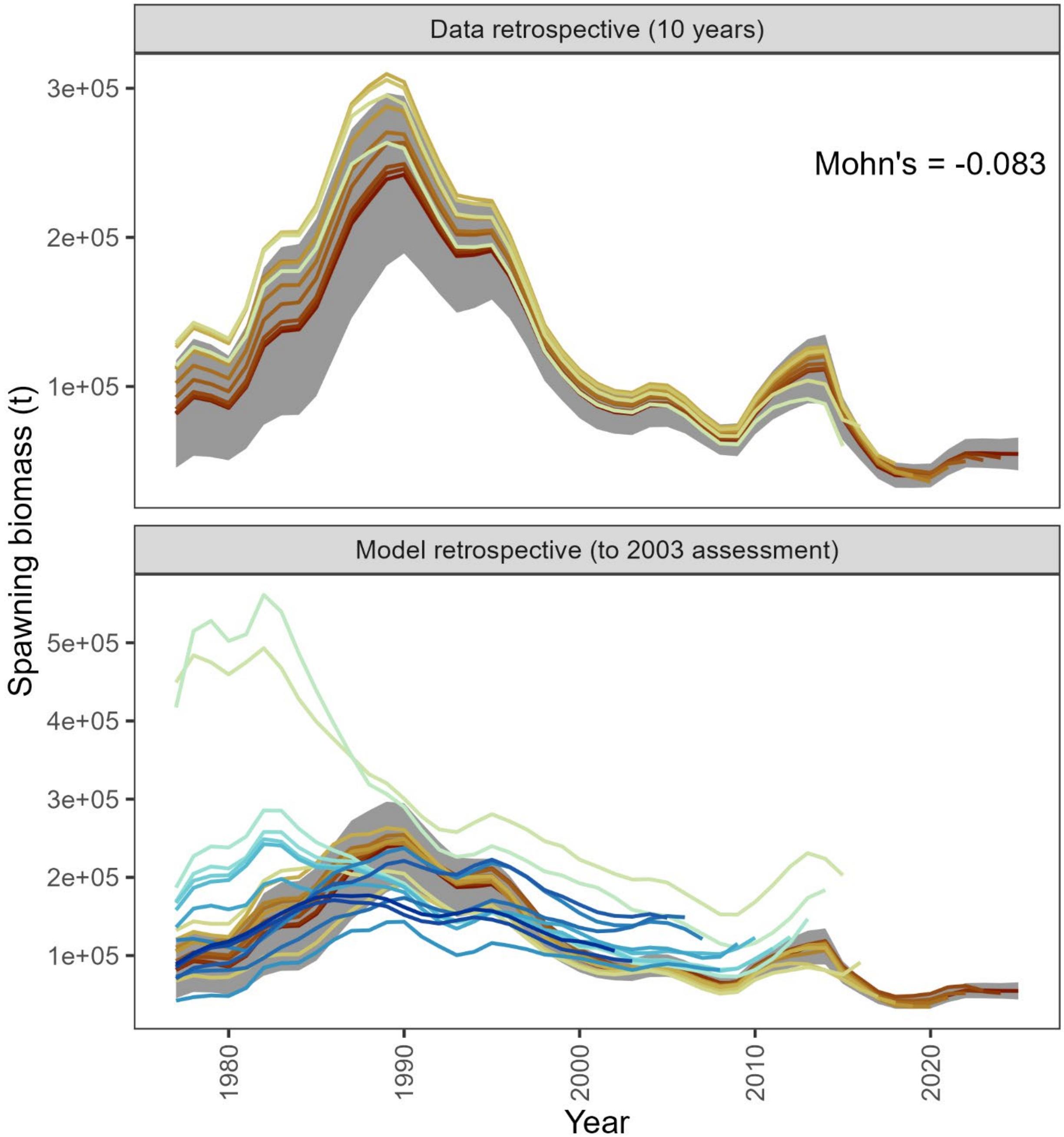

Figure 2.9. Retrospective analysis of spawning biomass upon removing data from Model 24.0 as applied in 2025 (top panel) and in comparison to previously accepted models (bottom panel). The shaded region is the 95% confidence intervals from Model 24.0.

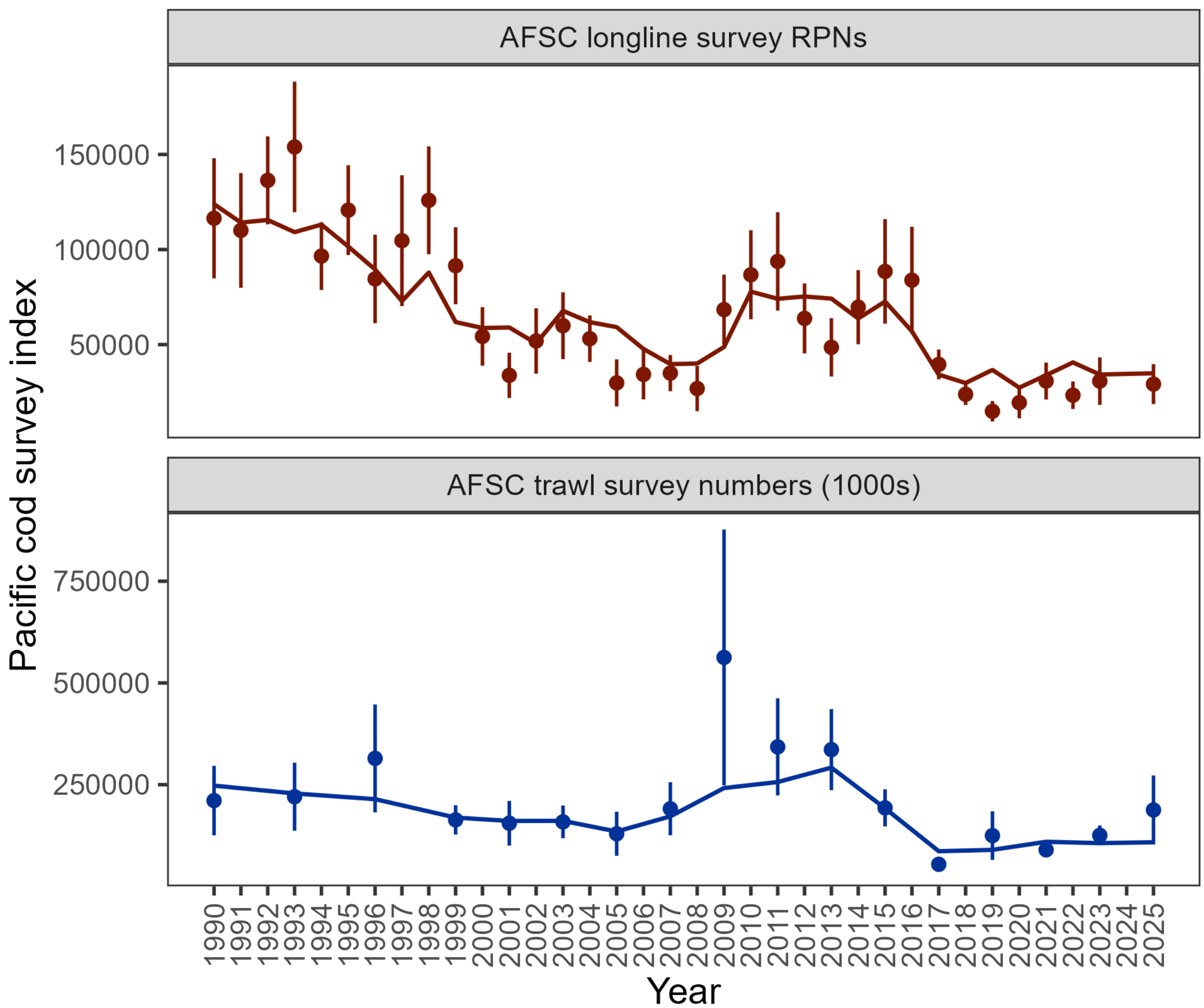

Figure 2.10. Population indices fit by the assessment model, including AFSC longline survey relative population numbers (RPN – top panel) and AFSC bottom trawl survey abundance (numbers – bottom panel). Model fit is shown as a solid line and observed data is shown as points (with error bars indicating the 95% confidence intervals).

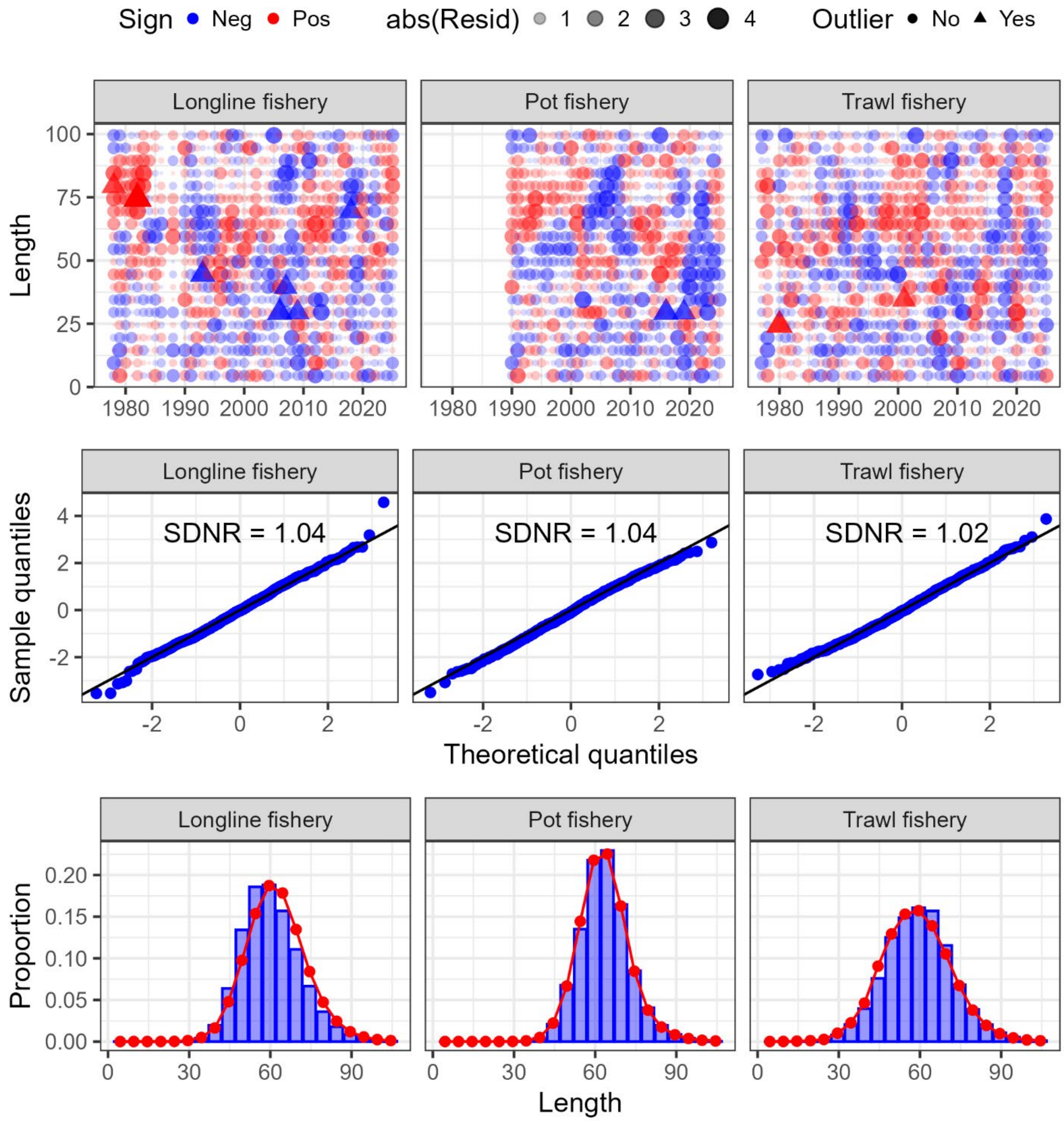

Figure 2.11. One-step ahead residuals (top panels), theoretical versus sample quantiles (middle panels), and aggregated model fit (bottom panels) for the fishery length composition data (fleets shown across the columns) fit in the author's recommended model.

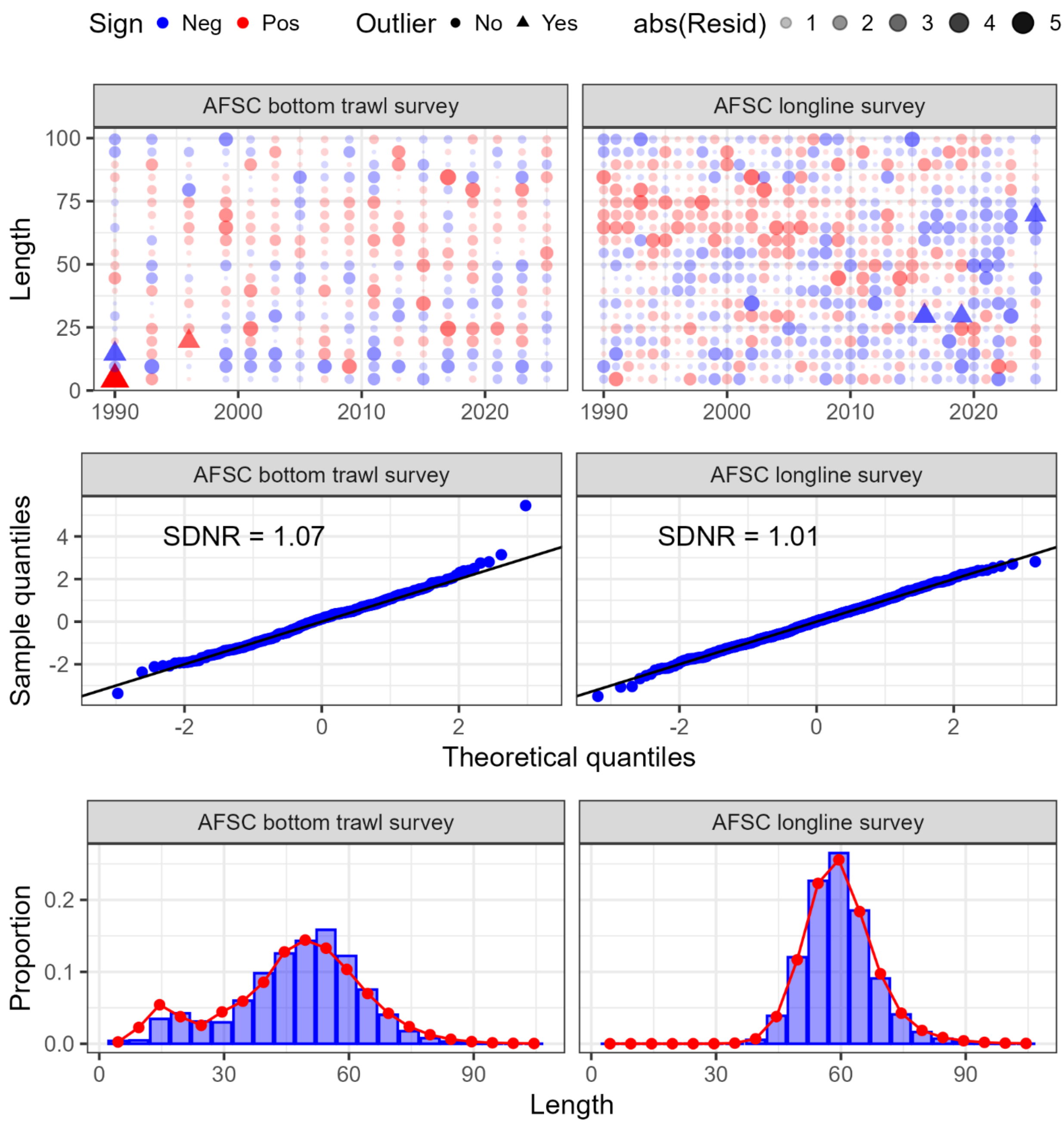

Figure 2.12. One-step ahead residuals (top panels), theoretical versus sample quantiles (middle panels), and aggregated model fit (bottom panels) for the survey length composition data (surveys shown across the columns) fit in the author's recommended model.

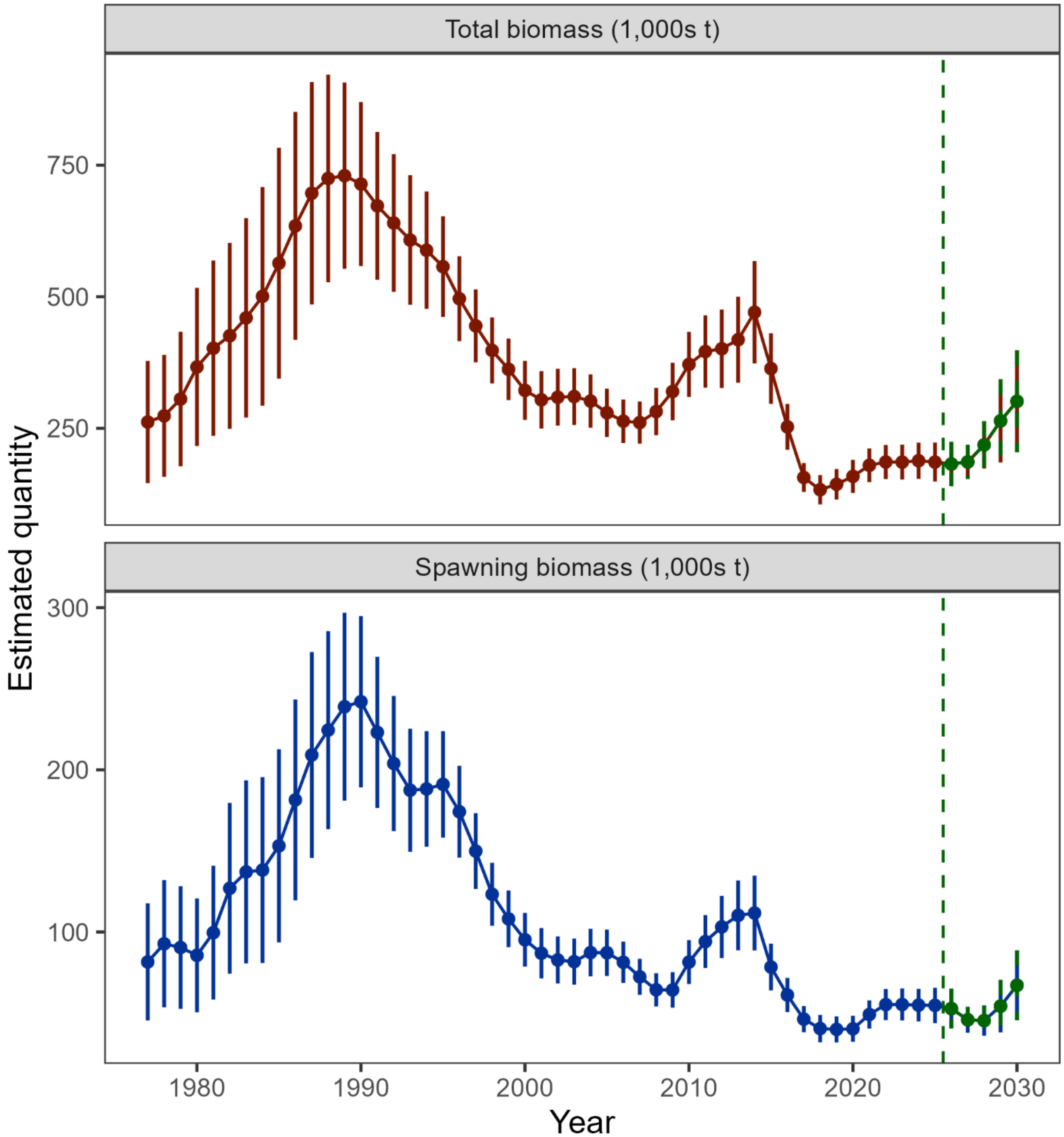

Figure 2.13. Estimated total biomass (top panel) and spawning biomass (bottom panel) from the author's recommended model with 95% confidence intervals. The five-year forecasted biomass values are denoted in green shading and with the vertical dashed line in each plot.

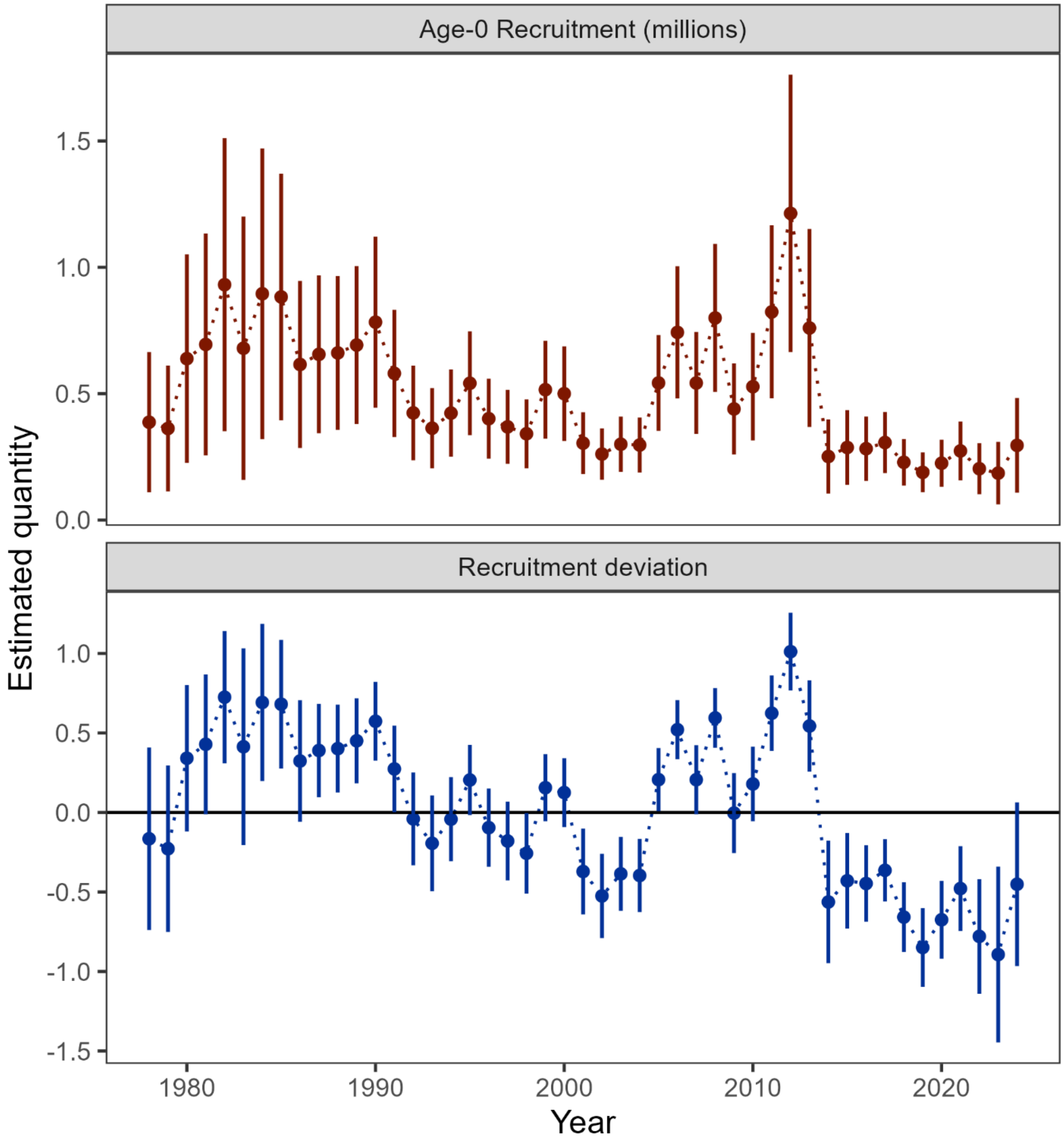

Figure 2.14. Age-0 recruitment (top panel) and log recruitment deviations (bottom panel) with 95% confidence intervals from the author's recommended model.

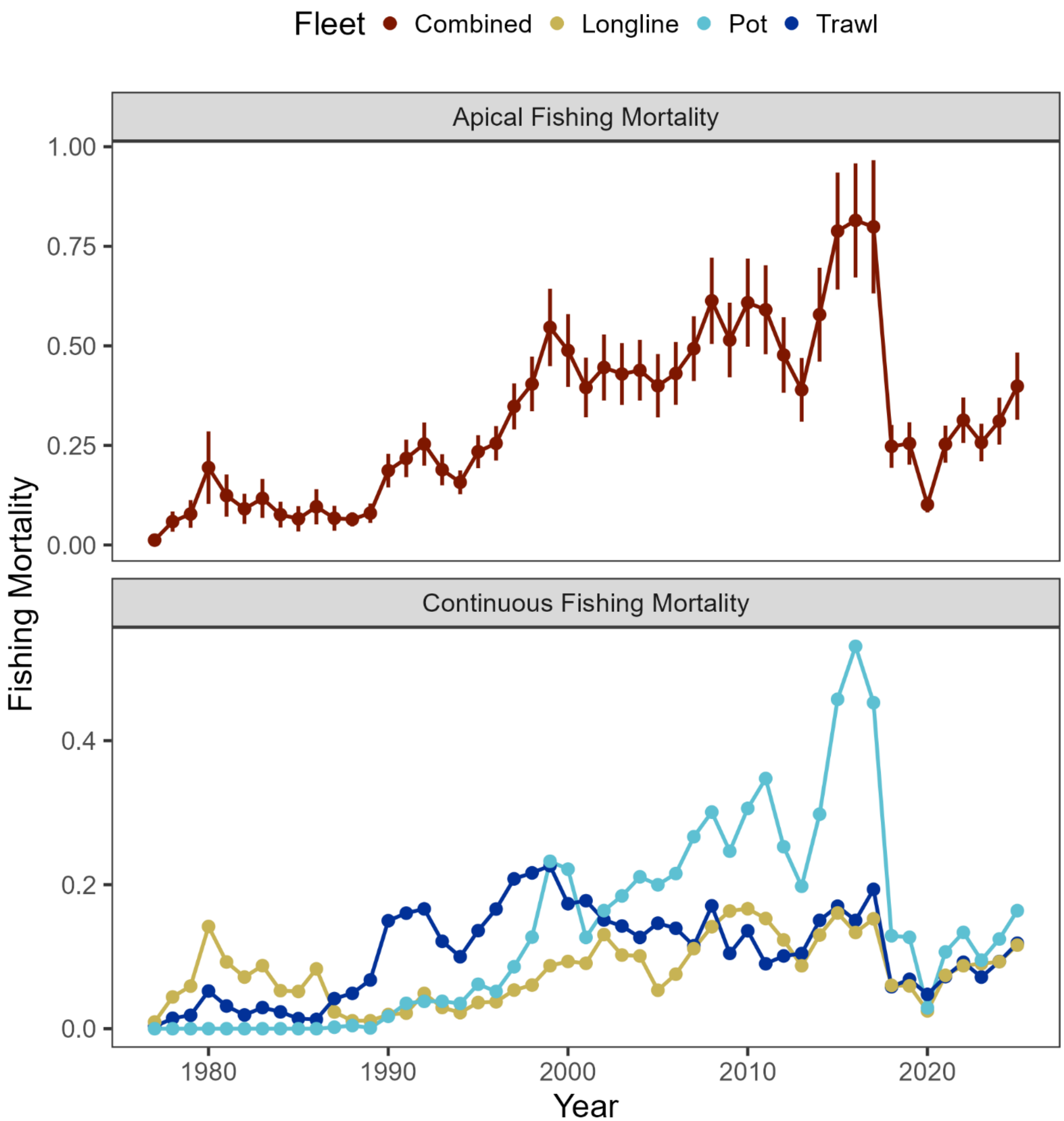

Figure 2.15. Sum of apical fishing mortality (top) and continuos fishing mortality by fisheries (bottom).

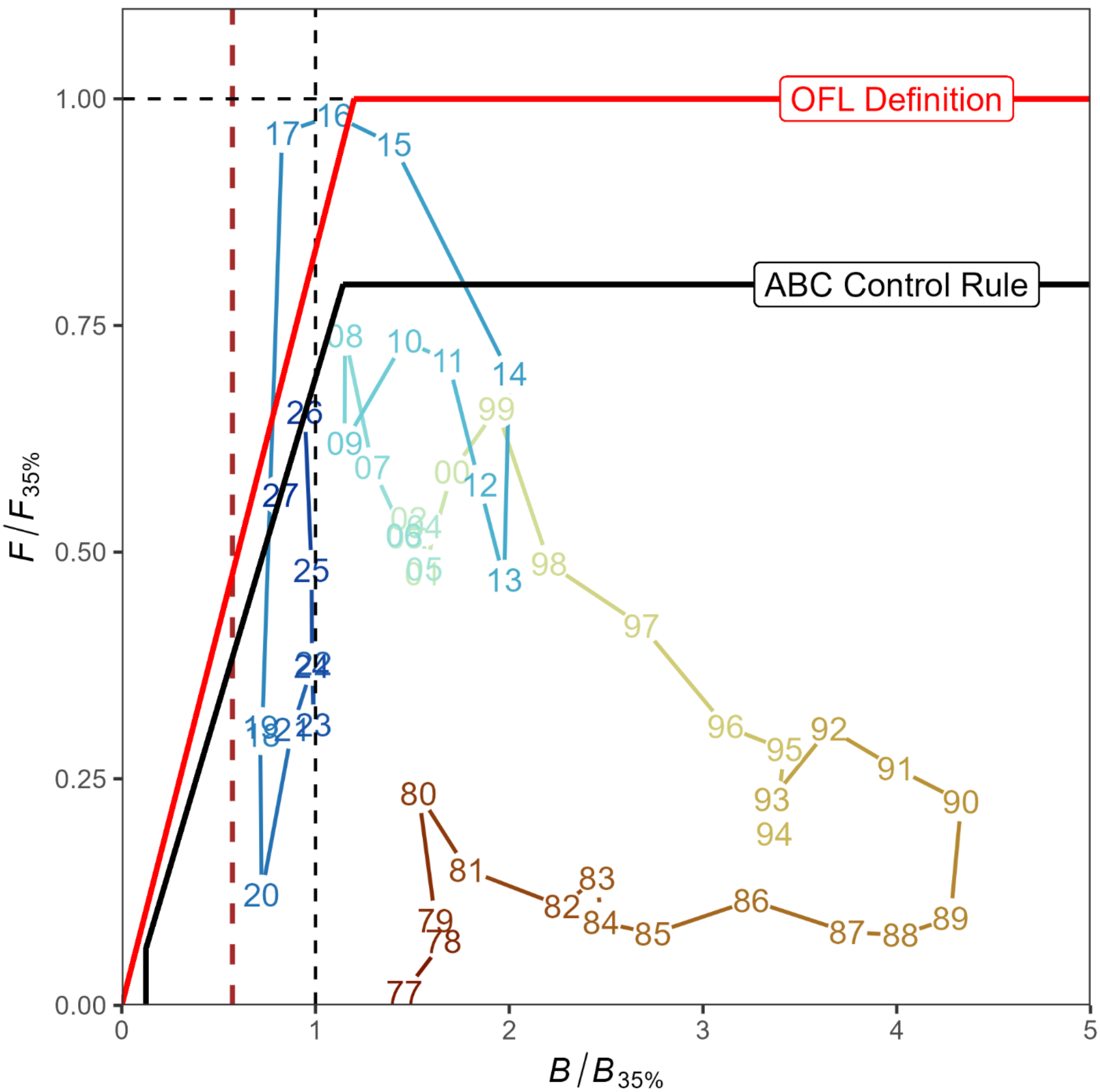

Figure 2.16. Ratio of historical $F/F_{35\%}$ versus female spawning biomass relative to $B_{35\%}$ for GOA pacific cod, 1977-2027. The Fs presented are the sum of the full Fs across fleets. Dashed vertical red line is at $B_{20\%}$, Steller sea lion closure rule for GOA Pacific cod.

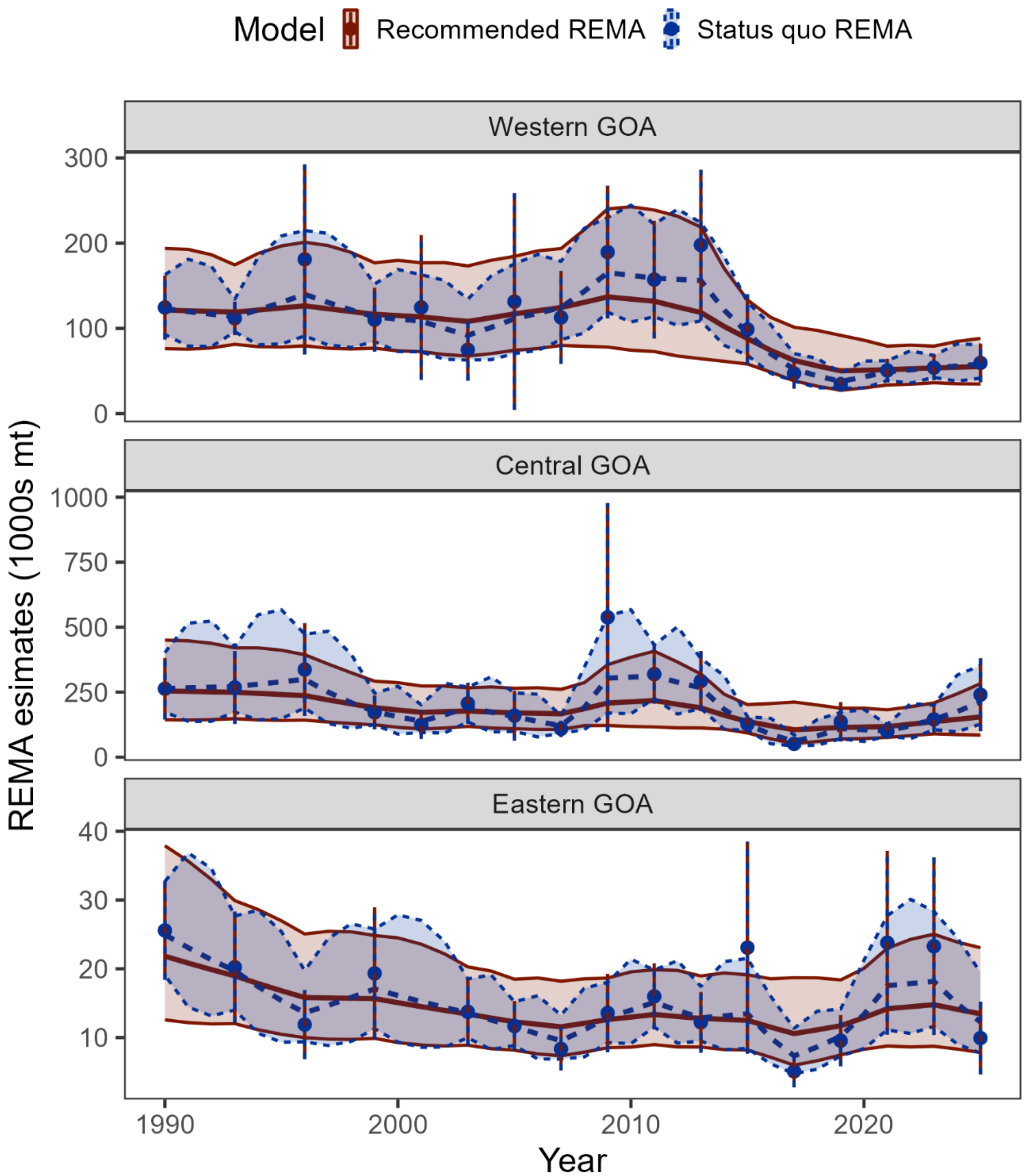

Figure 2.17. Recommended and status quo REMA results as fit to the AFSC bottom trawl survey by area.

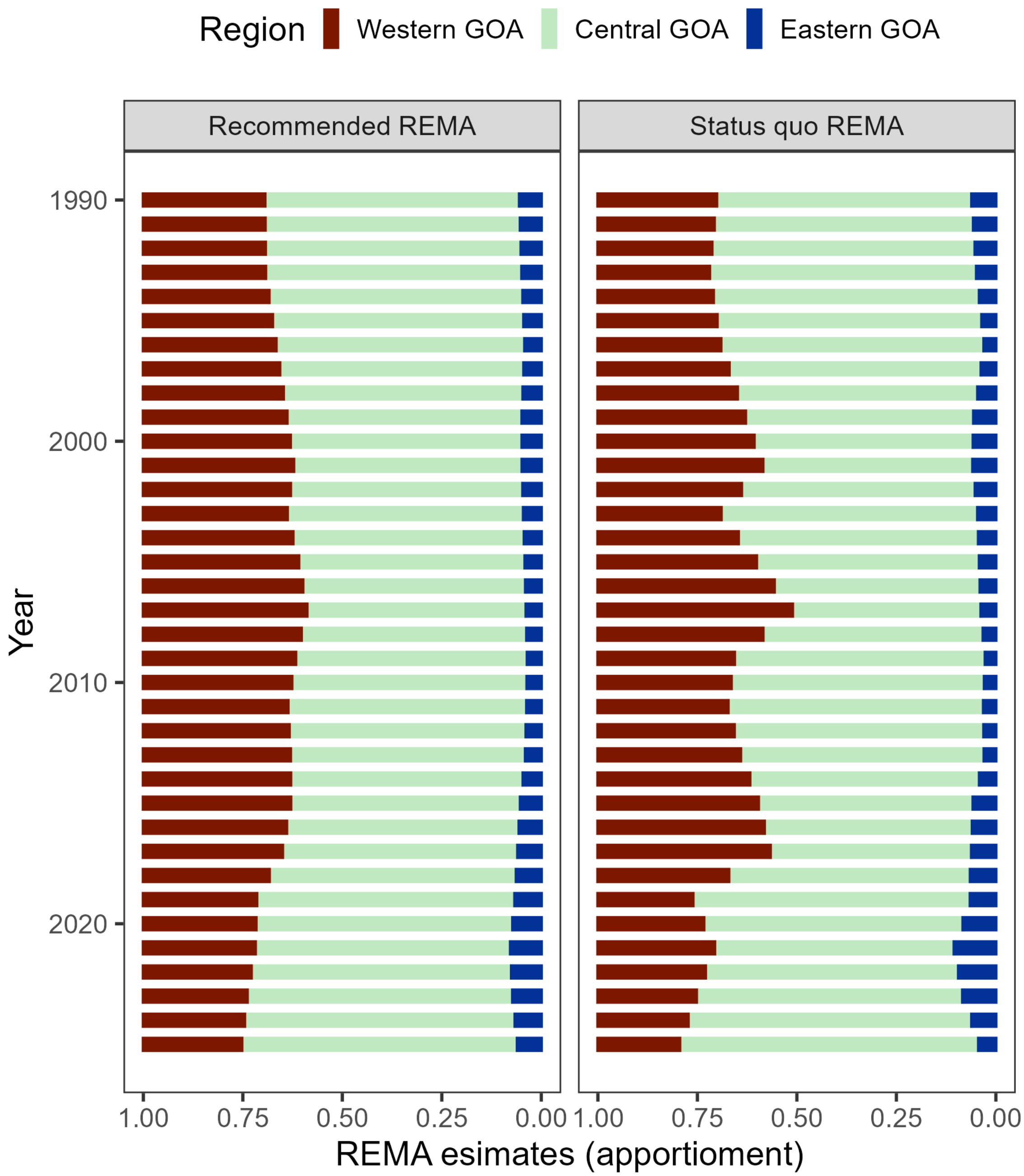

Figure 2.18. Recommended and status quo REMA apportionment results.

Appendix 2.1 Ecosystem and Socioeconomic Profile of the Pacific cod stock in the Gulf of Alaska - Report Card

The ESP can be found at this link.

Appendix 2.2 Analysis of the Gulf of Alaska Bottom Trawl survey restratification for Pacific cod

Pete Hulson, Zack Oyafuso, and Stan Kotwicki

Executive Summary

In 2025, the Alaska Fisheries Science Center's (AFSC) Gulf of Alaska (GOA) bottom trawl survey transitioned to a new stratified random design. The survey design from 1990-2023 consisted of 59 strata defined by INPFC management area, depth, and general habitat type (shelf, gully, and slope). The development of a new survey design started in 2019 and has undergone extensive simulation evaluation (Oyafuso et al. 2021, 2022) and review by management bodies (e.g., NPFMC Groundfish Plan Team and SSC) prior to implementation in 2025. This new survey design was implemented to increase sampling efficiency while maintaining unbiased estimates of population indices and composition data that are used within stock assessments conducted by the AFSC. The new survey design now consists of 28 strata defined by NMFS management area and depth.

In this appendix we compared the historical bottom trawl survey's time-series of design-based estimates of biomass and abundance to what the estimates could have been had historical stations been post-stratified under the new survey design. We use GOA Pacific cod as an example species because it is well sampled and consistently distributed across the continental shelf of the GOA. We find that the historical indices of biomass and abundance are remarkably similar when post-stratified under the new survey design. We conclude that the new survey design of the GOA bottom trawl survey provides consistent estimates with the historical time-series of important indices in both magnitude and trend. Furthermore, the 2025 estimates of biomass and abundance for Pacific cod under the new survey design follow and continue the recent trends observed in the population. We emphasize that the new survey design maintains a robust time-series of indices provided by the GOA bottom trawl survey that are based upon unbiased sampling designs and provide our best information available to understand population trends for stocks assessed within the GOA.

Data

Data used in this analysis included historical haul-level area-swept CPUE (in kg per km^2 for biomass estimation and in numbers per km^2 for abundance estimation) from the AFSC GOA bottom trawl survey. The time-series of the surveys investigated were triennially from 1990-1999, then biennially from 2001-2023.

Analytic Approach

To assess how the restratified survey design might have impacted historical biomass and abundance indices for GOA Pacific cod, we employed a two-step reanalysis. First, historical hauls were spatially reassigned to the strata under the new survey design. Second, we utilized the "survey" R package (Lumley 2024) to re-calculate total survey biomass/abundance and associated variances using post-stratified weights to correctly account for differences in stratum inclusion probabilities of the post-stratified stations. We recalculated total survey biomass and abundance across the GOA-wide region as well as GOA management subregions (Western, Central, and Eastern GOA).

Results

Reanalysis of the historical GOA bottom trawl survey time-series reveals high consistency between the original time-series and the original time-series post-stratified under the new design (Figures 2.2.1 and 2.2.2). GOA-wide biomass and abundance estimates (Figure 2.2.1) align most closely during periods of lower magnitude (e.g., 1990–2007 and 2015–2023), with minor divergence occurring during peak years (2009–2013), though given the high overlap in the 95% confidence intervals, these divergences do not appear to be statistically meaningful. Comparison of the coefficients of variation results in a mean increase of 0.6% in biomass and 1.4% in numbers after post-stratifying under the new design compared to the original time-series. Since 2015, the two time-series have been nearly indistinguishable. The 2025 indices under the new design continue the established historical trends in both magnitude and direction.

The consistencies between the two time-series also persist at the subregional scale (Figure 2.2.2). With the exception of some slight divergences in the point estimates in the Western GOA (1996, 2009), Central GOA (2009) and the Eastern GOA (1990, 2015), the subregional indices were also very similar between the original and post-stratified time series. Furthermore, in the cases of these years with slight divergences, the high overlap in their 95% confidence intervals suggest these differences are not statistically meaningful. The 2025 Eastern GOA index, while lower than recent years, remains within the historical range of biomass estimates in this subregion.

The remarkable consistency observed in well-sampled stocks like Pacific cod demonstrates that the new design continues an unbiased design for the GOA bottom trawl survey and is functioning as intended. Mismatches between the original and post-stratified estimators are to be expected given the random nature of the sampling process. For species with inherently patchy distributions (e.g., rockfish), no stratification design can fully overcome inherent sampling variability that then translates through to survey indices. Furthermore, for such species, within a reanalysis of historical survey data like undertaken for Pacific cod it is statistically impossible to disentangle the effects of the restratified survey design from the natural variability and "zero-heavy" skewed catch data associated with their distributions.

Literature Cited

Lumley, T.. 2024. "survey: analysis of complex survey samples." R package version 4.4.

Oyafuso, Z. S., L. A. K. Barnett, and S. Kotwicki. 2021. Incorporating spatiotemporal variability in multispecies survey design optimization addresses trade-offs in uncertainty. ICES Journal of Marine Science 78, 1288–1300.

Oyafuso, Z., L. A. K. Barnett, M. Siple, and S. Kotwicki. 2022. A flexible approach to optimizing the Gulf of Alaska groundfish bottom trawl survey design for abundance estimation. NOAA technical memorandum NMFS-AFSC ; 434.

Figures

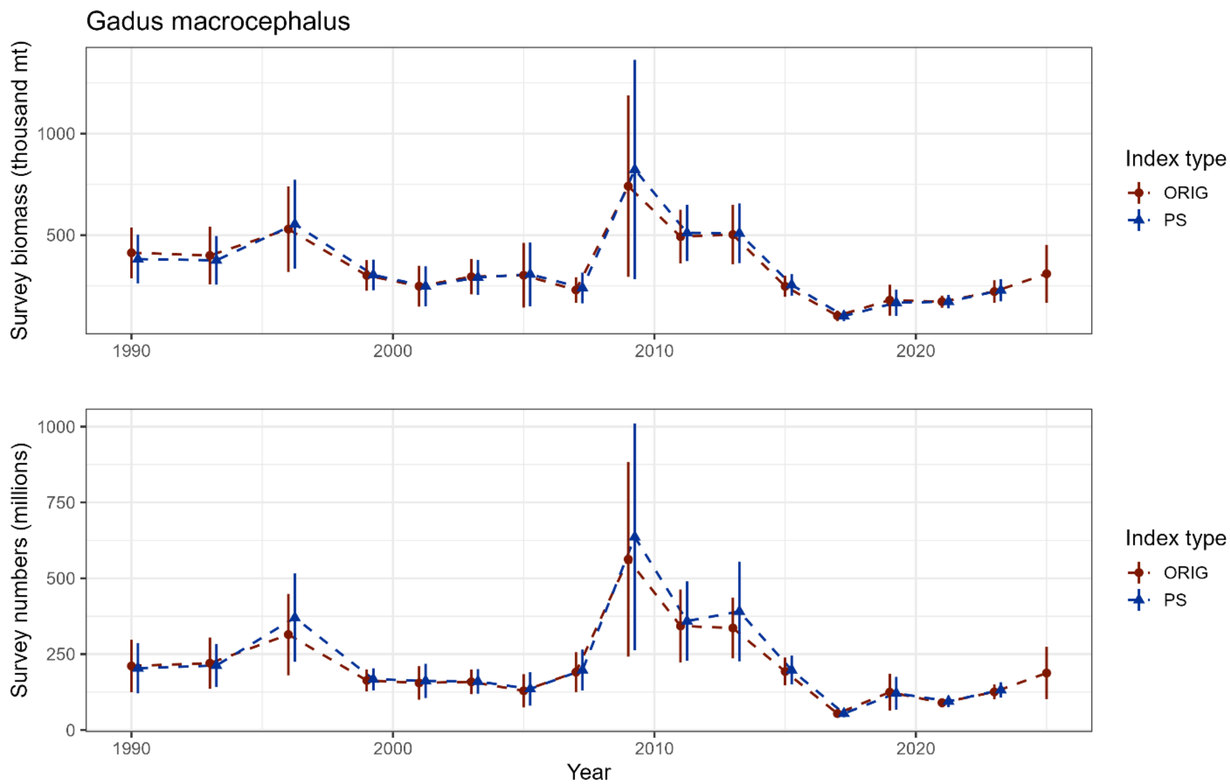

Figure 2.2.1. GOA bottom trawl survey population indices for Pacific cod from the original design-based estimates (ORIG) and the reanalyzed design-based estimates (PS) under the new survey design.

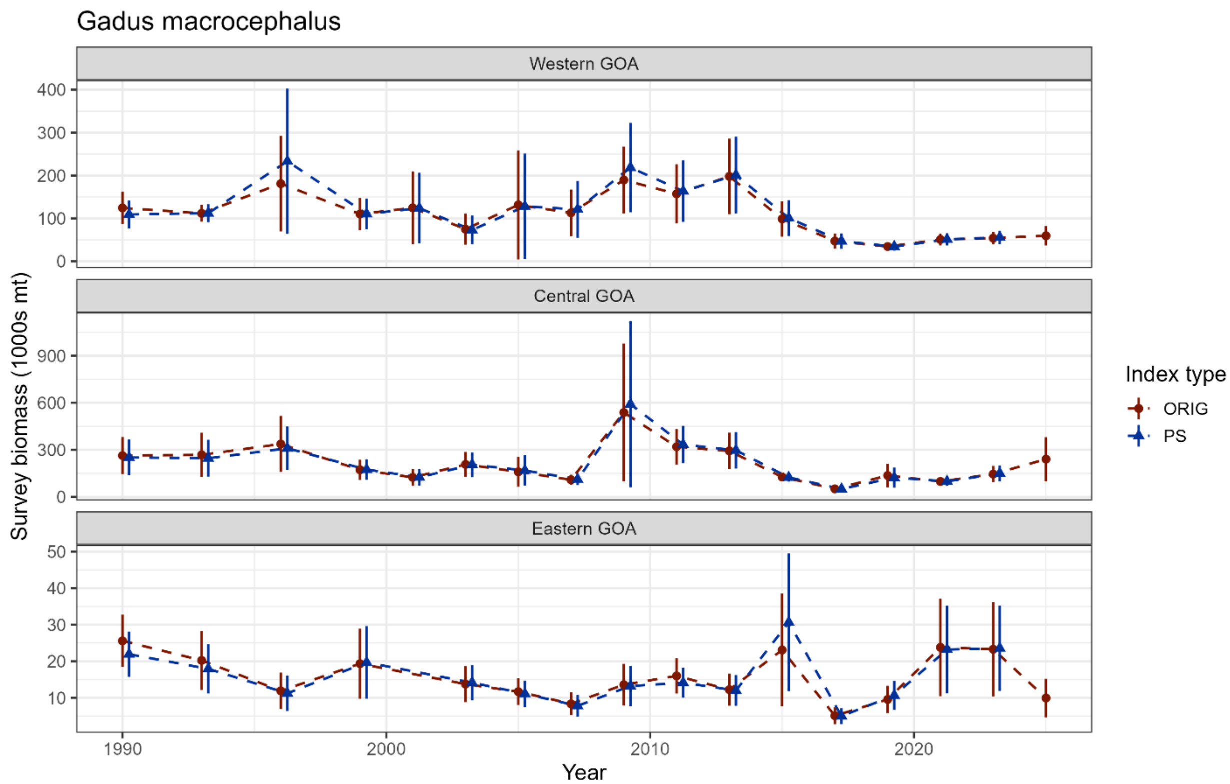

Figure 2.2.2. GOA subregion bottom trawl survey biomass indices for Pacific cod from the original design-based estimates (ORIG) and the reanalyzed design-based estimates (PS) under the new survey design.