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Assessment of the Pacific cod stock in the Aleutian Islands

Ingrid Spies, Maurice Goodman, Steve Barbeaux, Melissa Haltuch, Pete Hulson, Ivonne Ortiz

November 16, 2026

SSC and Plan Team comments

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Selected SSC and Plan Team comments

SSC :

Mortality block 2016-2024 accounted for warming temperatures, improved model fit and retrospective pattern.

However, consistently increased the recruitment estimates for this period, contrary to hypothesized effects on temperature on Pacific cod stock dynamics.

Raises a concern that there may be some other process affecting stock dynamics rather than changes in natural mortality.

Other processes that should be explored include a step change in recruitment or temperature-dependent catchability for the trawl survey. The SSC recommends the authors continue to consider alternative mechanisms for the poor fit to the trawl survey biomass.

Response:

We have evaluated a step change in recruitment, temperature-dependent catchability, as well as multiple other mechanisms, which are presented in an appendix to the assessment.

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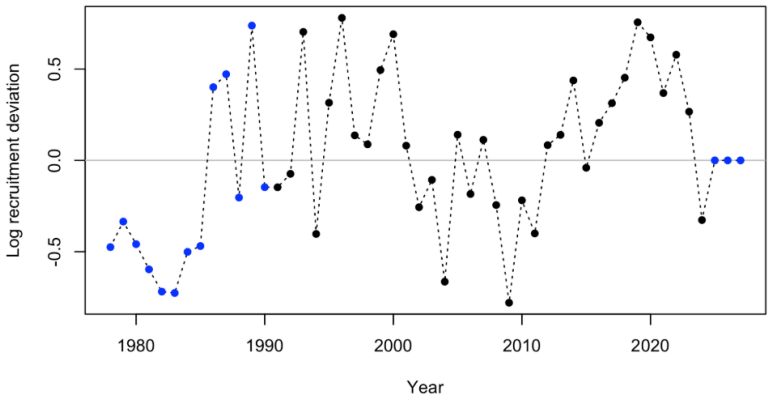
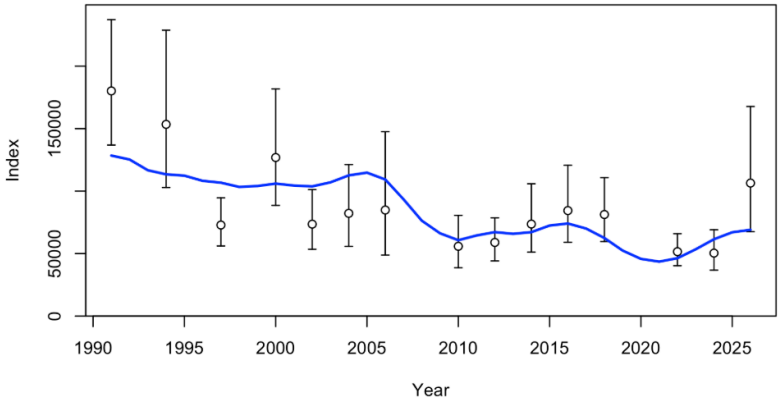
Recruitment deviations



Fit to survey index



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Models explored (Appendix), to be presented September 2027 *Maurice Goodman*

1. Recruitment Scaling and Block Configurations

- Fixed R_0 Unfished recruitment, $(\ln(R_0))$, was fixed to the value estimated by the no-block model (11.0502). This configuration prevented the model from artificially scaling baseline recruitment upward to offset increased natural mortality during the heatwave period.
- R_0 Block (2016 – 2024): A separate $(\ln(R_0))$ parameter was estimated specifically for the heatwave block. This allows the model to differentiate baseline recruitment from heatwave-era recruitment. Under this structure, forecast projections utilize the baseline R_0, closely aligning the projections with the standard no-block model.
- R_0 Block (2010 – 2024): The start of the recruitment block was moved four years earlier to encompass a period of elevated recruitment observed in the base model. This change captured cohorts entering adulthood during the heatwave. Because recruitment deviations appear consistently high throughout this decade, broadening the block duration could reduce their leverage on the long-term baseline R_0 . This configuration required defining a new time-block pattern.

2. Recruitment Deviation Constraints

- recdev1: Applied a strict sum-to-zero constraint on recruitment deviations.
- recdev4: Implemented a penalty on the sum of squared deviations to minimize overall recruitment variability.

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Models explored (Appendix), to be presented September 2027 *Maurice Goodman*

3. Environmentally Forced Sensitivity Models

The following model suites evaluated environmental covariates as direct drivers of either natural mortality (M) or recruitment (R) deviations, utilizing alternative temperature datasets:

- M_heatwave_sfc: Natural mortality forced by sea surface temperature anomalies.
- M_heatwave_btm: Natural mortality forced by bottom temperature anomalies.
- rec_heatwave_sfc: Recruitment deviations forced by sea surface temperature anomalies.
- rec_heatwave_btm: Recruitment deviations forced by bottom temperature anomalies.

4. Examine temperature-dependent catchability for the trawl survey.

- We examined whether linking catchability to MHW index would improve the fit to the data and reduce the inflation of recent recruitment.

5. Excess mortality as a fleet. Mortality due to heatwave modeled as a 'pseudo-fleet'.

*Marine heatwave indices: for sea surface and bottom temperature (<500m). Annual Indices represent the proportion of 5 or more consecutive days above the selected upper quantile of daily temperatures (used 90% and 95%).

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Selected SSC and Plan Team comments

SSC :

- Evaluate models where the upper and lower CV for length at age are estimated rather than fixed in the model. The availability of conditional age at length data should enable these parameters to be estimated and fixed parameters introduce undesirable rigidity into the model estimation process. If not estimated, provide a basis for the fixed values used.

Response:

The model configures the upper and lower CV as estimated values, which are informed by conditional age-at-length (SS3 Manual 8.5.2.5):

- Growth Model Selection: The model uses a Richards growth curve (GrowthModel = 2).
- Reference Ages: The first reference age L_1 is set to age 1, with linear growth assumed below this age. The second reference age L_2 is set to 999 to represent asymptotic length.
- Plus-Group Growth: The model disables growth changes within the plus-group in the initial year and omits time-varying shifts in the plus-group mean size (-998).
- CV Growth Pattern: Growth variability is defined using the CV_Growth_Pattern = 0 option. This specifies that CV is a function of length-at-age CV=f(LAA). No additional standard deviation is added to the length-at-age relationship (SD_add_to_LAA = 0).

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Data

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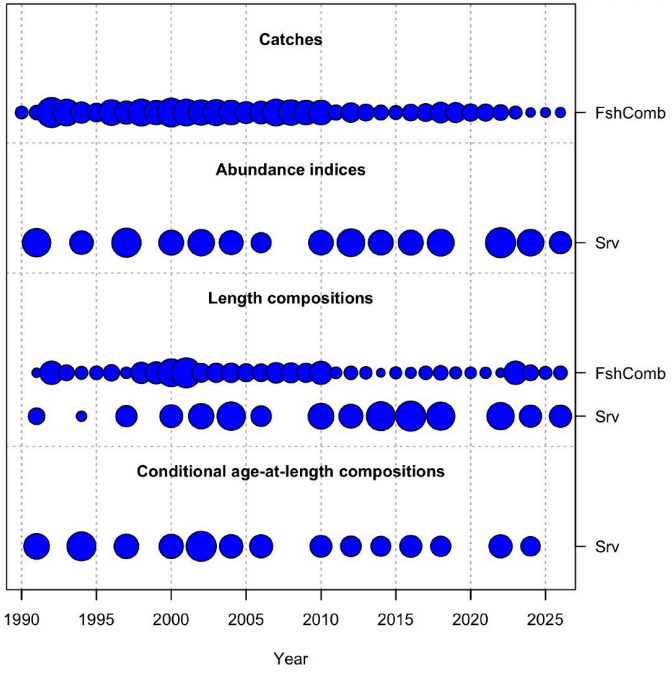
Age structured models - Data sources and relative weight

Data Source	Years
Survey index	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018, 2022, 2024, 2026
Fishery length composition	1991 – 2026
Survey length composition	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018, 2022, 2024, 2026
Conditional age-at-length compositions	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018, 2022, 2024



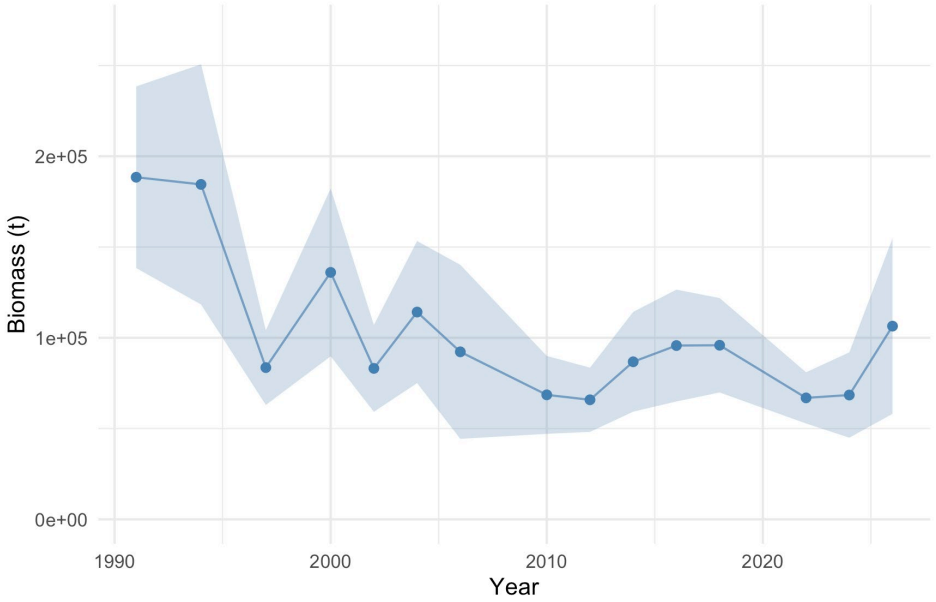
New:

- Catch: Complete data for 2025, 2026*.
- Fishery size compositions: Complete for 2025, 2026*.
- Ages: 2024.
- Survey: New survey index, standard error, and length composition data for 2026.

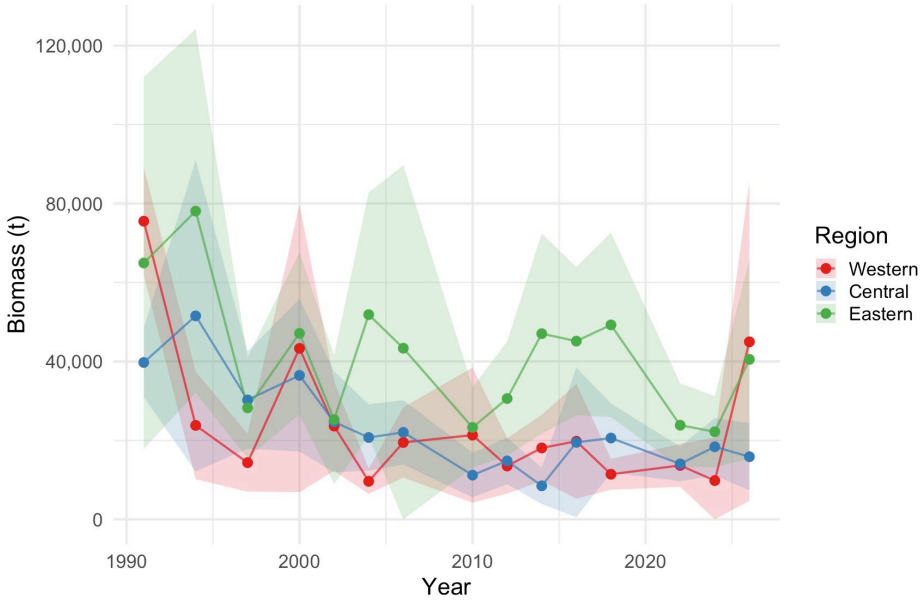
*Data current through October 1, 2026

Aleutian Islands Pacific cod survey biomass 1991 – 2026, with 95% confidence intervals.

AI survey biomass (total)



AI survey biomass (by area)



Survey Indices

- +19% change from the long term +211% change from previous year

Survey index increased from 50,382 t to 106,434 t (95% CI: 58,000 – 155,000 t).

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Survey data from 2026 – increase in the Western Aleutians stock proportion.

a. Biomass (t)

Year	Western	Central	Eastern
1991	75,515	39,729	64,926
1994	23,797	51,538	78,081
1997	14,357	30,252	28,239
2000	43,298	36,456	47,117
2002	23,623	24,687	25,241
2004	9,637	20,731	51,852
2006	19,480	22,033	43,349
2010	21,341	11,207	23,277
2012	13,514	14,804	30,592
2014	18,088	8,488	47,032
2016	19,775	19,496	45,138
2018	11,425	20,596	49,251
2022	13,661	14,045	23,837
2024	9,817	18,379	22,188
2026	44,958	15,860	40,515

b. Proportion by area

Year	Western	Central	Eastern
1991	0.419	0.221	0.360
1994	0.155	0.336	0.509
1997	0.197	0.415	0.388
2000	0.341	0.287	0.371
2002	0.321	0.336	0.343
2004	0.117	0.252	0.631
2006	0.230	0.260	0.511
2010	0.382	0.201	0.417
2012	0.229	0.251	0.519
2014	0.246	0.115	0.639
2016	0.234	0.231	0.535
2018	0.141	0.253	0.606
2022	0.265	0.272	0.462
2024	0.195	0.365	0.440
2026	0.444	0.157	0.400

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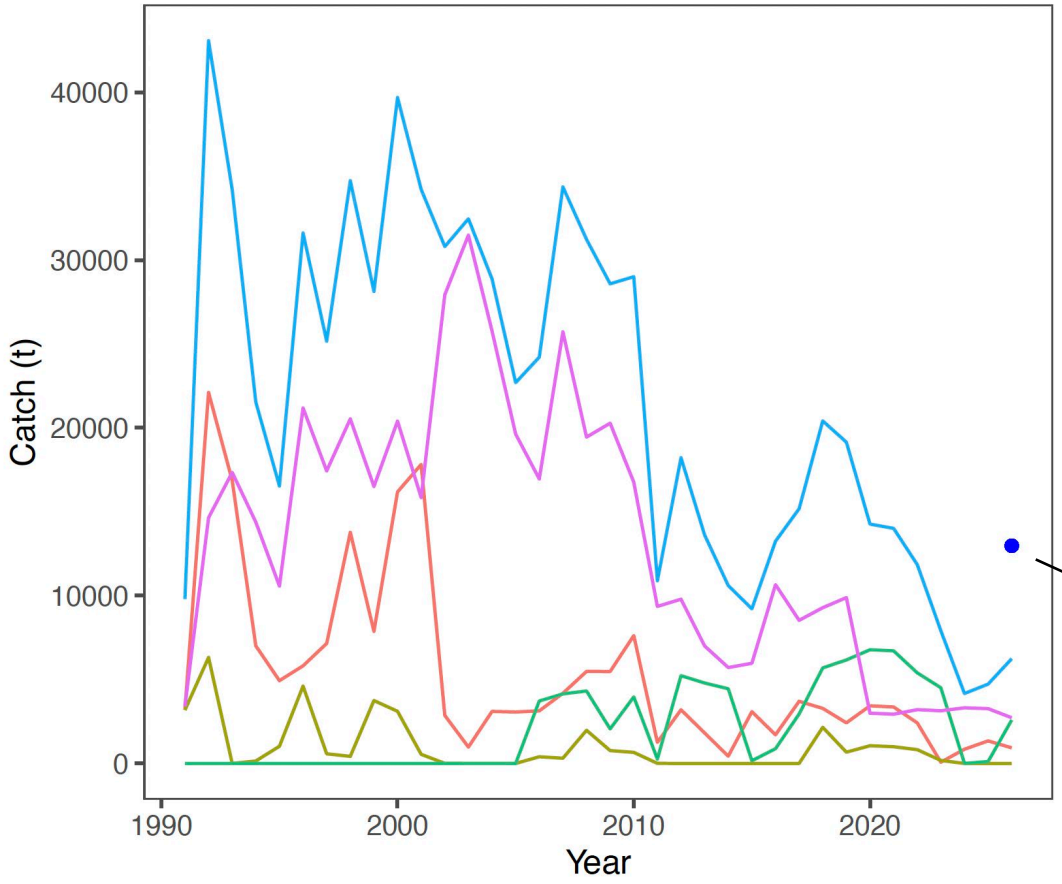
Aleutian Islands Pacific cod catch history, with federal catches by gear type, from 1991-2026 (through October 1)



Catch

- 2026 was 23% of long term mean.
- +4% Change from previous year.
- 35% of ABC in 2025.

Blue dot represents the ABC for 2026

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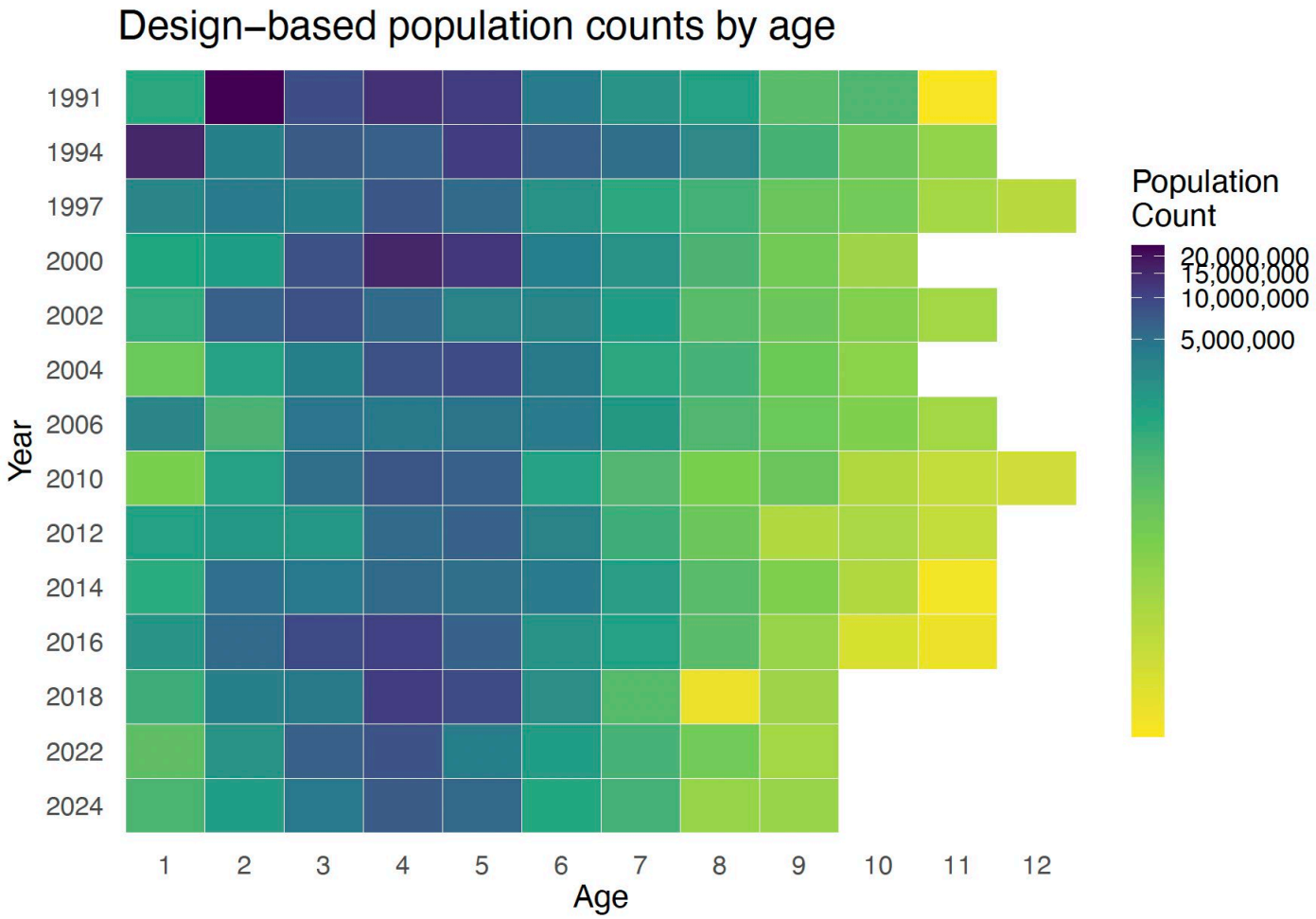
Survey age composition over time shows consistency over the past 10 years.



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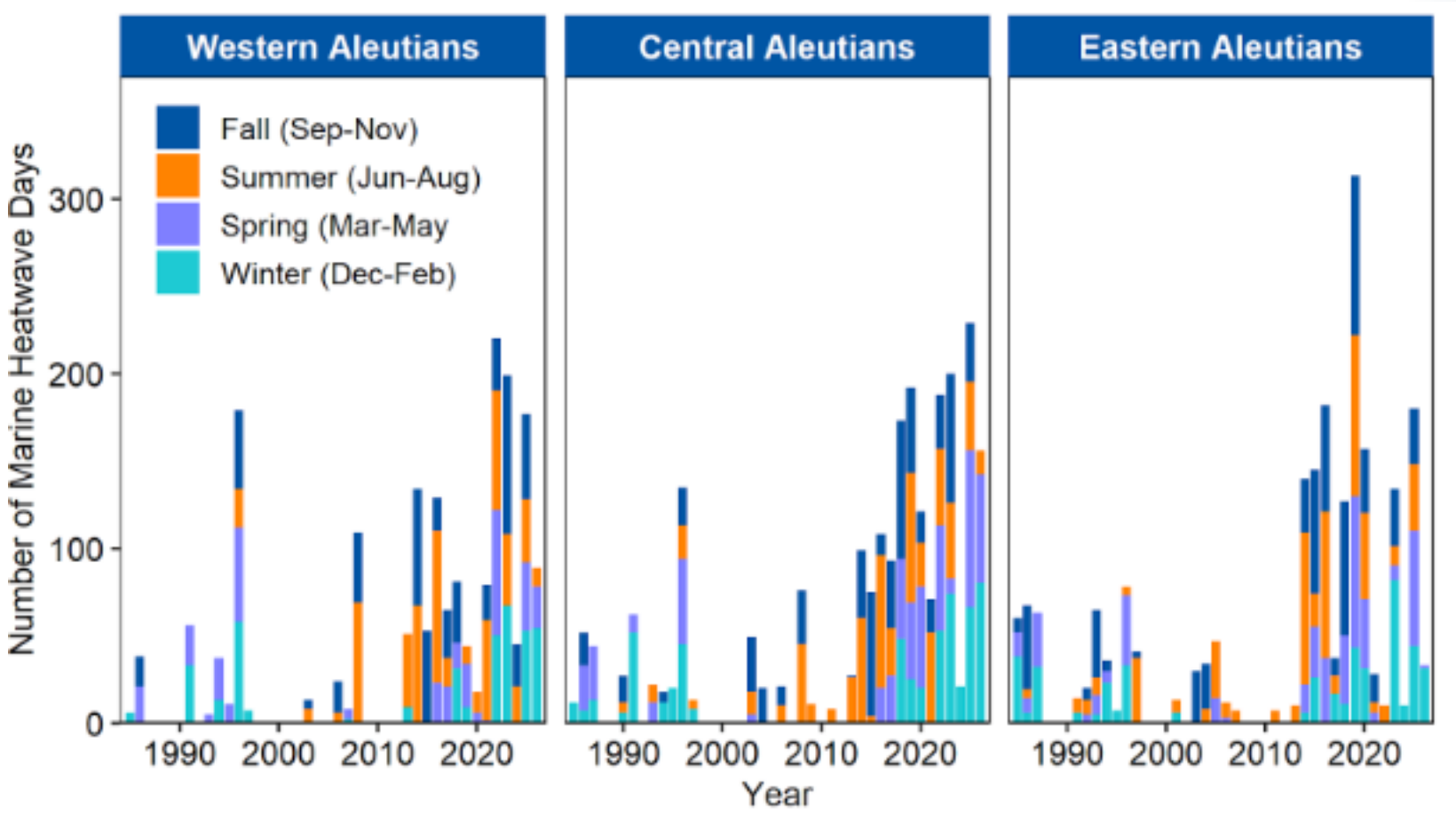
Natural mortality timeblock: 2026 conditions were warmer than 2024.



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Model description (Update assessment)

Model 24.1 features:

- Single sex model, 1:1 male female ratio.
- Survey age and length data were input as conditional age-at-length.
- Recruitment estimated as a mean with lognormally distributed deviations.
- Maturity-at-age was estimated externally using observer data, then input into the model.
- Single-fleet fishery that combines trawl, longline, and pot fishery data, weighted by quarter, gear, and NMFS area, from 1991 - current year (through October 1).
- Survey and fishery selectivity were modeled as logistic and constant over time.
- Base natural mortality was estimated externally.
- Natural mortality timeblock 2016 – 2026.
- A Richards growth curve was estimated within the model.
- Ages 0 to 13+ years.
- Fishery length composition 1 - 143 cm.

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Results

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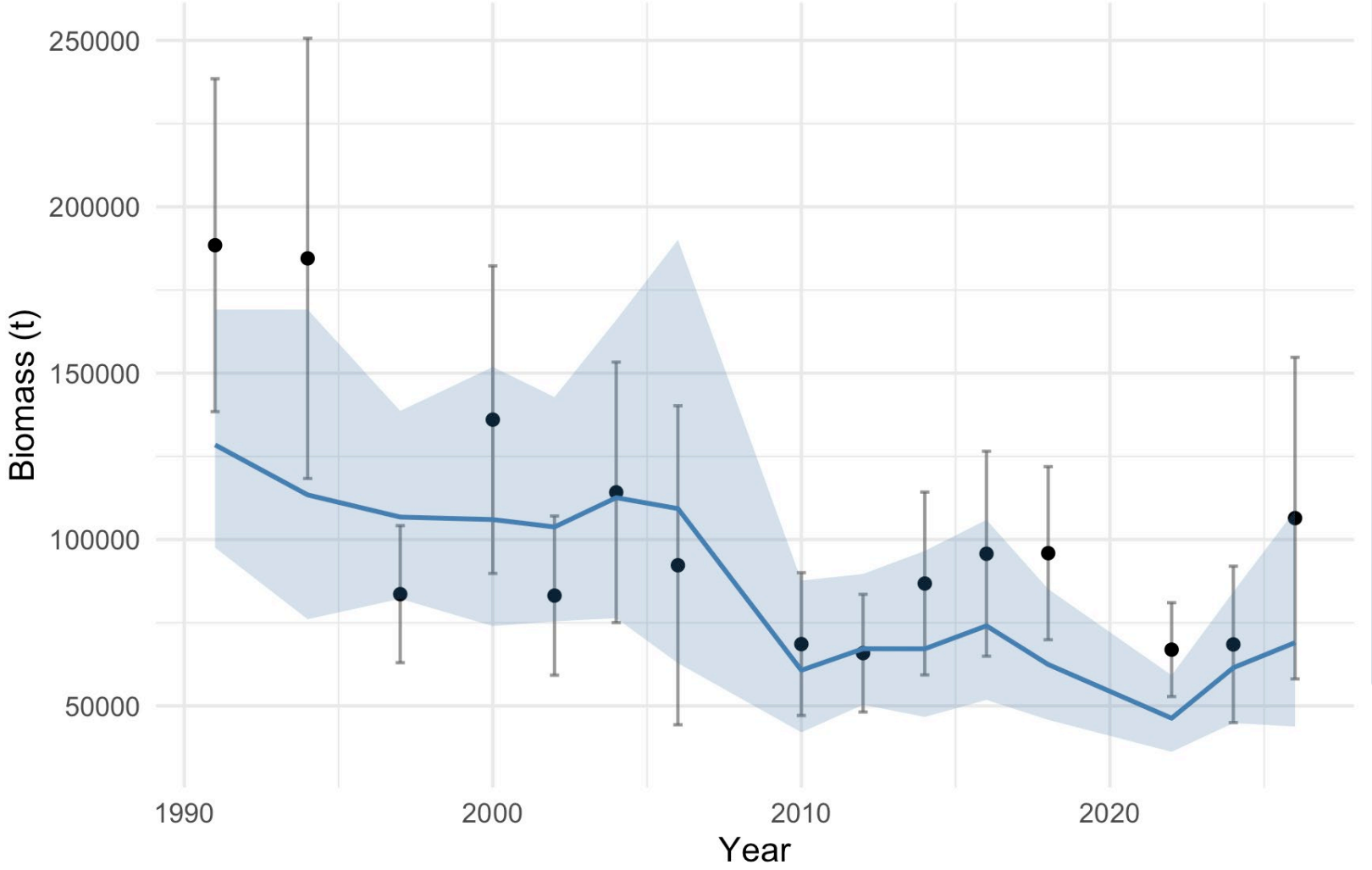
Model 24.1 fit to survey index, 1991 – 2026.



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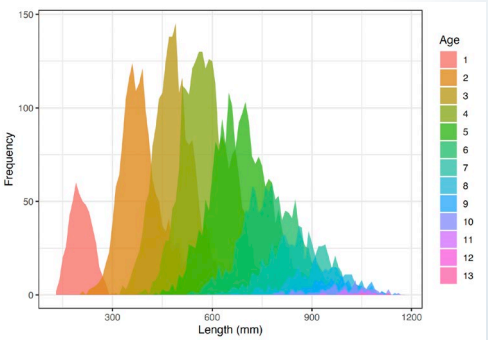
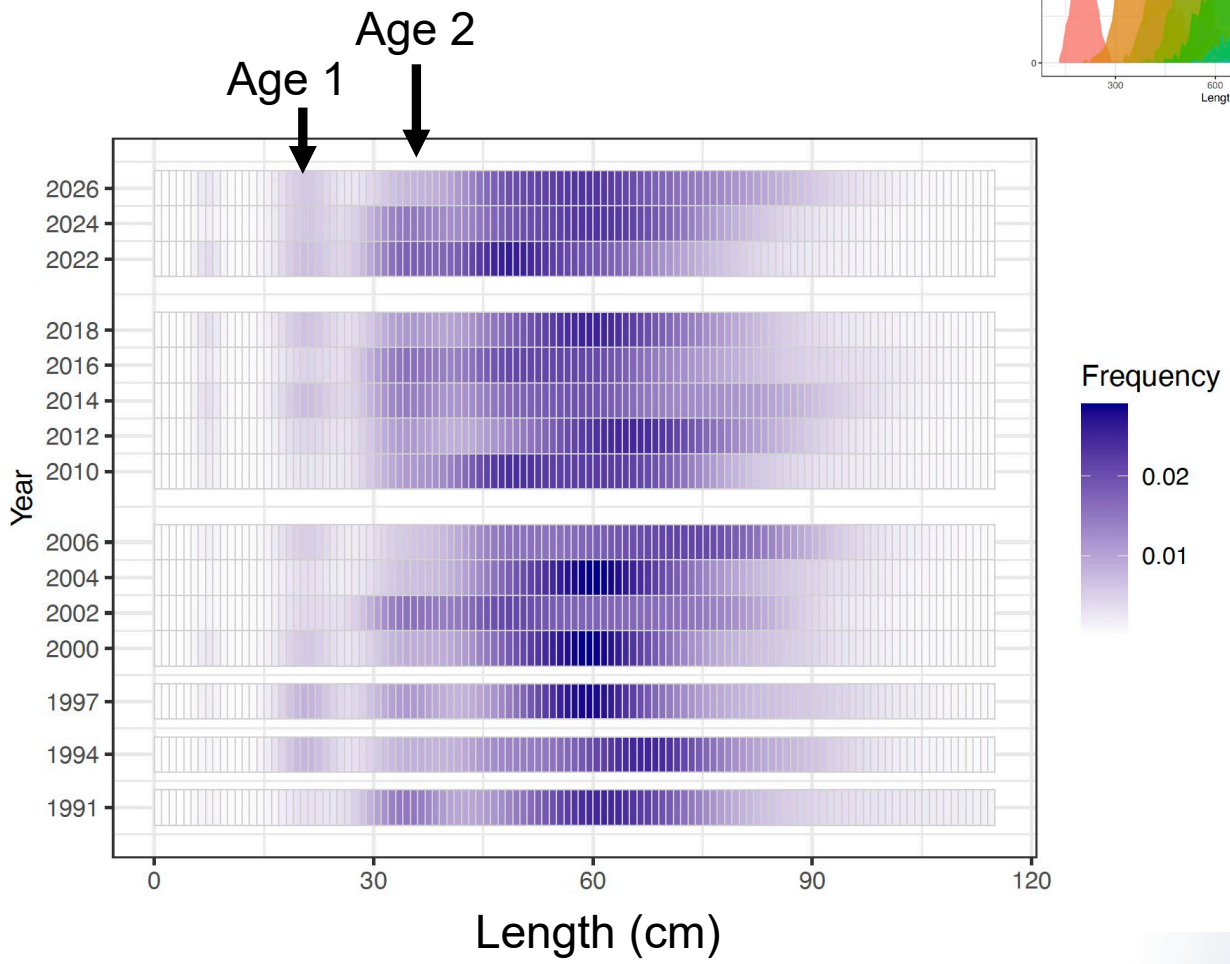
Aleutian Islands Pacific cod predicted length frequencies.





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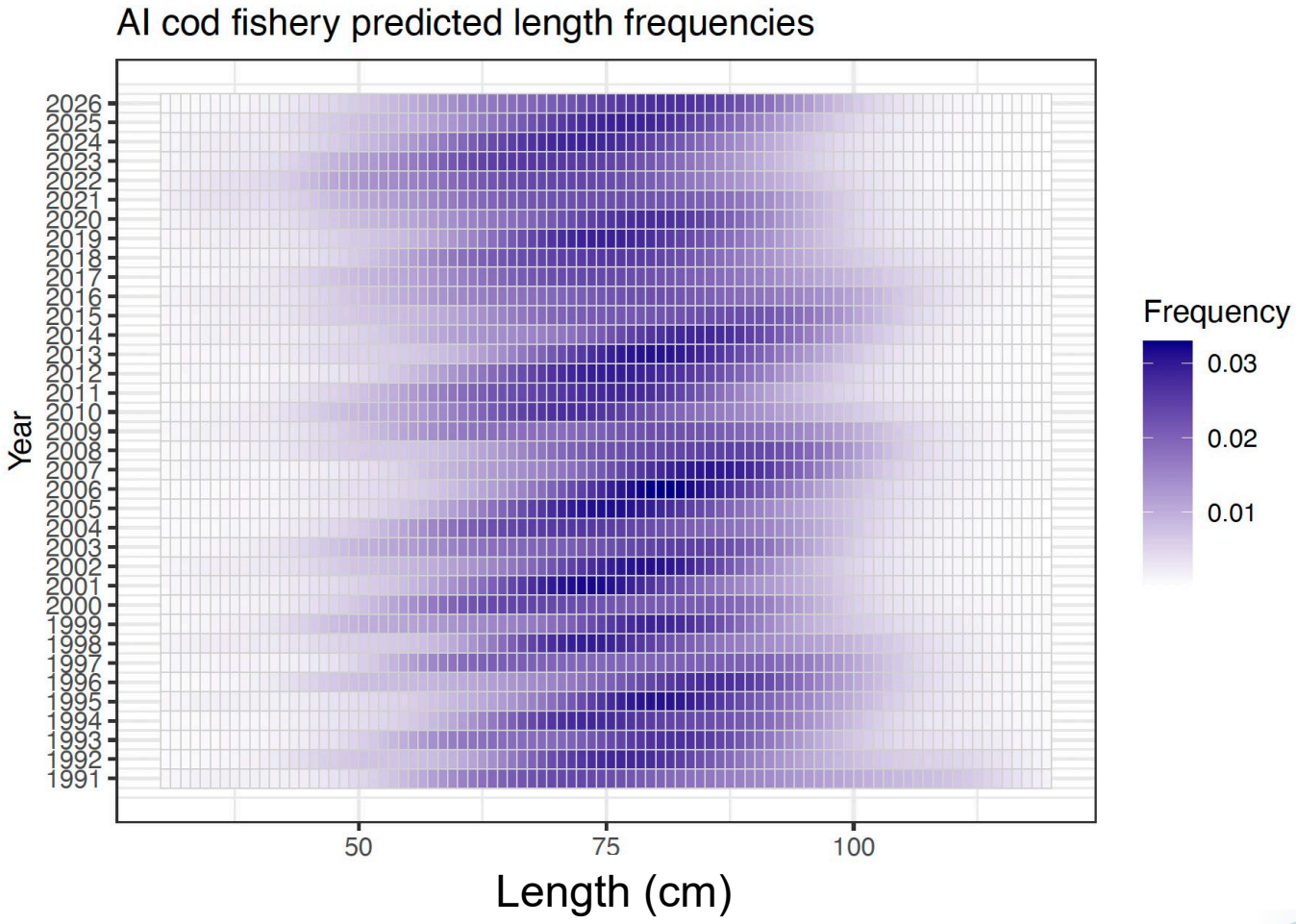
Predicted fishery length compositions indicate that the 2019 and 2020 year classes persist, as well as good current recruitment.



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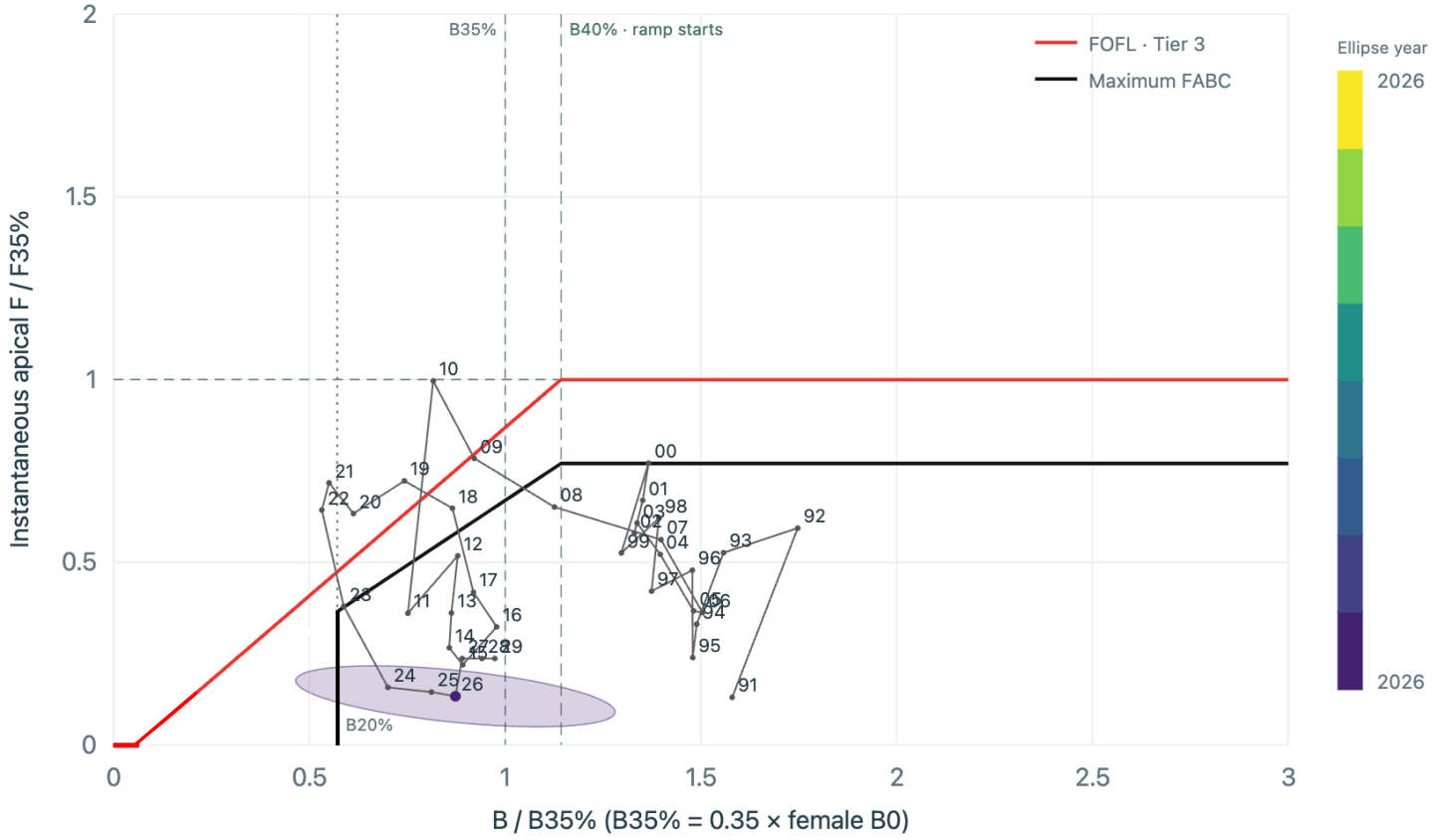
Phase plane diagram for Model 24.1

$B_{31\%}$ stock status.



Estimated spawning biomass: 32,619 t in 2026, 33,257 t in 2027, and 30,276 t in 2028.

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Summary table for Model 24.1

No maxABC reduction.
+61% ABC from previous year.

Quantity	As estimated or *specified in 2024* ∗ for: 2025	2026	As estimated or *recommended this* year for: 2027	2028
M (natural mortality rate)	0.417, 0.57*	0.417, 0.57*	0.417, 0.57*	0.417, 0.57*
Tier	3b	3b	3b	3b
Projected total (age 1+) biomass (t)	73,679	77,731	91,891	87,962
Projected female spawning biomass (t)	25,078	25,078	33,256	30,276
$B_{100\%}$	102,361	102,361	106,727	106,727
$B_{40\%}$	40,944	40,944	42,690	42,690
$B_{35\%}$	35,826	35,826	37,354	37,354
F_{OFL}	0.655	0.655	0.781	0.728
$maxF_{ABC}$	0.502	0.502	0.62	0.561
F_{ABC}	0.502	0.502	0.62	0.561
OFL	16,782	16,782	26,089	22,538
$maxABC$	13,376	13,376	21,597	18,135
ABC	13,376	13,376	21,597	18,135
	As determined in 2024 for			
Status	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

*Asterisk denotes natural mortality estimated in the timeblock 2016-2026.

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Model diagnostics

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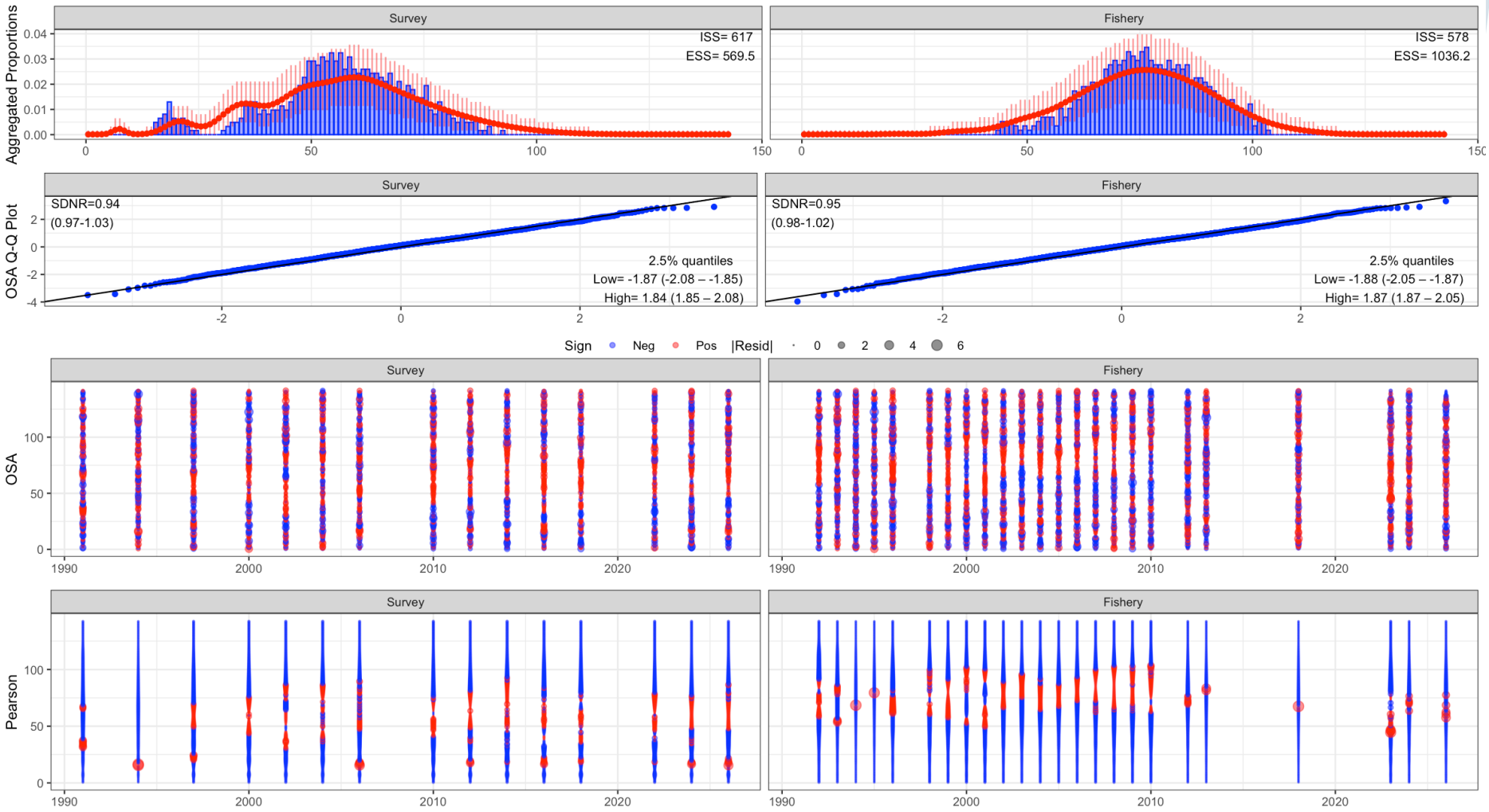
One-step-ahead residuals survey (left), fishery (right)



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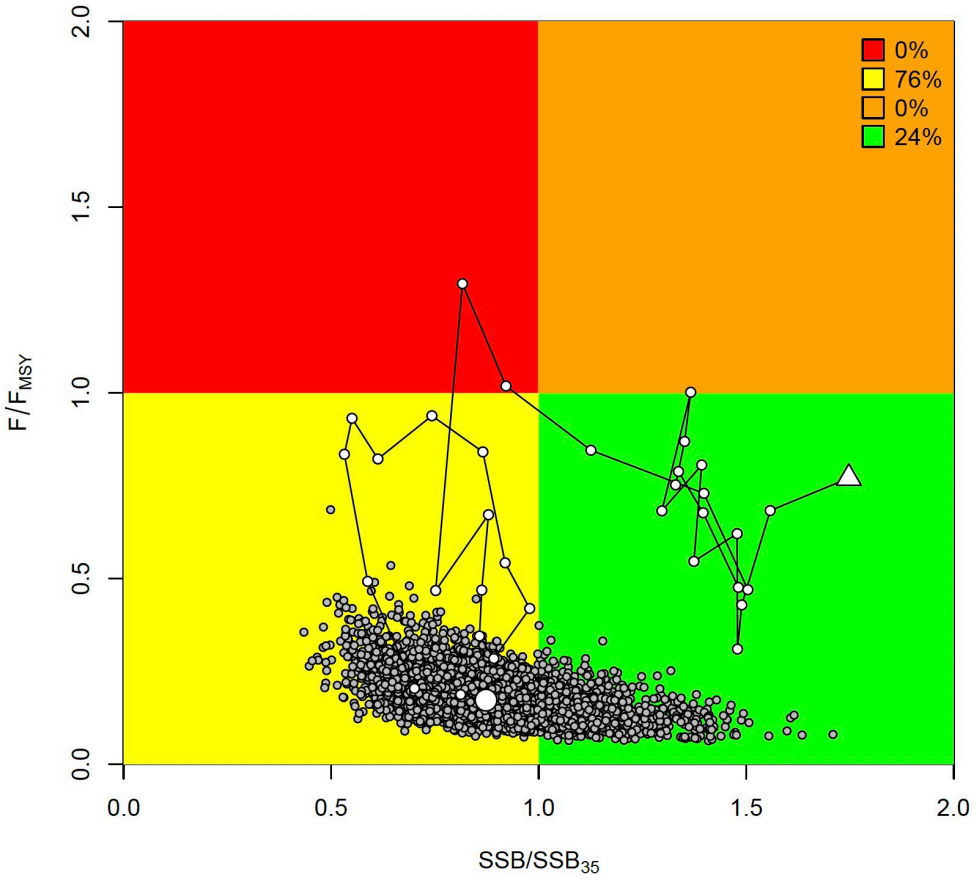
A Kobe plot for Model 24.1 indicates that the fishing mortality rate is below $F_{40\%}$, SSB > $SSB_{17.5\%}$, and < $SSB_{35\%}$ (76% probability).



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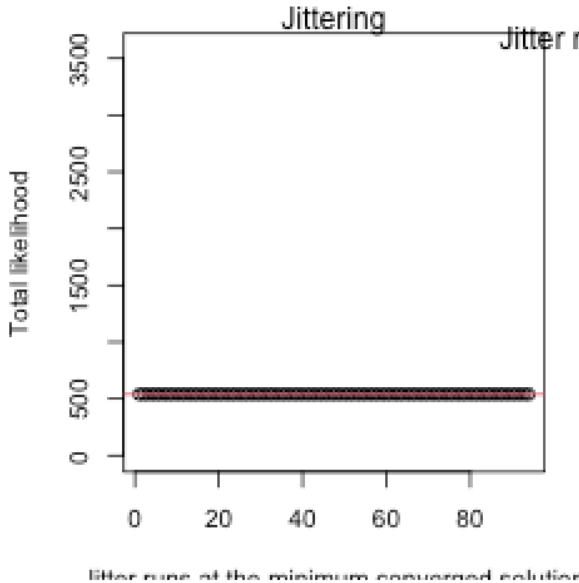
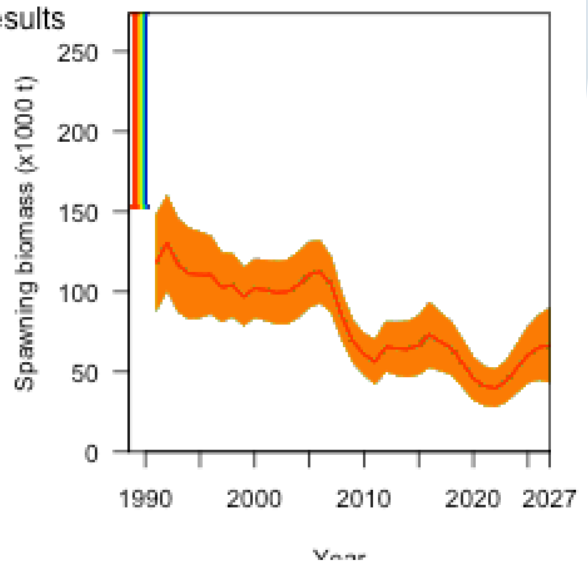
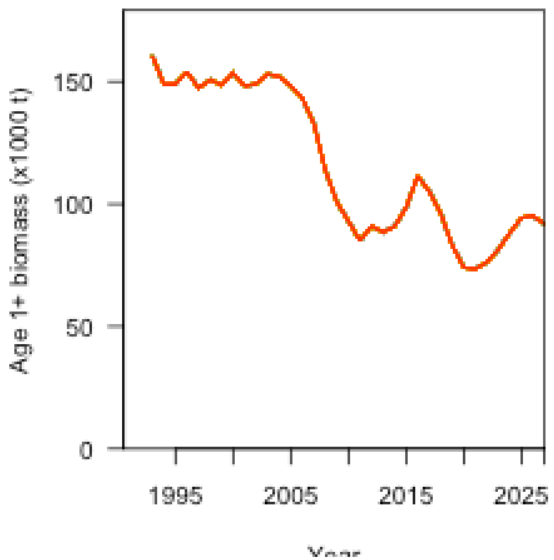
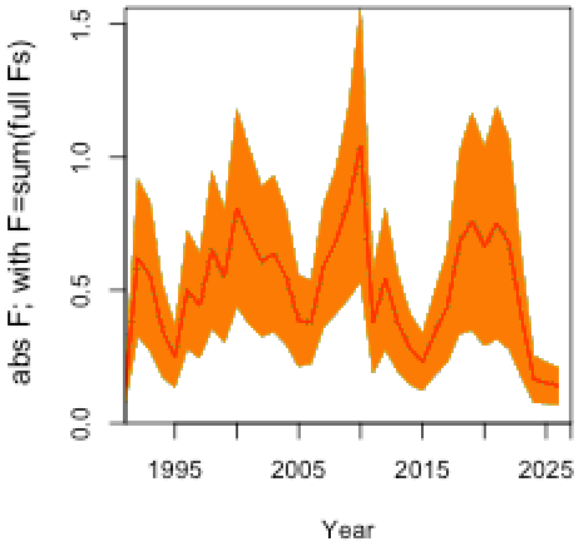
Jitter analysis

- 200 jitter iterations.
- 10% perturbation.
- 94 runs (47%) converged to base model's minimum NLL (within 0.01).
- No runs achieved lower NLL.
- Global convergence.









Risk Table

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Assessment considerations for Model 24.1

- Strong statistical convergence
- High parameter stability
- Favorable diagnostic performance
- One step ahead (OSA) residuals

  No systematic over- or under-fitting,

  Validates the assumption of randomly distributed error.
- Kobe plot projections track stock status uncertainty relative to management.
- The increase in recruitment in Model 24.1 is counter-intuitive.

Risk Level 1 – Normal (no concern)

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Population dynamics considerations

- Stock has transitioned from above $B_{35\%}$ in 1991 to below in the current period.
- The 2026 trawl survey biomass estimate was markedly higher than the 2024 estimate, at 106,434 t,
- The 2026 survey estimate – 2nd highest CV in the time series (95% confidence intervals 58,040 t to 154,805 t).

Risk Level 1 – Normal (no concern)

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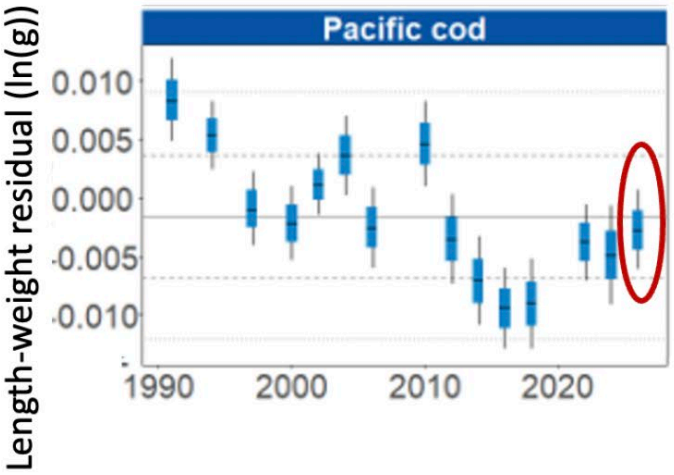
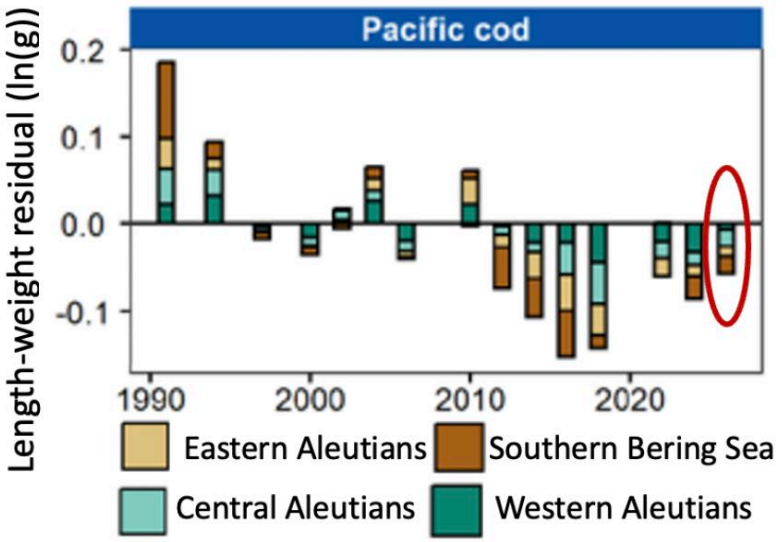
Environmental/Ecosystem Considerations

- Structural epifauna increasing (nursery and foraging habitat).
- Pacific cod's non-pelagic YOY feed largely on benthic amphipods and shrimp, which have increased in the east.
- SST temperatures were within the optimal range for pelagic larvae through May (this year).
- Adult fish condition has been increasing.





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Fishery performance

- Fishing reports from 2026 indicate an increase in catch per unit effort for Aleutian Islands Pacific cod.
- Overall catch appears slightly higher than at this time in 2024 and 2025.

- Risk Level 1 -- Normal (no concern).

Risk Table

Assessment consideration	Population dynamics	Environmental ecosystem	Fishery performance
Level 1: Normal	Level 1: Normal	Level 1: Normal	Level 1: Normal

We do not recommend a reduction in ABC.

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Questions?

