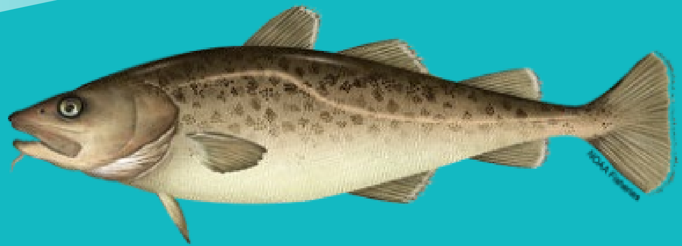

Assessment of the Pacific cod stock in the Aleutian Islands

Ingrid Spies, Maia Kapur, Steve Barbeaux, Melissa Haltuch, Pete Hulson, Ivonne Ortiz, Laura Spencer, Sandra Lowe

November 13, 2024

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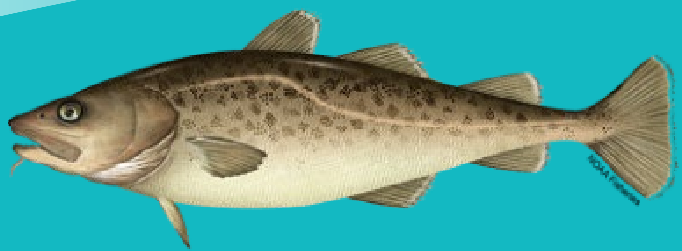

Assessment of the Pacific cod stock in the Aleutian Islands

Ingrid Spies, Maia Kapur, Steve Barbeaux, Melissa Haltuch, Pete Hulson, Ivonne Ortiz, Laura Spencer, Sandra Lowe

November 13, 2024

https://github.com/afsc-assessments/AI_PCOD/M24_0

https://github.com/afsc-assessments/AI_PCOD/M24_1

https://github.com/afsc-assessments/AI_PCOD/M24_1a

New research provides evidence that Aleutian Islands cod are a distinct population, with little movement into or out of the area.

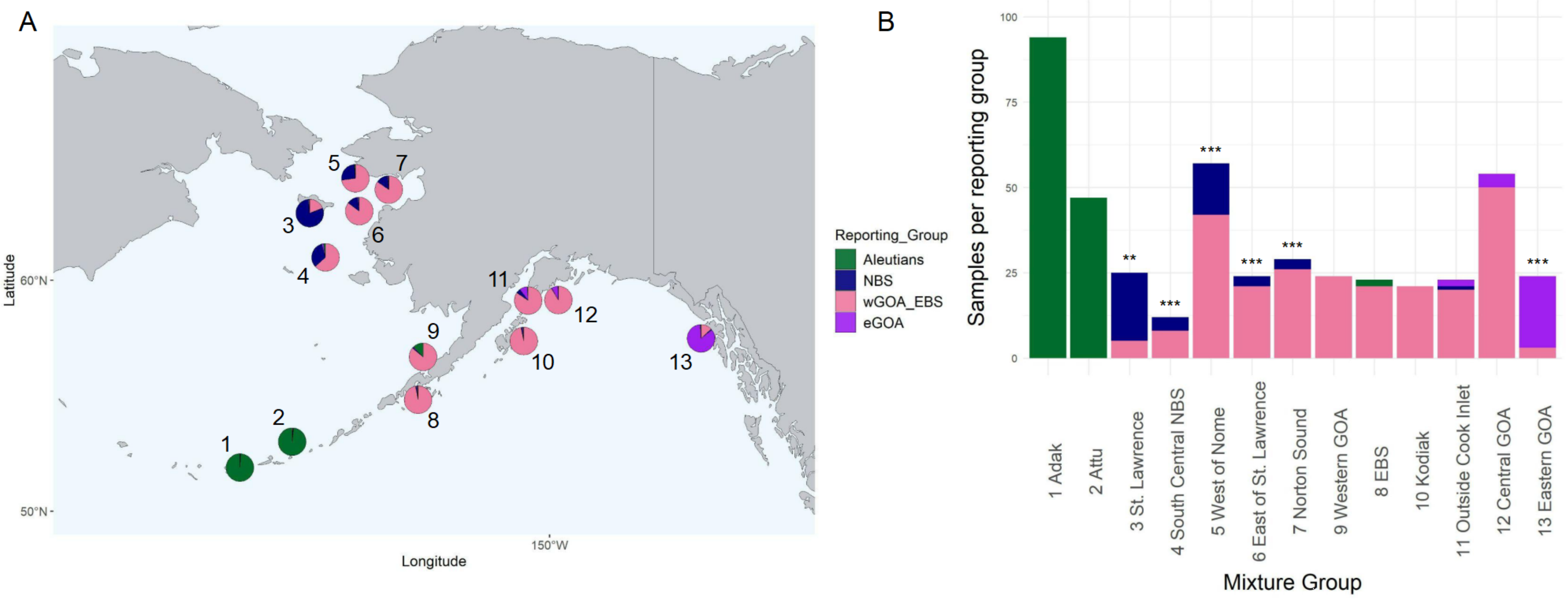

Figure 2: Stock compositions of adult Pacific cod caught in summer. A) mixed stock proportions of each genetic reporting group for mixture collections 1-13 and B) corresponding individual assignment based on mixture analysis. Significance values on panel B indicate whether the summer mixture collection differed from the local winter spawning group using a chi-square test.

Sara Schaal, Larson, W., Vollenweider, J., Miller, K., Klenz, T, Maselko, J, Neff, D,. Tobin, C., McDermott, S., Spies, I. Genetic data reveal non-local juvenile recruitment and variable seasonal movement of a highly mobile marine fish across Alaska

SSC and Plan Team comments

Selected SSC and Plan Team comments - 2

SSC October 2024:

One change that was unexpectedly impactful was the move to the Richard's growth curve. As the BSAI GPT noted, the change in likelihood between the model with the LVB growth and the model with the Richard's growth curves was quite substantial, given that the change represented the addition of one parameter only and the difference in shape of the two growth curves was fairly similar. The SSC concurs with the BSAI GPTs recommendation to explore how such a large improvement in likelihood occurred despite similar growth curves.

Response:

The substantial change was a result of the bridging method, and is addressed in Results of Tier 3 models. In a new set of bridging models, the Richards growth curve still provides a better fit to the data, but the improvement is closer to what would be expected.

Substantial change due to Richards vs. von Bertalanffy (September document) resulted from bridging method

September

628.11 | 902.625

Features	M24.1	M24.0	M24_0A	M24_0B	M24_0C	M24_0D	M24_0E	M24_0F	M24_0G
2024 Params (X)/Alt. Params (0)									
Max length 143/Max length 117+	X	X	X	0	0	0	0	0	0
M timeblock 2016-2024/None	X	0	X	0	0	0	0	[illegible]	[illegible]
smaller CV young growth/CV=0.3	X	X	0	0	0	0	0	[illegible]	[illegible]
logistic survey/dome survey	X	X	X	X	0	X	X	[illegible]	[illegible]
Max age 13/Max age 10+	X	X	X	X	X	0	0	[illegible]	[illegible]
InitF/no Init F	X	X	X	X	X	X	0	0	0
M fixed/M estimated	X	X	X	X	X	X	X	0	0
Richards Growth/von B growth	X	X	X	X	X	X	X	X	0
Results									
Label	M24_1	M24_0	M24_0A	M24_0B	M24_0C	M24_0D	M24_0E	M24_0F	M24_0G
TOTAL_like	474.77	515.367	733.187	696.616	727.079	735.48	743.955	628.11	902.625
Survey_like	-8.281	-4.043	-12.415	-3.829	-6.708	-3.308	-3.28	-9.997	-8.507
Length_comp_like	127.206	122.324	136.964	162.235	146.185	184.074	184.217	[illegible]	[illegible]
Age_comp_like	355.671	395.501	609.959	537.925	589.337	550.428	554.867	470.414	753.548
Recruitment_like_thousands	-1.171	0.225	-2.696	-1.209	-3.887	2.61	6.445	1.961	-1.182
Forecast_Recruitment_like	0.036	0.06	0.015	0.03	0.016	0.073	0.084	0.087	0.069
Recr_Virgin_millions	87.177	73.347	94.99	79.246	102.465	66.416	73.947	985.317	609.908
SR_BH_steep	1	1	1	1	1	1	1	1	1
Natural mortality	0.417	0.417	0.417	0.417	0.417	0.417	0.417	0.741	0.674
NatM_BLK2repl_2016	0.579	-	0.604	-	-	-	-	-	-
SmryBio_unfished	268,675	226,176	278,043	235,989	312,252	238,226	265,181	511,834	425,054
SSB_Virgin_thousand_mt	219.259	184.541	232.091	197.524	263.108	201.028	223.764	321.335	265.358
SSB_2024_thousand_mt	49.215	64.959	54.053	87.169	139.403	76.539	76.212	172.101	155.144
Bratio_2024	0.224	0.352	0.233	0.441	0.53	0.381	0.341	0.536	0.585
SPRratio_2024	0.149	0.173	0.12	0.115	0.075	0.125	0.125	0.031	0.031
Ret_Catch_MSY	33,966	28,671	39,351	33,647	42,657	34,416	38,303	121,098	120,801
SR_LN(R0)	11.376	11.203	11.462	11.28	11.537	11.104	11.211	13.801	13.321
Survey catchability (q)	0.872	0.928	0.769	0.743	0.597	0.857	0.854	0.368	0.406
Size_DblN_peak_FshComb(1)	101.979	103.989	90.127	94.813	85.362	91.73	91.675	97.635	115.995
Size_DblN_top_logit_FshComb(1)	25	25	25	25	25	25	25	25	25
Size_DblN_ascend_se_FshComb(1)	6.658	6.719	6.378	6.554	6.252	6.441	6.44	6.445	6.818
Size_DblN_peak_Srv(2)	69.435	68.774	64.198	62.791	60.635	63.928	63.905	70.589	76.957
Size_DblN_ascend_se_Srv(2)	6.5	6.539	6.267	6.289	6.16	6.35	6.351	6.297	6.641
Number of parameters	73	72	73	72	73	69	68	69	68

November

534.148 | 547.266

Features	M24.1	[illegible]	M24.0
2024 Params (X)/Alt. Params (0)			
M timeblock 2016-2024/ None	X	X	0
Richards Growth/ von B growth	X	0	X
Results			
TOTAL_like	534.148	547.266	544.019
Survey_like	-8.87	-7.606	-1.241
Length_comp_like	140.884	133.085	140.844
Age_comp_like	402.559	420.1	403.169
Recruitment_like_thousands	-0.43	0.608	0.355
Recr_Virgin_millions	80.596	75.858	62.969
SR_BH_steep	1	1	1
Natural mortality	0.417	0.417	0.417
NatM_BLK2repl_2016	0.572	0.564	NA
SmryBio_unfished	247,377	228,381	193,473
SSB_Virgin_thousand_mt	200.904	183.868	157.101
SSB_2024_thousand_mt	50.537	46.708	55.314
Bratio_2024	0.252	0.254	0.352
SPRratio_2024	0.188	0.165	0.197
Ret_Catch_MSY	31,133	29,262	24,372
SR_LN(R0)	11.2972	11.2366	11.0504
Survey catchability (q)	0.87	0.961	0.931
Size_DblN_peak_FshComb(1)	101.037	107.458	102.345
Size_DblN_top_logit_FshComb(1)	25	25	25
Size_DblN_ascend_se_FshComb(1)	6.636	6.754	6.681
Size_DblN_peak_Srv(2)	69.729	73.635	68.749
Size_DblN_ascend_se_Srv(2)	6.519	6.712	6.54
Number of parameters	55	54	54
AIC	1178.296	1202.532	1196.038

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Selected SSC and Plan Team comments - 3

SSC October 2024:

Ensure that the "F ballpark" penalty is turned off in the final estimation phase. It appeared from likelihood profiles that this penalty was still turned on at the end of model runs. This is a convergence aid and should not be affecting model results at the end of convergence.

Response:

This penalty has been turned off.

Selected SSC and Plan Team comments - 5

SSC October 2024:

…an important new feature of Model 24.1 was the inclusion of a natural mortality block….

1. current parameterization assumes that there is a distinct mechanism identified for the natural mortality block and that it is consistent over time without an identified threshold for returning to baseline natural mortality.
2. The temperature thresholds identified in Laurel and Rogers (2020) point to hatch success having a narrow optimum temperature range.
3. If hatch success was the main driver, then the SSC suggests it might be more appropriate to consider a recruitment covariate that utilizes bottom temperature predictions at the time of spawning based upon ROMS or future CEFI models.
4. Additionally, if the higher mortality affects young ages or all ages, then the rationale for the two year lag becomes unclear.
5. The higher temperatures in the AI are also lower than what were identified as high temperatures in the GOA.

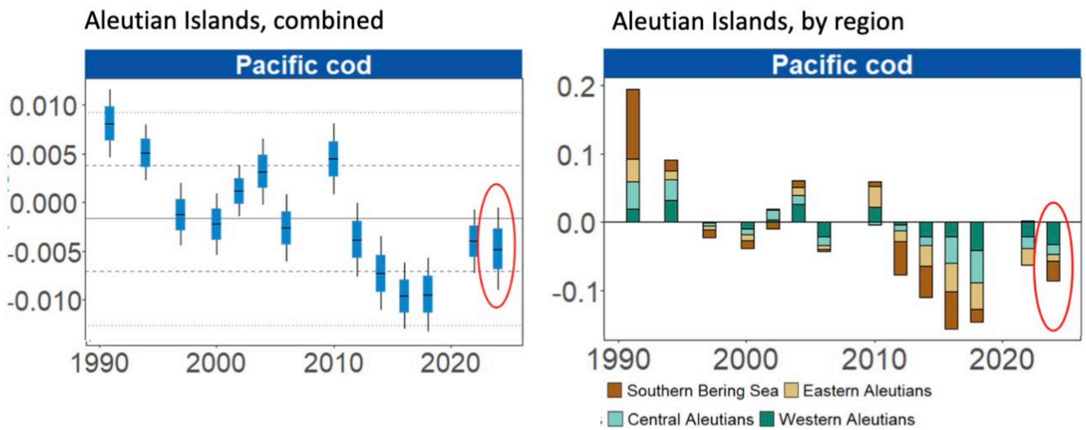
Response:

- Future research on incorporating climate-related parameters can be researched under management as a Tier 3 model.

Selected SSC and Plan Team comments - 6

Response (Continued):

- Heat stress has been shown to increase bioenergetic consumption rates.
- Prey may become a limiting factor.
- Low length-weight residuals have been observed in all regions since 2012.
- Lower fish condition, heatwave conditions, and decline in survey estimates of biomass are consistent with high temperatures having cumulative stress effect on cod in the AI, resulting in climate-induced mortality.



Selected SSC and Plan Team comments - 7

SSC October 2024:

…an important new feature of Model 24.1 was the inclusion of a natural mortality block….
…future efforts could be enhanced by tying parameters to a specific covariate which would adjust to baseline when it returns to “normal”.

Response:

- We agree that future efforts should tie parameters to a specific covariate which would adjust to baseline when it returns to “normal”.
- This is an aspect of the Model 24.1 that will improve with more time and data.

Selected SSC and Plan Team comments - 8

SSC October 2024:

The SSC recommends one additional model “24.0b” which removes the block on M and uses the LVB growth model as a simpler but improved model from last year as an alternative.

Response:

This new model (“24.0b”) was not presented due to the short turnaround between the October 2024 SSC meeting and the November assessment deadlines.

Removal of the Richards growth curve and the natural mortality timeblock would deteriorate the fit to the data.

Selected SSC and Plan Team comments - 9

Plan Team October 2024:

Consider a prior for M that accounts for maximum ages beyond what has been observed in recent survey data, which likely reflect a truncated age structure.

Response:

The base value of natural mortality was calculated using all available age data for Aleutian Islands Pacific cod, from NMFS surveys 1991 - 2022.

Future efforts to obtain ages from cod taken prior to 1991 can be made if there is interest and resources.

Model description

Models for 2024

Age structured models (SS3):

- Model 24.0: Base model.
- Model 24.1: Timeblock on natural mortality from 2016 - 2024.
- Model 24.1a: Model 24.1 with vonBertalanffy growth curve.

Tier 5 random effects model:

- Model 13.4: Base model M = 0.34 (Growth derived)
- Model 24.2: Incorporates M = 0.417 (Longevity derived)

Age-structured models - features consistent with the 2023 models:

- 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 (1991 – 2021).
- 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 September 22).
- Survey and fishery selectivity were modeled as logistic and constant over time.

Age-structured models - Changes in the assessment methodology

- Natural mortality was estimated externally.
- All parameters were constant over time except for the natural mortality timeblock in Model 24.1.
- A Richards growth curve was estimated within the model (previously von Bertalanffy).

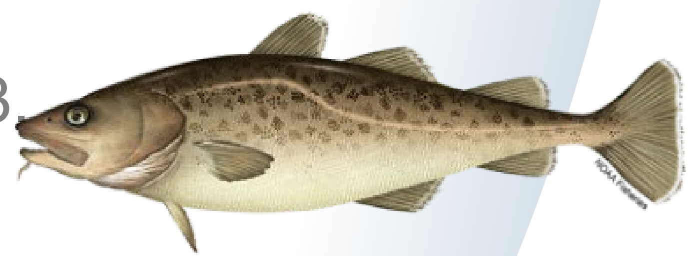
Presented at September (2024) meeting:

- Initial fishing mortality was estimated within the model.
- Maximum age was changed from 10^+ to 13 years.
- Fishery length composition extended to max = 143 cm (previously 117^+ cm).

Research suggests that longevity-based predictions of natural mortality rate are more precise than growth-based estimates

- Since 2007, M = 0.34 estimated using growth (Jensen 1996), and age-at-maturity of 4.9 years (Stark 2007).

- Longevity based estimator recently requested by SSC (Then et al. 2015).
- Analysis incorporates maximum age
  - EBS max age = 14, AI max age = 13.
- Aleutian Islands M = 0.417.
- Eastern Bering Sea M = 0.387.

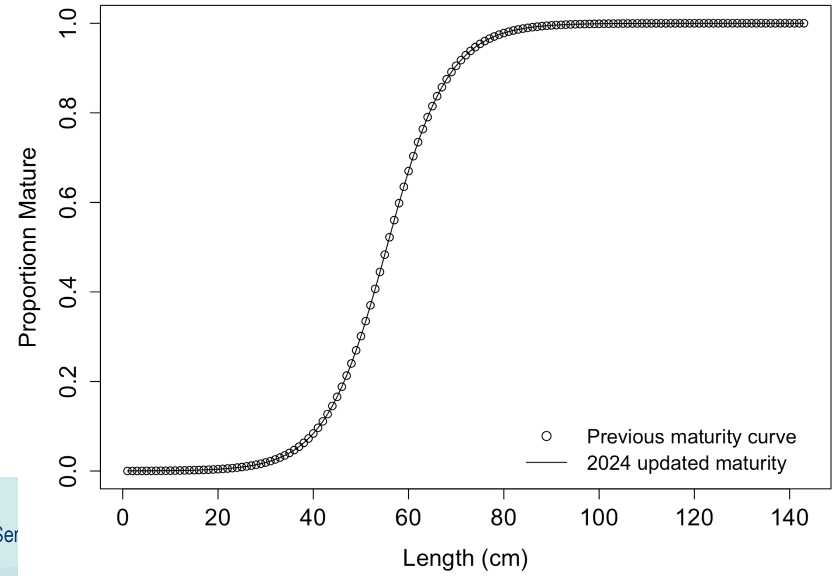


Maturity curve

Maturity curve was updated with new data and filtered for stomach scan data (which can be mistaken for maturity data in OBSINT).

- $L_{50\%}$ = 54.9 cm, and slope = -0.148.
- Reanalysis: $L_{50\%}$ = 55.4 cm (95% CI :53.7 - 57.3), slope = -0.155.

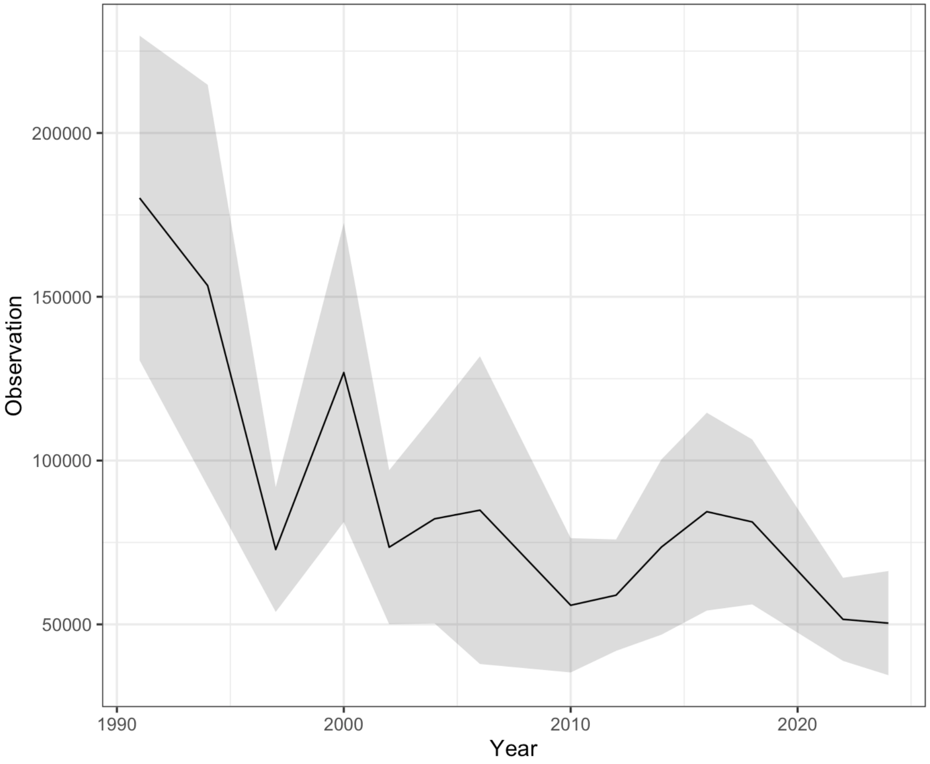
There were 1,331 records previously, approximately 1,355 including current data.



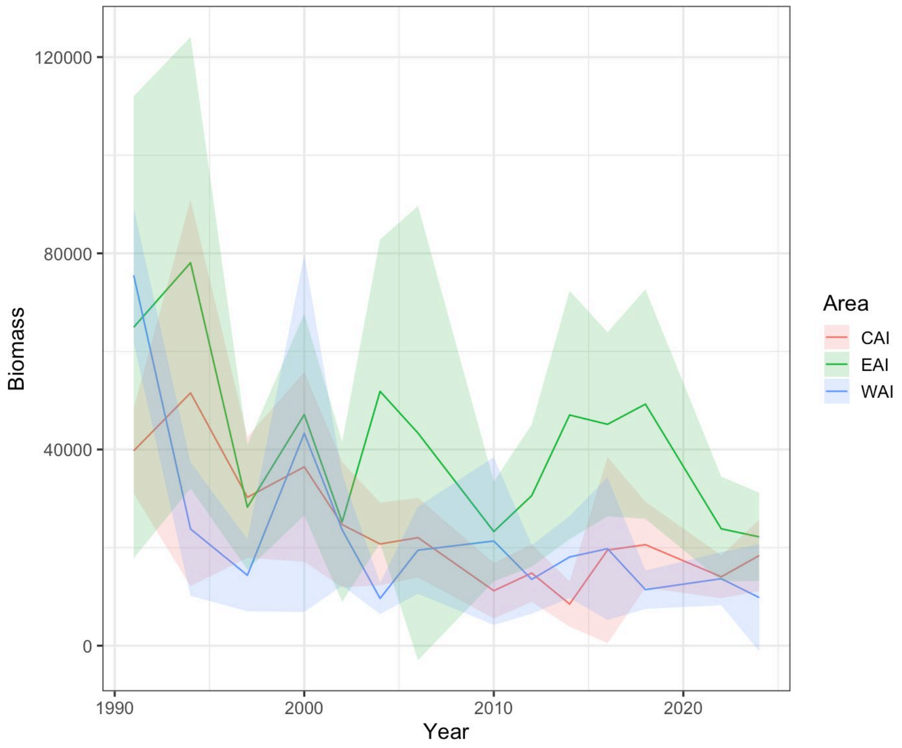
Data

Aleutian Islands Pacific cod survey biomass 1991 - 2024

AI survey biomass (total)



AI survey biomass (by area)



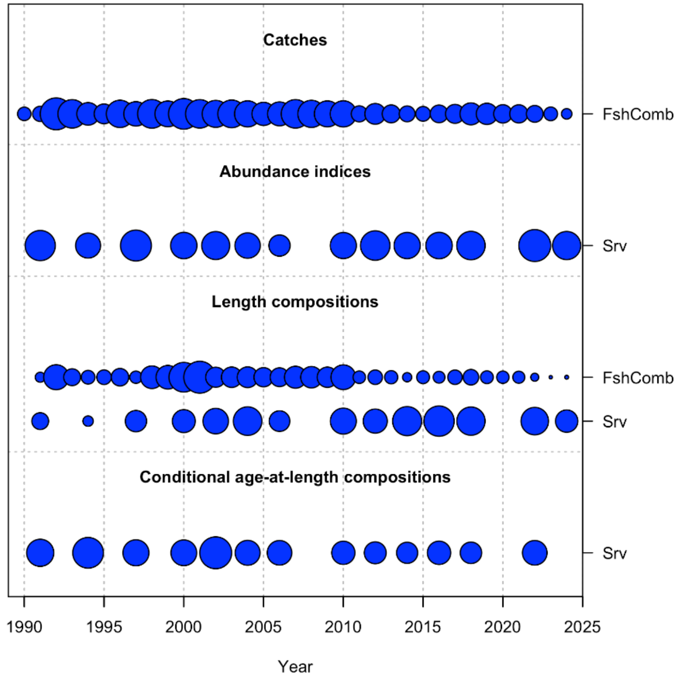
Survey data from 2024 – similar to 2022 estimates

Biomass (t)				
Year	Western	Central	Eastern	Total
1991	75,514	39,729	64,926	180,170
1994	23,797	51,538	78,081	153,416
1997	14,357	30,252	28,239	72,848
2000	43,298	36,456	47,117	126,870
2002	23,623	24,687	25,241	73,551
2004	9,637	20,731	51,851	82,219
2006	19,480	22,033	43,348	84,861
2010	21,341	11,207	23,277	55,826
2012	13,514	14,804	30,592	58,911
2014	18,088	8,488	47,032	73,608
2016	19,775	19,496	45,138	84,409
2018	11,425	20,596	49,251	81,272
2022	13,661	14,041	23,837	51,539
2024	9,817	18,379	22,188	50,384

Proportion by area				
Year	Western	Central	Eastern	Total
1991	0.419	0.221	0.360	1
1994	0.155	0.336	0.509	1
1997	0.197	0.415	0.388	1
2000	0.341	0.287	0.371	1
2002	0.321	0.336	0.343	1
2004	0.117	0.252	0.631	1
2006	0.230	0.260	0.511	1
2010	0.382	0.201	0.417	1
2012	0.229	0.251	0.519	1
2014	0.246	0.115	0.639	1
2016	0.234	0.231	0.535	1
2018	0.141	0.253	0.606	1
2022	0.265	0.272	0.463	1
2024	0.195	0.365	0.440	1

Age structured models - Data sources and relative weight

Source	Type	Years
Fishery (Trawl, Pot, LL)	Catch biomass	1991-2024*
Fishery (Trawl, Pot, LL)	Length composition	1991-2024
AI bottom trawl survey	Biomass estimate + Length composition	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018, 2022, 2024
AI bottom trawl survey	Age composition	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018, 2022, 2024

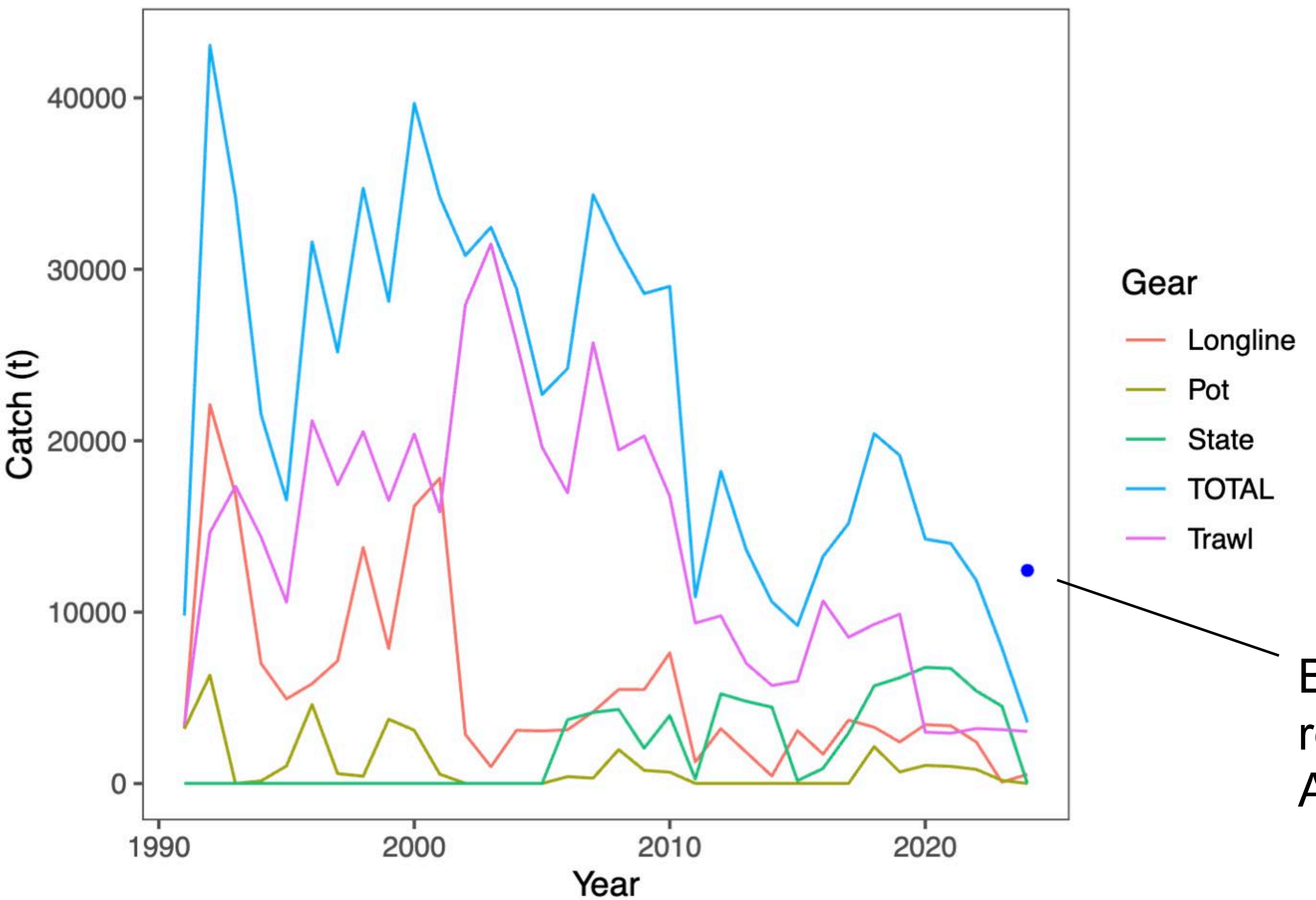


Catch: Complete data for 2023, 2024*. Fishery size compositions: Complete for 2023, 2024*.

Survey: New survey index, standard error, and length composition data for 2024.

*Data current through September 22, 2024

Aleutian Islands Pacific cod catch history, with federal catches by gear type, from 1991-2024 (through September 22)



Blue dot represents the ABC for 2024

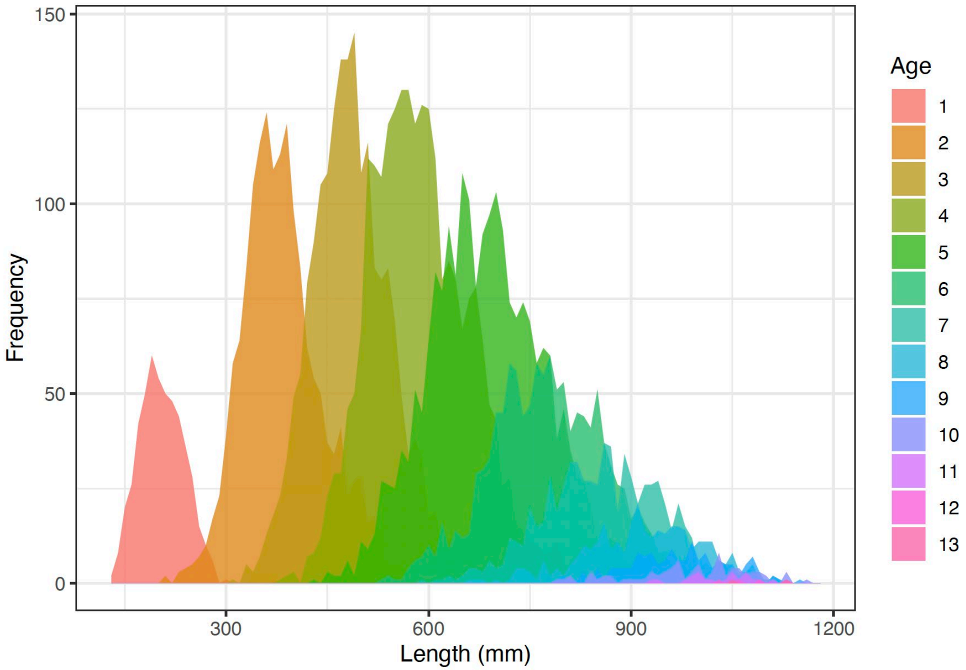
Sensitivity testing

Sensitivity testing – M timeblock and growth

Features	M24.1	M24.1a	M24.0
2024 Params (X)/Alt. Params (0)			
M timeblock 2016-2024/ None	X	X	0
Richards Growth/ von B growth	X	0	X
Results			
TOTAL_like	534.148	547.266	544.019
Survey_like	-8.87	-7.606	-1.241
Length_comp_like	140.884	133.085	140.844
Age_comp_like	402.559	420.1	403.169
Recruitment_like_thousands	-0.43	0.608	0.355
Recr_Virgin_millions	80.596	75.858	62.969
SR_BH_steep	1	1	1
Natural mortality	0.417	0.417	0.417
NatM_BLK2repl_2016	0.572	0.564	NA
SmryBio_unfished	247,377	228,381	193,473
SSB_Virgin_thousand_mt	200.904	183.868	157.101
SSB_2024_thousand_mt	50.537	46.708	55.314
Bratio_2024	0.252	0.254	0.352
SPRratio_2024	0.188	0.165	0.197
Ret_Catch_MSY	31,133	29,262	24,372
SR_LN(R0)	11.2972	11.2366	11.0504
Survey catchability (q)	0.87	0.961	0.931
Size_DblN_peak_FshComb(1)	101.037	107.458	102.345
Size_DblN_top_logit_FshComb(1)	25	25	25
Size_DblN_ascend_se_FshComb(1)	6.636	6.754	6.681
Size_DblN_peak_Srv(2)	69.729	73.635	68.749
Size_DblN_ascend_se_Srv(2)	6.519	6.712	6.54
Number of parameters	55	54	54
AIC	1178.296	1202.532	1196.038

Improving fit to growth curve

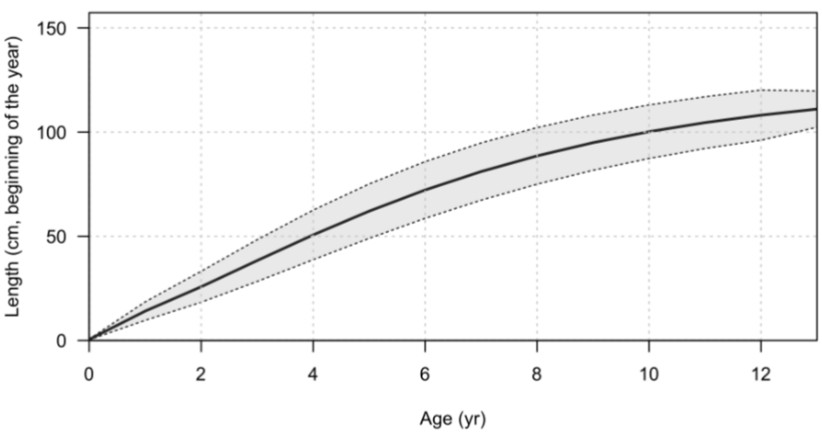
- Incorporated Richards growth curve rather than von Bertalanffy.
- Cod grow quickly and continue to increase in length.
- Length frequency by age of cod collected from Aleutian Island surveys 1991-2022



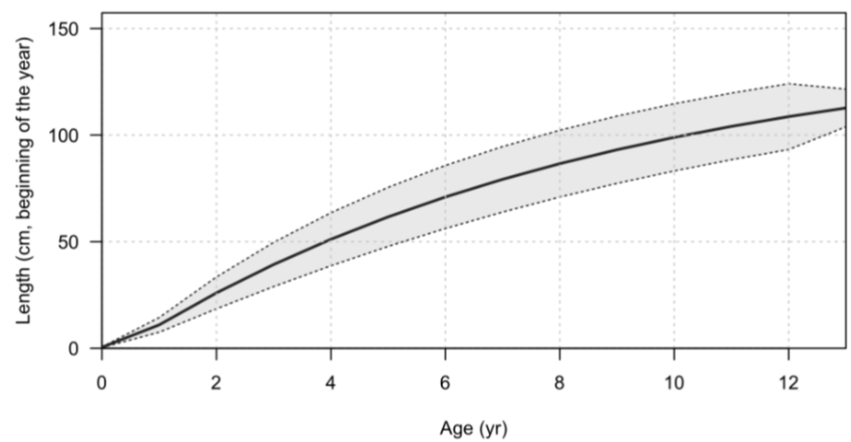
Growth curve

- The Richards growth curve adds an additional parameter.
- This allows for an inflection point between younger (age 2) and older cod (age 4+) that is not available in the von Bertalanffy.

Richards growth curve
Model 24.1



Von Bertalanffy growth curve
Model 24.1a



Growth curve

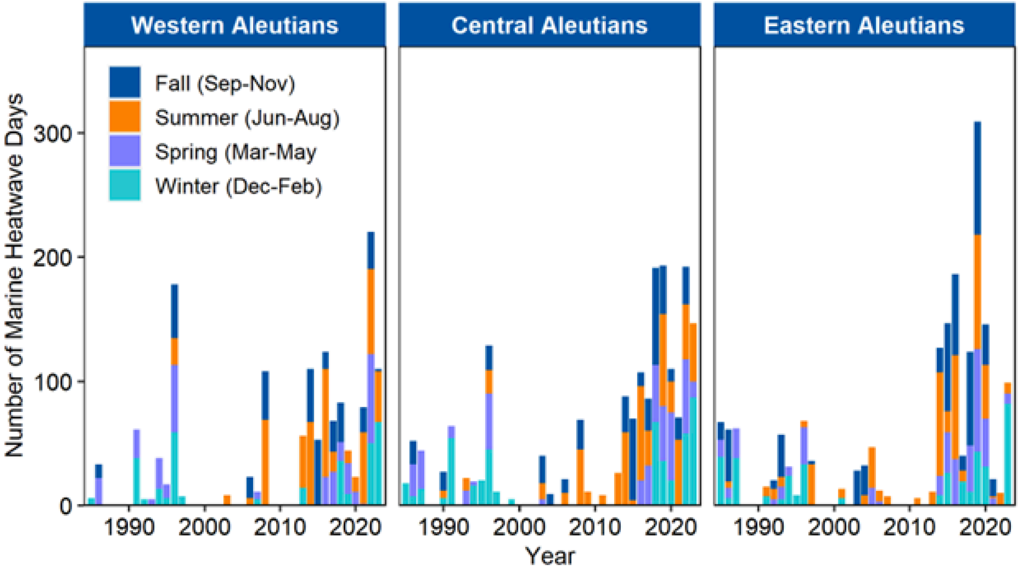
- Past models used the von Bertalanffy growth curve.
- The Richards growth curve improved the fit to the data.

Features	M24.1 (Richards)	M24.1a (Von Bertalanffy)
2024 Params (X)/Alt. Params (0)		
M timeblock 2016-2024/ None	X	X
Richards Growth/ von B growth	X	0
Results		
TOTAL_like	534.148	547.266
Survey_like	-8.87	-7.606
Length_comp_like	140.884	133.085
Age_comp_like	402.559	420.1
Recruitment_like_thousands	-0.43	0.608
Recr_Virgin_millions	80.596	75.858
SR_BH_steep	1	1
Natural mortality	0.417	0.417
NatM_BLK2repl_2016	0.572	0.564
SmryBio_unfished	247,377	228,381
SSB_Virgin_thousand_mt	200.904	183.868
SSB_2024_thousand_mt	50.537	46.708
Bratio_2024	0.252	0.254
SPRratio_2024	0.188	0.165
Ret_Catch_MSY	31,133	29,262
SR_LN(R0)	11.2972	11.2366
Survey catchability (q)	0.87	0.961
Size_DblN_peak_FshComb(1)	101.037	107.458
Size_DblN_top_logit_FshComb(1)	25	25
Size_DblN_ascend_se_FshComb(1)	6.636	6.754
Size_DblN_peak_Srv(2)	69.729	73.635
Size_DblN_ascend_se_Srv(2)	6.519	6.712
Number of parameters	55	54
AIC	1178.296	1202.532

Note improvements in age comp likelihood, survey, and total likelihood

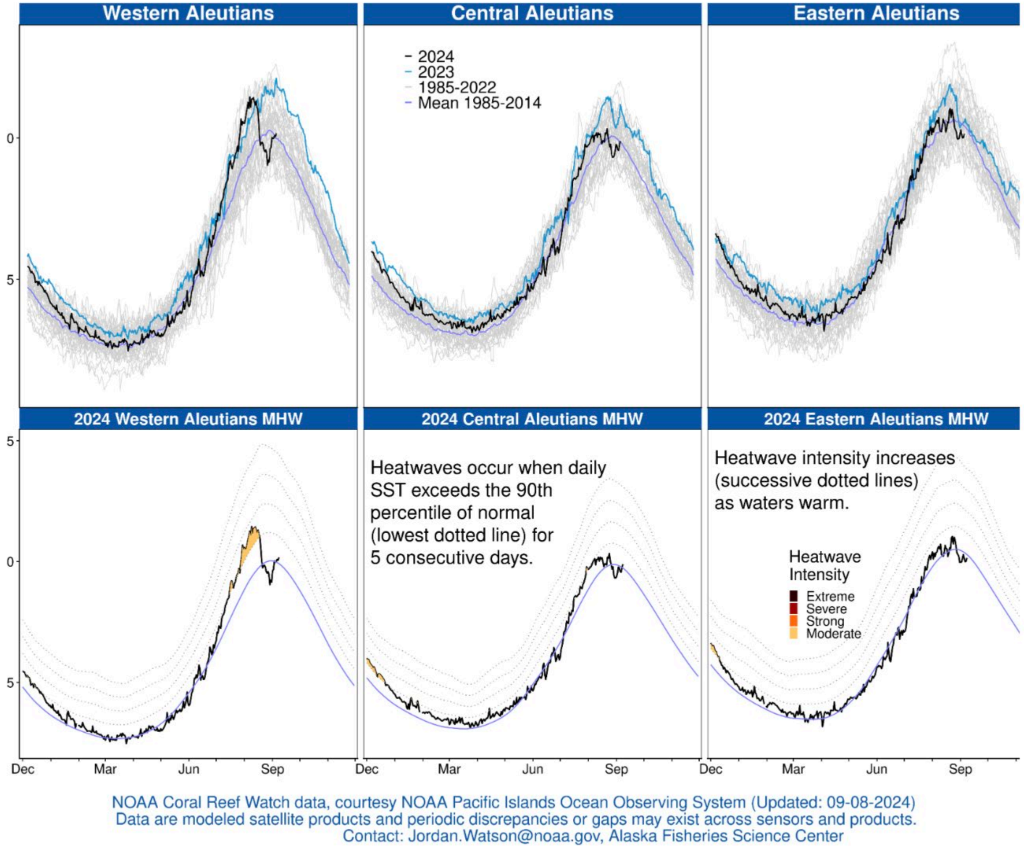
Natural mortality timeblock: The number of days under heatwave conditions for the western, central, and eastern Aleutian Islands has increased since 2014

Number of days during which marine heatwave conditions persisted in a given year. Seasons are summer (Jun–Aug), fall (Sept – Nov), winter (Dec – Feb), spring (Mar – Jun). Years are shifted to include complete seasons so December of a calendar year is grouped with the following year to aggregate winter data (e.g., Dec 2020 occurs with winter of 2021). Data extends through Sep 2, 2023.



Natural mortality timeblock: In 2024 there were several short periods considered heatwave conditions in the Aleutian Islands, but less than in previous years

Lemagie and Callahan satellite derived SST & MHW

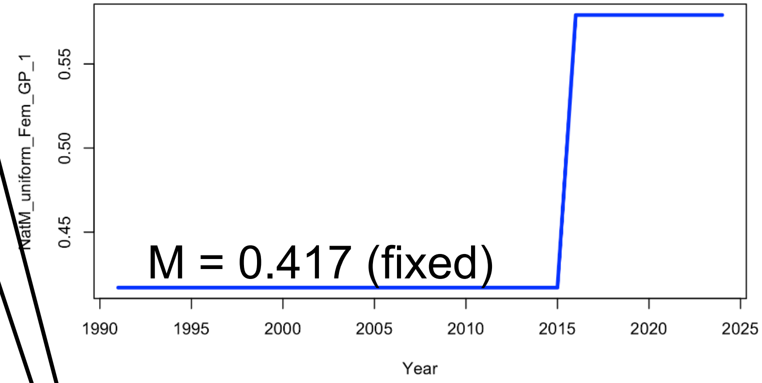


Lemagie, E. and M. Callahan. 2024. Regional Sea Surface Temperature and Marine Heatwaves. In: Ortiz, I. and S. Zador. 2024. Ecosystem Status Report 2024: Aleutian Islands, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West 3rd Ave., Suite 400, Anchorage, Alaska 99501.

Natural mortality timeblock improves multiple aspects of the fit to the data

Features	M24.1	M24.0
2024 Params (X)/Alt. Params (0)		
M timeblock 2016-2024/ None	X	0
Richards Growth/ von B growth	X	X
Results		
TOTAL_like	534.148	544.019
Survey_like	-8.87	-1.241
Length_comp_like	140.884	140.844
Age_comp_like	402.559	403.169
Recruitment_like_thousands	-0.43	0.355
Recr_Virgin_millions	80.596	62.969
SR_BH_steep	1	1
Natural mortality	0.417	0.417
NatM_BLK2repl_2016	0.572	NA
SmryBio_unfished	247,377	193,473
SSB_Virgin_thousand_mt	200.904	157.101
SSB_2024_thousand_mt	50.537	55.314
Bratio_2024	0.252	0.352
SPRratio_2024	0.188	0.197
Ret_Catch_MSY	31,133	24,372
SR_LN(R0)	11.2972	11.0504
Survey catchability (q)	0.87	0.931
Size_DblN_peak_FshComb(1)	101.037	102.345
Size_DblN_top_logit_FshComb(1)	25	25
Size_DblN_ascend_se_FshComb(1)	6.636	6.681
Size_DblN_peak_Srv(2)	69.729	68.749
Size_DblN_ascend_se_Srv(2)	6.519	6.54
Number of parameters	55	54
AIC	1178.296	1196.038

M = 0.570 (estimated)



Note improvements in total likelihood, survey likelihood, age comp likelihood, recruitment likelihood age comp likelihood and AIC

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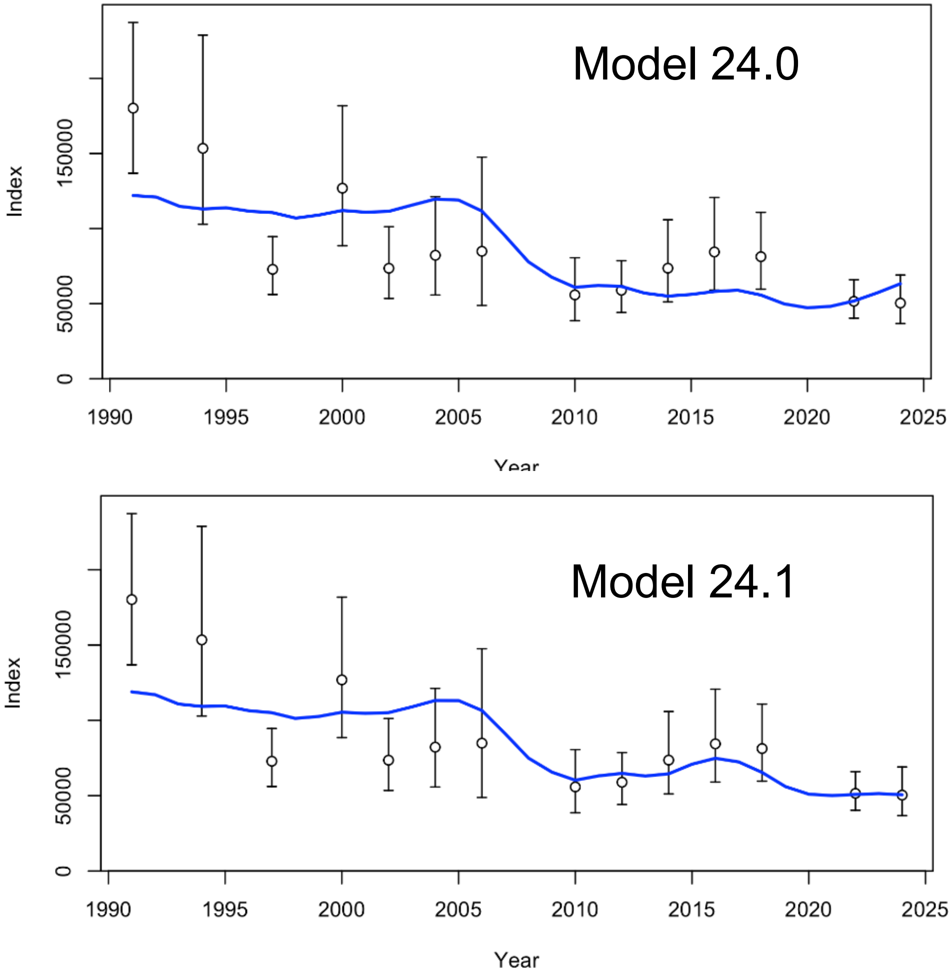
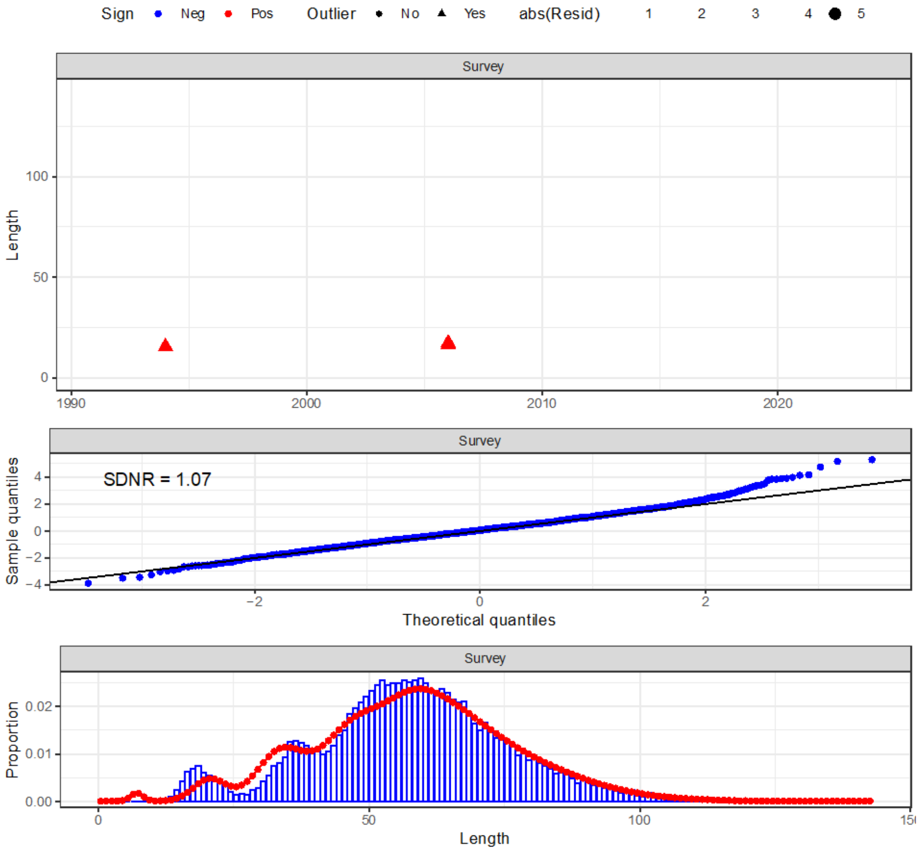
Model 24.0 (upper panel) and Model 24.1 (lower panel) fit to survey index, 1991 - 2024



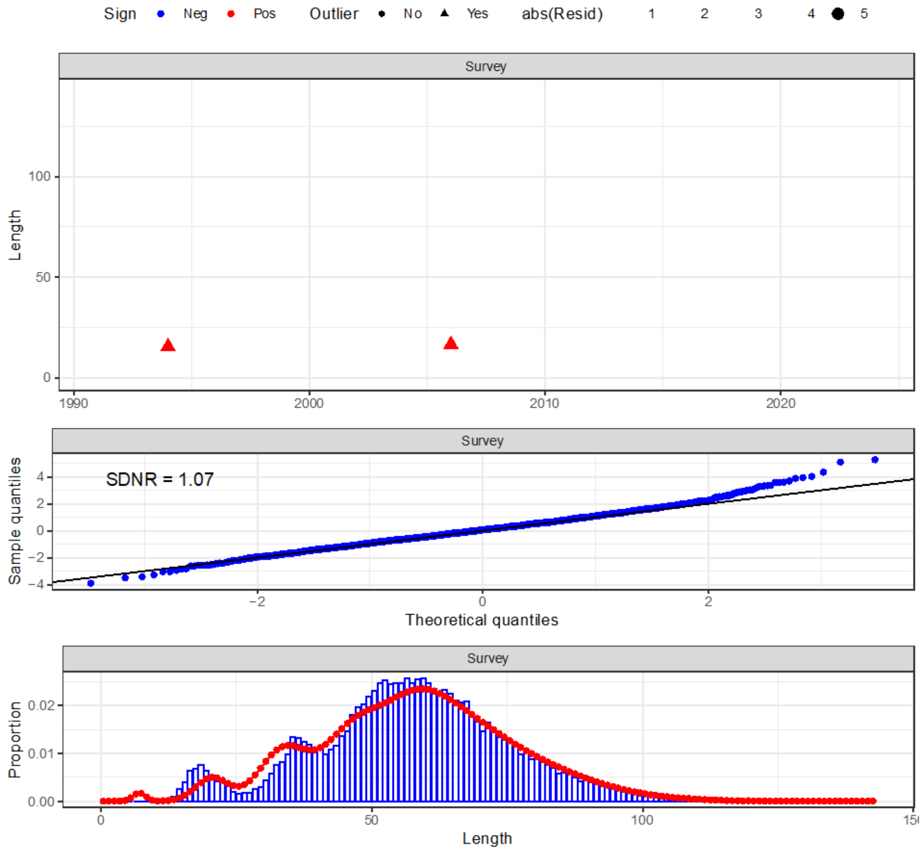
Model diagnostics

One-step-ahead residuals, survey

Model 24.1

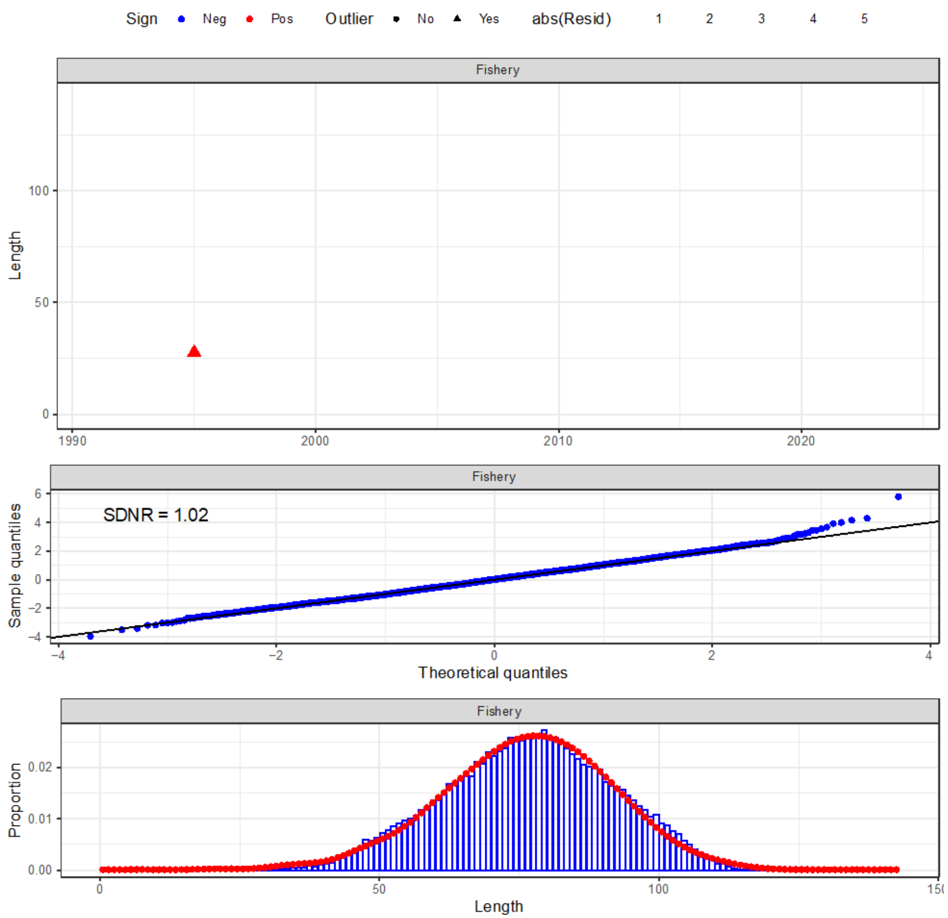


Model 24.0

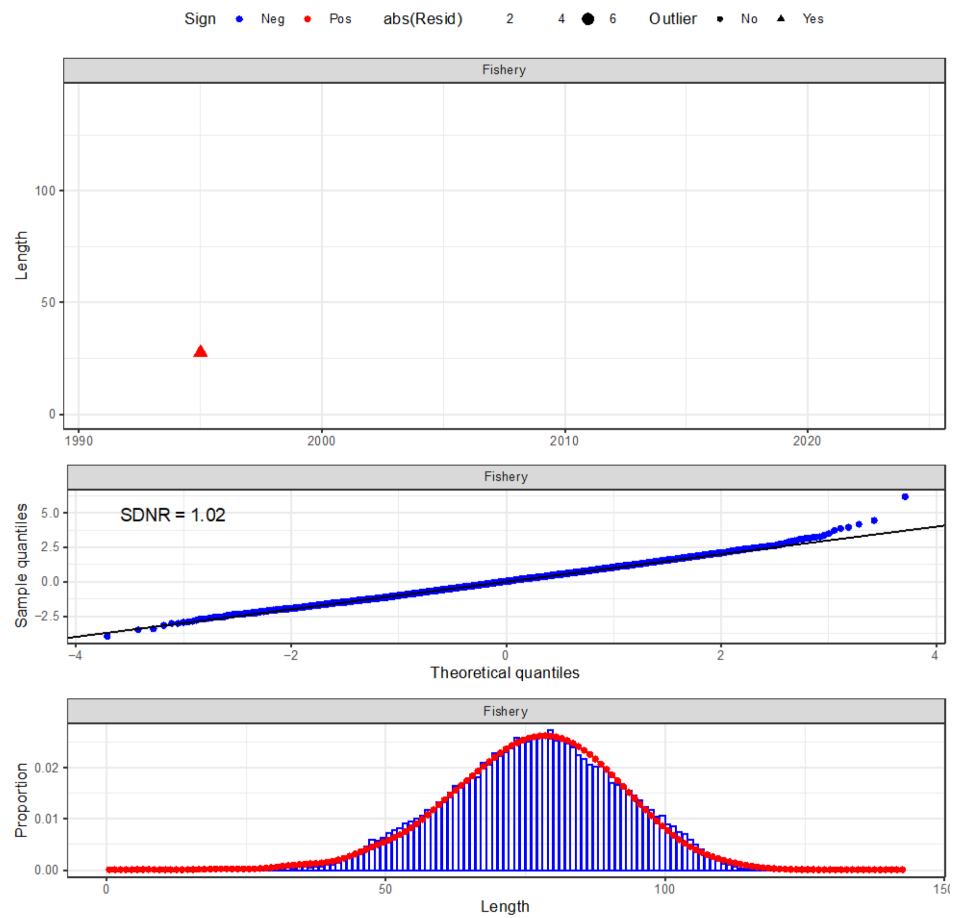


One-step-ahead residuals, fishery

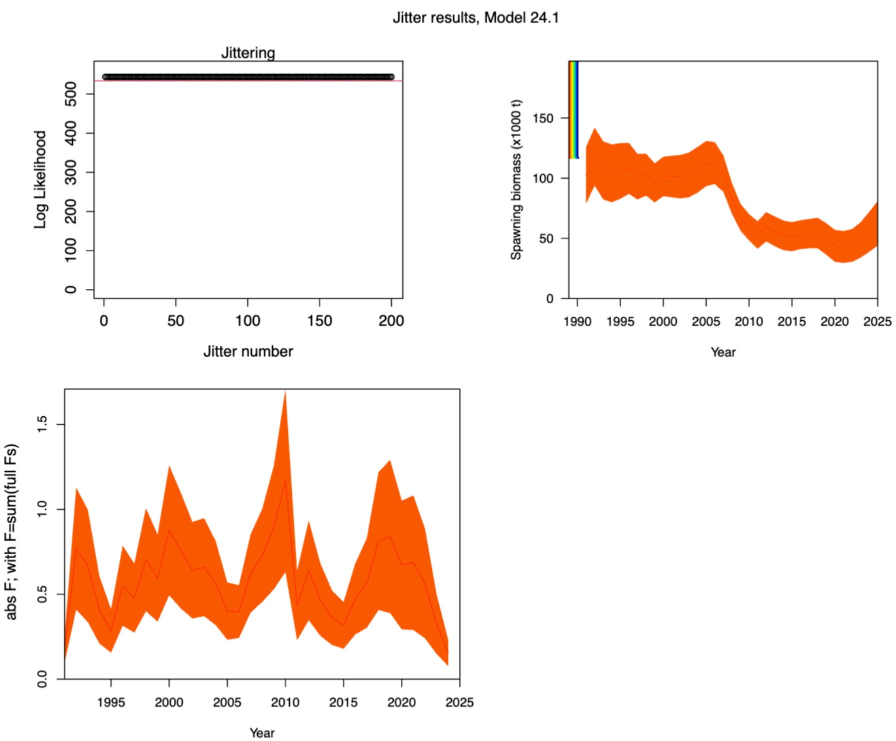
Model 24.1



Model 24.0



The Model 24.1 jitter diagnostic for global convergence conducted on the Aleutian Islands Pacific cod assessment. (10%)

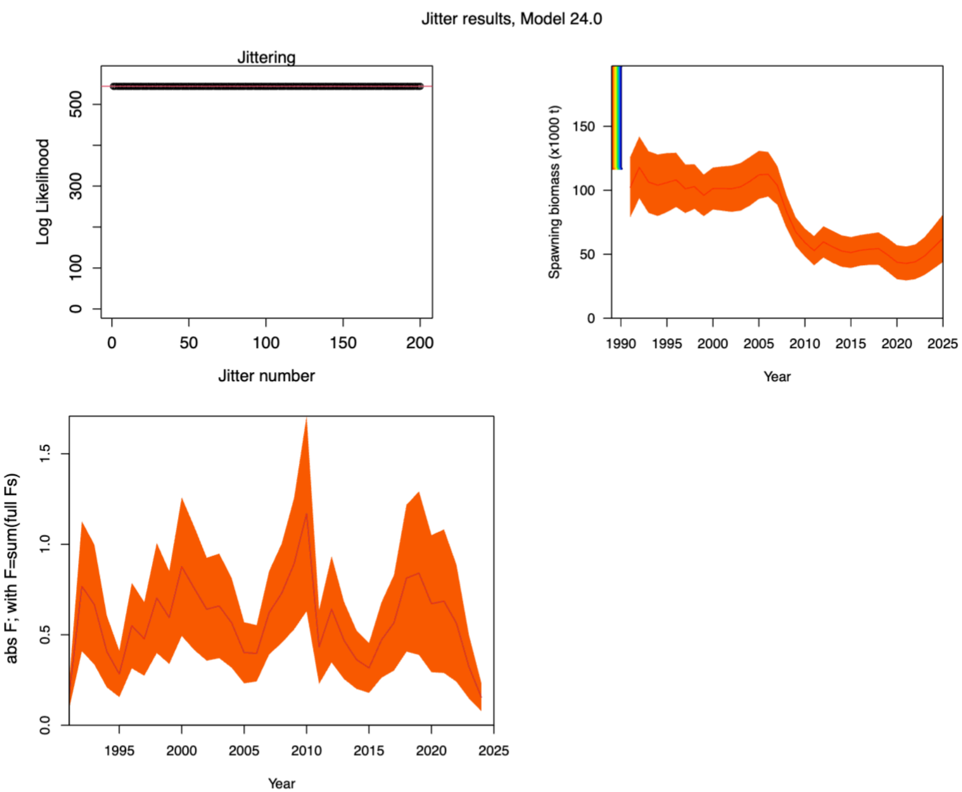


- Upper left: solid black circles represent the total likelihood obtained from 200 jittered model runs and the red horizontal dashed line represents the total likelihood value from the base-case model.

- Upper right: spawning stock biomass (SSB) from jittered model runs.

- Lower panel: the estimate of absolute fishing mortality, F, with F=sum(full Fs).

The Model 24.0 jitter diagnostic for global convergence conducted on the Aleutian Islands Pacific cod assessment. (10%)



- Upper left: solid black circles represent the total likelihood obtained from 200 jittered model runs and the red horizontal dashed line represents the total likelihood value from the base-case model.
- Upper right: spawning stock biomass (SSB) from jittered model runs.
- Lower panel: the estimate of absolute fishing mortality, F, with F=sum(full Fs).

Forecasting

Forecasting should always use base natural mortality

Model 24.1

Time-varying parameters:	Constant parameters:
Natural mortality	Selectivity Growth Recruitment

Model 24.0

Time-varying parameters:	Constant parameters:
	Selectivity Growth Recruitment Natural mortality

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Climate mortality should not be used for forecasting.

Natural mortality
+ Fishing mortality
Total mortality

Natural mortality
Fishing mortality
+ Climate mortality
Total mortality

Image credit: ParabolStudio | Shutterstock.com)

Forecasting for all models done with base parameters.

Model 24.1

Time-varying parameters:	Constant parameters:
Natural mortality (2016 – 2024)	Recruitment Growth Selectivity Natural mortality base value

Model 24.0

Time-varying parameters:	Constant parameters:
None	Recruitment Growth Selectivity Natural mortality base value

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Forecasting for all models done with base parameters.

- Model 24.1 forecasts performed using the base value of natural mortality from 1991-2015, 0.417.
- Forecasts used mean recruitment, selectivity, growth over all years they were estimated.

Risk Table

Assessment considerations

- Currently categorized as Tier 5 (requiring reliable biomass estimate and estimate of M).
- We prefer the SSC adopt the age-structured assessment model (24.1) using Tier 3 because of

1. Available estimates of recruitment, biomass, and SPR rates.
2. Tier 3 allows Council to be informed on the status determination of the stock.

Therefore, assessment concerns are level 1, no concern.

Population dynamics considerations

- The long-term (1991-2024) trawl survey biomass trend is downward
- The 2024 index is the lowest of the time series.
- Research indicates that Aleutian Islands cod have do not move out of the region and it is unlikely that the decline is due to emigration.

Therefore, population dynamics considerations were rated as level 2

Environmental/Ecosystem Considerations

- Despite the cooler temperatures, and good quality small pollock, the fish condition of cod stayed similar to that in 2022 as opposed to continue to improve.
- This together with continued warm winter and potentially suboptimal foraging conditions in the western Aleutians suggests adverse signals relevant to the stock, but the pattern is not consistent across all areas.

Environmental/ ecosystem considerations were rated as level 2 (multiple indicators showing consistent adverse signals across the same trophic level).

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Fishery performance

- Market considerations, vessels selective about fishing locations to maximize CPUE.
- Reduced catch unlikely to be a negative indicator.

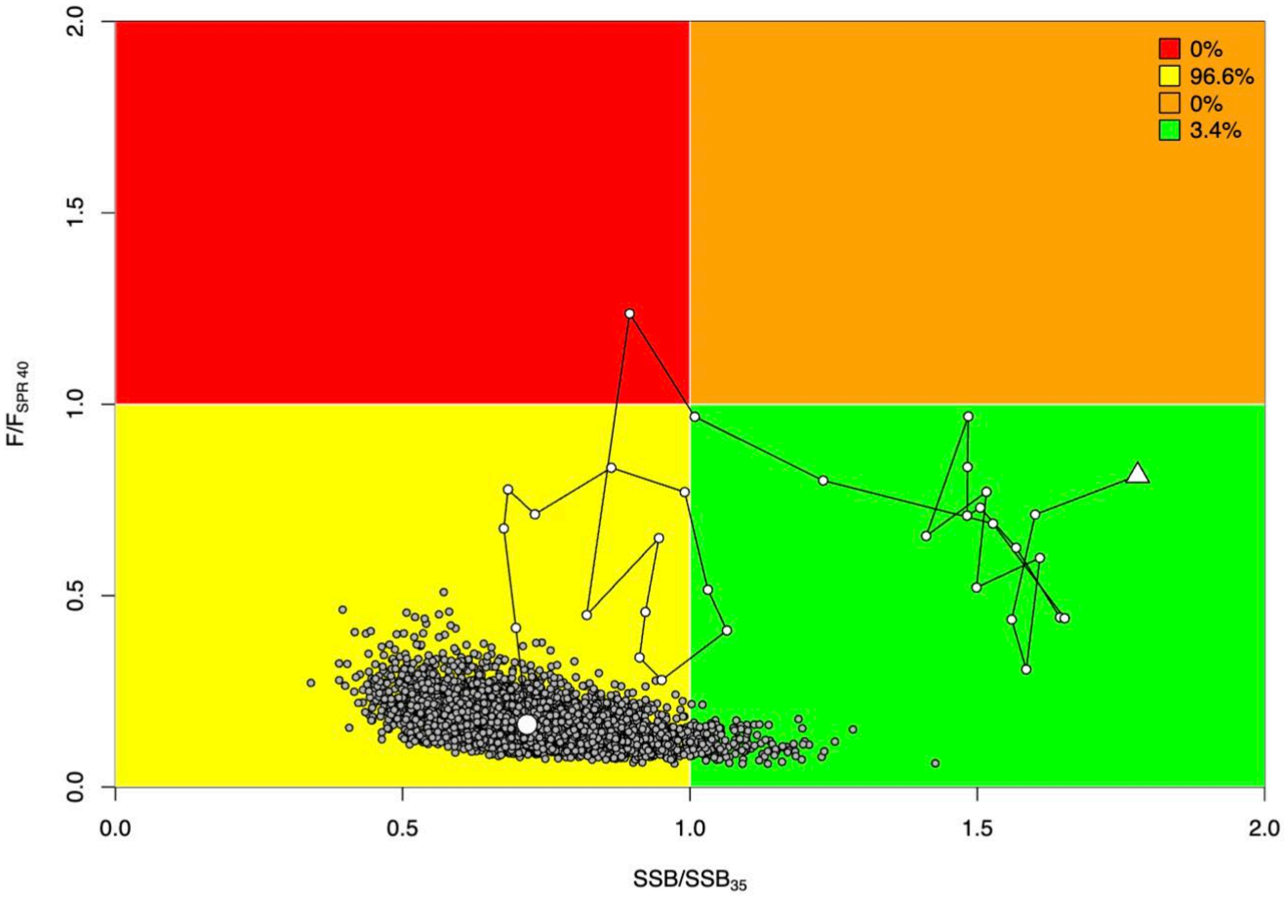
Fishery performance considerations were rated as level 1

Risk Table

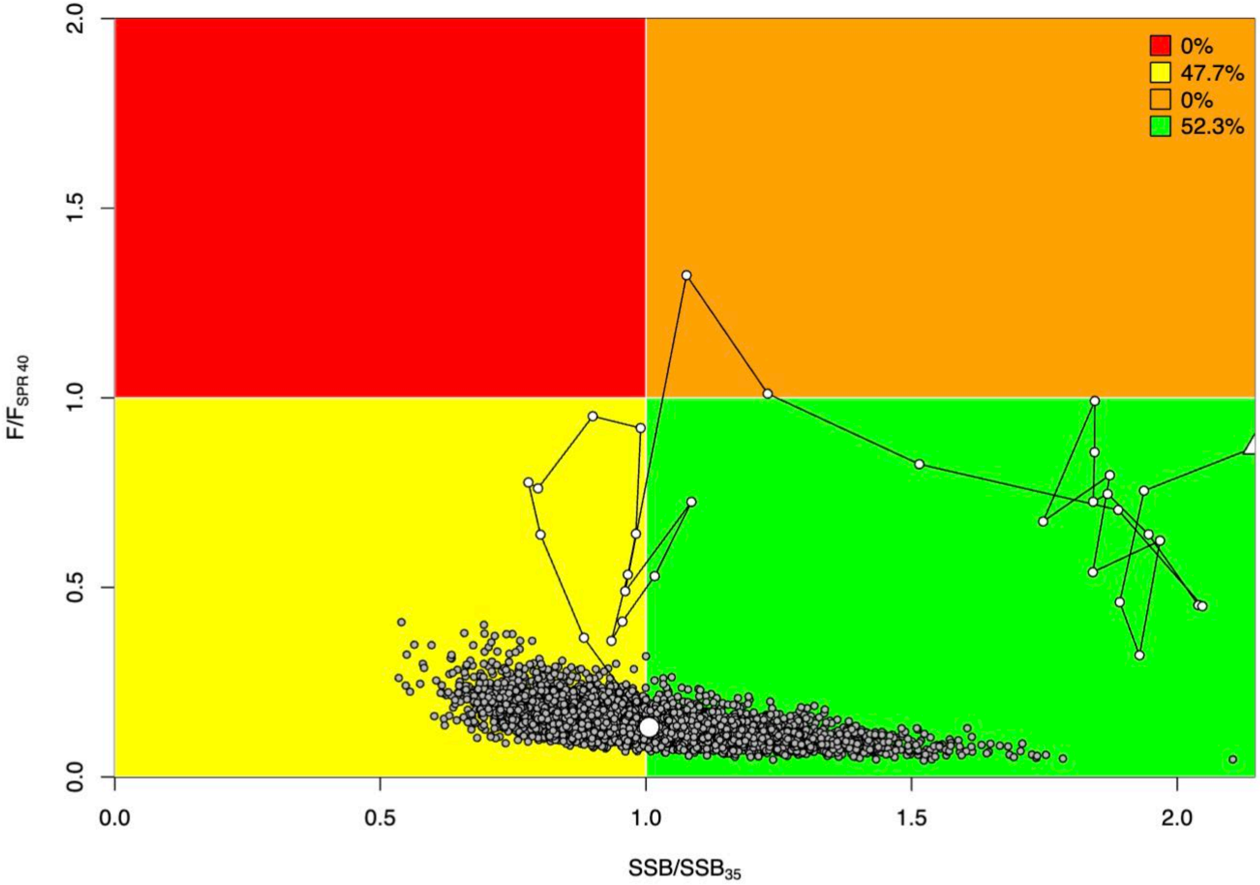
Assessment consideration	Population dynamics	Environmental ecosystem	Fishery performance
Level 1: Normal	Level 2: Increased concerns	Level 2: Increased concerns	Level 1: Normal

Results

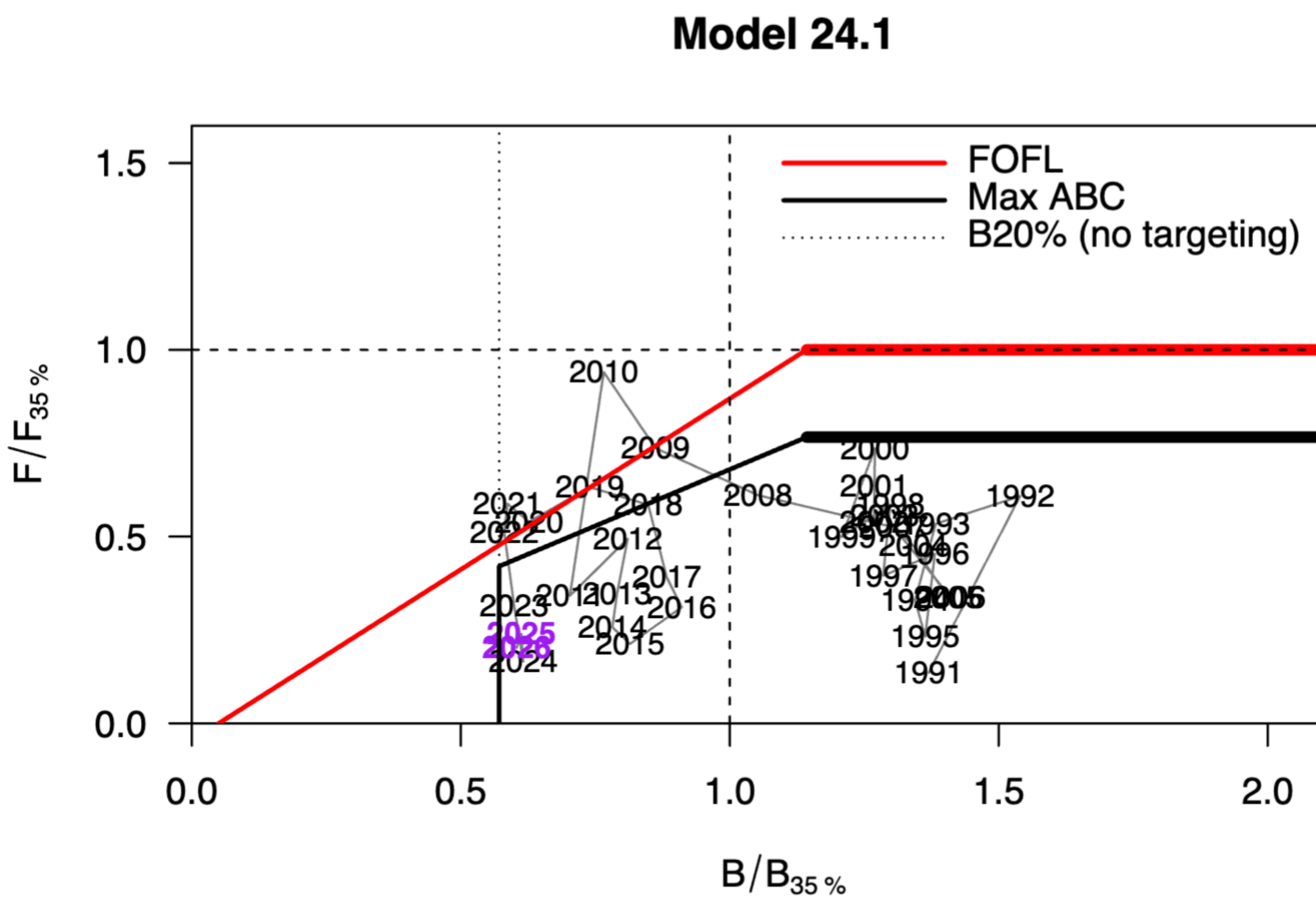
A Kobe plot for Model 24.1 indicates a 97.6% probability that the stock status is between $SSB_{8\%}$ and $SSB_{35\%}$, and that the fishing mortality rate is below $F_{40\%}$.



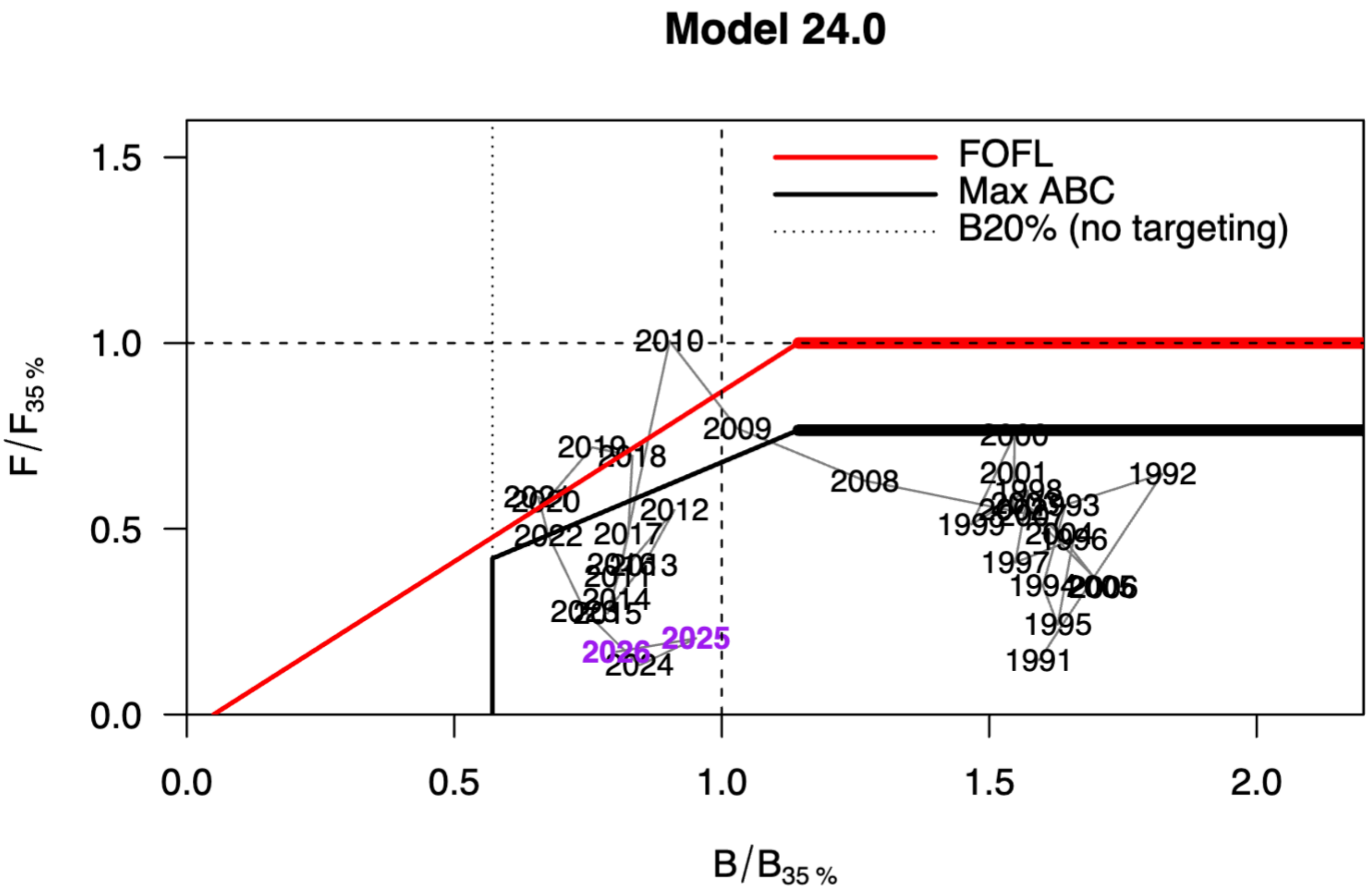
A Kobe plot for Model 24.1 indicates a 47.7% probability that the stock status is between $SSB_{17.5\%}$ and $SSB_{35\%}$, 52.3% probability that the stock status is greater than $SSB_{35\%}$.



Phase plane diagram for Model 24.1



Phase plane diagram for Model 24.0



Tier 5 model comparison

	Model 13.4 (2023) As estimated or *specified* *last* year for:		Model 13.4 As estimated or *recommended* *this* year for:		Model 24.2 As estimated or *recommended* *this* year for:	
Quantity	2024	2025	2025	2026	2025	2026
M	0.34	0.34	0.34	0.34	0.417	0.417
Tier	5	5	5	5	5	5
Biomass (t)	54,165	54,165	51,503	51,503	51,503	51,503
F_{OFL}	0.34	0.34	0.34	0.34	0.417	0.417
$maxF_{ABC}$	0.255	0.255	0.255	0.255	0.313	0.313
F_{ABC}	0.255	0.255	0.255	0.255	0.313	0.313
OFL	18,416	18,416	17,511	17,511	21,477	21,477
$maxABC$	12,431	12,431	13,133	13,133	16,107	16,107
ABC	12,431	12,431	13,133	13,133	13,376	12,973
Status	2022	2023	2023	2024	2023	2024
Overfishing	No	n/a	No	n/a	No	n/a

13,376 t and 12,973 t were used in place of the Model 24.2 ABCs for 2025 and 2026. These value are the Model 24.1 ABCs for 2025 and 2026.

Tier 3 models

	Model 24.1		Model 24.1a		Model 24.0	
Quantity	2025	2026	2025	2026	2025	2026
M (natural mortality rate)	0.42, 0.57*	0.42, 0.57*	0.42, 0.56*	0.42, 0.56*	0.42	0.42
Tier	3	3	3	3	3	3
Projected total (age 1+) biomass (t)	73,679	77,731	70,151	74,284	89,608	83,115
Projected female spawning biomass (t)	25,078	24,729	23,410	23,148	31,388	26,475
$B_{100\%}$	102,361	102,361	94,685	94,685	82,429	82,429
$B_{40\%}$	40,944	40,944	37,873	37,873	32,971	32,971
$B_{35\%}$	35,826	35,826	33,139	33,139	28,850	28,850
F_{OFL}	0.655	0.645	0.959	0.947	1.088	0.909
$maxF_{ABC}$	0.502	0.494	0.719	0.71	0.833	0.494
F_{ABC}	0.502	0.695	0.719	0.71	0.833	0.695
OFL	16,782	16,273	17,037	16,541	31,205	22,230
$maxABC$	13,376	12,973	13,399	13,021	25,439	17,925
ABC	13,376	12,973	13,399	13,021	25,439	17,925
Status	2023	2024	2023	2024	2023	2024
Overfishing	No	n/a	No	n/a	No	n/a
Overfished	n/a	No	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No	n/a	No

Summary table with a comparison of proposed 2024 Model 24.1

Quantity	As estimated or *specified* *last* year for: 2024	2025	As estimated or *recommended* *this* year for: 2025	2026
M (natural mortality rate)	0.34	0.34	0.42, 0.57*	0.42, 0.57*
Tier	5	5	3b	3b
Projected total (age 1+) biomass (t)	54,165	54,165	73,679	77,731
Projected female spawning biomass (t)	-	-	25,078	24,729
$B_{100\%}$	-	-	102,361	102,361
$B_{40\%}$	-	-	40,944	40,944
$B_{35\%}$	-	-	35,826	35,826
F_{OFL}	0.34	0.34	0.655	0.645
$maxF_{ABC}$	0.255	0.255	0.502	0.494
F_{ABC}	0.255	0.255	0.502	0.494
OFL	18,416	18,416	16,782	16,273
$maxABC$	12,431	12,431	13,376	12,973
ABC	12,431	12,431	13,376	12,973
Status	2022	2023	2023	2024
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 2016-2024.