Bering Sea Pacific Cod Stock Assessment Development for September 2024

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Supplementary information:
Github website for September 2024 BS Pcod
Appendix 1: September 2024 Models.zip
Appendix 2: Supplementary Figures.pdf
Note: Links provided in document for each model contain the full r4ss plots e.g. Model 24.6.0

1.0 Introduction

For 2024 we will be exploring minor model modifications to improve model efficiency and meet SSC requests. For this stock assessment cycle, we explored four modifications to Model 23.1.0.d:

1) Bin Size Analysis: Model 23.1.0.d includes VAST derived survey indices and age compositions, but not length compositions due to the computational burden required and limited time to create the estimates at the 1 cm size bins. We explore larger bin sizes for length composition data in order to employ VAST derived size compositions. Model 23.1.0.d from last year and all previous models use 1 cm bins resulting in 119 bins. In addition, it is expected that aggregating the data may result in more stable models as aggregating data into larger bin sizes results in less noisy data due to aggregation. We therefore propose reducing the number of bins by increasing the bin size. Here we explore 3 cm and 5 cm bins, reducing the number of bins to 40 and 24, down from 119.
2) Non-time varying survey selectivity: we explore the consequences of static, rather than annually varying survey selectivity.
3) Conditional age-at-length: In order to incorporate fisheries age data into the model, as per a longstanding request by the SSC, we added conditional age at length (CAAL) data, both fishery and survey data, into the model. The inclusion of CAAL data should improve our annual growth estimations. Therefore, alternative growth models were explored alongside this addition.
4) Updated ageing error matrix: The aging error matrix was updated including the latest aging data.

2.0 Bin Size Analysis

A VAST derived length composition would allow for spatial autocorrelation in the biomass and age composition estimates, as opposed to simple raw composition data. Fewer size bins are required to incorporate VAST due to computational constraints. The currently accepted model employs 119, 1 cm length bins. At this bin size, the computational needs are significant and problematic due to the limited time available between data delivery and stock assessment delivery each year. In this analysis we examined different size bins in Model 23.1.0.d to evaluate how changing bin size would impact model performance and results. We compare last year's accepted model Model 23.1.0.d with 1 cm (119 bins), 3 cm (40 bins), and 5 cm (24 bins) length bins (Figure 1).

Results indicate that there is little difference among models with length composition data binned at 1 cm, 3 cm, and 5 cm (Table 1, Figure 2, and Figure 3). There is a minimal improvement in the fit to the survey with a lower negative log likelihood and RMSE as bin size is increased. Similarly, the RMSE for the length and age composition data decreases (improving the fit to the data) with increased bin size. Retrospective analysis shows minimal change, as did the runs test with fits to all data components passing the tests. There were minimal changes to the growth parameters fit in the model and a less than 0.1% difference in female spawning biomass among bin sizes.

To improve model performance and allow for the future use of VAST derived size composition data, we recommend the model change bin size from 1 cm bins to 5 cm bins. All further models discussed will be configured with data at 5 cm bins.

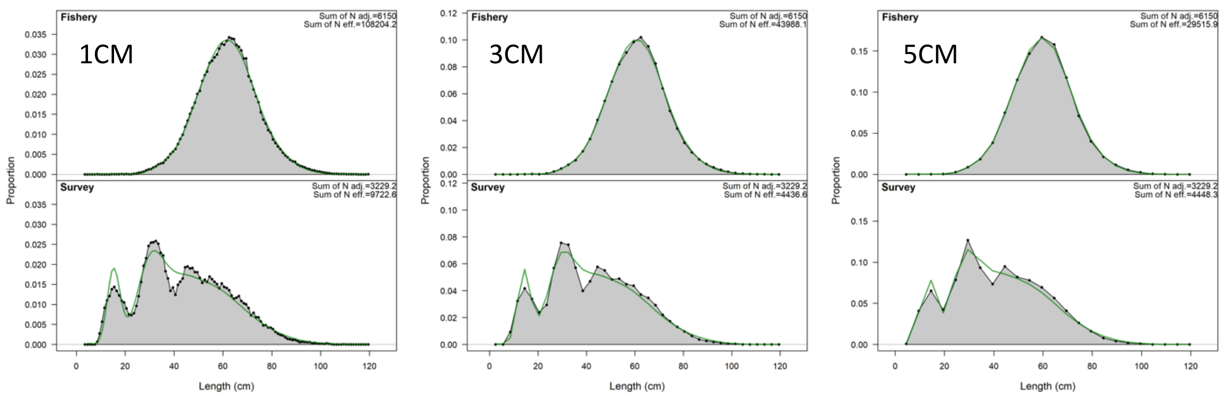

Figure 1 Length compositions, aggregated across time by fleet for 1 cm, 3 cm, and 5 cm bins with model fit (green line).

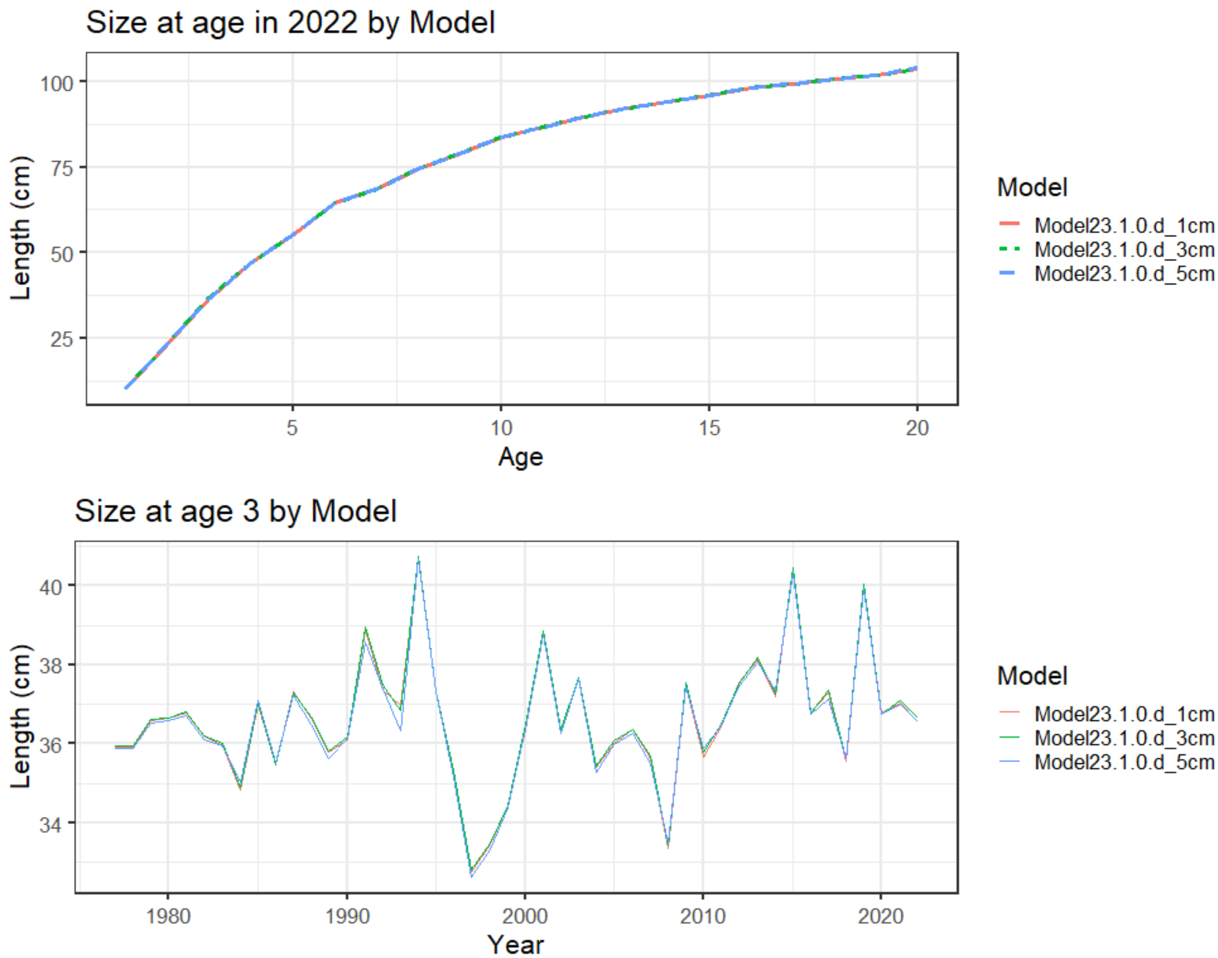

Figure 2 Model comparisons of length-at-age with (top) size-at-age in 2022 and (bottom) size over time-at-age 3 for Model 23.1.0.d with data binned at 1cm, 3cm, and 5cm. Lines are overlapping and not visually distinguishable.

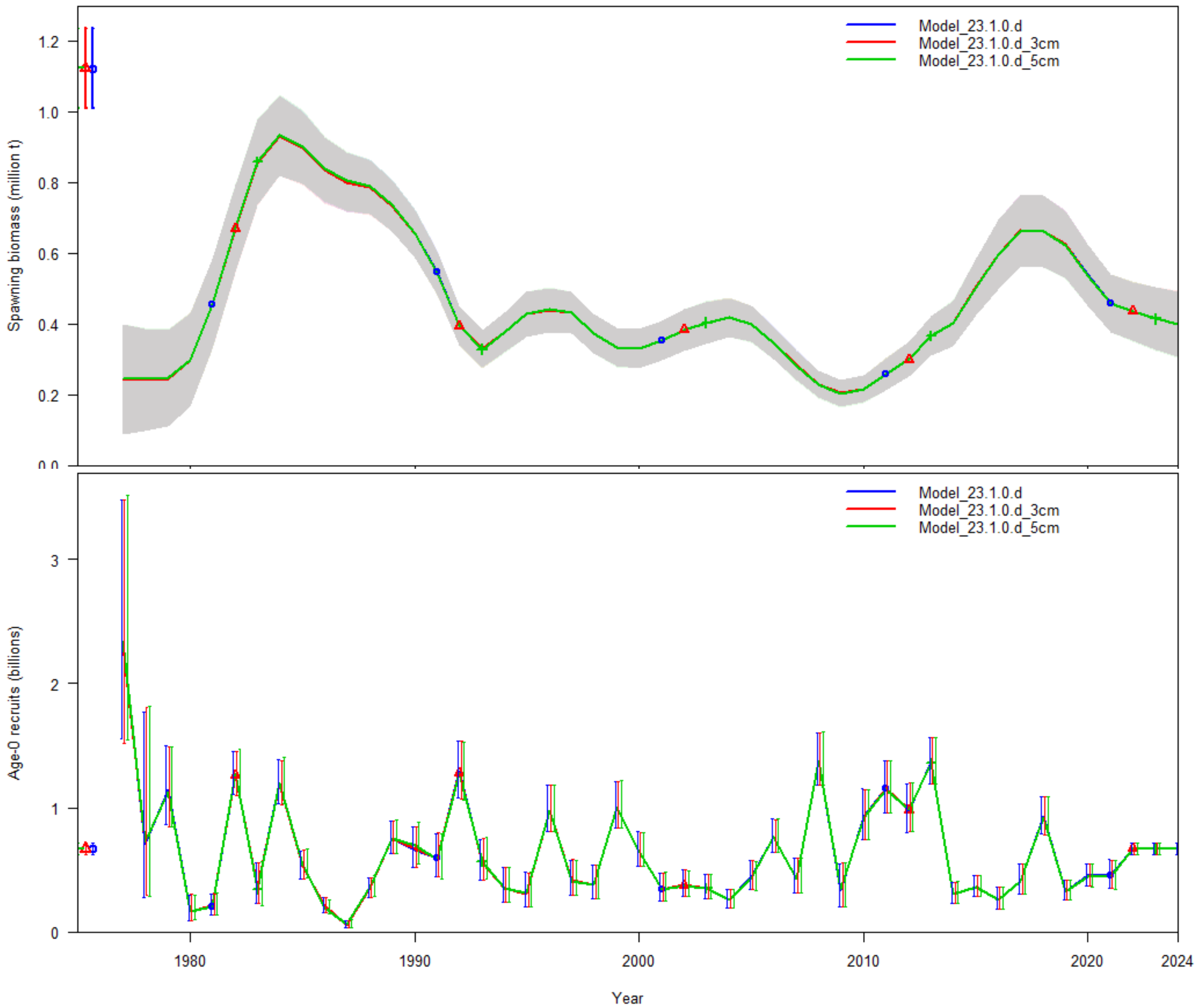

Figure 3 (Top) Comparisons of spawning biomass and (bottom) age-0 recruitment from Model 23.1.0.d with data binned at 1cm, 3cm, and 5cm.

Table 1 Comparison of Model 23.1.0.d results with data binned at 1cm, 3cm, and 5cm, Model 24.1.0 with non-time varying survey selectivity, and Model 24.2.0 with conditional-age-at-length.

	Model 23.1.0.d 1CM	**Model 23.1.0.d 3CM**	**Model 23.1.0.d 5CM**	**Model 24.1.0**	**Model 24.2.0**
	Last year's model	M23.1.0.d W/ 3cm length bins	M 23.1.0.d W/ 5cm length bins	M23.1.0.d 5CM W/static survey selectivity	M24.1.0 W/ CAAL
Parameters #	201	201	201	160	147
Likelihoods					
Total	350.77	292.71	246.93	258.64	813.80
Index	-79.51	-80.34	-80.57	-76.30	-42.39
Agecomp	94.74	93.78	92.04	91.71	491.00
Sizecomp	297.88	242.47	199.71	210.75	340.34
AIC	1103.5	987.4	895.9	837.3	1921.6
Retrospective					
Mohn's Rho	-0.0307	-0.0307	-0.0296	-0.0258	-0.050
Predictive Rho	-0.0804	-0.0812	-0.0801	-0.0759	-0.059
Runs test p-Value					
Index	0.982	0.982	0.982	0.929	1.00
Fishery Length	0.231	0.231	0.231	0.231	0.252
Survey Length	0.677	0.677	0.338	0.887	0.135
Survey Age	0.174	0.174	0.174	0.174	NA
RMSE					
Index	0.077	0.076	0.076	0.081	0.107
Input N/Har. Eff. N					
Fishery Length	130.9 /540.1	130.9/218.2	130.9/139.3	269.1 / 139.6	124.65/145.98
Survey Length	269.1 /610.5	269.1/243.9	269.1/170.6	130.9 / 141.8	62.05/58.92
Fishery Age					1.31/4.37
Survey Age	269.7/54.3	269.7/54.8	269.7/55.5	89.6 / 56.1	2.77/0.96
OSA SDNR					
Survey Age	0.96	0.96	0.96	0.96	
Survey Length	0.95	0.96	0.96	0.96	0.98
Fishery Length	1.08	1.08	1.07	1.07	1.08
Growth Parameters					
Lmin	14.542	14.438	14.202	14.047	13.61
Lmax	111.967	112.032	112.138	112.614	95.82
K	0.117	0.117	0.116	0.114	0.23
Richard's Rho	1.399	1.408	1.414	1.432	0.85
Survey Catchability					
	0.93	0.93	0.92	0.92	1.14
Derived Quantities					
Unfished SSB	573,675	574,200	573,695	572,660	558,755
F_{40}	0.38	0.38	0.38	0.38	0.36
Bratio 2023	0.36	0.36	0.36	0.37	0.38

3.0 Non-time Varying Survey Selectivity

Model 23.1.0.d allowed bottom trawl survey selectivity to vary annually (Figure 4), while Model 24.1.0 incorporates constant survey selectivity over time (Figure 5). While this change results in a slightly higher objective function, the AIC is lower due to the reduced number of pseudo-parameters by 41 (Table 1). Results were comparable between models with and without annually varying selectivity for the bottom trawl survey index (Figure 6) and retrospectives were marginally improved. We therefore recommend the simpler configuration for future model development. All further models presented will be configured with non-time varying selectivity for the bottom trawl survey.

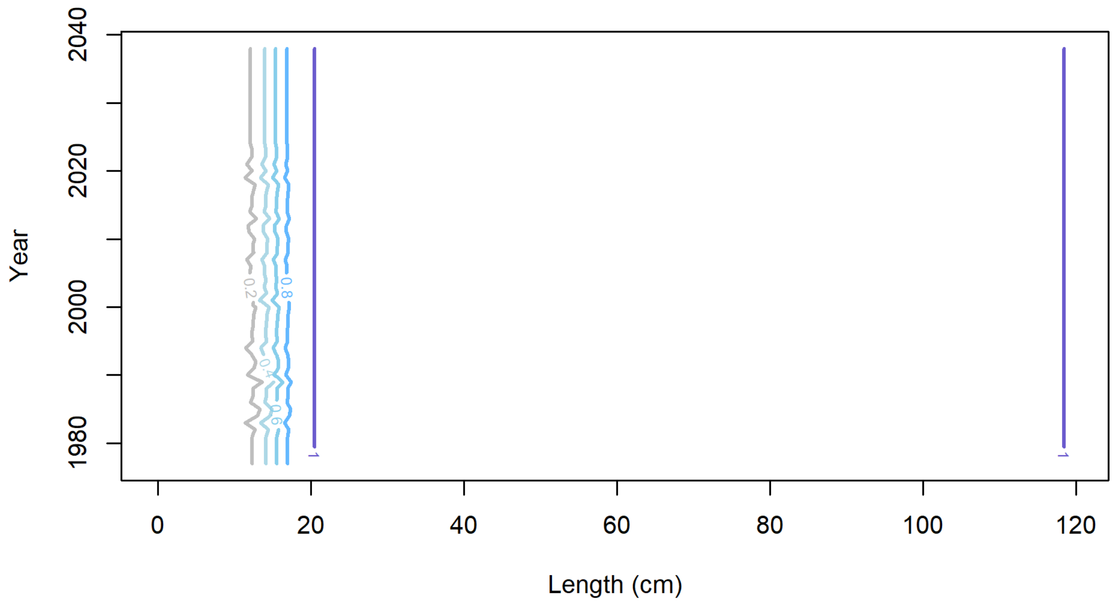

Figure 4 Bottom trawl survey index selectivity for Model 23.1.0.d showing annual variability.

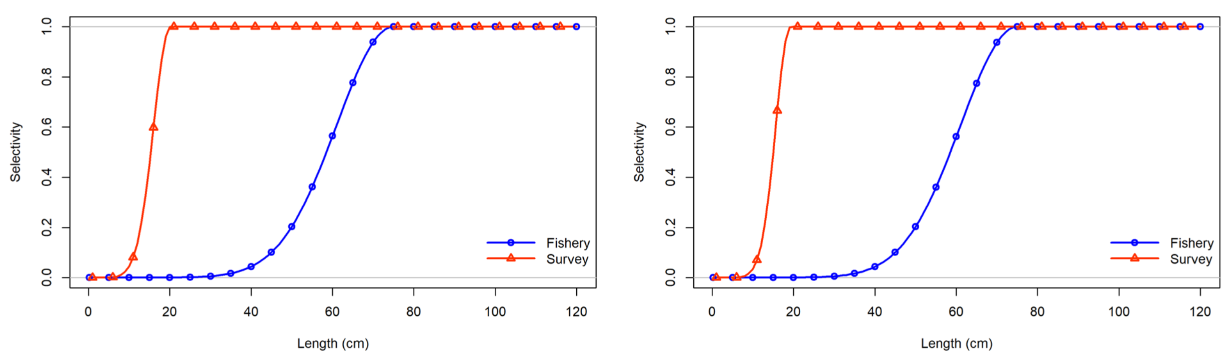

Figure 5 End year fishery and bottom trawl survey selectivity at length for (left) Model 23.1.0.d and (right) Model 24.1.0. Note that fishery selectivity was not changed between models.

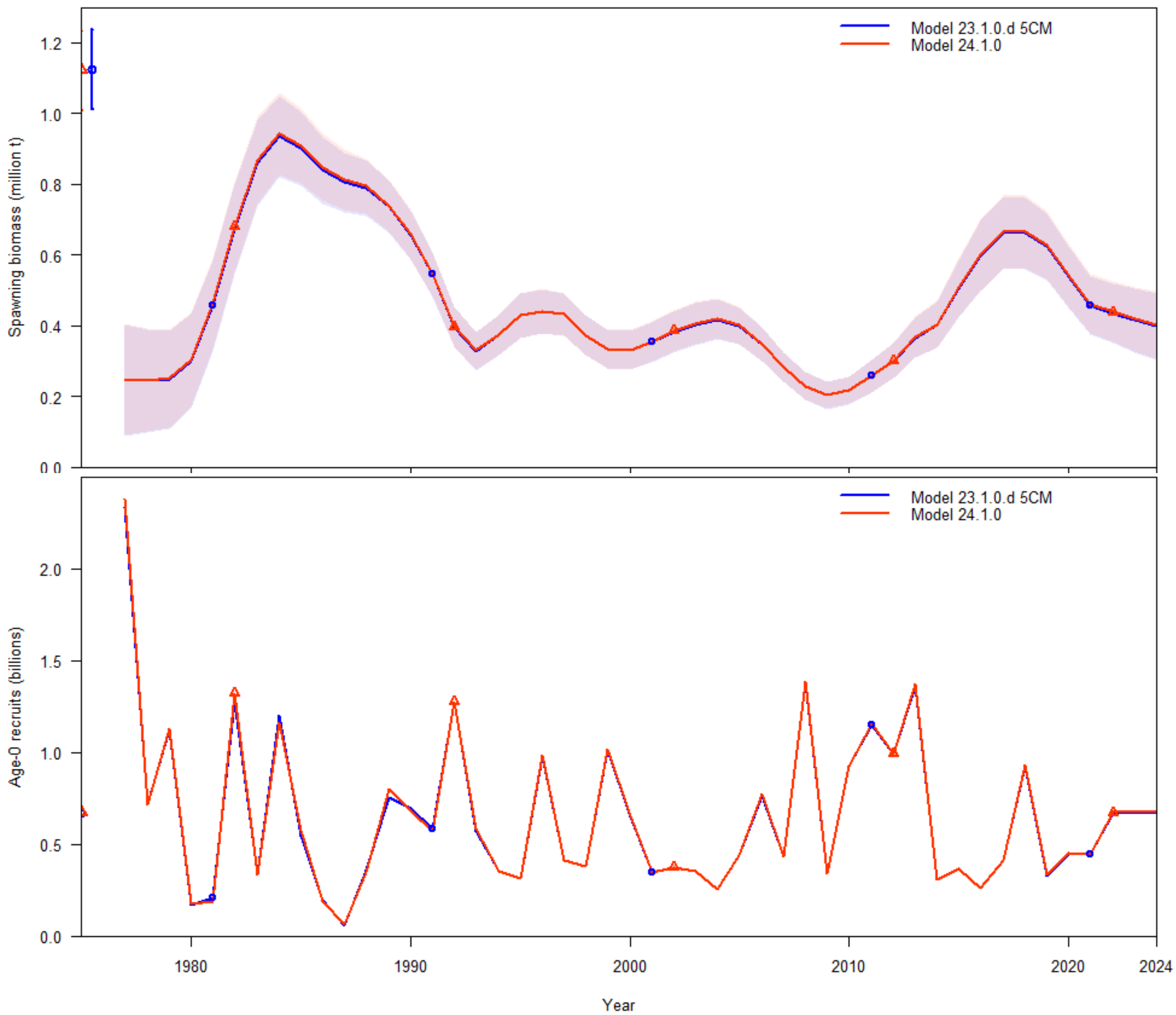

Figure 6 Comparison of (top) spawning biomass and (bottom) age-0 recruitment from Model 23.1.0.d 5CM and Model 24.1.0.

4.0 Survey and Fishery Conditional Age at Length

There are conditional age-at-length (CAAL) data available for the fishery from 2007-2022 (Figure 7) and for the bottom trawl survey for 2000-2023 (Figure 8). These are raw CAAL data, representing non-weighted estimates independent of CPUE or catch. In this use of the data it is assumed that the observer and survey collections were representative of the underlying populations (randomly selected). Under this assumption CAAL data should provide additional information on growth and should better inform annually varying growth within the model. Input sample size are nominal sample sizes, defined as the number of individual samples by year and size bin. For all the models using CAAL we included all of the available length composition data, but excluded the 1994-2023 marginal age composition data to prevent double use of data.

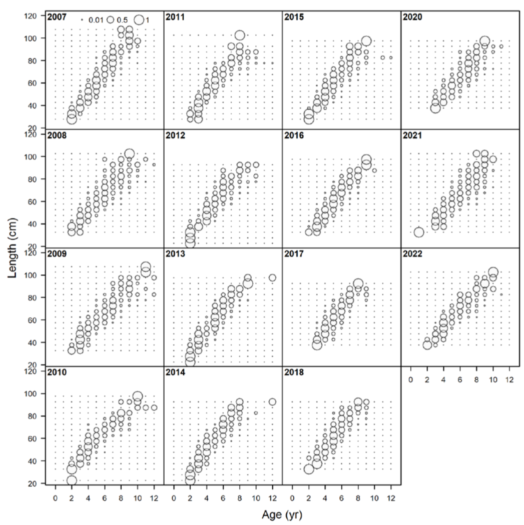

Figure 7 Fishery conditional age-at-length data for 2007-2022 in 5cm bins.

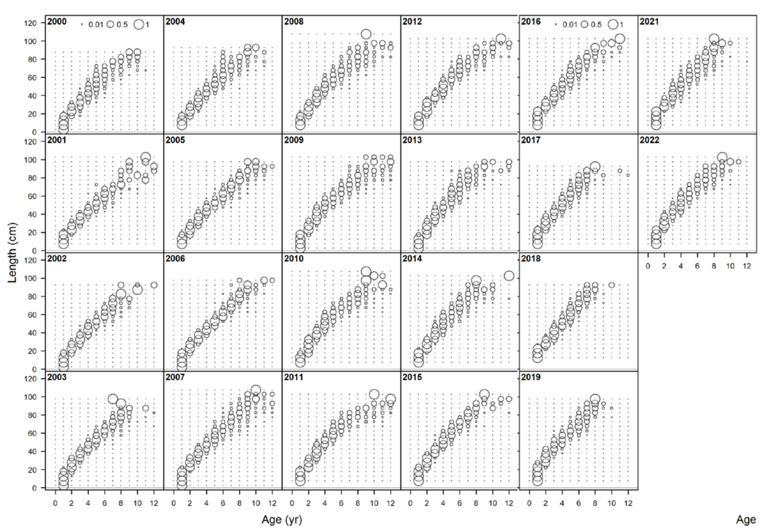

Figure 8 Bottom trawl survey conditional age-at-length data for 2000-2022 in 5cm bins.

4.1 Model 24.2.0

Model 24.2.0 uses the same configuration as Model 24.1.0, but incorporates CAAL data and retuned the model using the *tune_comps* function in the r4ss library which employs the TA1.8 method from Francis (2011) to adjust to the addition of CAAL data (Table 2). Because of the change in data and weighting, comparison between the overall likelihoods is not useful; however, the index likelihood and RMSE of the index are comparable (Table 1) and show a marked degradation in fit from Model 24.1.0. Model 24.2.0 fit to the survey is worse (Figure 9) compared to the previous models without CAAL.

Table 2 New model configurations evaluated.

Model	CAAL		Input variance adjustments factors*				σ_R	σ		
	Survey	Fishery	LFish	LSurv	A Fish	ASurv		L_{min}	K	Richards
M24.1.0	N	N	0.078	0.179	NA	0.332	0.7381	0.473	NA	0.116
M24.2.0	Y	Y	0.075	0.027	0.012	0.037	0.7381	2.000	NA	0.200
M24.2.1	Y	N	0.075	0.027	NA	0.037	0.7381	2.000	NA	0.200
M24.3.0	Y	Y	0.075	0.027	0.012	0.037	0.7381	2.000	0.200	NA
M24.3.1	Y	N	0.075	0.027	NA	0.037	0.7381	2.000	0.200	NA
M24.4.0	Y	Y	0.074	0.035	0.010	0.061	0.7381	2.000	0.200	NA
M24.4.1	Y	N	0.077	0.035	NA	0.063	0.7381	2.000	0.200	NA
M24.5.0	Y	Y	0.073	0.034	0.010	0.064	0.6404	0.370	0.149	NA
M24.5.1	Y	N	0.081	0.038	NA	0.055	0.6642	0.367	0.149	NA
M24.6.0	Y	Y	0.081	0.043	0.059	0.005	0.5917	0.391	0.165	NA
M24.6.1	Y	N	0.094	0.068	NA	0.007	0.8043	0.528	0.213	NA

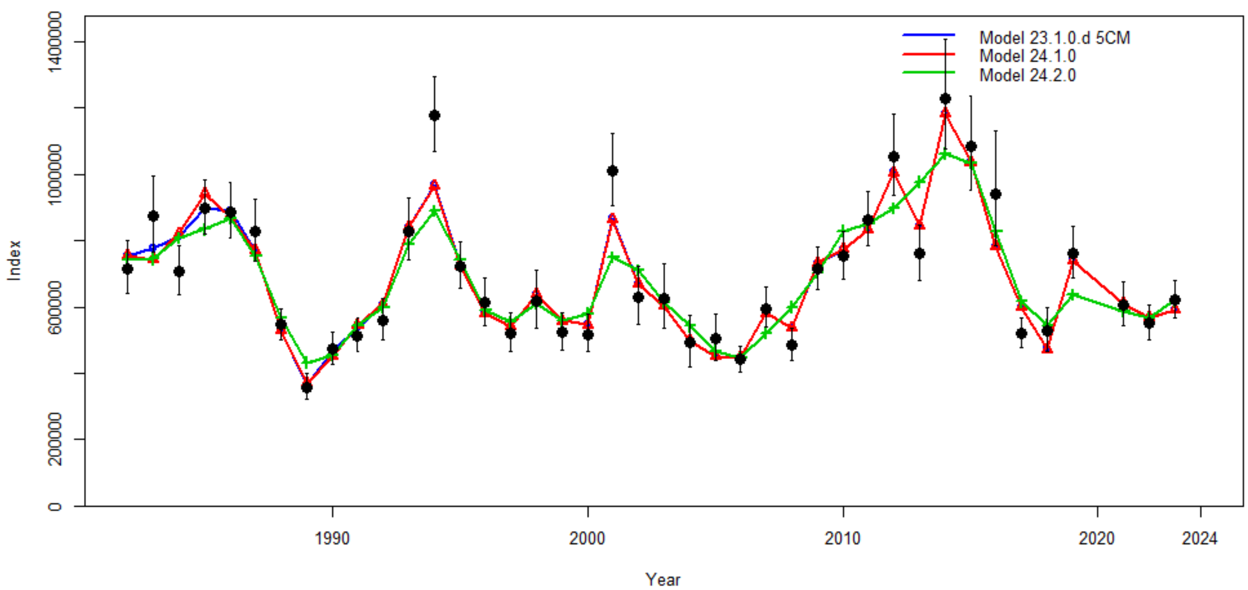

Figure 9 Model fit to the bottom trawl survey index.

Although the overall trends in the results are similar, there are some dissimilarities in estimates of spawning stock biomass and recruitment (Figure 10). Including the CAAL data in the model resulted in an overall reduction in estimated spawning stock biomass with an uptick in the estimate for the most recent two years compared to a continued down trend in the previous models (Figure 10). The reduction in spawning stock biomass may be partially due not only to the marked increase in survey catchability from 0.92 to 1.14, but also a reduction in growth in the model with a lower L_{max} and higher K than the models without CAAL resulting in smaller fish at the older ages (Figure 11). A difference in the most recent trajectory spawning stock biomass with a rise predicted in Model 24.2.0 is due to Model 24.2.0 fitting the most recent survey abundance estimate more closely after a poor fit to the 2019 survey point (Figure 12) created by an increase in the estimated 2021 recruitment above the earlier models (Figure 13).

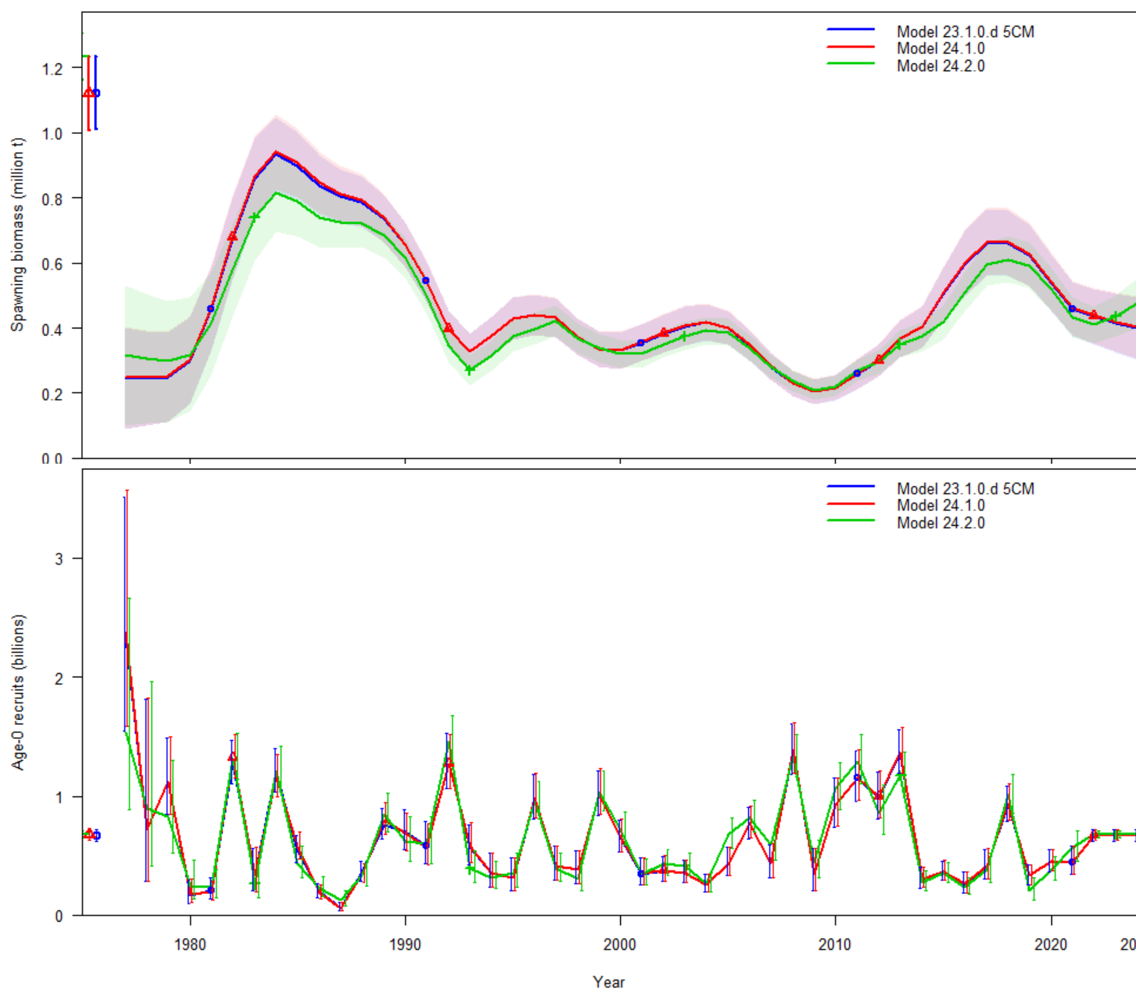

Figure 10 (top) spawning stock biomass an (bottom) age-o recruitment for selected models.

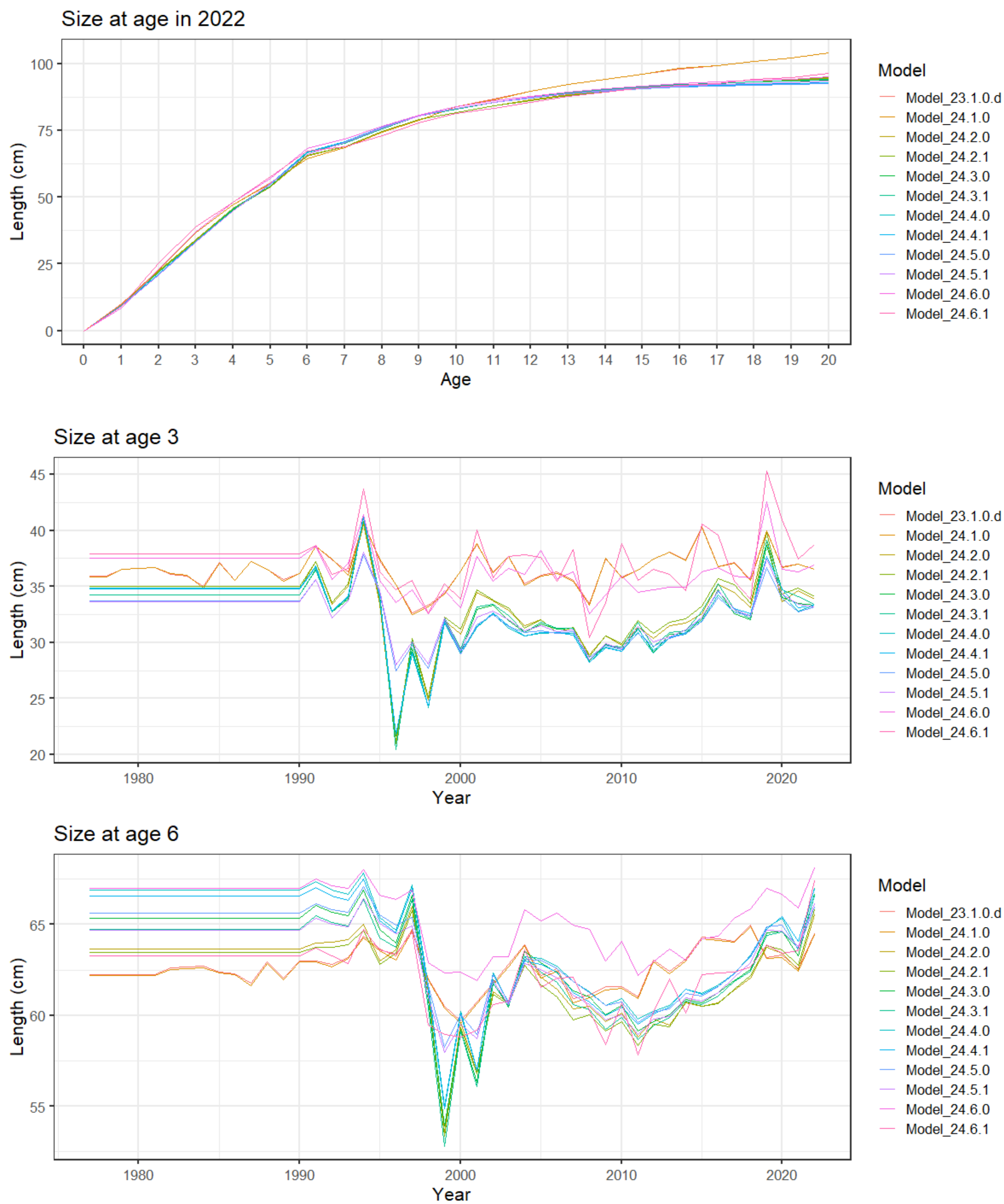

Figure 11 Model comparisons of length at age with (top) size at age in 2022 and (middle) size over time at age 3 and (bottom) at age 6.

4.2 Model 24.2.1 Survey CAAL only

Model 24.2.1 is configured as Model 24.2.0 but without the fishery CAAL. Although a direct comparison of the objective functions is not meaningful between models with different data included, both survey index likelihood and RMSE (Table 3) show an improved fit to the bottom trawl survey for Model 24.2.1 over Model 24.2.0. This improvement of fit to the survey in Model 24.2.1 suggests a conflict between the fishery CAAL data and the bottom trawl survey index data. In excluding the fishery CAAL data the survey catchability reverts back to a value more similar to the base Model 23.1.0.d at 0.92. Growth parameters do change slightly, but the growth curve remains more similar to that of Model 24.2.0. Retrospective bias becomes slightly more negative compared to any of the previous models (Table 1) and the fits to the fishery length.

Table 3 Comparison of models with conditional age-at-length data.

	Model 24.2.0	**Model 24.2.1**	**Model 24.3.0**	**Model 24.3.1**
	+ Survey and Fishery CAAL	+Survey CAAL	Model 24.2.0 with alt. growth model	Model 24.2.1 with alt. growth model
Parameters #	147	147	147	147
Likelihoods				
Total	813.80	700.44	800.88	690.99
Index	-42.39	-46.33	-38.61	-42.5
Agecomp	491.00	386.56	472.56	373.26
Sizecomp	340.34	336.46	347.35	341.45
AIC	1921.6	1694.88	1895.8	1675.98
Retrospective				
Mohn's Rho	-0.050	-0.050	-0.050	-0.042
Predictive Rho	-0.059	-0.059	-0.027	-0.018
Runs test p-Value				
Index	1.00	0.923	0.996	0.996
Fishery Length	0.252	0.238	0.103	0.115
Survey Length	0.135	0.135	0.135	0.331
Survey Age	NA	NA	NA	NA
RMSE				
Index	0.107	0.105	0.110	0.108
Input N/Har. Eff. N				
Fishery Length	124.65/145.98	124.65/143.03	124.65/142.27	124.65/143.06
Survey Length	62.05/58.92	62.02/55.86	62.05/55.69	62.05/55.83
Fishery Age	1.31/4.37		1.31/4.39	
Survey Age	2.77/0.96	2.77/0.97	2.77/0.94	2.77/0.96
OSA SDNR				
Survey Age				
Survey Length	0.98	0.98	0.99	0.99
Fishery Length	1.08	1.07	1.08	1.07
Growth Parameters				
Lmin	13.61	13.52	13.95	13.81
Lmax	95.82	96.2	94.69	95.14
K	0.23	0.21	0.28	0.26
Richard's Rho	0.85	0.92	0.54	0.62
Survey Catchability				
	1.14	1.09	1.23	1.18
Derived Quantities				
Unfished SSB	558,755	564,805	573,115	573,825
F_{40}	0.36	0.36	0.34	0.34
B_{ratio} 2023	0.38	0.39	0.37	0.39

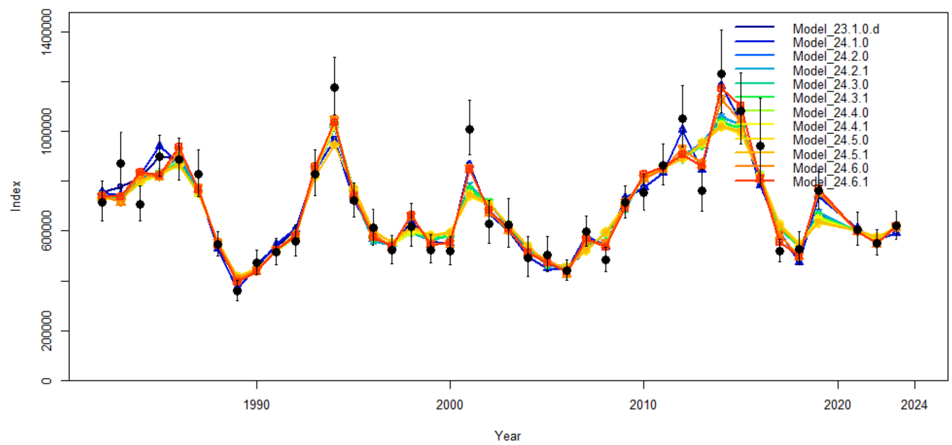

Figure 12 Model fit to the bottom trawl survey index for all models.

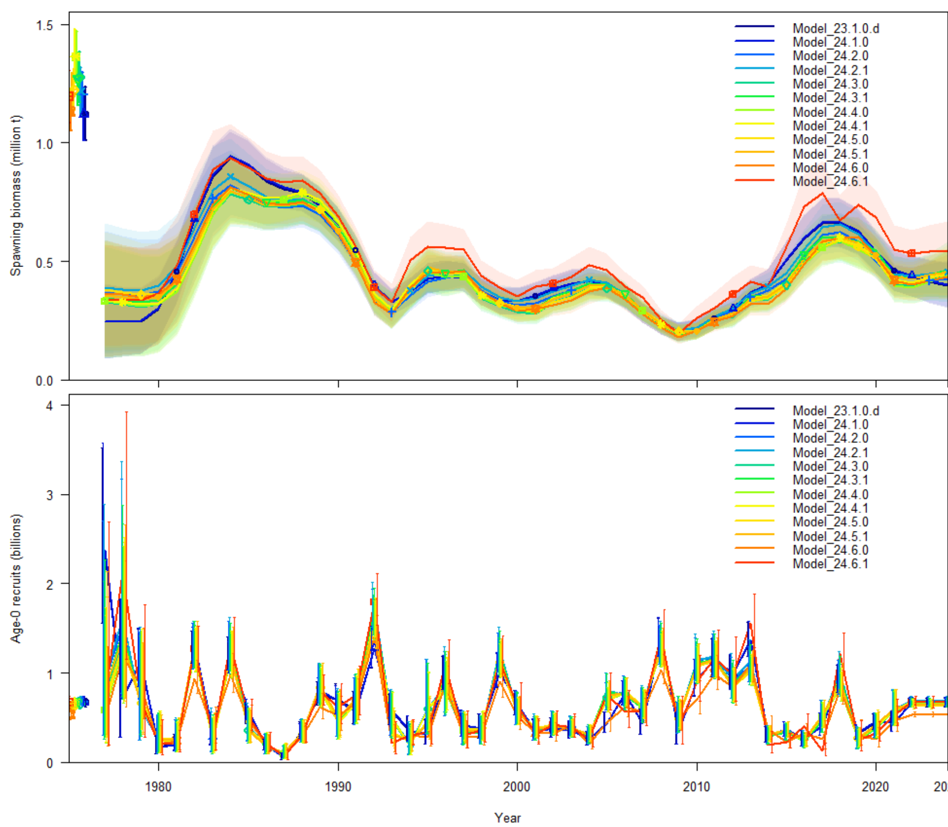

Figure 13 (top) spawning stock biomass and (bottom) age-o recruitment for selected models.

4.3 Models 24.3.0 and 24.3.1 alternative growth models

In the two 24.3 models we examine alternative growth model configurations. For this examination we explored all possible combinations of the four Richards growth curve and three von Bertalanffy parameters with annual variability (Table 4) using Model 24.2.1 as a base model for the examination. Results show that the Richard's parameterization with annually varying L_{min} and K were the most parsimonious models with the lowest AIC. This differed from Model 23.1.0.d with an annually varying K instead of an annually varying Richards parameter.

Model 24.3.0 and Model 24.3.1 were parameterized with a random walk (option 5 in Stock Synthesis) on both L_{min} and K. Both models were based on Model 24.2.x series with Model 24.3.0 having both fishery and survey CAAL, and Model 24.3.1 only having survey CAAL data. For Model 24.3.0 the change in growth parameterization improved the fit to the CAAL data while both the fit to the survey index and length composition data were degraded (Table 3). The improvement to the CAAL fit resulted in an overall improvement to the objective function despite the degradation in fit to the index and length composition data. For Model 24.3.1 there was an improvement to both the CAAL data and size composition data, but a greater degradation in the fit to the index (Figure 14). Model 24.3.1 showed an overall increase in the objective function compared to Model 24.2.1. However, Model 24.3.1 did show an improvement with a passing runs test for both size composition residuals (Table 3).

Table 4 Growth curve explorations with Y indicating the parameter is annually varying with a random walk, in the log Likelihood and AIC columns blue indicates high values and red indicates low values. The bolded box indicates the preferred model.

Growth Curve	L_{min}	L_{max}	K	R	log Likelihood	Delta LL	#Par	AIC
Richards	N	N	N	N	849.2	278.2	137	1972.3
Richards	**Y**	N	N	N	652.7	81.7	184	1673.3
Richards	N	**Y**	N	N	717.9	147.0	184	1803.7
Richards	N	N	**Y**	N	640.6	69.7	184	1649.3
Richards	N	N	N	**Y**	651.4	80.5	184	1670.8
Richards	**Y**	**Y**	N	N	627.8	56.9	231	1717.7
Richards	**Y**	N	**Y**	N	590.3	19.4	231	1642.6
Richards	**Y**	N	N	**Y**	599.5	28.5	231	1660.9
Richards	N	**Y**	**Y**	N	634.5	63.6	231	1731.0
Richards	N	**Y**	N	**Y**	617.6	46.7	231	1697.3
Richards	N	N	**Y**	**Y**	596.9	25.9	231	1655.7
Richards	**Y**	N	**Y**	**Y**	581.5	10.6	278	1719.1
Richards	**Y**	**Y**	N	**Y**	598.9	28.0	278	1753.8
Richards	**Y**	**Y**	**Y**	N	585.2	14.3	278	1726.4
Richards	**Y**	**Y**	**Y**	**Y**	570.9	0.0	325	1791.8
von Bert	N	N	N		854.0	283.1	136	1980.1
von Bert	**Y**	N	N		697.3	126.4	183	1760.6
von Bert	N	**Y**	N		719.6	148.7	183	1805.2
von Bert	N	N	**Y**		644.0	73.1	183	1654.0
von Bert	**Y**	**Y**	N		664.1	93.2	230	1788.2
von Bert	**Y**	N	**Y**		622.9	52.0	230	1705.9
von Bert	N	**Y**	**Y**		638.1	67.2	230	1736.3
von Bert	**Y**	**Y**	**Y**		619.8	48.9	277	1793.7

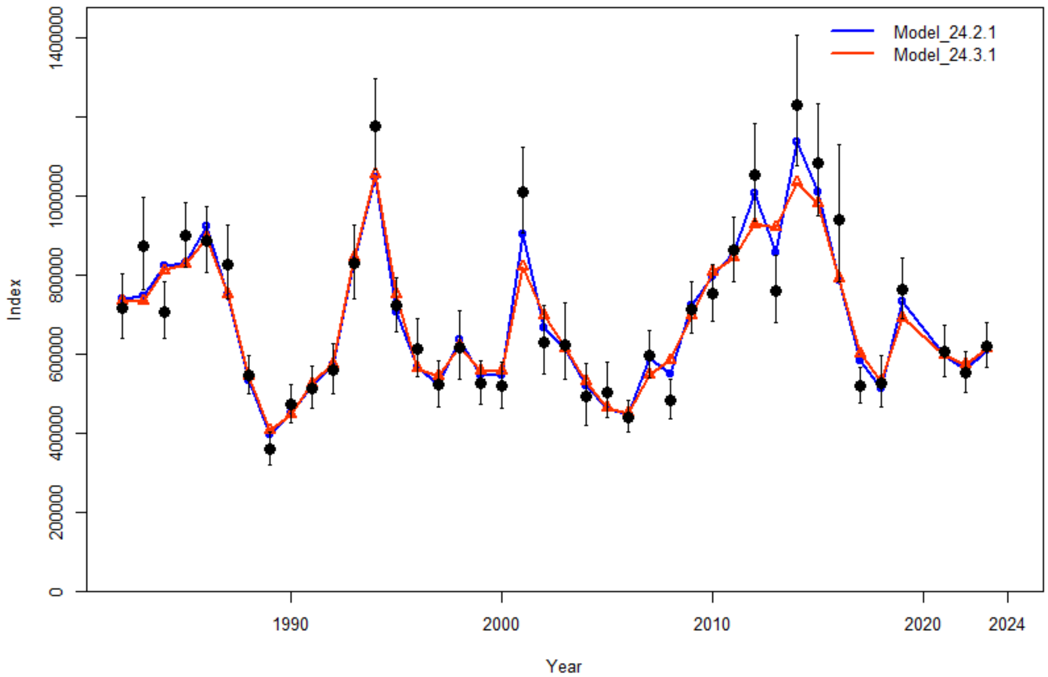

Figure 14 Fit to the bottom trawl survey index for Model 24.2.1 and Model 24.3.1

4.4 Models 24.4.0 and 24.4.1 Tuning of variance input adjustment factors

Model 24.4.0 and Model 24.4.1 are configured the same as Model 24.3.0 and Model 24.3.1 except they have been iteratively tuned using the **r4ss** R library function *tune_comps*. The tuning resulted in slightly lower input variance adjustment factor (IVAF) values for the survey size and survey CAAL data and a slightly larger increase in the IVAF for fishery size and survey CAAL data (Table 2). The tuning in both cases resulted in a worse fit to the bottom trawl survey index data and a lower RMSE for both survey and fishery size composition data. It also resulted in a marginally higher harmonic mean effective sample size for fishery CAAL data. All residual runs test passed and retrospective bias remained negative and low for both models (Table 5).

4.5 Models 24.5.0 and 24.5.1 retuning of sigmas (σ_R, σL_{min}, and σK)

Model 24.5.0 and Model 24.5.1 have the same configuration as Model 24.4.0 and 24.4.1 except that the σs for recruitment variability and annual variability in the growth parameters have been iteratively tuned employing the Thompson and Thorson (2019) method with a link to an R function, provided here. The tuning resulted in lower σs for all three parameters (Table 2). This resulted in a degradation in the model fit across all data types (Table 5). Model 24.5.0 passed all of the residual runs tests; however, Model 24.5.1 failed the residual runs tests for both the survey and fishery length compositions, suggesting autocorrelation in the residuals for mean length in both. The retrospective bias was marginally improved in both models, remaining small and negative. Model 24.4.x and Model 24.5.x series models spawning stock biomass and recruitment results were rather similar (Figure 15).

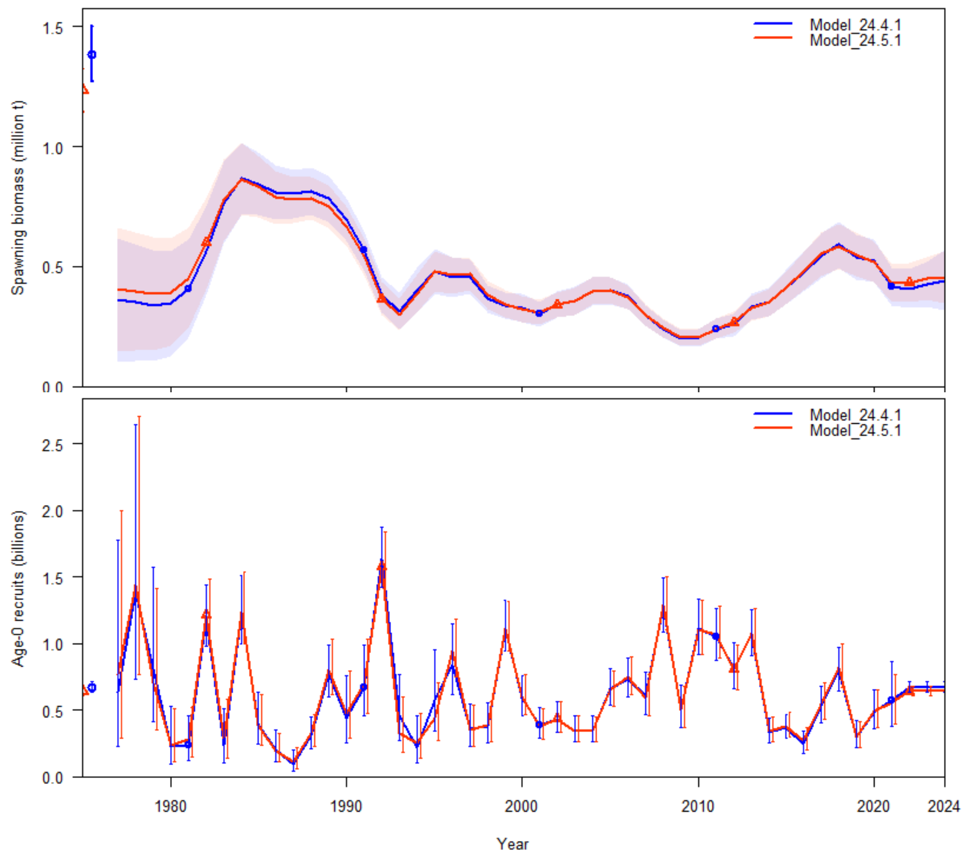

Figure 15 (top) spawning stock biomass an (bottom) age-o recruitment for Model 24.4.1 and Model 24.5.1.

Table 5 Comparison of models with conditional age-at-length data. For runs test bold red indicates a failed test (p-Value < 0.05).

	Model 24.4.0	**Model 24.4.1**	**Model 24.5.0**	**Model 24.5.1**
	Model 24.3.0 w/ 'Francis' tuning	Model 24.3.1 w/ 'Francis' tuning	Model 24.4.0 w/ σ tuning	Model 24.4.1 w/ σ tuning
Parameters #	147	147	147	147
Likelihoods				
Total	938.43	857.42	980.81	858.53
Index	-32.04	-33.55	-20.88	-24.17
Agecomp	598.38	514.24	624.67	480.32
Sizecomp	349.96	355.4	344.15	370.86
AIC	2170.9	2008.84	2255.6	2011.06
Retrospective				
Mohn's Rho	-0.048	-0.04	-0.029	-0.024
Predictive Rho	-0.015	-0.35	-0.024	-0.021
Runs test p-Value				
Index	0.996	0.98	0.997	0.982
Fishery Length	0.103	0.115	0.115	**0.031**
Survey Length	0.135	0.072	0.135	**0.041**
Survey Age	NA	NA	NA	NA
RMSE				
Index	0.114	0.113	0.120	0.118
Input N/Har. Eff. N				
Fishery Length	123.14/139.11	128.17/140.60	121.8/136.93	135.16/140.93
Survey Length	57.60/53.02	58.93/53.28	55.99/52.68	63.93/54.35
Fishery Age	1.24/4.45		1.23/4.50	
Survey Age	4.41/0.95	4.55/0.96	4.62/0.93	3.99/0.94
OSA SDNR				
Survey Age				
Survey Length	0.98	0.99	0.98	0.99
Fishery Length	1.09	1.08	1.09	1.07
Growth Parameters				
Lmin	14.26	14.14	13.57	13.48
Lmax	93.37	93.59	93.15	94.23
K	0.32	0.31	0.31	0.28
Richard's Rho	0.42	0.46	0.43	0.54
Survey Catchability				
	1.25	1.22	1.24	1.21
Derived Quantities				
Unfished SSB	594,315	597,305	552,245	551,085
F_{40}	0.33	0.33	0.33	0.34
B_{ratio} 2023	0.35	0.36	0.39	0.4

4.6 Updated ageing error matrix

The aging error used in the previous years accepted model (Model 23.1.0.d) was based on a linear vector from age 1 to age 20 for data collected from 1990 – 2018 using the method devised by Punt et al. (2008). For this year the data were updated to include only data aged 2000 to 2023. In addition, discussions with the age and growth laboratory indicate that ages read prior to 2000 were likely not consistent with those read using current best practices (Beth Matta, pers. comm.). For these the AgeingError R library 2.0.2 (Punt et al. 2024) was used to estimate an aging error matrix using a spline. The configuration used was a spline (option 5) with five knots at 2, 4, 6, 8, and 10. Because there are few ages older than 12 in the database, 12 was used as a plus group and aging error for ages 12-20 were set at the age 12 value (Table 6). Overall the estimated standard deviation at age increased for all ages compared to the aging error vector applied last year.

The new matrices were applied to last year's model (Model 23.1.0.d), Model 24.1.0, and Model 24.2.0 without retuning, then on Model 24.5.0 and 24.5.1 with retuning the σs and IVAFs as Model 24.6.0 and Model 24.6.1 (Table 1 and Figure 16).

Table 6 Standard deviation in ageing error for old and new aging error matrices.

	0	1	2	3	4	5	6	7	8	9	10	11	12
Old	0.0850	0.0850	0.1696	0.2542	0.3388	0.4234	0.5080	0.5926	0.6772	0.7618	0.8464	0.931	1.0156
New	0.1885	0.1885	0.3067	0.3787	0.4331	0.4939	0.5607	0.6356	0.7556	0.9643	1.2988	1.7941	2.4854

Table 7 Comparison of models with updated aging error matrix. For runs testing bold and red indicate a failed test (p-Value < 0.05).

	Model 23.1.0.d.e	**Model 24.1.0.e**	**Model 24.2.0.e**	**Model 24.6.0**	**Model 24.6.1**
	M23.1.0.d W/ error matrix update	M24.1.0 W/error matrix update	M24.2.0 W/ error matrix update	24.5.0 W/ error matrix update	24.5.1 W/ error matrix update
Parameters #	201	160	147	147	147
Likelihoods					
Total	281.18	283.70	769.18	827.17	668.65
Index	-81.64	-77.95	-84.15	-76.06	-78.03
Agecomp	124.57	118.35	460.55	478.92	253.71
Sizecomp	201.52	209.97	371.35	394.60	454.22
AIC	964.36	887.39	1832.36	1948.34	1631.30
Retrospective					
Mohn's Rho	-0.030	-0.029	-0.055	-0.111	-0.004
Predictive Rho	-0.081	-0.079	-0.074	-0.126	-0.006
Runs test p-Value					
Index	0.577	0.329	0.992	0.929	0.996
Fishery Length	0.231	0.231	0.252	0.209	0.152
Survey Length	0.677	0.887	**0.021**	0.089	0.439
Survey Age	0.488	0.448	NA	NA	NA
RMSE					
Index	0.075	0.079	0.072	0.081	0.08
Input N/Har. Eff. N					
Fishery Length	136.08/140.73	130.85/140.25	138.14/146.07	135.32/137.35	156.74/146.94
Survey Length	264.91/175.56	269.10/146.22	74.50/58.15	72.54/54.59	112.88/62.58
Fishery Age			2.94/3.77	4.19/4.07	
Survey Age	94.46/45.67	89.58/45.78	1.18/0.98	1.00/0.95	1.02/1.03
OSA SDNR					
Survey Age	0.95	0.94			
Survey Length	0.97	0.97	0.95	0.97	0.94
Fishery Length	1.07	1.07	1.07	1.07	1.05
Growth Parameters					
Lmin	13.962	13.777	11.62	11.60	12.31
Lmax	112.594	112.865	97.915	96.32	101.51
K	0.117	0.115	0.183	0.225	0.14
Richard's Rho	1.405	1.422	1.363	1.092	1.53
Survey Catchability					
	0.959	0.949	1.137	1.198	0.96
Derived Quantities					
Unfished SSB	563,885	563,200	557,240	524,005	563,665
F_{40}	0.378	0.380	0.356	0.341	0.490
B_{ratio} 2023	0.358	0.362	0.374	0.400	0.480

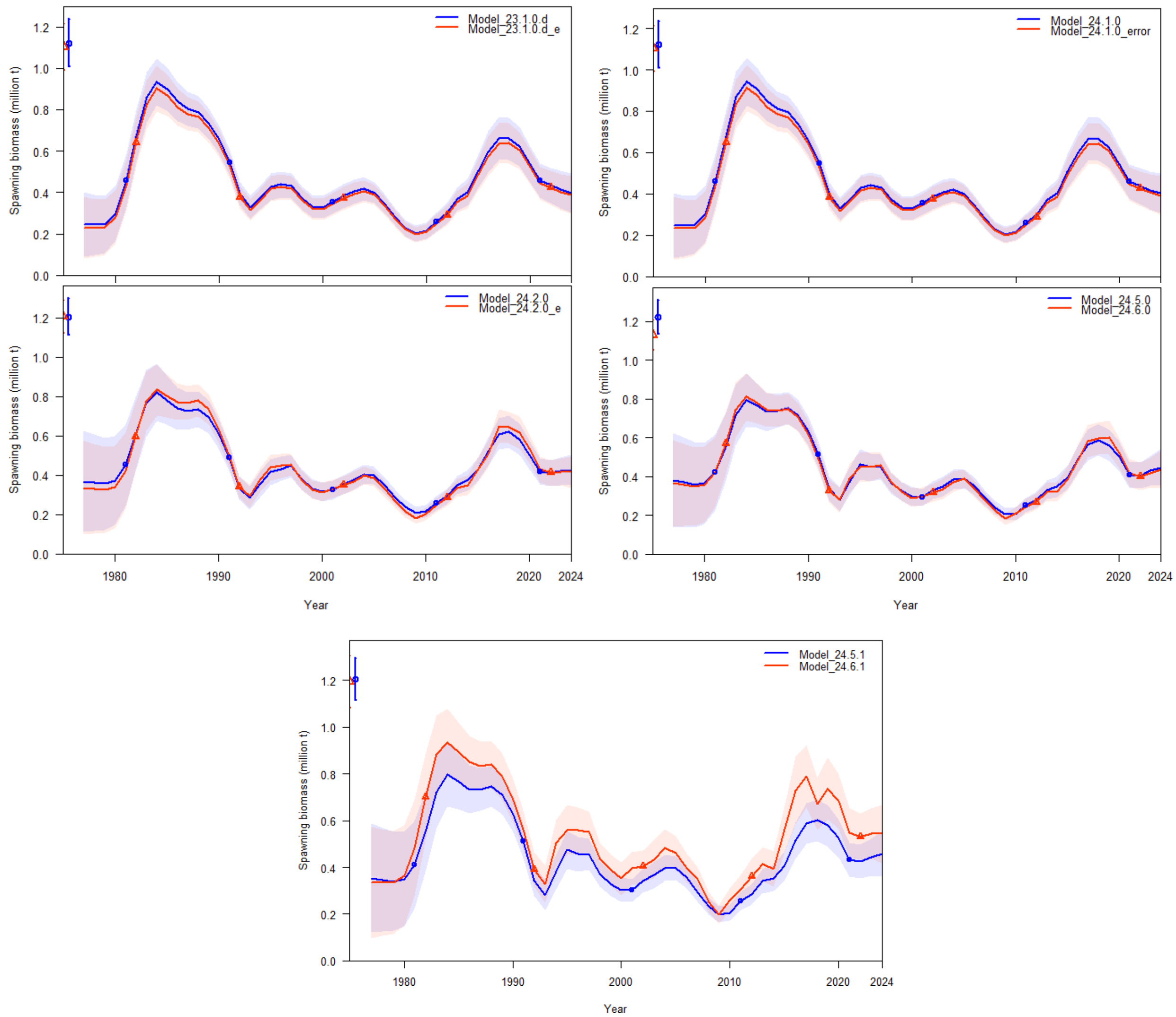

Figure 16 Spawning stock biomass figures for models with inclusion of the new aging error matrix compared to the old aging error vector for models 23.1.0.d, Model 24.1.0, Model 24.2.0, Model 24.5.0 and Model 24.5.1.

The change in the aging error made little difference in model results for all model configurations except from Model 24.5.1 to Model 24.6.1. Retuning of the σs resulted in a drop in σ_R in Model 24.6.0, but an increase in σ_R for Model 24.6.1 (Table 2) compared to the 24.5.x models. The retuning of the IVAFs resulted in a large drop in the adjustment factors for the survey CAAL data from 0.064 to 0.005 greatly down-weighting the survey CAAL data in the model. With this change in emphasis on the survey CAAL data Model 24.6.1 settled at a lower survey catchability from 1.2 to 0.96. This survey catchability value is more consistent with models without CAAL data. All of the models lacking CAAL data had higher σ_R and survey catchability estimated below 1.0 compared to models with CAAL which had survey catchability estimated at greater than 1.0. Model 24.6.1 also has an increase in L_{max} with a value closer to the models without CAAL data (Table 7). In contrast, Model 24.6.0 remained consistent with Model 24.5.0 with a survey catchability near 1.2. However, model 24.6.0 retained fishery CAAL data with higher weighting in the model with the fishery CAAL IVAF five-fold higher than previous models (Table 2). The OSA analyses show potential issues with the fishery length composition in all models examined (Appendix 2). Despite the aggregated fits adhering closely to the aggregated distribution, the OSA SDNR for all models were between 1.09 and 1.05, above the 95th percentile (1.04) for acceptability using the $\chi 2$ test proposed by Francis (2011). The data fits are all very similar. The survey length composition OSA residuals appear to be near normally distributed (Figure 17) and the aggregated fits closely match the aggregated length composition. However, the fishery length composition OSA residuals are not strictly normally distributed as there appears to be several high value outliers between the 24.5 and 34.5 cm bins (Figure 18).

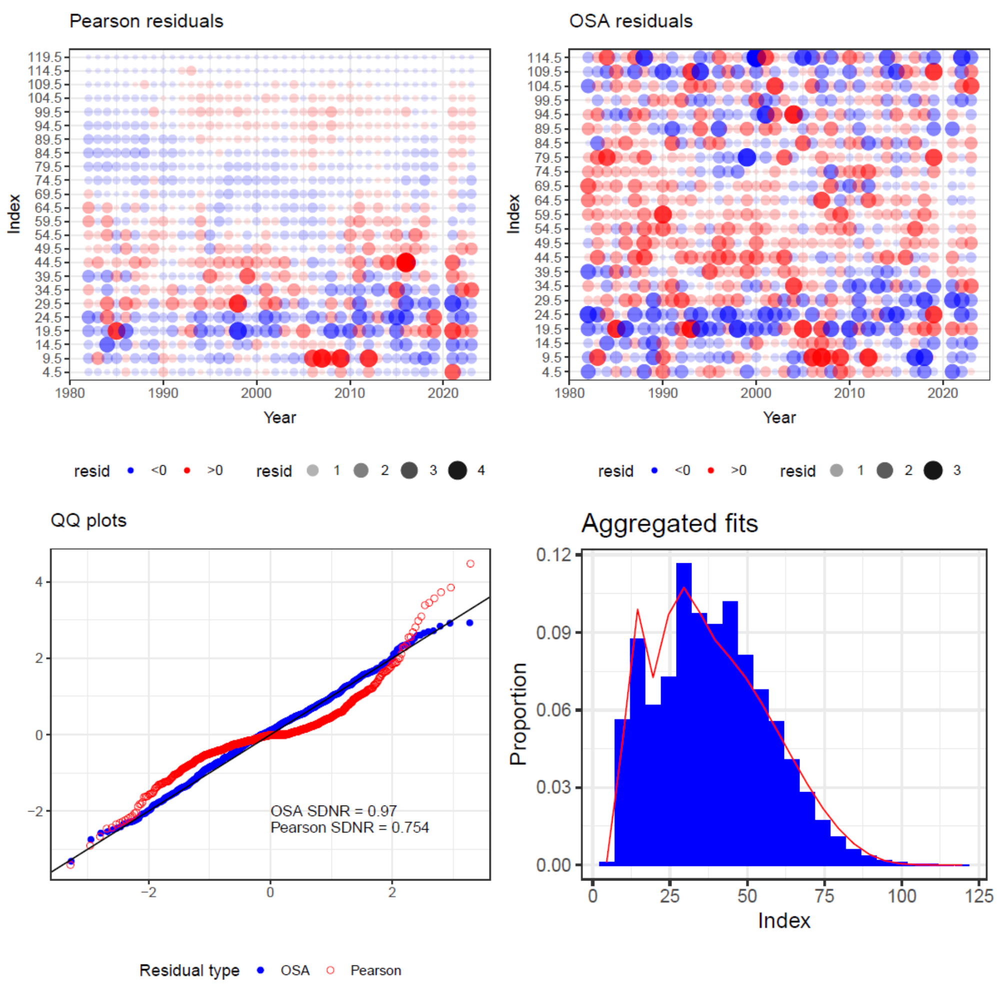

Figure 17 Survey length composition data residual analysis for Model 24.6.0 showing Pearson and OSA residuals as well as the aggregated distribution and fits.

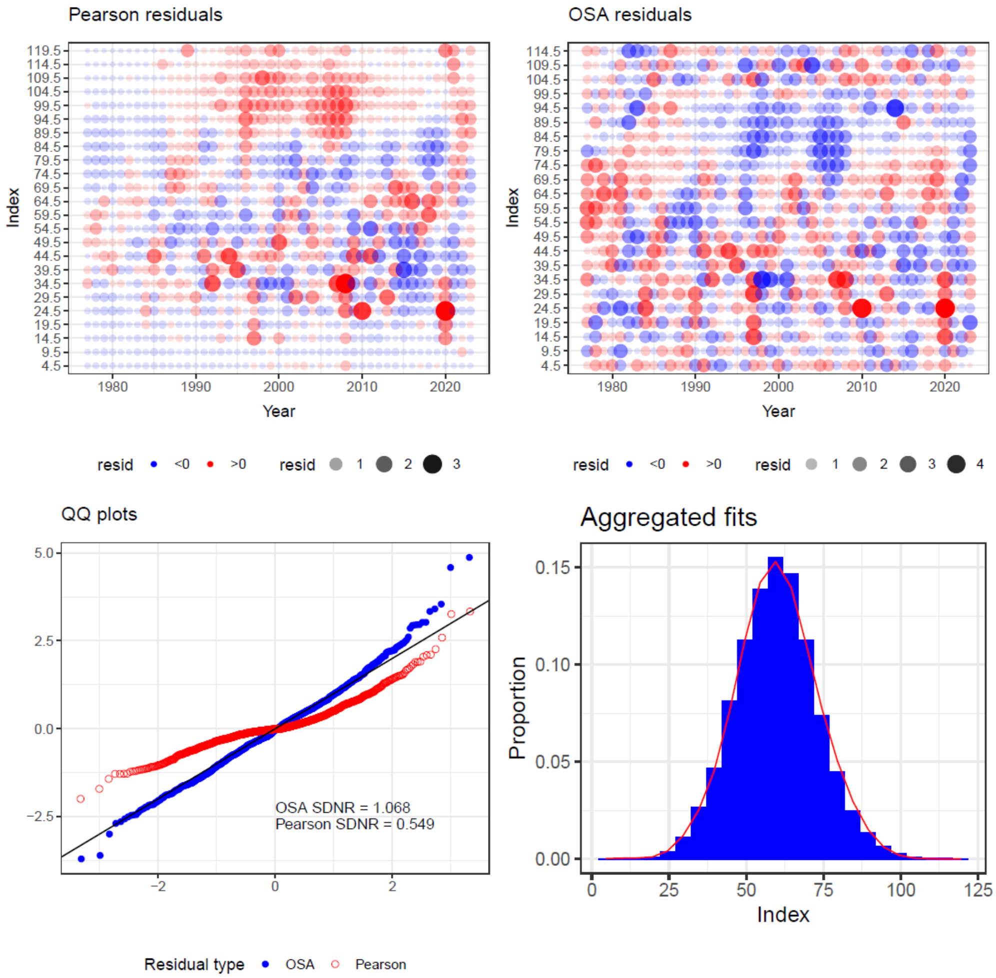

Figure 18 Fishery length composition data residual analysis for Model 24.6.0 showing Pearson and OSA residuals as well as the aggregated distribution and fits.

Likelihood profiles for σ_R (Figure 19), survey catchability (Figure 20), and R_0 (Figure 21) were conducted on Model 24.6.0 and 24.6.1. All of the profiles were well behaved, but the resultant MLEs were much different between the two models despite the only difference between the two models was the inclusion of fishery CAAL in Model 24.6.0.

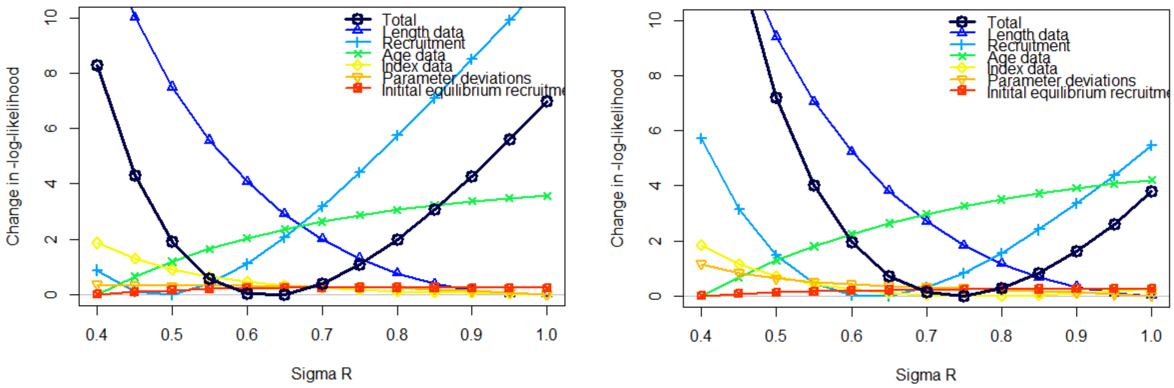

Figure 19 Likelihood profiles over sigma R for (left) Model 24.6.0 and (right) Model 24.6.1.

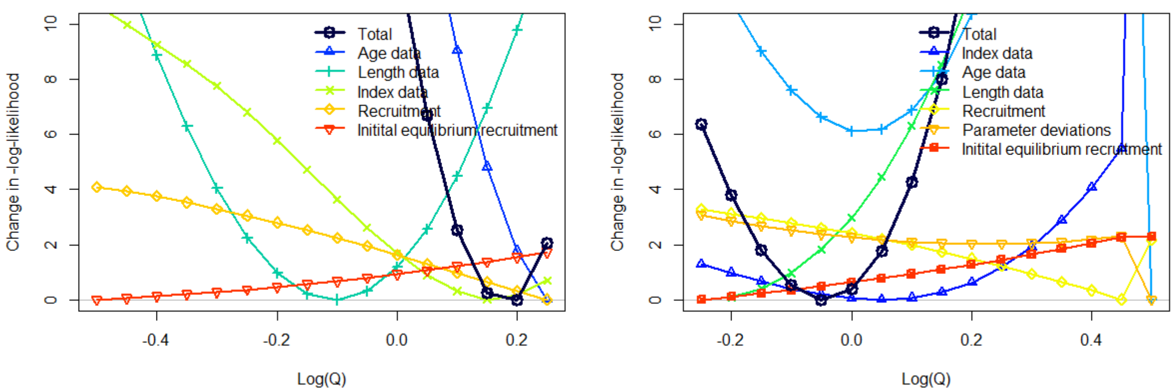

Figure 20 Likelihood profiles over bottom trawl survey catchability for (left) Model 24.6.0 and (right) Model24.6.1.

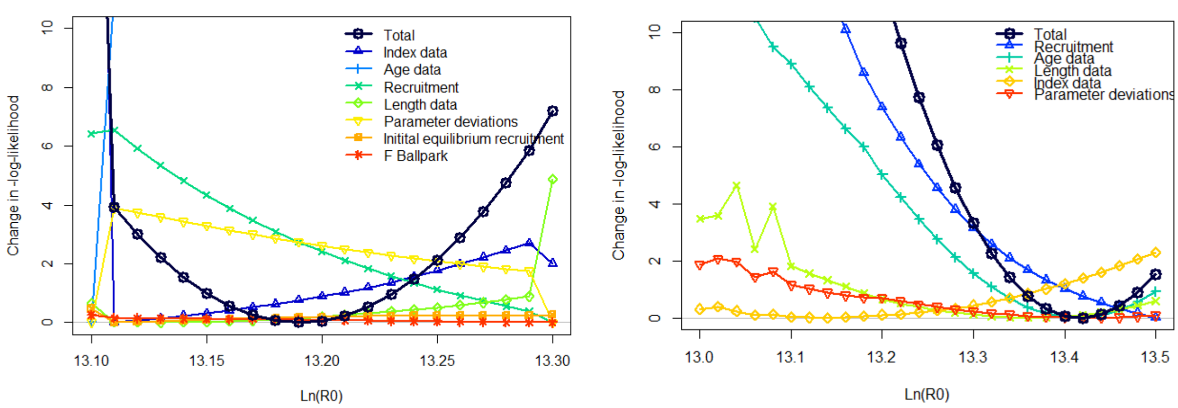

Figure 21 Likelihood profiles over Ln(R_0) (left) Model 24.6.0 and (right) Model24.6.1.

Summary

Changing of the model to a lower bin resolution had little impact on model results and provides a simpler model that runs much faster and allows more flexibility in data choices in the future. Changing to a fixed survey selectivity did little to the model and AIC would indicate the simpler model to be more parsimonious. Explorations of annual variability in the growth curve parameters and different parameterizations of the growth curve show that the Richard's growth model with random walks on L_{min} and K provided the most parsimonious model configuration. The improvement to model fits and drop in AIC can be seen between the 24.2.x and 24.3.x models due entirely to an improvement in the fit to the CAAL data. Although not improving model fits per se, retuning of the models both for σ values and variance input adjustment factors is considered best practice.

The addition of CAAL to the model is more difficult to evaluate. CAAL is meant to improve our estimates of growth. The addition of survey and fishery CAAL starting in Model 24.2.0 shows a marked decrease in L_{max} and Richards rho along with an increase in K (Table 3). This resulted in fish generally being smaller and lighter at age, particularly for ages greater than 10 (Figure 22).

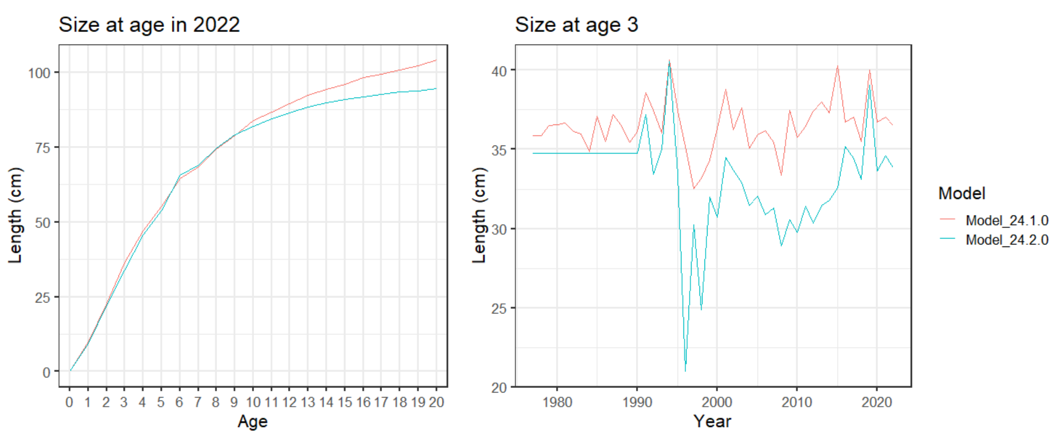

Figure 22 Size at age (left) in 2022 and (right) at age 3 across time from Model 24.1.0 and Model 24.2.0.

The addition of CAAL data in Model 24.2.0 also resulted in a degradation in the fit to the bottom trawl survey index as the model placed more emphasis on fitting the CAAL data. The poorer fit to the survey index was reversed when the new aging error matrix was applied with larger error around the age data in Model 24.2.0.e. This shift allowed more flexibility in fitting the CAAL data and therefore the model was better able to rectify the disagreement between the CAAL data and the index. Changes in the variance tuning adjustment factors made it difficult to compare fits to the length composition data, however the OSA residuals and SDNR for the length composition data remained comparable between Models 24.1.0.e and 24.2.0.e. The improvement of fit to the survey index with the addition of the new aging error matrix was consistent in the 24.6.x models.

One aspect to explain in these models is the change in results from Model 24.6.0 to Model 24.6.1 with removal of the fishery CAAL data (Table 7). The changes observed in the final model are inconsistent with the previous 24.x.0 to 24.x.1 model results which were relatively stable with and without the fishery CAAL. This has to do with tuning of the IVAF. IVAF tuning in Model 24.6.0 results in a five-fold increase in the IVAF for the fishery IVAF and a ten-fold decrease in the survey IVAF, increasing the influence of the fishery CAAL while decreasing the influence of the survey CAAL. Tuning Model 24.6.1 similarly reduced the IVAF of the survey CAAL by ten-fold thus greatly reducing the influence of CAAL data in the model. The CAAL data in Model 24.6.0 is the most influential data informing survey catchability, pulling the catchability estimate above 1.0 (Figure 20). In Model 24.6.1 the CAAL data is no longer as influential, being surpassed by the index data in informing survey catchability and like the models without any CAAL the survey catchability drops below 1.0.

November Model Proposals

For November the authors would like to present two model alternatives to the base model. These would be Model 24.1.0.e which has data binned at 5cm, a single selectivity curve for the survey, and the new aging error matrix and Model 24.6.0 which has data binned at 5cm, survey and fishery CAAL data, a Richards growth curve with random walks on L_{min} and K, and the new aging error matrix. Both models will need to be retuned for σs using the Thompson and Thorson (2019) method and using the Francis (2011) method provided in the r4ss package as the *tune_comps* function for finding the IVAFs.

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