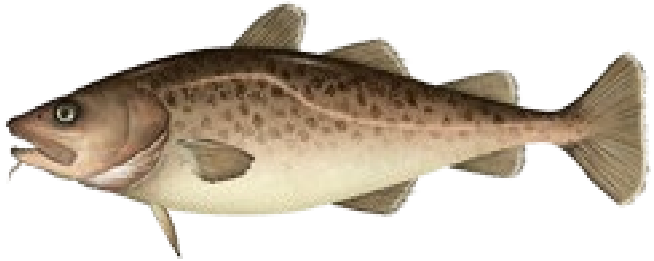
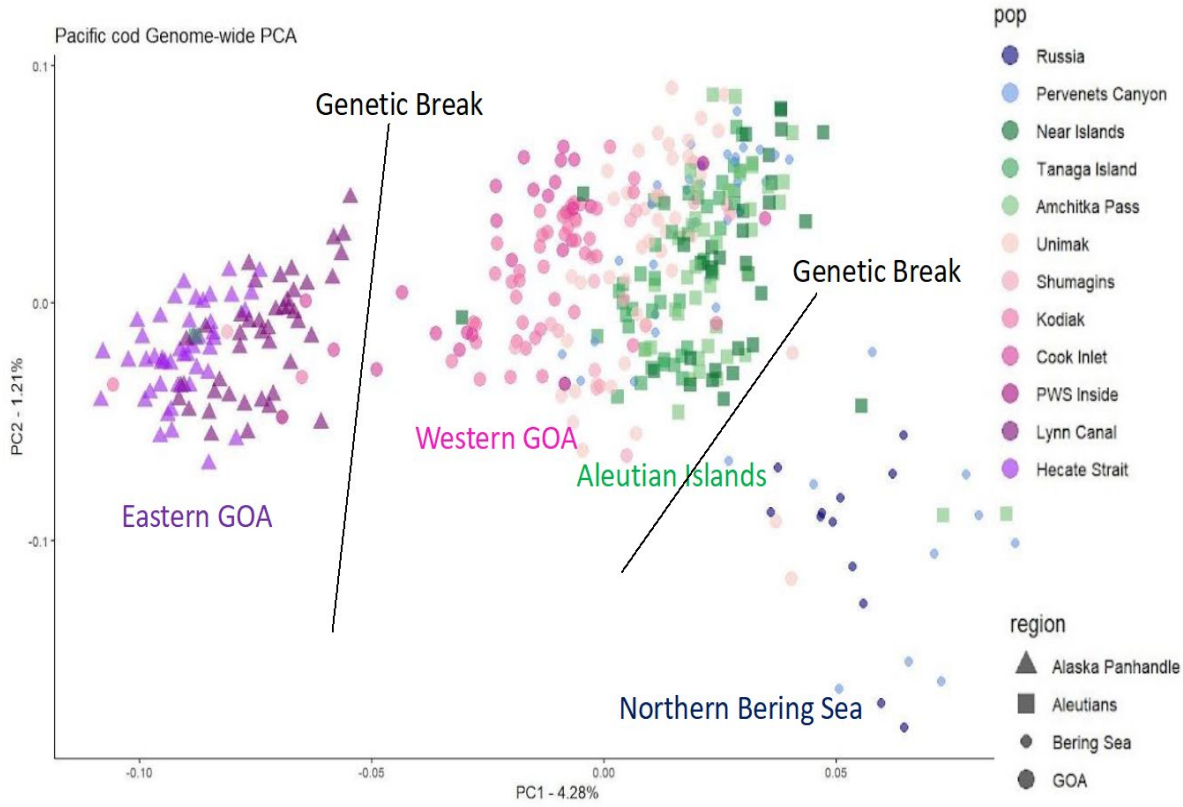
Bering Sea Pacific Cod November 2024



Authors: Steven J. Barbeaux, Lewis Barnett, Pete Hulson, Julie Nielsen, S. Kalei Shotwell, Elizabeth Siddon, and Ingrid Spies

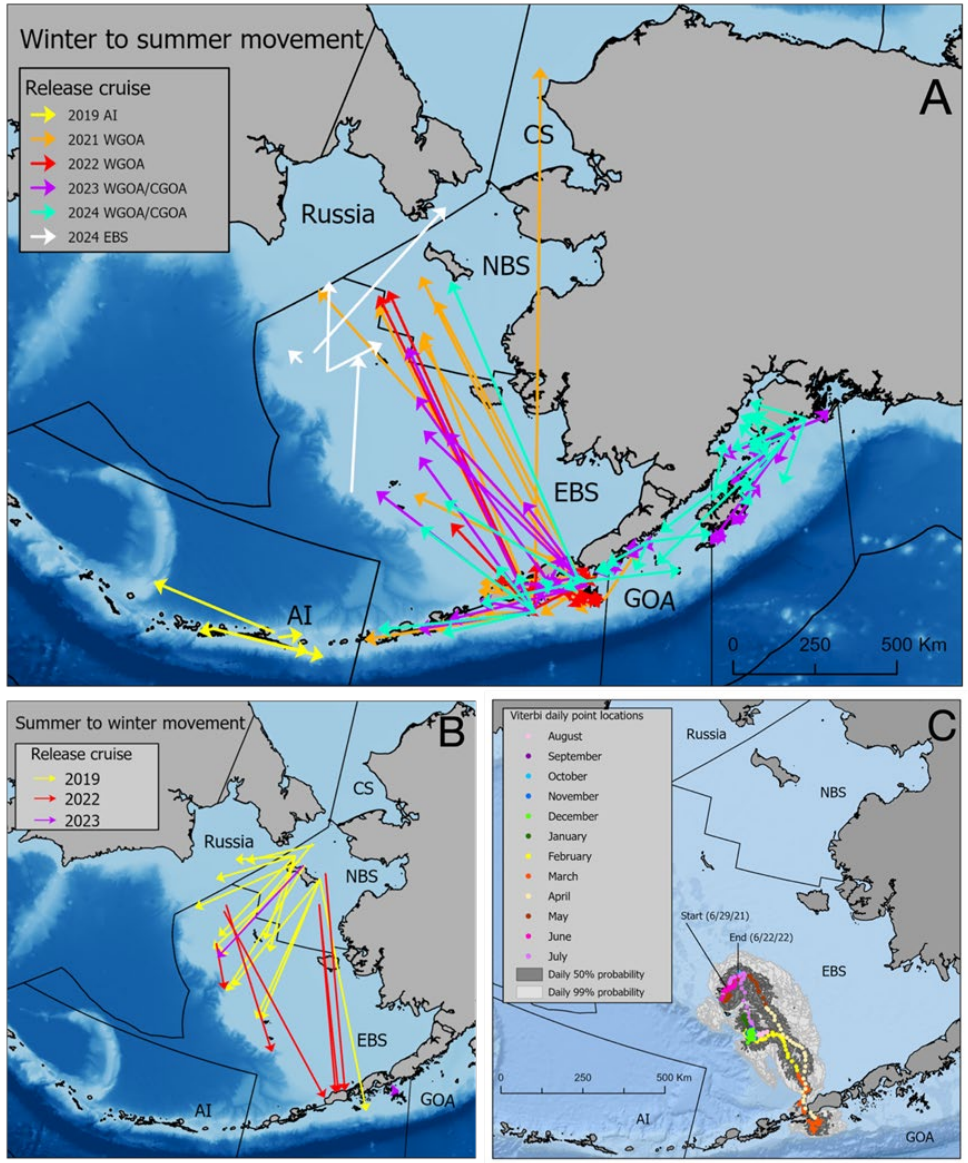
Pacific cod genetics

- Isolation-by-distance was observed from western Gulf of Alaska through Unimak Pass and the eastern Aleutian Islands
- Genetic break from EBS to NBS/Russia
- Genetic break from E. GOA to W. GOA
- No break in genetic structure between the W. GOA and EBS



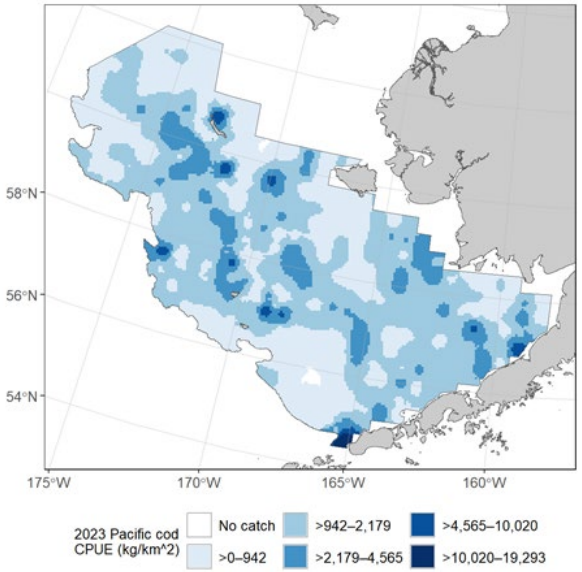
PSAT Tagging Results

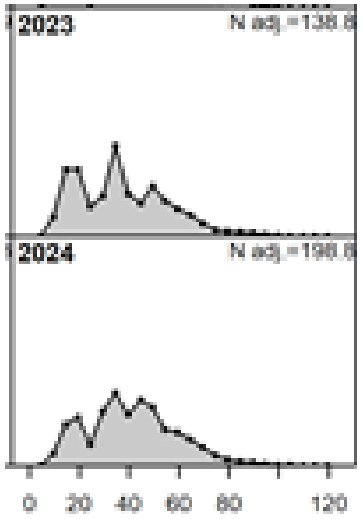
- Multi-year tagging program
- Consistent seasonal migration pattern
- Substantial connection between western GOA and EBS
- Some movement into and out of Russian EEZ
- No connection between AI and EBS
- Low to no connection from eastern central GOA to EBS

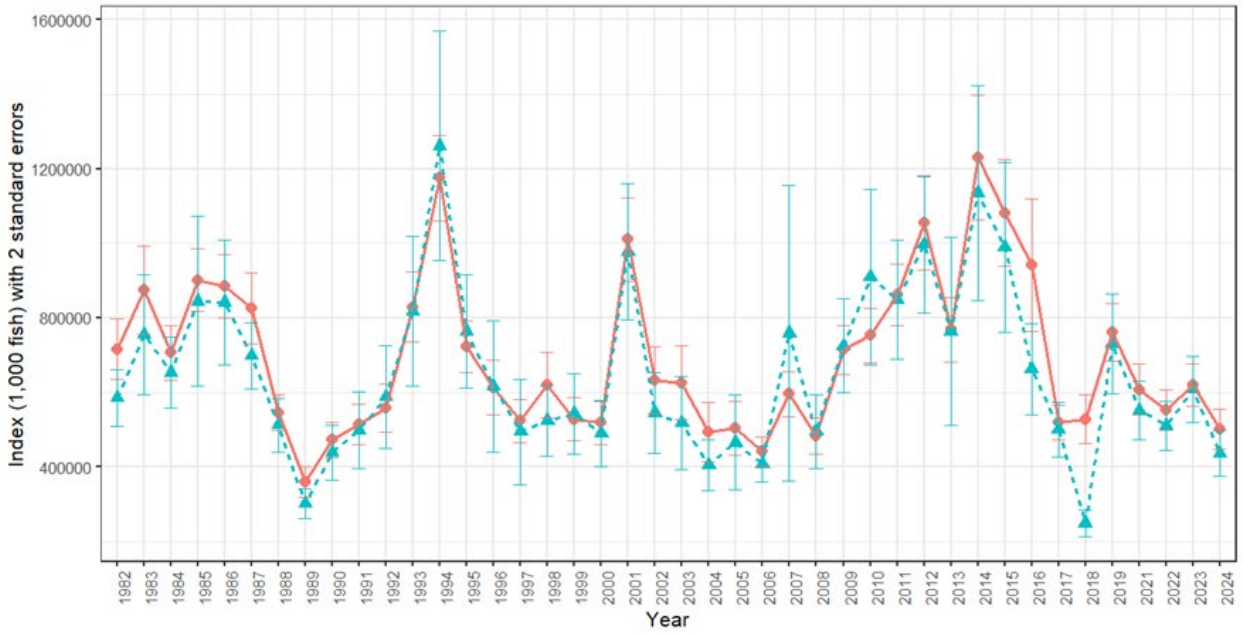


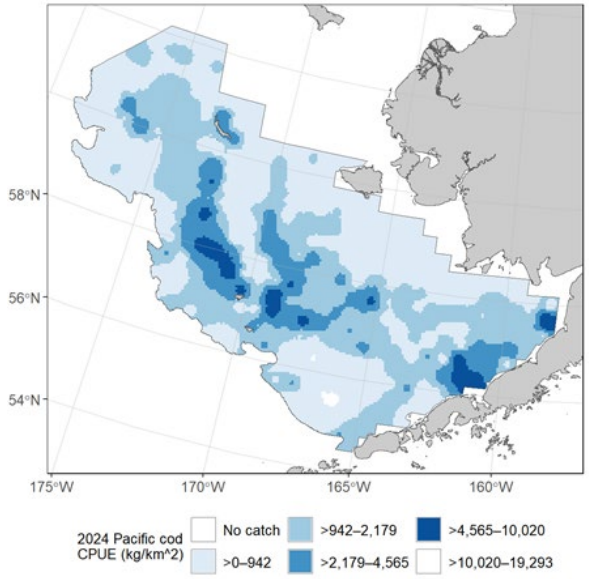
2024 EBS bottom trawl survey

- No Northern Bering Sea extension
- VAST estimate using ice-extent as covariate
  - 19% decline in abundance from 2023
  - 8% decline in biomass from 2023
  - Continued southward shift in distribution



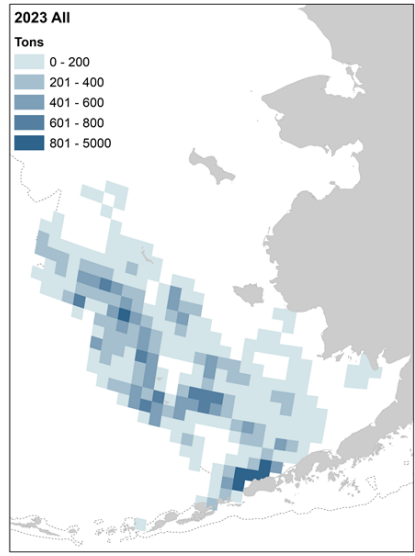


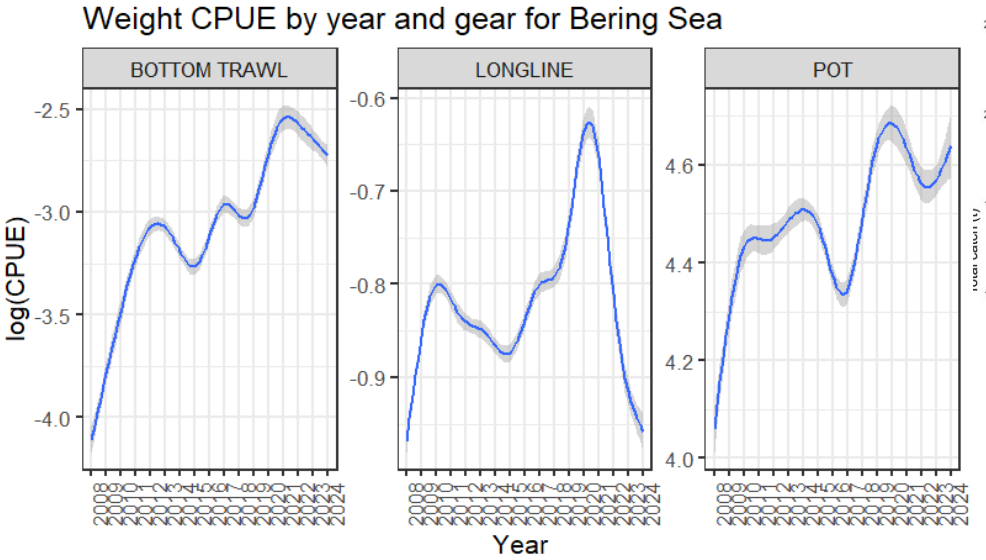


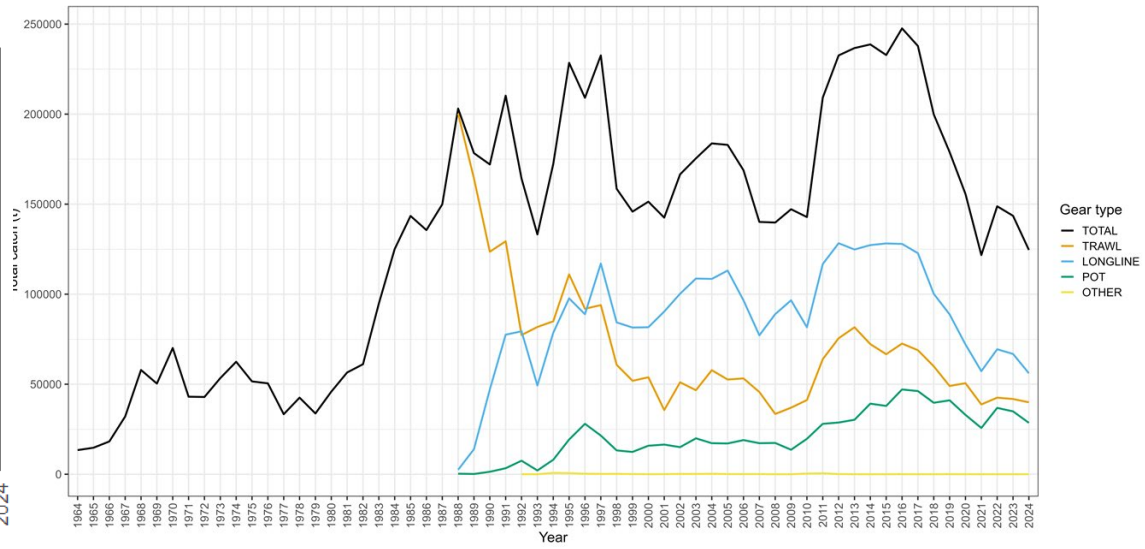


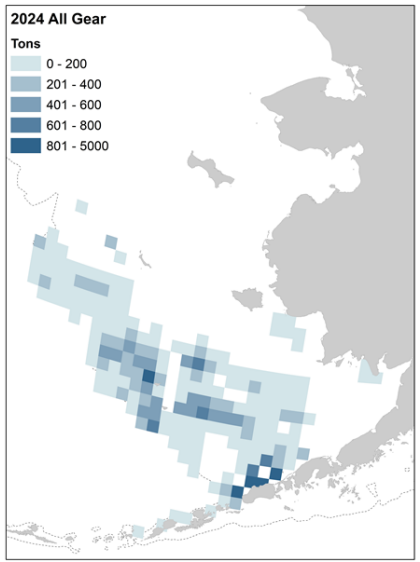
2024 Fishery

- Southward shift in distribution
  - CPUE increase in Pot
  - CPUE decrease in Bottom trawl and Longline
- 2024 Catch at 131,015 t of 167,952 t ABC (78%) as of October 24, compared to 97-99% in previous 5 years at this time
  - Poor market conditions for shoreside sector







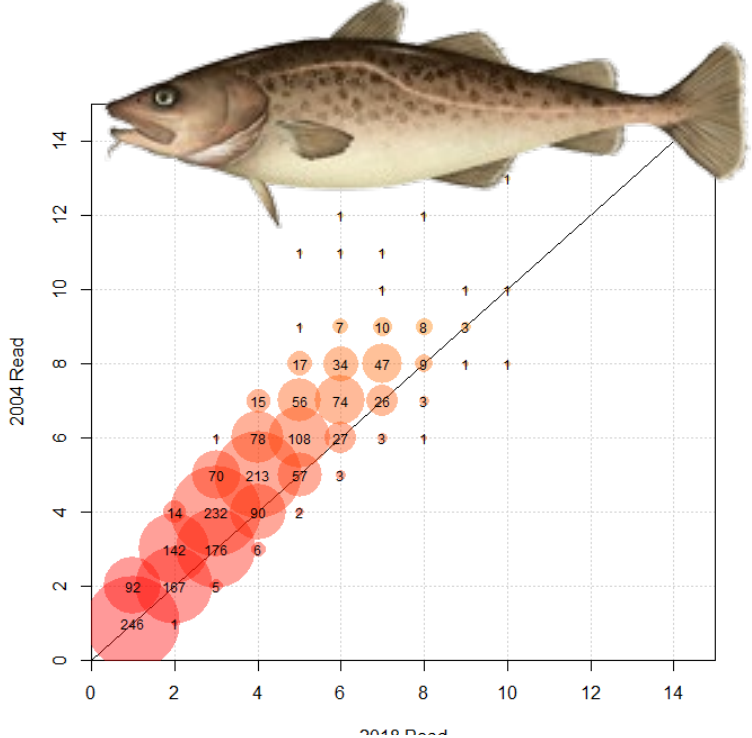


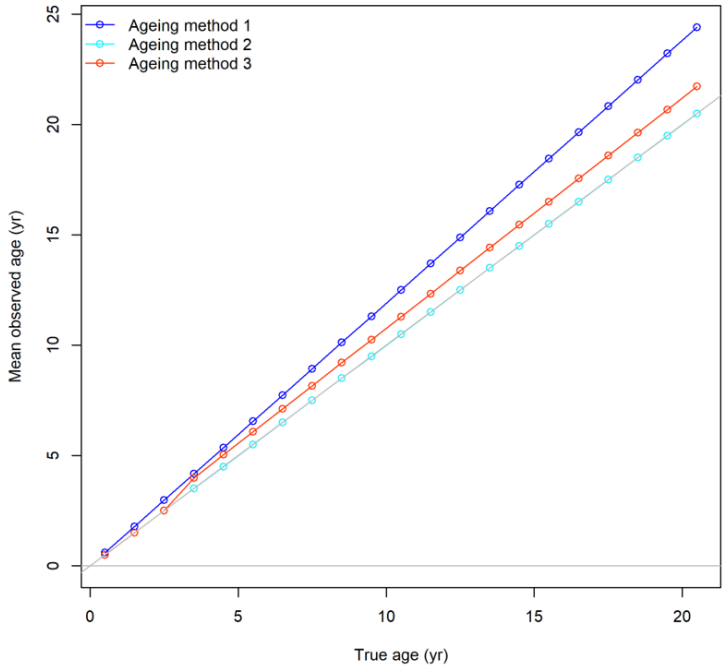
Model bridging from 2023

- Addition of 2024 data
  - Aging error and aging bias update
  - Updated survey index with 2024 VAST index abundance estimate
  - Refit SD adjustment to survey index
  - Update survey age comps (2000-2023)
  - Update survey length composition (1982-1999, and 2024)
  - Update fishery length composition (1977-2024)
  - Annual variability in growth limited to 2000-2024
- Retuning of sigmas and Francis tuning of variance adjustment factors

Aging Bias

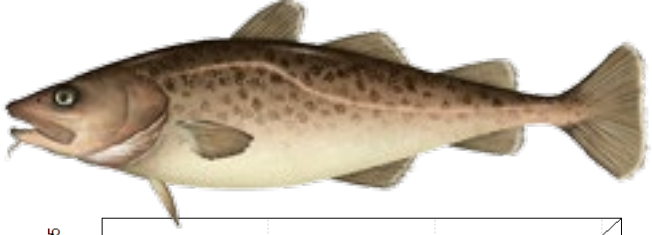
- 2,057 otolith read in 2004 reread in 2018
- Processed in Ageing Error R library
  - 5 knot spline model fit with single bias parameter
- Results show more extreme over-aging bias than used in previous models

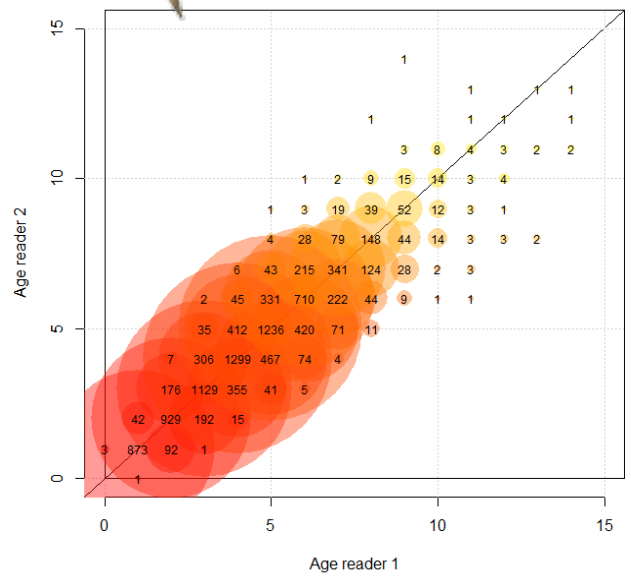


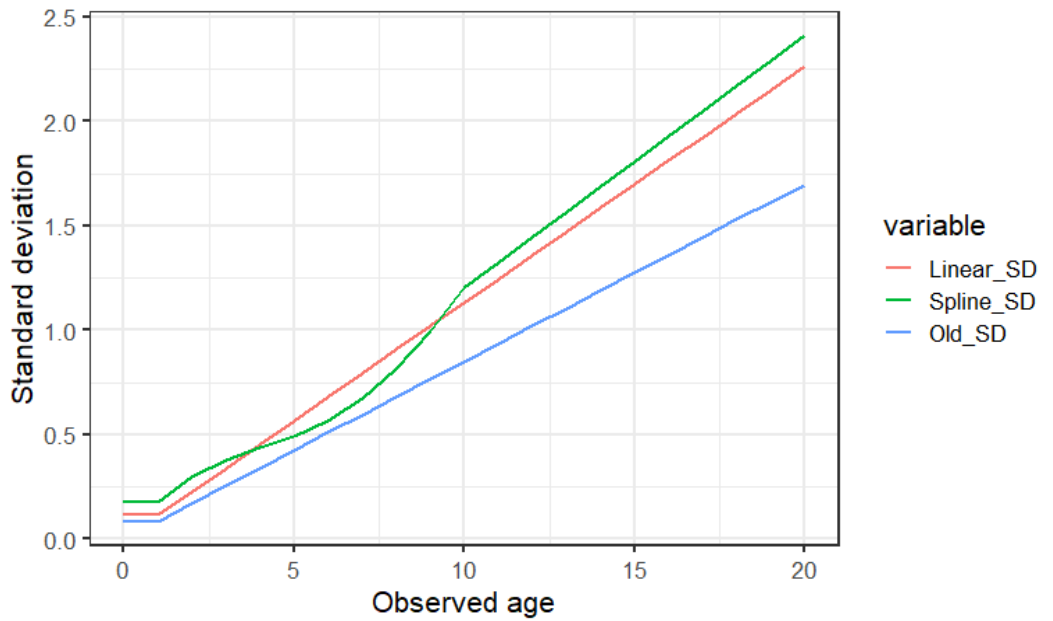


Aging Error

- 17,477 paired otolith readings from 2000-2023
- Processed in Ageing Error R library using two different models
  - 1 parameter single CV model
  - 5 knot spline model fit
- Larger standard deviation across all ages for both models than previously modeled

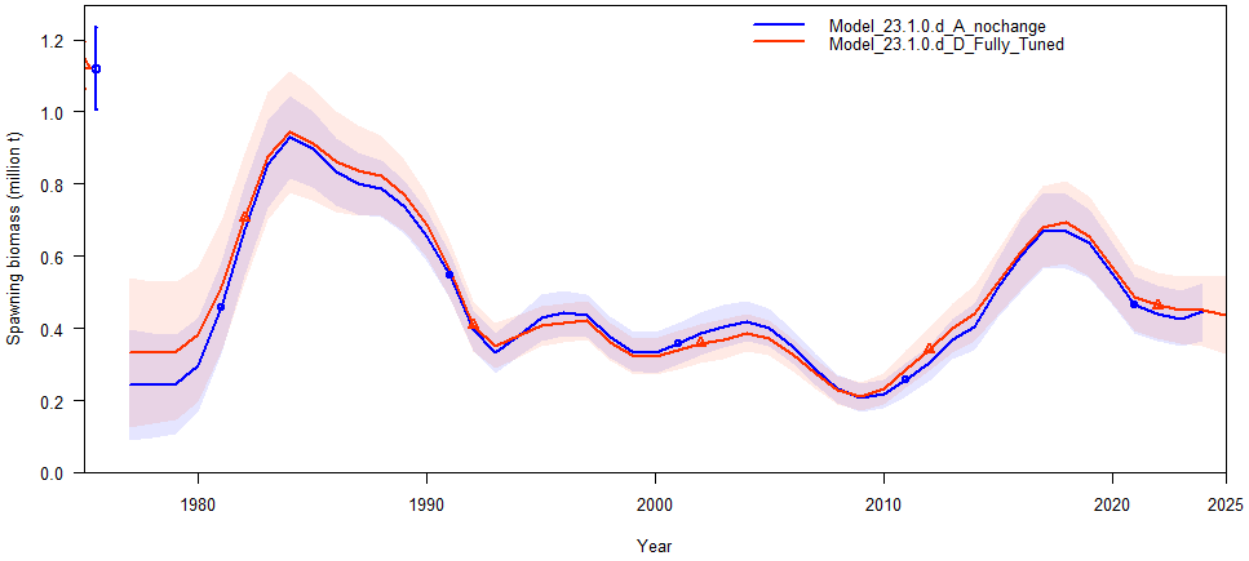


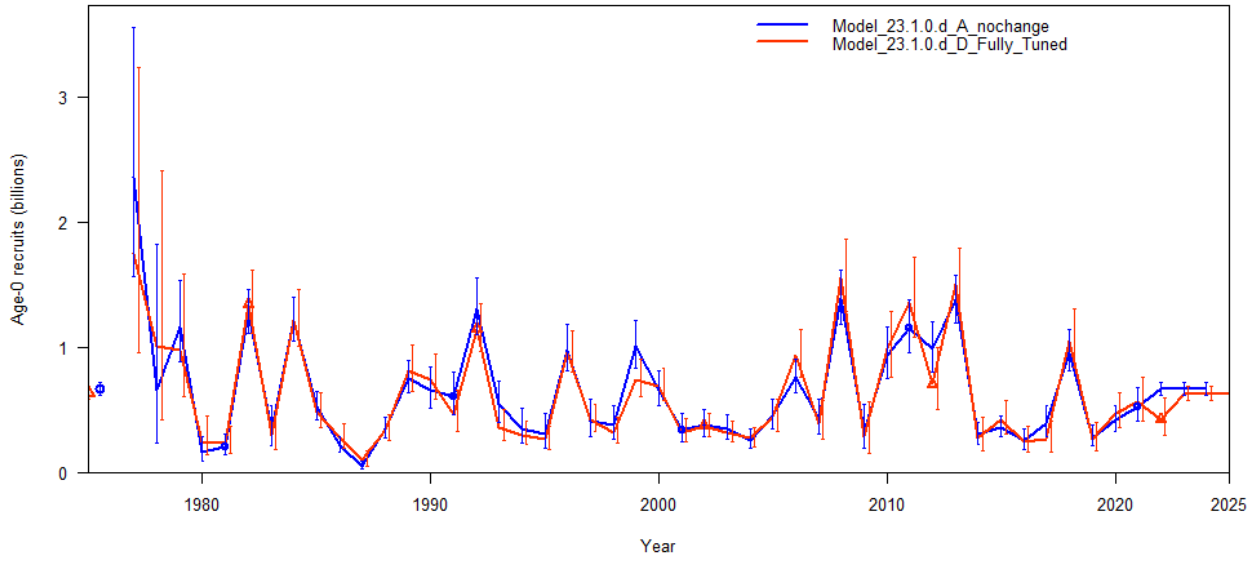




Model bridging from 2023

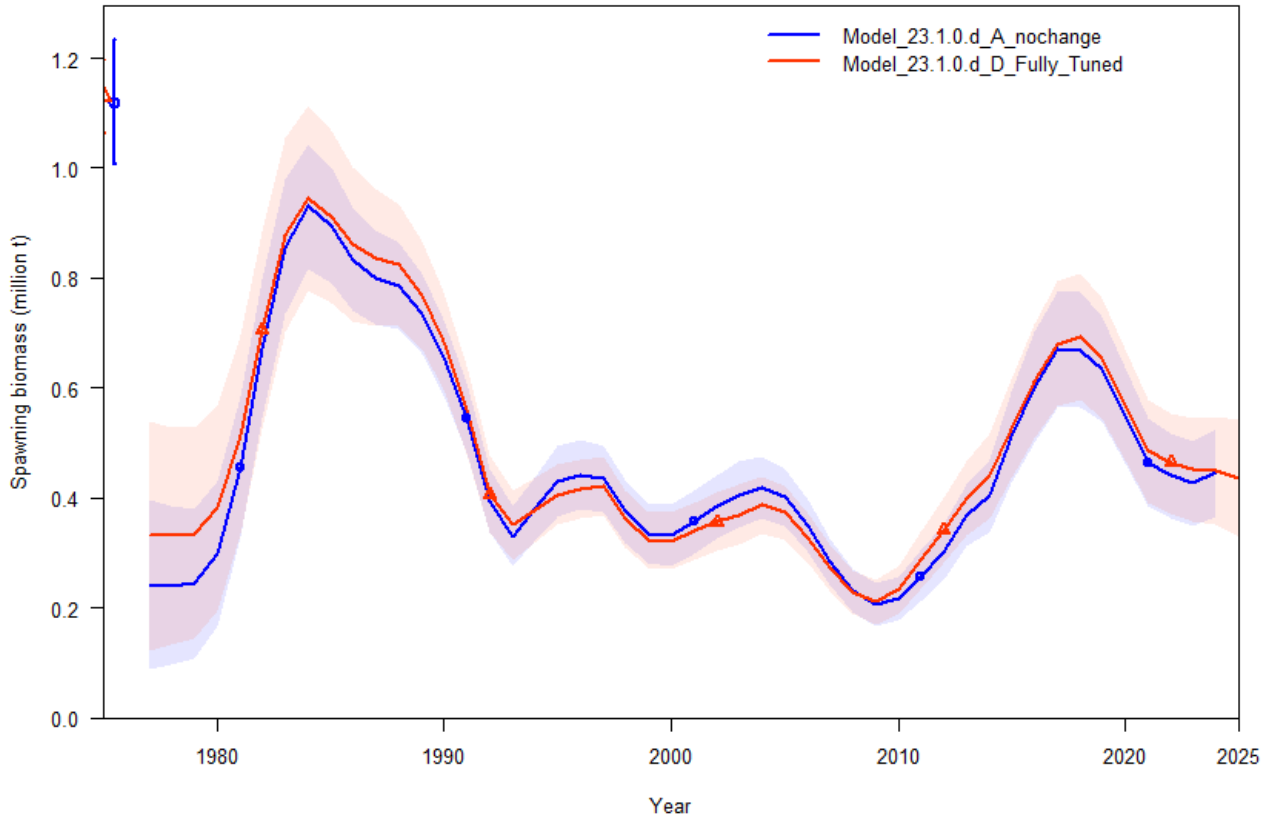
- Differences in results
  - L_{20} 2023 = 112.39 2024 = 112.78
  - $LN(R_0)$ 2023 = 13.44 2024 = 13.36
  - $B_{100\%}$ 2023 = 572kt 2024 = 567kt
  - $B_{2025}\%$ 2023 = $B_{37\%}$ 2024 = $B_{38\%}$
  - $L_{1.5}$ 2023 = 14.87 2024 = 13.99
  - Q 2023 = 0.93 2024 = 0.97
  - B_{2025} 2023 = 211kt 2024 = 218kt
  - ABC_{2025} 2023 = 150kt 2024 = 156kt

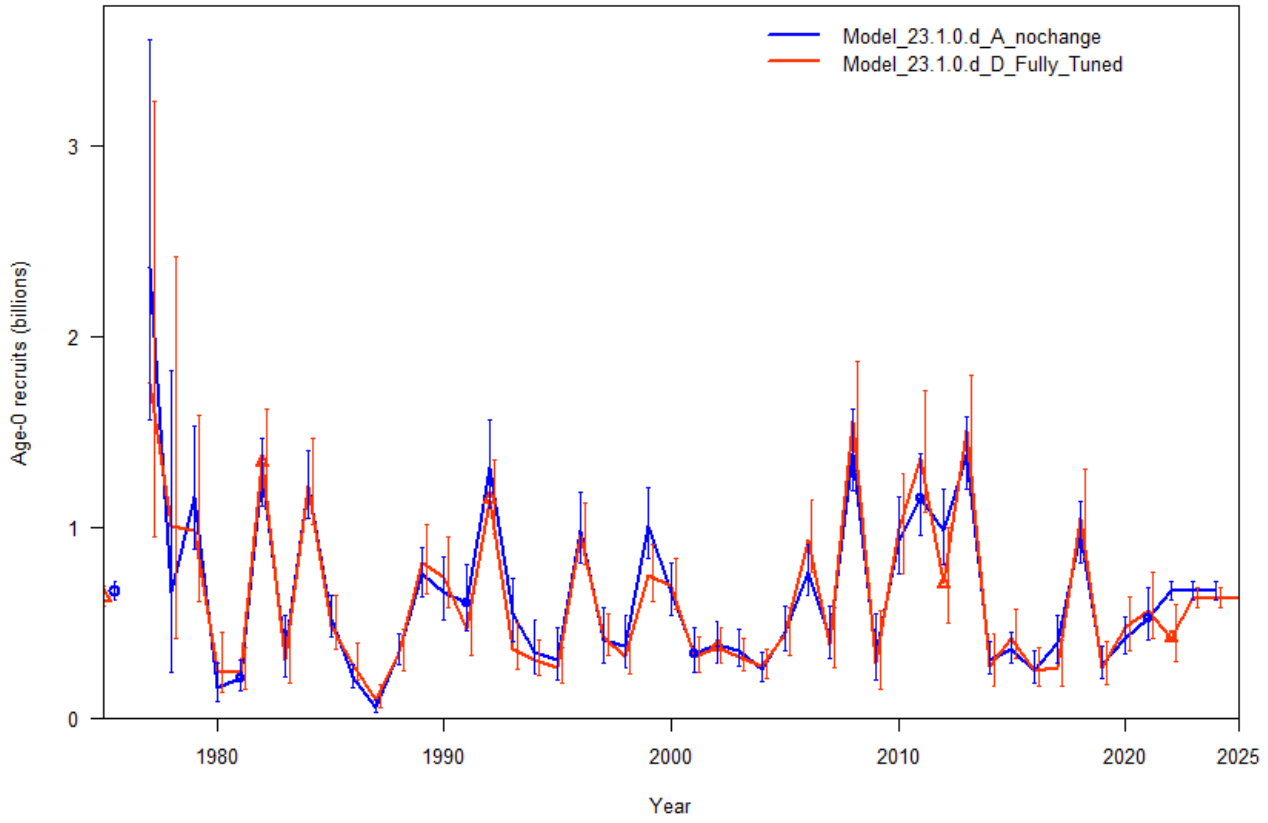




Model bridging from 2023

- Change in recruitment in some large pre-2000 cohorts
- 2022 recruitment dropped from average
- Slightly lower average recruitment





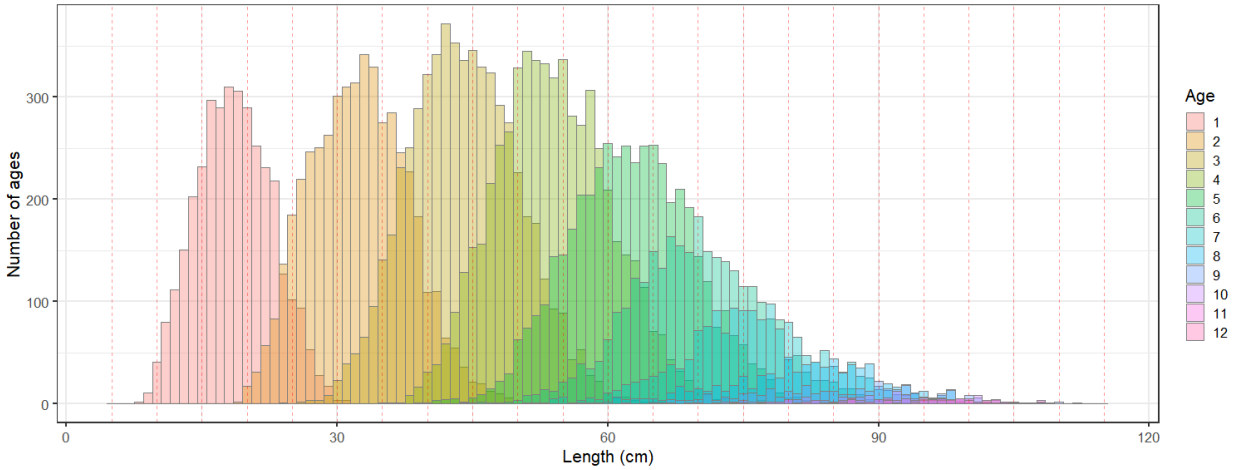
Model development

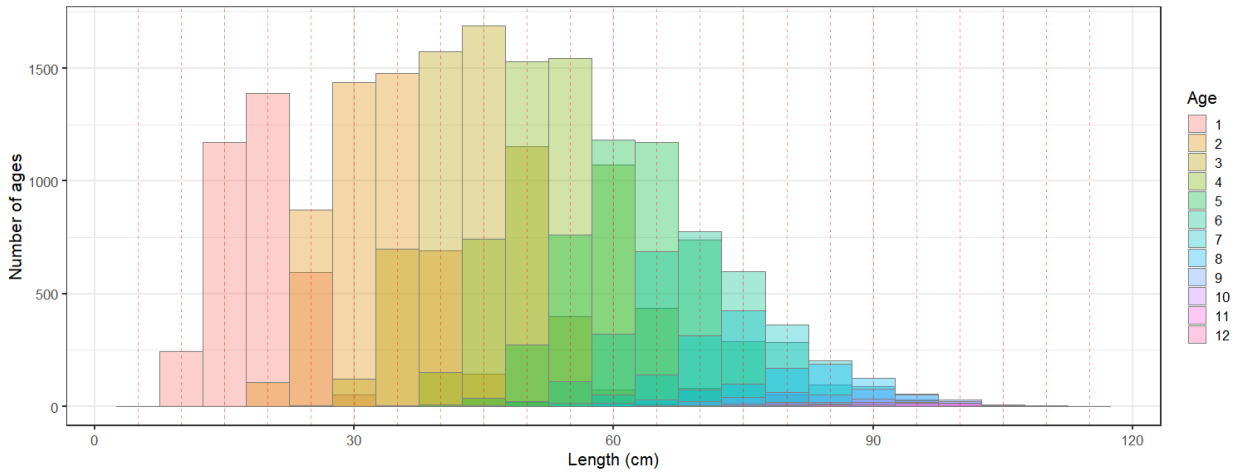
Models	Size bins	Annually varying growth Parameters	Aging error model	Survey selectivity with annually varying ascending width parameter?
M 23.1.0.d	1cm	$L_{1.5}$, Richard's ρ	Linear	Yes
M24.0	5cm	$L_{1.5}$, Richard's ρ	Linear	Yes
M24.1	5cm	$L_{1.5}$, Richard's K	Spline	Yes
M24.3	5cm	$L_{1.5}$, Richard's K	Spline	No

Note: Model 24.2 was for demonstration purposes only, same data and parameterization as Model 24.3, but untuned

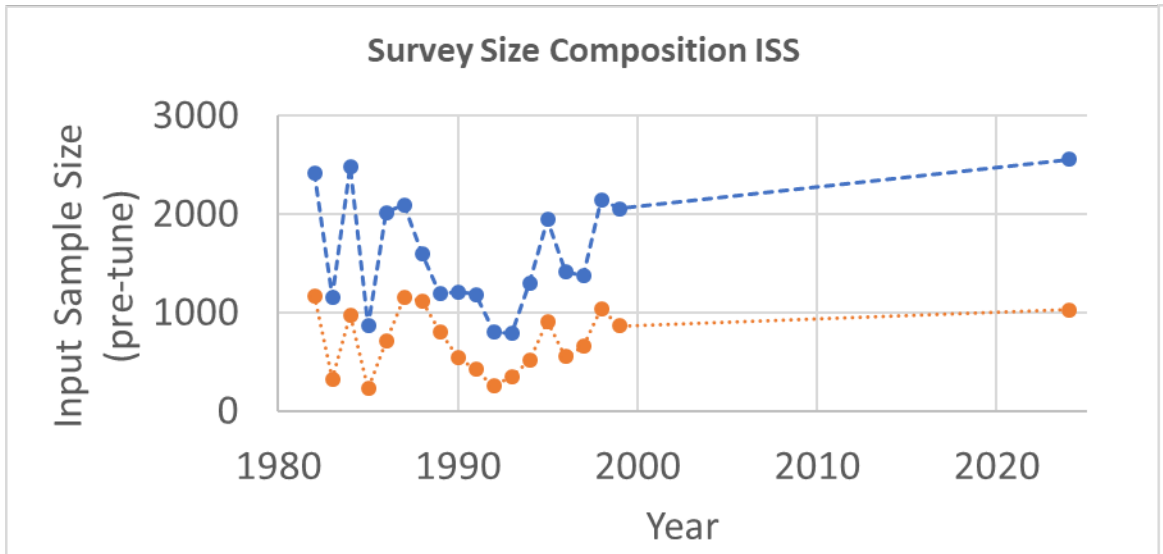
1cm to 5cm size bins

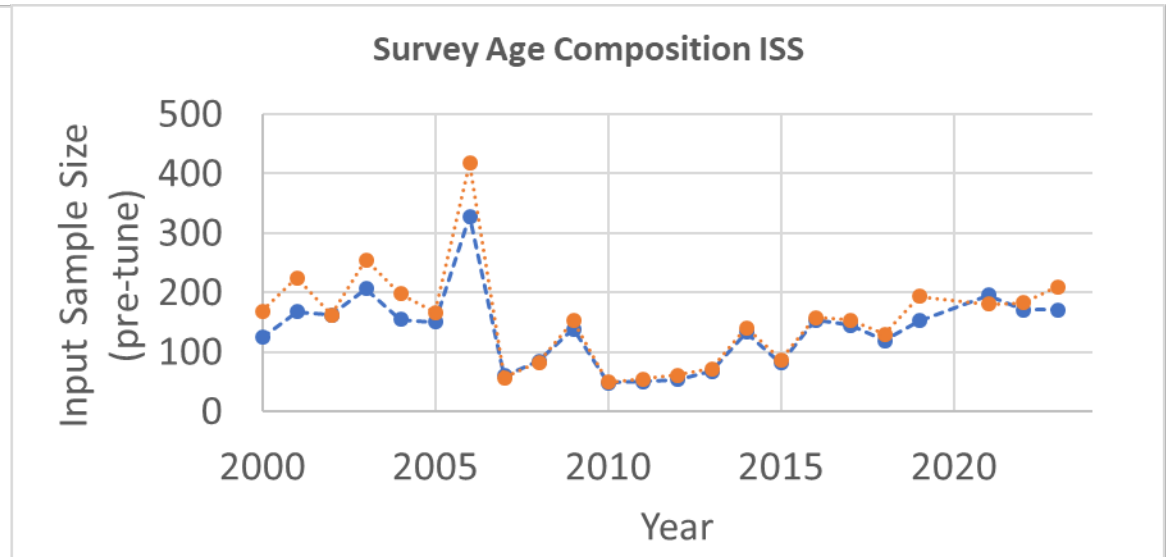
- At least 5 size bins per age class
- Results in new input sample sizes for size and age composition data
- Requires retuning of variance adjustment factors in model which adds some additional variability in results

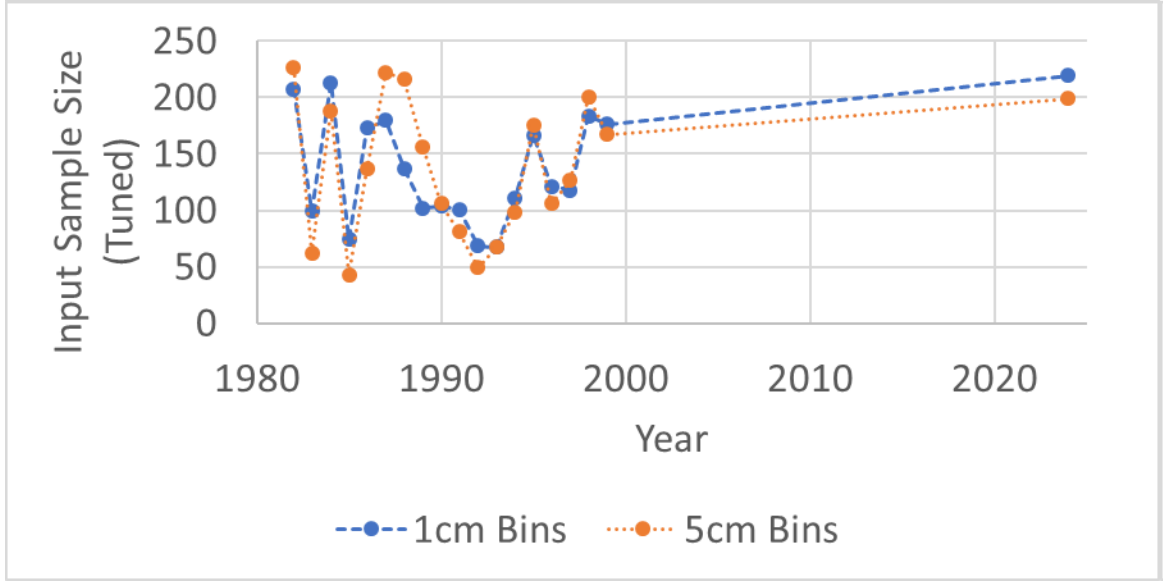


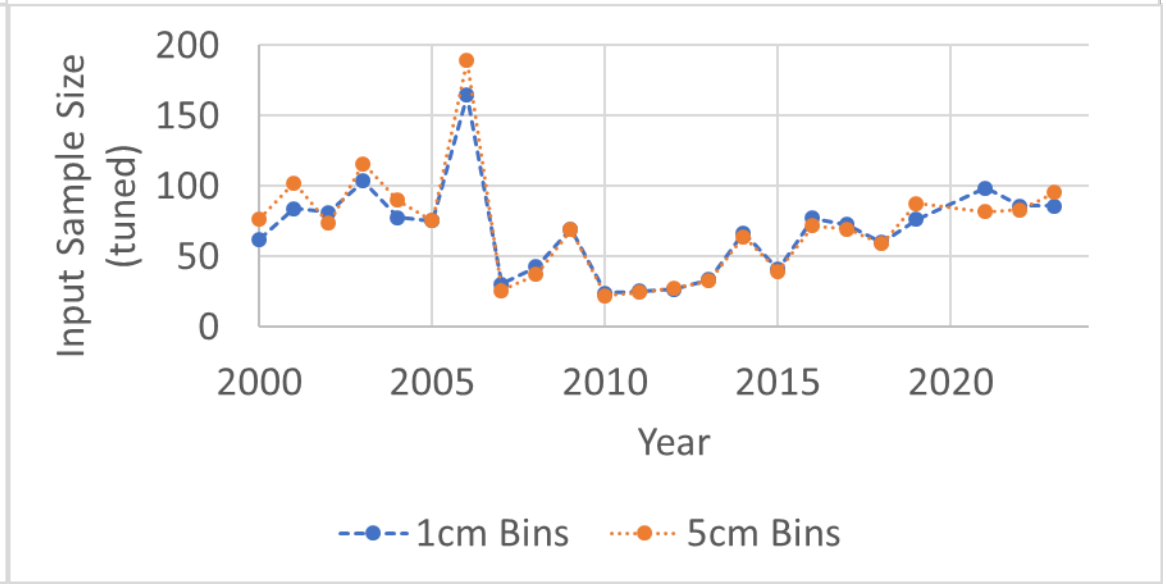


1cm to 5cm size bins VAF tuning

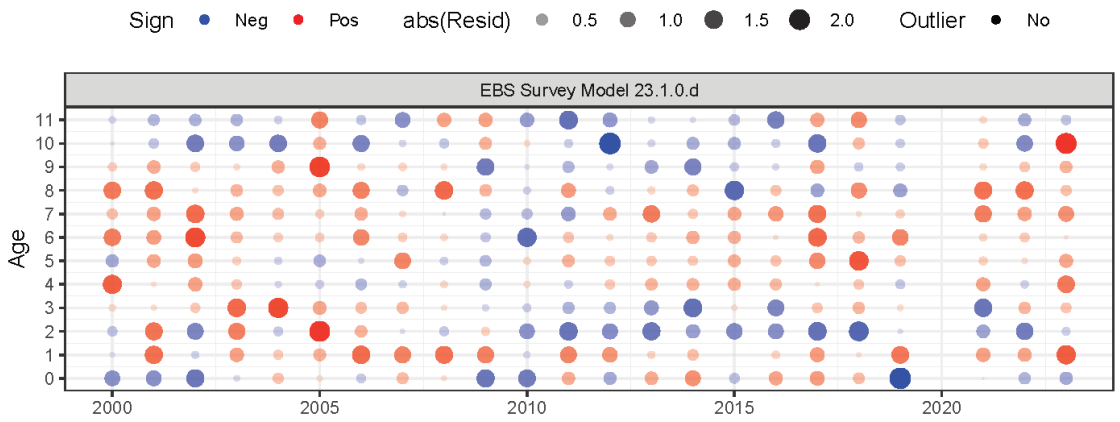


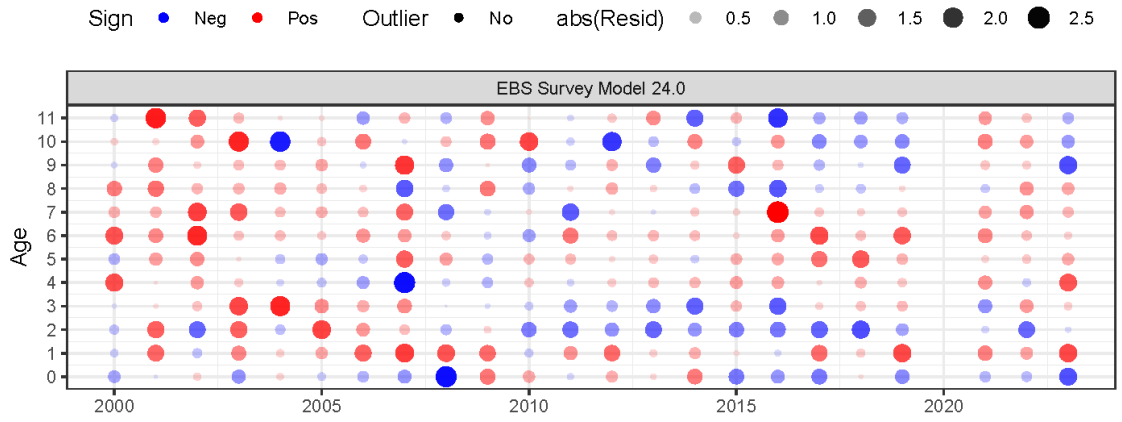


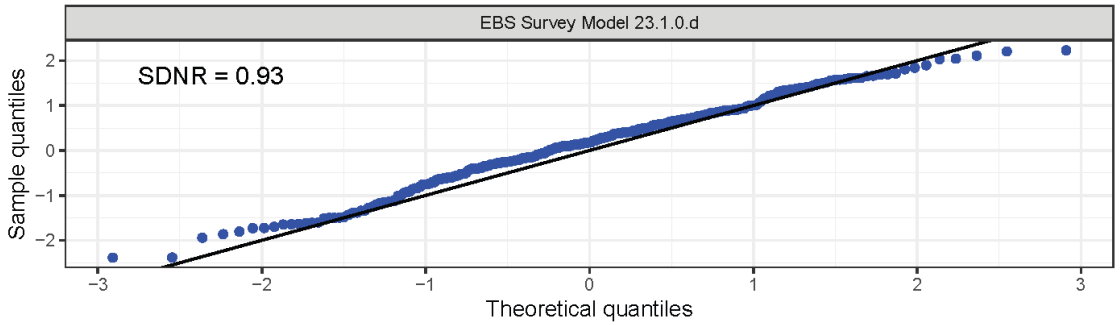


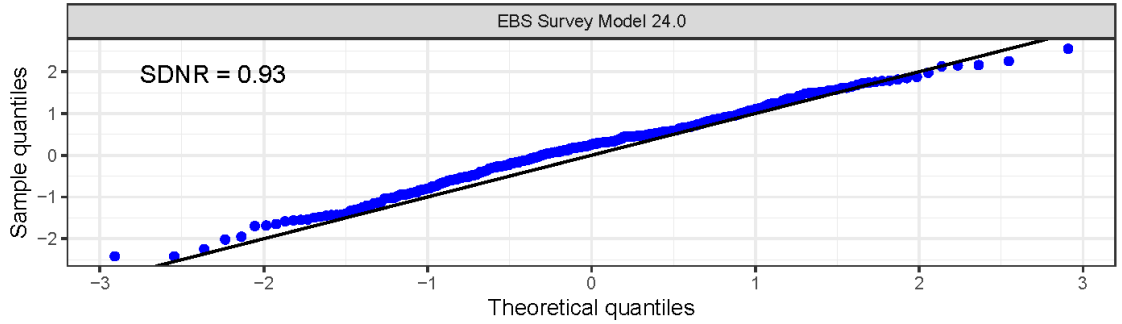


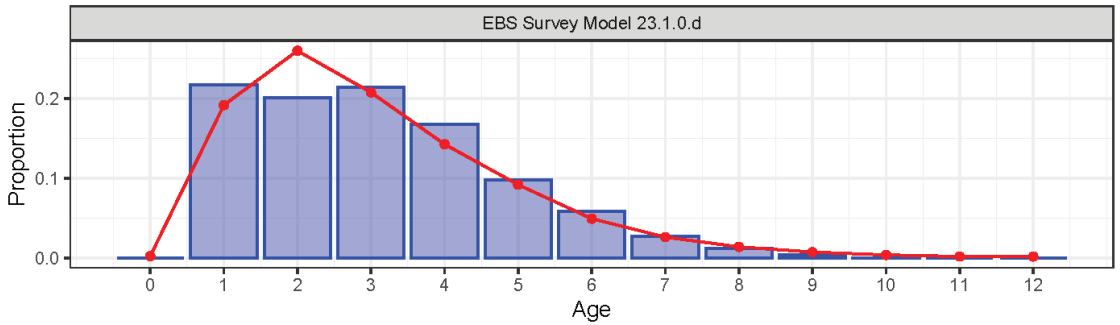
1cm to 5cm size bins OSA Ages

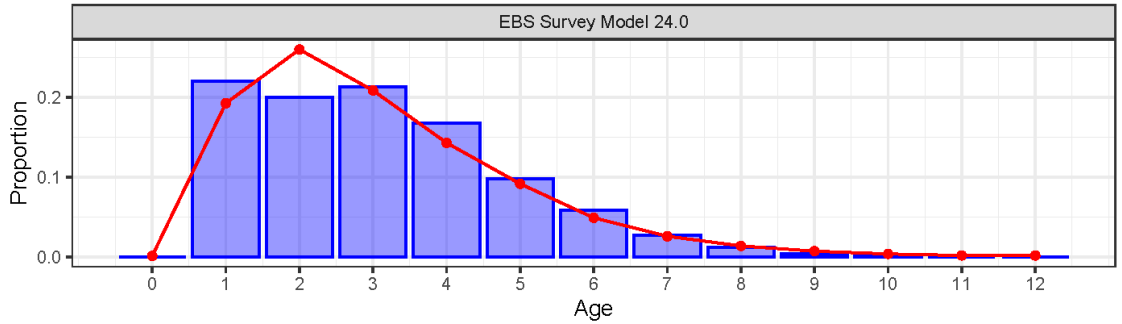




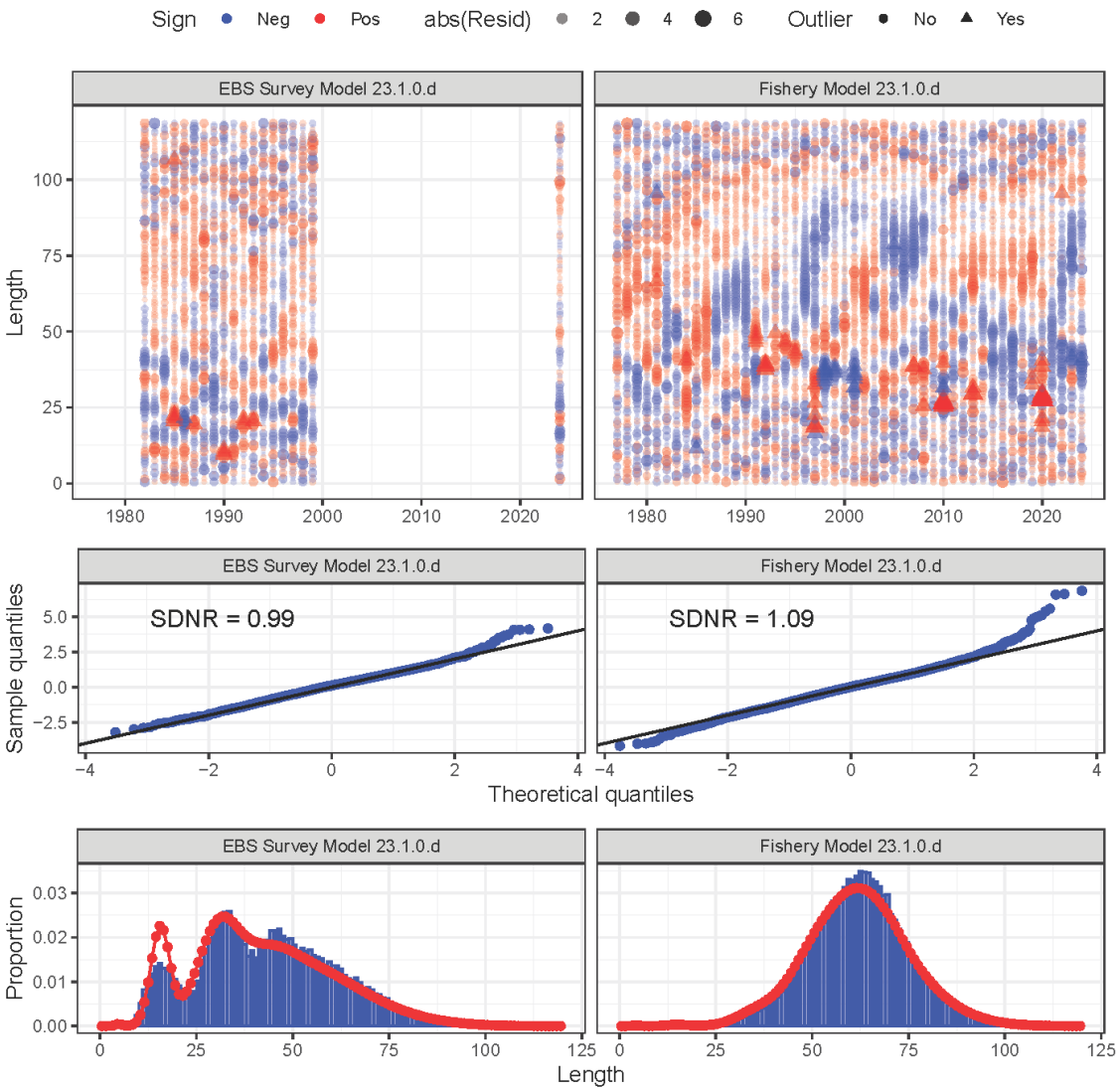


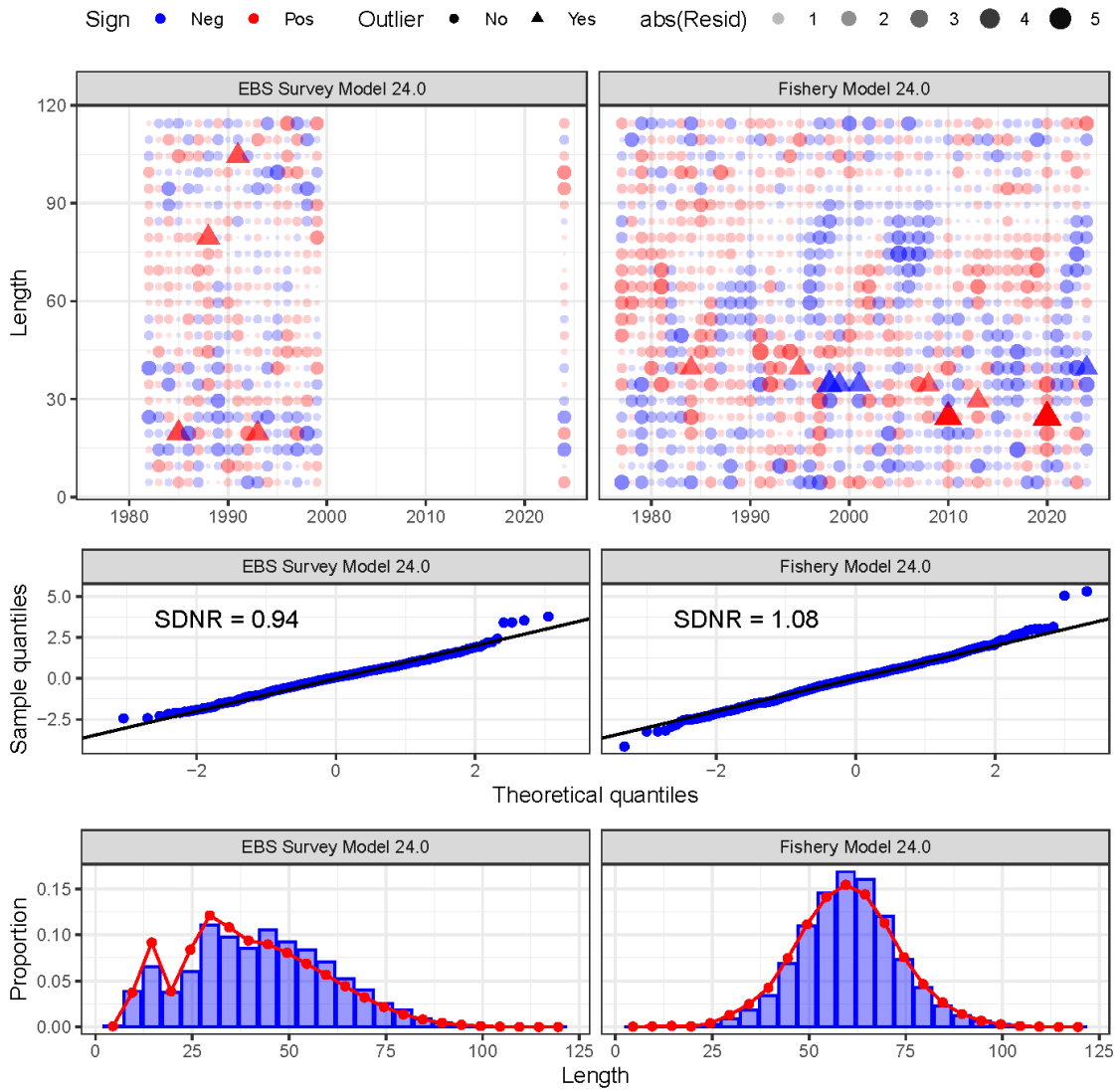






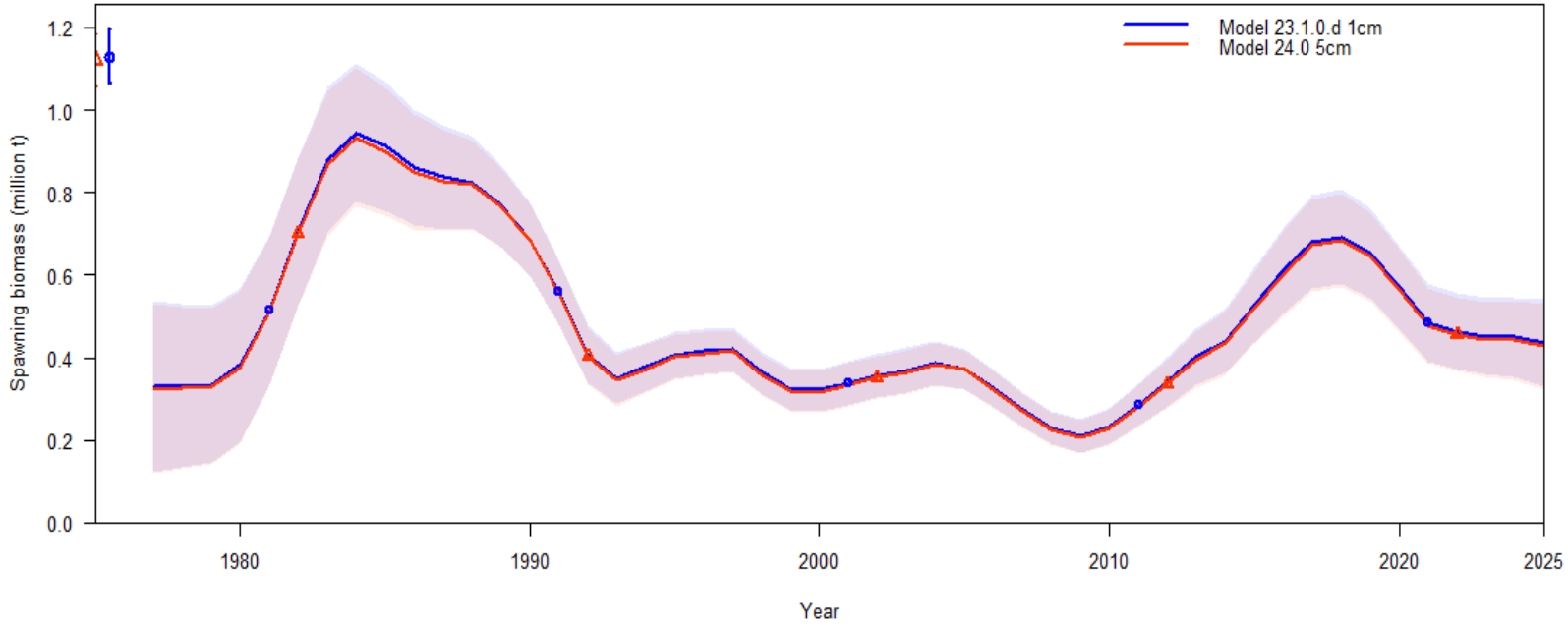
1cm to 5cm size bins OSA Length





1cm to 5cm size bins

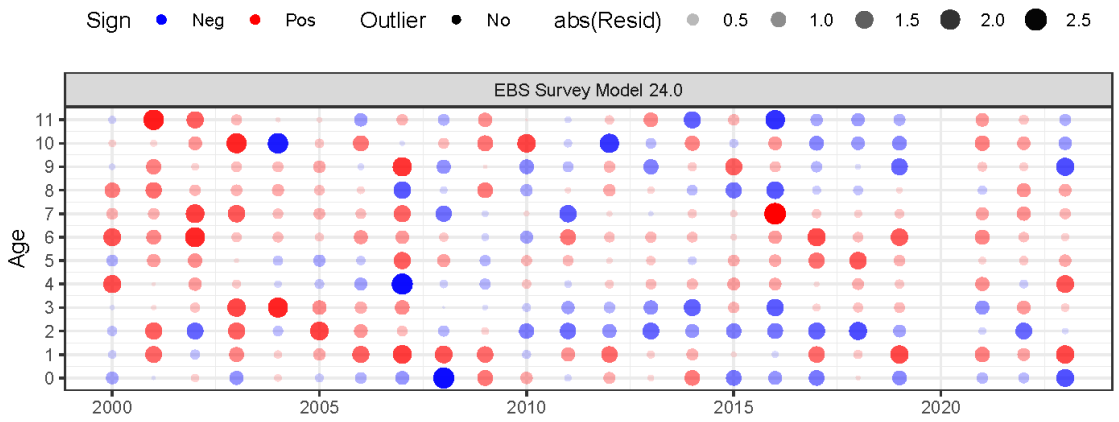
- Differences in results
  - L_{20} 1cm = 112.78 5cm = 113.28
  - $LN(R_0)$ 1cm = 13.36 5cm = 13.35
  - $B_{100\%}$ 1cm = 567kt 5cm = 562kt
  - $B_{2025}\%$ 1cm = $B_{38\%}$ 5cm = $B_{38\%}$
  - $L_{1.5}$ 1cm = 13.99 5cm = 13.87
  - Q 1cm = 0.97 5cm = 0.99
  - B_{2025} 1cm = 218kt 5cm = 213kt
  - ABC_{2025} 1cm = 156kt 5cm = 151kt

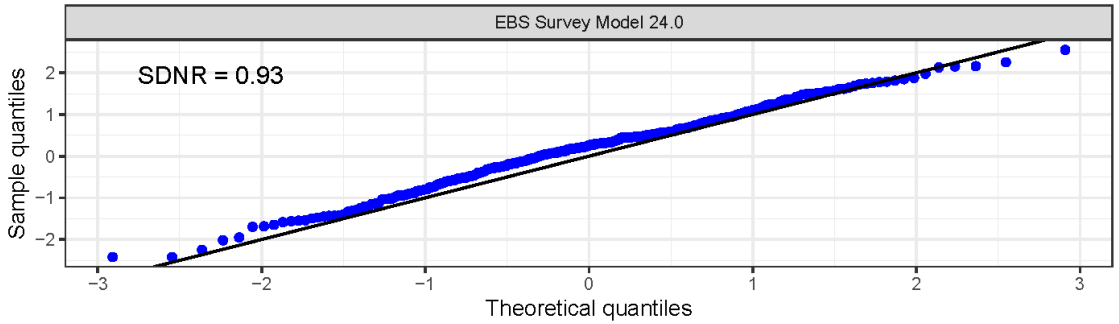


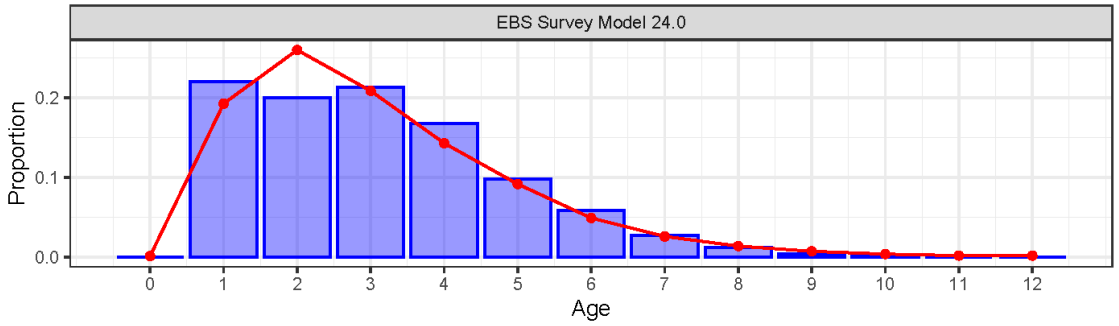
Model 24.0 vs 24.1

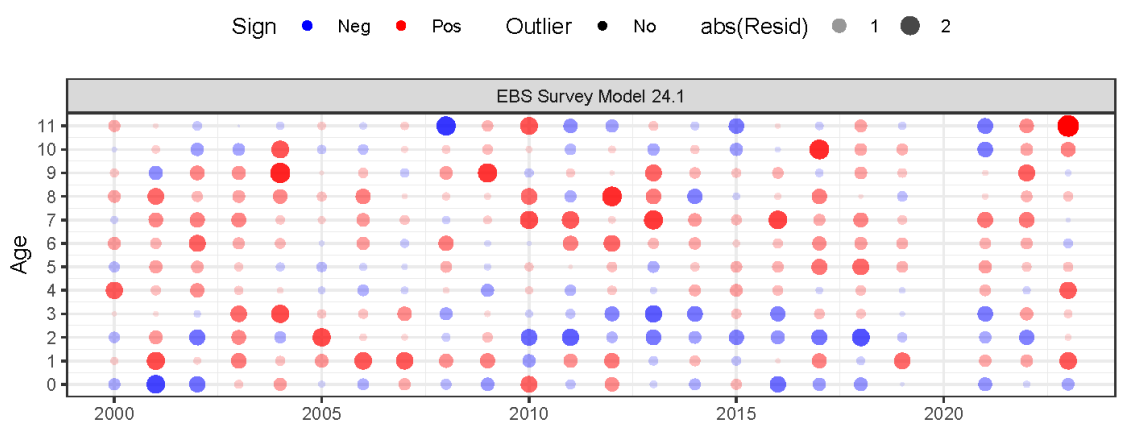
- Differences in models
  - Spline aging error instead of linear
  - Annual variability in growth on Richards K instead of Richards rho
- Differences in model fits
  - Tuning and data the same between models
  - Small improvement in overall fit (-3.7 nll)
    - Marginal survey age composition (-4.3)
    - Marginal length composition (+0.1)
    - Survey Index (+0.3)
    - Parameter deviations (+0.1)
  - Similar Retrospective bias and MASE
    - Mohn's ρ M24.0 = -0.11 and M24.1 = -0.10
    - MASE
      - Survey Index M24.0 = 0.47 M24.1 = 0.45
      - Fishery Size Comp M24.0 = 0.16 M24.1 = 0.15
      - Survey Age Comp M24.0 = 0.15 M24.1 = 0.14

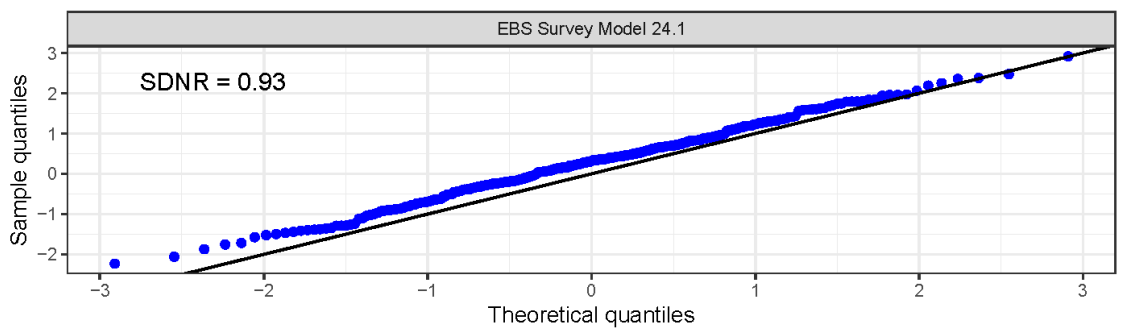
Model 24.0 vs 24.1 OSA Residuals Age

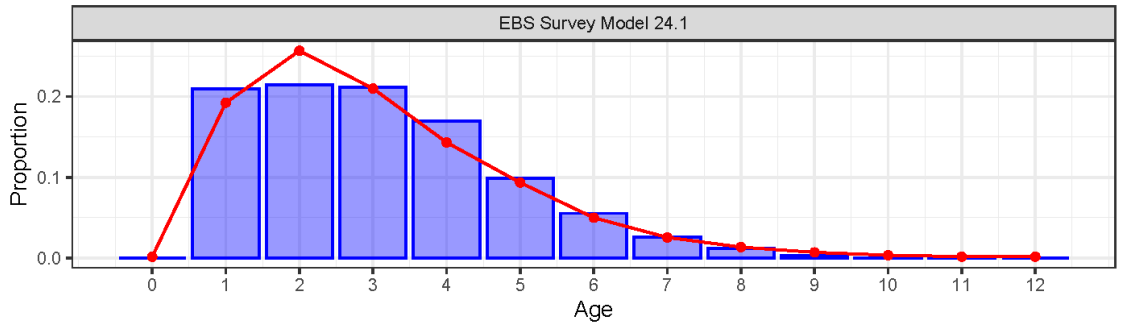




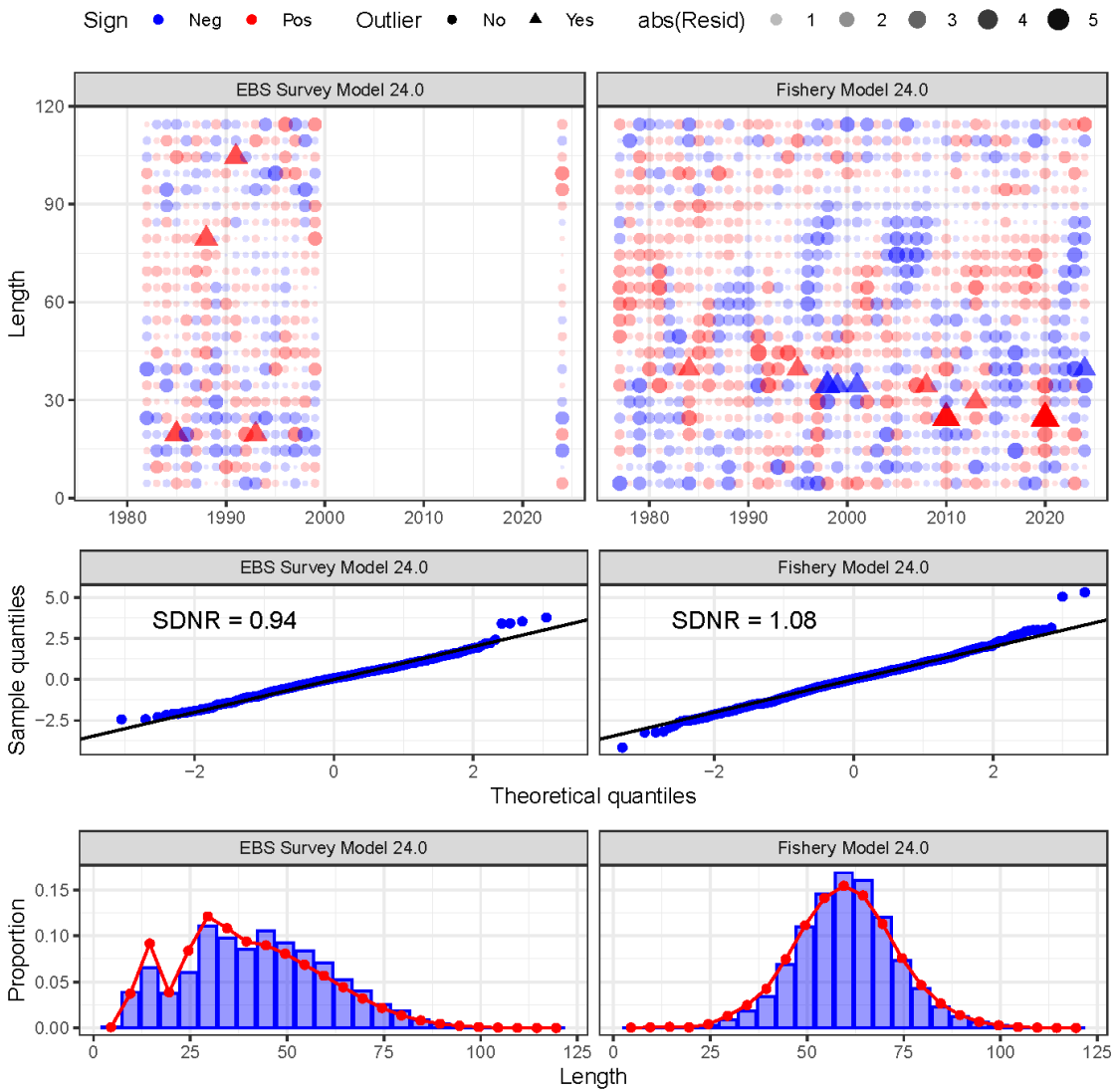


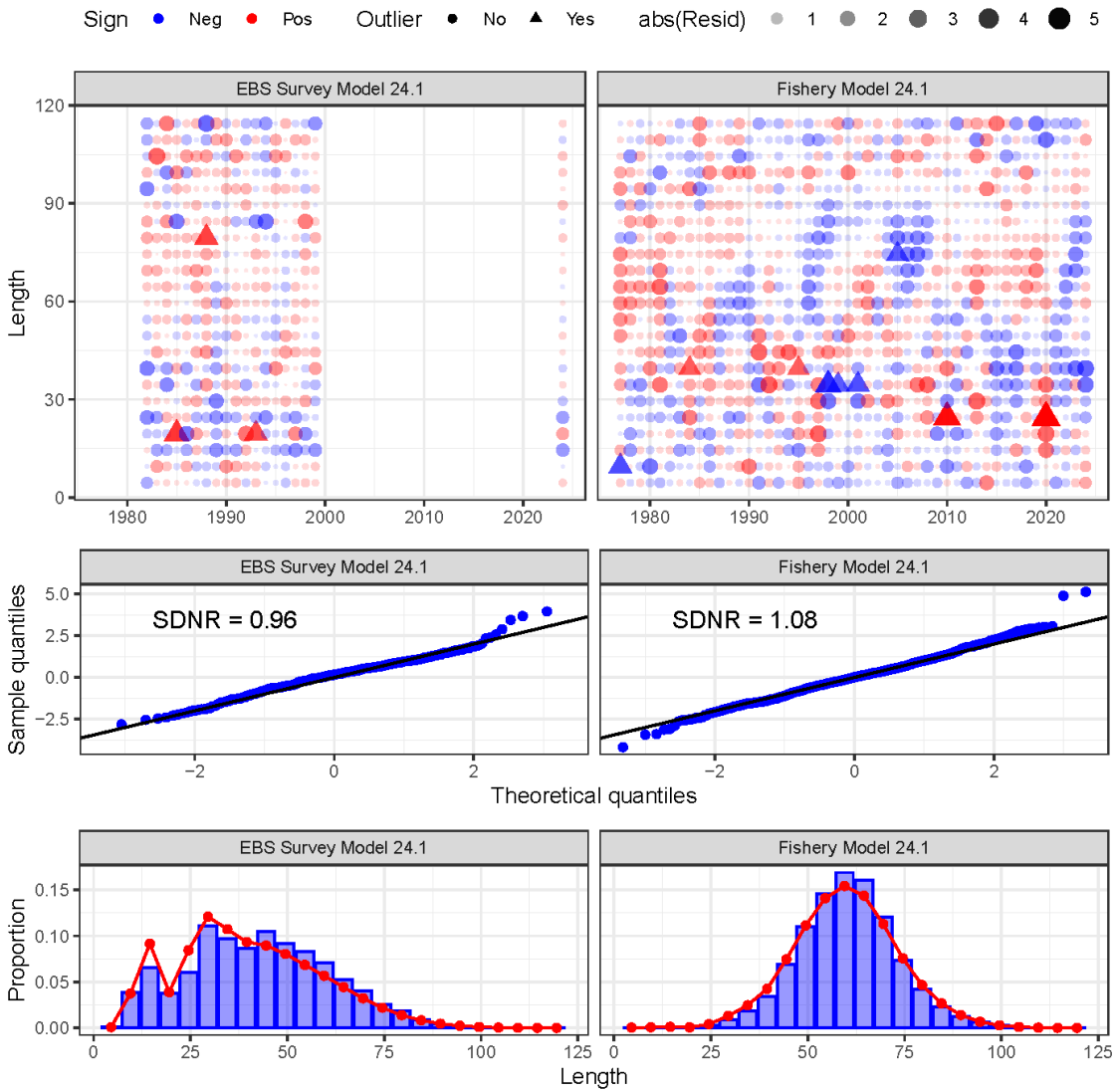






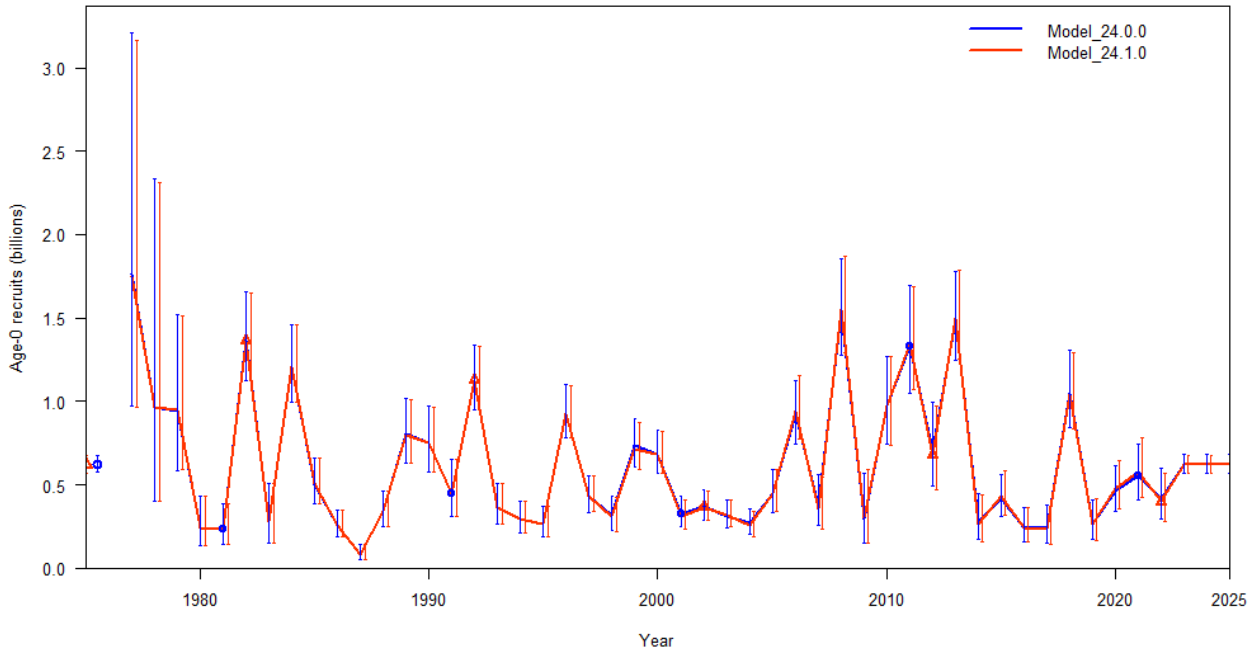
Model 24.0 vs 24.1 OSA Residuals Length

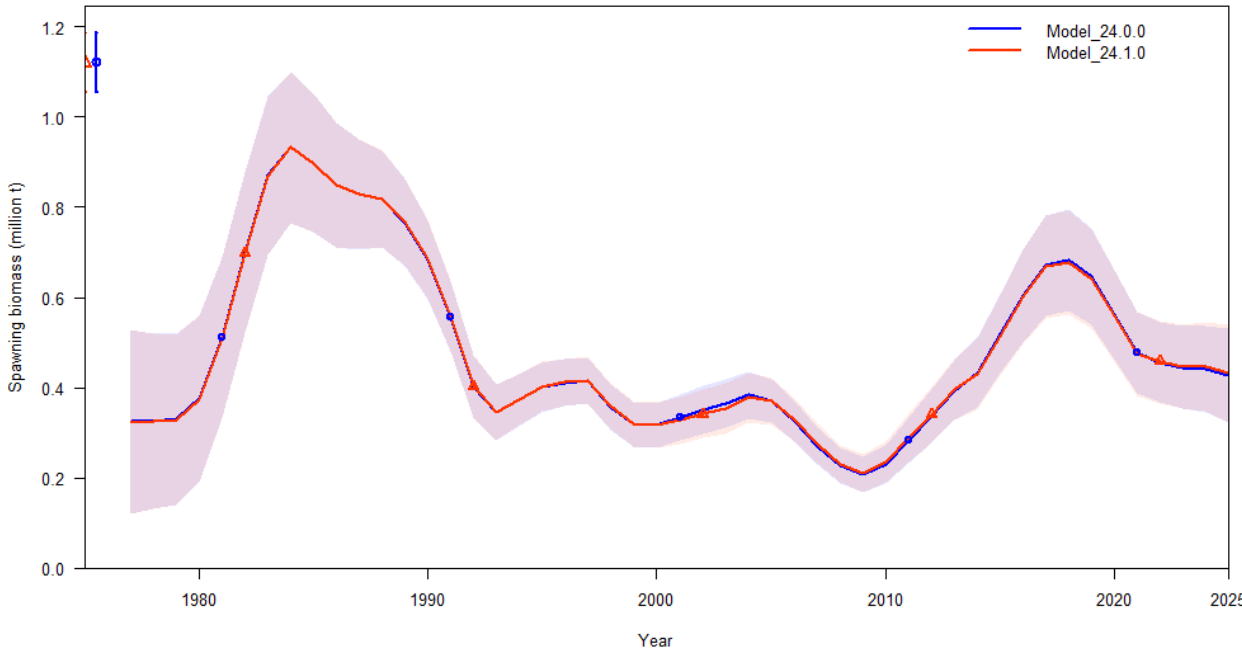




Model 24.0 vs 24.1

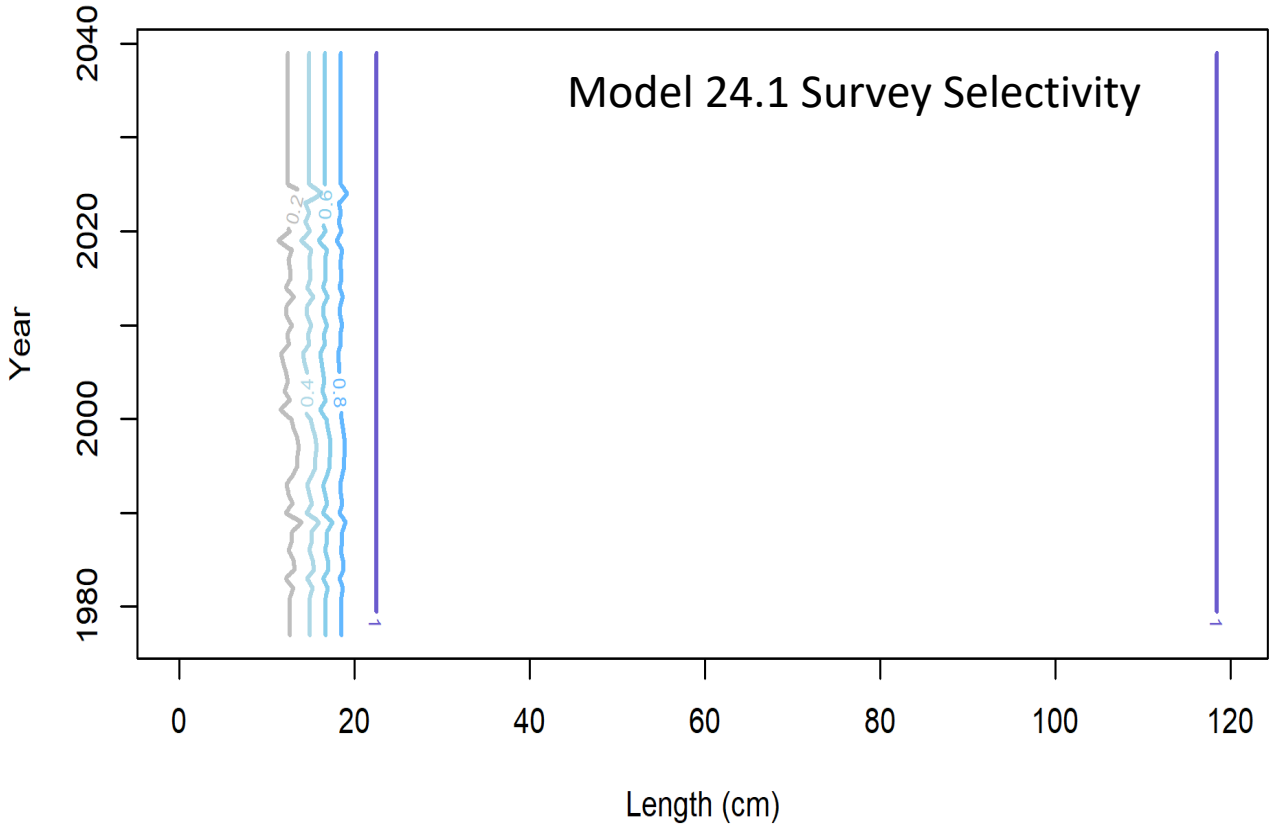
- Differences in results
  - L_{20} M24.0 =113.28 M24.1= 112.26
  - LN(R_0) M24.0 = 13.35 M24.1 = 13.34
  - $B_{100\%}$ M24.0 = 562kt M24.1 = 562kt
  - B_{2025}% M24.0 = $B_{38\%}$ M24.1 = $B_{38\%}$
  - $L_{1.5}$ M24.0 = 13.87 M24.1 = 13.85
  - Q M24.0 = 0.99 M24.1 = 0.99
  - B_{2025} M24.0 = 213kt M24.1 = 216kt
  - ABC_{2025} M24.0 = 151kt M24.1 = 154kt

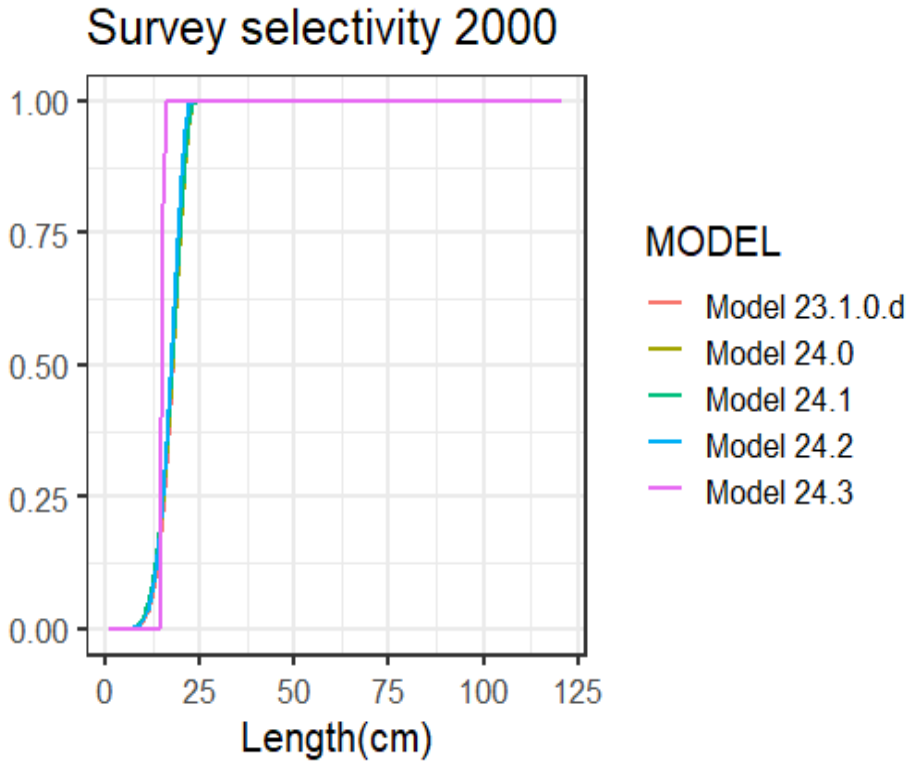




Model 24.1 vs 24.3

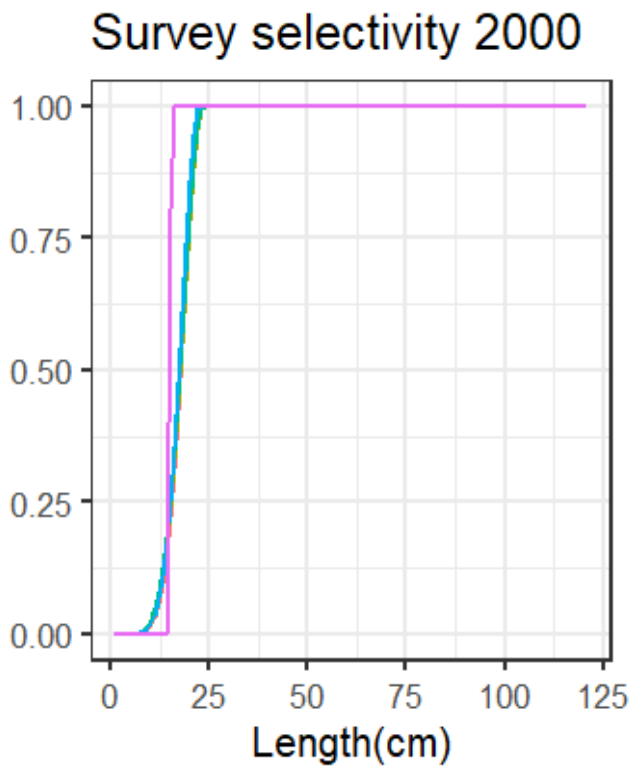
- Differences in models
  - Annually varying survey selectivity
    - Random walk on width of the ascending slope in Model 24.1
    - Annually non-varying survey selectivity for Model 24.3

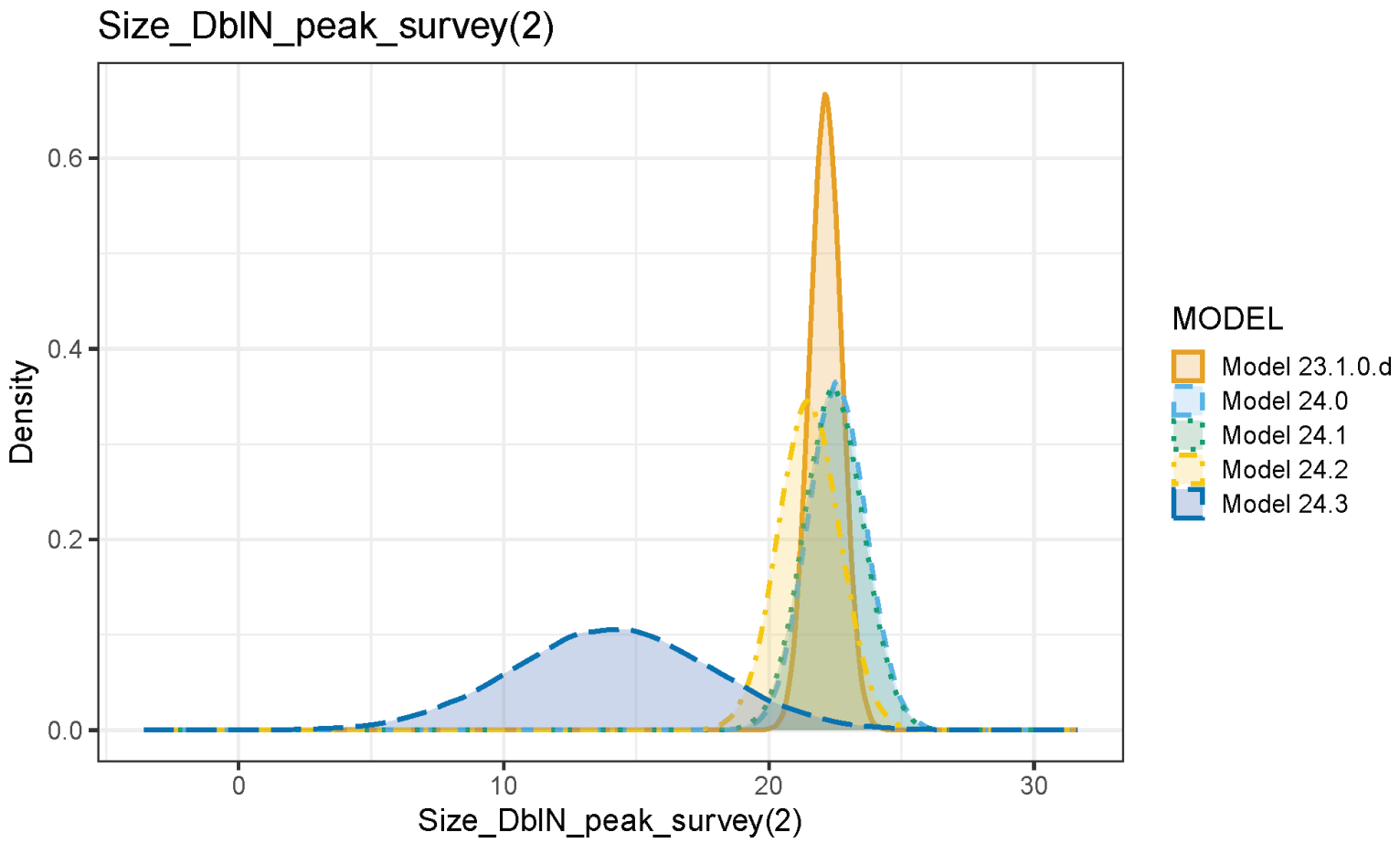




Model 24.1 vs. 24.3

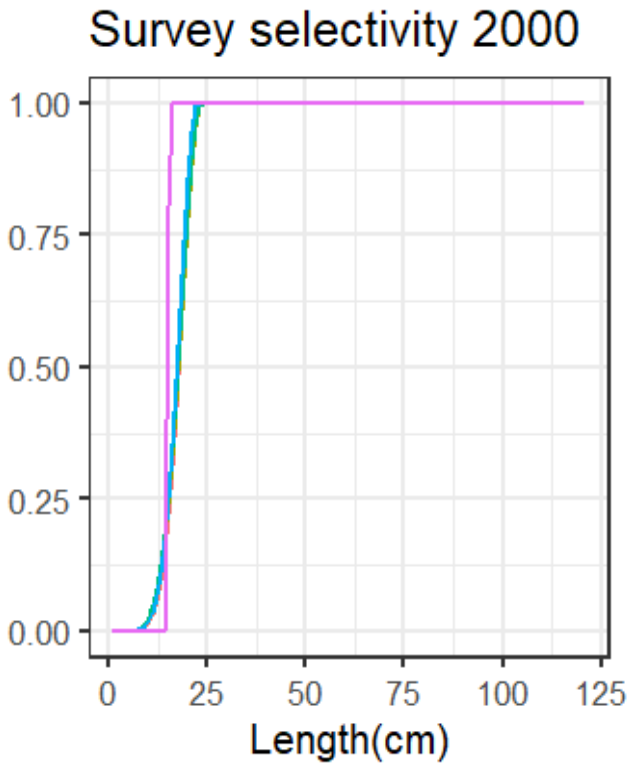
- Model 24.3 peak survey selectivity
  - Smaller less certain peak survey
    - M24.3 14.09 CV = 27%
    - M24.1 22.45 CV = 5%

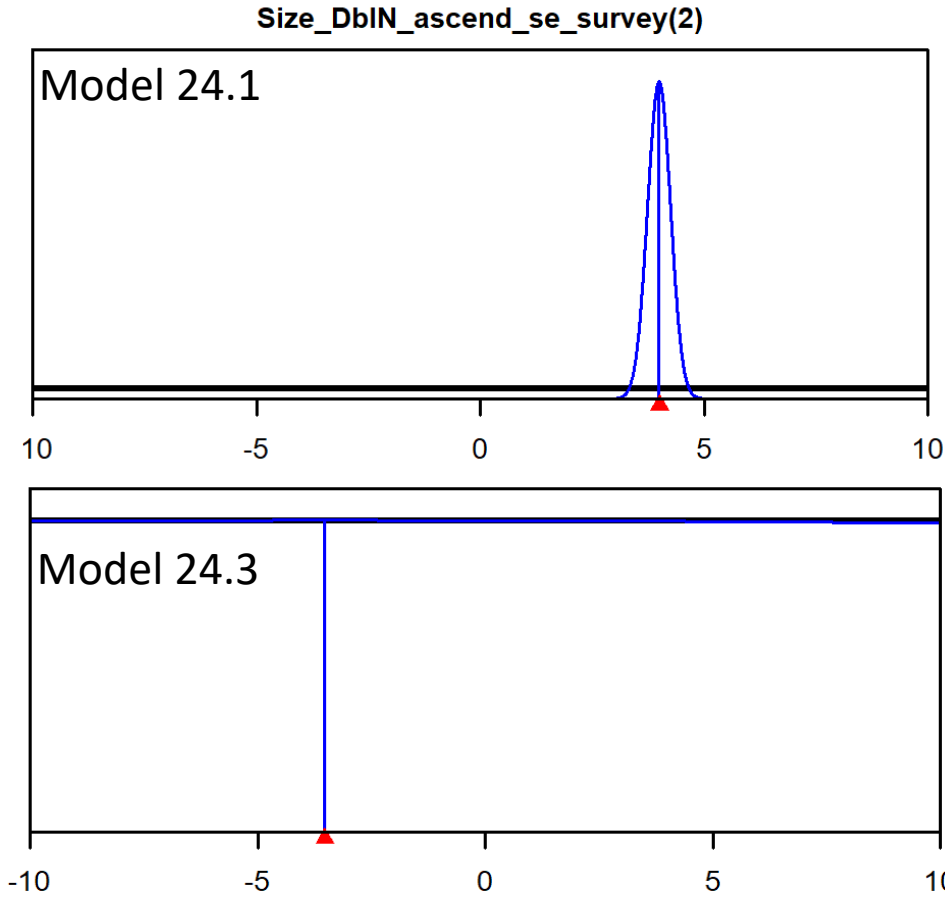




Model 24.1 vs. 24.3

- Model 24.3 width of the ascending slope
  - Knife edge (value = -3.52)
  - Highly uncertain in Model 24.3 (CV = 2781%)
  - Potentially pointing to model misspecification





Model 24.1 vs 24.3

- Differences in models
  - Re-tuning of Sigma R and growth sigmas

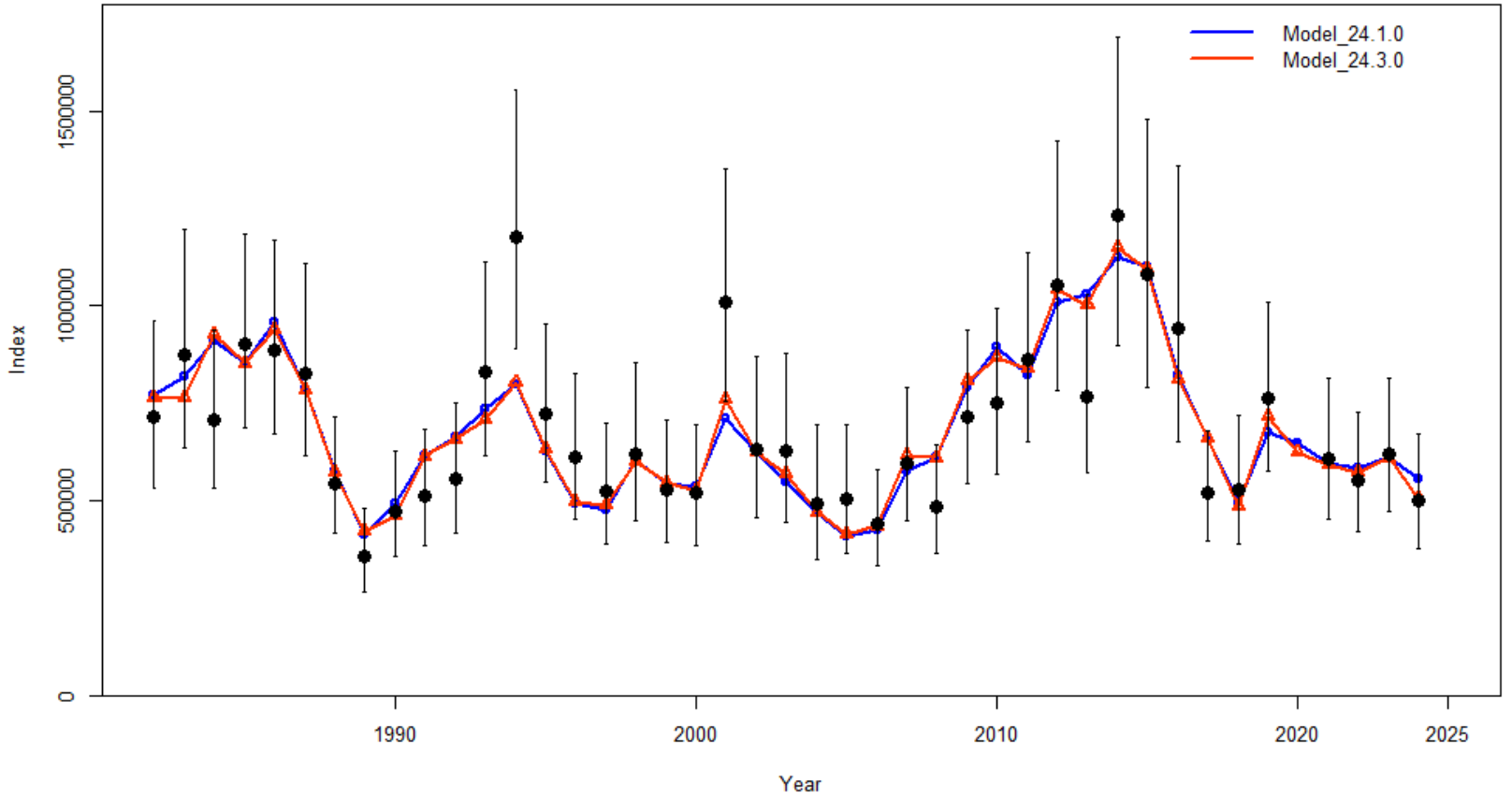
Model	Sigma R	Sigma $L_{1.5}$	Sigma K
Model 24.1	0.6908	0.2903	0.0624
Model 24.3	0.6646	0.2855	0.0511

  - Re-tuning of Variance Adjustment Factors

Model	Fishery Length	Survey Length	Survey Age
Model 24.1	0.428	0.194	0.454
Model 24.3	0.445	0.135	0.604

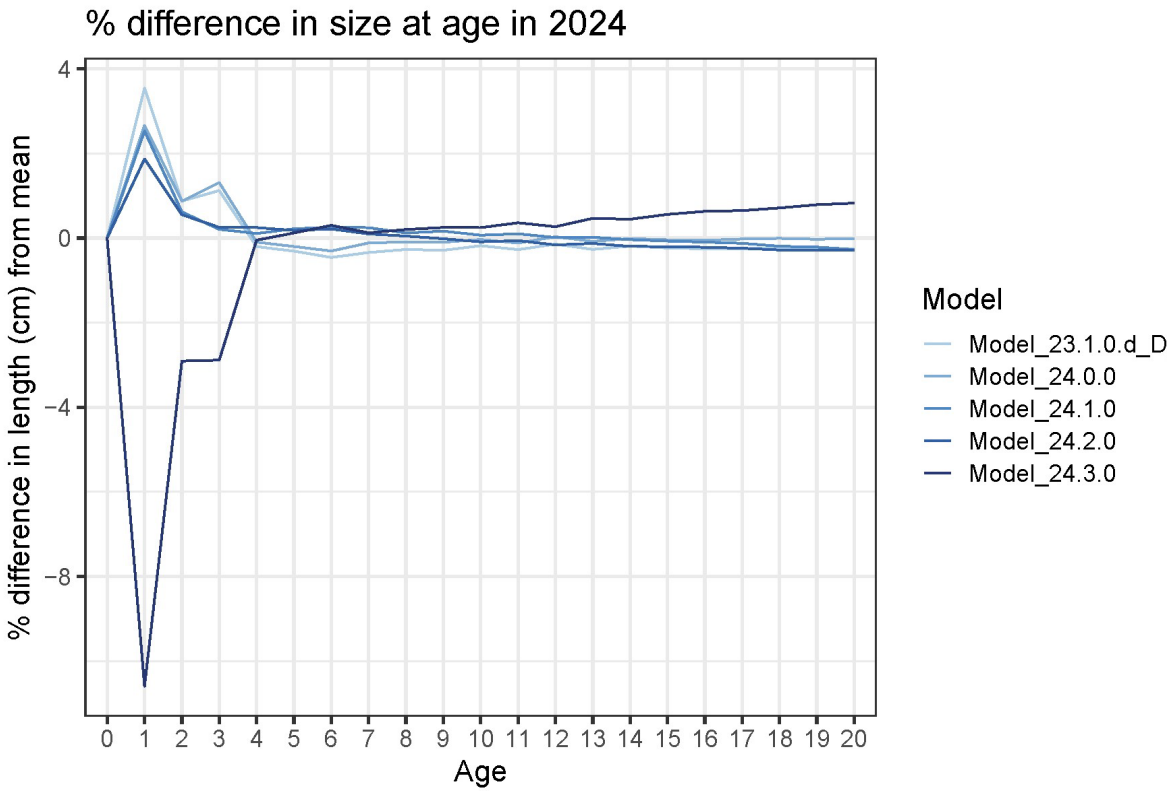
Model 24.1 vs 24.3 Index fit

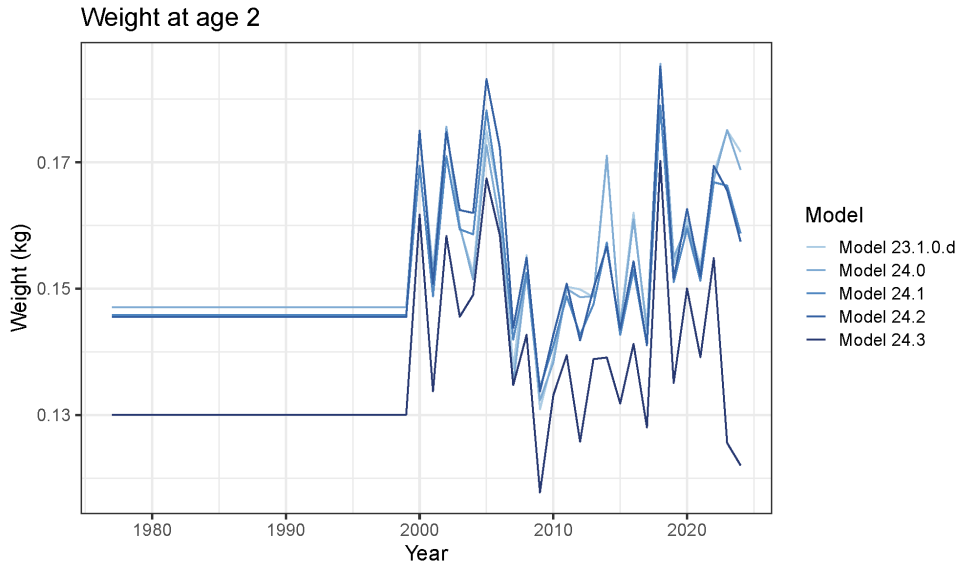
- Differences in model fits
  - Model 24.3 slight improvement in fit to survey index (-1.9 nll)

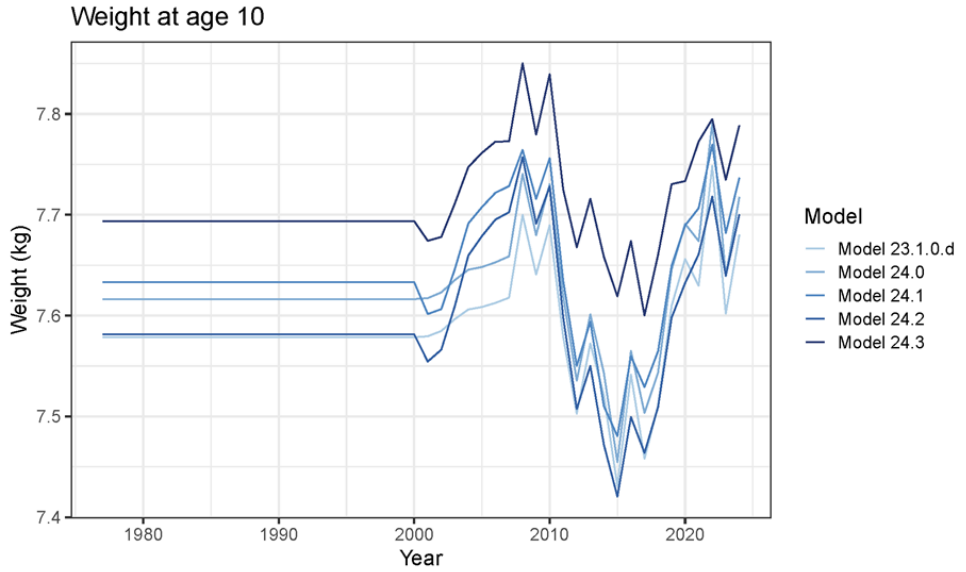


Model 24.1 vs 24.3

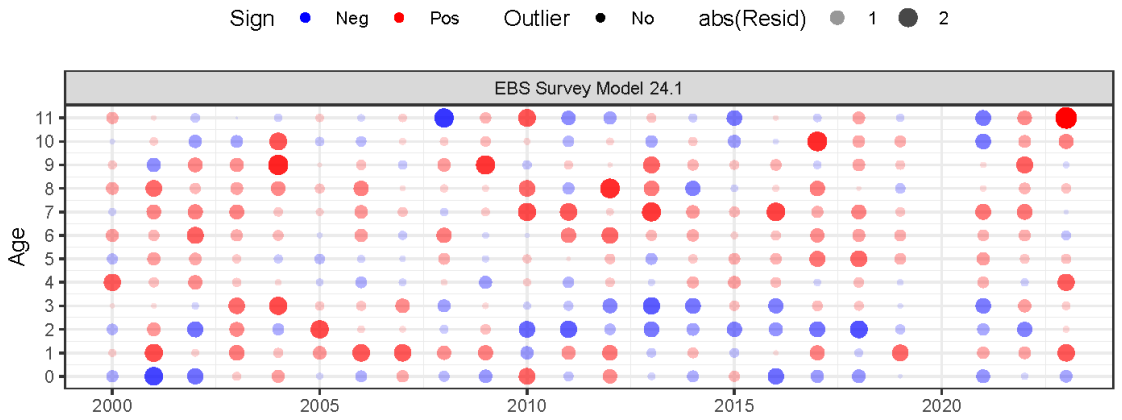
- Differences in models
  - Change in growth
    - Smaller fish at younger ages
    - Larger fish at older ages

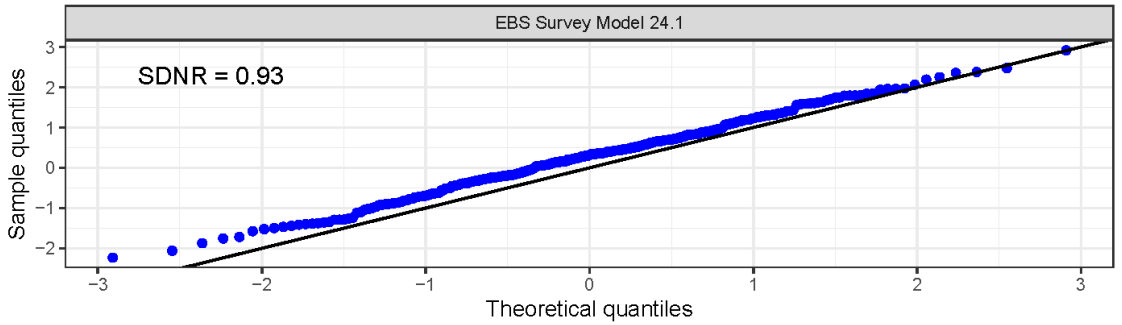


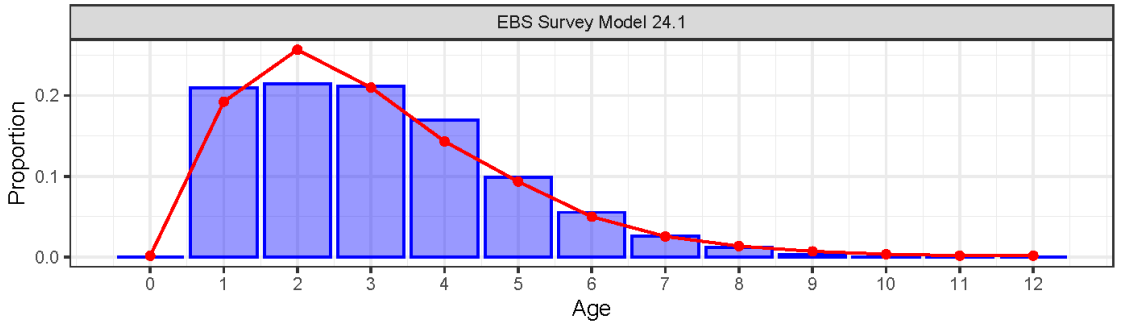


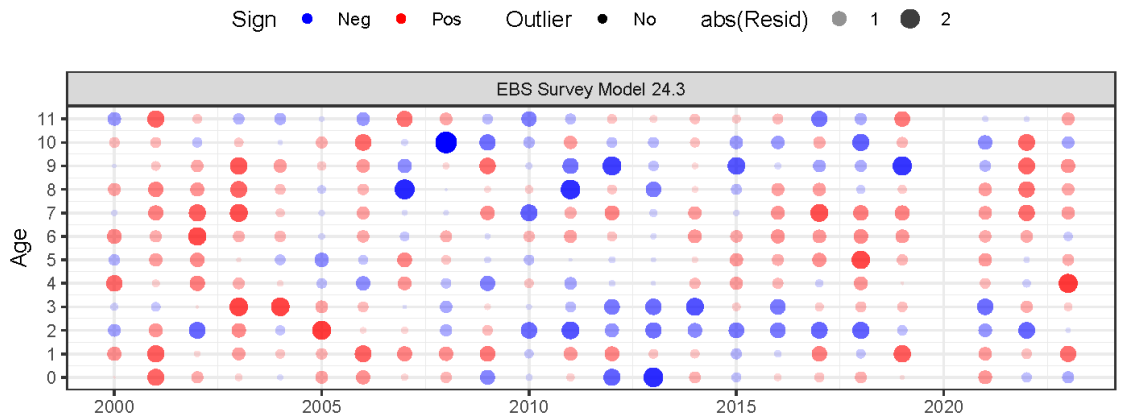


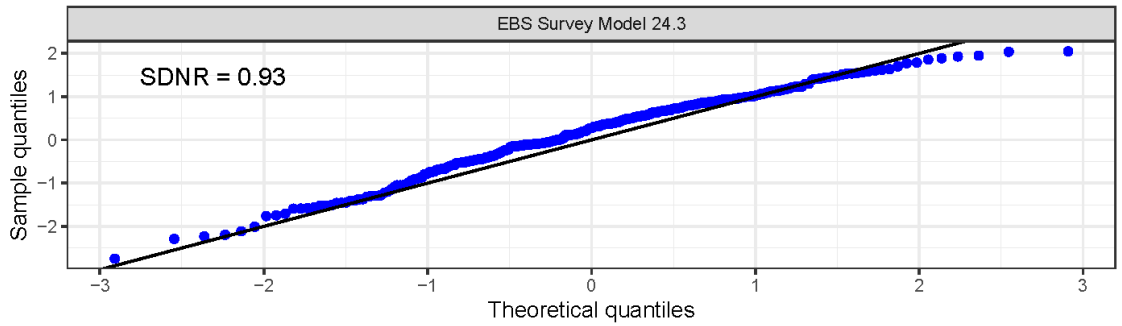
Model 24.1 vs 24.3 OSA Residuals Age

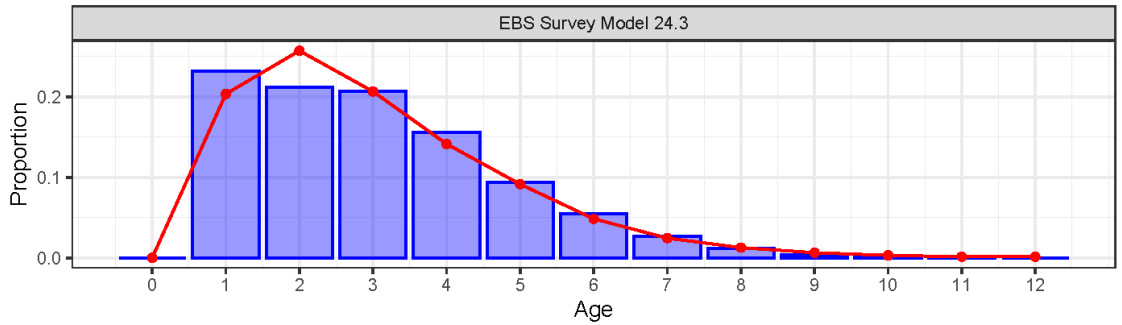








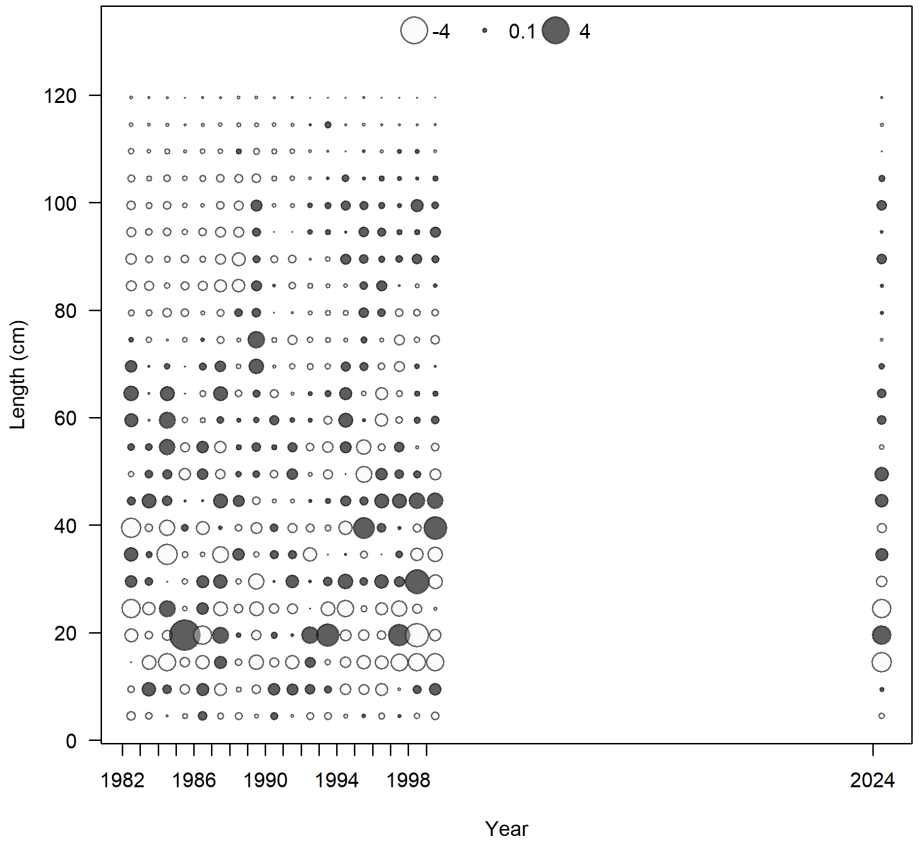




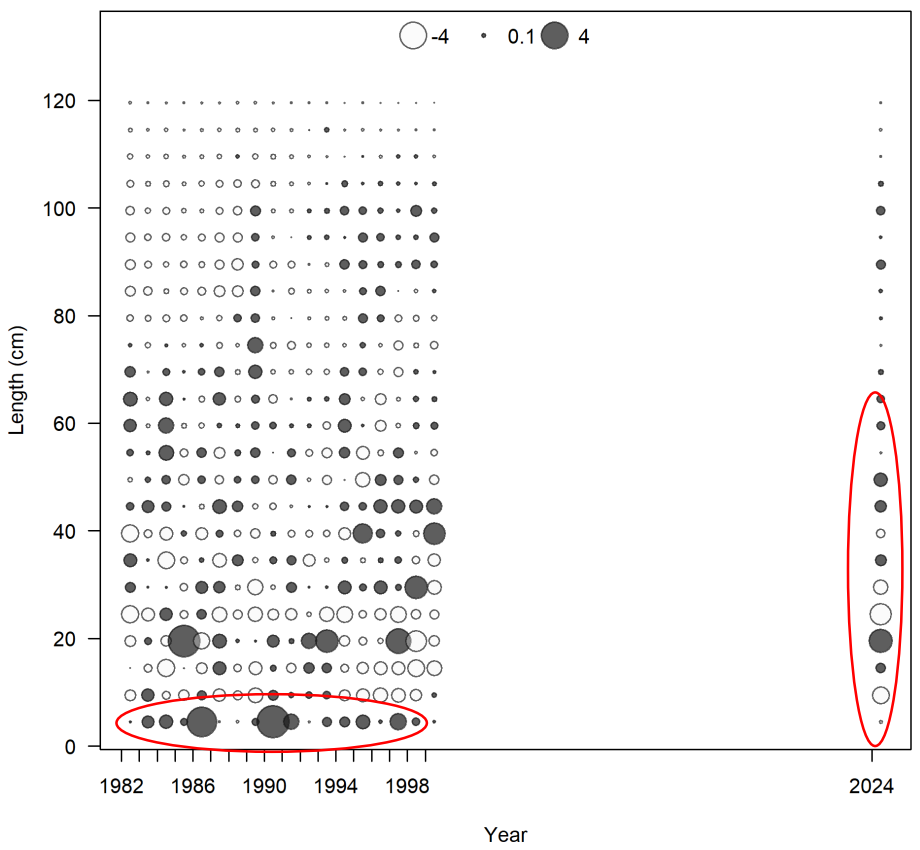
Model 24.1 vs 24.3 Pearson Survey Length

- Differences in model fits
  - Model 24.3 degradation in fit to survey length composition

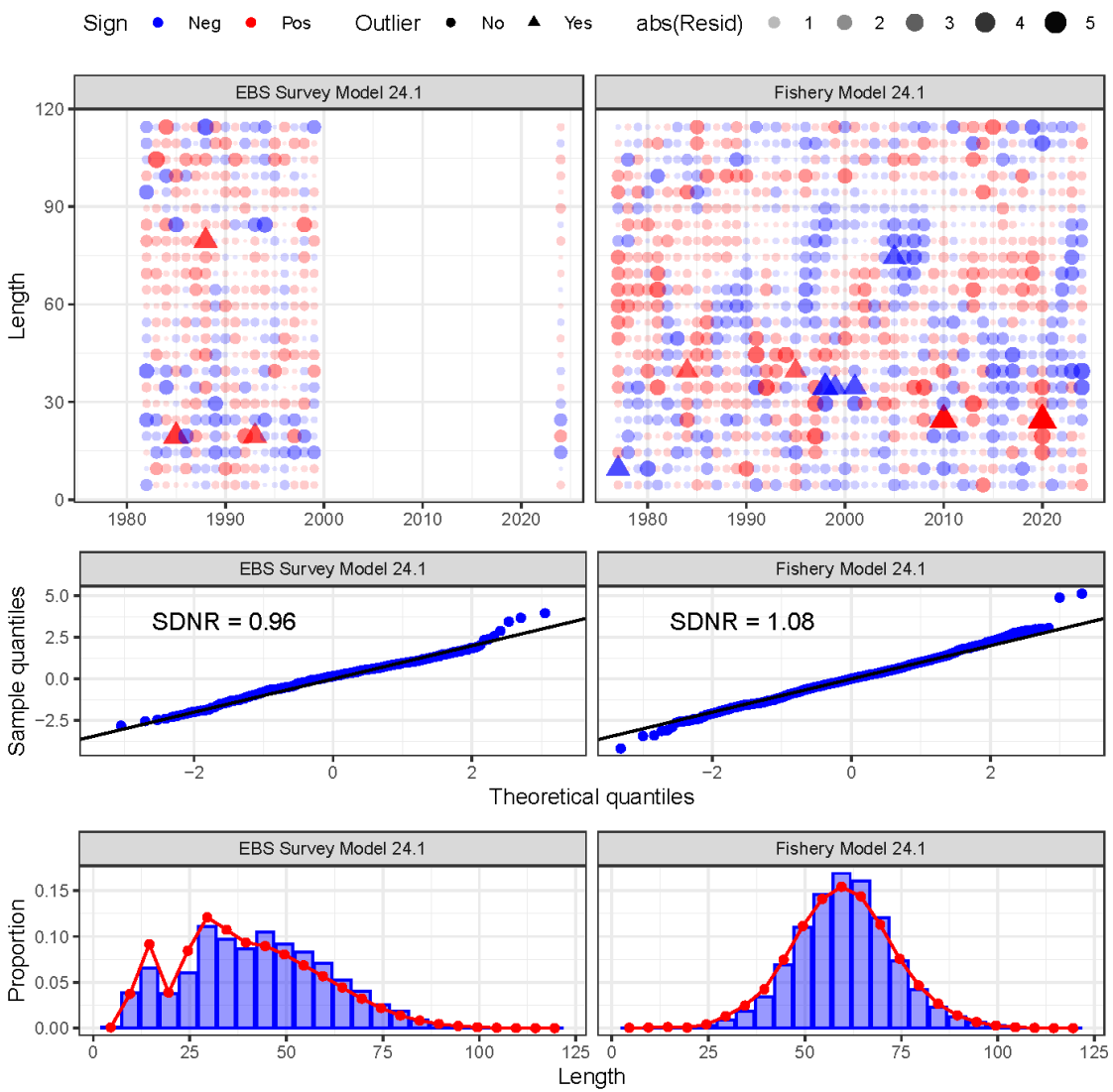
Model 24.1

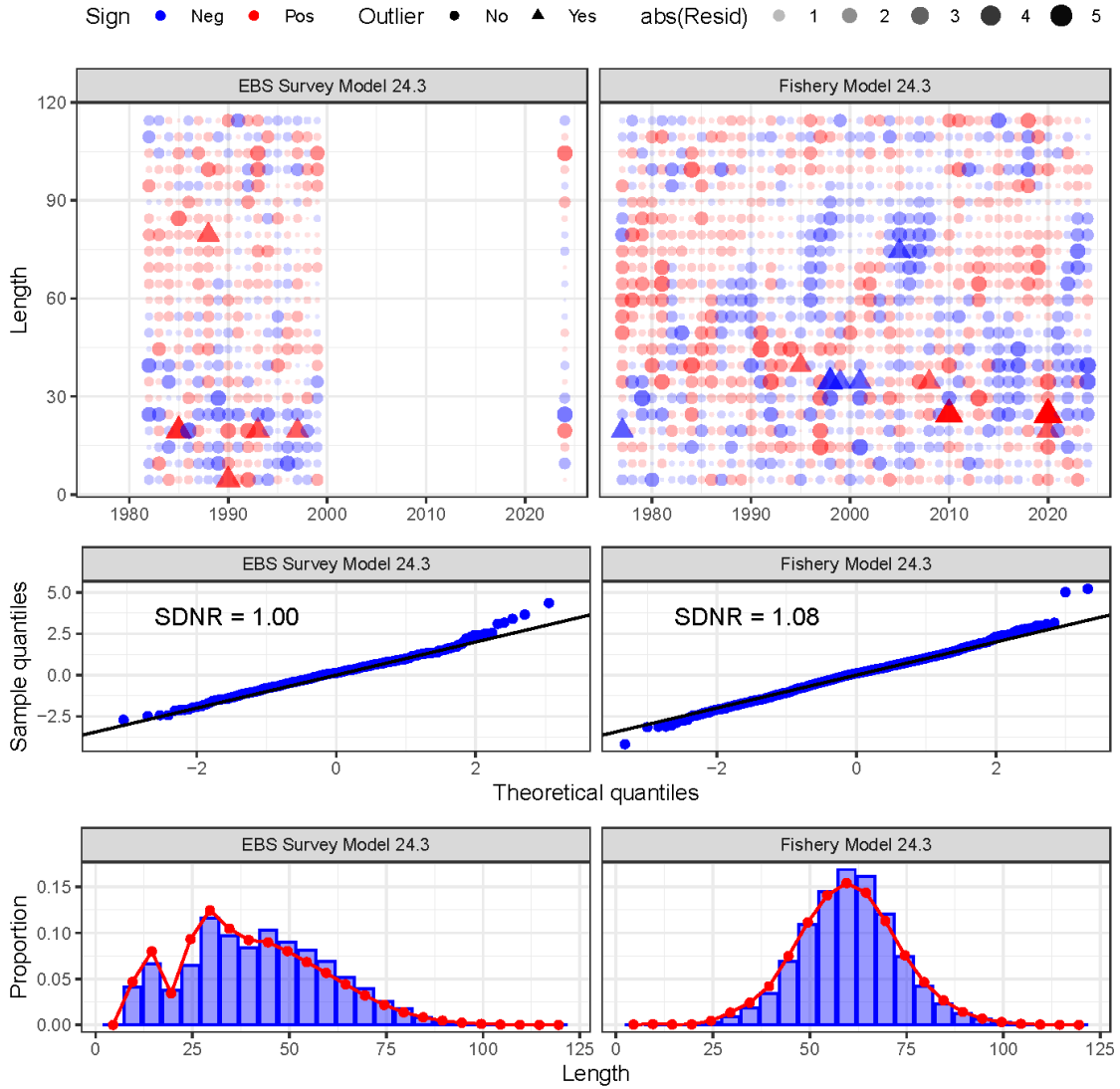


Model 24.3



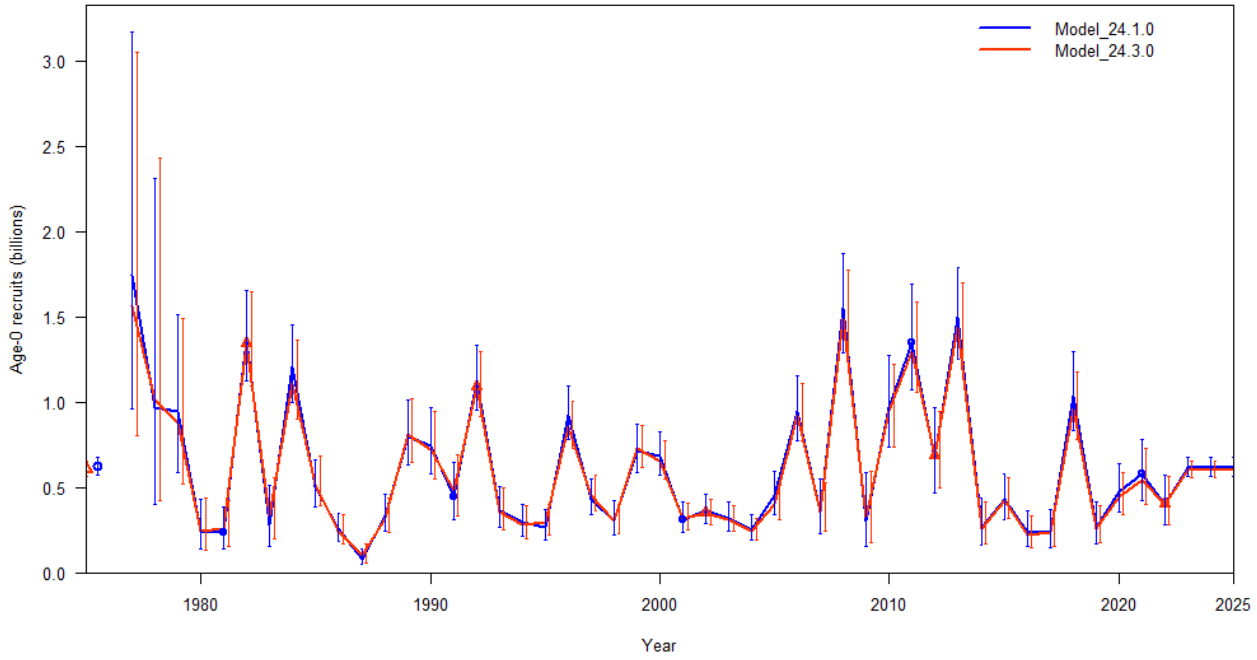
Model 24.1 vs 24.3 OSA Residuals Length

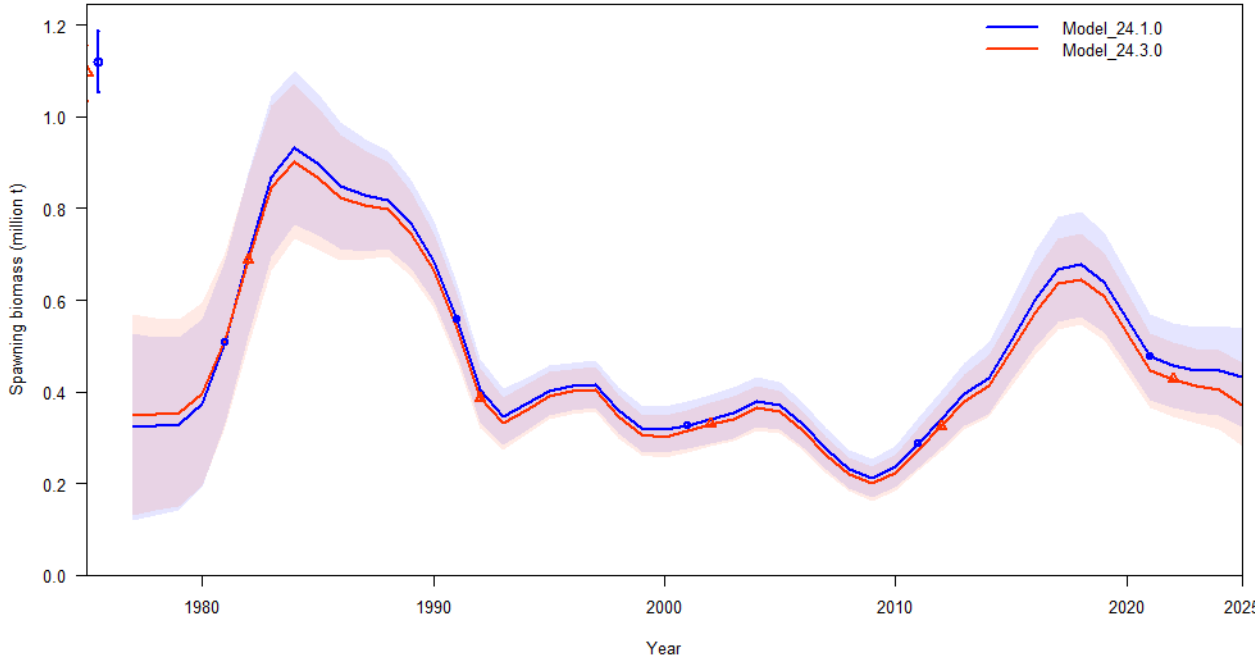




Model 24.1 vs 24.3

- Differences in results
  - L_{20} M24.1= 112.26 M24.3 = 114.73
  - LN(R_0) M24.1 = 13.85 M24.3 = 13.32
  - $B_{100\%}$ M24.1 = 562kt M24.3 = 552kt
  - B_{2025}% M24.1 = $B_{38\%}$ M24.3 = $B_{34\%}$
  - $L_{1.5}$ M24.1 = 13.85 M24.3 = 12.08
  - Q M24.1 = 0.99 M24.3 = 1.01
  - B_{2025} M24.1 = 216kt M24.3 = 186kt
  - ABC_{2025} M24.1 = 154kt M24.3 = 117kt



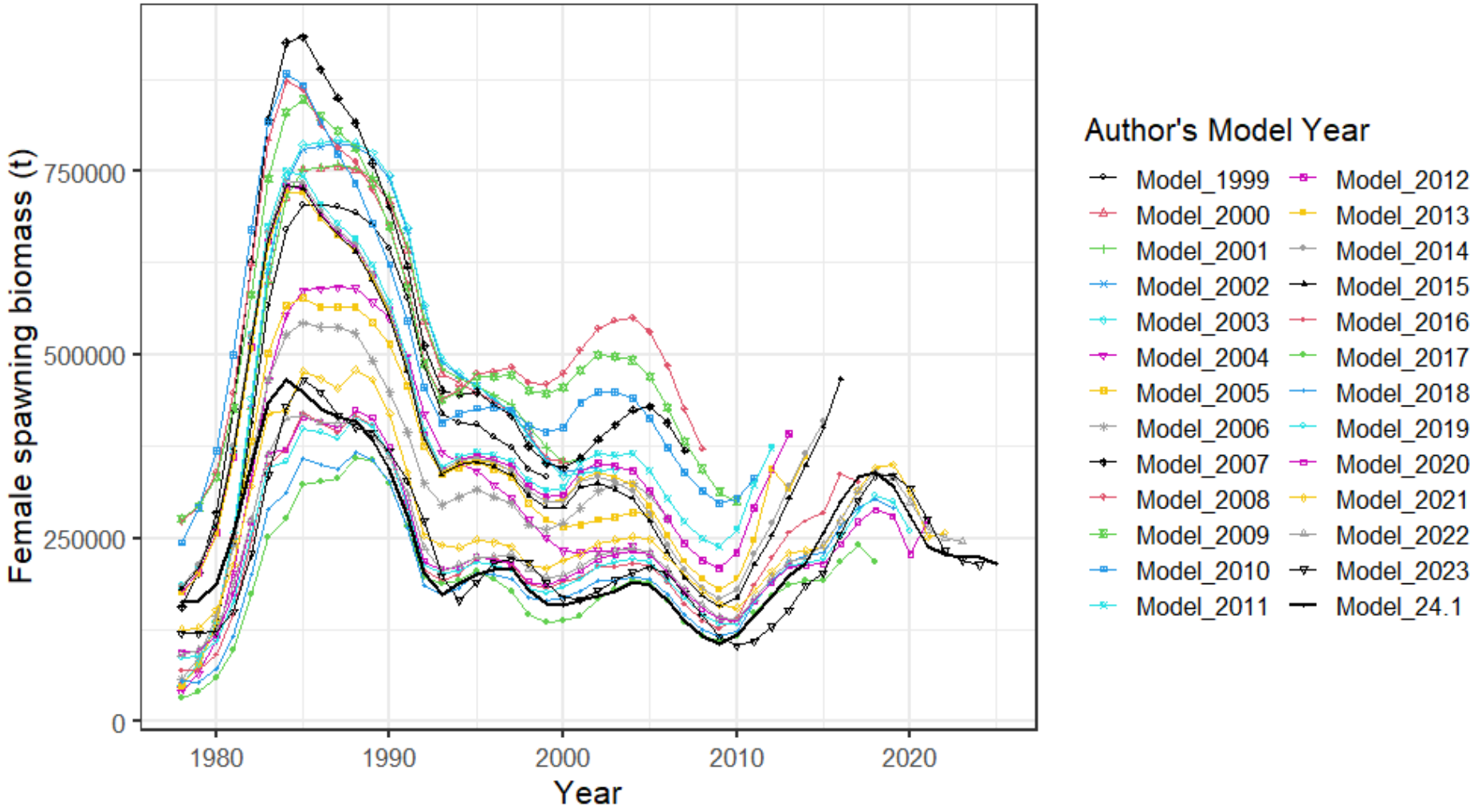


Why Model 24.1?

- All models had comparable fits, MASE, retrospectives, and jitter results
- Model 24.3 survey selectivity is problematic
  - knife edge, highly uncertain parameter estimate on ascending limb
- Slightly overall better performance in Model 24.1
  - Most in survey length comps
- Results are consistent with last year's model
  - Similar reference points and management values

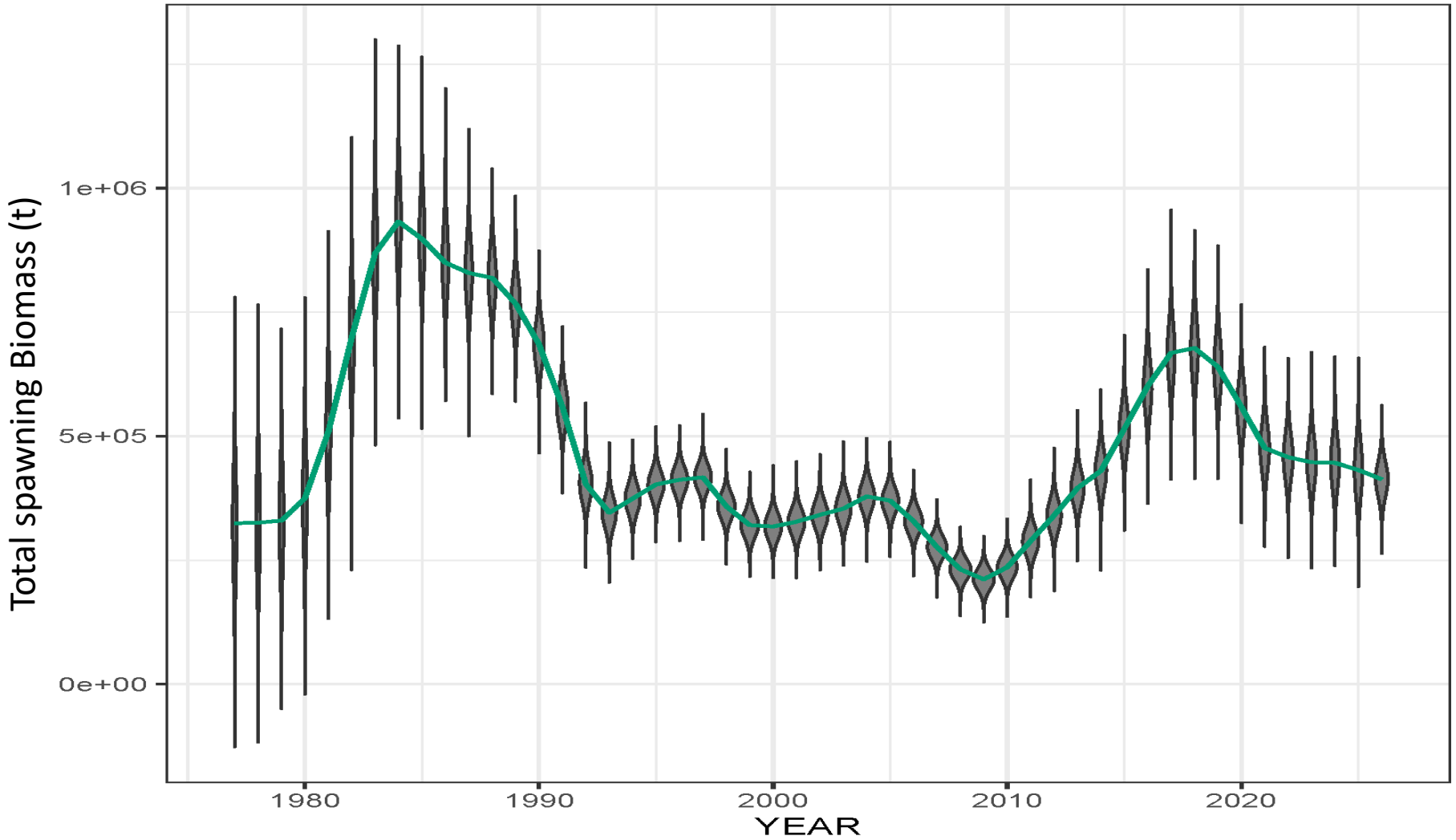
Model 24.1 compared to previous years

- 26 year review
- Similar to previous 8 years



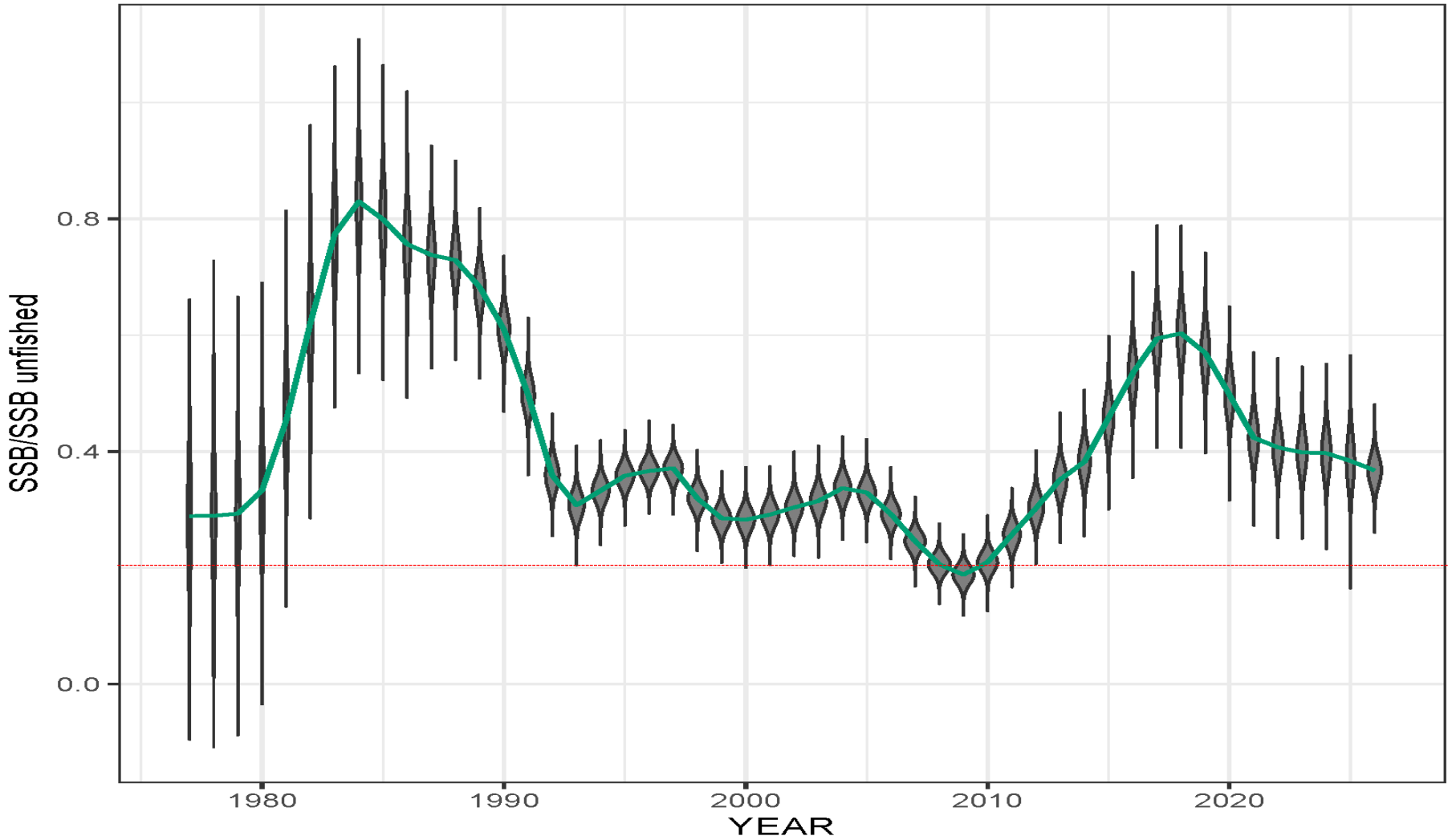
Model 24.1 Spawning biomass

- Dropping from 2018 high
- $B_{38\%}$

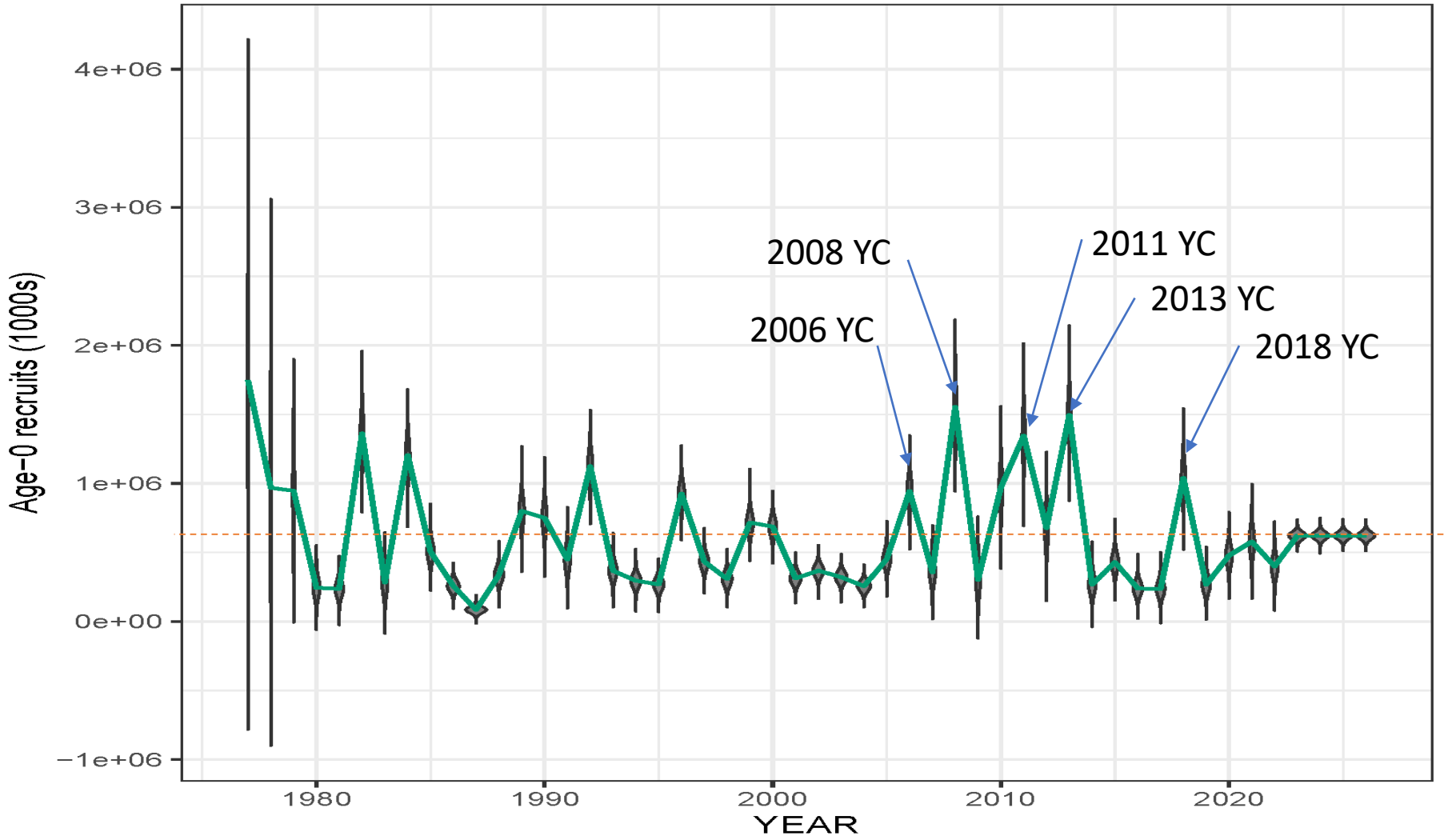


Model 24.1 Status

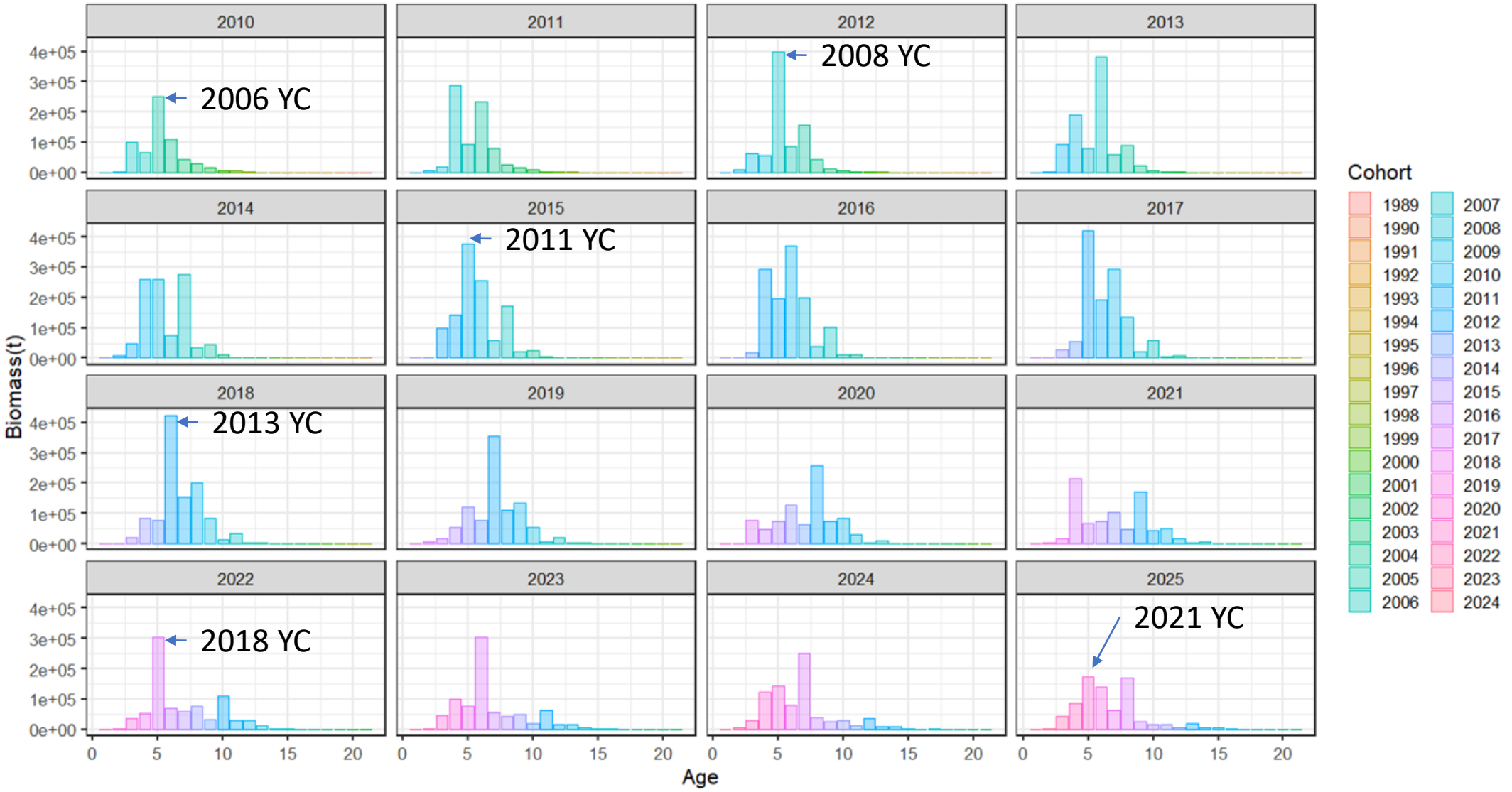
- Dropping from 2018 high
- $B_{38\%}$



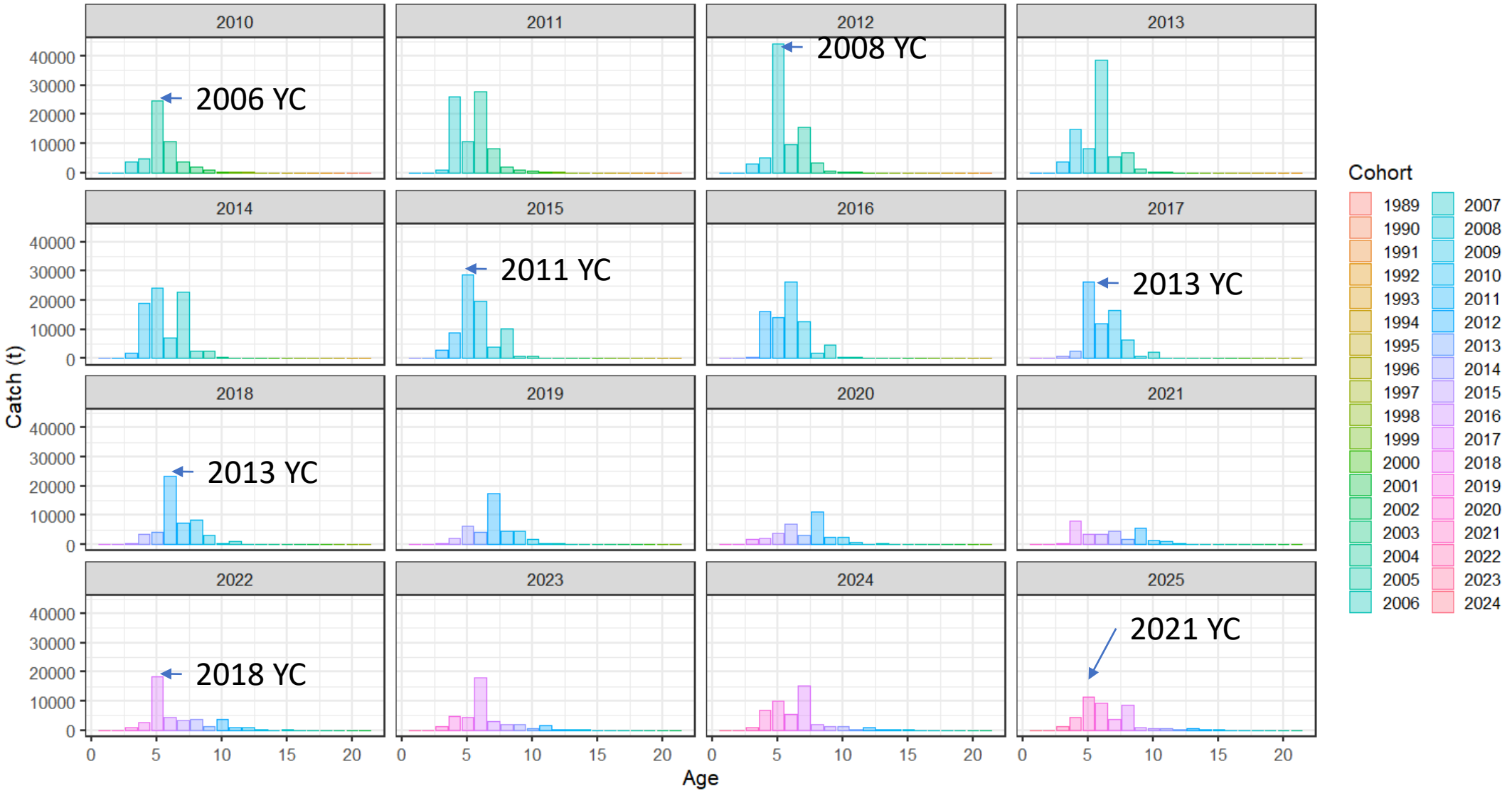
Model 24.1 Recruitment



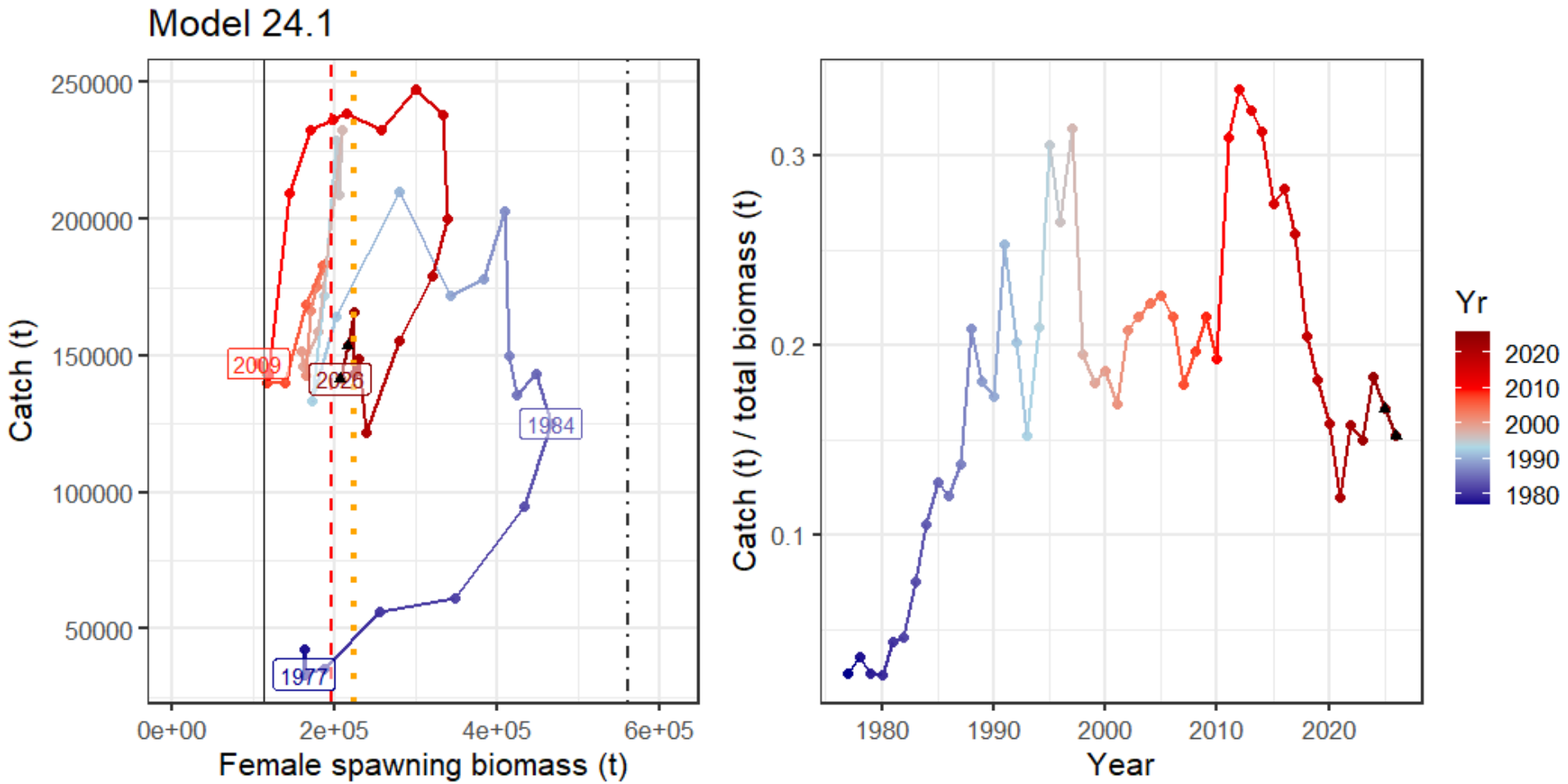
Model 24.1 Biomass by cohort



Model 24.1 Catch by cohort

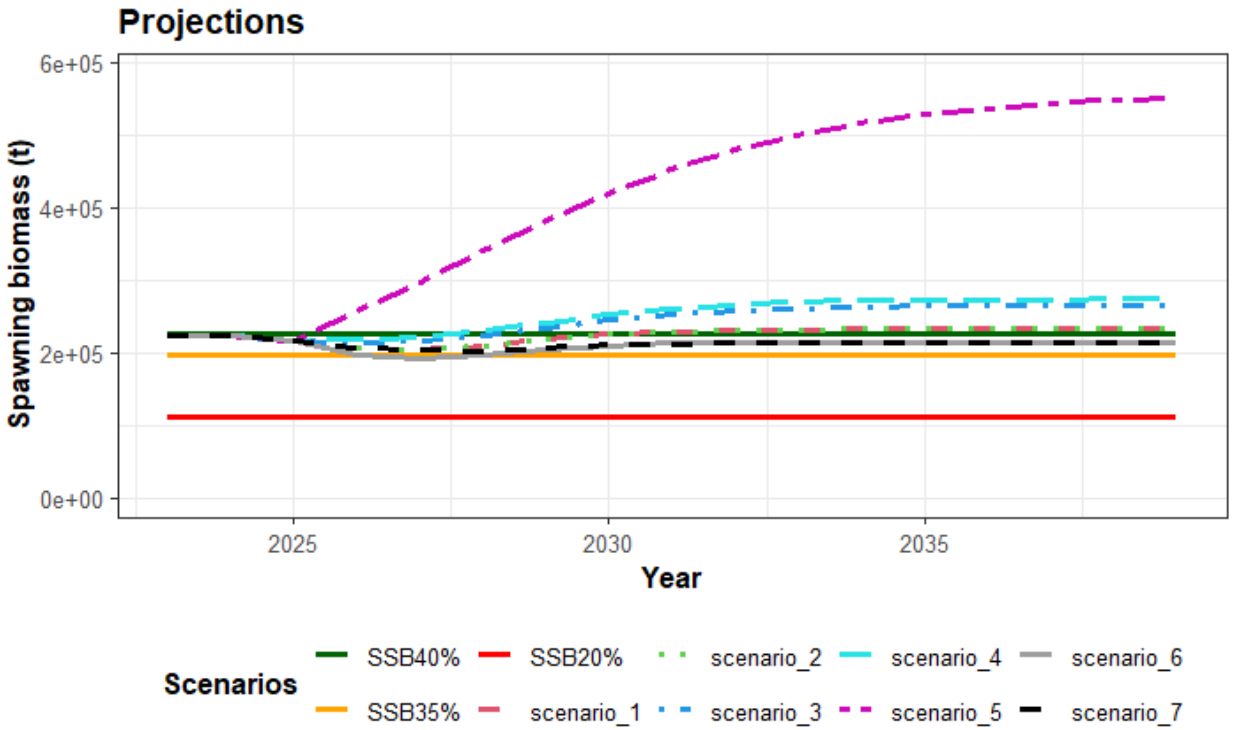


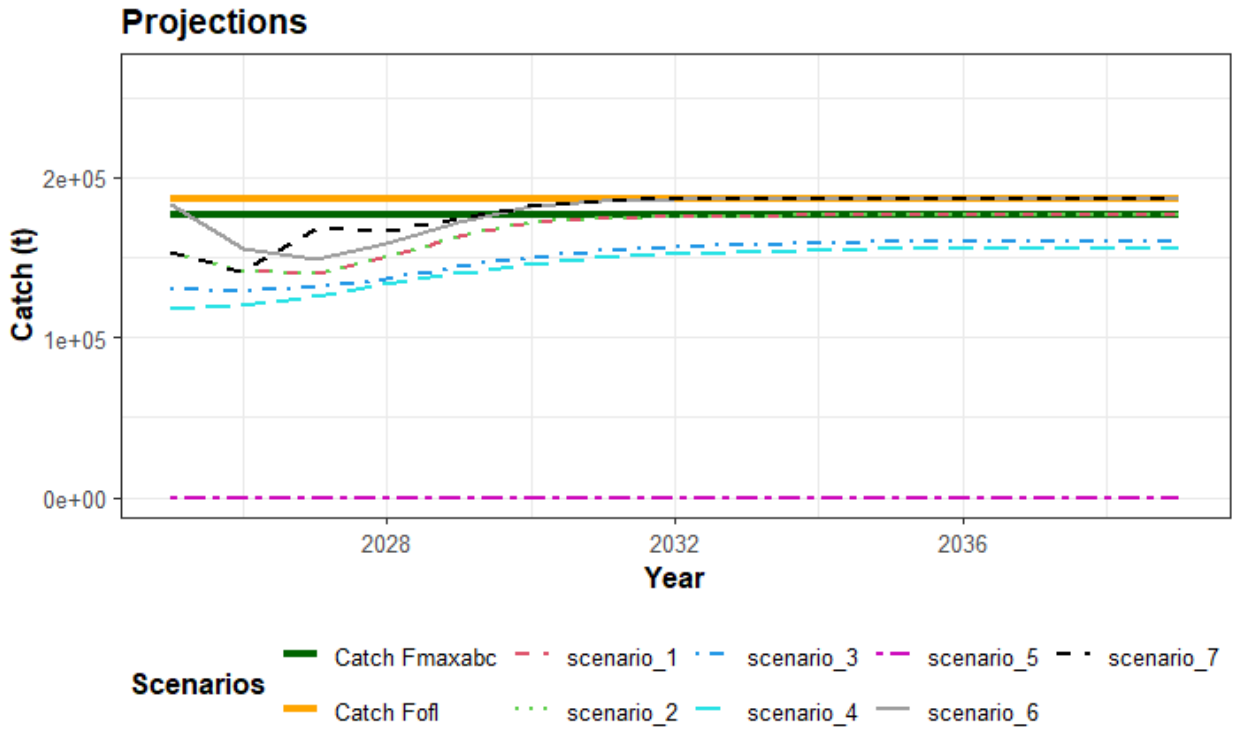
Model 24.1 Results



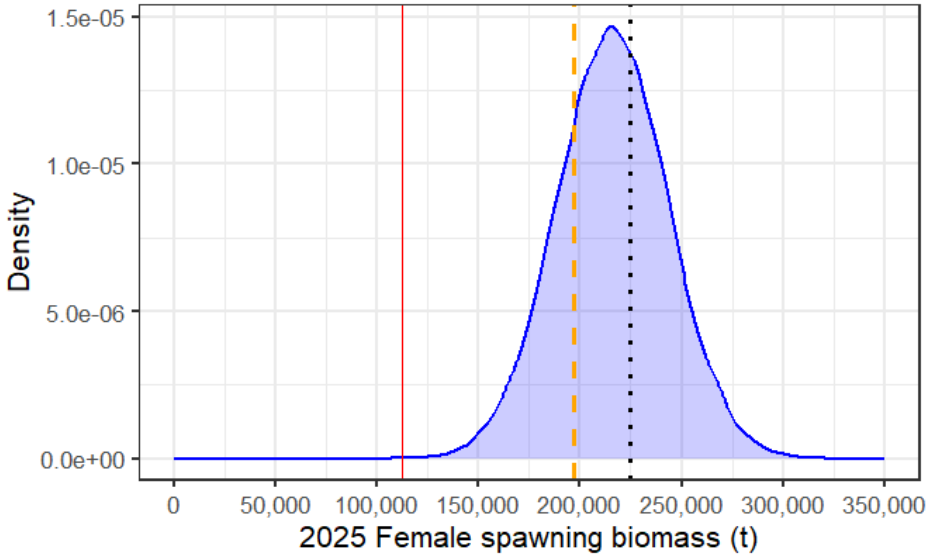
Model 24.1 standard harvest scenarios

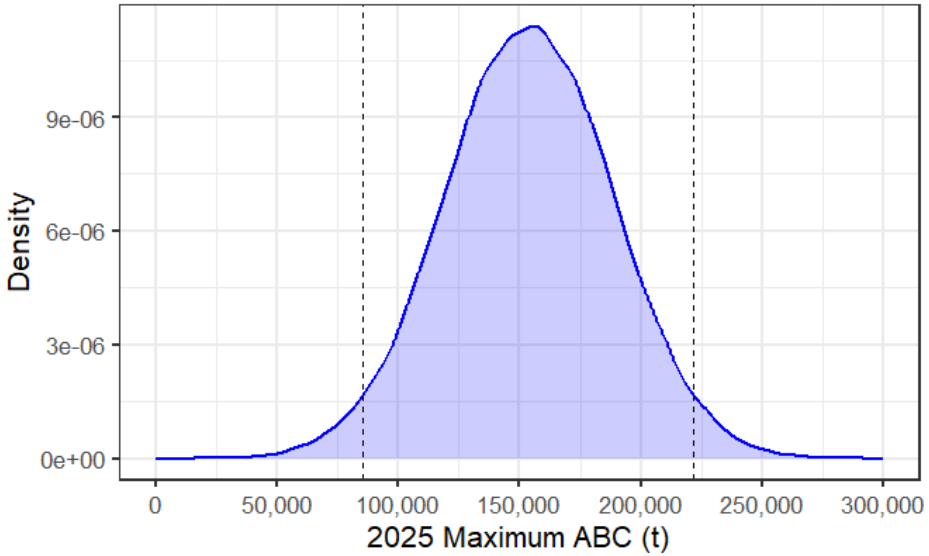
- Tier 3B - Not overfished or overfishing
- Dropping catch through 2027





Model 24.1 Results





Quantity	As estimated or *specified last* year for: 2024	2025	As estimated or *recommended this* year for: 2025*	2026*
M (natural mortality rate)	0.386	0.386	0.386	0.386
Tier	3b	3b	3b	3b
Projected total (age 0+) biomass (t)	808,203	787,837	769,813	762,206
Projected female spawning biomass	223,107	211,131	215,747	206,498
$B_{100\%}$	567,465		561,915	
$B_{40\%}$	226,986		224,767	
$B_{35\%}$	198,612		196,671	
F_{OFL}	0.46	0.43	0.43	0.41
$maxF_{ABC}$	0.37	0.35	0.35	0.33
F_{ABC}	0.37	0.35	0.35	0.33
OFL (t)	200,995	180,798	183,509	169,243
maxABC (t)	167,952	150,876	153,617	141,520
ABC (t)	167,952	150,876	153,617	141,520
Status	As determined *last* year for: 2022	2023	As determined *this* year for: 2023	2024
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projections are based on assumed catches of 165,659 t, and 153,617 t in 2024 and 2025, respectively.

Model 24.1 Results

- ABC 2025
  - 9% decrease from 2024
  - 2% increase from expected for 2025

- Ecosystem considerations at level 2 Concern
  - Lower condition
  - Low prey

- **No reduction from Max ABC recommended**

Quantity	As estimated or *specified last* year for: 2024	2025	As estimated or *recommended this* year for: 2025*	2026*
M (natural mortality rate)	0.386	0.386	0.386	0.386
Tier	3b	3b	3b	3b
Projected total (age 0+) biomass (t)	808,203	787,837	769,813	762,206
Projected female spawning biomass	223,107	211,131	215,747	206,498
$B_{100\%}$	567,465		561,915	
$B_{40\%}$	226,986		224,767	
$B_{35\%}$	198,612		196,671	
F_{OFL}	0.46	0.43	0.43	0.41
$maxF_{ABC}$	0.37	0.35	0.35	0.33
F_{ABC}	0.37	0.35	0.35	0.33
OFL (t)	200,995	180,798	183,509	169,243
maxABC (t)	167,952	150,876	153,617	141,520
ABC (t)	167,952	150,876	153,617	141,520
Status	As determined *last* year for: 2022	2023	As determined *this* year for: 2023	2024
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projections are based on assumed catches of 165,659 t, and 153,617 t in 2024 and 2025, respectively.

Model 24.3 Results

- ABC 2025
  - 30% decrease from 2024
  - 23% decrease from expected for 2025

Quantity	As estimated or *specified last* year for: 2024	2025	As estimated or *recommended this* year for: 2025*	2026*
M (natural mortality rate)	0.386	0.386	0.386	0.386
Tier	3b	3b	3b	3b
Projected total (age 0+) biomass (t)	808,203	787,837	680,076	710,201
Projected female spawning biomass	223,107	211,131	186,337	187,854
$B_{100\%}$	567,465		552,100	
$B_{40\%}$	226,986		220,840	
$B_{35\%}$	198,612		193,235	
F_{OFL}	0.46	0.43	0.37	0.37
$maxF_{ABC}$	0.37	0.35	0.30	0.30
F_{ABC}	0.37	0.35	0.30	0.30
OFL (t)	200,995	180,798	139,917	143,191
maxABC (t)	167,952	150,876	116,770	119,491
ABC (t)	167,952	150,876	116,770	119,491
Status	As determined *last* year for: 2022	2023	As determined *this* year for: 2023	2024
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projections are based on assumed catches of 165,659 t, and 116,770 t in 2024 and 2025, respectively.

What if we are wrong?

- Although point estimates for max ABC and OFL are substantially different, confidence bounds overlap
  - Increased risk if managed under M24.1, but M24.3 is correct (+3% probability $B_{2026} < B_{20\%}$)
  - Substantial loss of revenue if managed under M24.3 but M24.1 correct (-59 kt for 2025 and 2026 combined)