Assessment of the Pacific Cod Stock in the Eastern Bering Sea

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November 13, 2023 Presentation to the BSAI Plan Team

NOAA FISHERIES

https://afsc-assessments.github.io/EBS_PCOD/2023_ASSESSMENT/NOVEMBER_MODELS/

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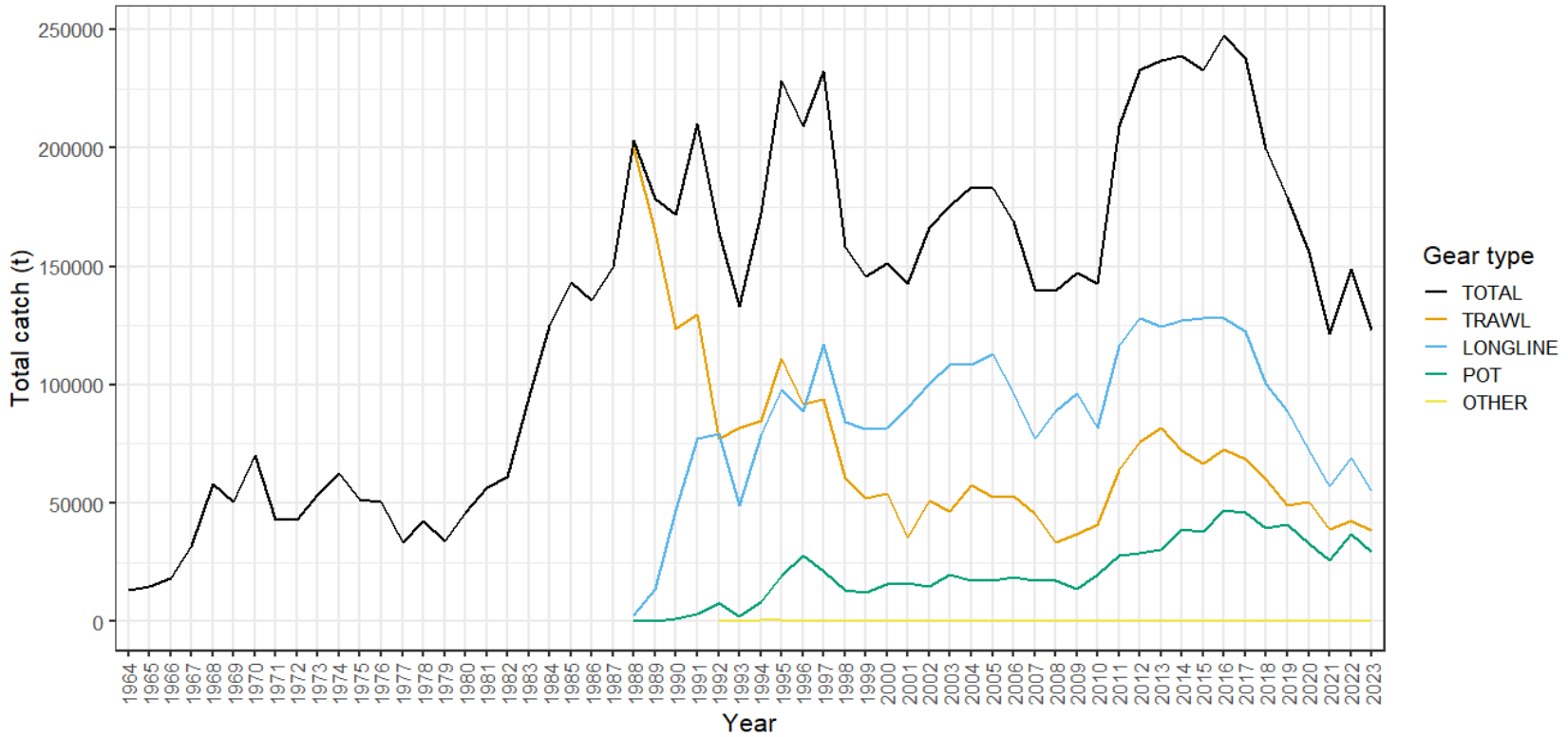
- Model Timeseries

Projections from recommended model

- Scenarios and projections
- Risks

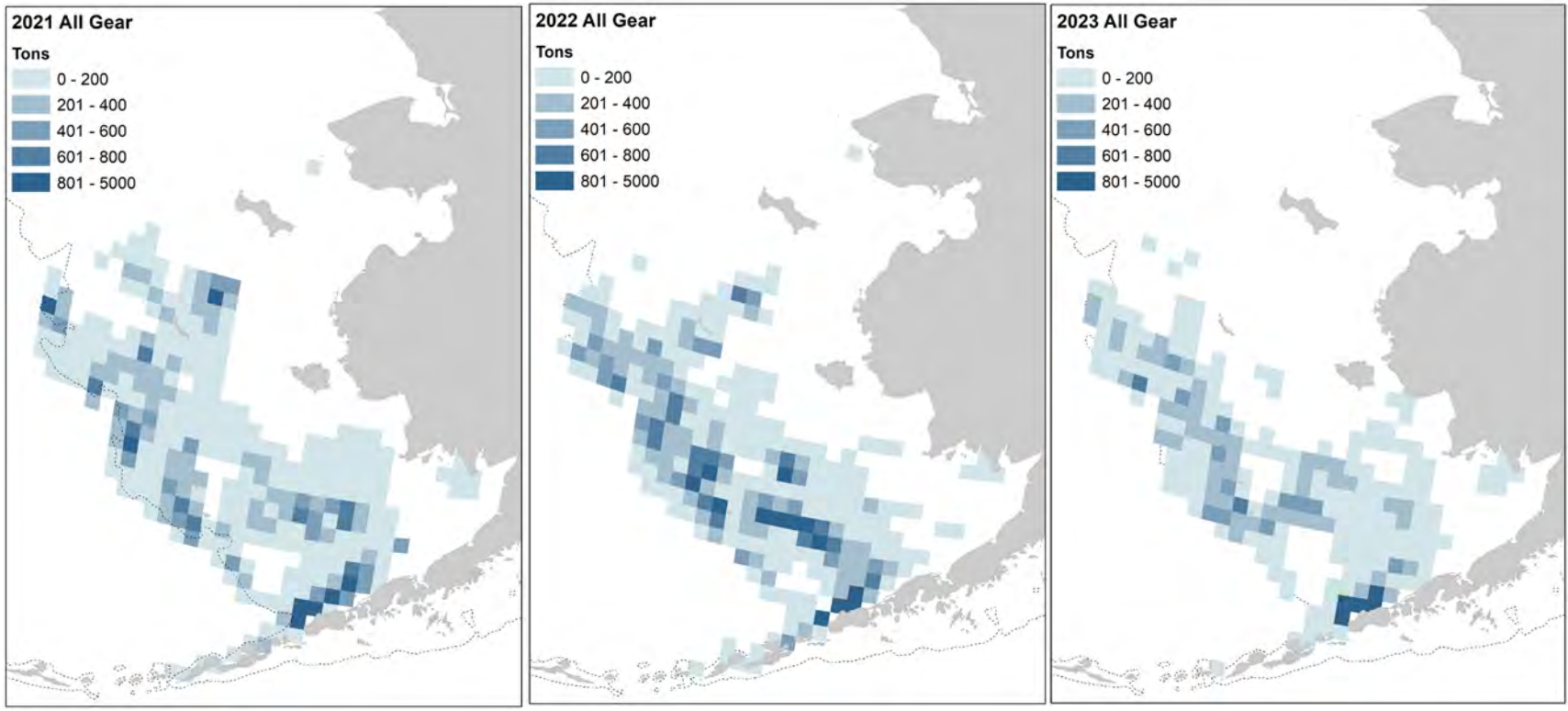
Fishery data

- 2023 ABC is 144,834 t and catch as of Oct. 3 = 123,208t
- Longline still highest proportion



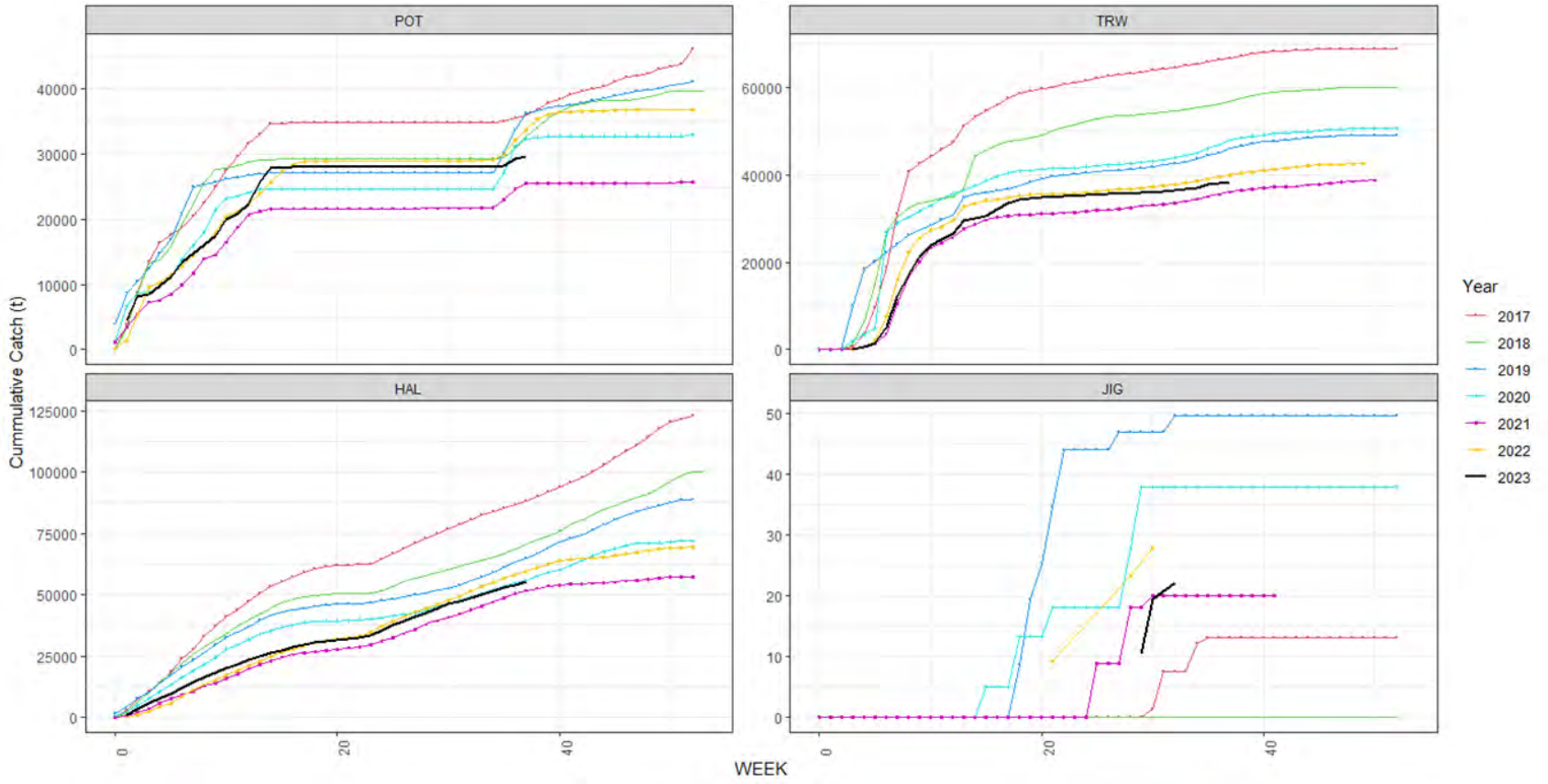
Fishery spatial distribution

- Continued southward shift in fishery
- Little observed fishing north of St. Mathews Island in 2023



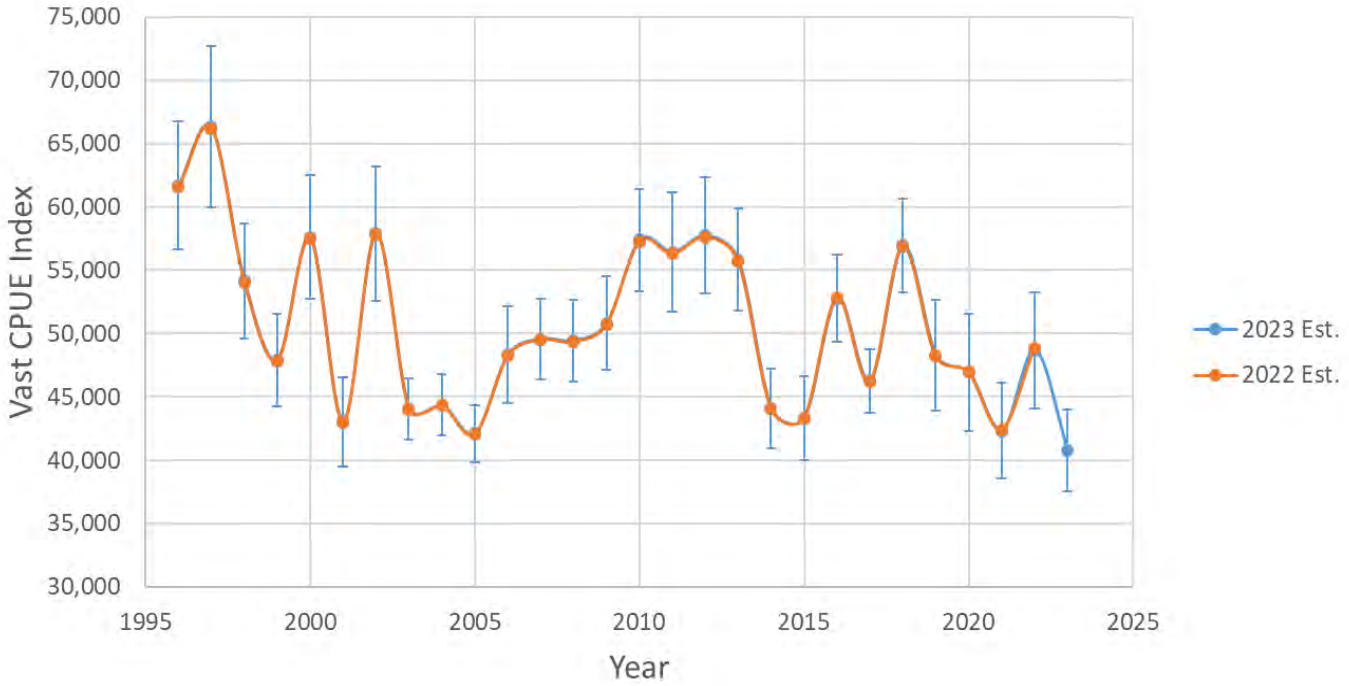
Fishery temporal distribution

- **All gear slower than 2017-2019**
- Fixed gear very similar to 2022
- Trawl similar to 2021, slightly slower than 2022

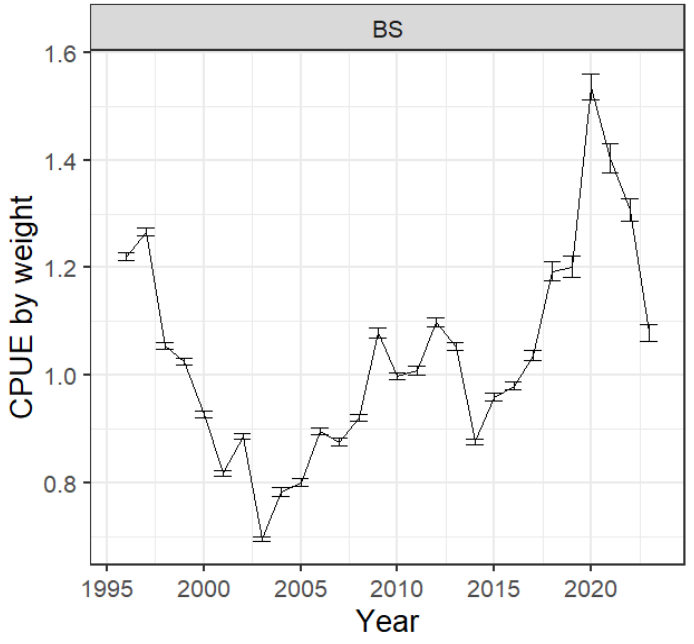


CPUE indices

- VAST longline winter CPUE index
  - Downward trend overall with 16% drop from 2022

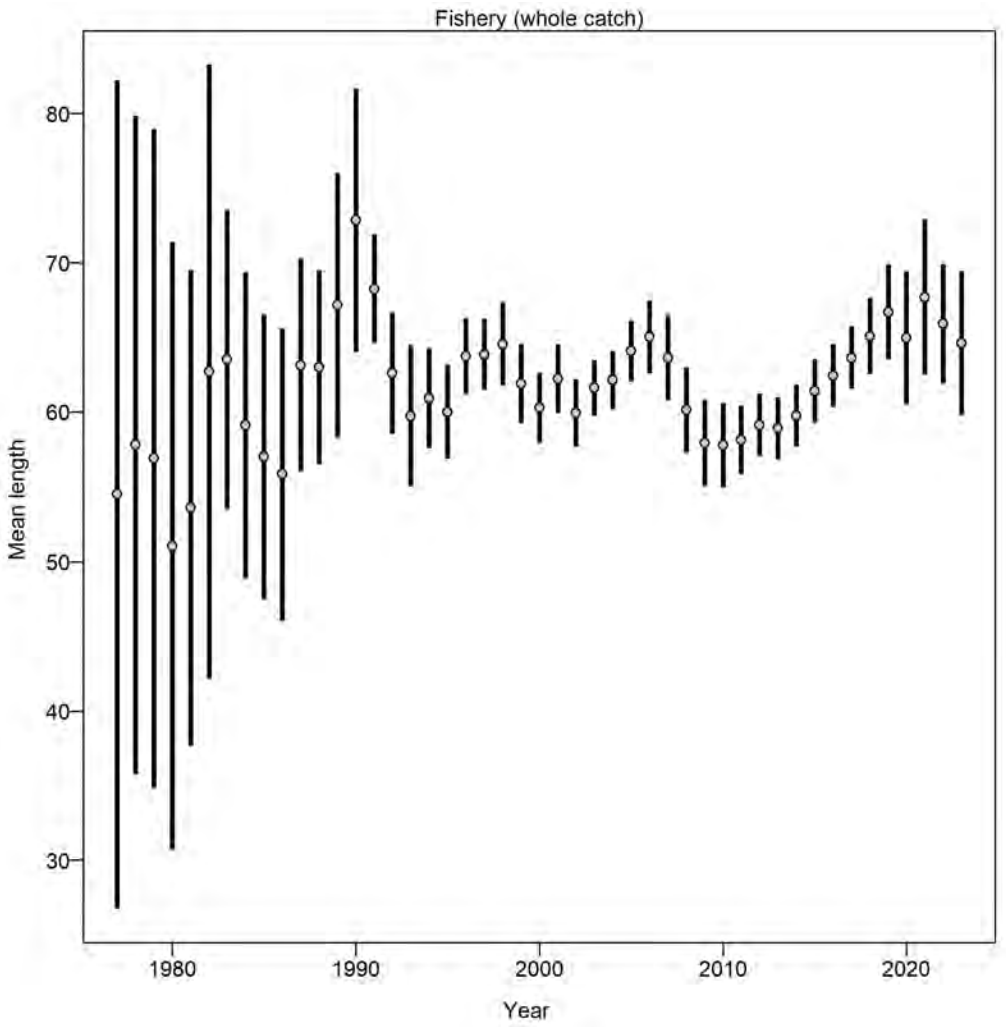


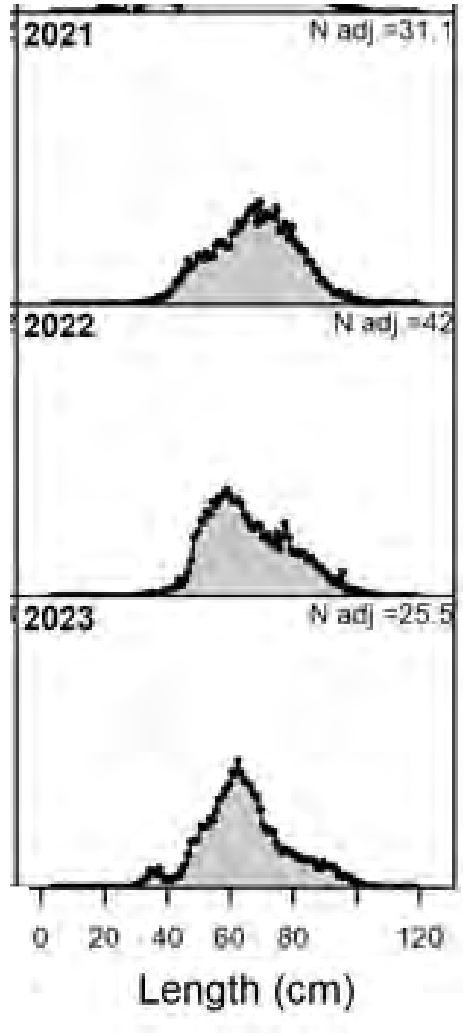
- All gear naïve CPUE index
  - Downward trend to near average since all-time high in 2020



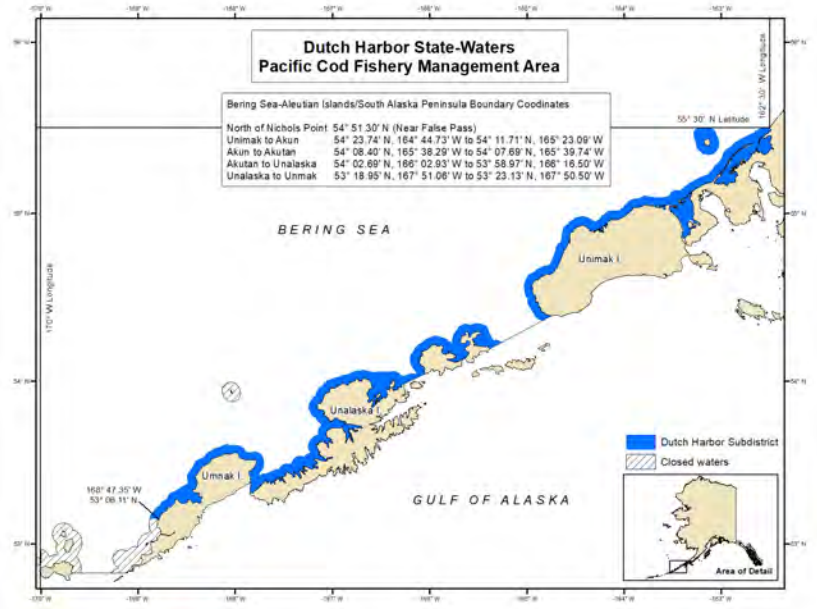
Fishery size distribution

- On average smaller fish than 2022
- Increase in <40 cm fish in catch
- Largest mode at 65cm, likely 2018 year class

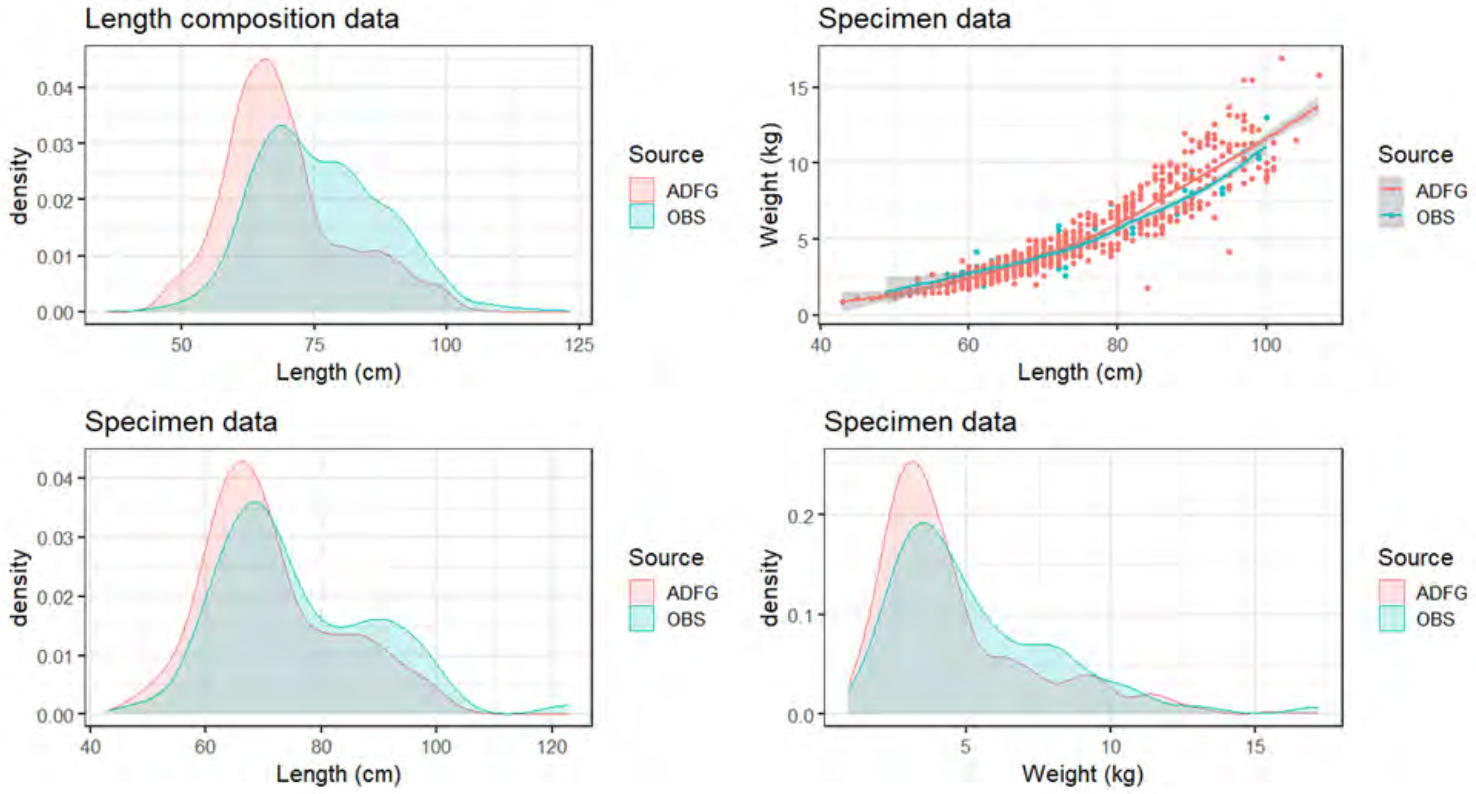




Area O state fishery

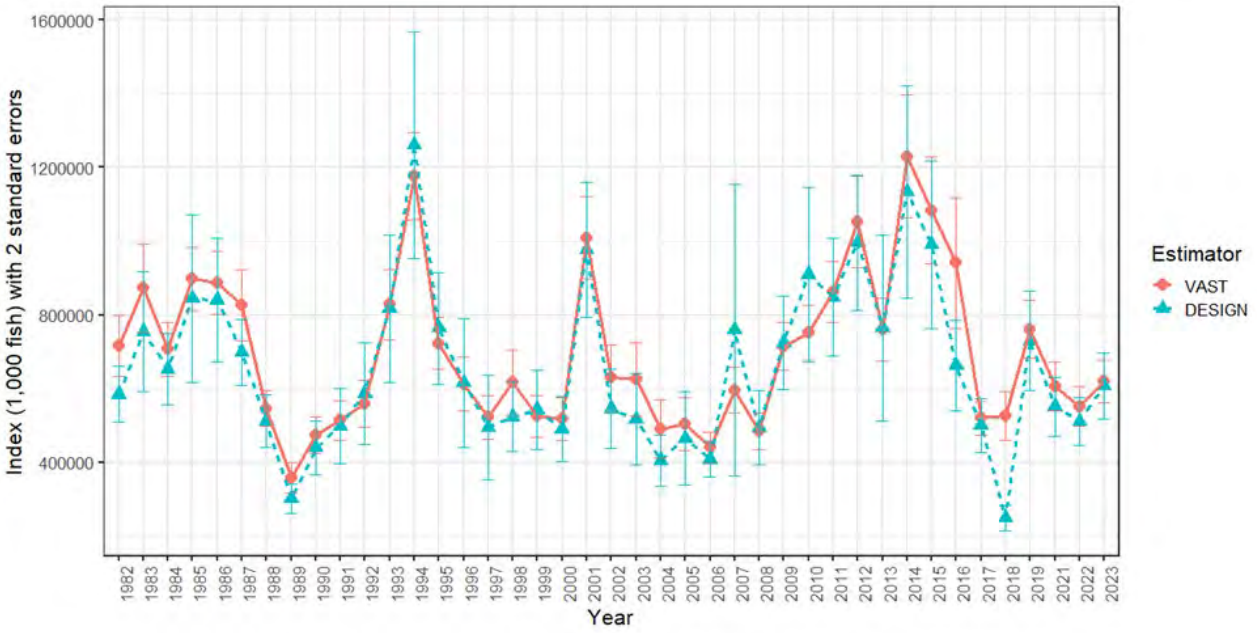


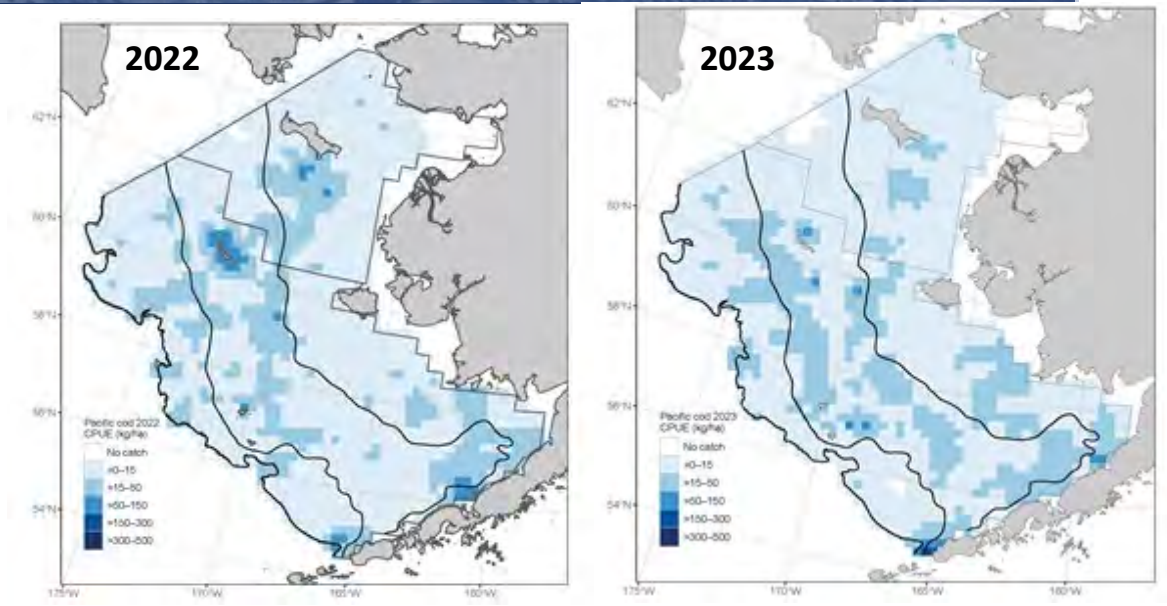
- GHL = 12% of BSAI ABC, 98% harvested so far in 2023 (pot and jig)
- ADF&G port sampling provided data on length and weight of cod catch in Feb-Apr
- Higher proportion of smaller fish in Dutch Harbor Subdistrict (DHS)

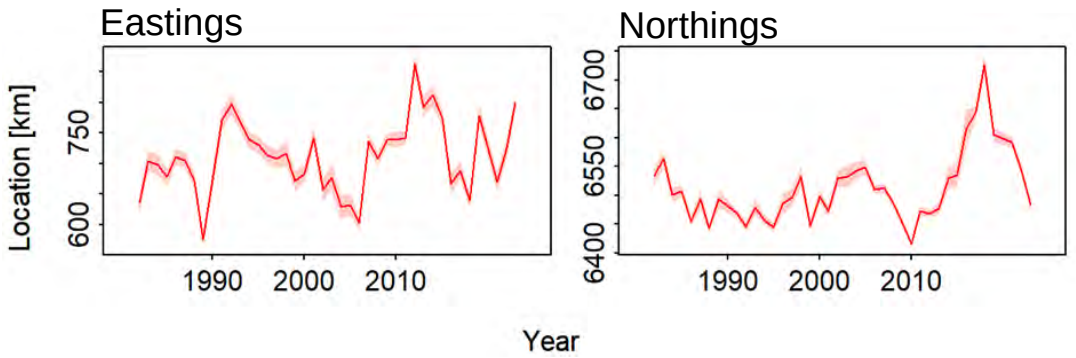


Bottom trawl survey

- Increase in abundance (+12%)
- Small decline in biomass (-4%)
- Southeastern shift in distribution

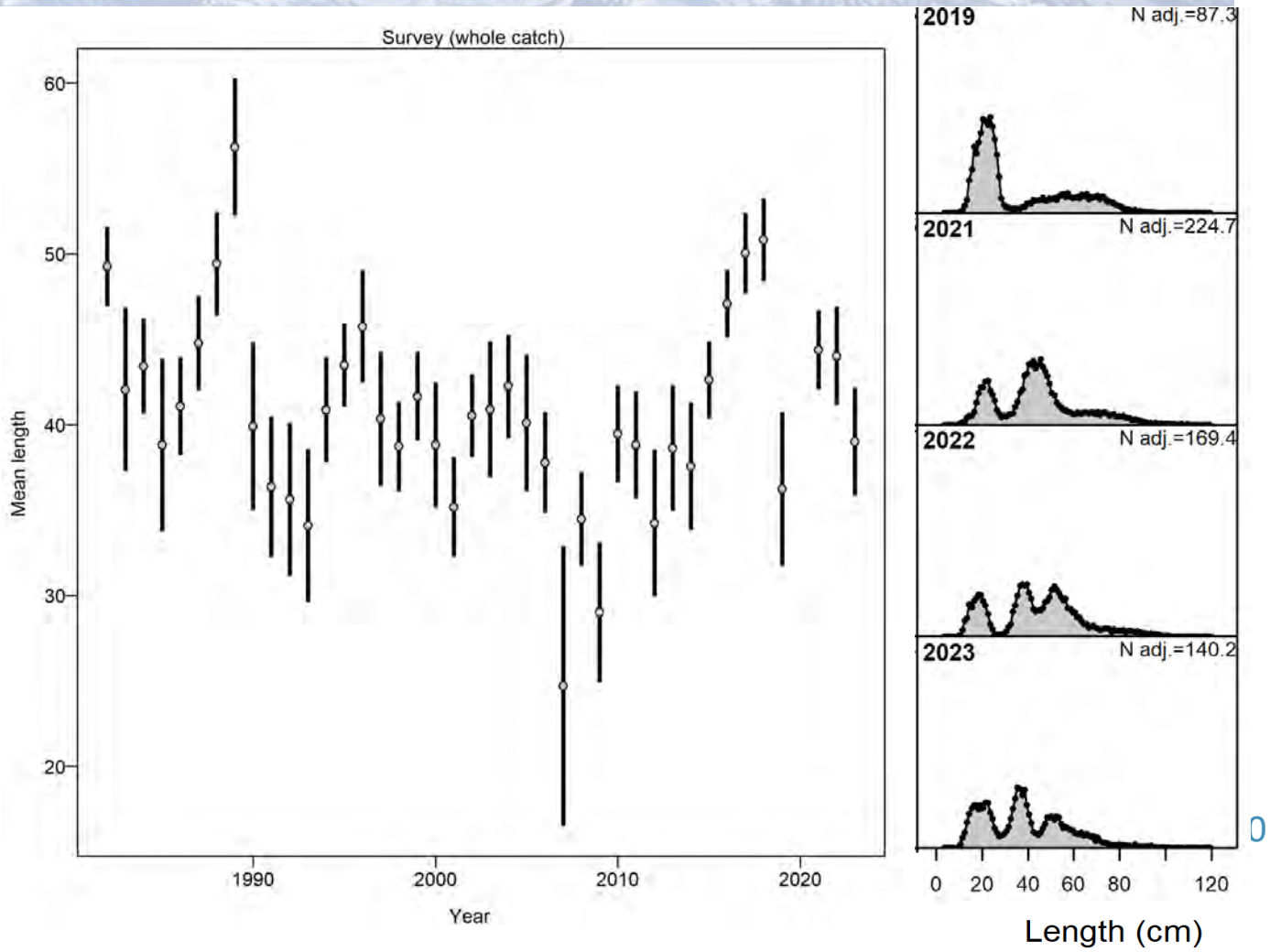






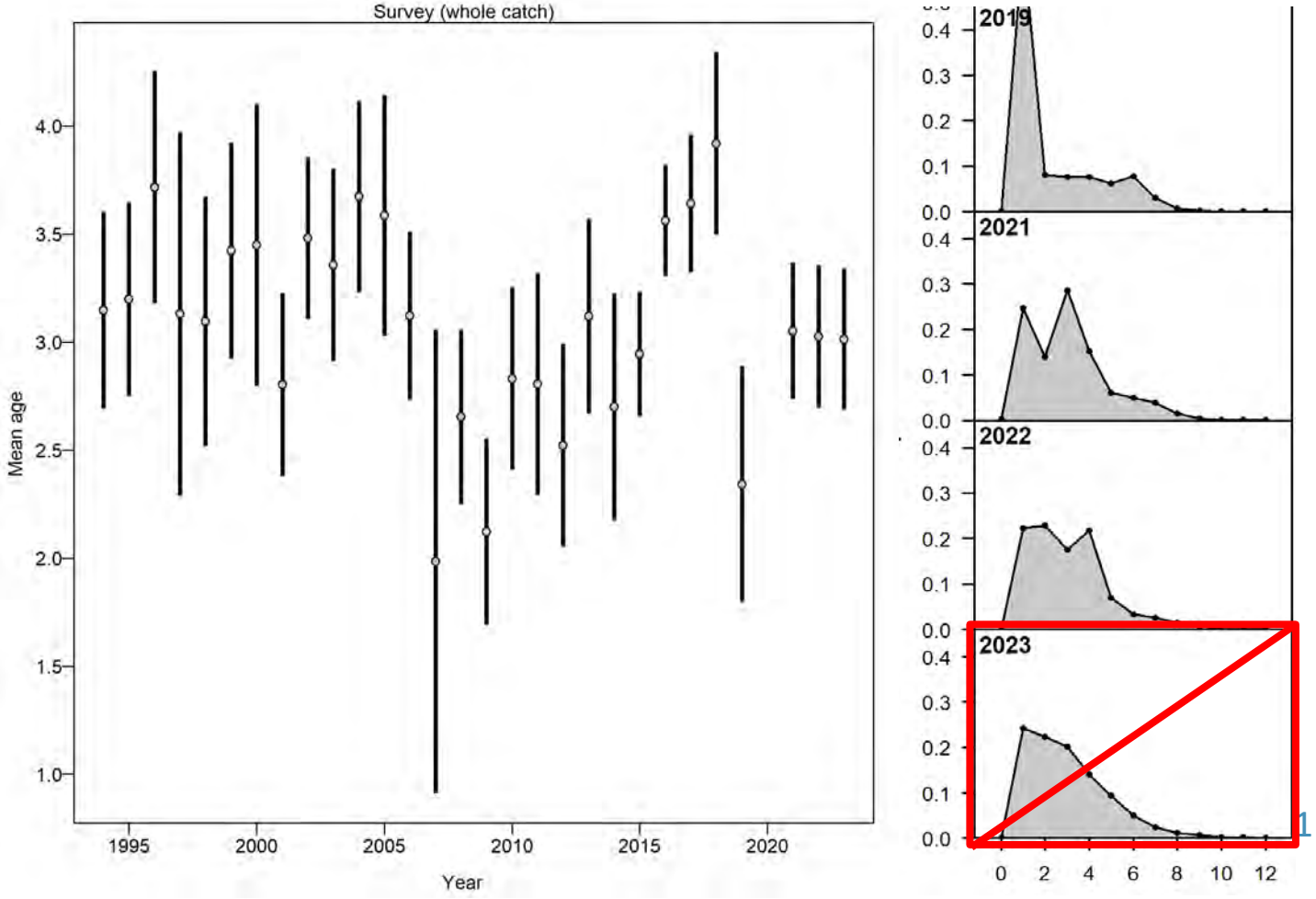
Bottom trawl survey length composition

- 2023 smaller fish on average
  - Larger proportion of small fish with two modes <40 cm
- 2018 year class persisting but becoming smaller proportion of population



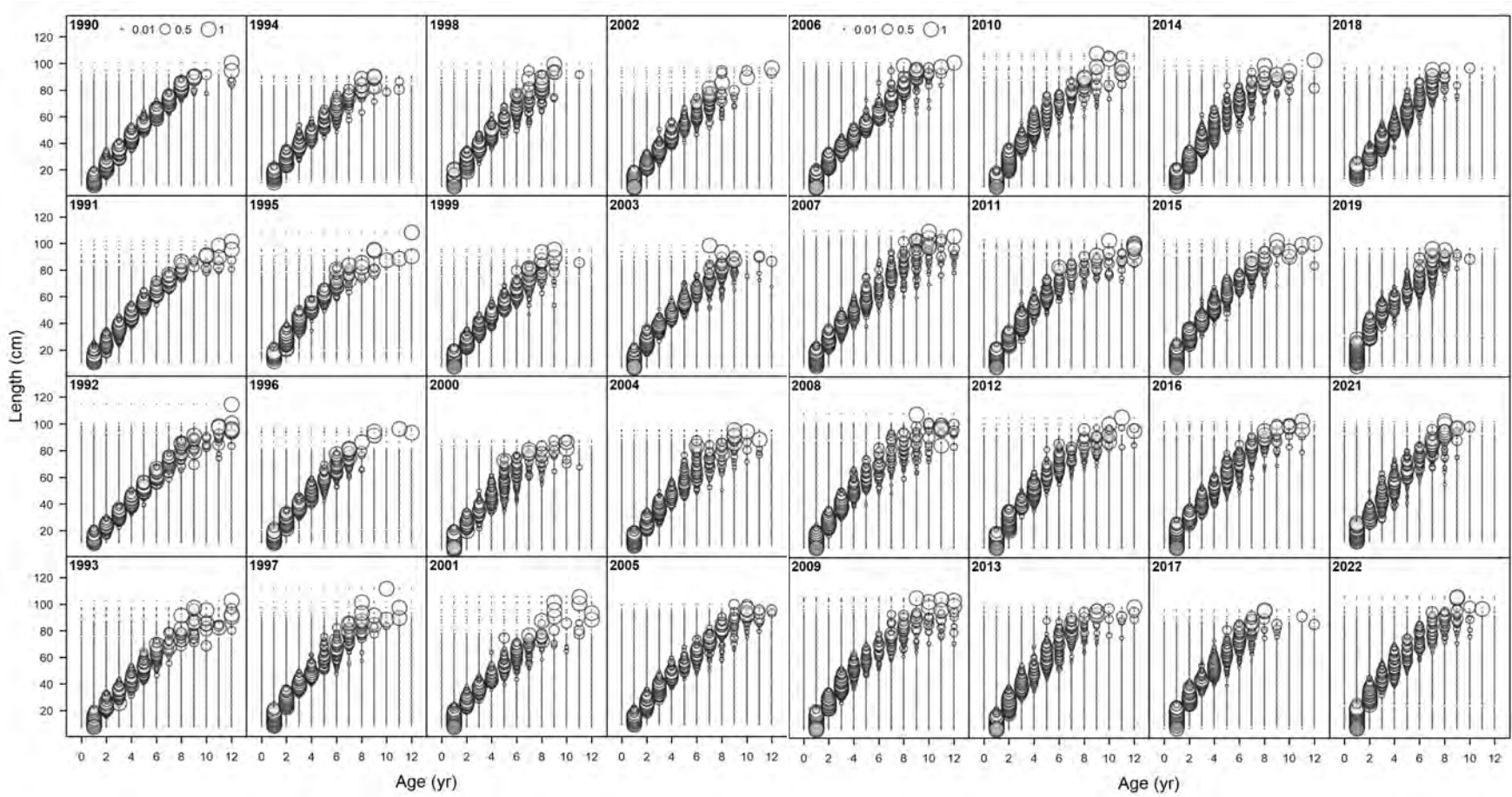
Bottom trawl survey age composition (VAST)

- 2023 age-length key based on average for full time series and not used in assessment
- 2022 shows persistence of 2018 year class, and
- Substantial 2020 and 2021 year classes



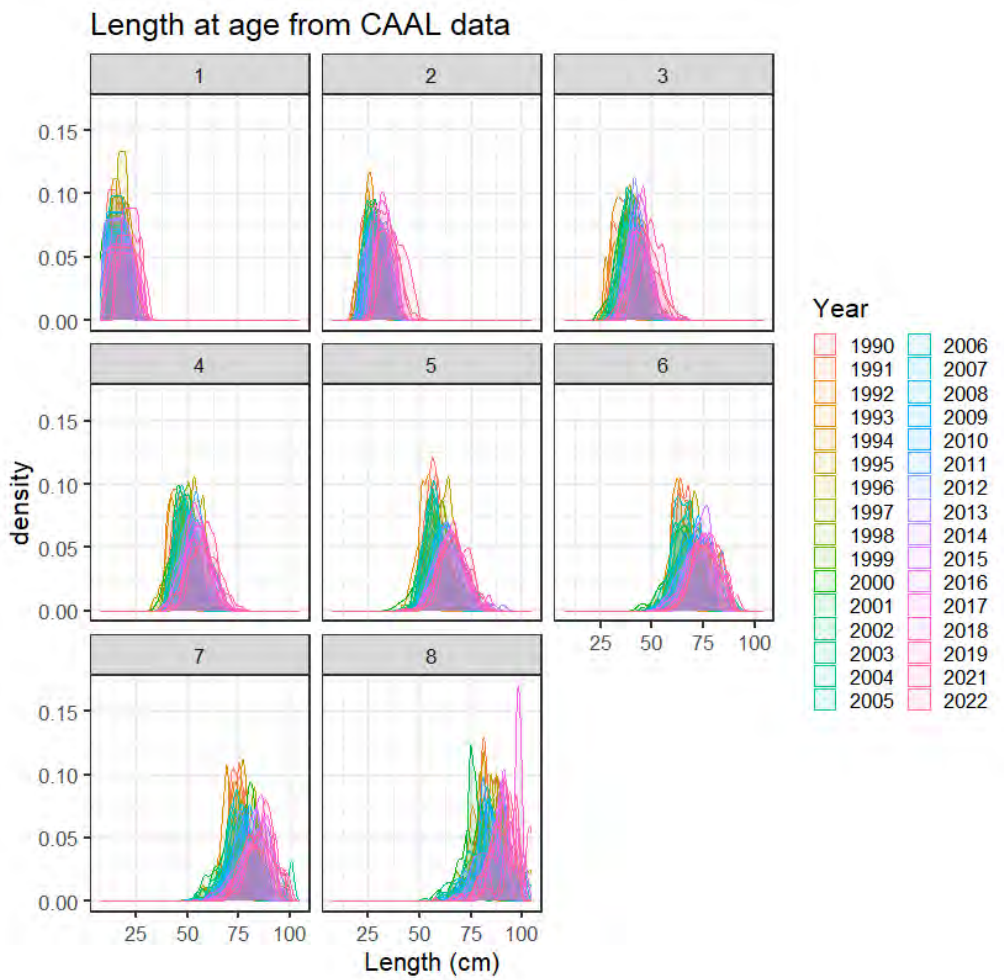
Bottom trawl survey Conditional-age-at-length (CAAL)

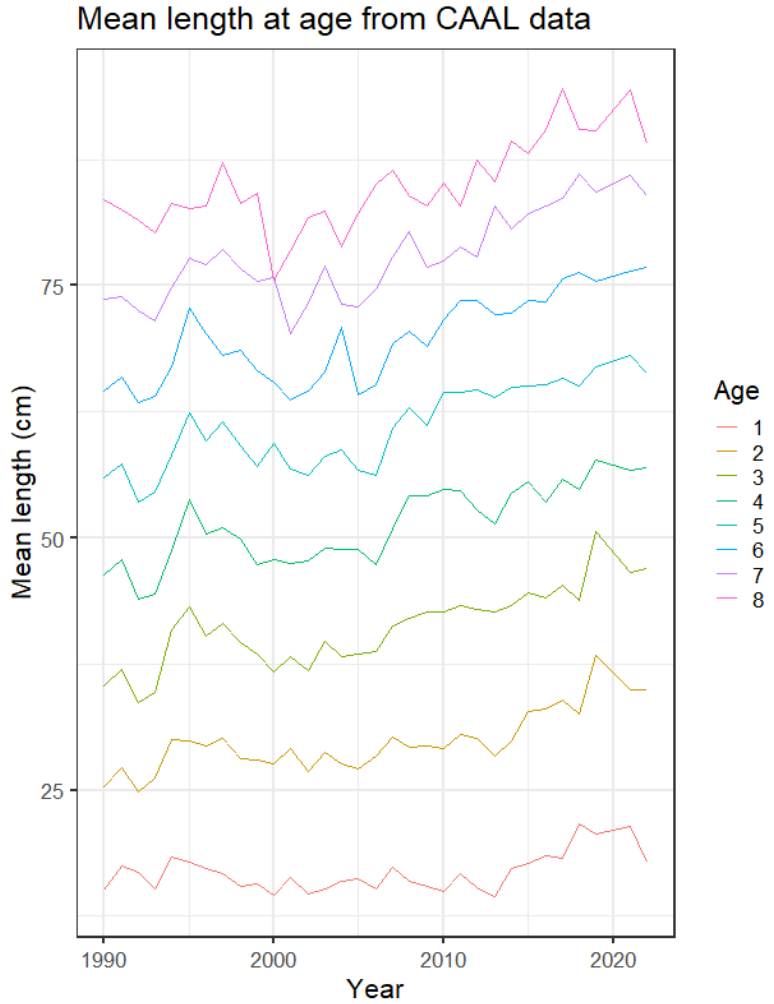
- Demonstrates change in aging post-2007, and
- Increasing growth trend since 2007



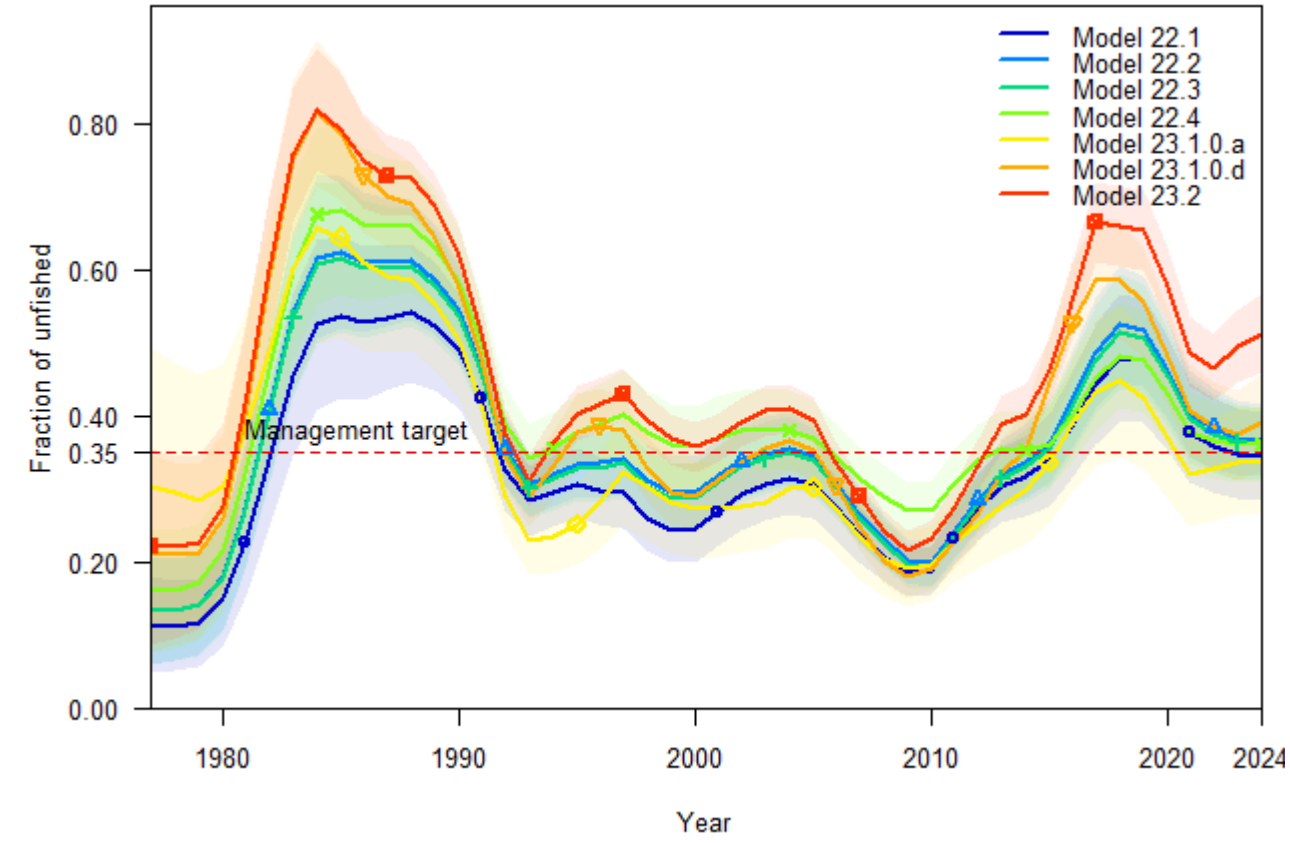
Bottom trawl survey CAAL

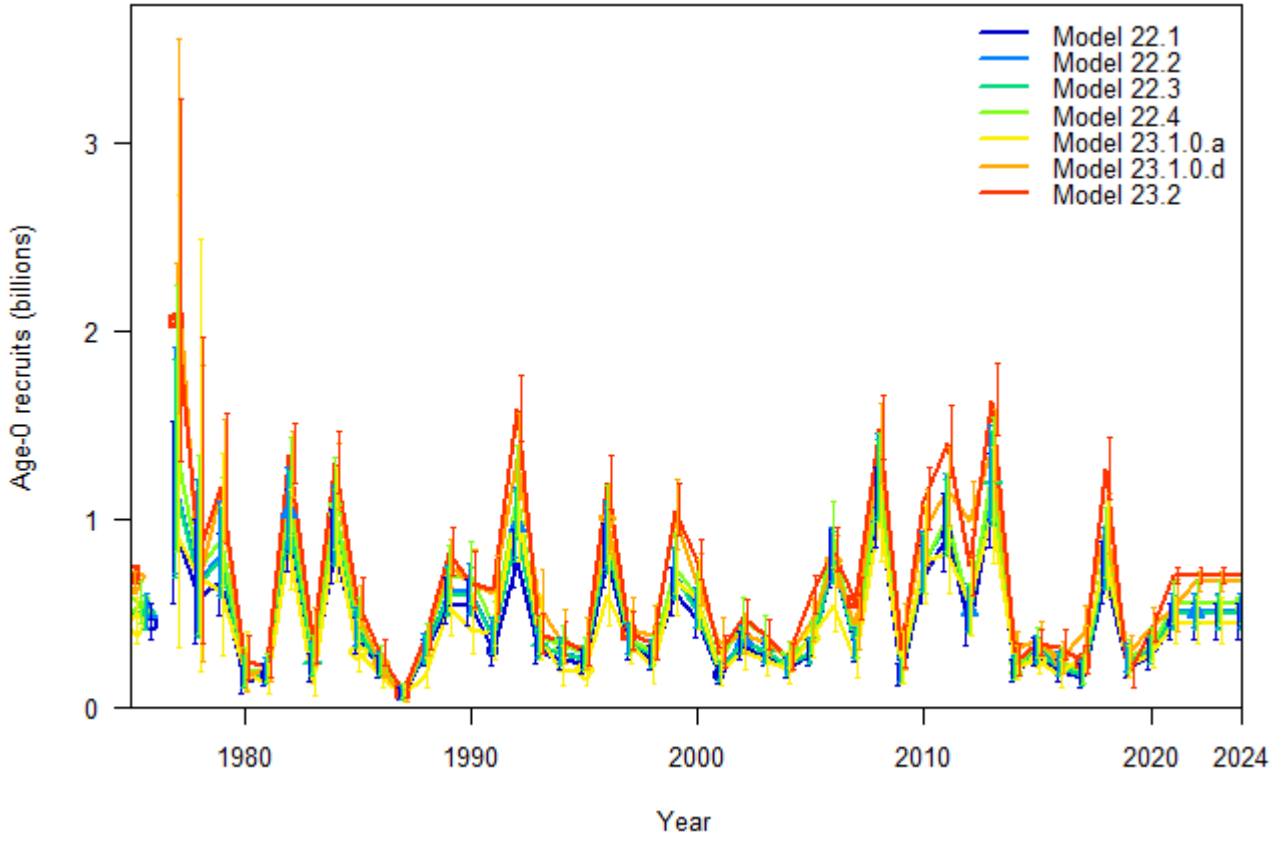
- Demonstrates change in aging post-2007, and
- Increasing growth trend since 2008





Assessment models





Assessment Models

https://afsc-assessments.github.io/EBS_PCOD/2023_ASSESSMENT/NOVEMBER_MODELS/

- 2022 Ensemble
  - Same as 2022 New Ensemble with updated data
    - Models 22.1, 22.2, 22.3, and 22.4

- 2023 new models
  - Model 23.1.0.a
    - Simplification of Model 22.2
  - Model 23.1.0.d
    - Model 23.1.0.a with time varying growth and selectivity
  - Model 23.2
    - Model 23.1.0.d with survey conditional age-at-length data

2022 Ensemble Models

- Same configuration as the 2022 New Series but with updated data
- Same ensemble weighting as 2022

Feature		M 22.1	M 22.2	M 22.3	M 22.4
Feature 1: Allow catchability to vary?		yes	no	no	no
Feature 2: Allow domed survey selectivity?		no	no	yes	no
Feature 3: Use fishery CPUE?		no	no	no	yes
Criterion	Emph.	M 22.1	M 22.2	M 22.3	M 22.4
General plausibility of the model	3	1	2	0.6667	1
Acceptable retrospective bias	3	2	2	1.3333	1
Uses properly vetted data	3	2	2	2	0
Acceptable residual patterns	3	2	2	2	2
Comparable complexity	2	1	2	1	2
Fits consistent with variances	2	2	1	1	0
Average emphasis:		1.6875	1.875	1.375	1
Model weight:		0.2842	0.3158	0.2316	0.1684

2023 New Models

- Model 23.1.0.a
  - Simplification of Model 22.2
    - Non-time varying parameters for growth and selectivity
    - Aging bias fixed
    - Generic multinomial instead of Dirichlet multinomial
    - Input sample sizes based on bootstrap
    - Francis TA1.8 iterative weighting

2023 Models	Fixed natural mortality	Annually varying growth	Annually varying survey selectivity	Time block* on fishery selectivity	CAAL
23.1.0.a					
23.1.0.d	X	X	X	X	
23.2	X	X	X	X	X

* Fishery time blocks are 1977-1989 and 1990-2023

Models reviewed

- Mostly a reduction in dev parameters in the 2023 models

Series	2022 Ensemble				2023 Models		
Model	**22.1**	**22.2**	**22.3**	**22.4**	**23.1.0.a**	**23.1.0.d**	**23.2**
Early recruitment deviations	20	20	20	20	20	20	20
Main recruitment deviations	44	44	44	44	44	45	44
Length at age 1.5 deviations	47	47	47	47		47	47
Richard's Rho deviations						34	34
Selectivity (fishery) deviations	94	94	94	94			
Selectivity (survey) deviations	84	84	84	84		41	41
Log catchability (survey) deviations	42						
Annual deviations	331	289	289	289	64	187	186
Natural mortality	1	1	1	1	1		
Growth	6	6	6	6	4	4	4
Ageing error	2	2	2	2			
Stock-recruitment	2	2	2	2	2	2	2
Initial fishing mortality	1	1	1	1	1	1	1
Dirichlet-multinomial coefficients	1	1	1	1			
Log catchability (survey)	1	1	1	1	1	1	1
Selectivity (fishery)	5	4	5	4	2	4	4
Selectivity (survey)	2	2	5	2	2	2	2
Log catchability (fishery)				1			
TRUE parameters	21	20	24	21	13	14	14
Total parameters	352	309	313	310	77	201	200

Model Evaluation: Ensemble vs. 2023

- For the Ensemble the Dirichlet multinomial log(Θ) continued to tend to the upper bound for length comp data and needed to be fixed there for the models to converge.

- 2022 Ensemble models consistently failed jitter tests (50 jitters at 0.1)
    - For all Ensemble models **no** jitter run converged to the same MLE or even the same objective function suggesting complex likelihood surface with substantial local minima.
    - For the three 2023 models > 76% of runs converged to MLE

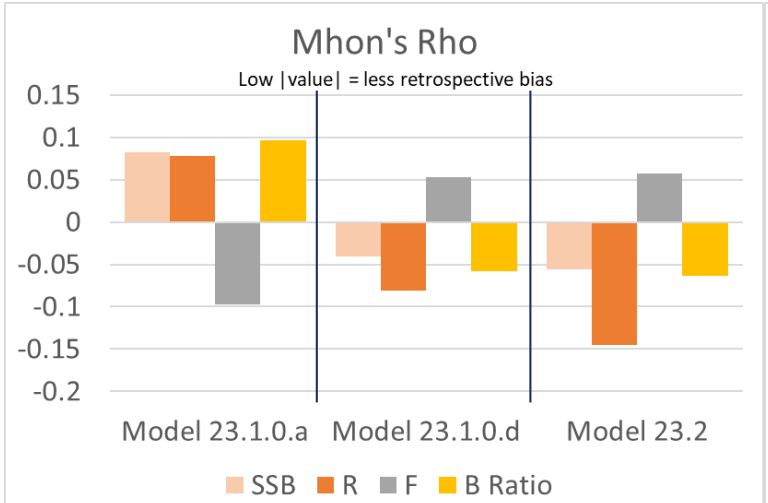
- **In the Authors' opinion the failure of the Ensemble models to consistently converge at the MLE is enough to disqualify them for consideration for use in management**

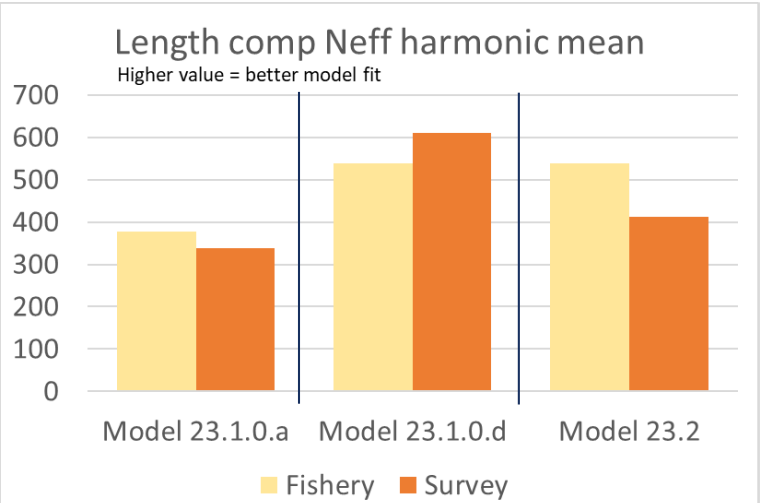
2023 Model Diagnostics

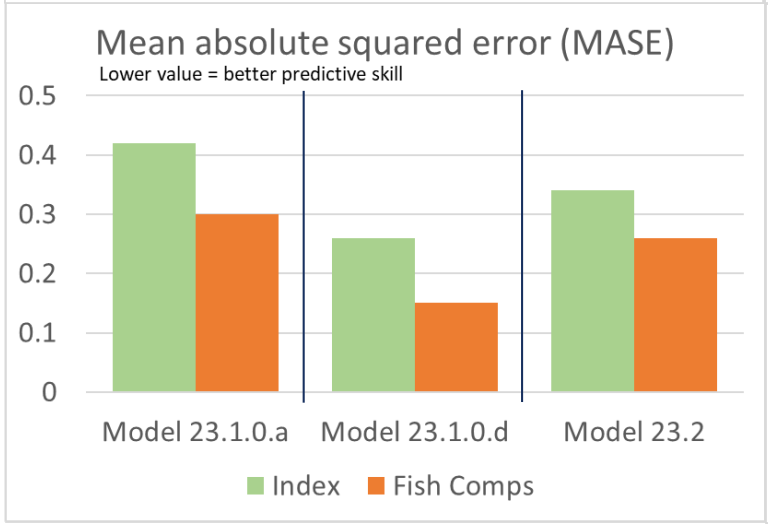
- Jitter run performance
  - 50 runs at 0.1 – higher proportion = consistent convergence
- Retrospective bias
  - 10 year peals – lower $|\rho|$ = lower retrospective bias
- Effective N harmonic mean
  - Higher Neff = better fit
- Root mean squared standardized residual (RMSSR)
  - Closer to 1 = closer fit to data
- Mean absolute squared error (MASE)
  - Lower value = better predictive skill
- Residual runs tests
  - > 0.05 = passed with acceptable autocorrelation in residuals

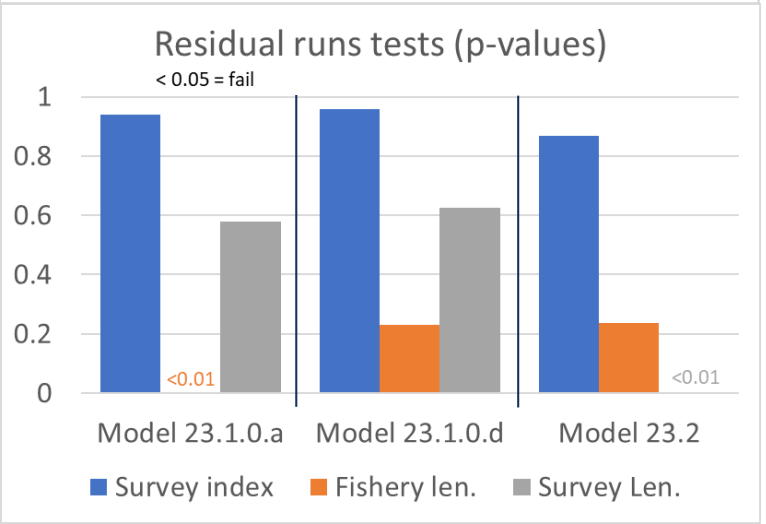
2023 Model Diagnostic Comparison

- Model 23.1.0.d best overall performance
  - Least retrospective bias
  - Best overall fit to comp and index data
  - Best MASE predictive skill
  - Passed all residual runs tests
  - Index RMSSR closest to 1.0
- Model 23.1.0.a best jitter performance with 98% convergence at the MLE
  - Model 23.1.0.d at 86%
  - Model 23.2 at 76%.



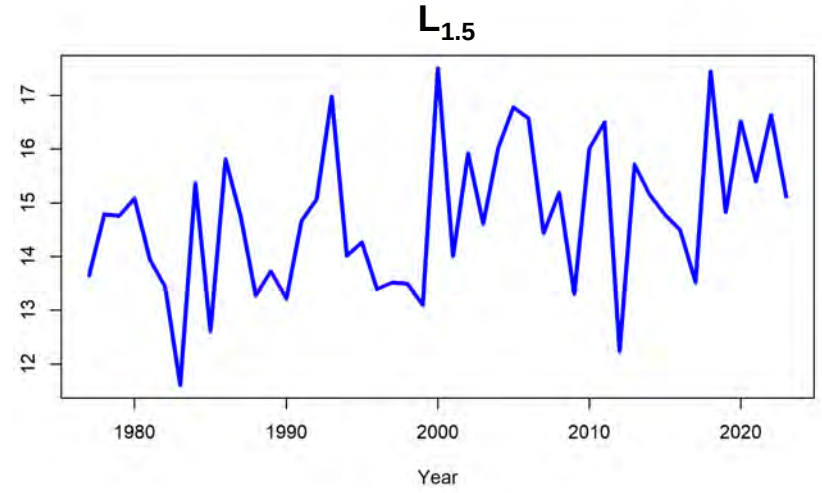


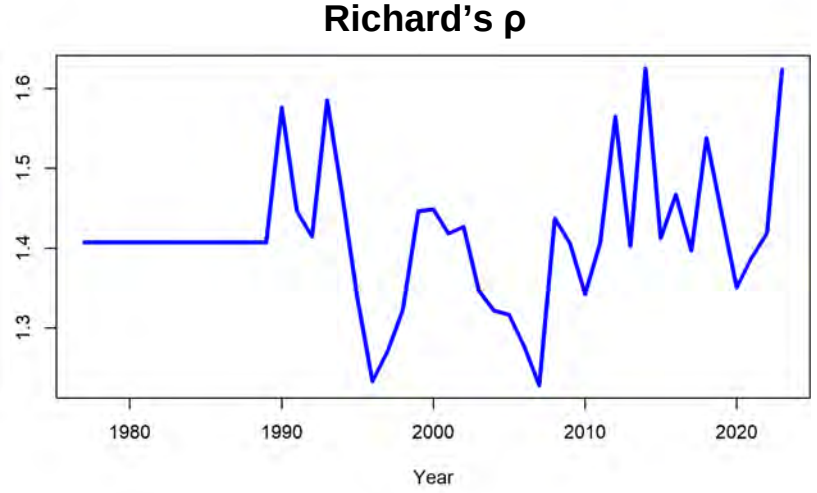


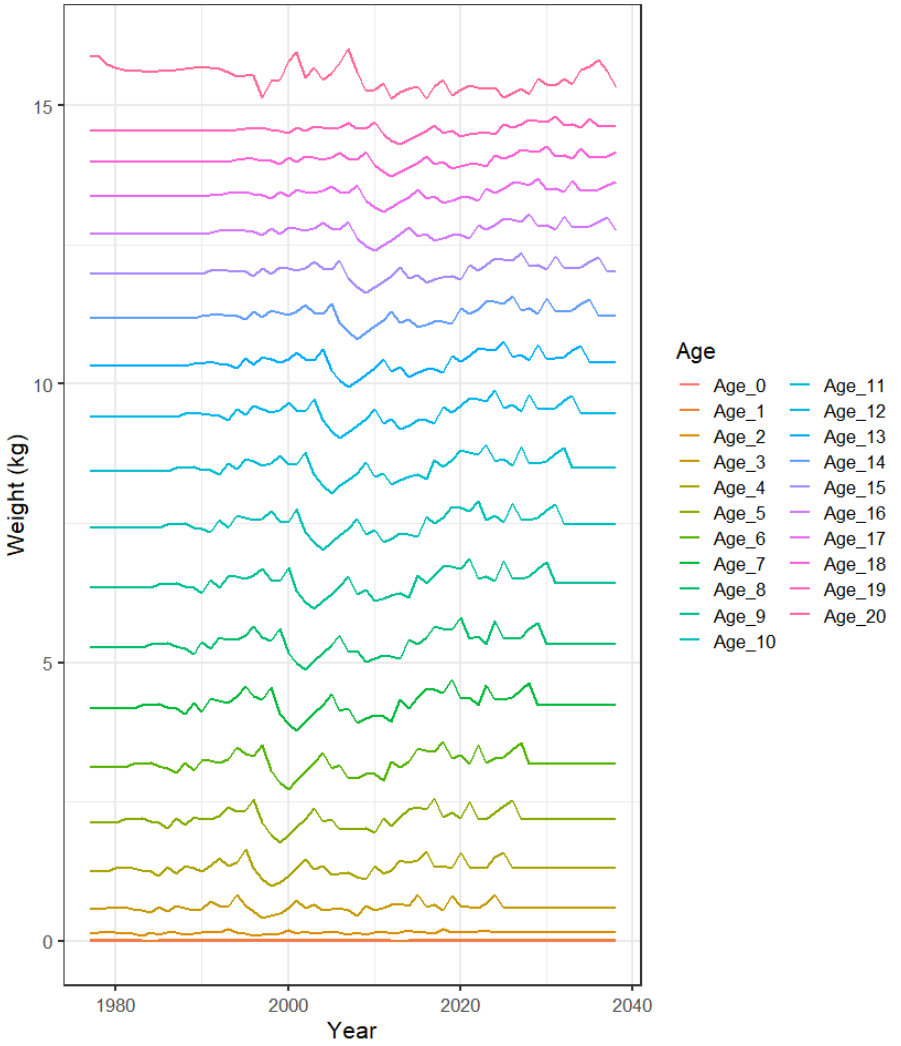


Model 23.1.0.d Results - Growth

- Richards with time varying parameters
  - $L_{1.5}$ - Models initial size and acts as a cohort effect
    - Variable with an overall increasing trend over time
  - Richard's ρ - Shapes growth curve and acts as annual effect
    - Variable with increasing trend since 2010

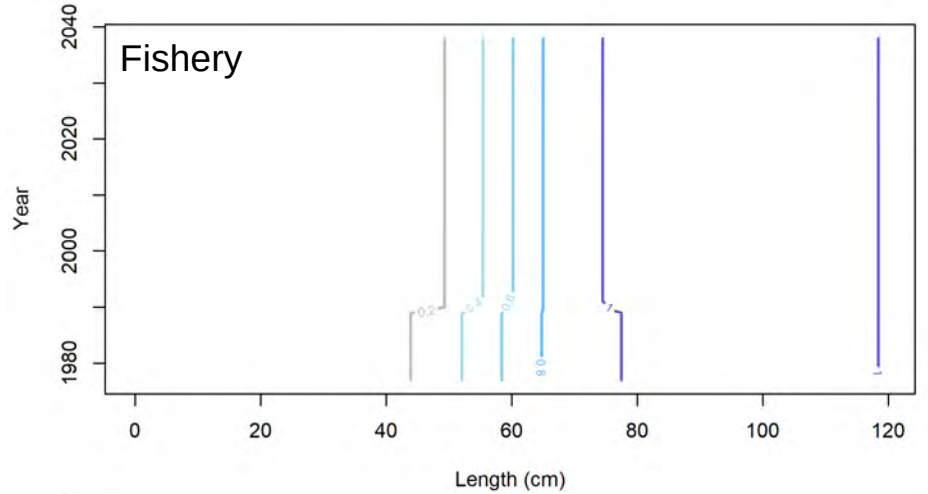


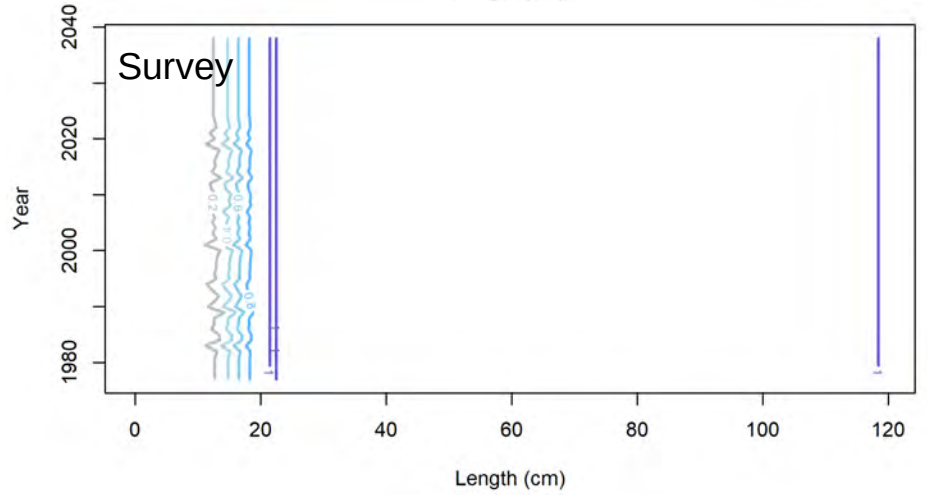




Model 23.1.0.d Results - Selectivity

- Fishery - Time blocks 1977-1989 and 1990-2023
  - Asymptotic double normal with peak and ascending width fit for the two time blocks
- Survey – Time varying 1977-2023
  - Asymptotic double normal with peak and ascending width fit
  - Peak parameter fit with random deviations with σ tuned iteratively to set the variance of the estimates plus the sum of the estimates' variances equal to 1.0.

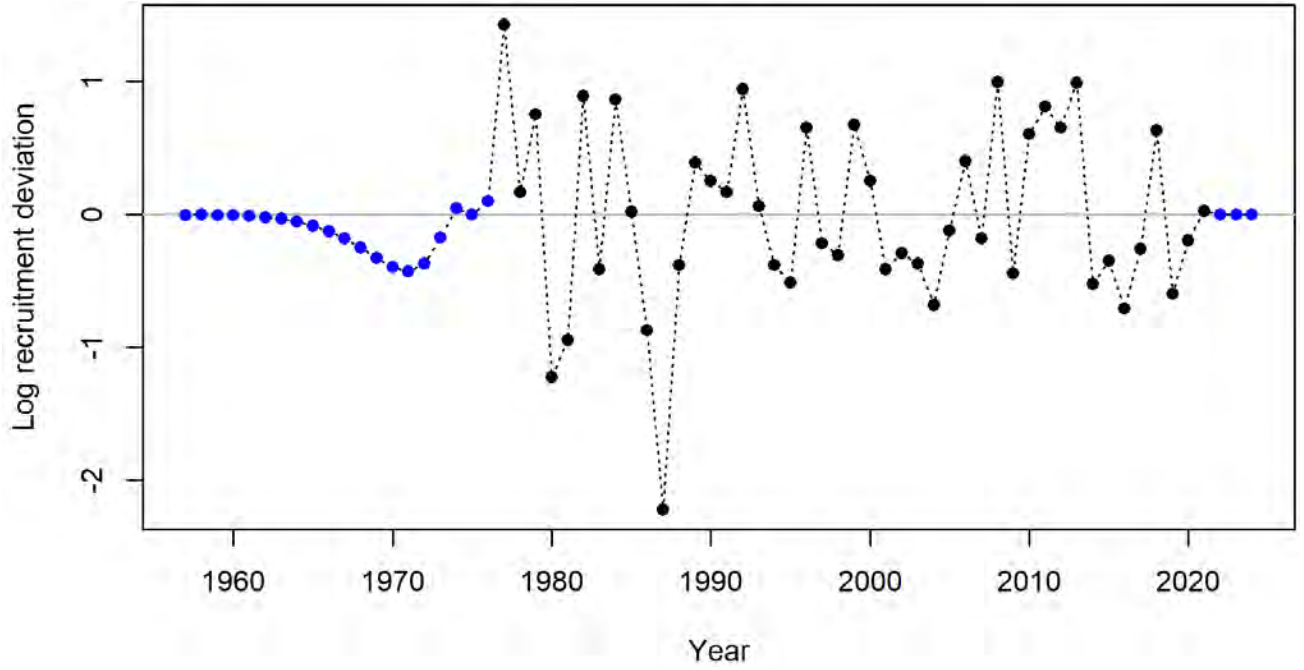




Model 23.1.0.d Results - Recruitment

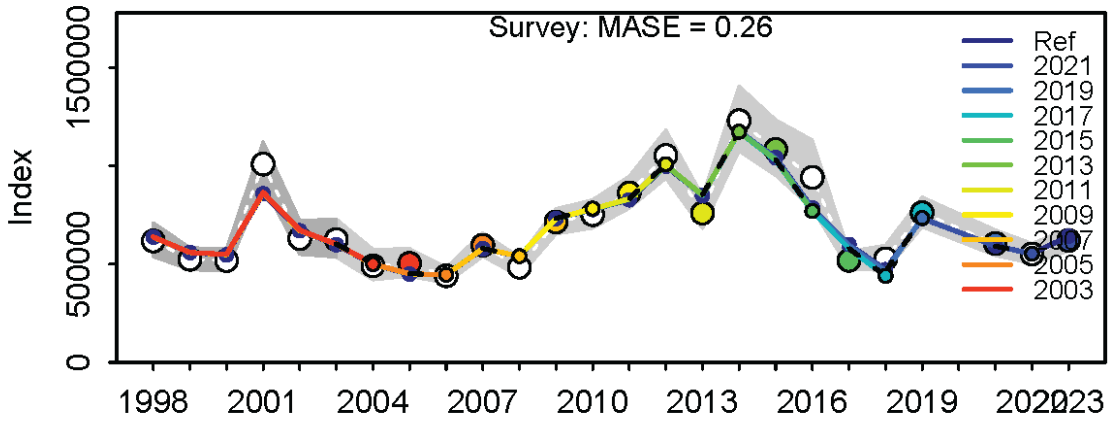
- σ_R = 0.74
  - Iteratively tuned to match the square root of the variance of the estimates plus the sum of the estimates' variances (Methot and Taylor 2011)

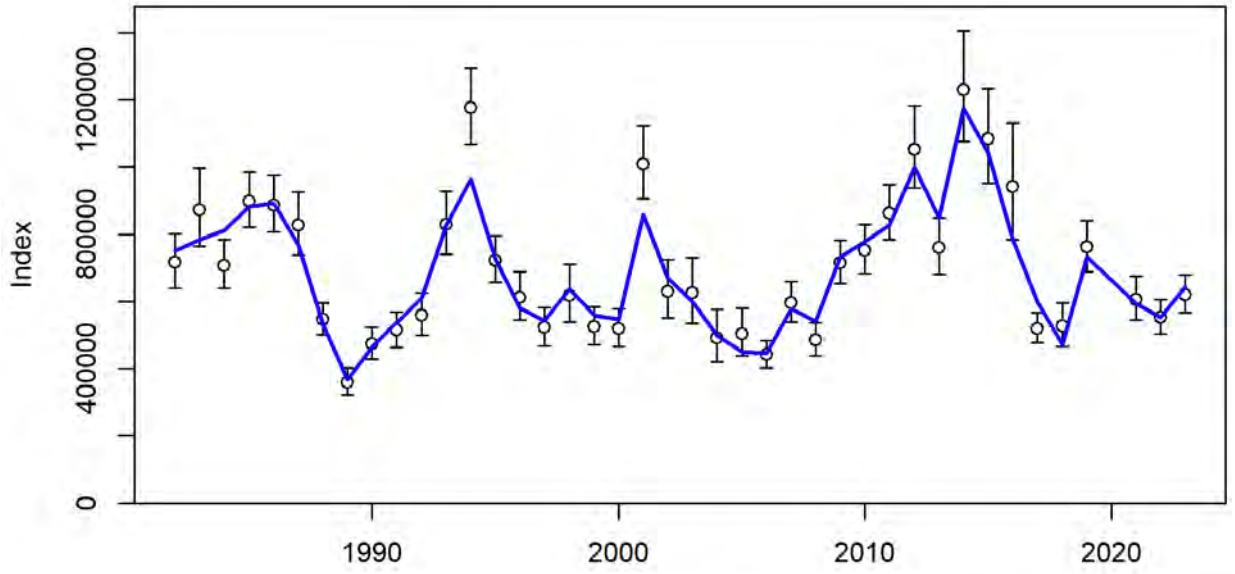
- Highly variable 1977-1989
- Recent recruitment
  - Good 2010-2013
  - Poor 2014-2017 and 2019-2020
  - 2018 above average
  - 2021 near average

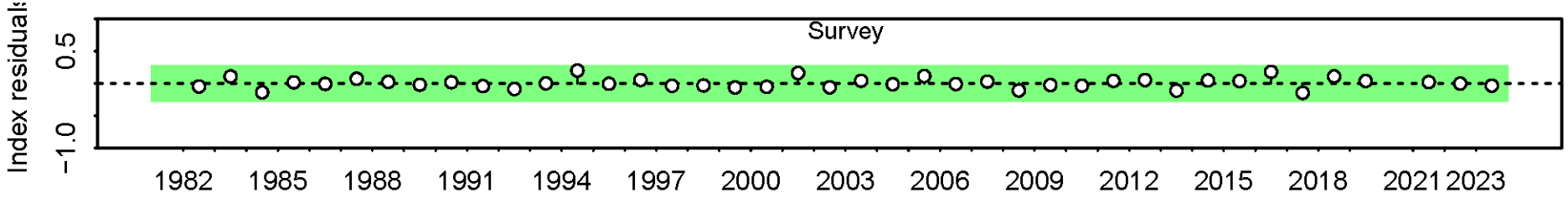


Model 23.1.0.d Results - Index

- Tight fit to the survey index
  - Insignificant autocorrelation in residuals (p-value = 0.959)
  - Good MASE predictive score (0.26)

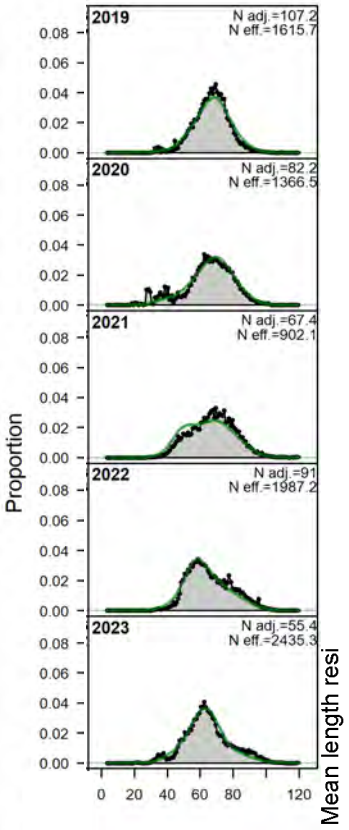


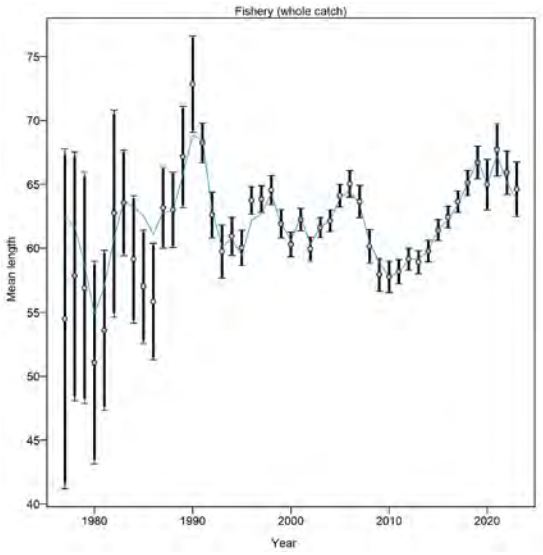


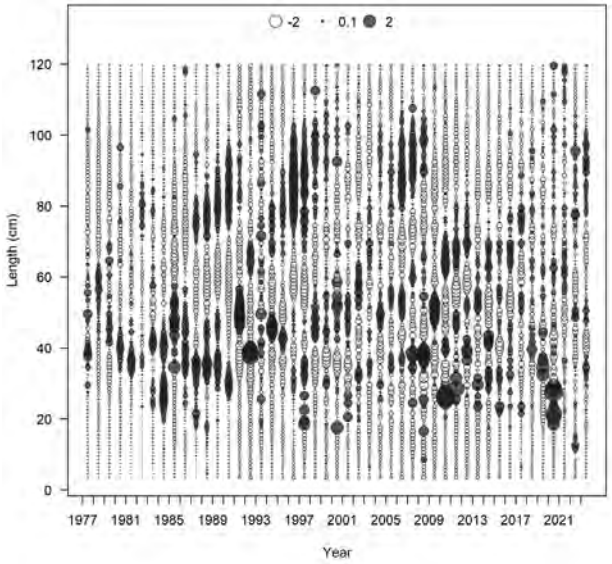


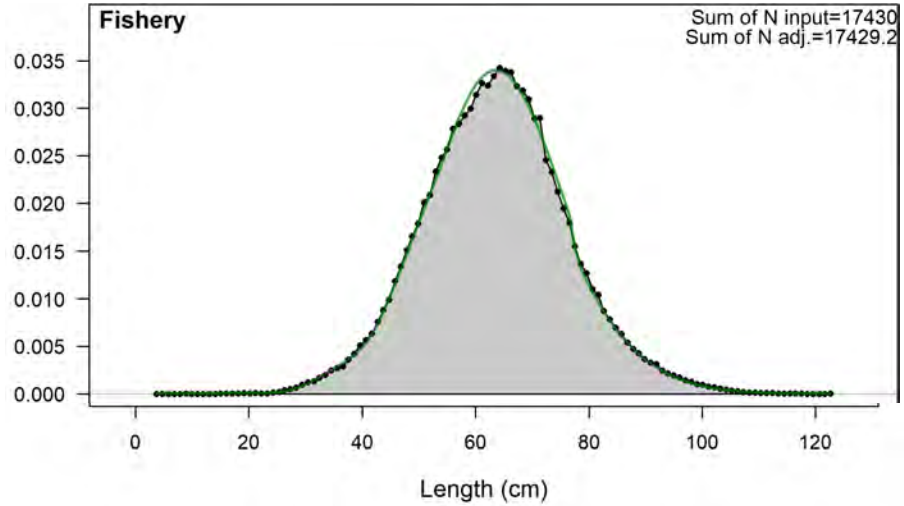
Model 23.1.0.d Results – Fishery lengths

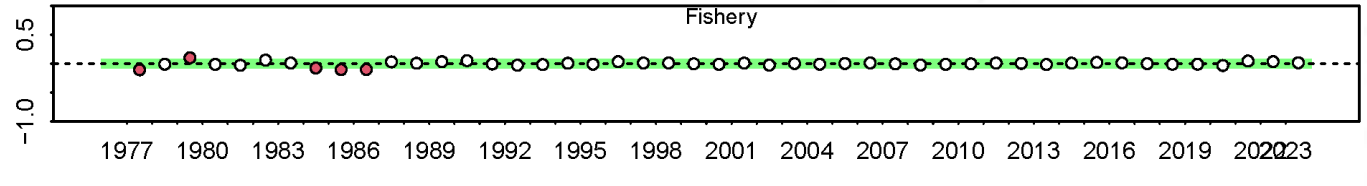
- Good fit to the fishery length composition
  - Insignificant autocorrelation in residuals (p-value = 0.231)
  - Good MASE predictive skill (0.15)

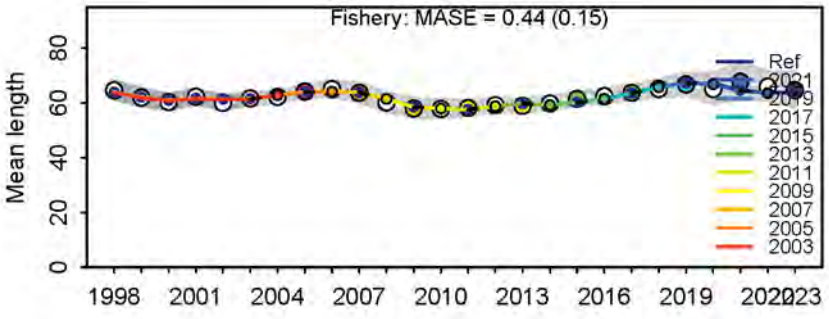






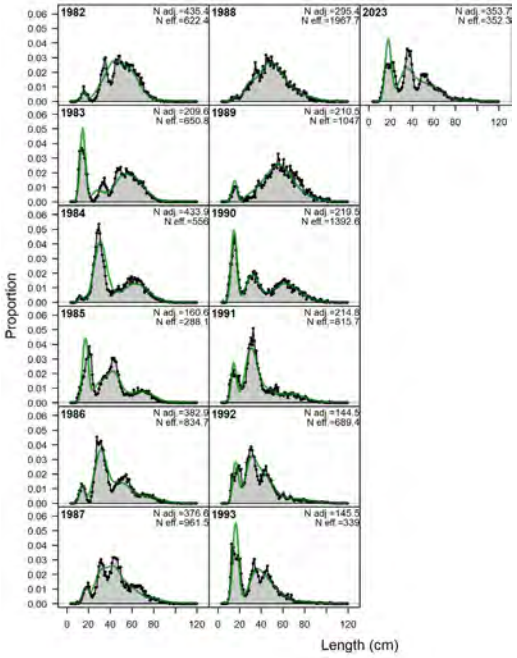


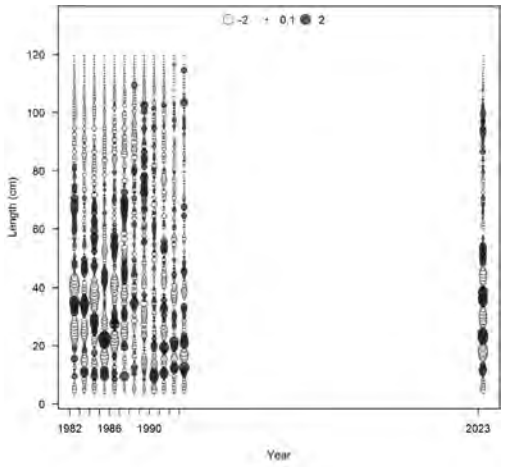


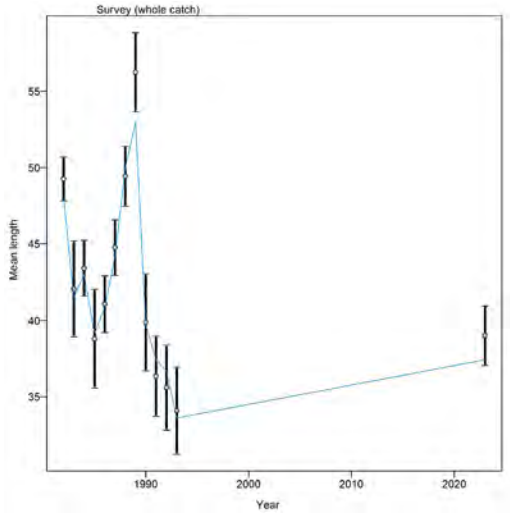


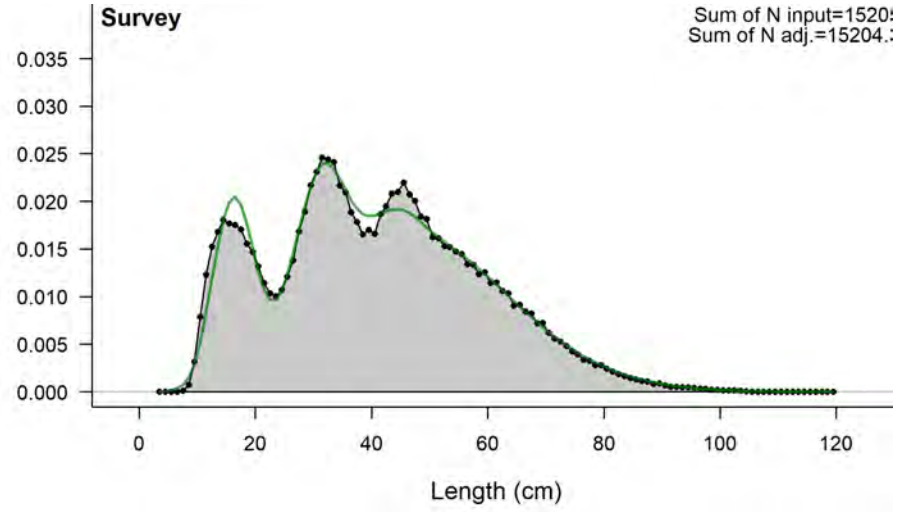
Model 23.1.0.d Results – Survey lengths

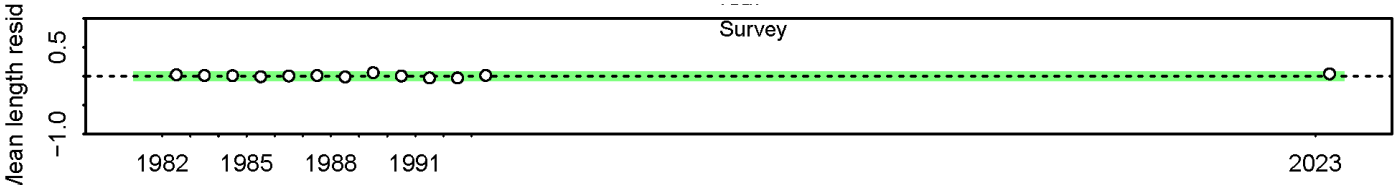
- Good fit to the survey length composition
  - Insignificant autocorrelation in residuals (p-value = 0.625)
  - Tendency to overestimate large modes < 20 cm





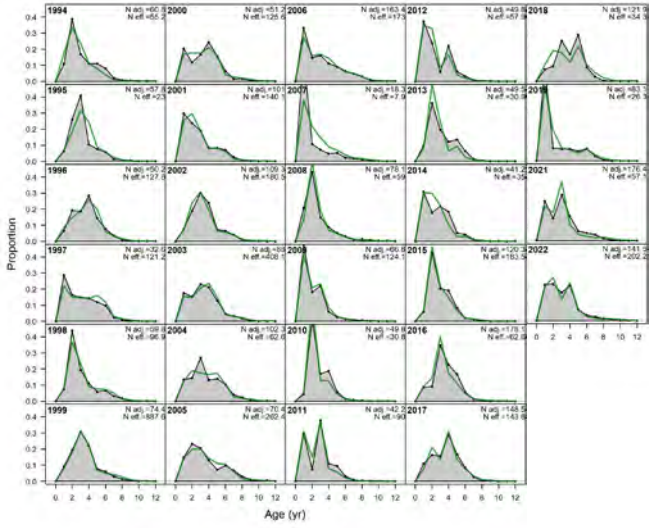


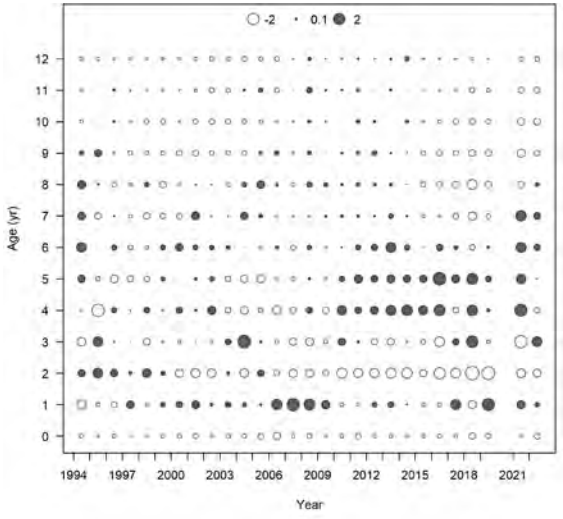


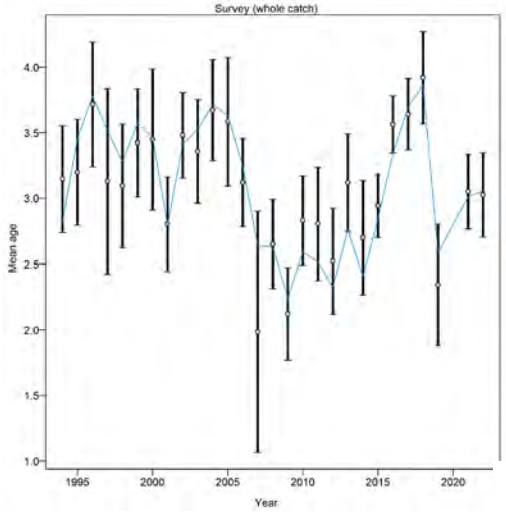


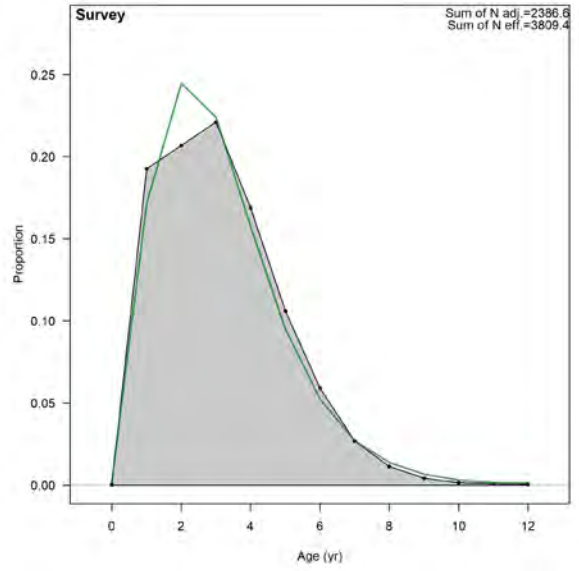
Model 23.1.0.d Results – Survey Ages

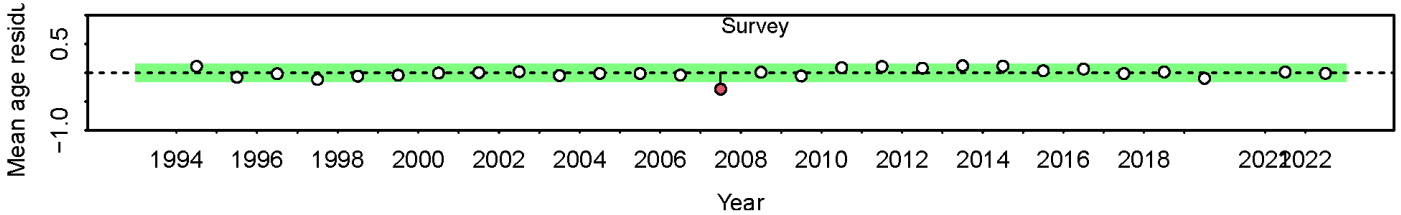
- Good fit to the survey age composition
  - Insignificant autocorrelation in residuals (p-value = 0.128)
  - Good MASE predictive skill (0.23)

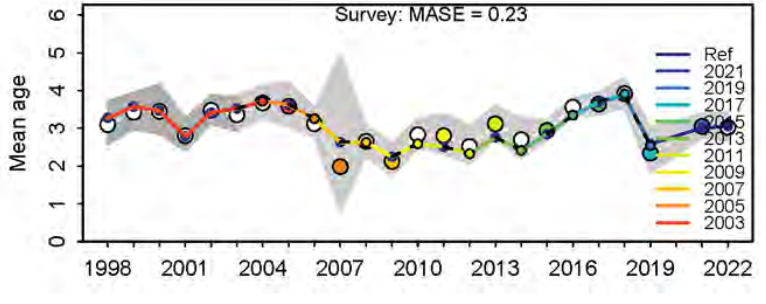






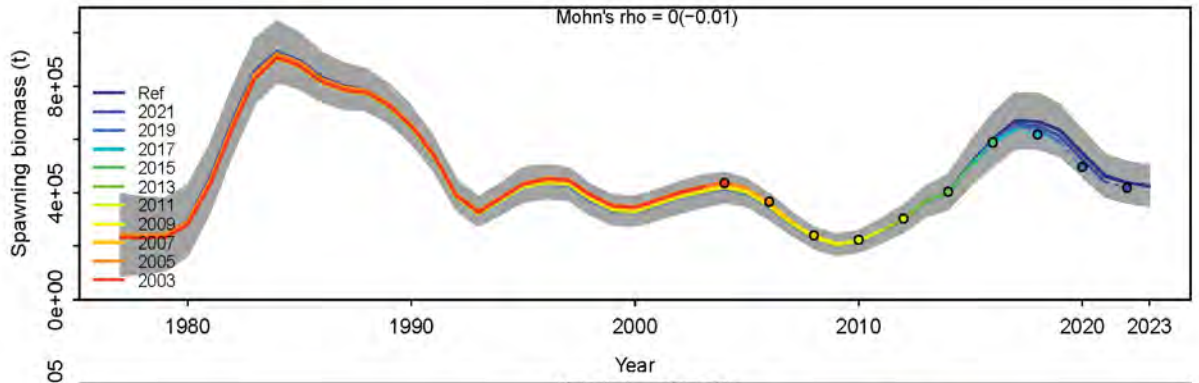


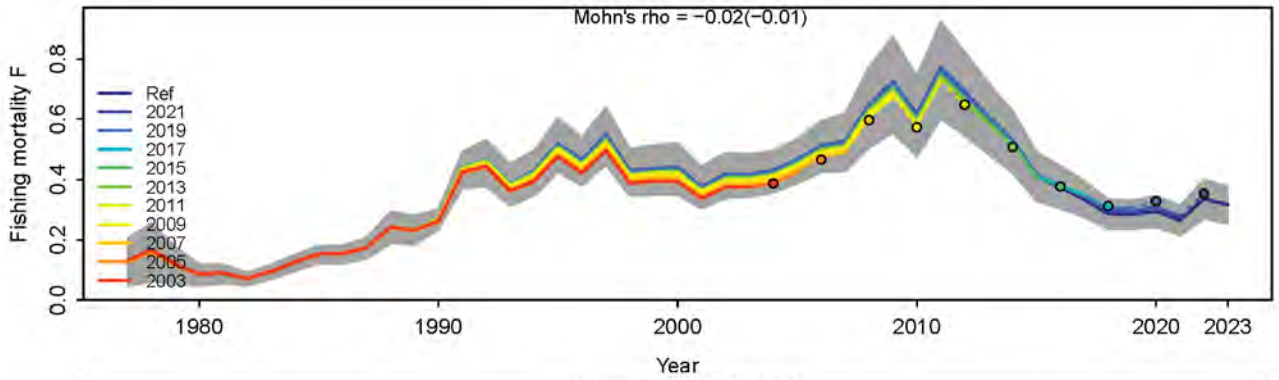


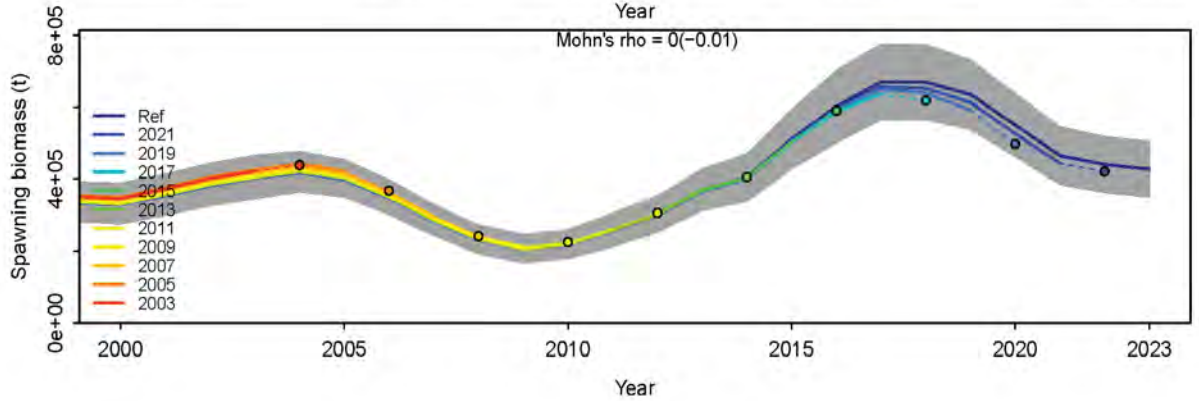


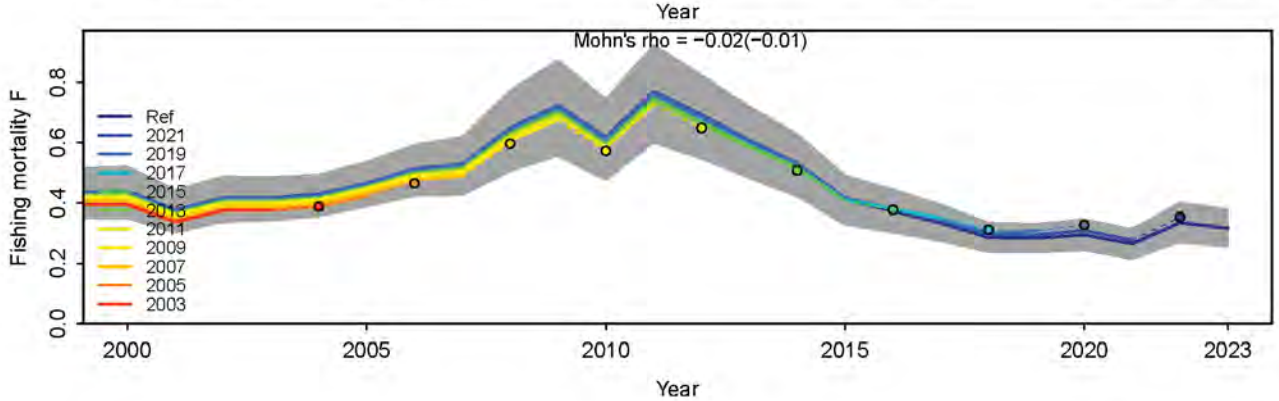
Model 23.1.0.d Results – Retrospective

- Good retrospective behavior with low negative retrospective bias for SSB
  - SSB Mohn's ρ = -0.041



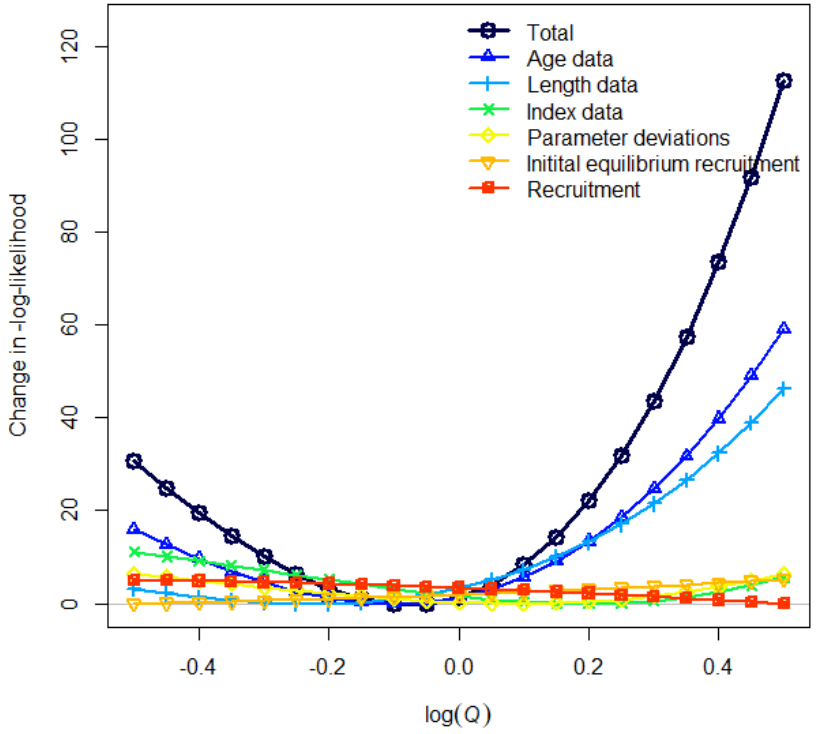


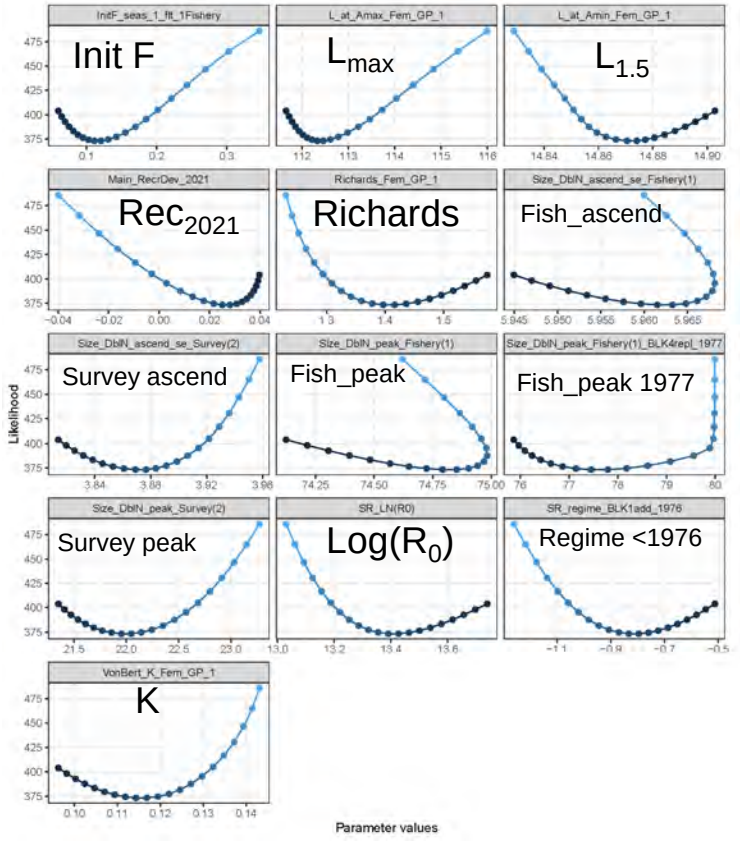


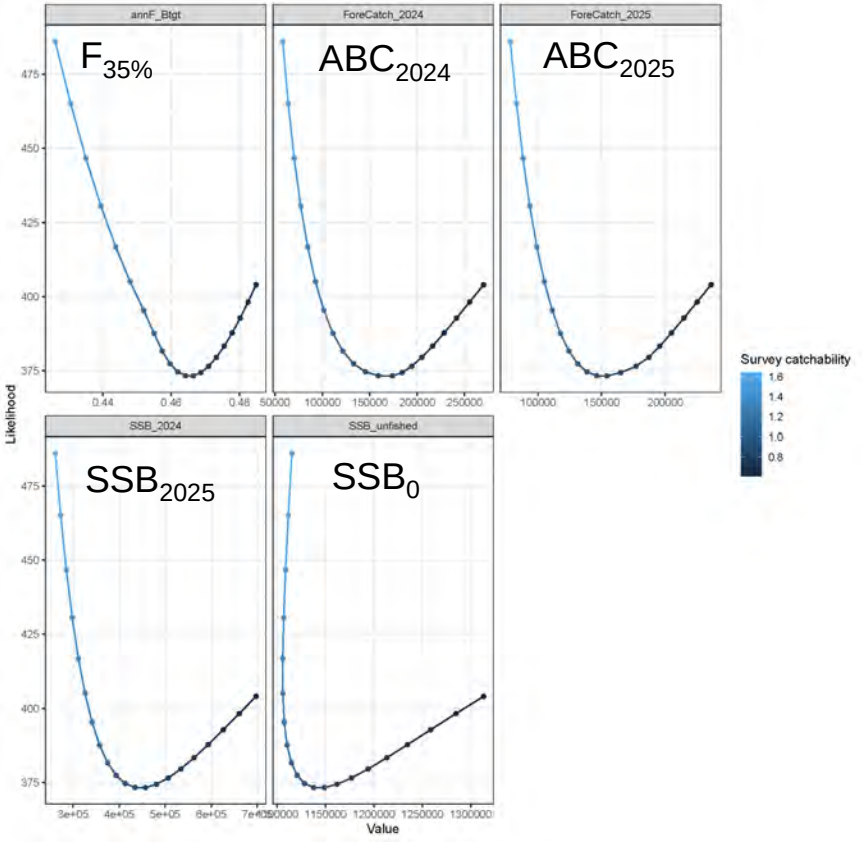


Model 23.1.0.d Results – Q Profile

- Profile over survey catchability shows model with fixed natural mortality less sensitive

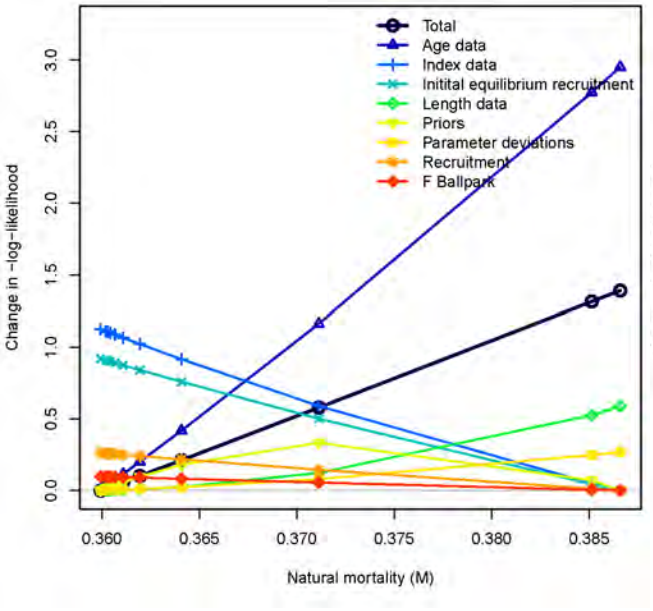


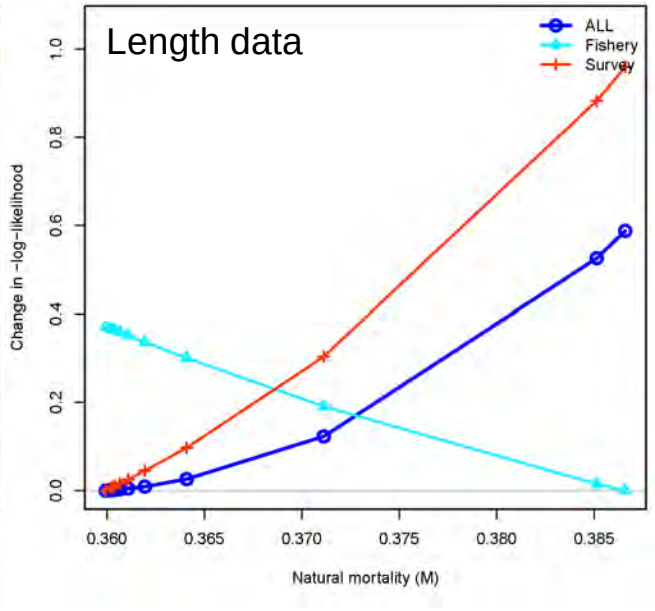


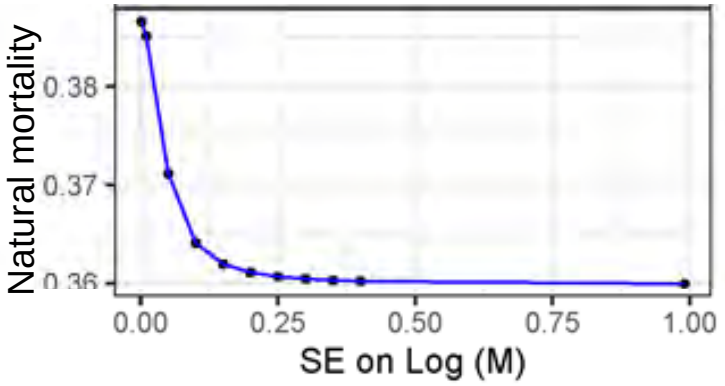


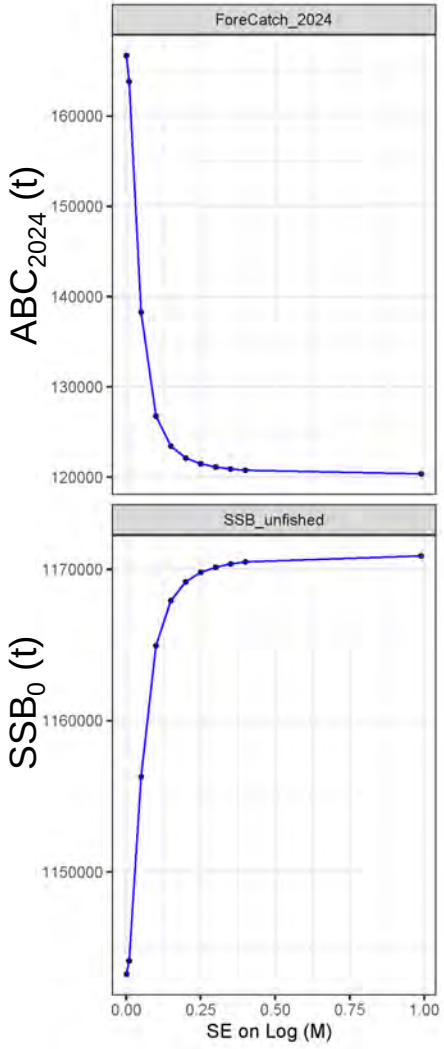
Model 23.1.0.d Results – SE of M Profile

- Profile over SE of the M prior shows model sensitive to assumptions on natural mortality
  - Data conflicts
    - Index and fishery length composition indicate higher M
    - Survey length and age composition indicate lower M



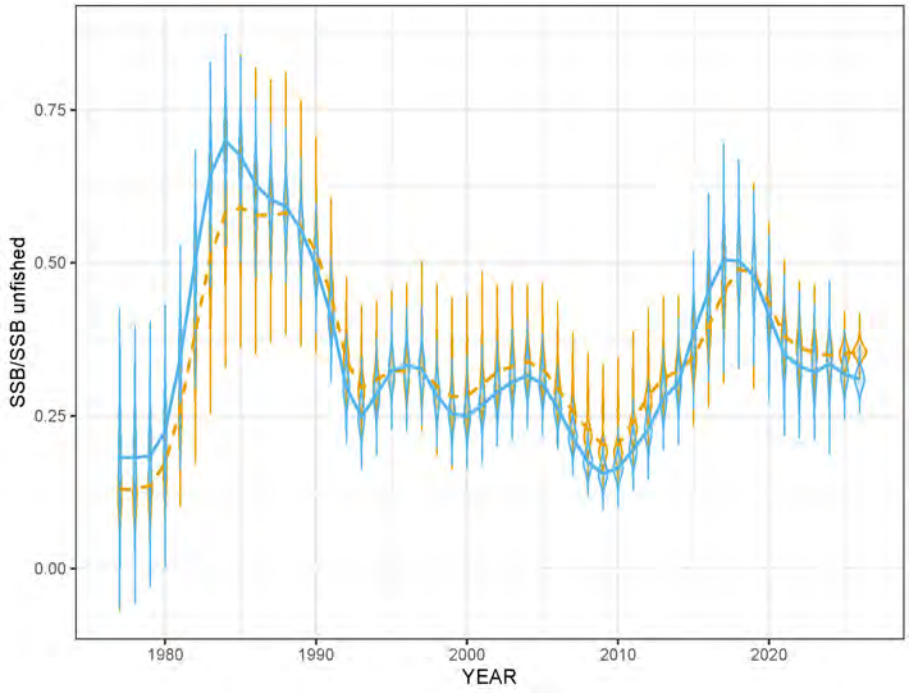


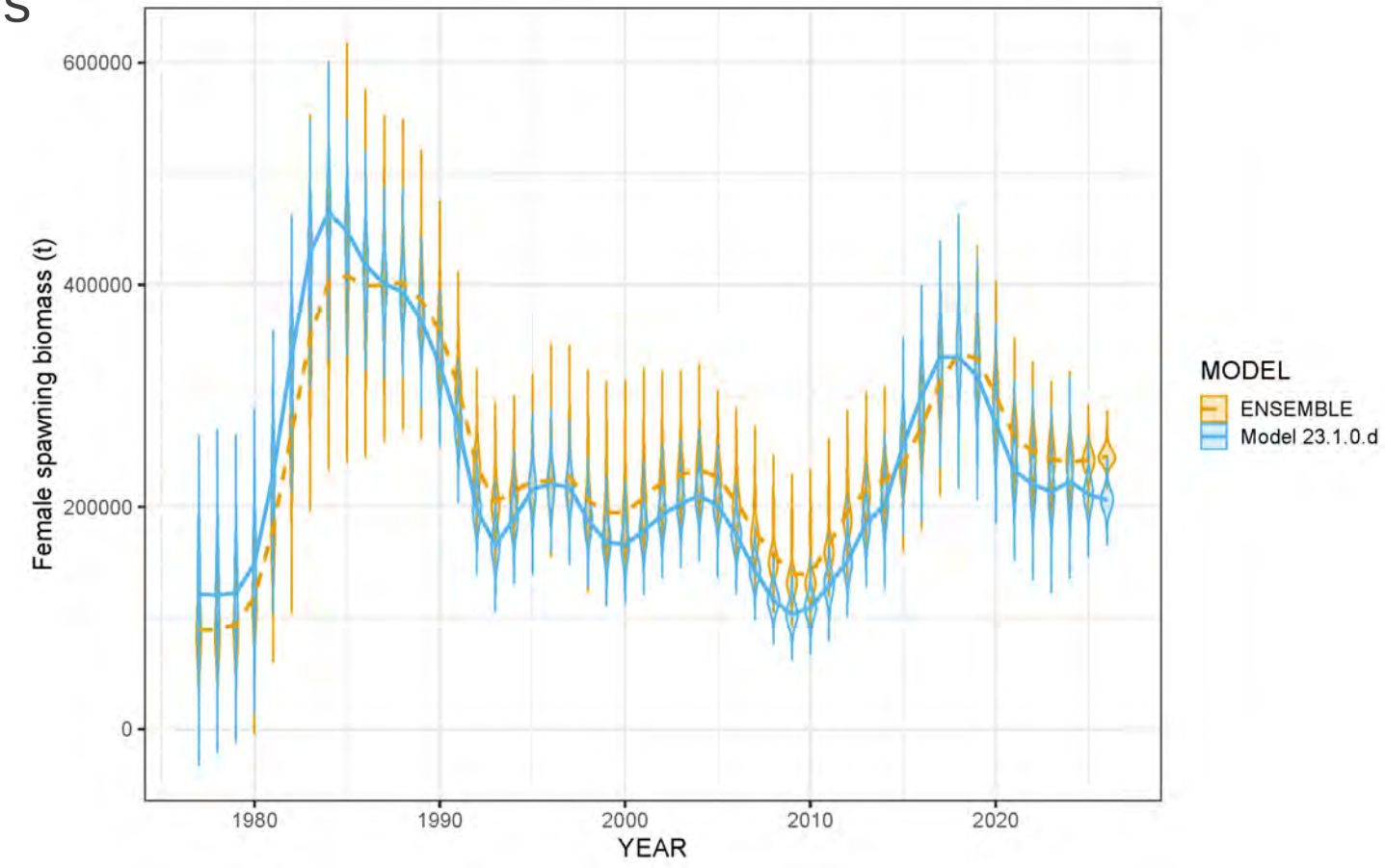




Model 23.1.0.d Timeseries – SSB

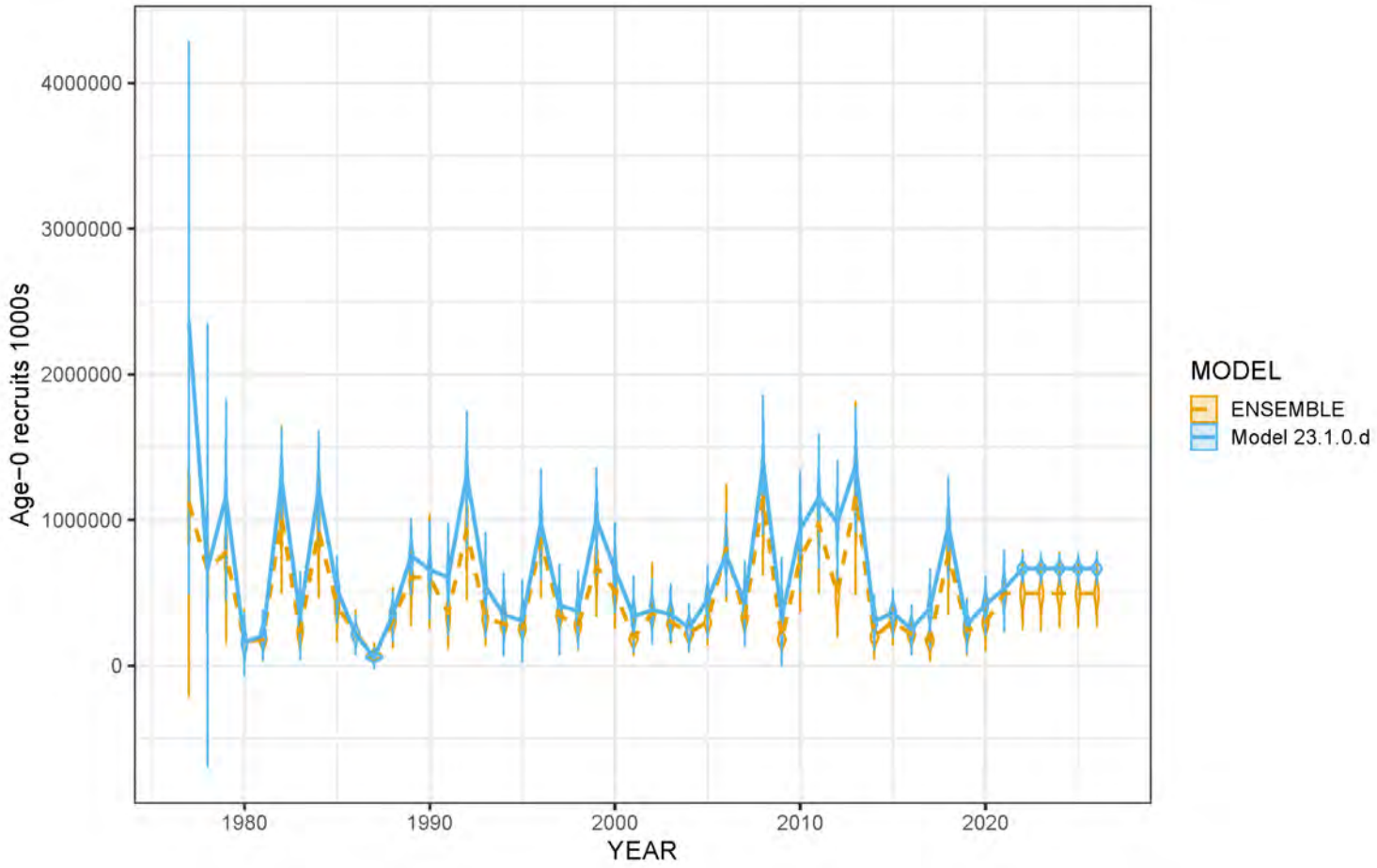
- Similar trends to 2022 ensemble
  - Higher peaks and lower troughs
  - Lower SSB in projection





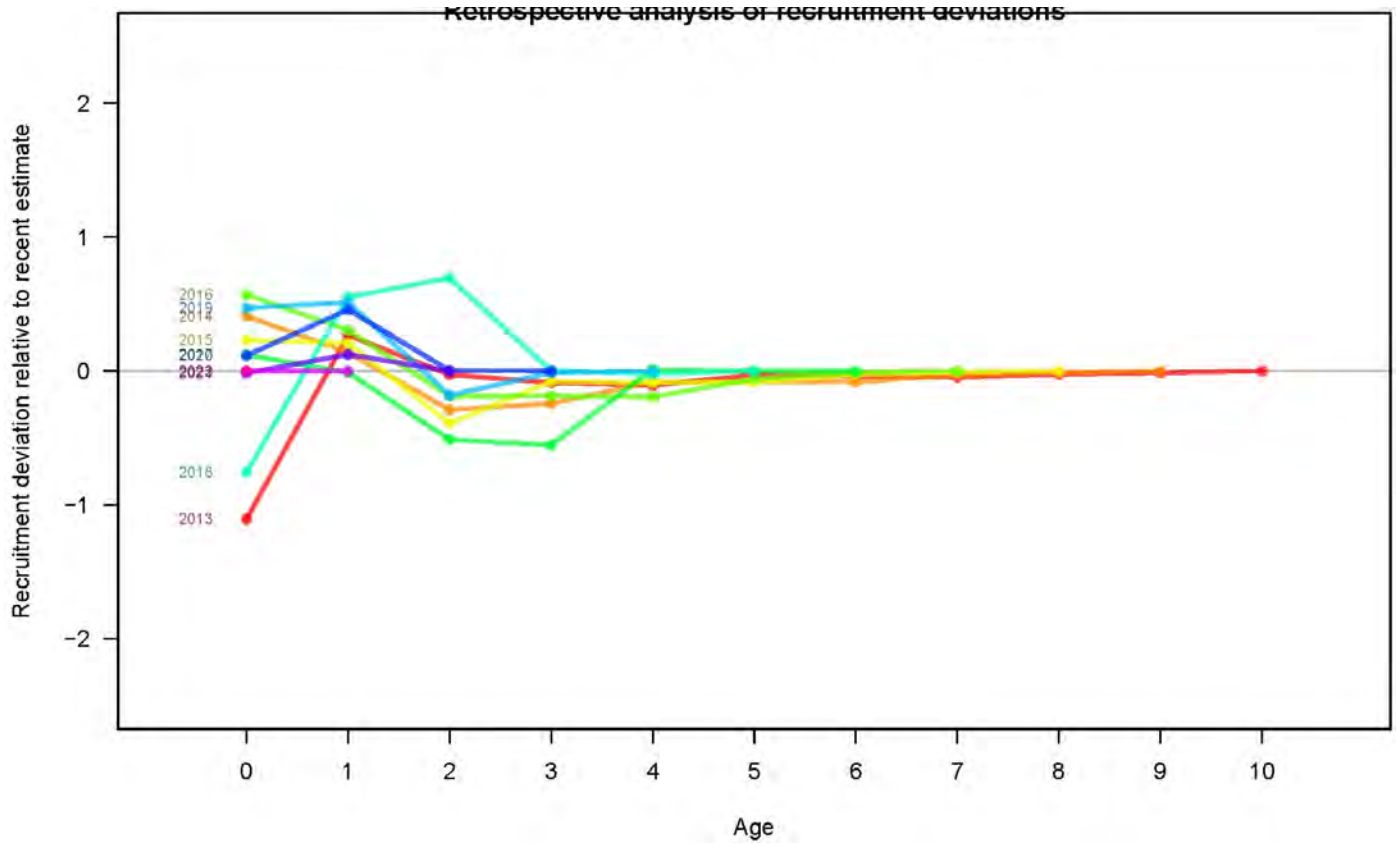
Model 23.1.0.d Timeseries – Recruitment

- Same peaks and valleys to 2022 ensemble
  - Higher M results in higher recruitment
  - Lower uncertainty overall than 2022 ensemble



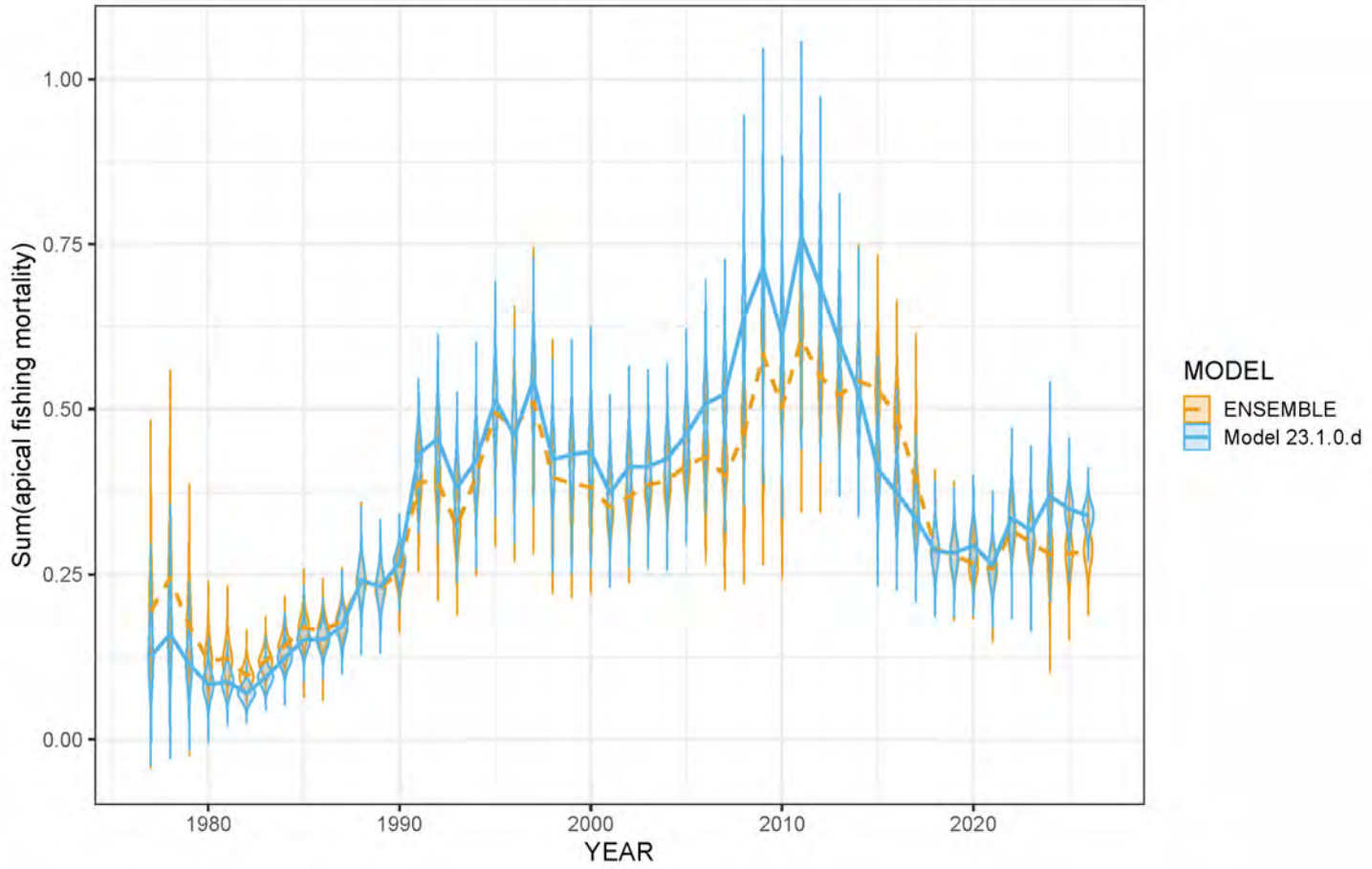
Model 23.1.0.d Timeseries – Recruitment

- Mostly consistent as data are removed
  - All start at average at age 0
  - Most year classes smaller than estimated at age 2
  - 2018 year class much smaller now than what it would have been at age 3
  - Consistent recruitment estimates by age 4 on



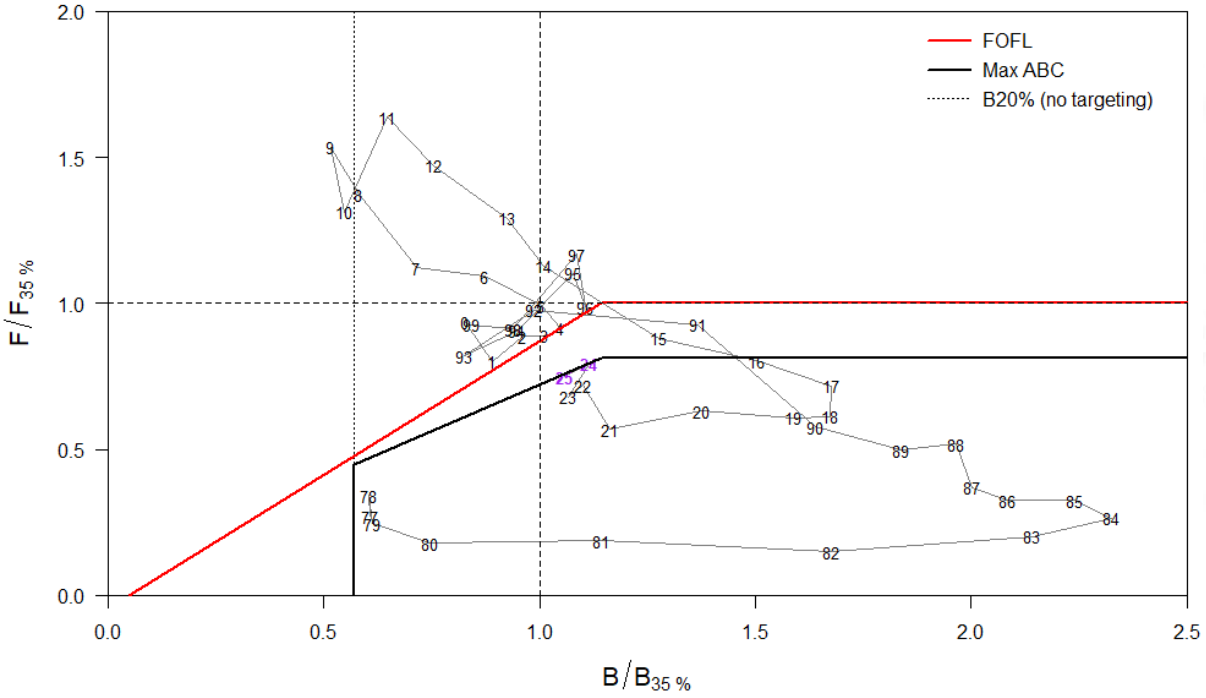
Model 23.1.0.d Timeseries – F

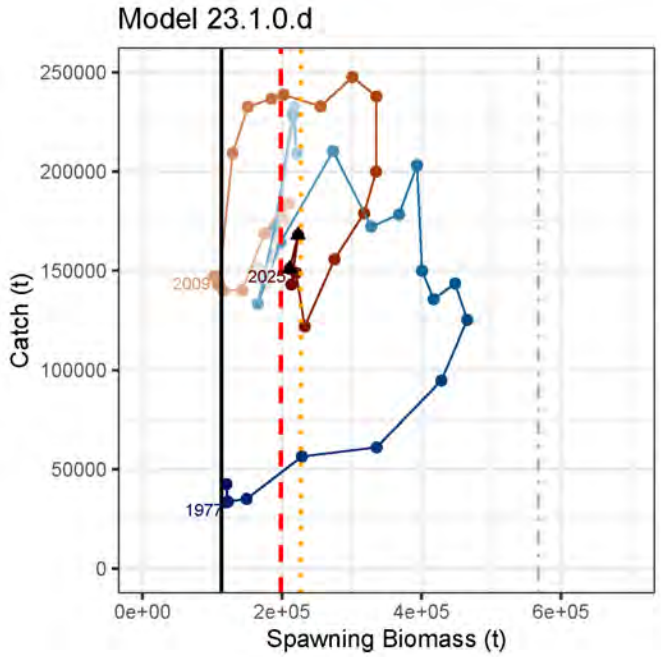
- Similar to 2022 ensemble but some key differences
  - Higher F 1991-2015
  - Lower F 2016-2021
  - Projected higher F for $F_{40\%}$ in 2024-2026

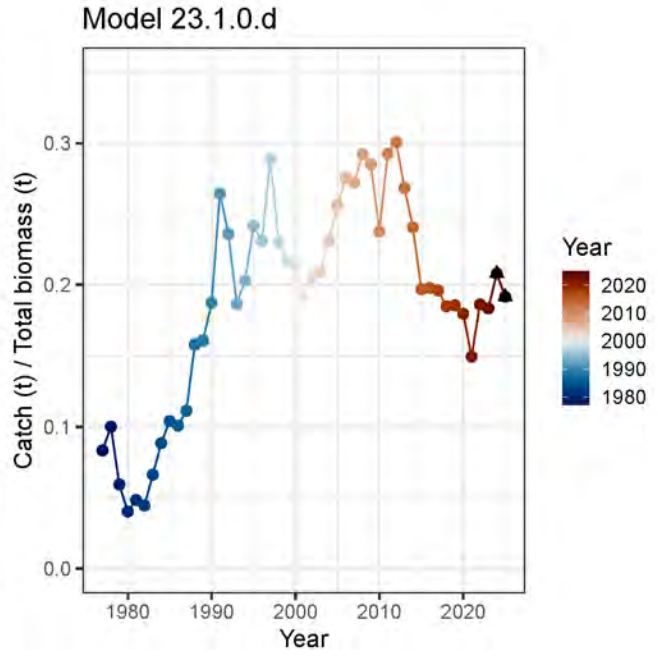


Model 23.1.0.d Timeseries – Phase plane

- Recent lower fishing pressure 2015-2023
- High fishing pressure 2006-2014

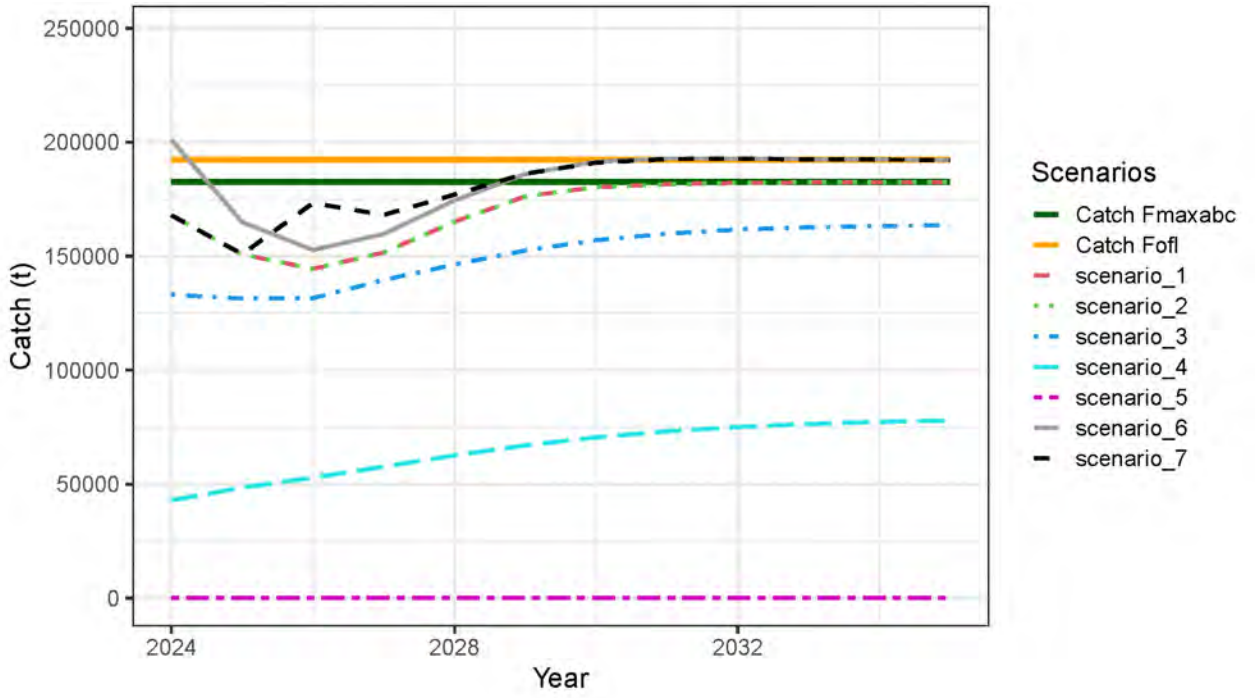


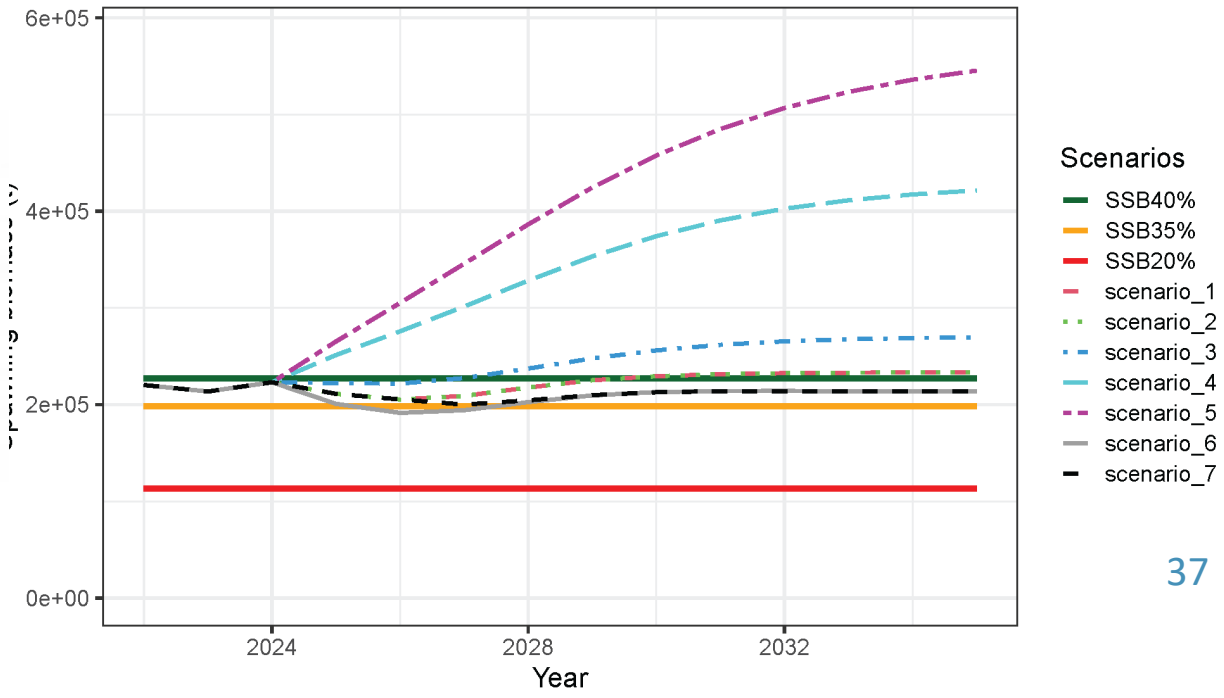




Model 23.1.0.d Projections

- Not overfished or overfishing
- $B_{38\%}$ in 2023 with the expectation of decline through 2026 to a low of $B_{36\%}$
- Under all scenarios above $B_{35\%}$ by 2035

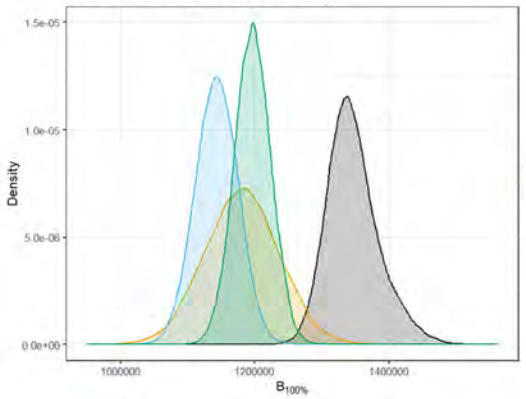




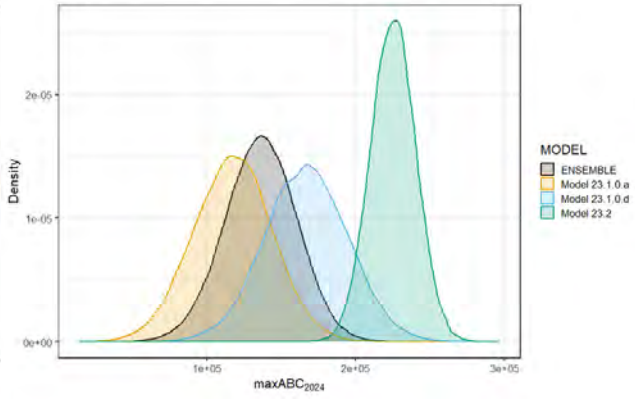
Model 23.1.0.d Projections

- Higher M and lower $B_{100\%}$ results in higher F and higher ABC/OFL
- No risk table concerns
- Not overfished or overfishing

$B_{100\%}$



$maxABC_{2024}$

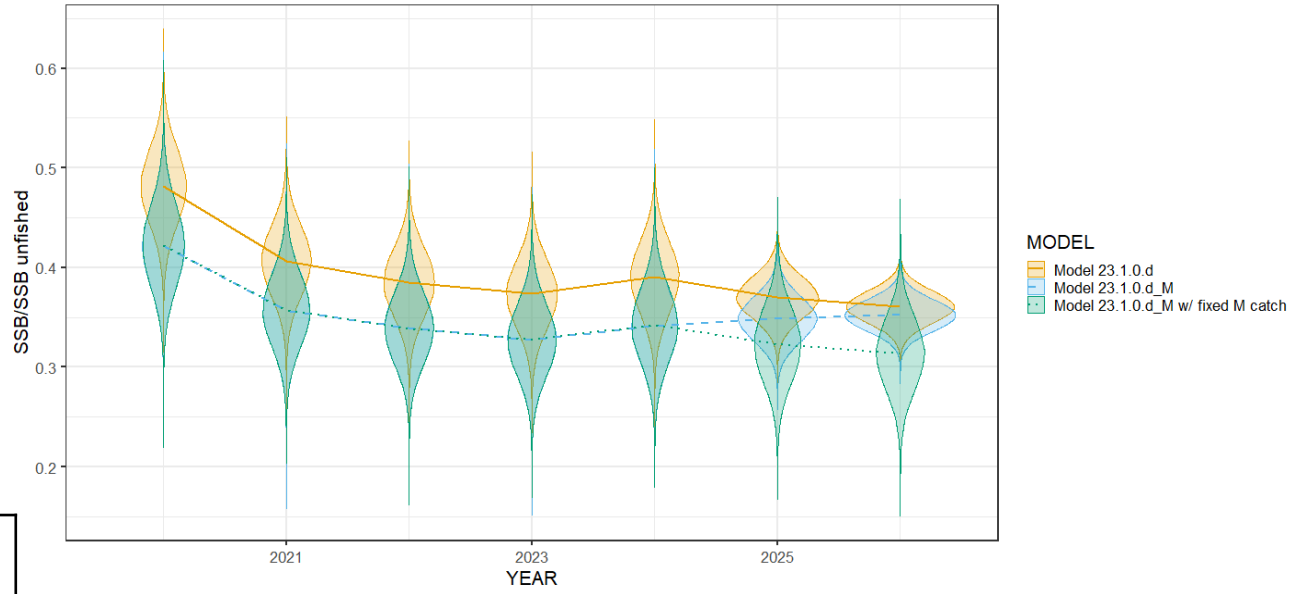


Assessment-related	Population dynamics	Environmental/ ecosystem	Fishery Performance
Level 1: No Concern	Level 1: No Concern	Level 1: No Concern	Level 1: No Concern

Quantity	As estimated or *specified last* year for: 2023	2024	As estimated or *recommended this* year for: 2024*	2025*
M (natural mortality rate)	0.34	0.34	0.386	0.386
Tier	3b	3b	3b	3b
Projected total (age 0+) biomass (t)	844,578	831,566	808,203	787,837
Projected female spawning biomass (t)	245,594	242,911	223,107	211,131
$B_{100\%}$	668,477		567,465	
$B_{40\%}$	267,391		226,986	
$B_{35\%}$	233,467		198,612	
F_{OFL}	0.36	0.35	0.46	0.43
$maxF_{ABC}$	0.29	0.29	0.37	0.35
F_{ABC}	0.29	0.29	0.37	0.35
OFL (t)	172,495	166,814	200,995	180,798
maxABC (t)	144,834	140,159	167,952	150,876
ABC (t)	144,834	140,159	167,952	150,876
Status	As determined *this* year for: 2021	2022	2022	2023
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Model 23.1.0.d Assumptions on M

- What if our assumptions on M are wrong?
  - Projection of SSB with catch set at ABC from Model 23.1.0.d but with lower M shows increase in uncertainty and lower status in projections to 2026



	Model 23.1.0.d fixed natural mortality w/ catch at fixed maxABC	Model 23.1.0.d Fit natural mortality w/ catch at fit maxABC	Model 23.1.0.d Fit natural mortality w/ catch at fixed maxABC
$B_{2025}/B_{100\%}$	0.370	0.348	0.322
$B_{2026}/B_{100\%}$	0.360	0.352	0.313
$Pr(B_{2025} > B_{35\%})$	82.45%	46.86%	22.96%
$Pr(B_{2026} > B_{35\%})$	74.34%	55.21%	15.60%
$Pr(B_{2025} < B_{20\%})$	<0.001%	<0.001%	0.055%
$Pr(B_{2026} < B_{20\%})$	<0.001%	<0.001%	0.111%

Thank You!

Questions?

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Phone: (206) 526-4211