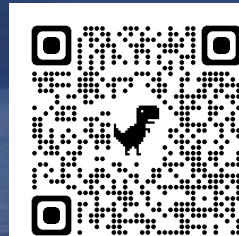


# Assessment of the Pacific Cod Stock in the Eastern Bering Sea

Steven J. Barbeaux, Lewis Barnett, Madison Hall, Pete Hulson, Julie Nielsen, S. Kalei Shotwell, Elizabeth Siddon, Ingrid Spies, and James Thorson



December 4, 2023 Presentation to the NPFMC SSC

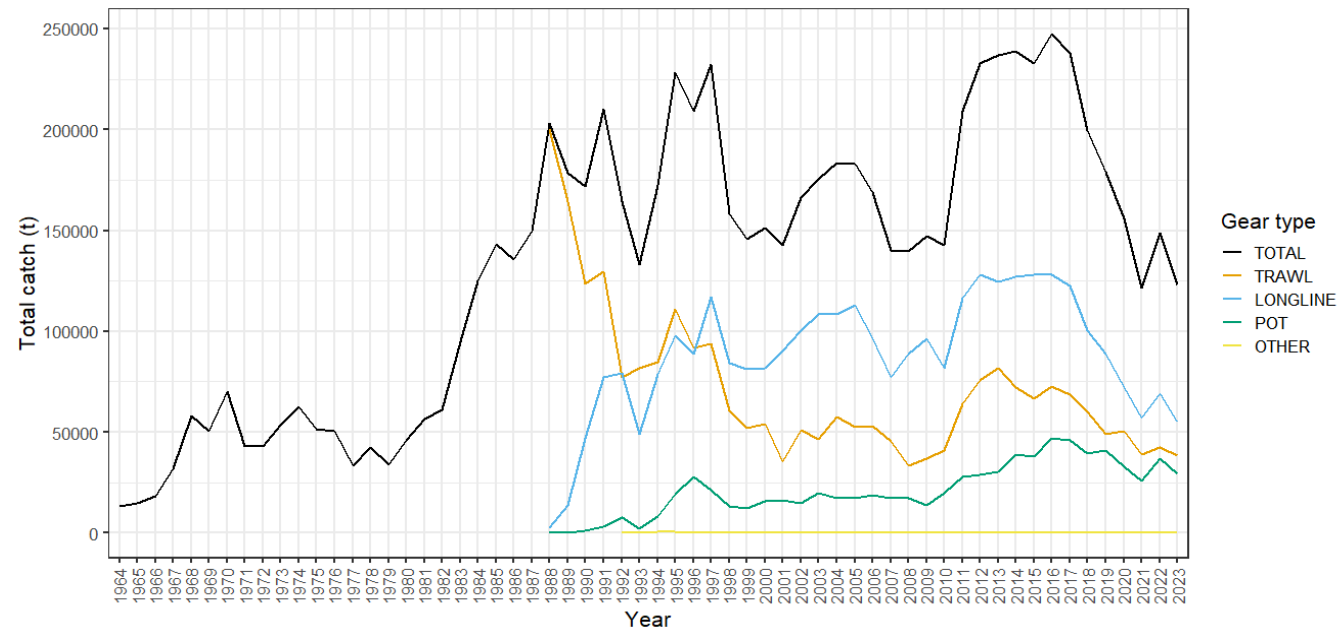
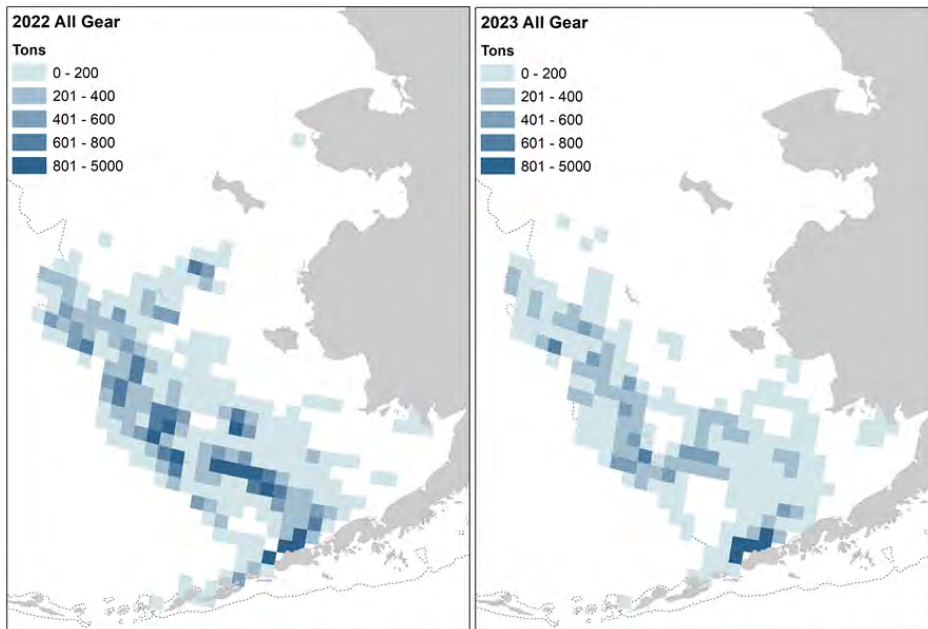


[https://afsc-assessments.github.io/EBS\\_PCOD/2023\\_ASSESSMENT/NOVEMBER\\_MODELS/](https://afsc-assessments.github.io/EBS_PCOD/2023_ASSESSMENT/NOVEMBER_MODELS/)

# Fishery data



- 2023 ABC is 144,834 t and catch as of Oct. 3 = 123,208 t
  - Longline is the highest proportion
  - Continued southward shift in fishery
  - Little observed fishing north of St. Mathews Island in 2023

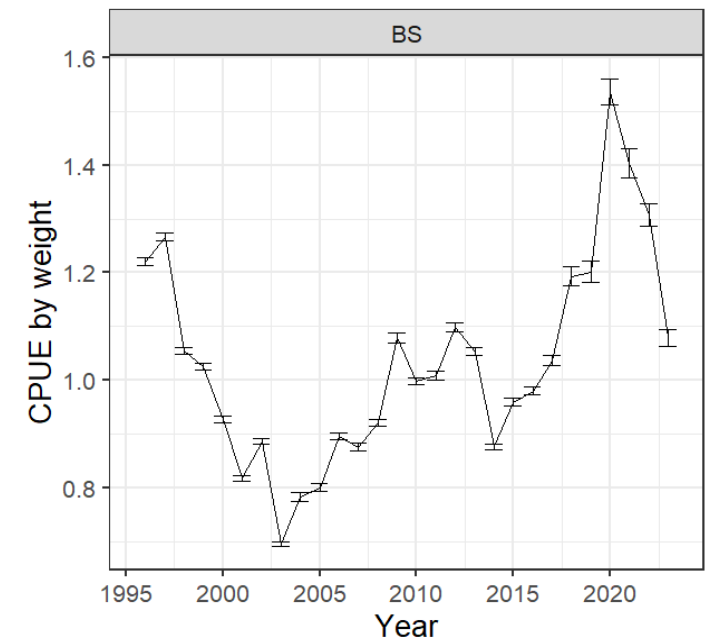
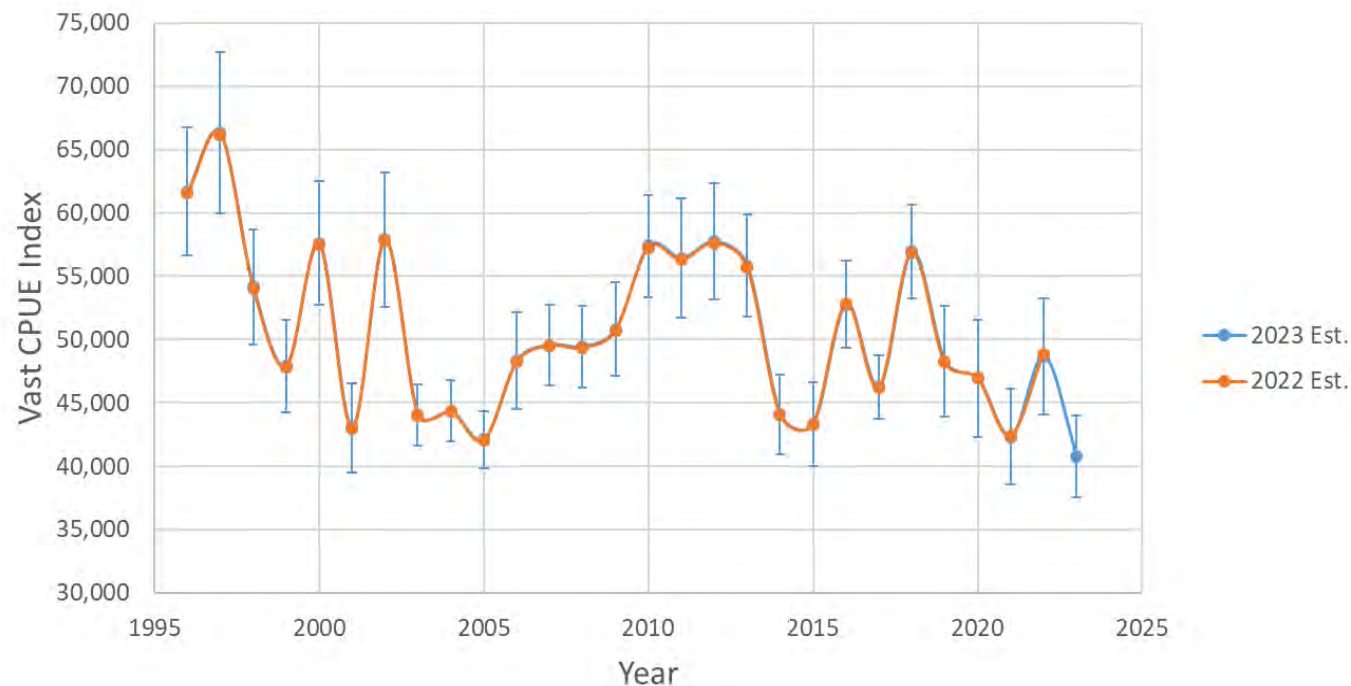


# CPUE indices



- 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

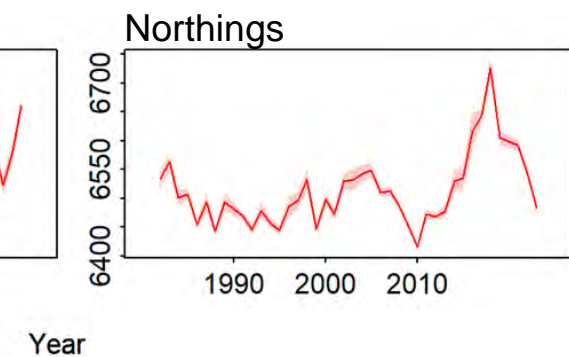
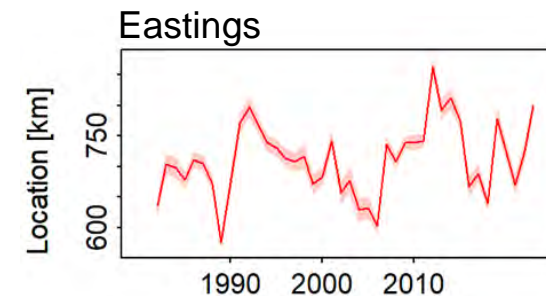
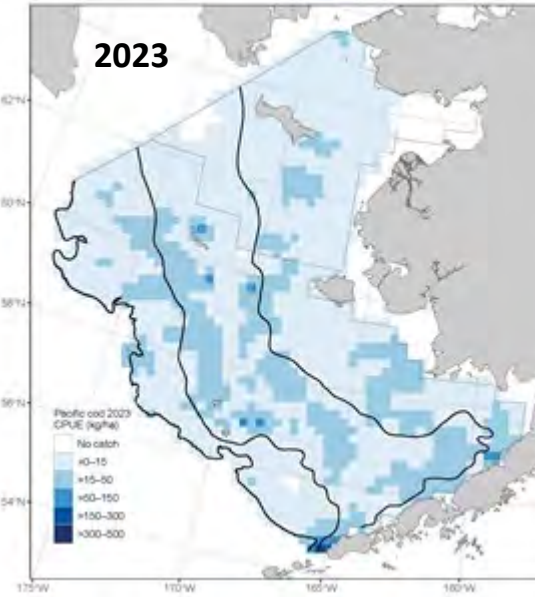
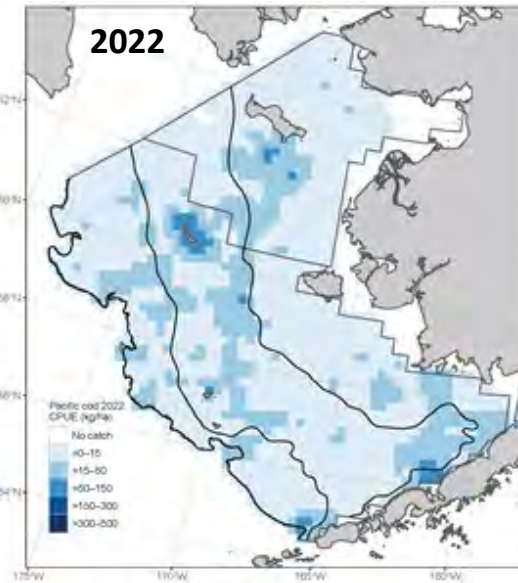
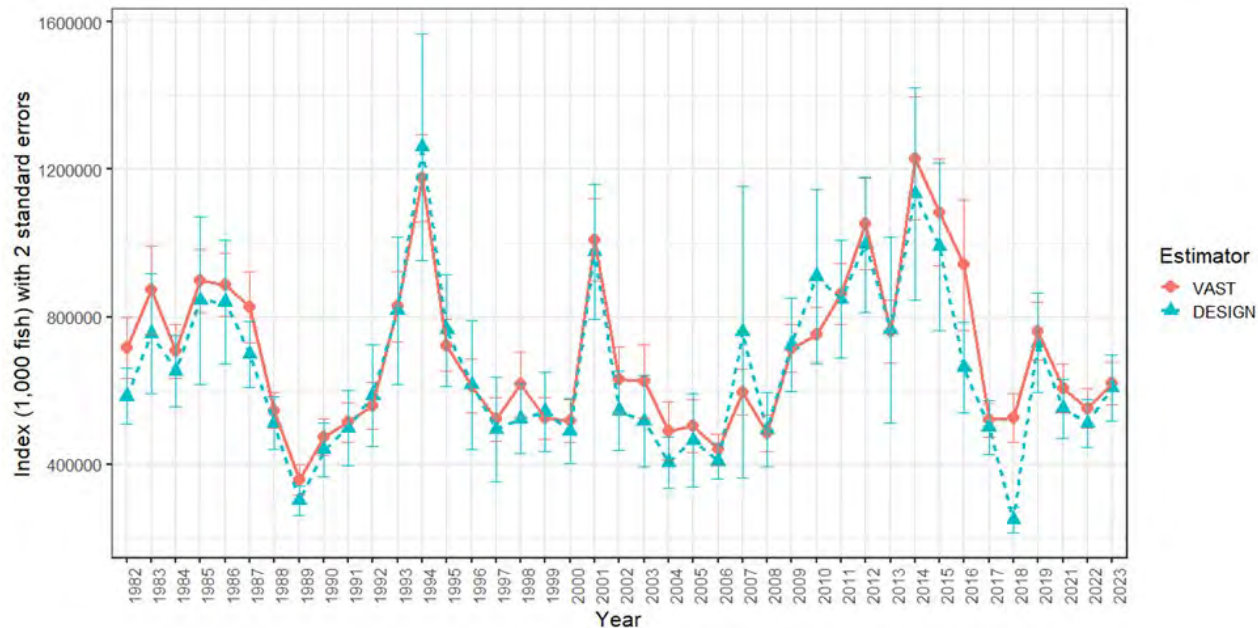




# Bottom trawl survey



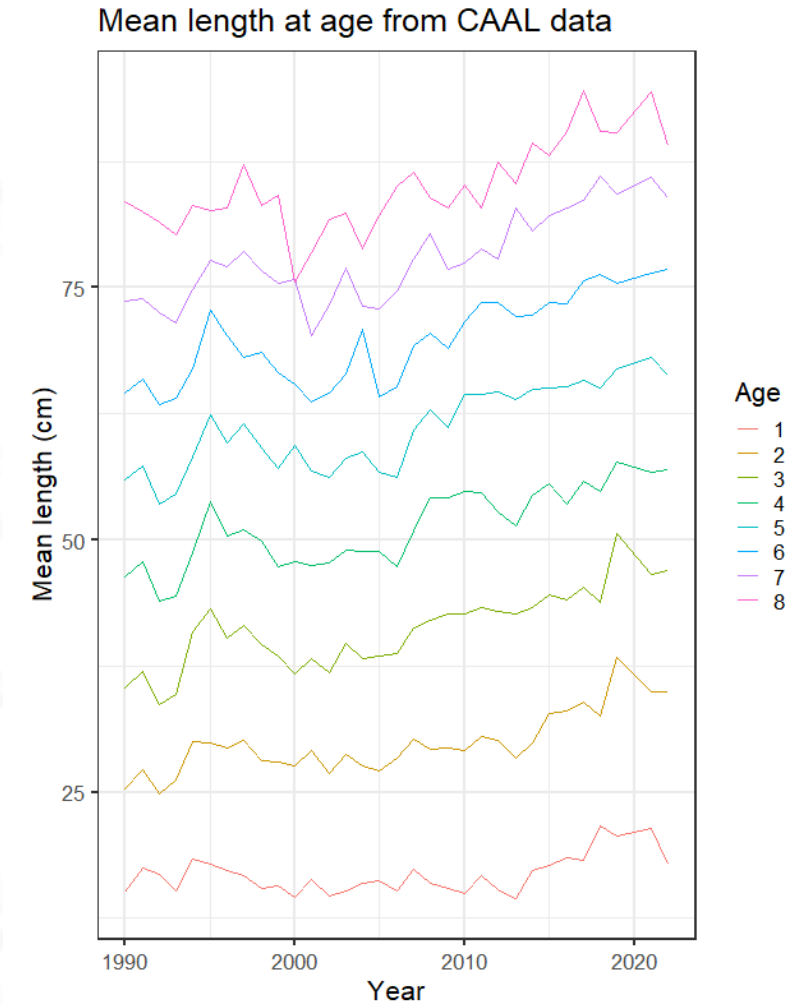
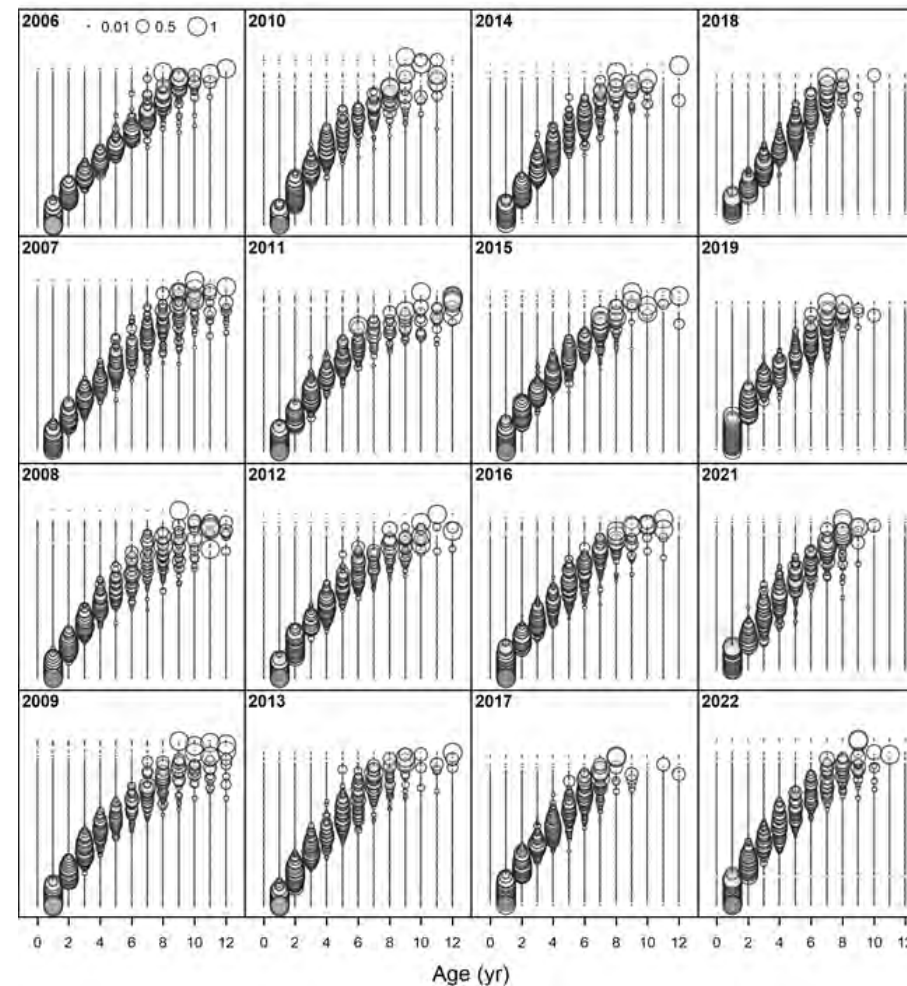
- Increase in abundance (+12%)
- Small decline in biomass (-4%)
- Southeastern shift in distribution



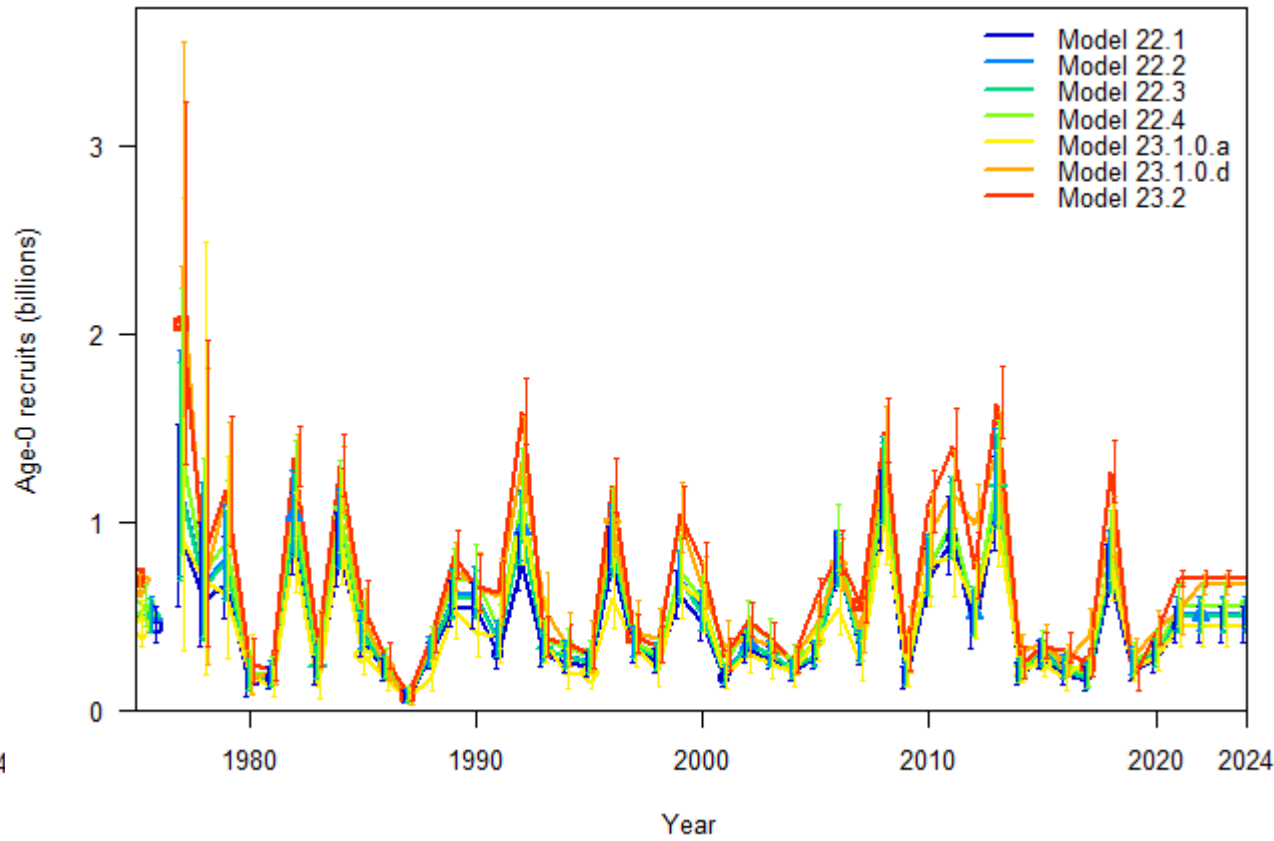
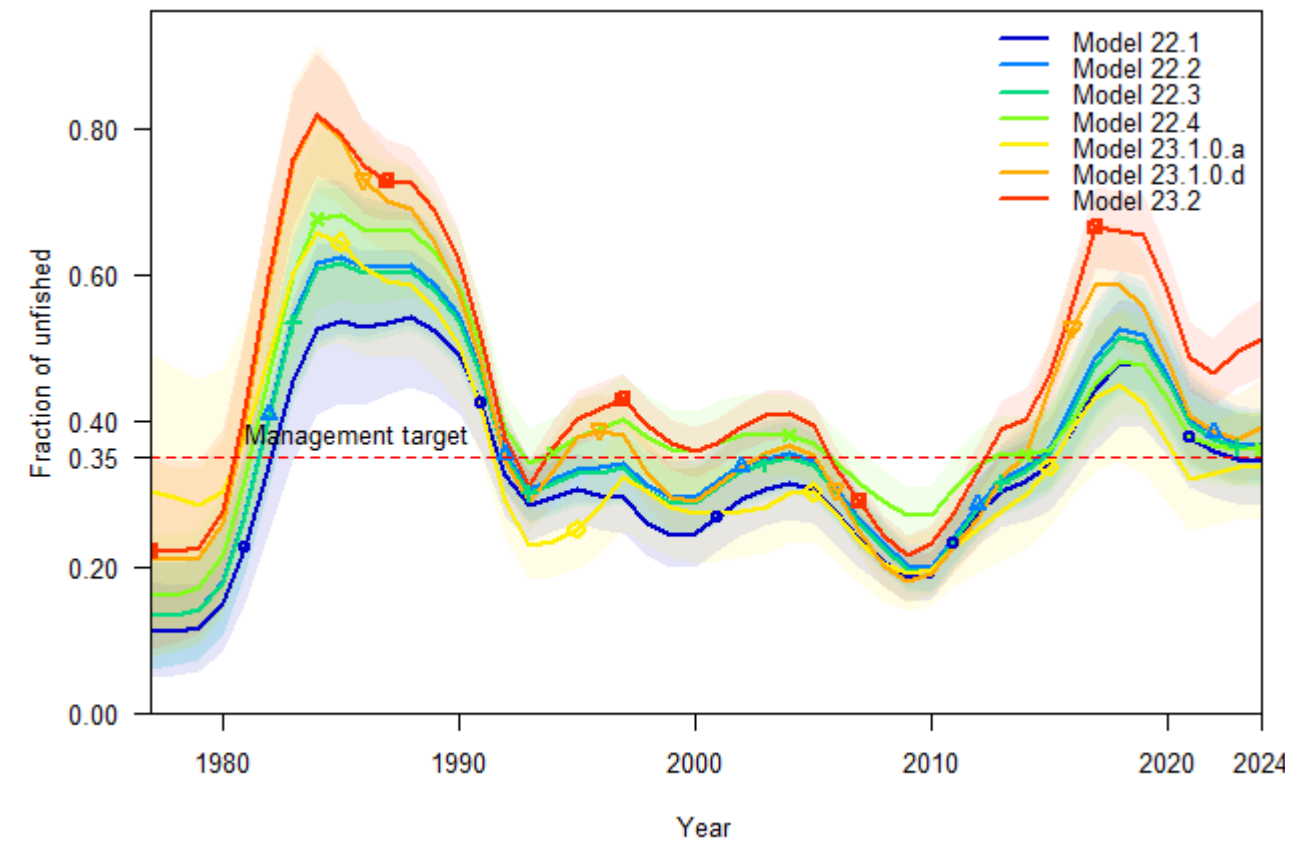
# Bottom trawl survey CAAL



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



- 2022 Ensemble
  - Same models and weighting as 2022 New Ensemble
    - Updated data
- 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



# 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



# Model Evaluation: Ensemble vs. 2023



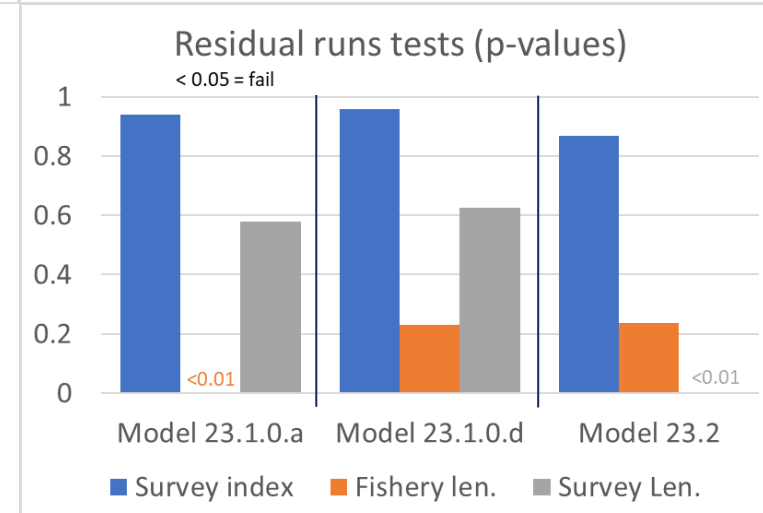
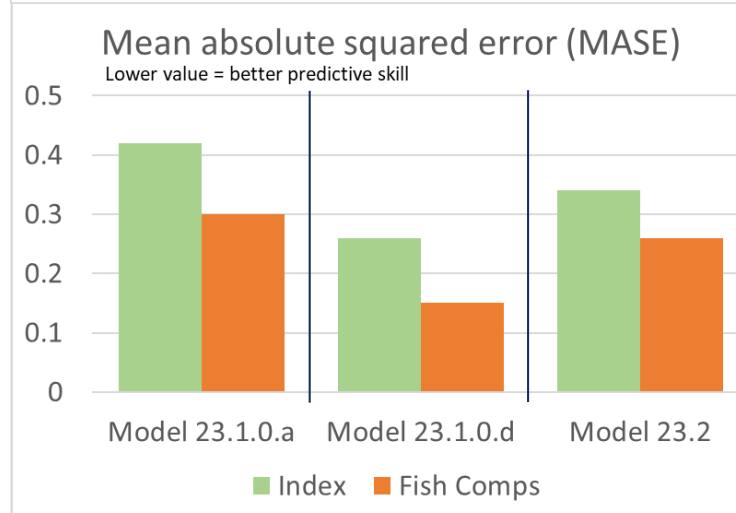
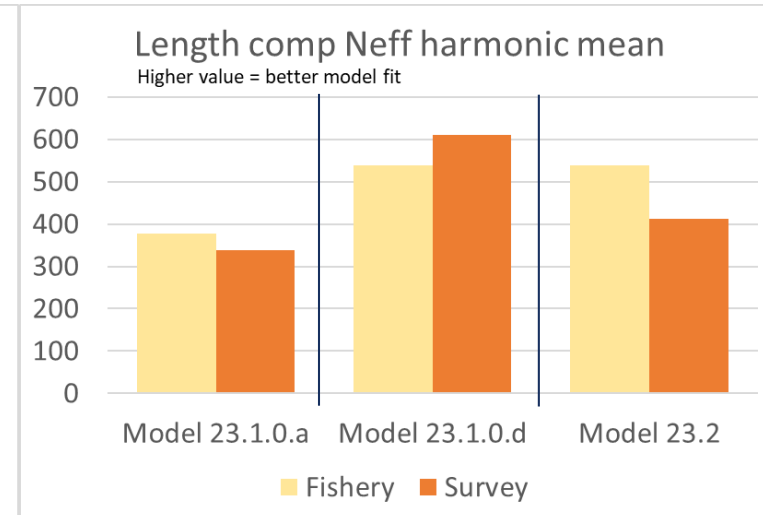
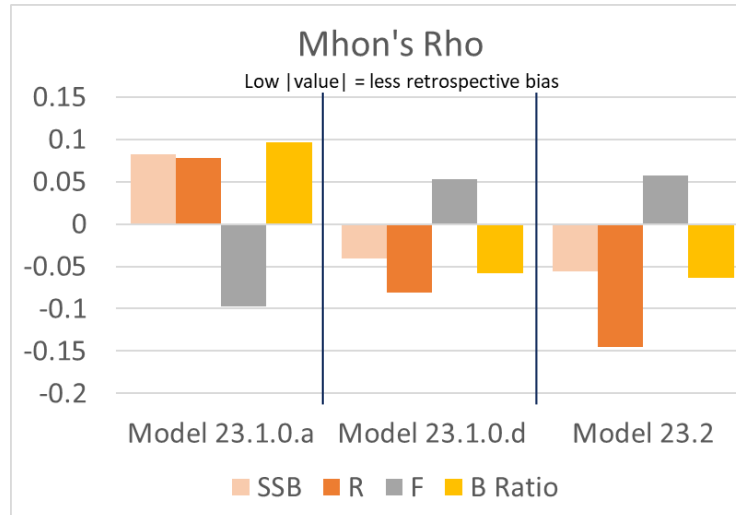
- For the Ensemble the Dirichlet multinomial  $\log(\Theta)$  continued to tend to the upper bound for length comp data and needed to be fixed there for the models to converge.
- 2022 Ensemble models consistently failed jitter tests (50 jitters at 0.1)
  - For all Ensemble models no jitter run converged 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 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%.

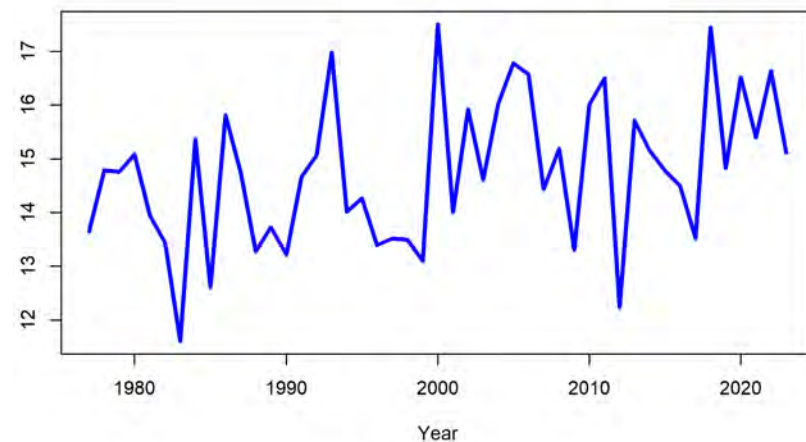


# Model 23.1.0.d Results - Growth

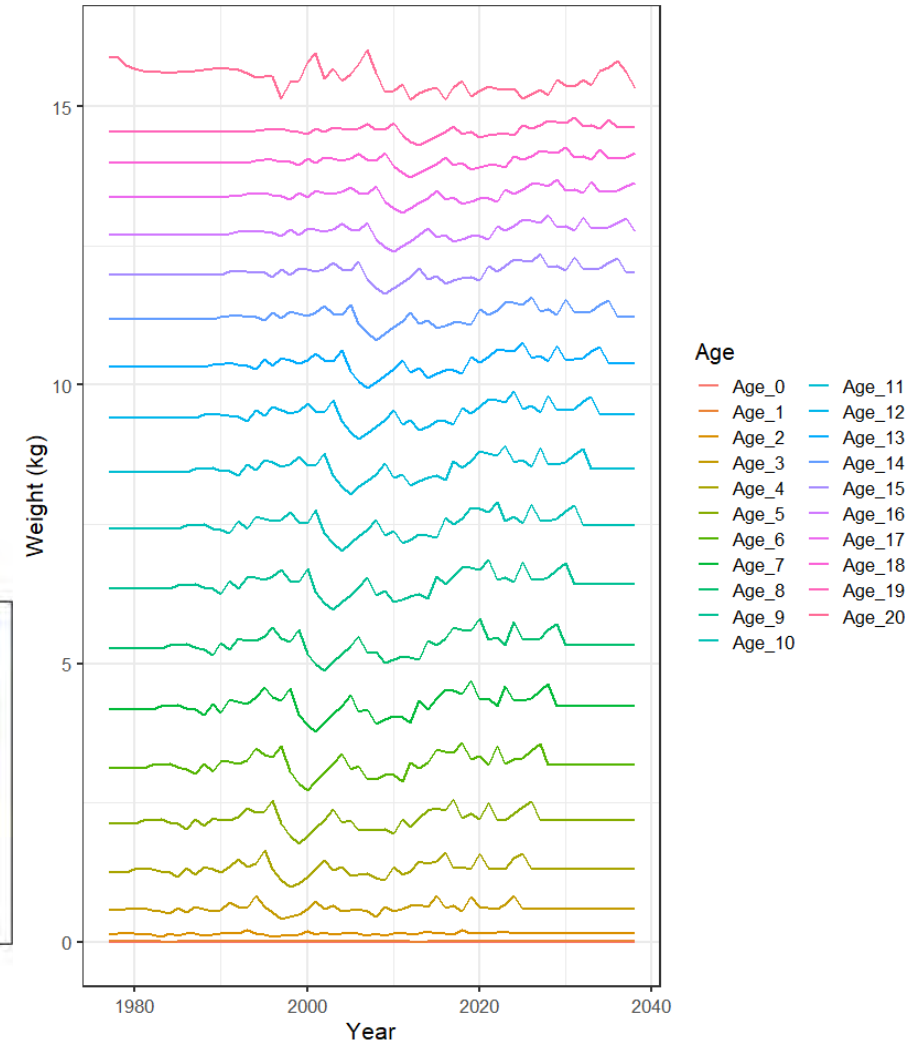
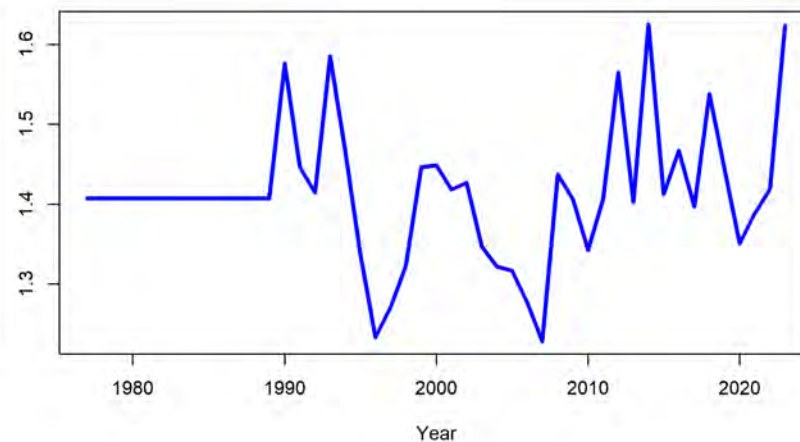


- Richards with time varying parameters
  - $L_{1.5}$  - Models initial size and acts as a cohort effect
    - Variable with an overall increasing trend over time
  - Richard's  $\rho$  - Shapes growth curve and acts as annual effect
    - Variable with increasing trend since 2010

$L_{1.5}$



Richard's  $\rho$

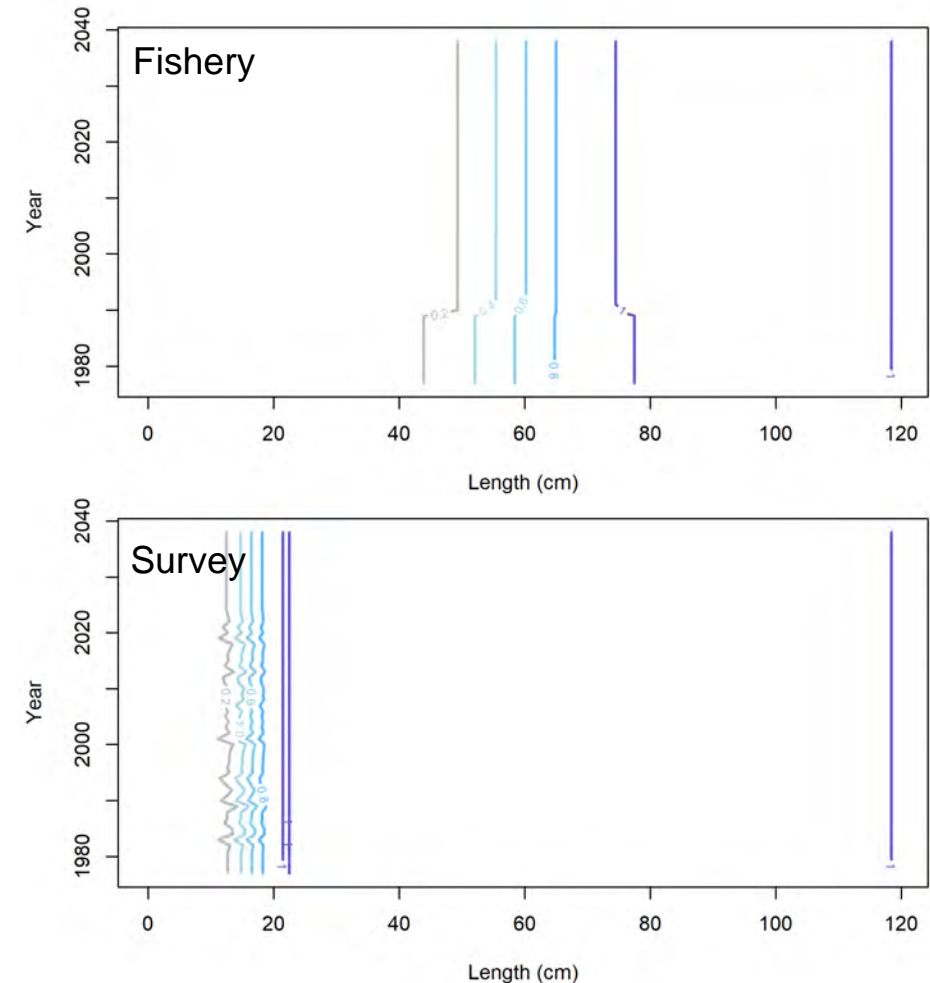




# Model 23.1.0.d Results - Selectivity



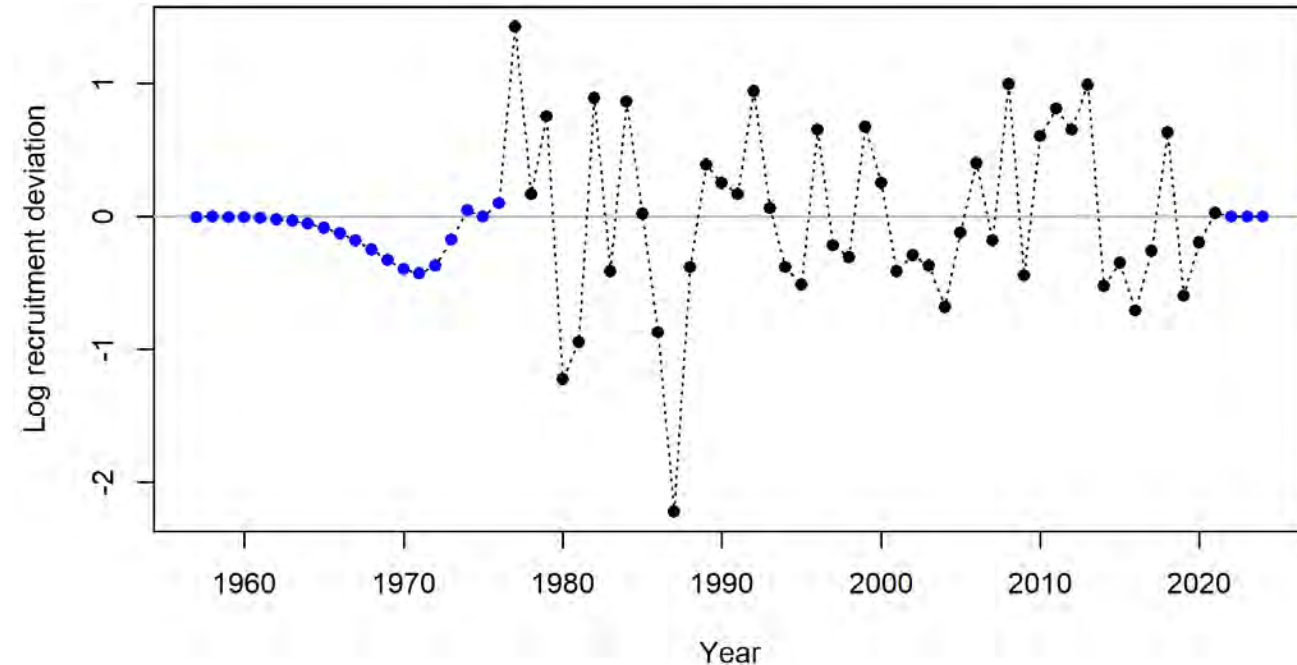
- Fishery - Time blocks 1977-1989 and 1990-2023
  - Asymptotic double normal with peak and ascending width fit for the two time blocks
- Survey – Time varying 1977-2023
  - Asymptotic double normal with peak and ascending width fit
  - Peak parameter fit with random deviations with  $\sigma$  tuned iteratively 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



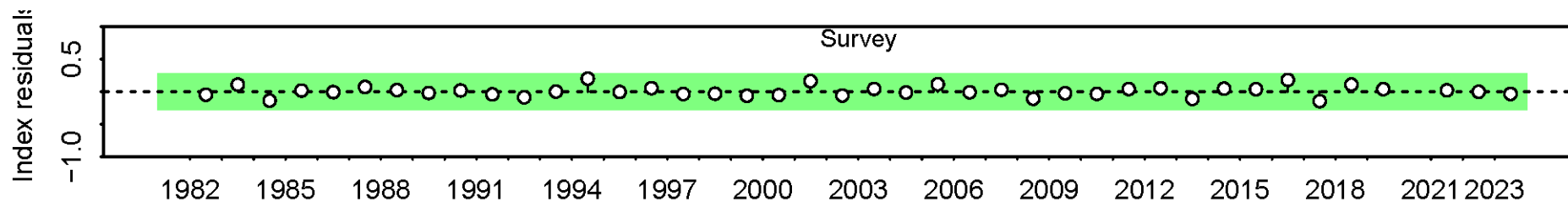
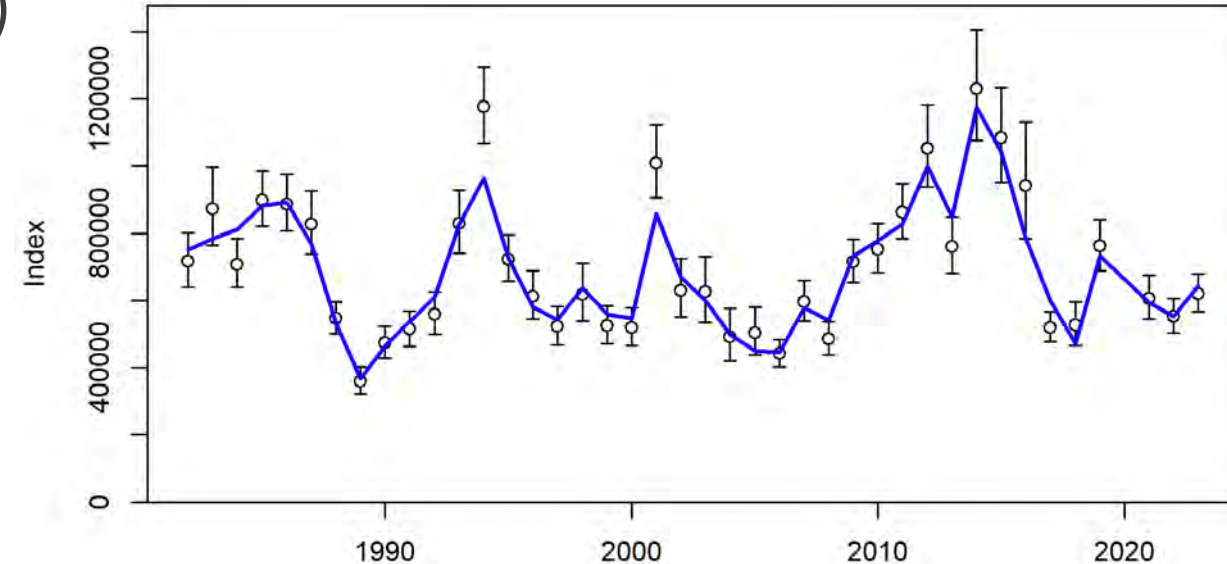
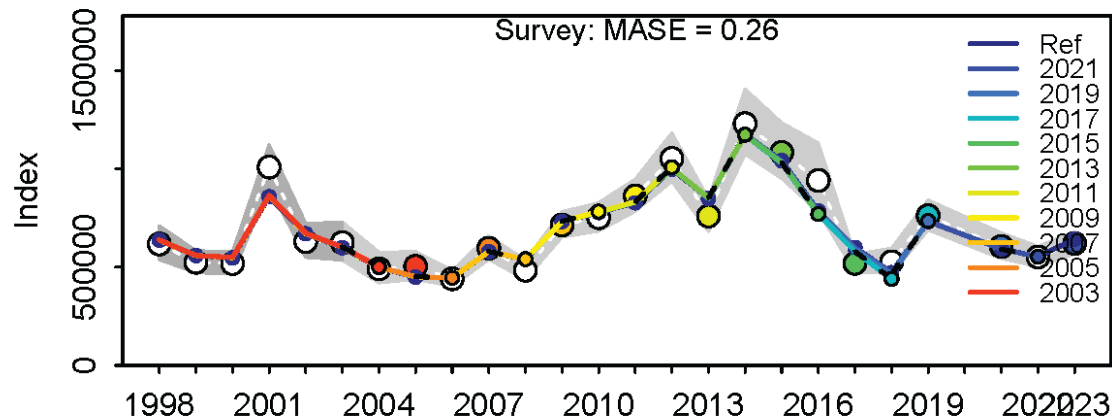
- $\sigma_R = 0.74$ 
  - Iteratively tuned to match the square root of the variance of the estimates plus the sum of the estimates' variances (Methot and Taylor 2011)
- Highly variable 1977-1989
- Recent recruitment
  - Good 2010-2013
  - Poor 2014-2017 and 2019-2020
  - 2018 above average
  - 2021 near 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)

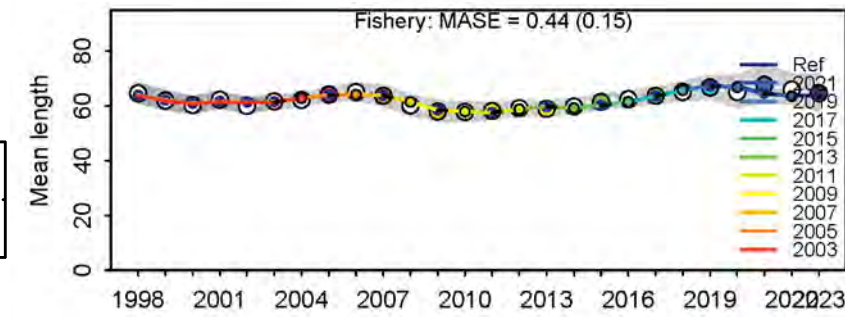
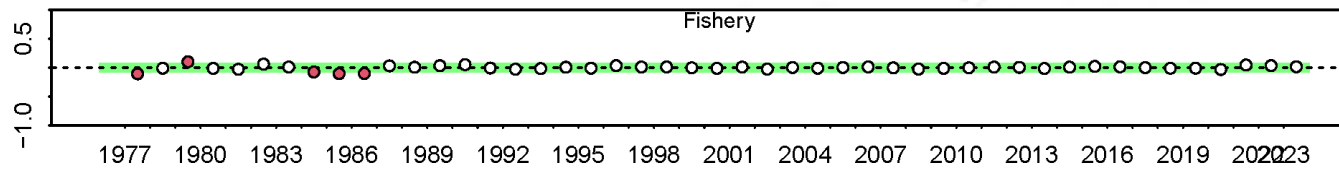
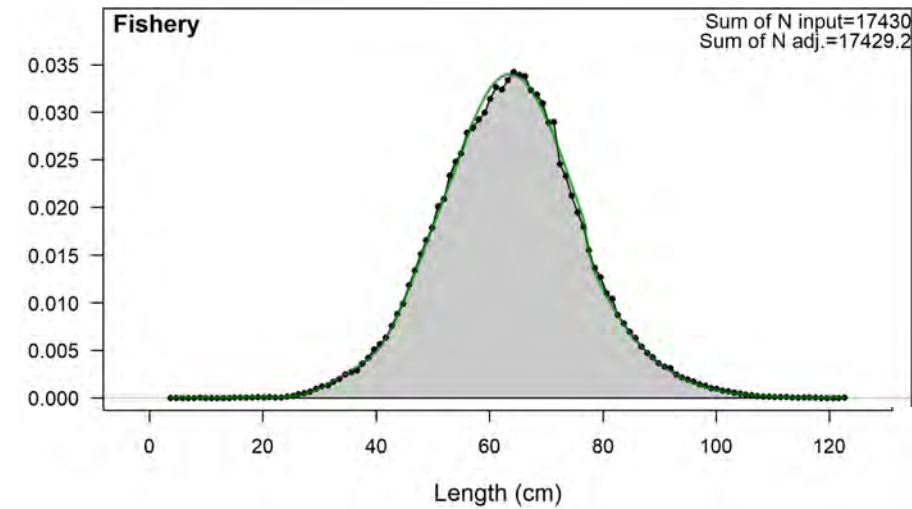
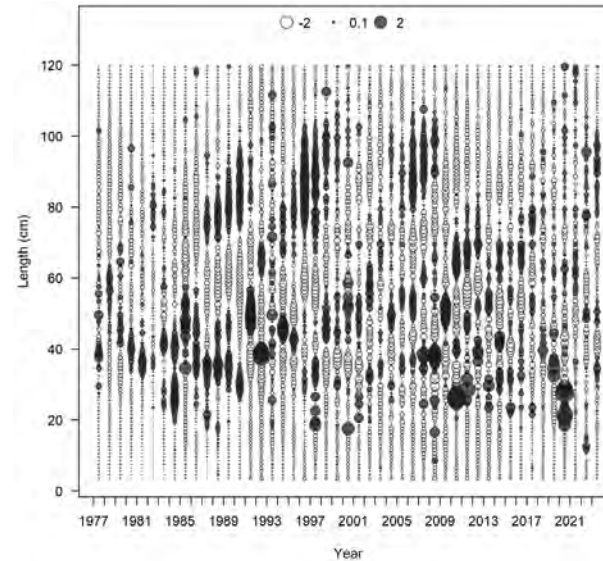
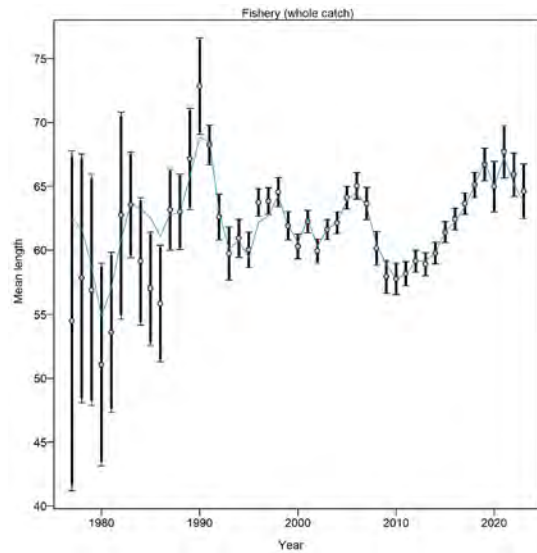
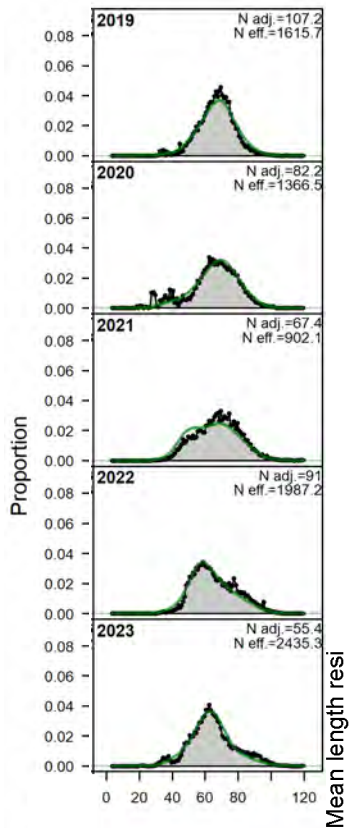




# Model 23.1.0.d Results – Fishery lengths



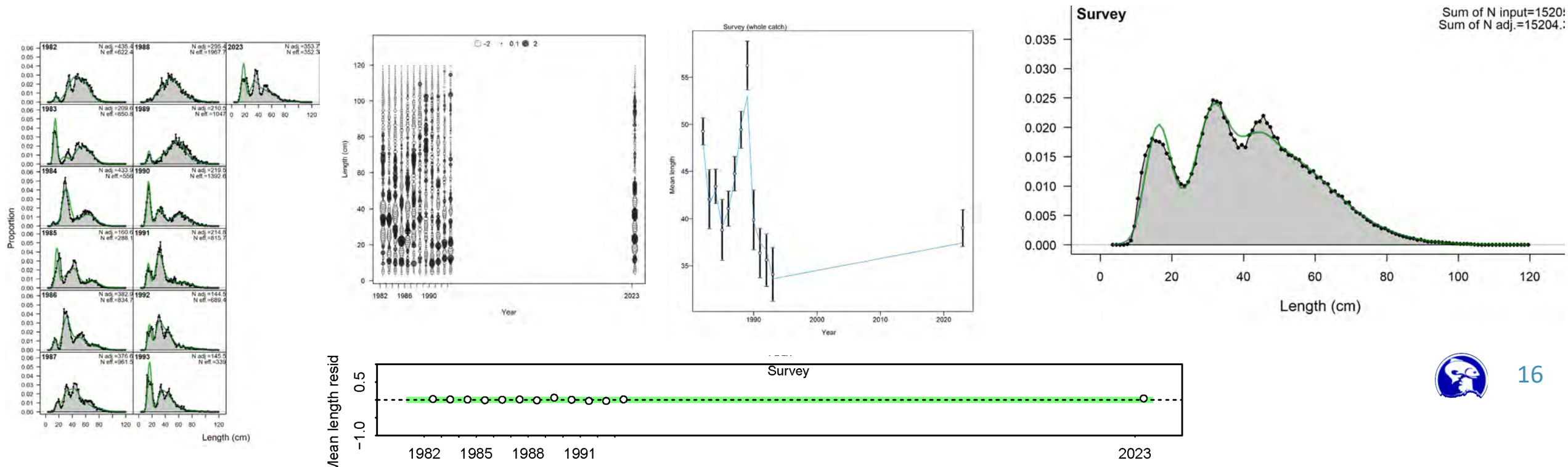
- Good fit to the fishery length composition
  - Insignificant autocorrelation in residuals (p-value = 0.231)
- Good MASE predictive skill (0.15)



# 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

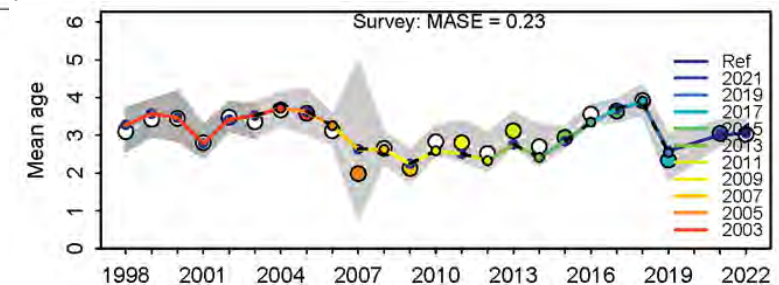
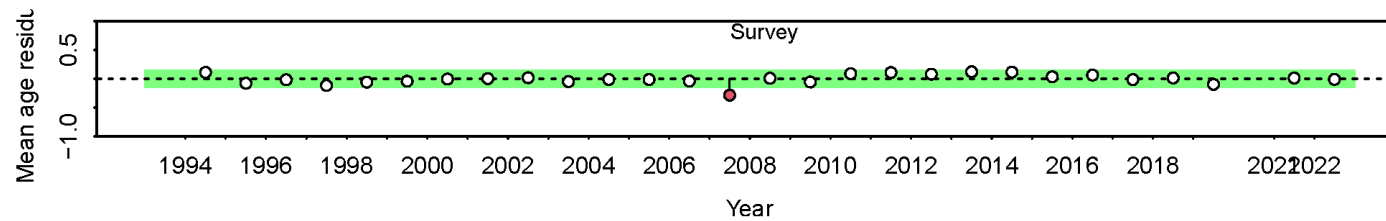
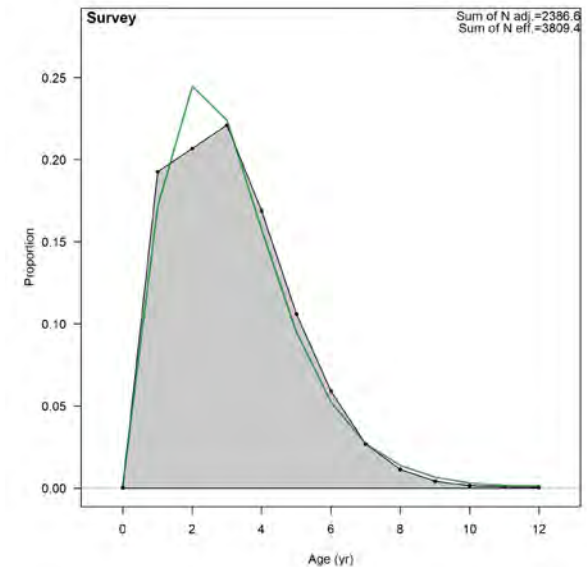
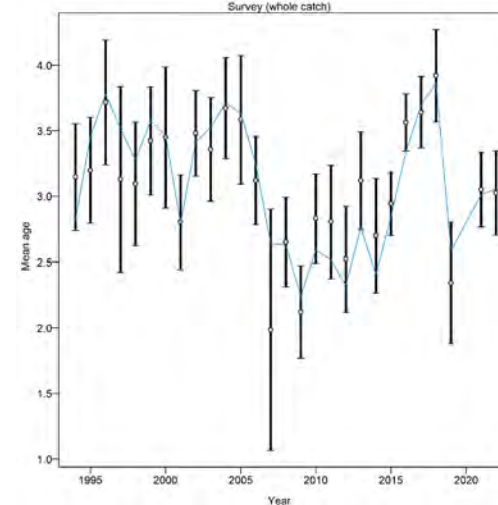
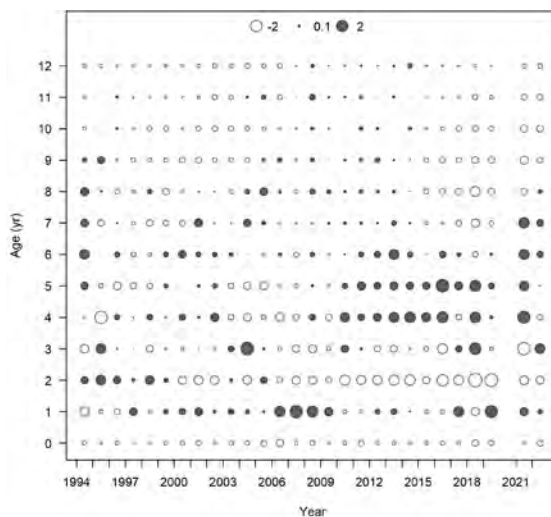
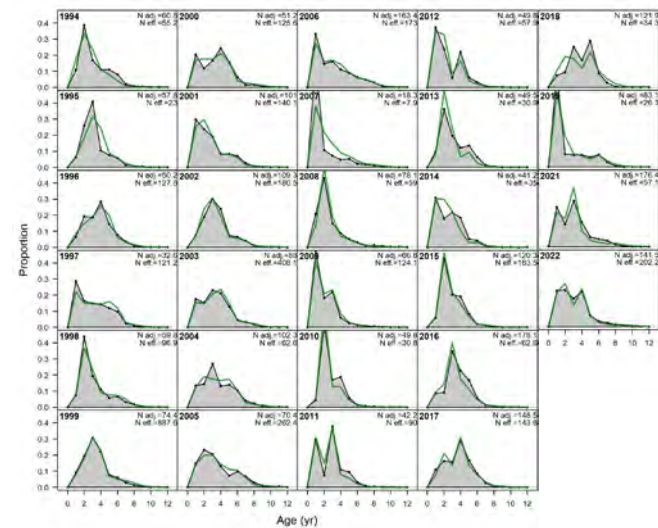




# Model 23.1.0.d Results – Survey Ages



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

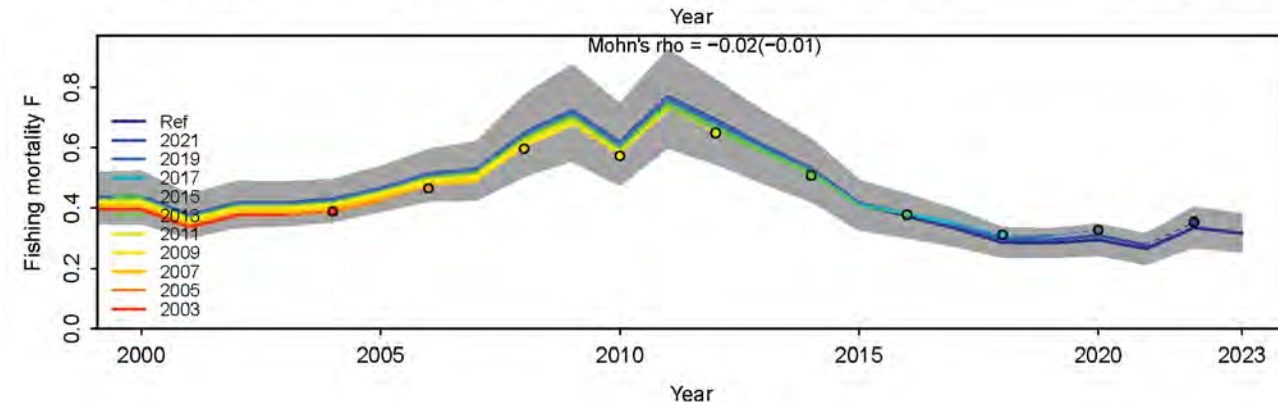
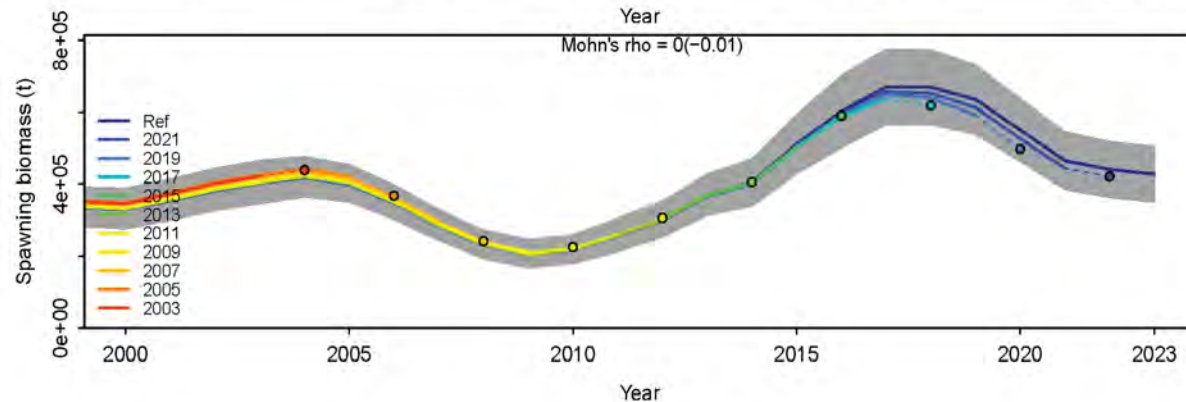
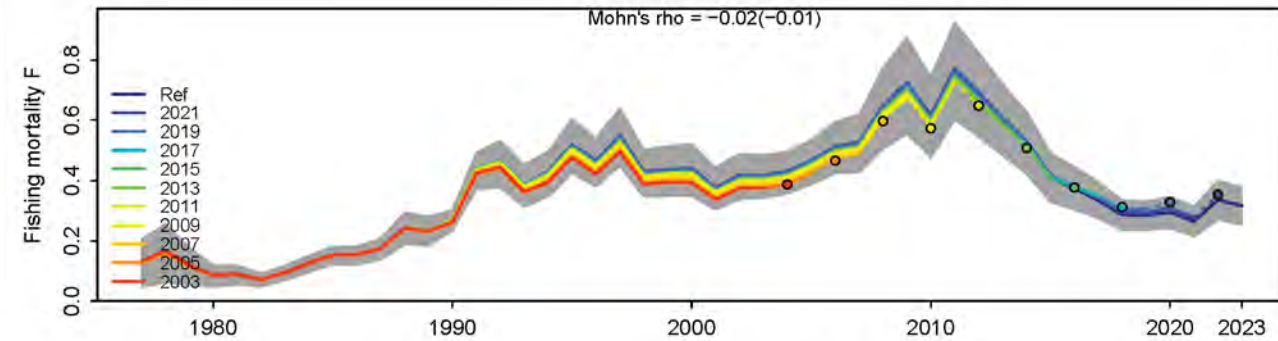
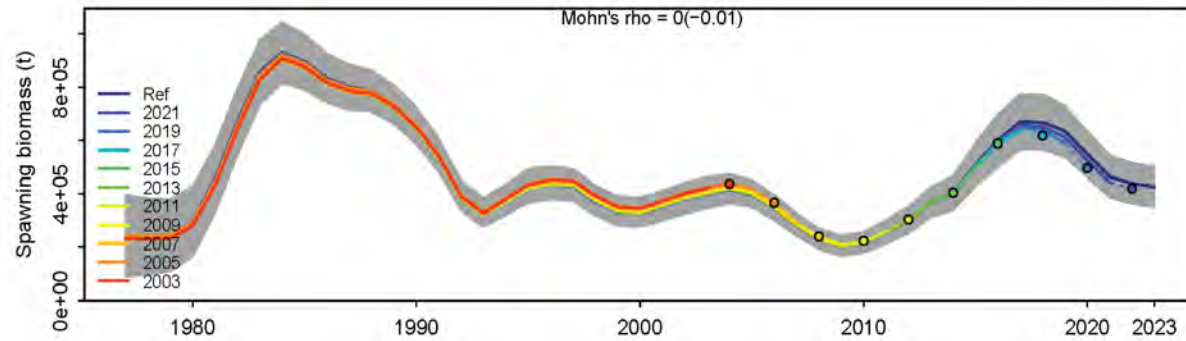




# Model 23.1.0.d Results – Retrospective



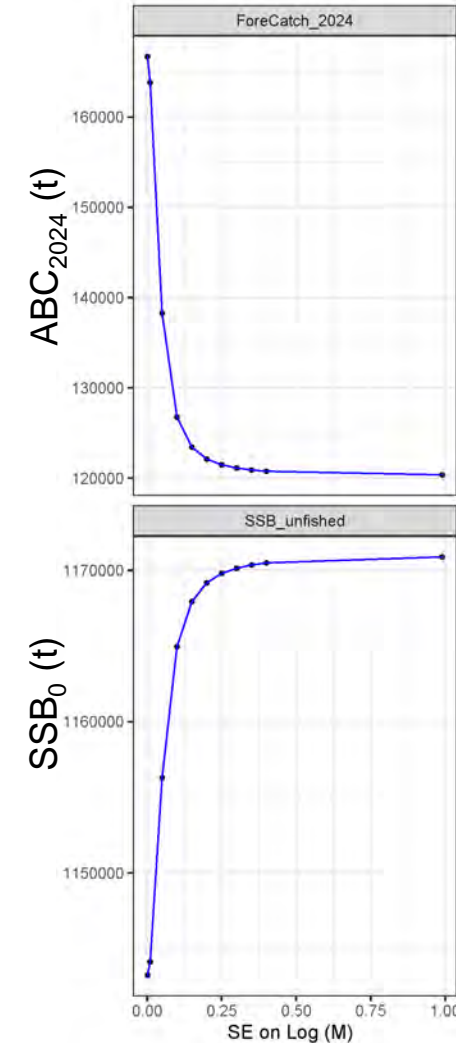
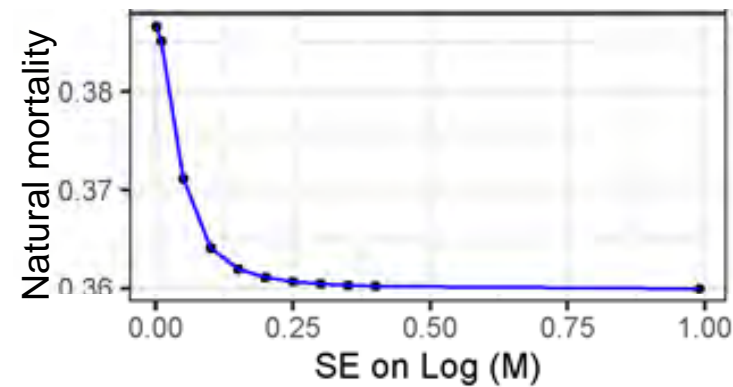
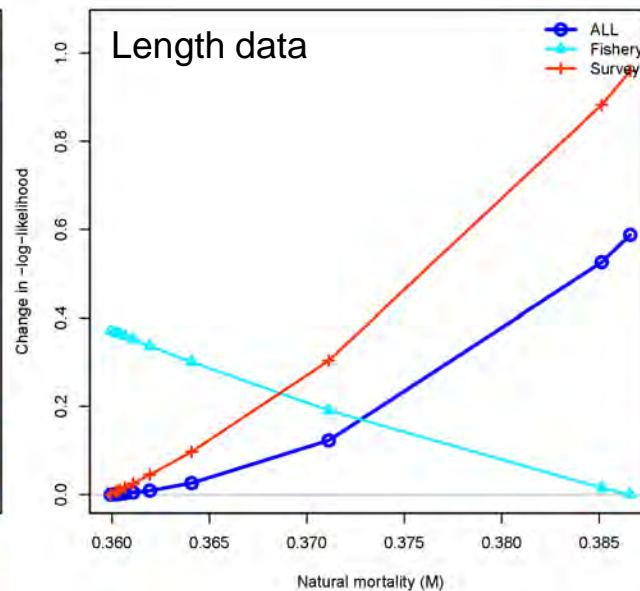
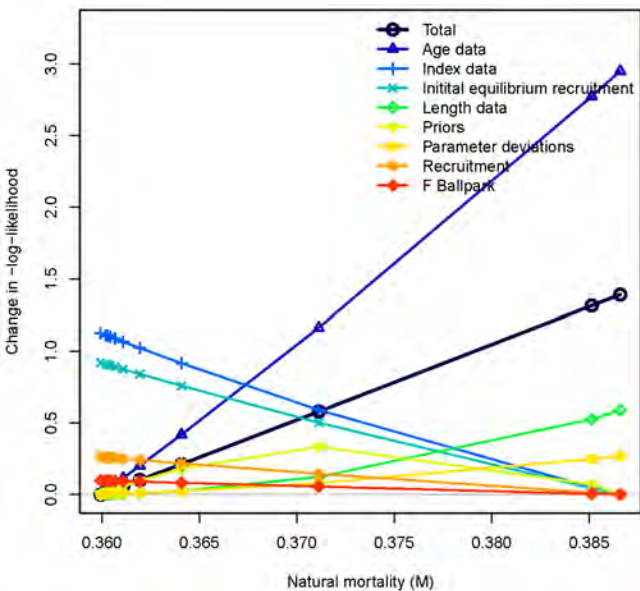
- Good retrospective behavior with low negative retrospective bias for SSB
  - SSB Mohn's  $\rho = -0.041$



# 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

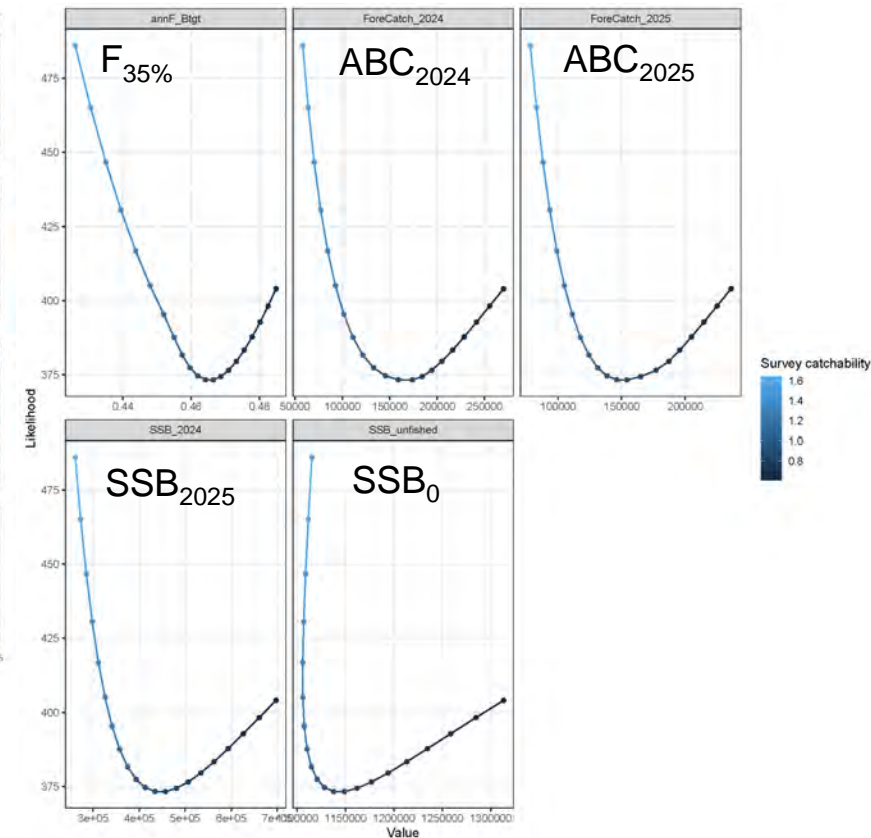
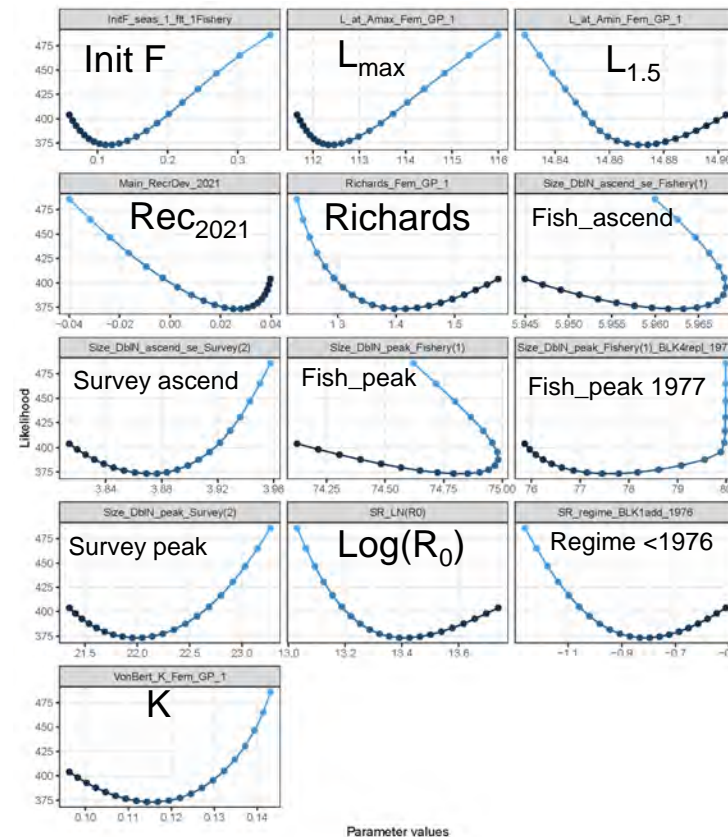
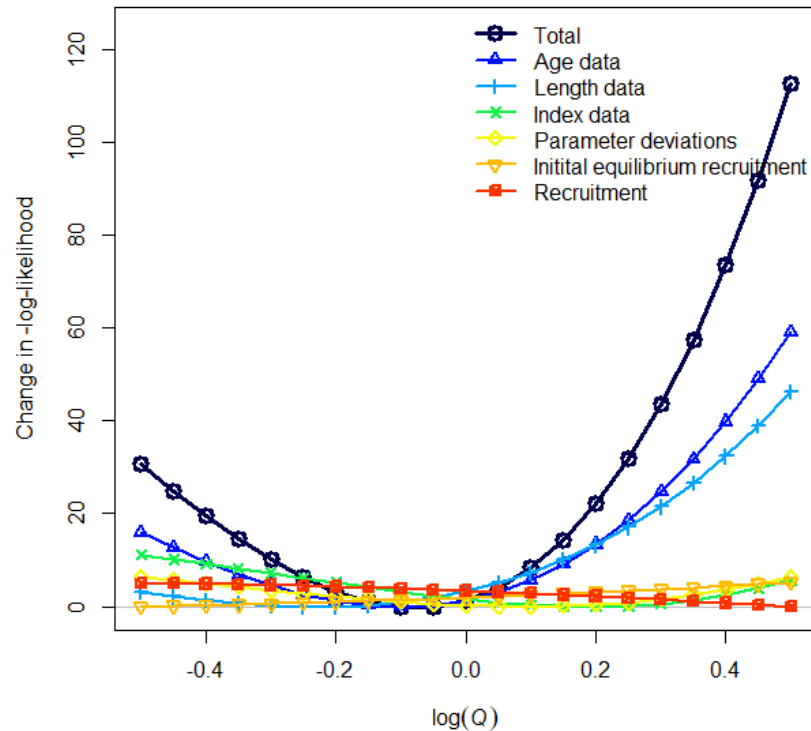




# Model 23.1.0.d Results – Q Profile



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

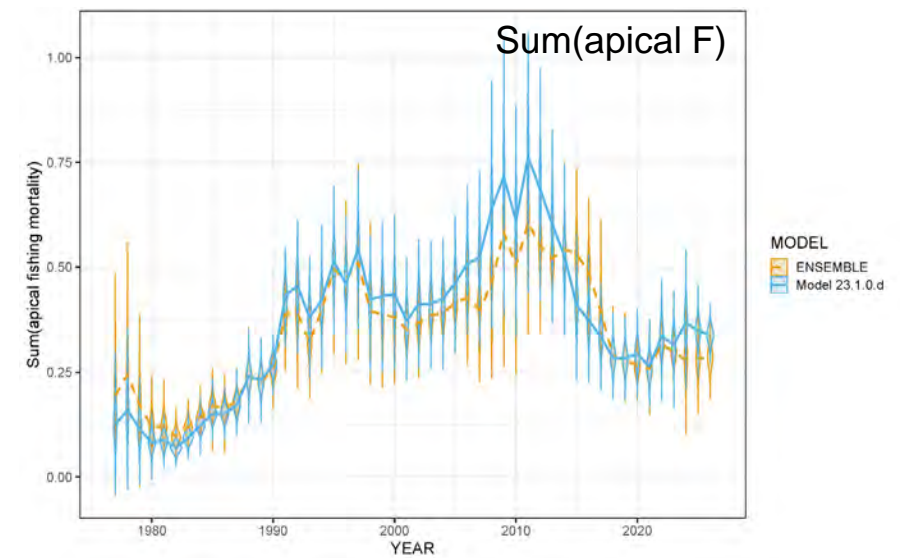
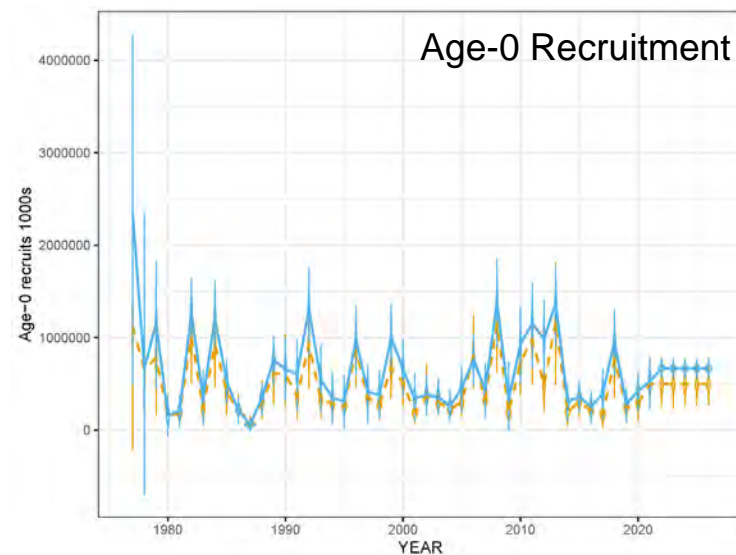
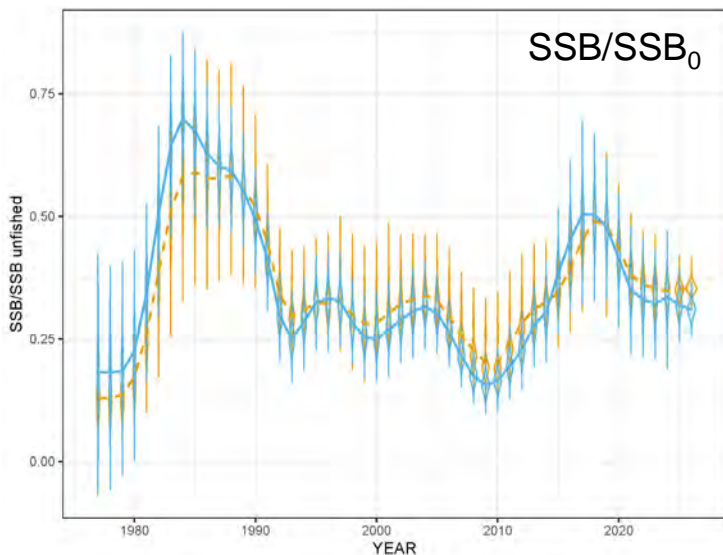




# Model 23.1.0.d Timeseries



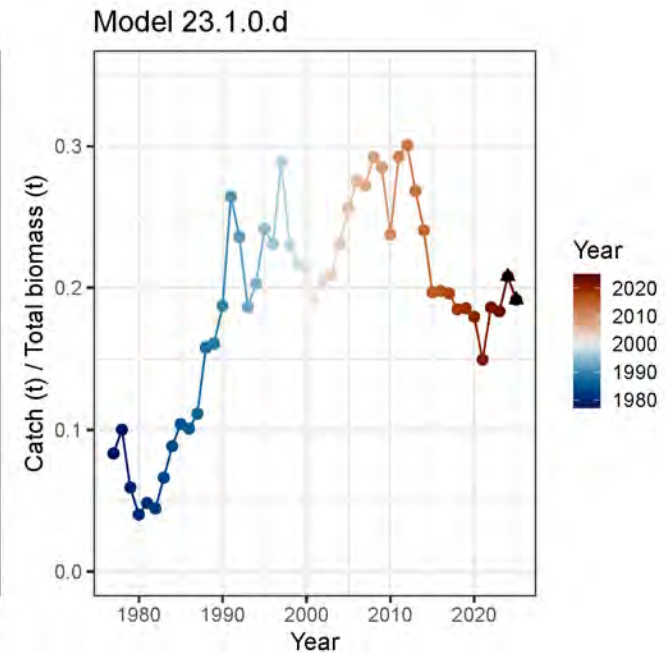
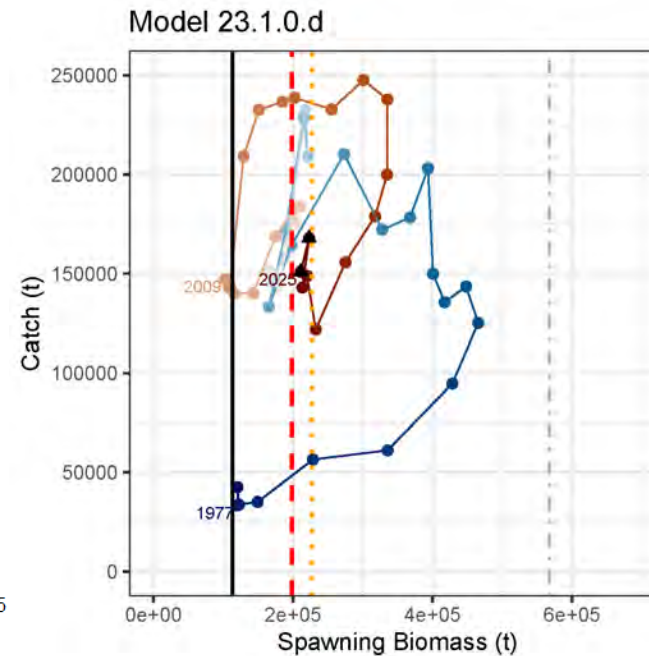
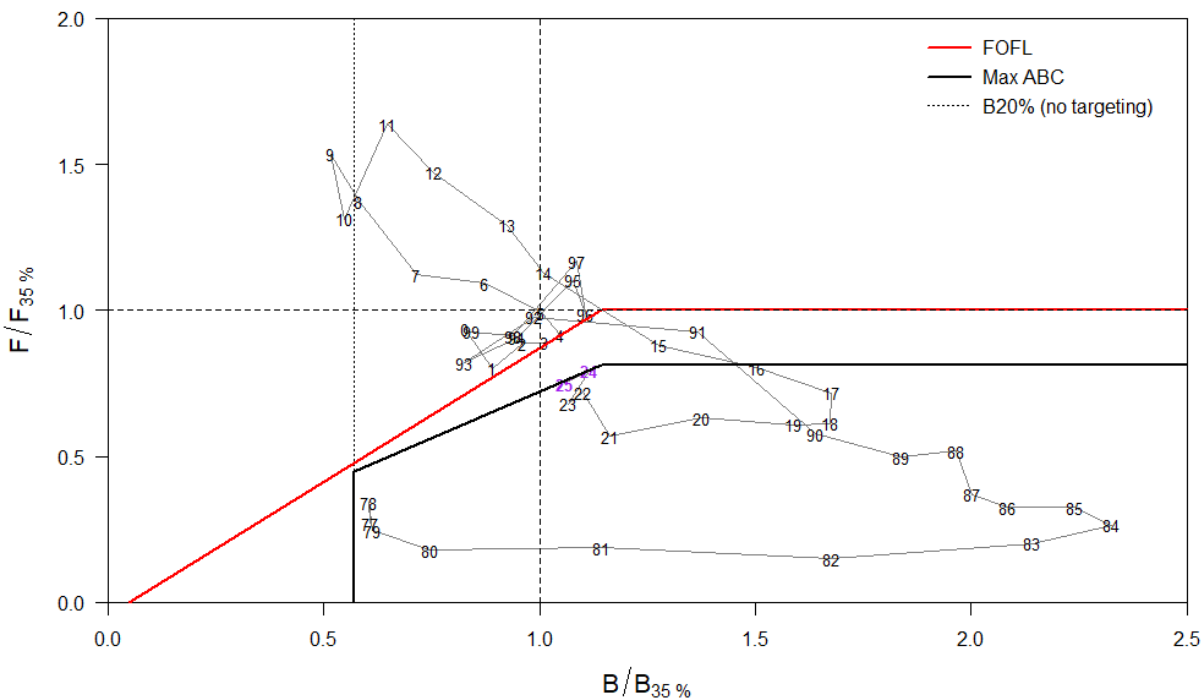
- SSB - Similar trends to 2022 ensemble
  - Higher peaks and lower troughs
- R - Same peaks and valleys to 2022 ensemble
  - Strong 2018 year class w/ low surrounding year classes
- F - Similar to 2022 ensemble but some key differences
  - Higher F 1991-2015
  - Lower F 2016-2021



# Model 23.1.0.d Timeseries – Phase plane



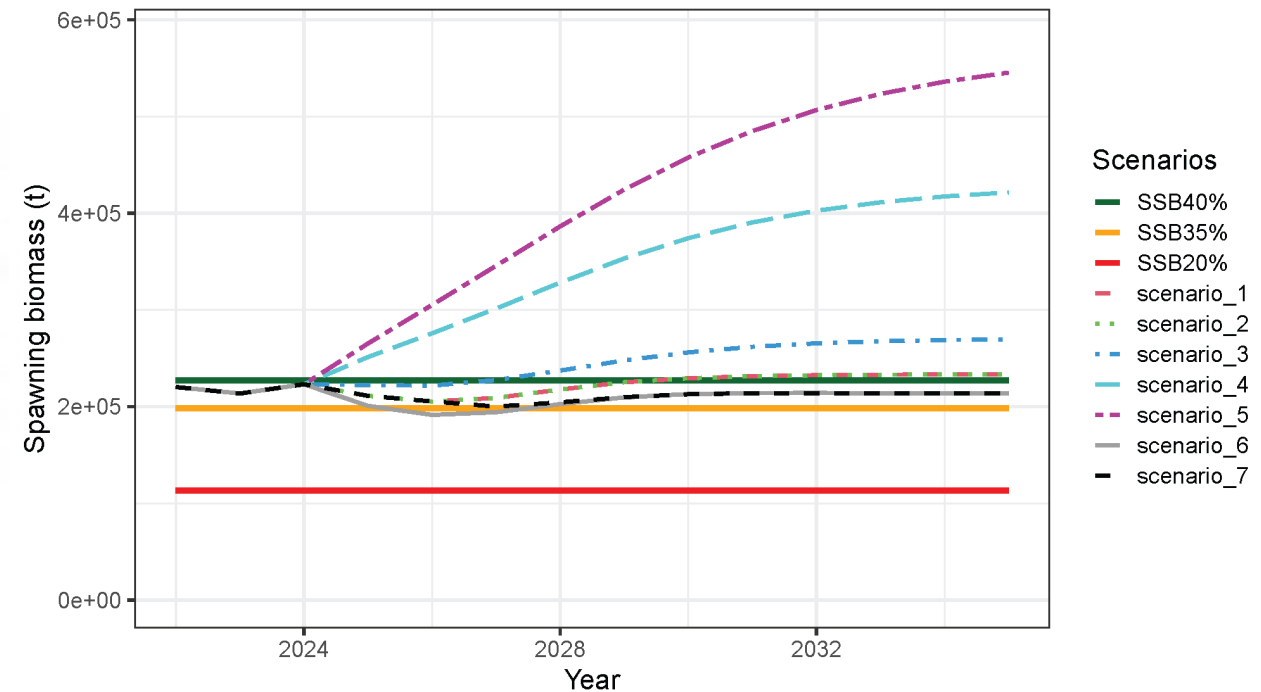
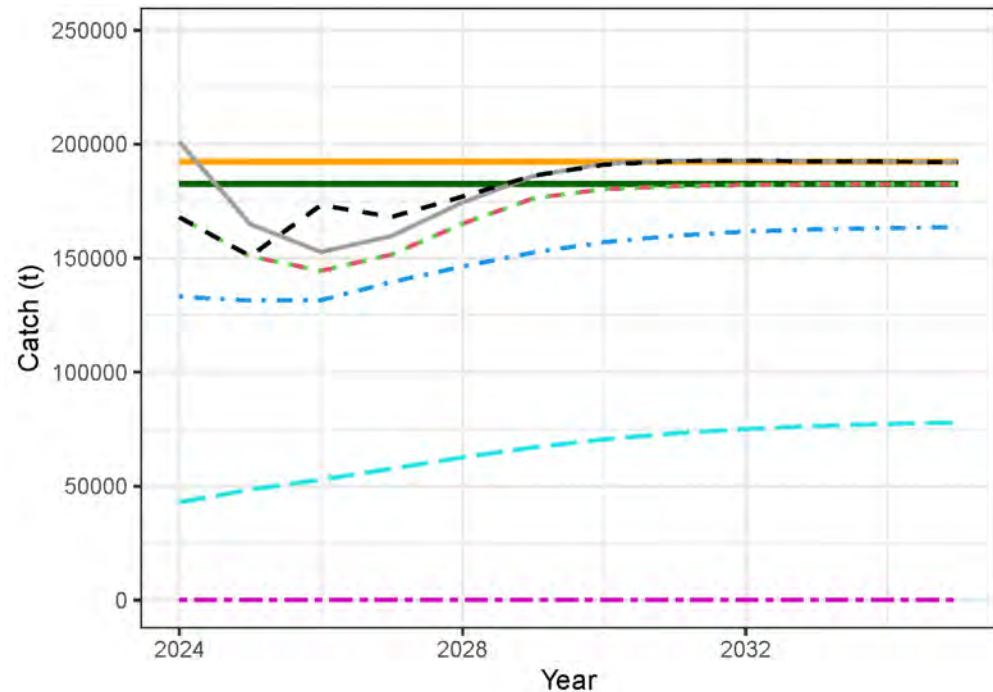
- Recent lower fishing pressure 2015-2023
- High fishing pressure 2006-2014



# 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





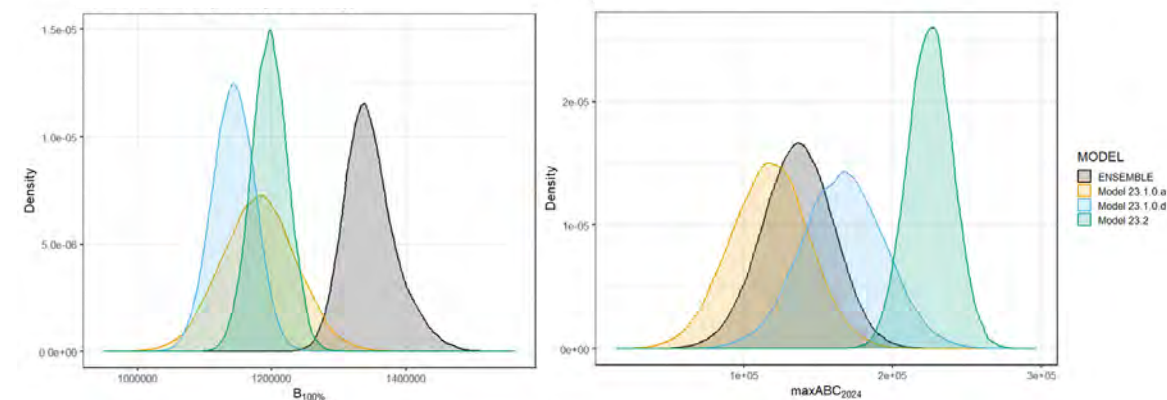
# Model 23.1.0.d Projections



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

$B_{100\%}$

$\max ABC_{2024}$



	As estimated or <i>specified last year for:</i>		As estimated or <i>recommended this year for:</i>	
	2023	2024	2024*	2025*
<b>Quantity</b>				
$M$ (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
$\max F_{ABC}$	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
$\max ABC$ (t)	144,834	140,159	167,952	150,876
ABC (t)	144,834	140,159	167,952	150,876
	As determined <i>this year for:</i>			
<b>Status</b>	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

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

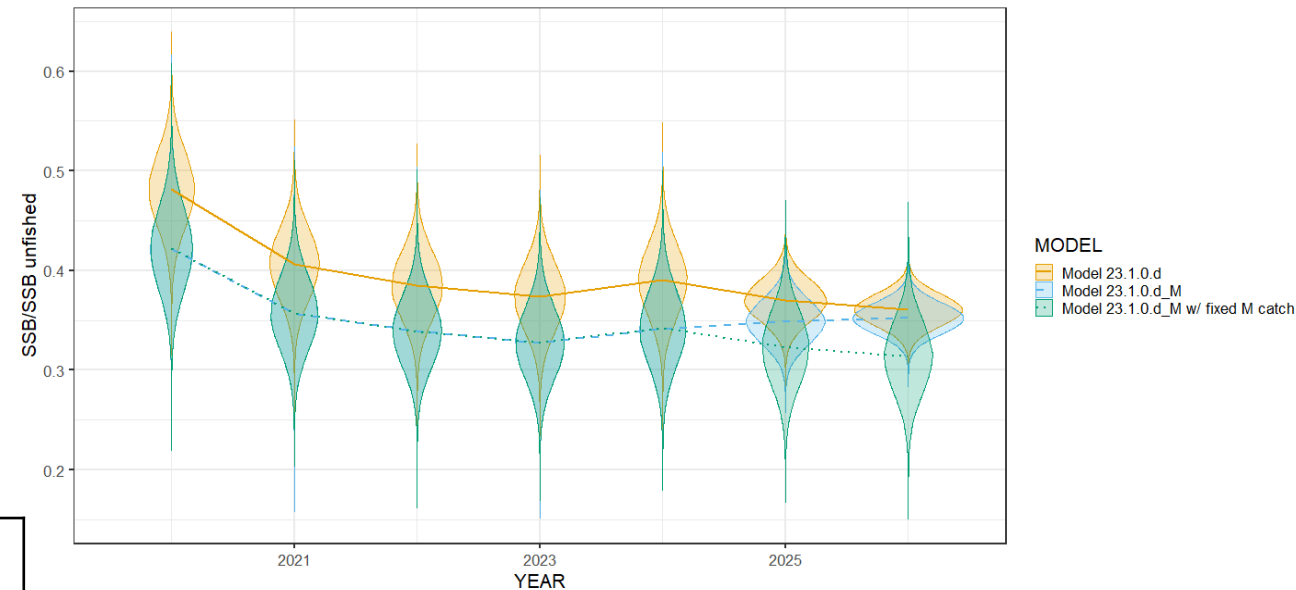


# Model 23.1.0.d Assumptions on M



- 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%

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# Thank You!



# Questions?

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Phone: (206) 526-4211

