EBS Pacific cod
BSAI Groundfish Plan Team

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Thanks to the many contributors to this assessment

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Stock Overview

- Tier: 3b

- Area: Eastern Bering Sea (EBS) and Northern Bering Sea (NBS)

- Current year status

- BRIEF summary of changes to the current assessment data/model

Teams or SSC Comments

- *Given that an ensemble model structure has been endorsed by the SSC in 2021, representing a fairly large change in the assessment process, if the new authors choose to propose an ensemble in the future it may be prudent to minimize changes to the suite of models comprising the ensemble so that the potential benefits of a stable ensemble can be realized.*

  - **The authors presented a series of minor changes to the model this year. The Plan Team and SSC endorsed removing of the weight-at-length adjustments and the aging bias for post-2007. These model changes resulted in very minimal changes to the resulting model and are described in the document below.**

Teams or SSC Comments

- *If model ensembles are brought forward in the future, the authors should work with the BSAI GPT to define a process whereby GPT members themselves assign model scores based on the same, or an updated set, of scoring criteria. This would allow for future development of ensemble member weightings based upon independent review, and the SSC believes this would address one of the concerns highlighted in public comment.*

    - **In light of the above recommendation, model changes were kept to a minimum and the weighting criteria used for this year's ensemble were judged to rate the same as the weights generated by the CIE and endorsed by the SSC in 2021.**

Teams or SSC Comments

- *The SSC recommends that inclusion of [fishery age composition data] be fully explored in a later assessment cycle, either within a single model or multiple ensemble members, highlighting that it views this as a top priority for future research.*

 - **Given the already monumental task of taking this stock over from Dr. Thompson, the authors chose not to investigate the use of fishery age composition data. This also in light of the SSCs recommendation to minimize changes to the suite of models comprising the ensemble. The authors intend to investigate the use of fishery age composition data in the future.**

Pacific cod genetics

- Isolation-by-distance
  - western Gulf of Alaska through Unimak Pass and eastern Aleutian Islands
- Break in the population structure between western and eastern GOA
- Break western Bering Sea shelf, adjacent to Russia, and all other regions.
- Aleutian Island populations are highly diverged at a few genomic regions that may be adaptively significant
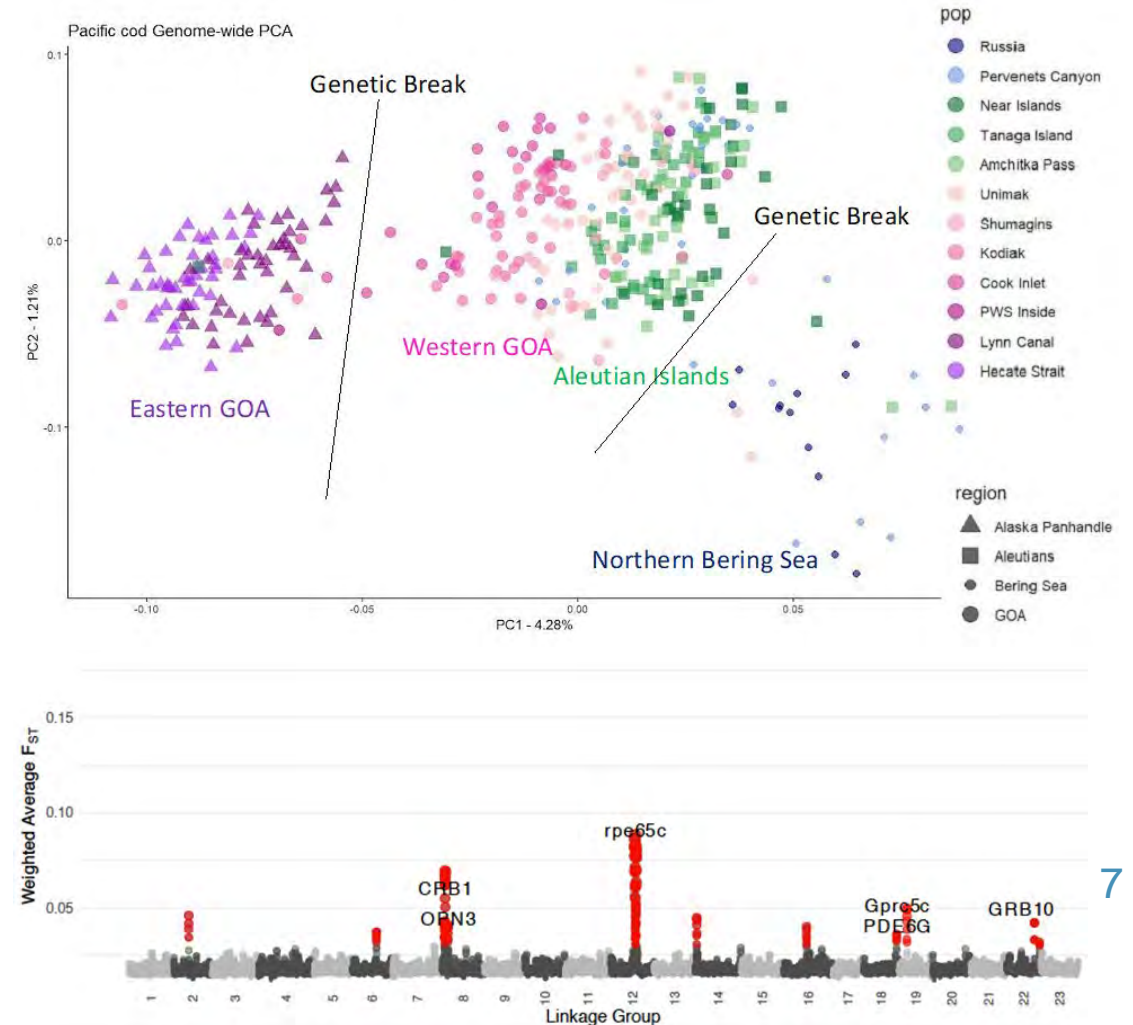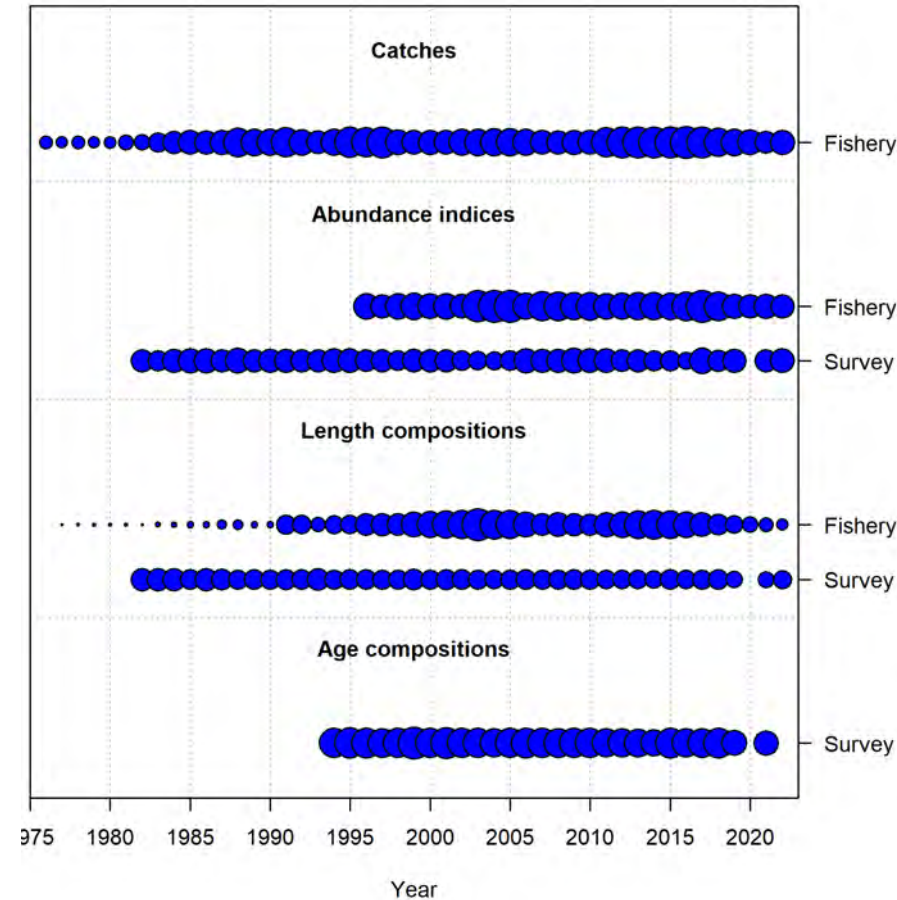
Pacific cod PSAT
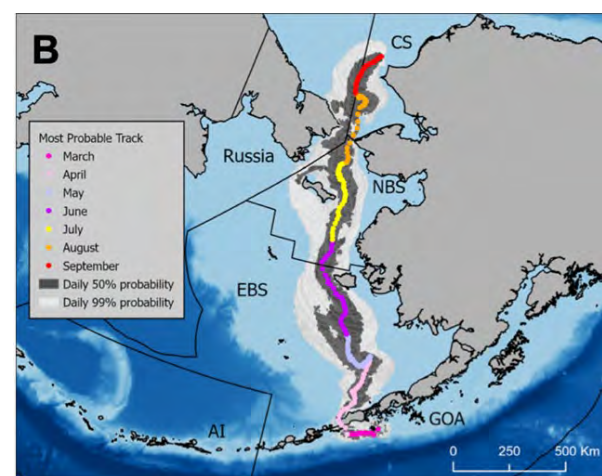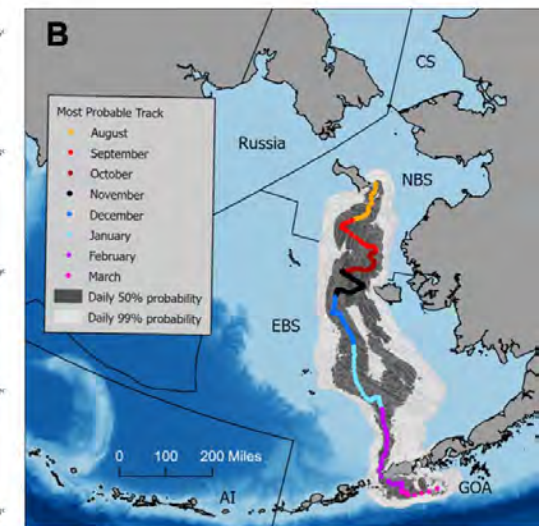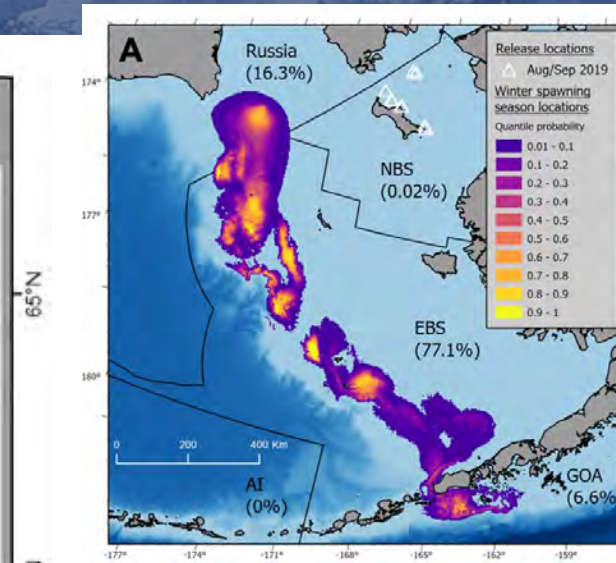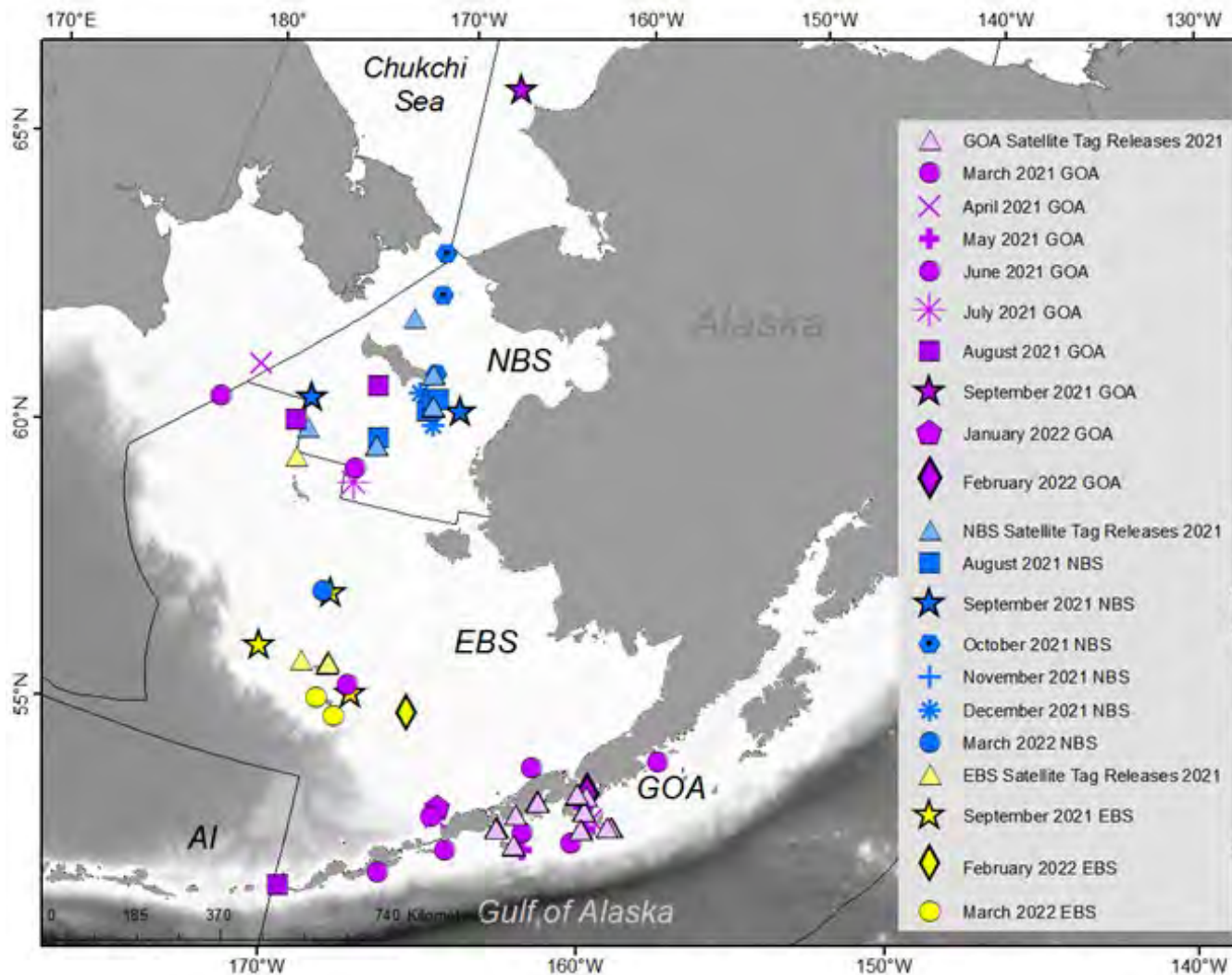
Data Summary

| Source	Type	Years
Fishery	Catch biomass	1977-2022
Fishery	Catch size composition	1977-2022
Fishery	Catch per unit effort (VAST)	1996-2022
EBS+NBS trawl survey	Survey numerical abundance (VAST)	1982-2019, 2021-2022
EBS+NBS trawl survey	Survey age composition (VAST)	1994-2019,2021

Data changes
Fishery Length Composition

- New algorithm for constructing fishery length composition (described in September)

- Data weighted by haul, vessel, gear, month, NMFS area, and year

- Resulted in shift to more smaller fish in distribution

1977-1989

1990-1999

2000-2010

2011-2020
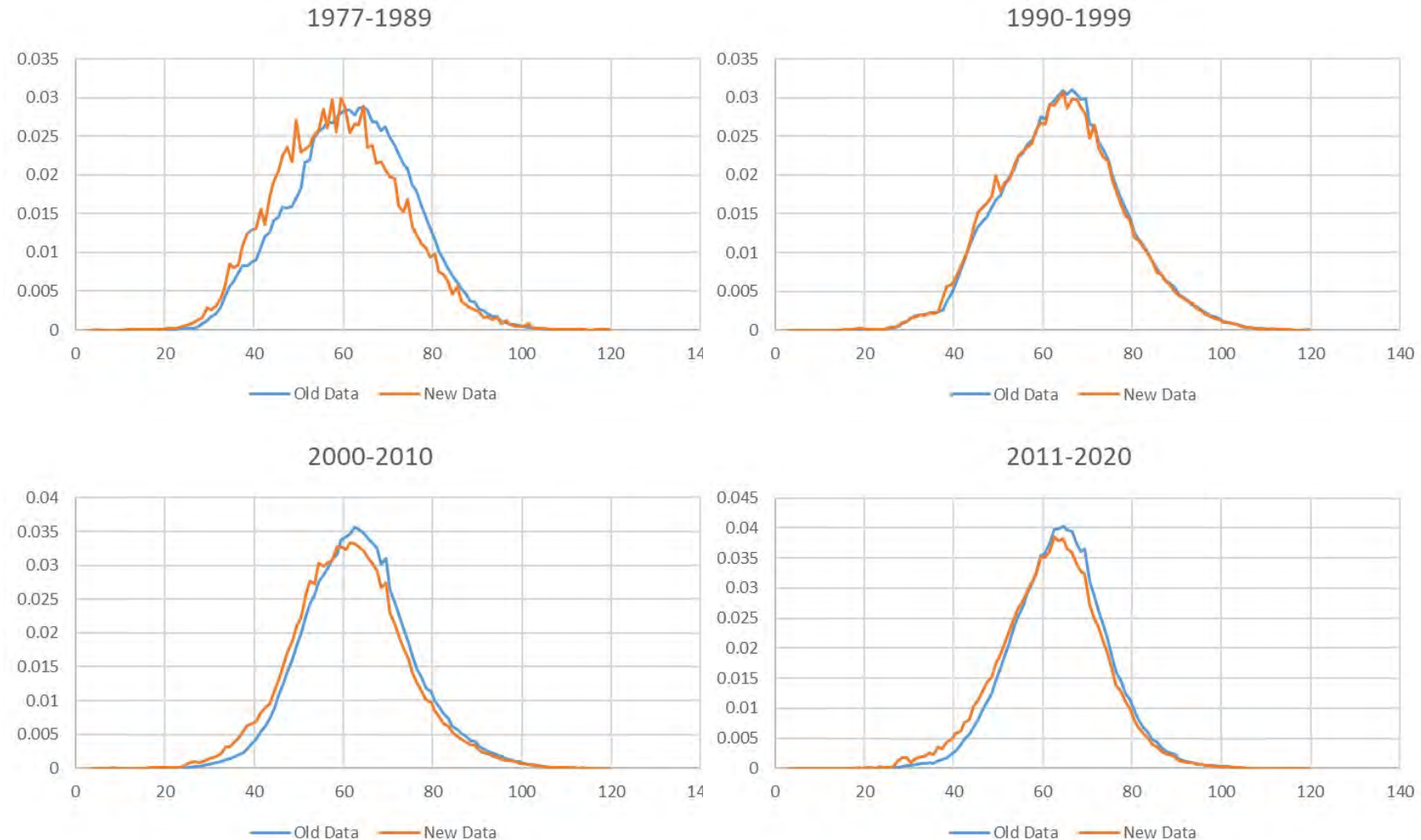
Data changes –
Annual Weight-at-Length Adjustments

- Switch from linear Mathcad algorithm to GAM in R mgcv library (described in September)
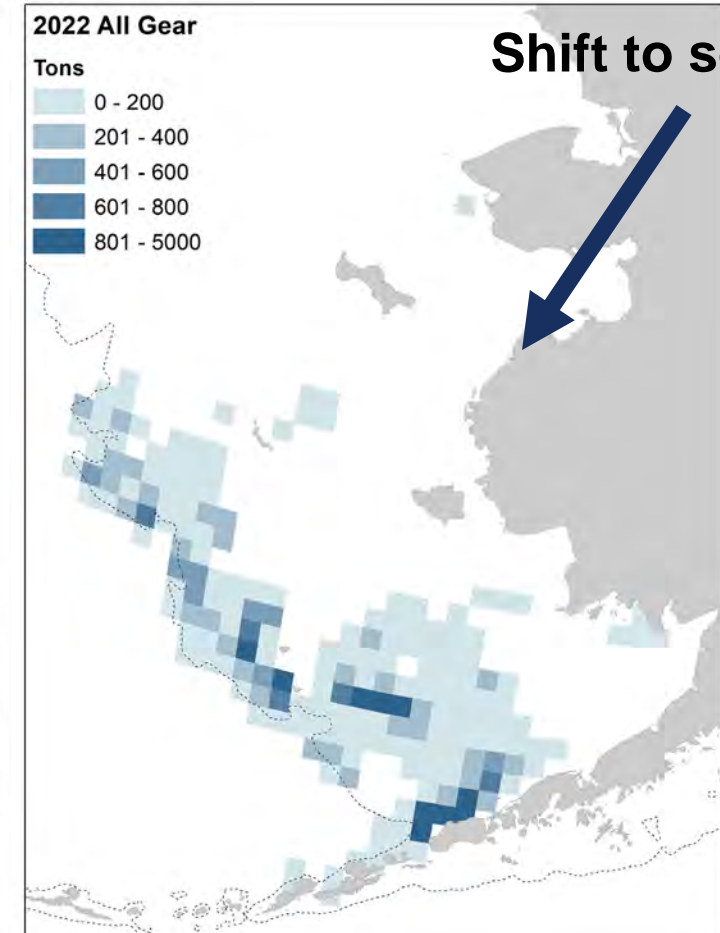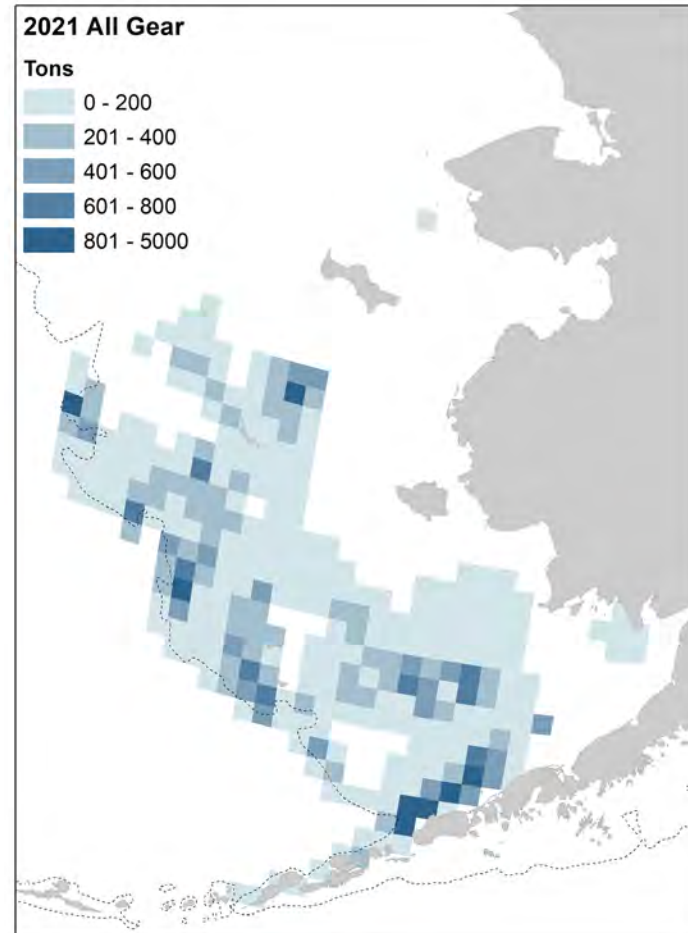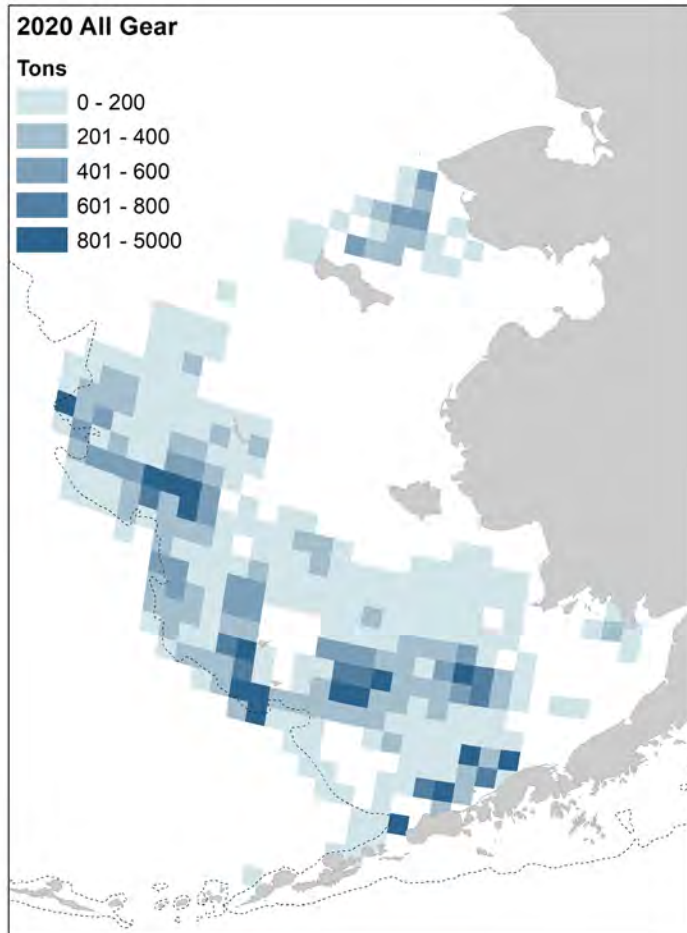
- Similar resulting trend in adjustments
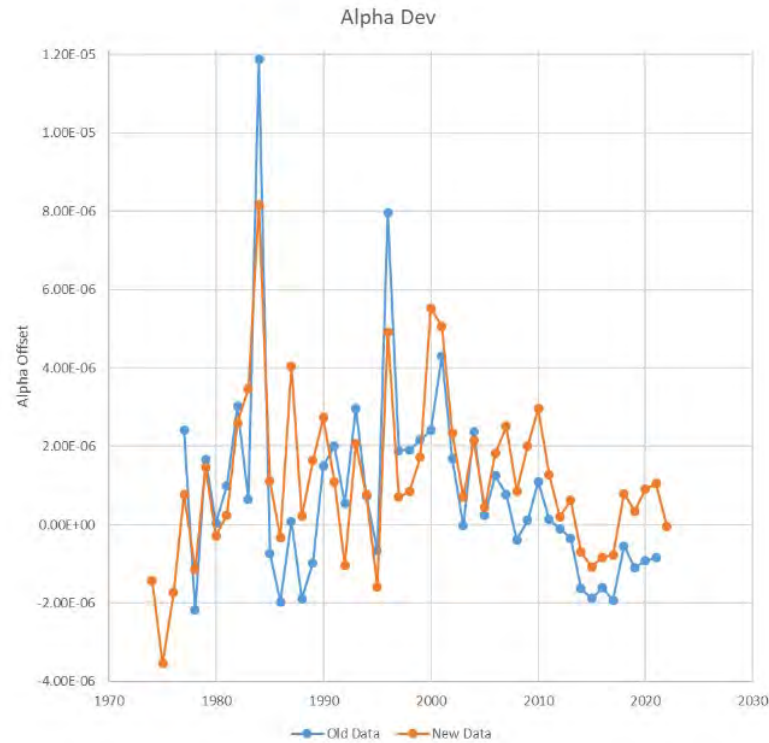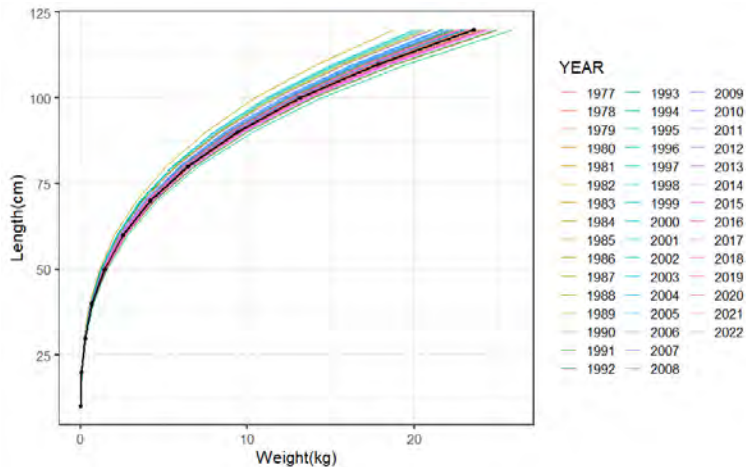
Catch –
Fishery Sector

- Increase in catch from 2021 but lower than 10-year average

- Longline remains dominant

- Continued increasing trend in pot proportion and decreasing trend in trawl proportion
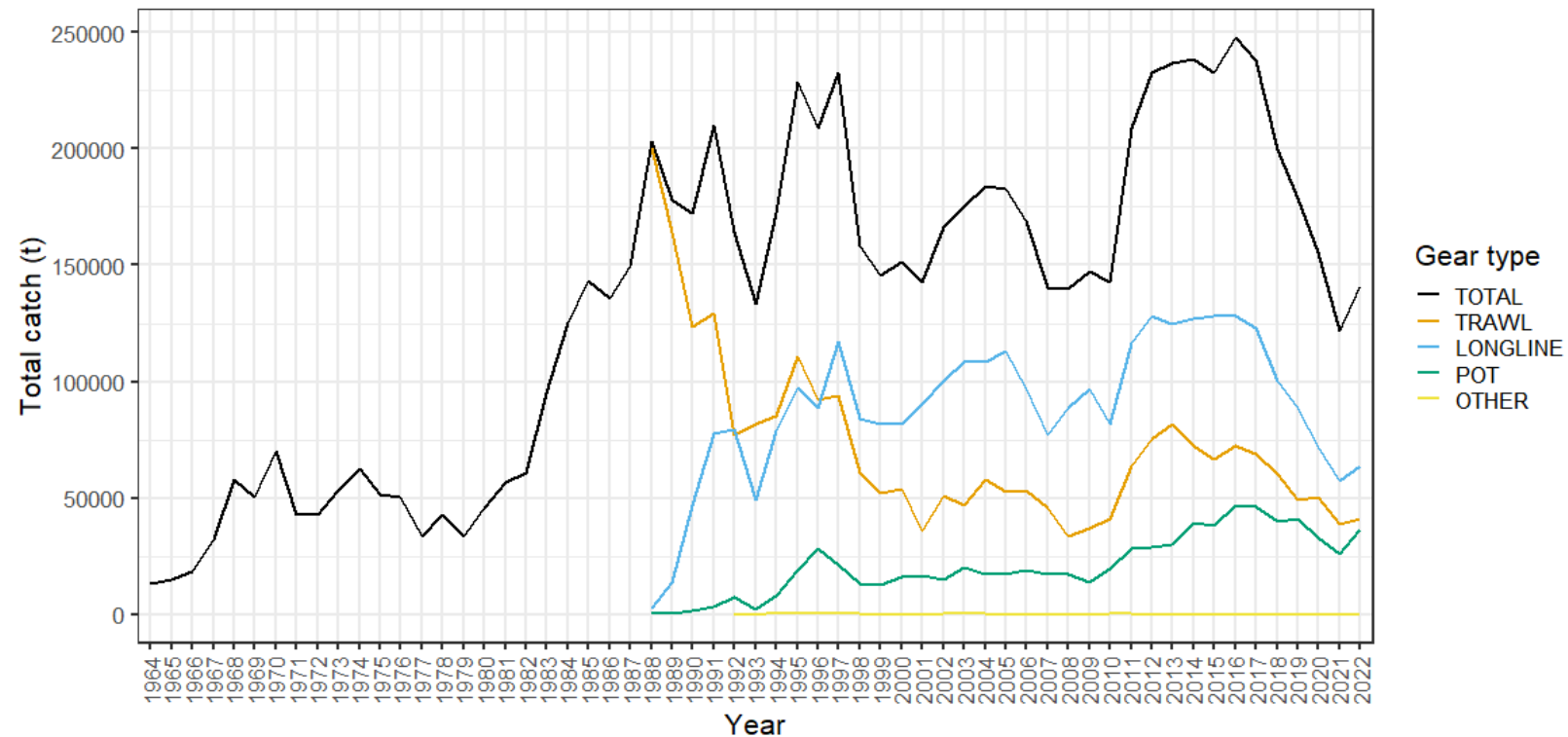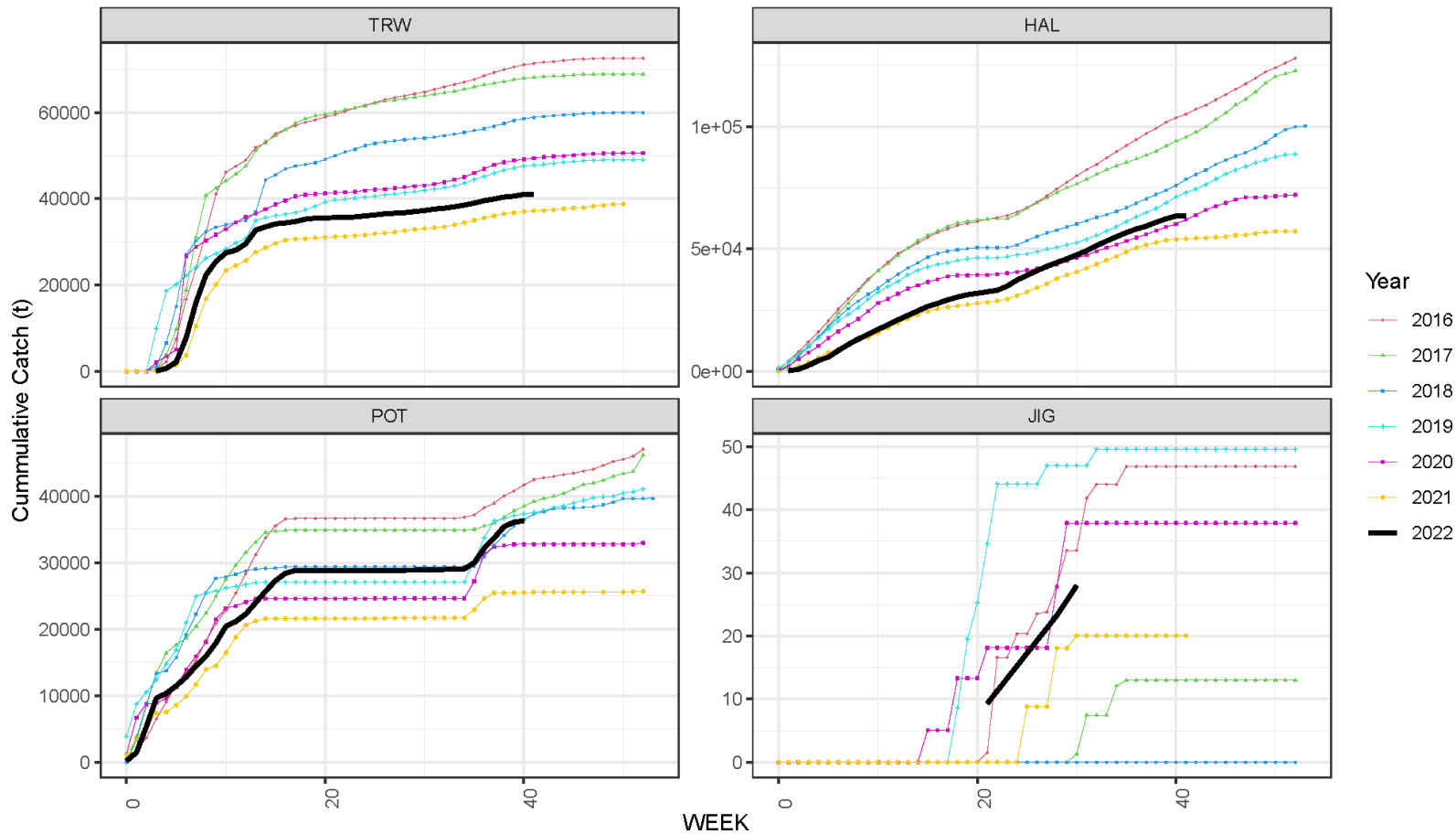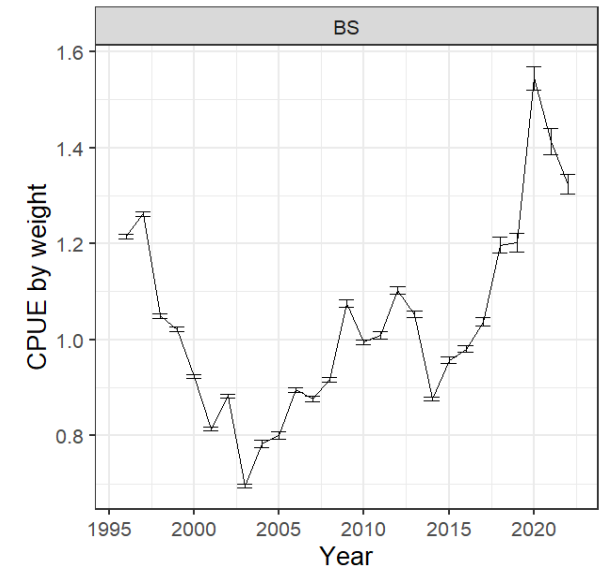
Catch – Distribution

Through October 9, 2022

13
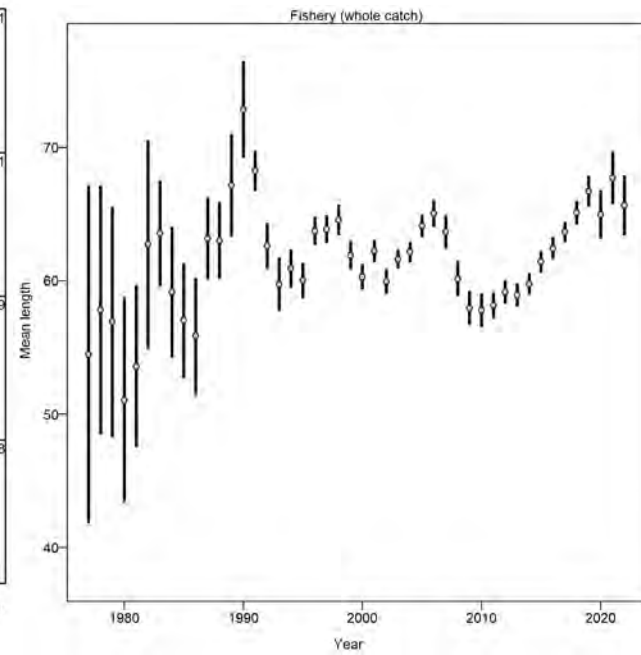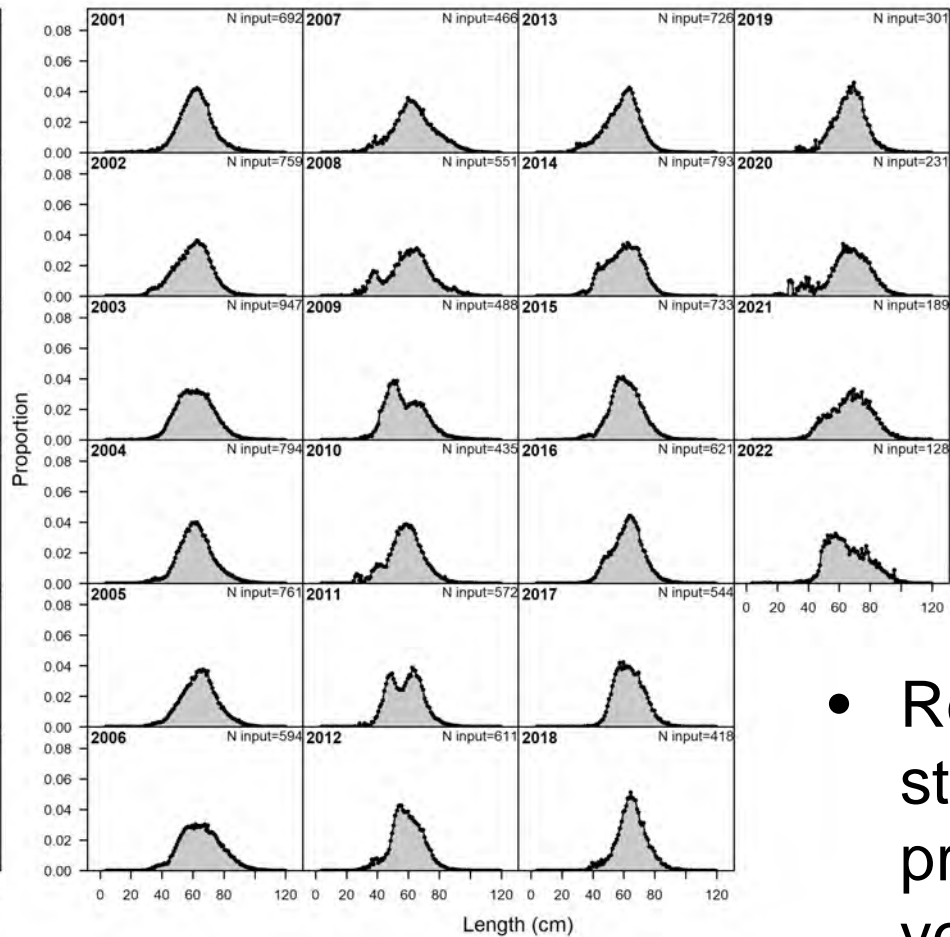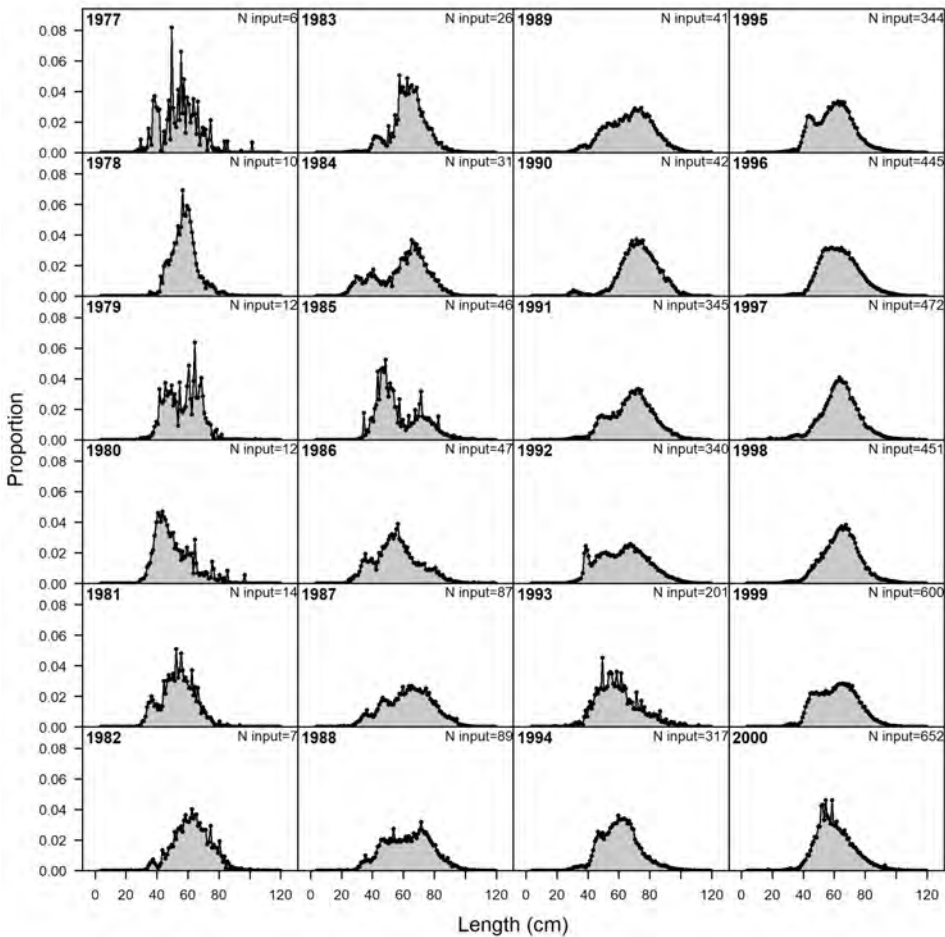
Catch – Cumulative and RAW CPUE

CPUE by weight of fish

- Catch rates better than 2021

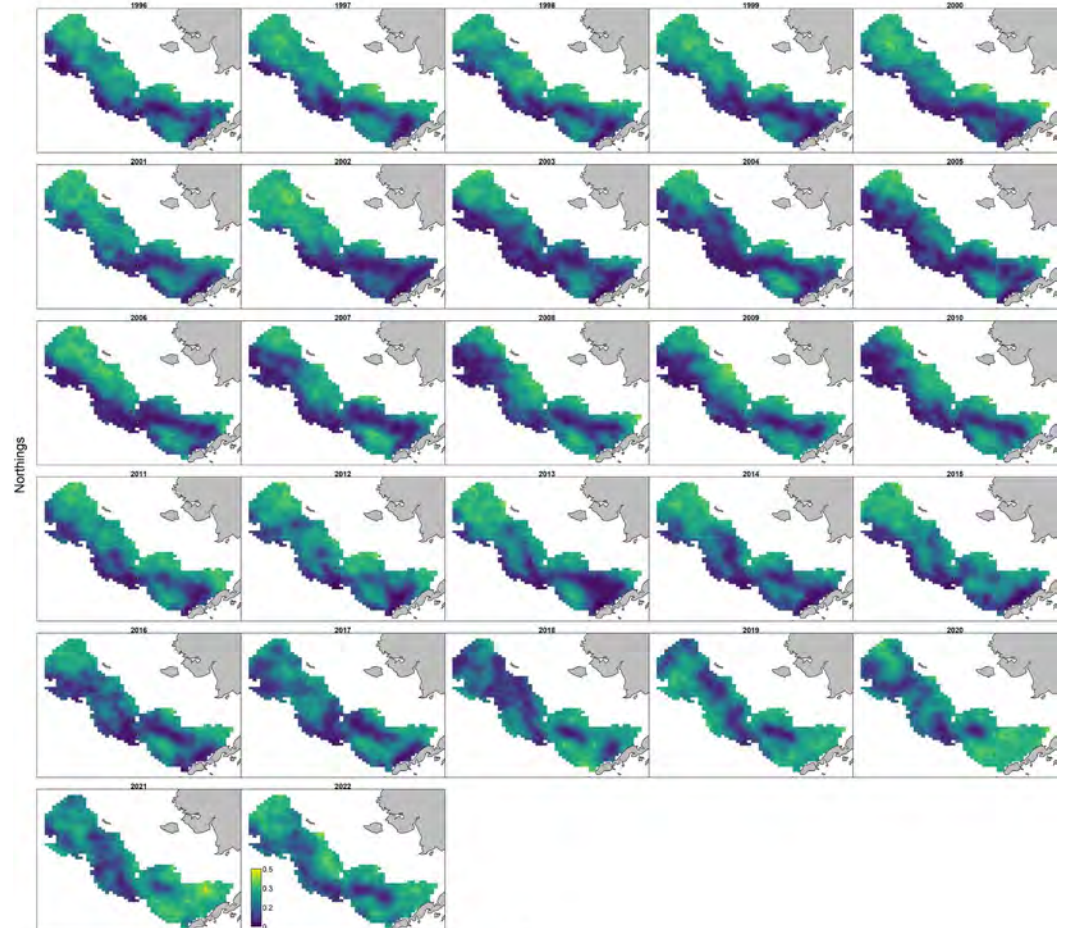- Raw aggregated CPUE lower than 2021, but remains higher than average
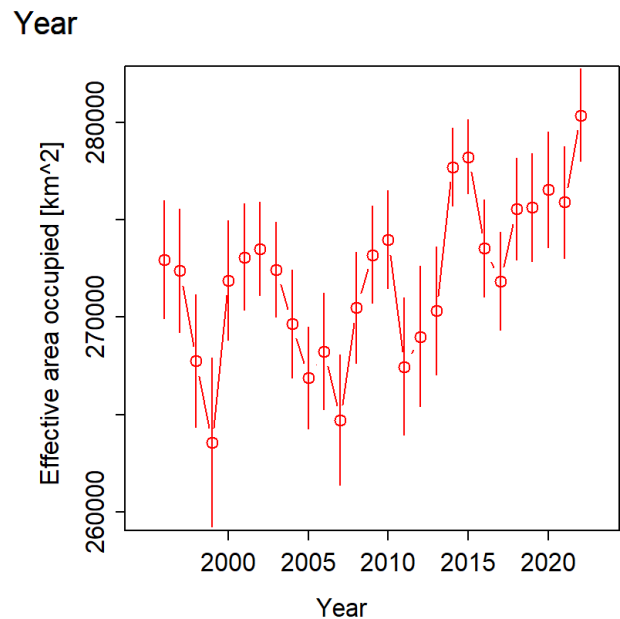
Fishery Size Composition
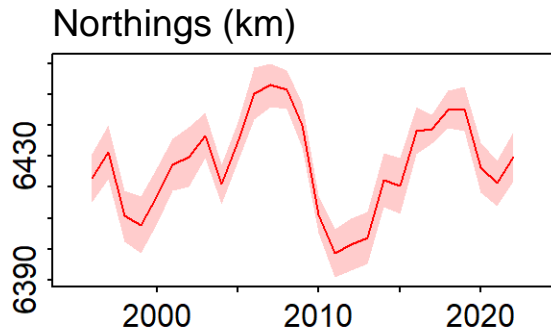

- Relatively stable size for previous 5 years

VAST CPUE Index – Jan-Feb Longline Fishery

Eastings (km)

Northings (km)
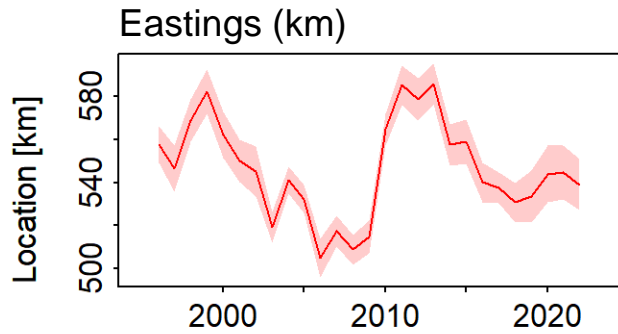
- COG shifted to the northwest since 2021

- Overall extent has continued to increase

VAST CPUE Index – Jan.-Feb. Longline Fishery

- Difference in spatial extent resulted in overall inflation of index

- Trend remains the same with high correlation between indices

- 15% Increase in 2022 from 2021

Survey –
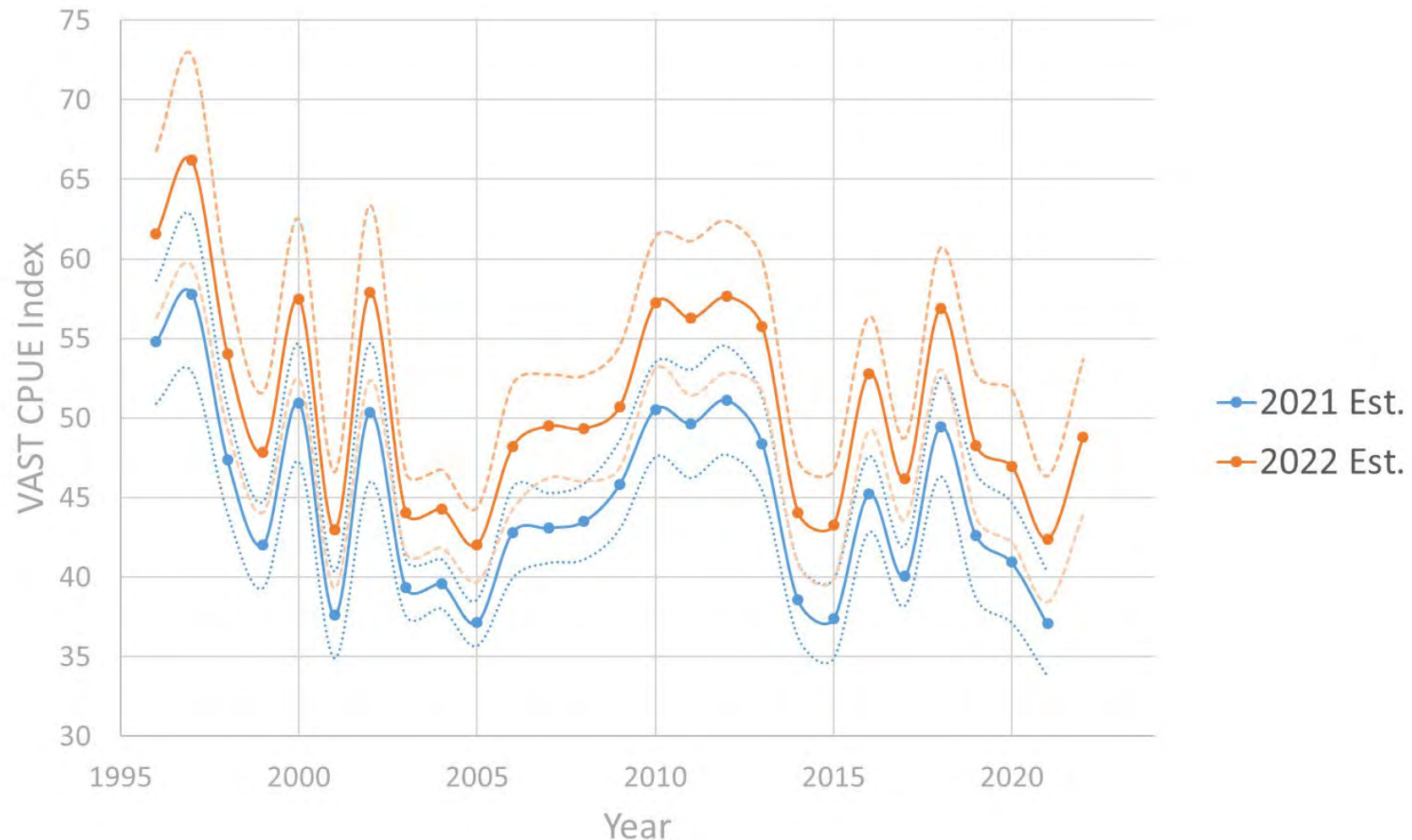# Bering Sea Shelf Bottom Trawl

2019
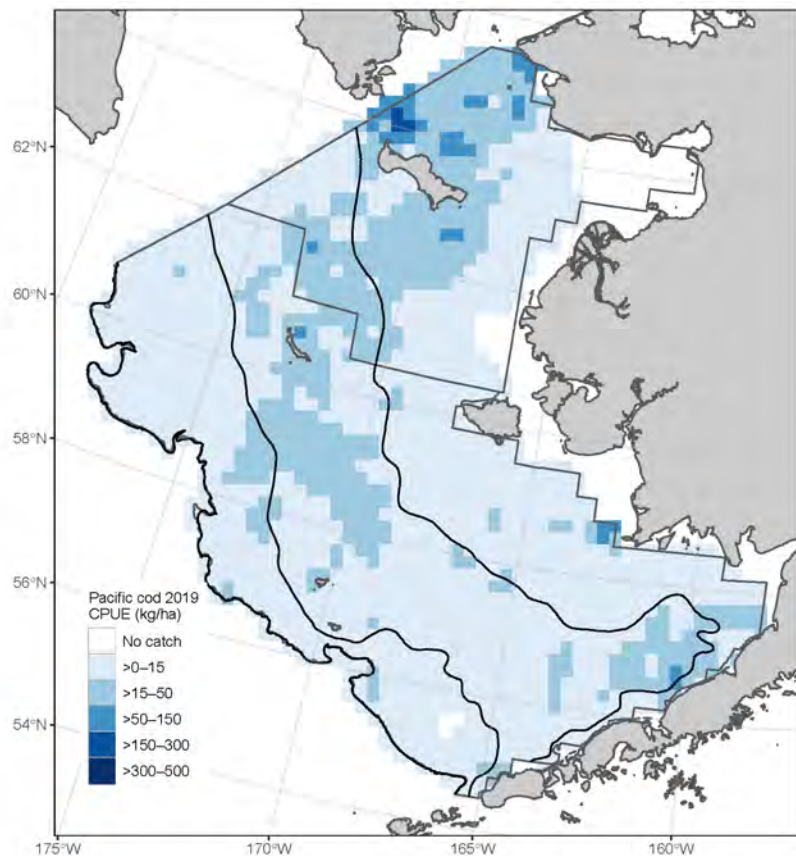
2021
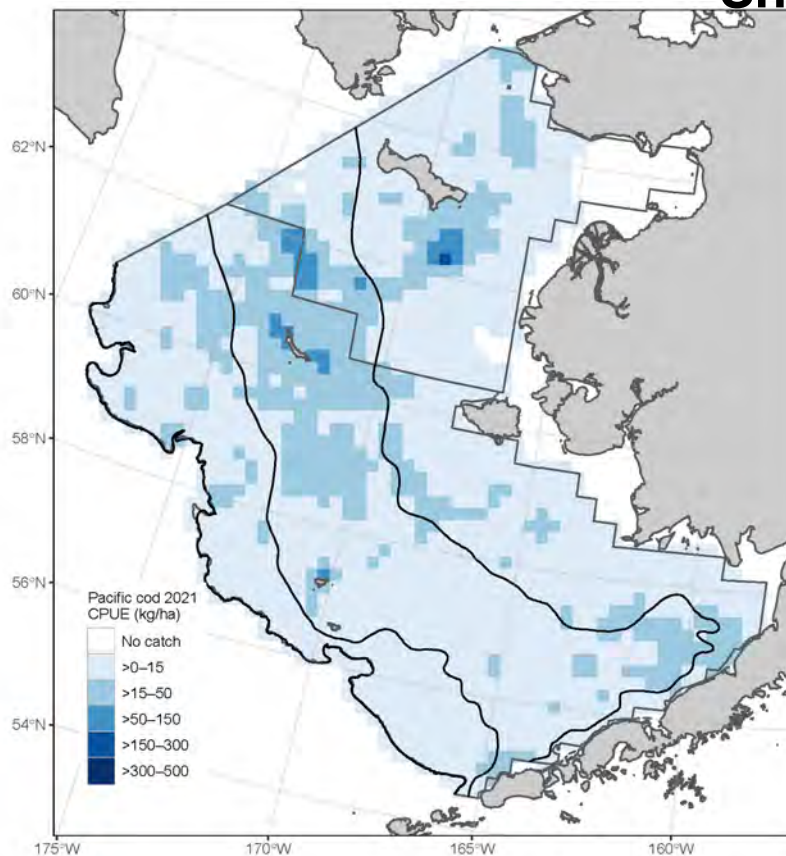
2022

Shift to southeast
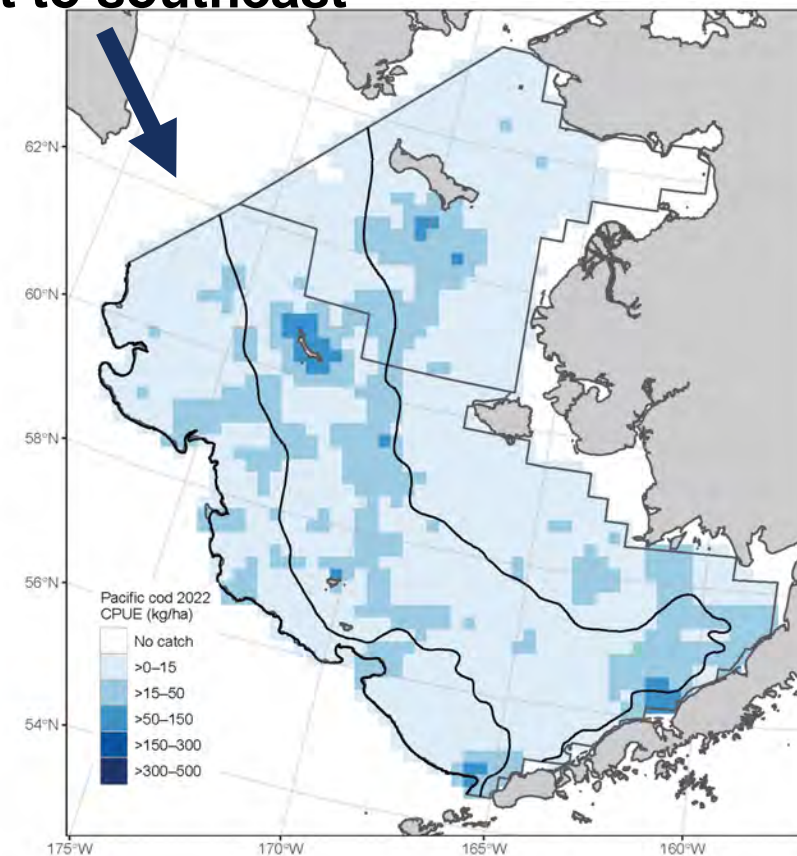
VAST Survey Index – Bering Sea Shelf Bottom Trawl

- VAST NBS and EBS bottom trawl survey data

- Cold-pool extent index as a covariate
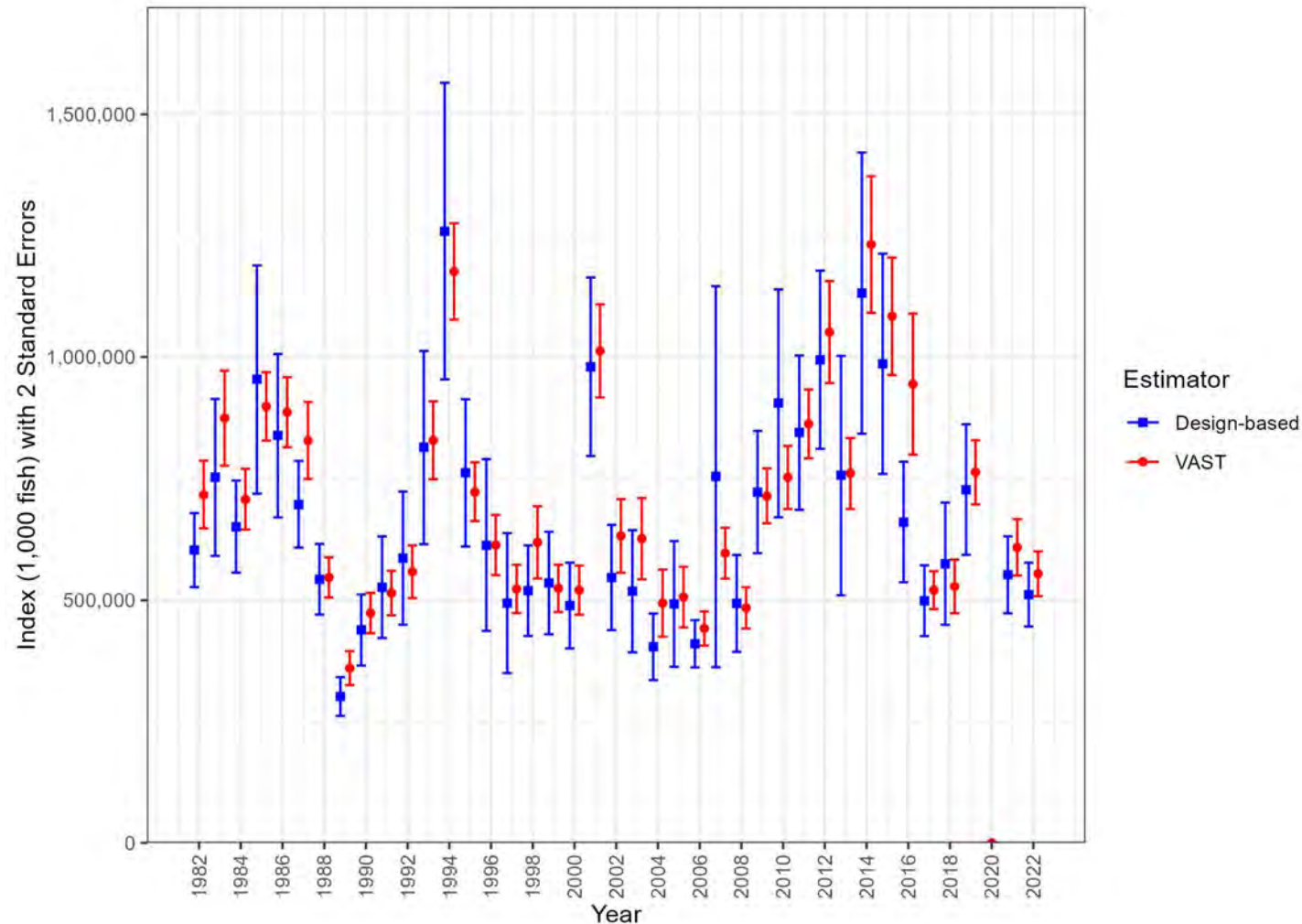
VAST Survey Index – Bering Sea Shelf Bottom Trawl

- Small changes in time series from previous years

- 8.9% decrease in 2022 abundance from 2021
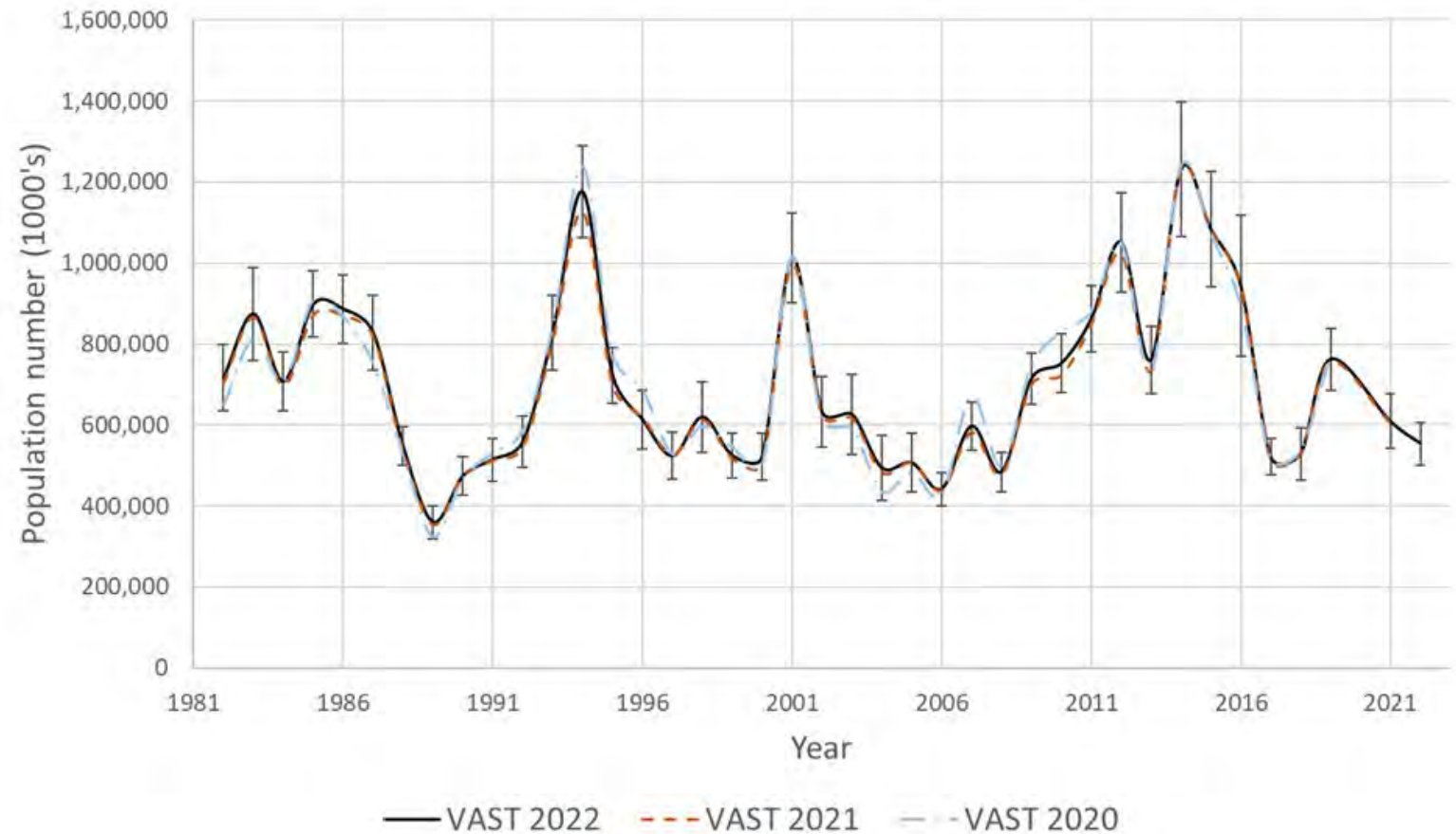
VAST Survey Index – Bering Sea Shelf Bottom Trawl

- COG shifted to the southeast since 2021

- Overall extent has increased, while decreasing in the NBS since 2021

Eastings (km)

Northings (km)
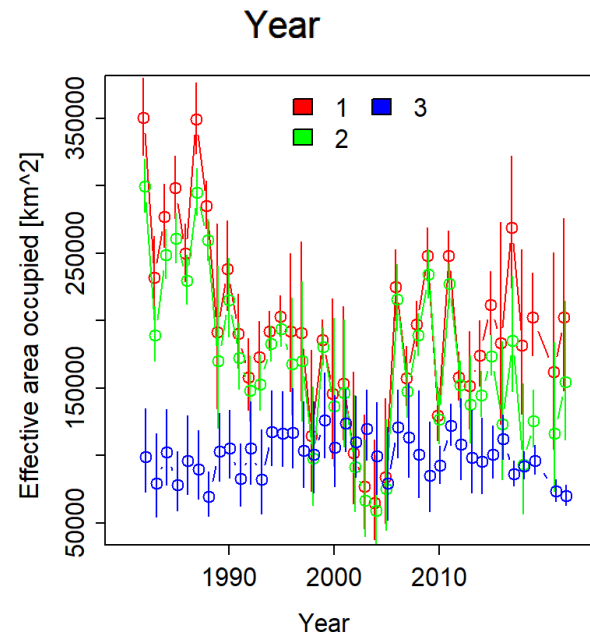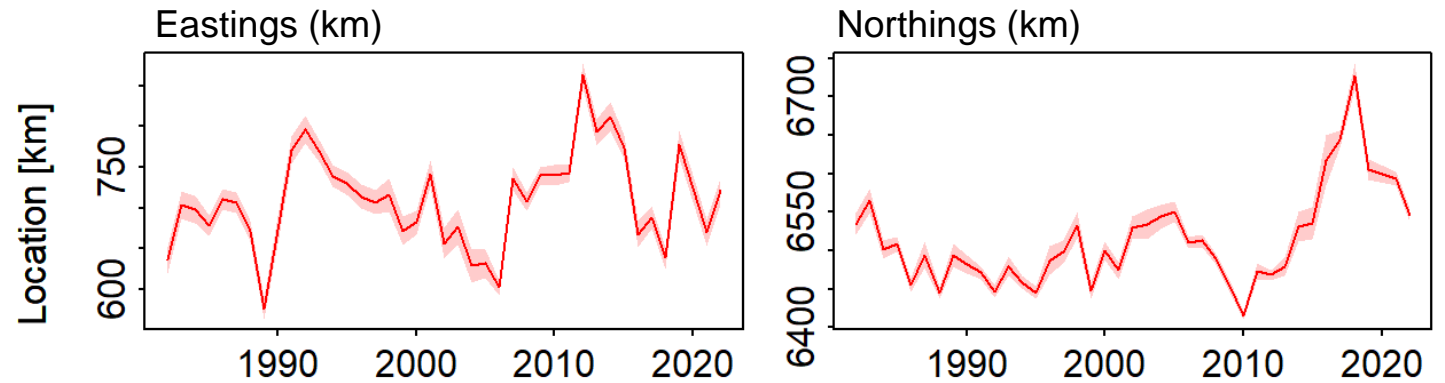
Year

Survey Size Composition – EBS Shelf Bottom Trawl
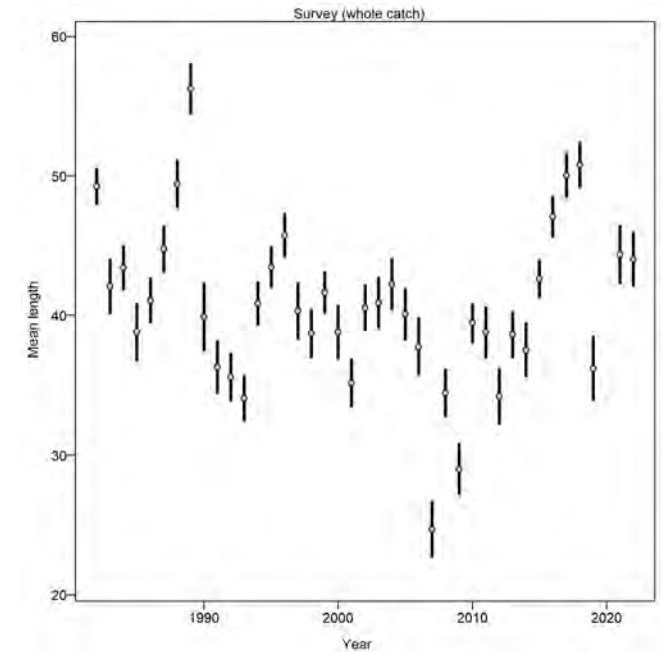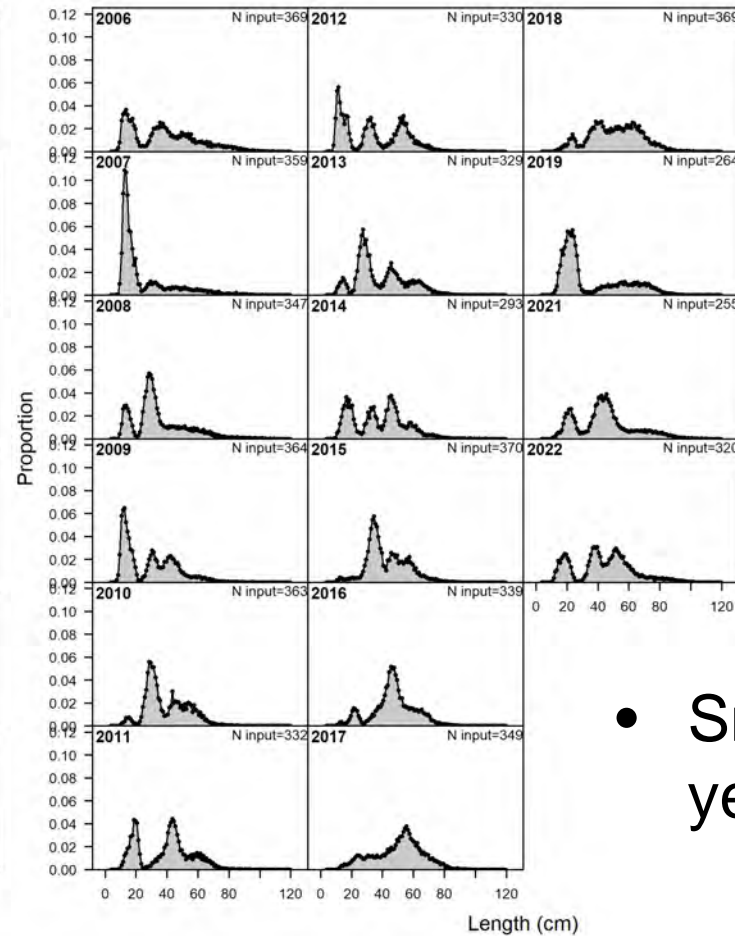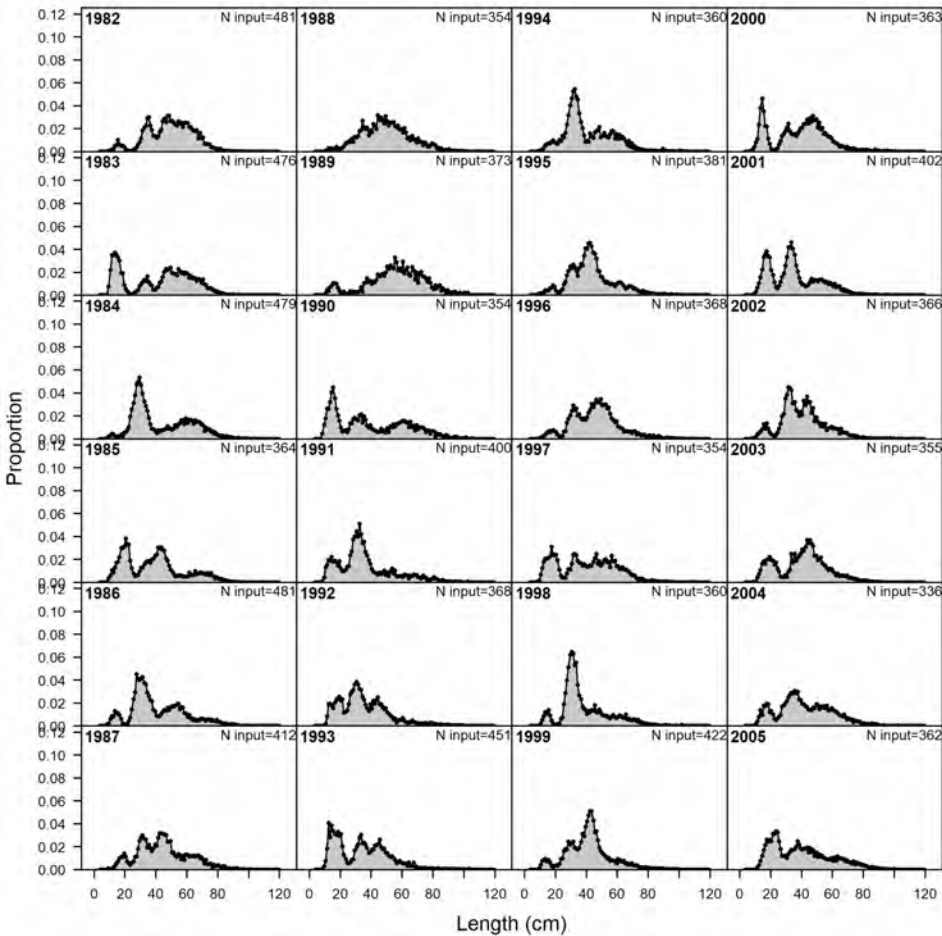
- Small fish 2018-2020 year classes evident

Survey Age Composition – EBS Shelf Bottom Trawl
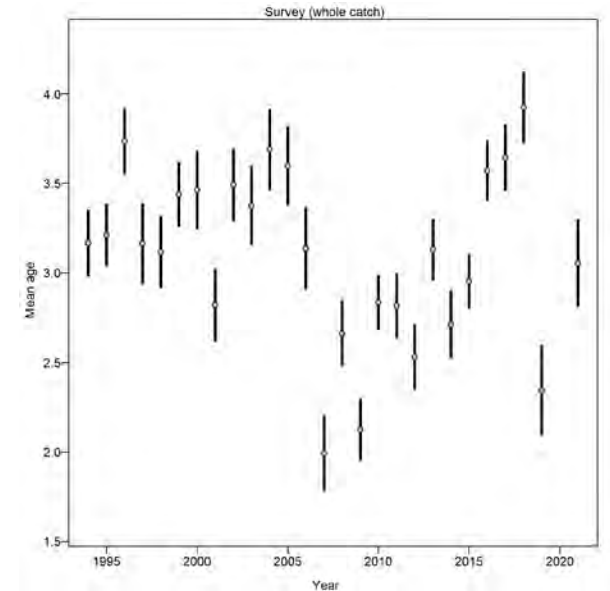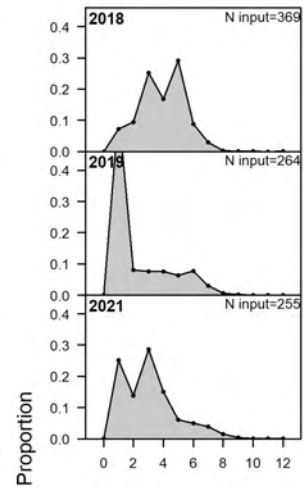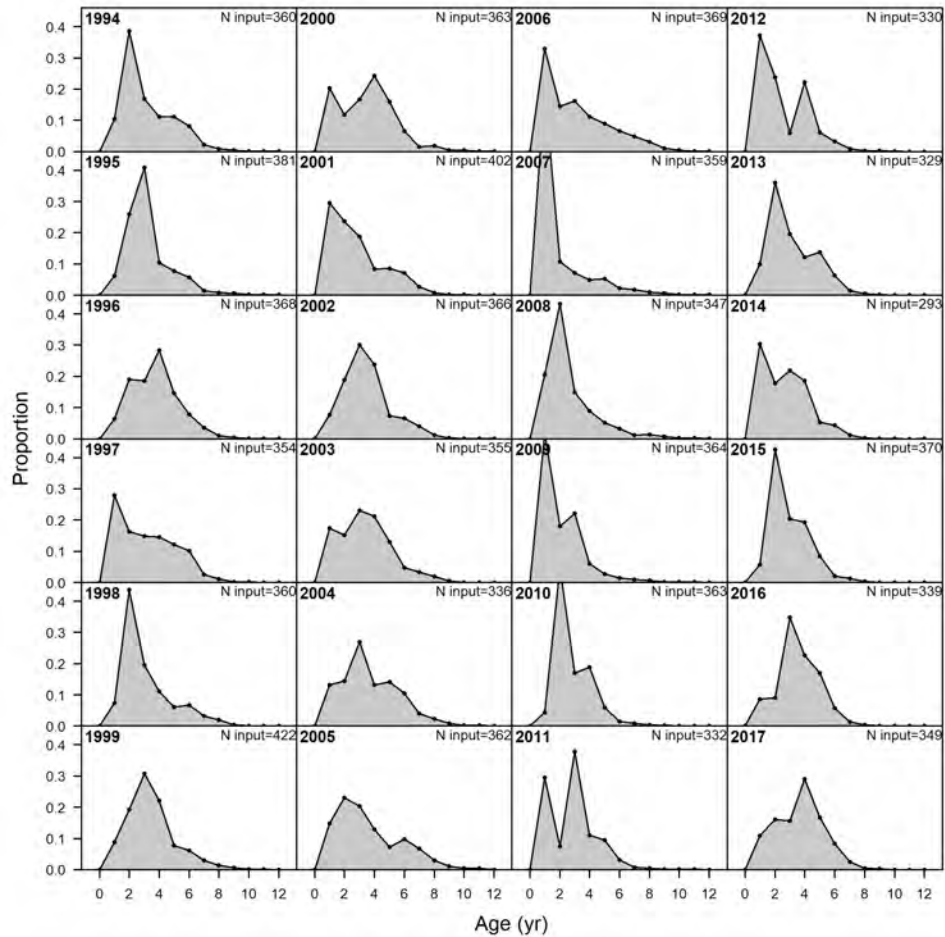
- 2018 year class dominant in 2019 and 2021
- 2019 year class evident in 2021
- Few older fish

AFSC Longline Survey – Relative population numbers

Not used in models

Bering Sea
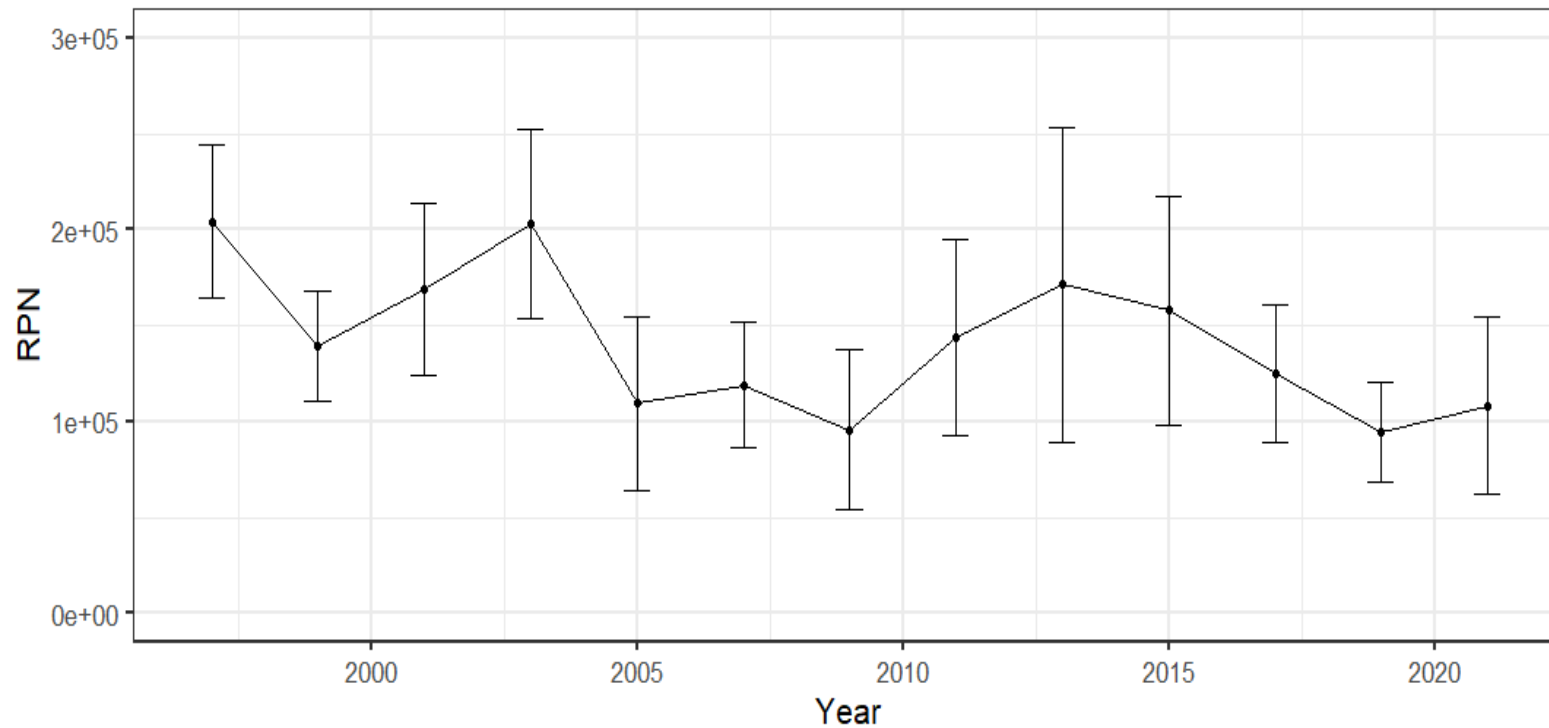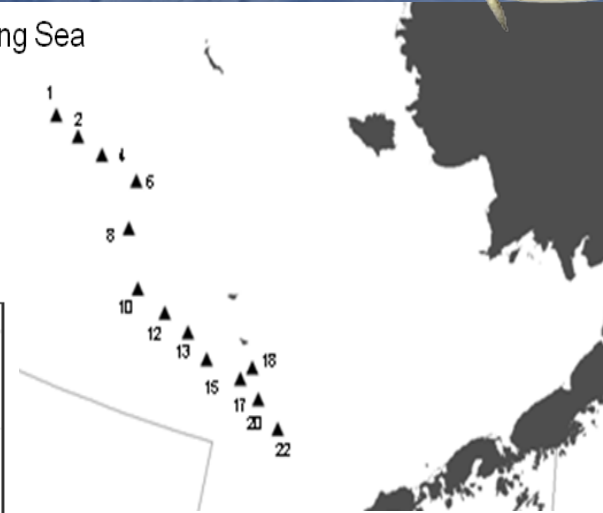
- Limited extent

- 2021 increase from 2019 record low

Stock Assessment Models

- Diverse set of models over the past 22 years

- Current base model is an ensemble of 4 models
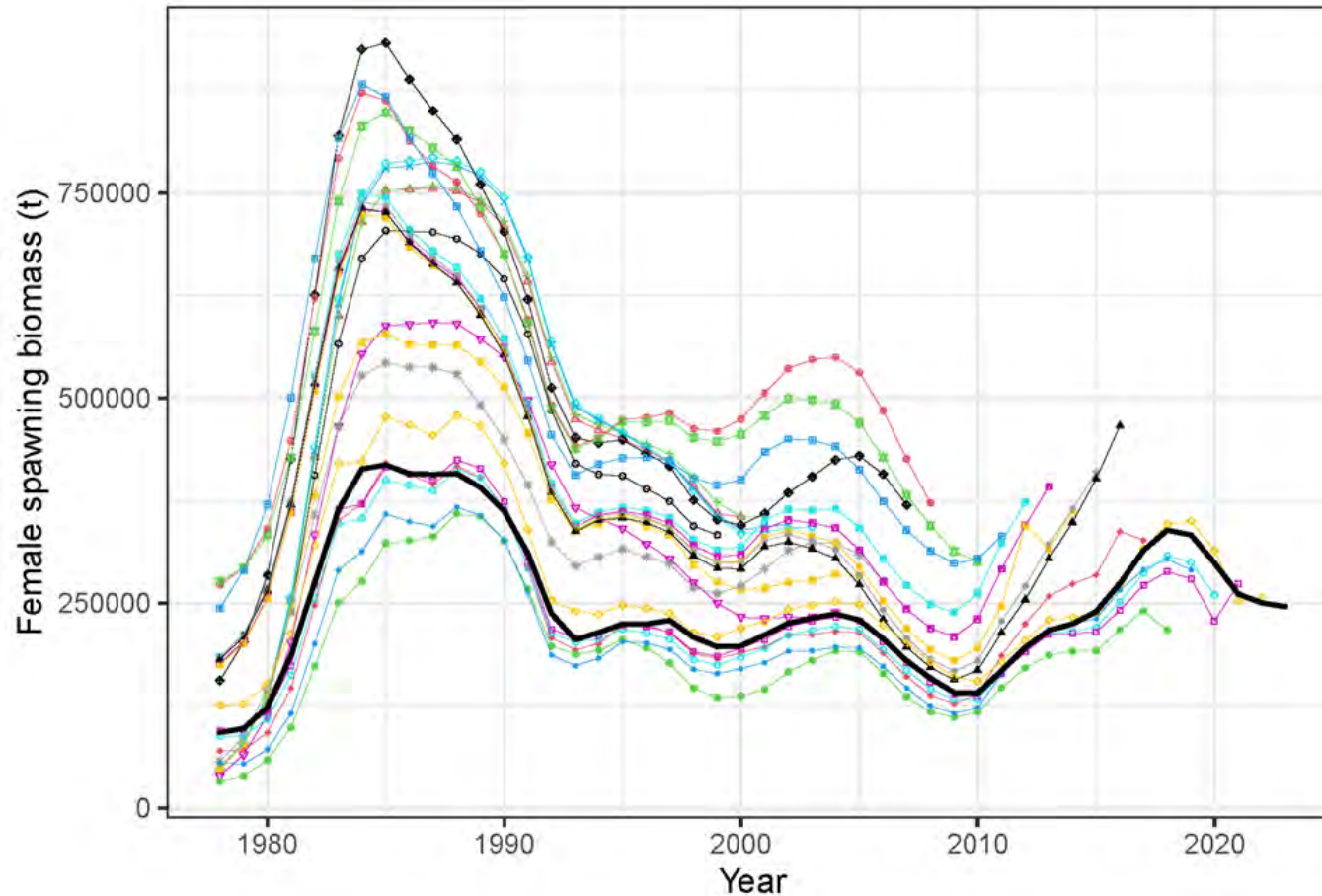
Model configurations

Thompson Series models	M 19.12	M 19.12A	M 21.1	M 21.2
New Series models	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

New Series models - Same as Thompson Series models except
- Seasonally corrected annual weight-at-length adjustments removed
- Post-2007 aging bias block removed
- Although minor model changes, substantial changes in data processing resulting in model name changes for this year.

Model weighting (same as last year)

Feature	M 19.12 M 22.1	M 19.12A M 22.2	M 21.1 M 22.3	M 21.2 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 19.12 M 22.1	M 19.12A M 22.2	M 21.1 M 22.3	M 21.2 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

Model Fits

- Exploration of individual models and their fits can be found at the link provided

- Model fits and results were nearly identical between the Thompson and New Series models

- Largest difference was the fit to the age composition data with a degraded fit due to the removal of the post-2007 aging bias

https://afsc-assessments.github.io/EBS_PCOD/2022_ASSESSMENT/NOVEMBER_MODELS/
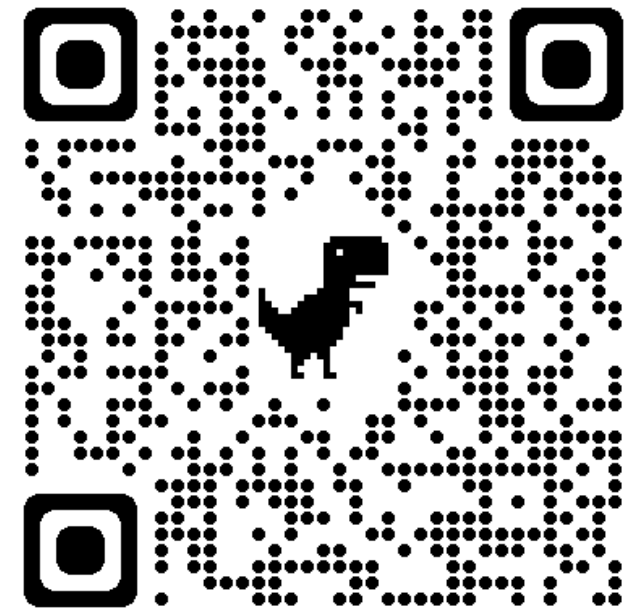
Models –
Objective function

- Can not compare across models in a series, but can look at between models across series

- Largest difference between series is the fit to the age composition
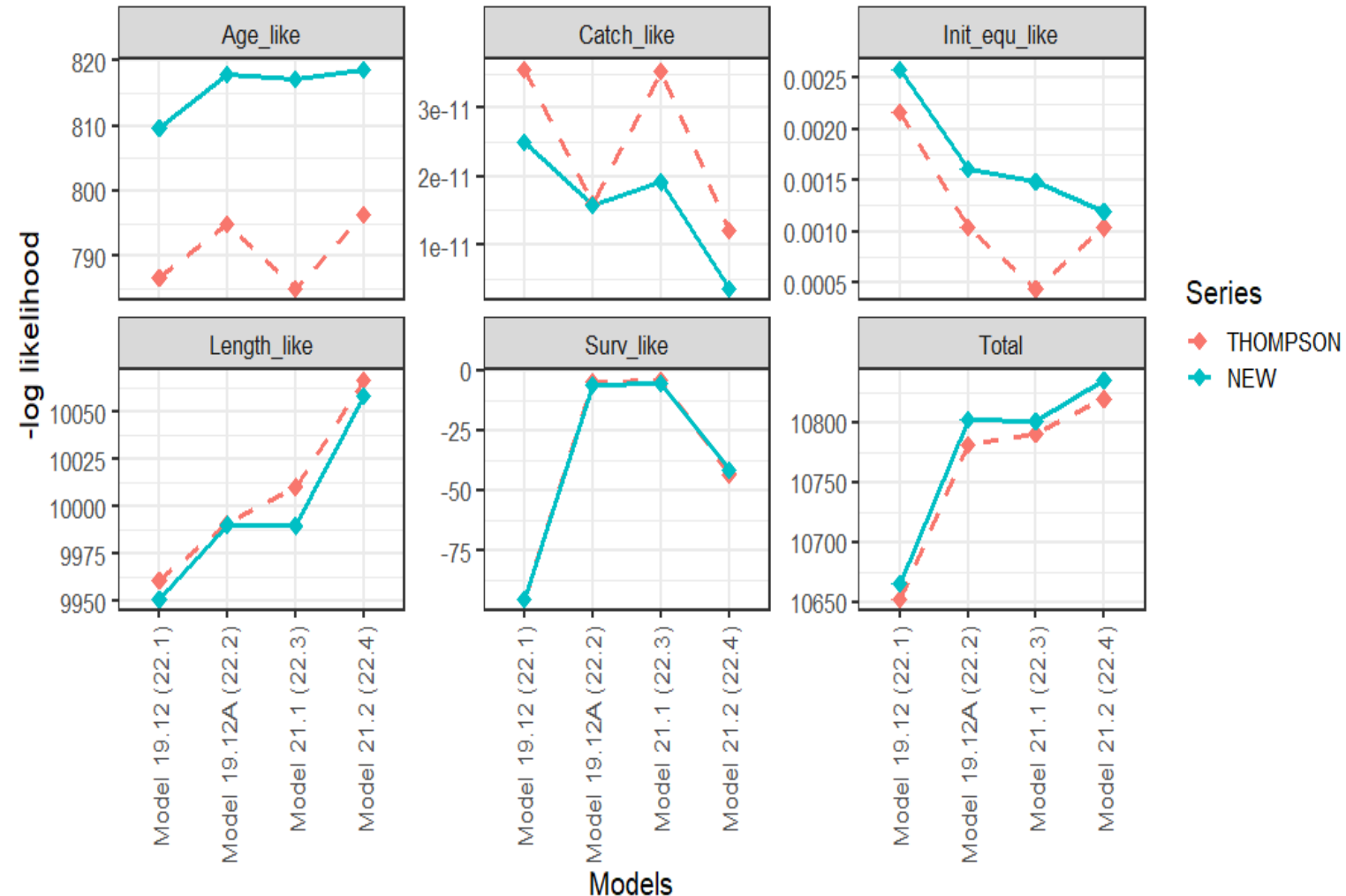
Models – Parameters

- Similar values between the ensembles

- Higher variability in parameters from the individual Thompson Series models
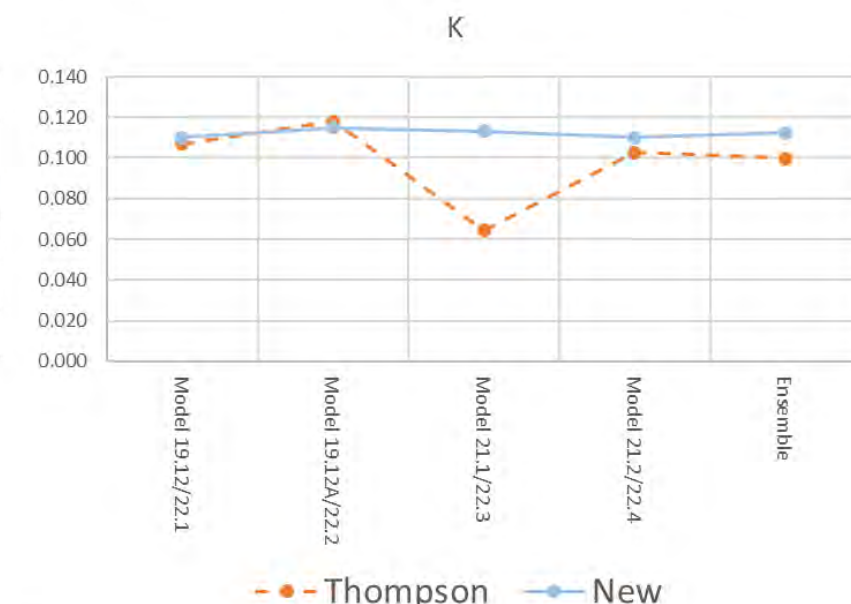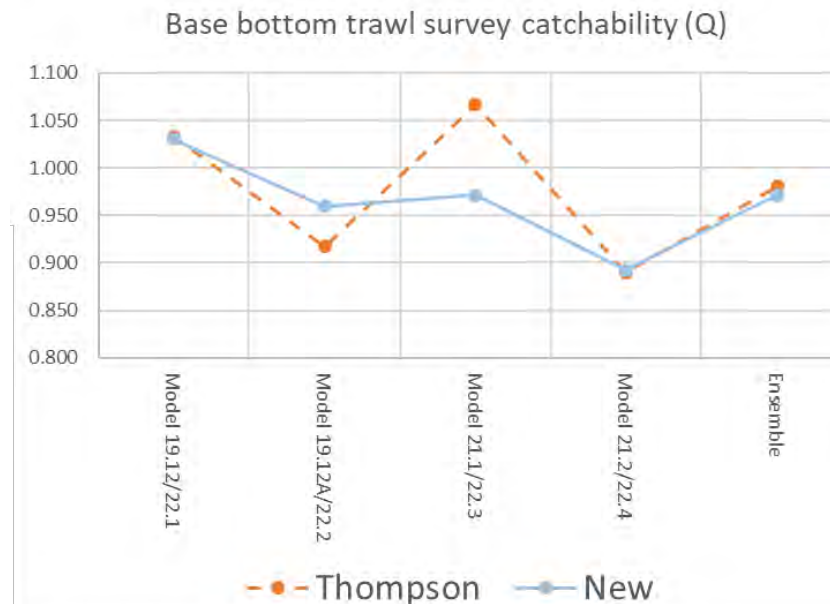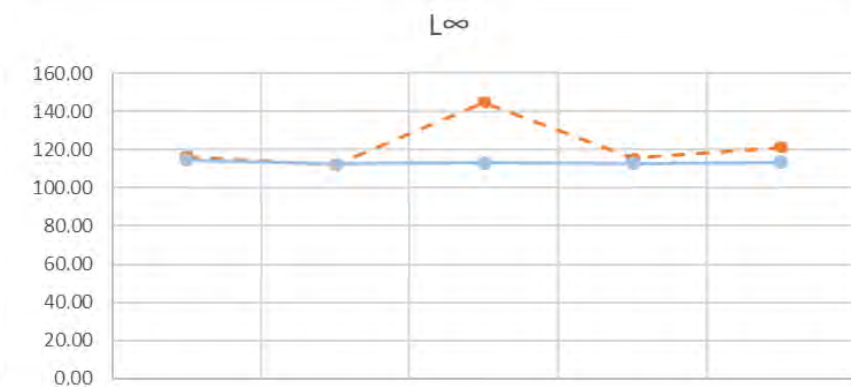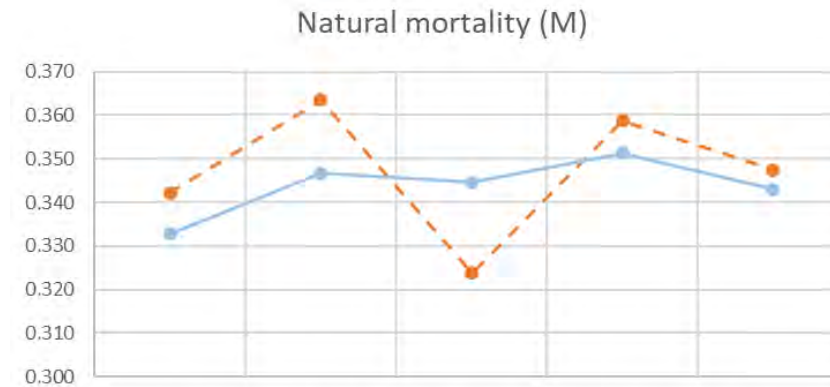
Models –
Parameters (Catchability for Model 19.12 and 22.1)

- Nearly identical trends

- Slightly more extreme values in the Thompson series
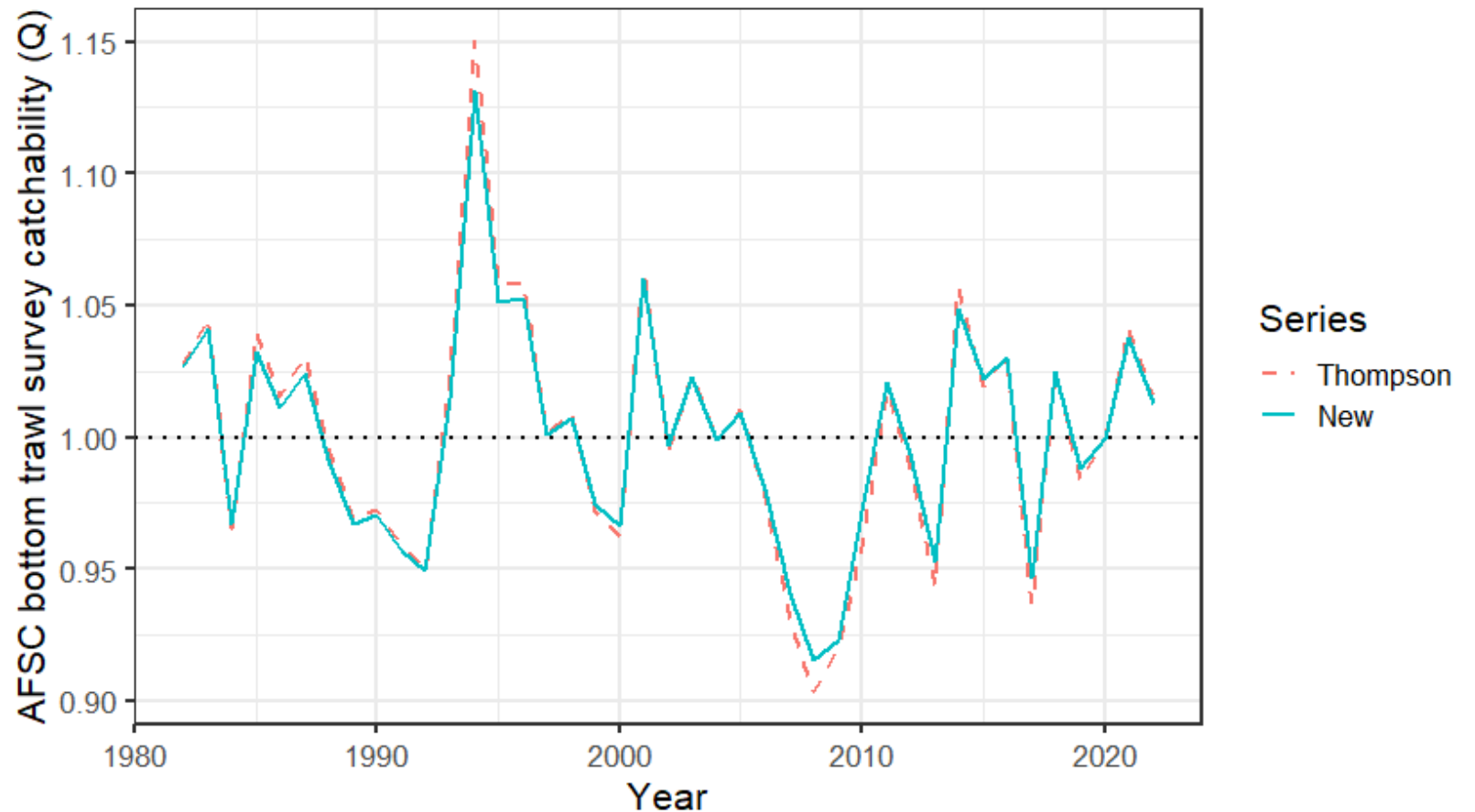
Models –
Fits to AFSC bottom trawl survey

- Nearly identical fits within model sets

- Models 19.12 and 19.12A much tighter fit with annually varying catchability.

- Worse fit in models 21.2 and 22.4 with inclusion of the CPUE index
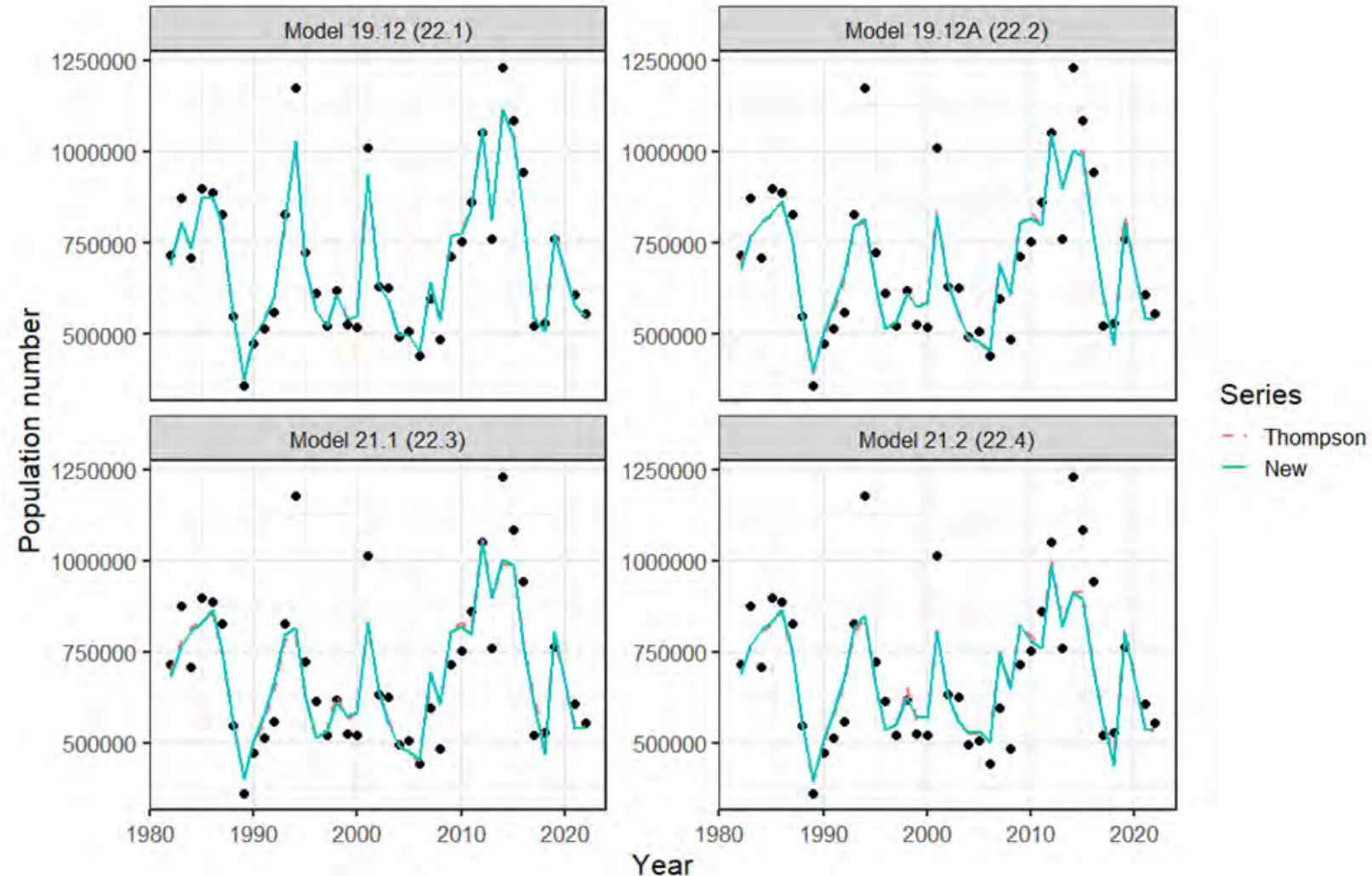
Models –
Fits to winter longline fishery CPUE index

- Again nearly identical fits
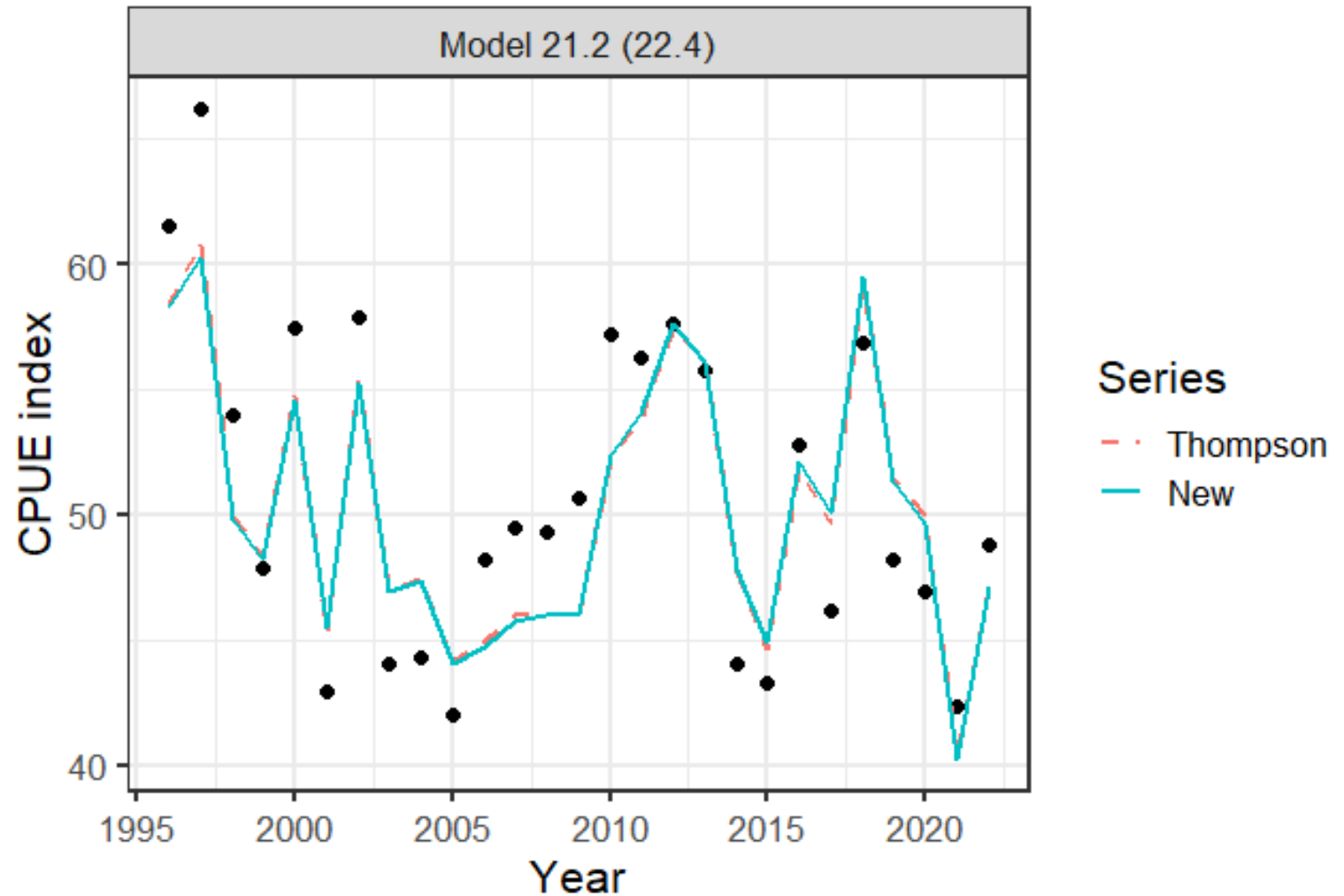
Models –
Fits length and age composition data

- Visually indistinguishable fits for length composition

- Slightly degraded fit for the New Series ensemble models to post-2007 age composition data
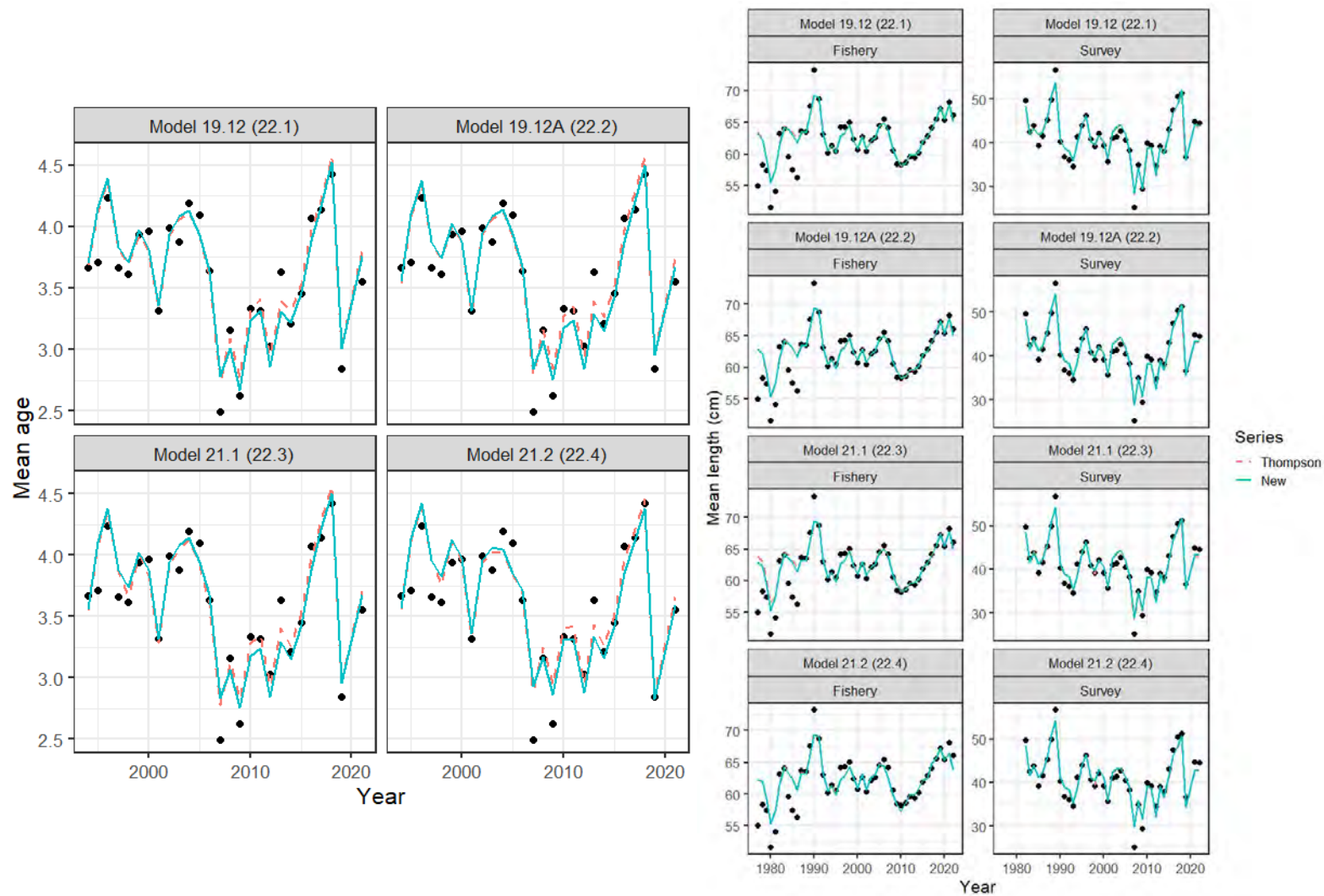
Models – Retrospective analysis

- Consistently low positive bias on Mohn's ρ for SSB from both series
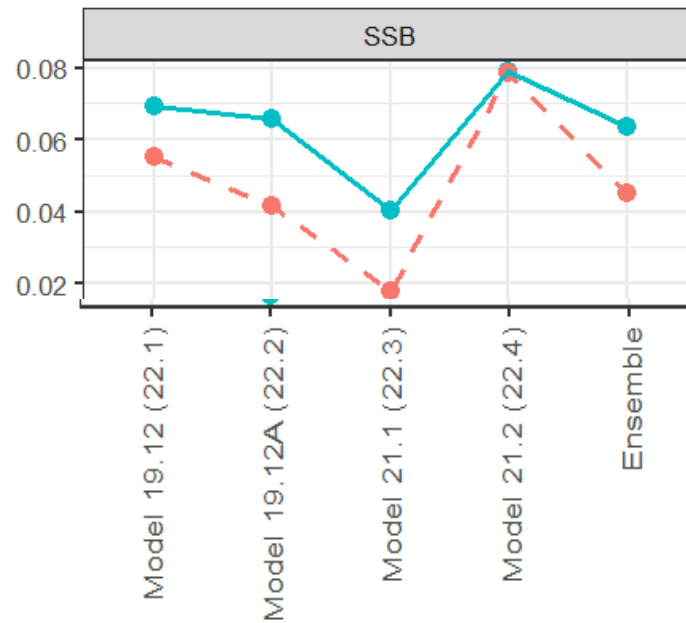
Ensemble retrospective analysis
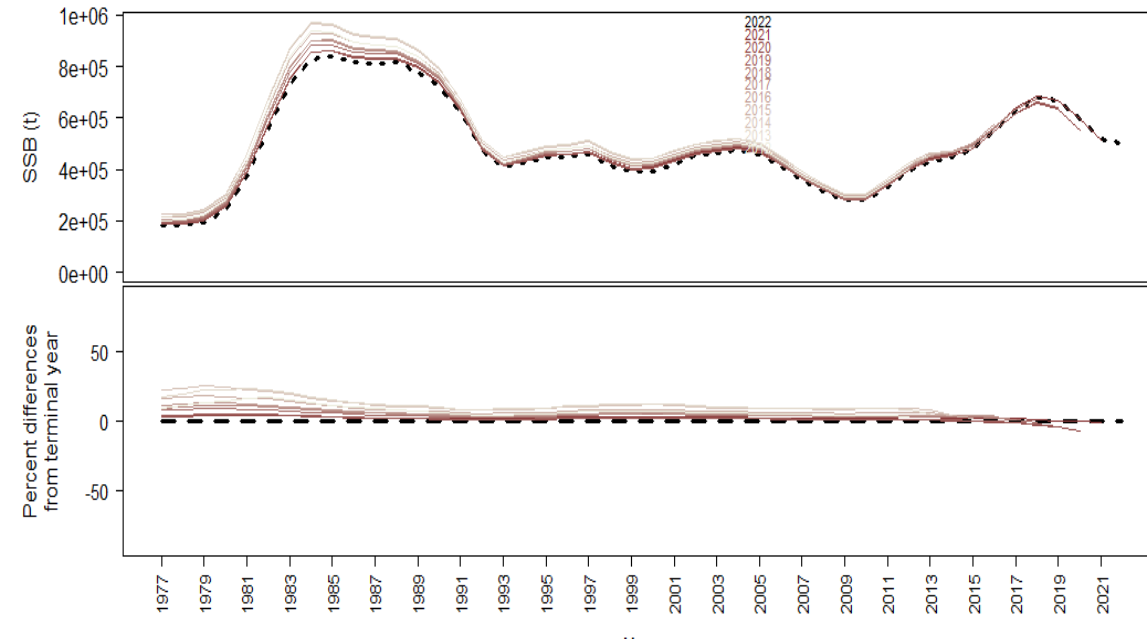
Models – Selectivity generic shapes

- Consistent fishery selectivity shape for New Series models

- Survey selectivity consistent for all asymptotic models

- Small difference in survey selectivity for Model 21.1 and 22.3 which allow for dome-shape

Fishery Selectivity

Survey Selectivity

Models – Derived quantities

- As with the parameters the derived quantities are similar, but less variable for the New Series.

- Ensemble values are very similar.

Female SSB$_{100\%}$ (10^6 t)

$R_0(10^9)$

$F_{40\%}$

MaxABC$_{2023}$ (t)

Model 19.12/22.1   Model 19.12A/22.2   Model 21.1/22.3   Model 21.2/22.4   Ensemble

- - Thompson   — New
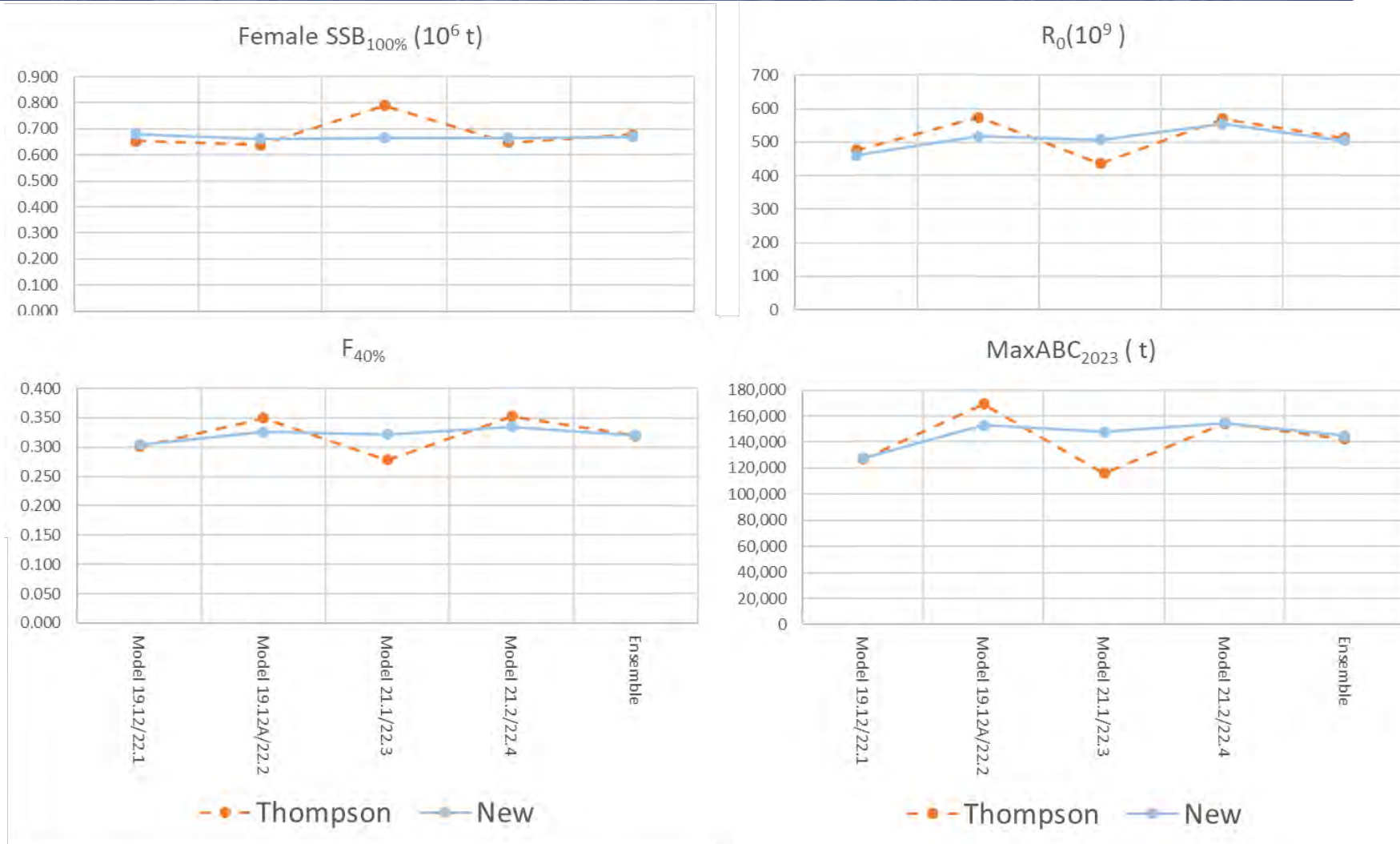
Models –
Runs Test - indices

- Test for autocorrelation in residuals

- Both tests with the CPUE index failed the runs test for the Bottom trawl survey

- All other runs passed

Model	Type	Index	p-value	Test
M19.12	cpue	Survey	0.266	Passed
M19.12A	cpue	Survey	0.280	Passed
M21.1	cpue	Survey	0.100	Passed
M21.2	cpue	Fishery	0.093	Passed
M21.2	cpue	Survey	0.027	Failed
M22.1	cpue	Survey	0.266	Passed
M22.2	cpue	Survey	0.280	Passed
M22.3	cpue	Survey	0.100	Passed
M22.4	cpue	Fishery	0.093	Passed
M22.4	cpue	Survey	0.027	Failed

Models –
Runs Test – Length composition

- Test for autocorrelation in mean length residuals

- All runs except model 19.12 survey length comps failed

Model	Type	Index	p-value	Test
M19.12	len	Fishery	0.010	Failed
M19.12	len	Survey	0.102	Passed
M19.12A	len	Fishery	0.009	Failed
M19.12A	len	Survey	0.001	Failed
M21.1	len	Fishery	0.001	Failed
M21.1	len	Survey	0.005	Failed
M21.2	len	Fishery	0.000	Failed
M21.2	len	Survey	0.000	Failed
M22.1	len	Fishery	0.001	Failed
M22.1	len	Survey	0.028	Failed
M22.2	len	Fishery	0.002	Failed
M22.2	len	Survey	0.000	Failed
M22.3	len	Fishery	0.002	Failed
M22.3	len	Survey	0.000	Failed
M22.4	len	Fishery	0.000	Failed
M22.4	len	Survey	0.000	Failed

Models – Runs Test – Age composition

- Test for autocorrelation in mean age residuals
- All Thompson Series runs passed
- All New Series runs failed except for M22.1
- Accepting no bias in post-2007, failure suggests change in growth that isn't captured in current models.

Model	Type	Index	p-value	Test
M19.12	age	Survey	0.724	Passed
M19.12A	age	Survey	0.494	Passed
M21.1	age	Survey	0.447	Passed
M21.2	age	Survey	0.451	Passed
M22.1	age	Survey	0.724	Passed
M22.2	age	Survey	0.039	Failed
M22.3	age	Survey	0.039	Failed
M22.4	age	Survey	0.039	Failed

Models –
Mean absolute scaled error (MASE)

- Test prediction skill (better than random walk <1.0)

- All data components passed for all models, except…

- All models failed for survey length composition.

| Model | Index | | Lengths | | Age |
	Fishery	Survey	Fishery	Survey	Survey
Model 19.12		0.19	0.31	1.23	0.71
Model 19.12A		0.44	0.33	1.22	0.71
Model 21.1		0.44	0.34	1.21	0.68
Model 21.2	0.41	0.47	0.42	1.28	0.71
Model 22.1		0.20	0.31	1.22	0.76
Model 22.2		0.45	0.32	1.20	0.76
Model 22.3		0.45	0.32	1.19	0.75
Model 22.4	0.42	0.47	0.42	1.28	0.77

Models – Derived quantities

- Spawning biomass slightly higher in early part for Thompson Series

- Higher variability in F in Thompson Series

- Bratio follows same trend as spawning biomass
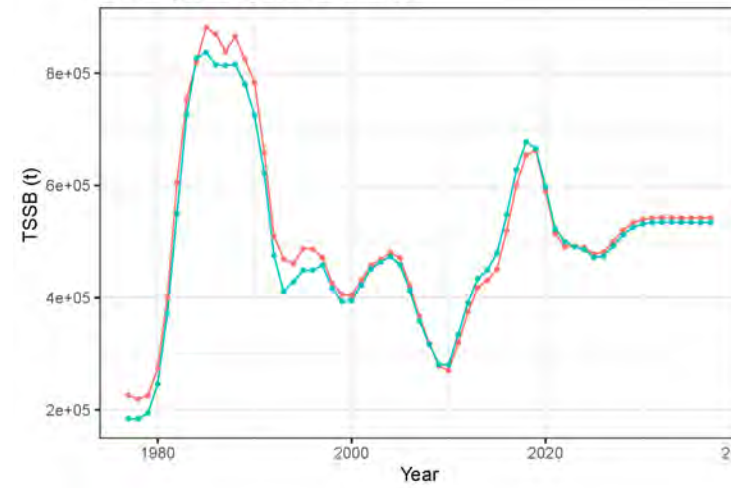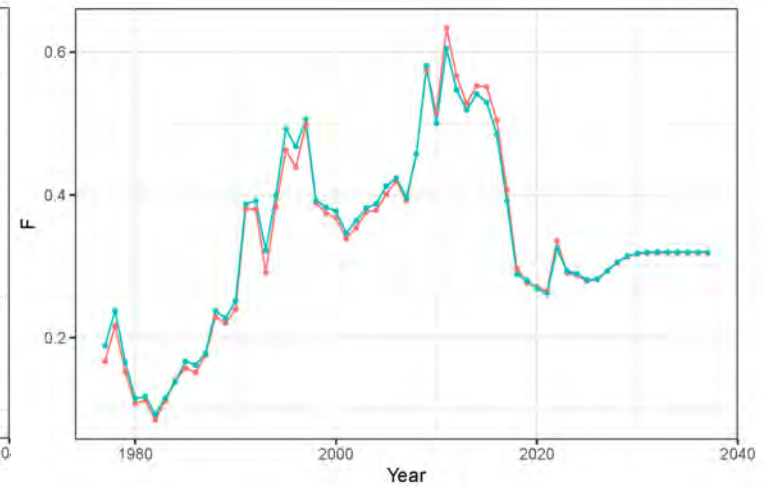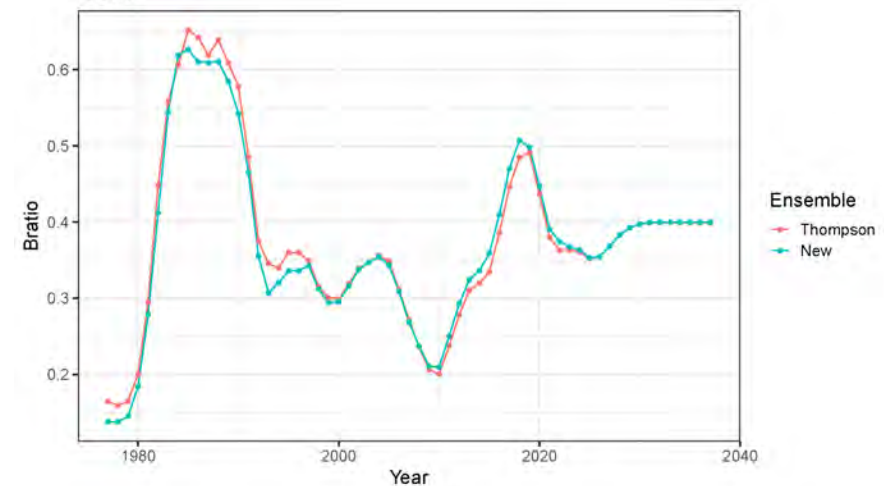
New Series Results – Female spawning biomass

- All four models show reduction from 2018 high point.

- Model 22.4 with CPUE index indicates higher SSB earlier in the time series and lower in most recent
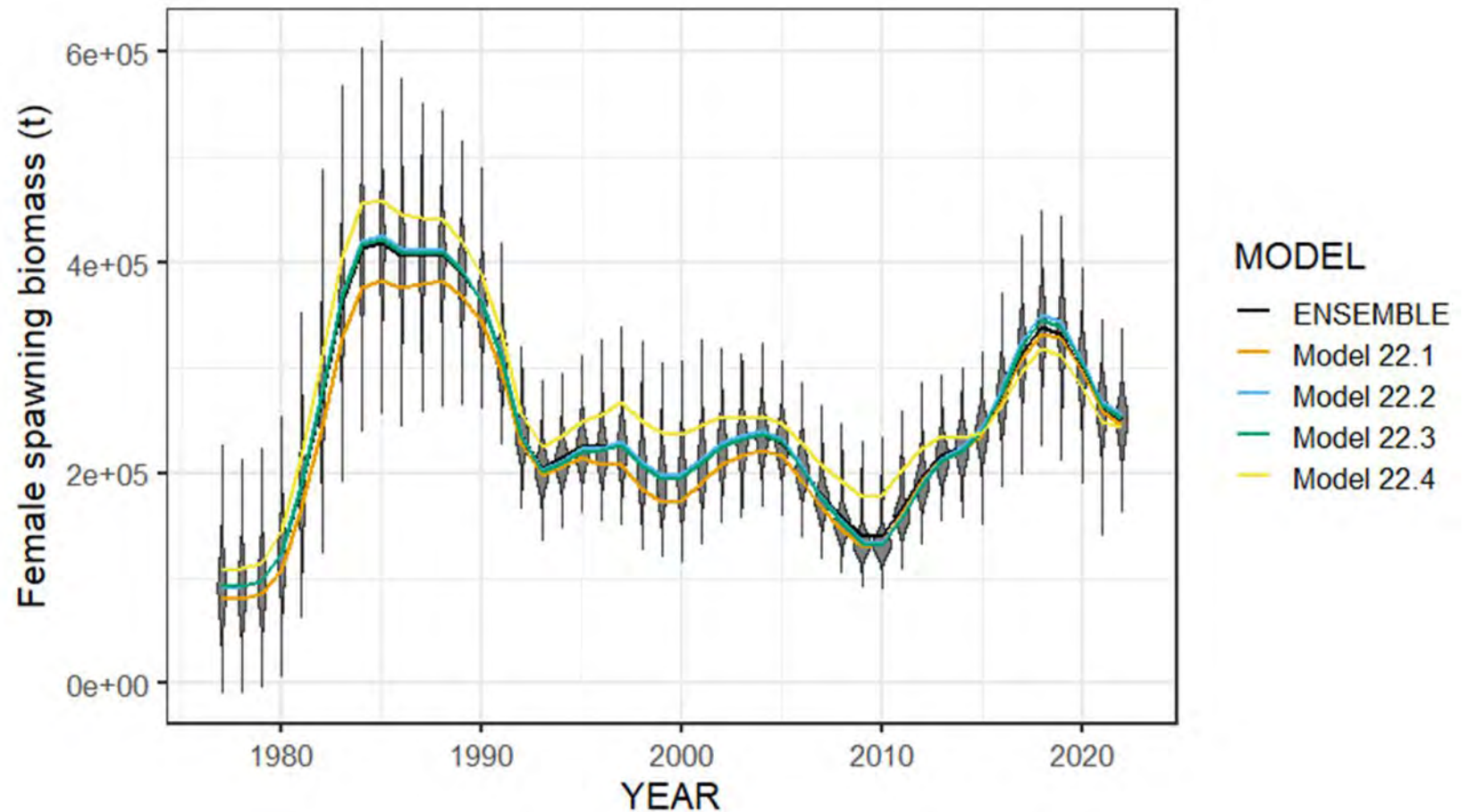
New Series Results – Female spawning biomass

- High point in the mid to late 1980s

- Low point in 2010 at $B_{21\%}$

- Currently below $B_{40\%}$
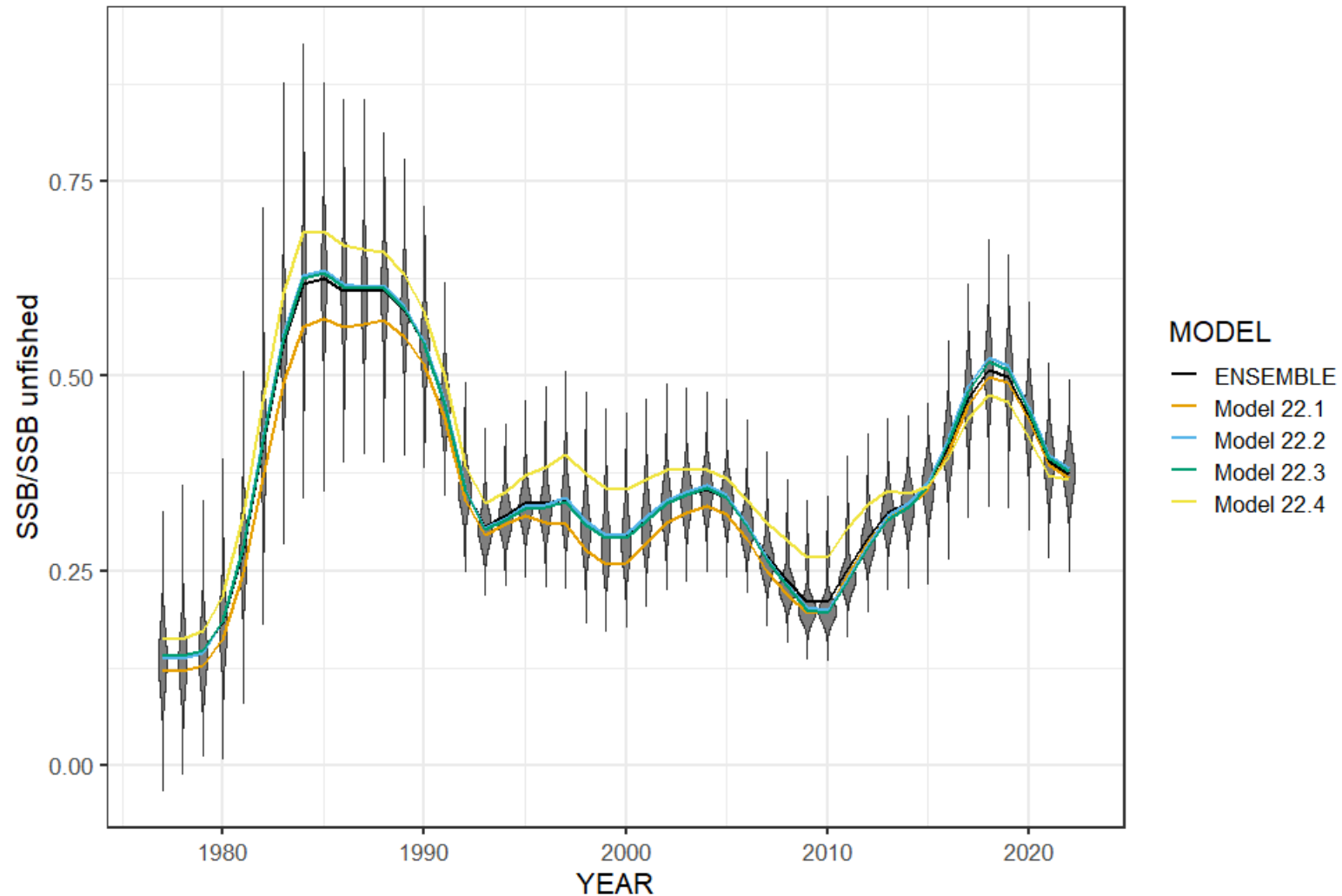
New Series Results – Age-0 recruitment

- Large 2018 year class

- 2014-2017, 2019, and 2020 estimated to be below average

- 2021 and 2022 set at $\sim R_0$ as not yet well defined in the data.
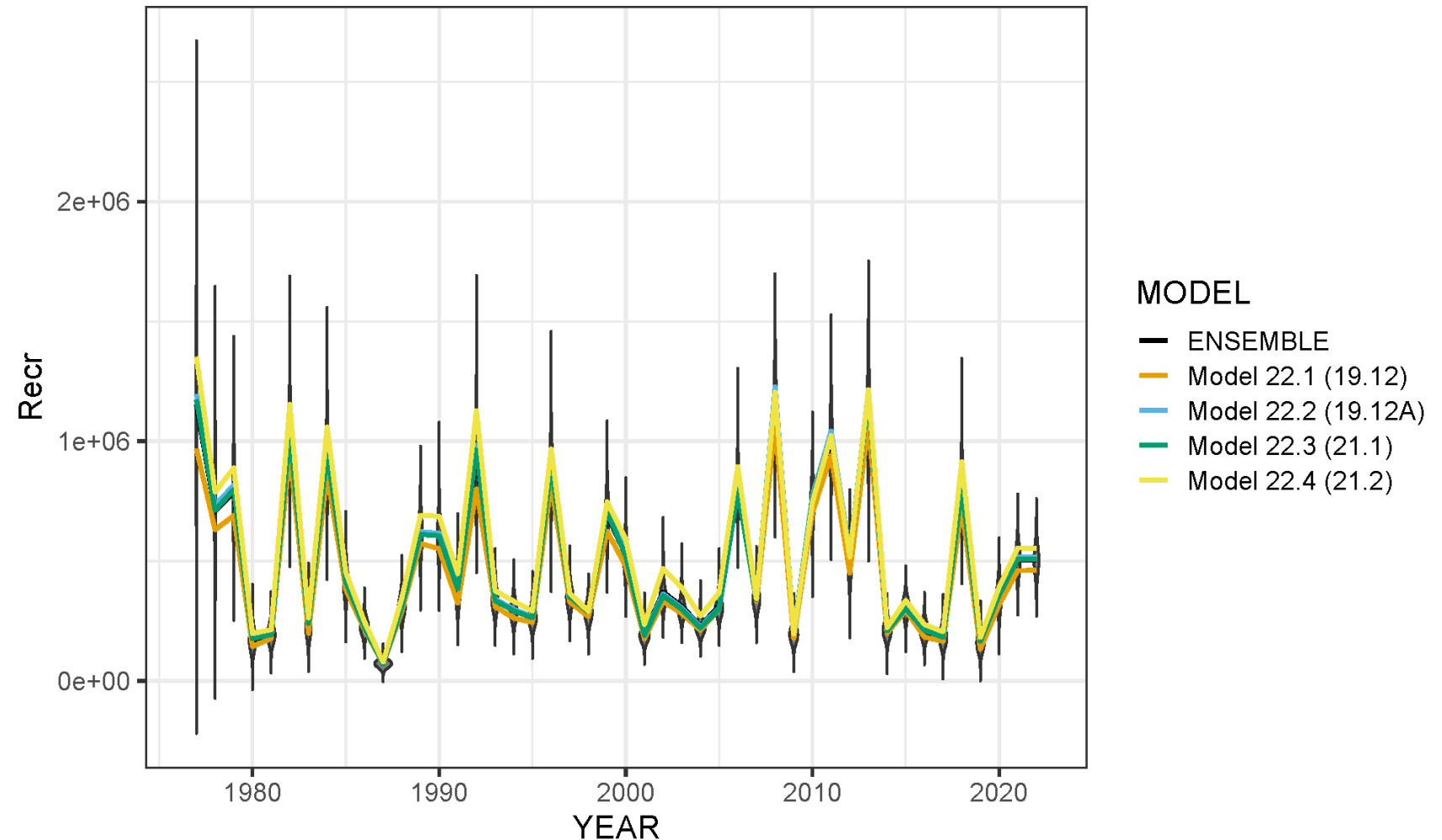
New Series Results – Apical fishing mortality

- High fishing mortality from 2008-2016 with dome-shaped survey selectivity

- Drop in F 2017-2021 change to asymptotic survey selectivity.

- Increase in 2022 due again to change in model with ensemble
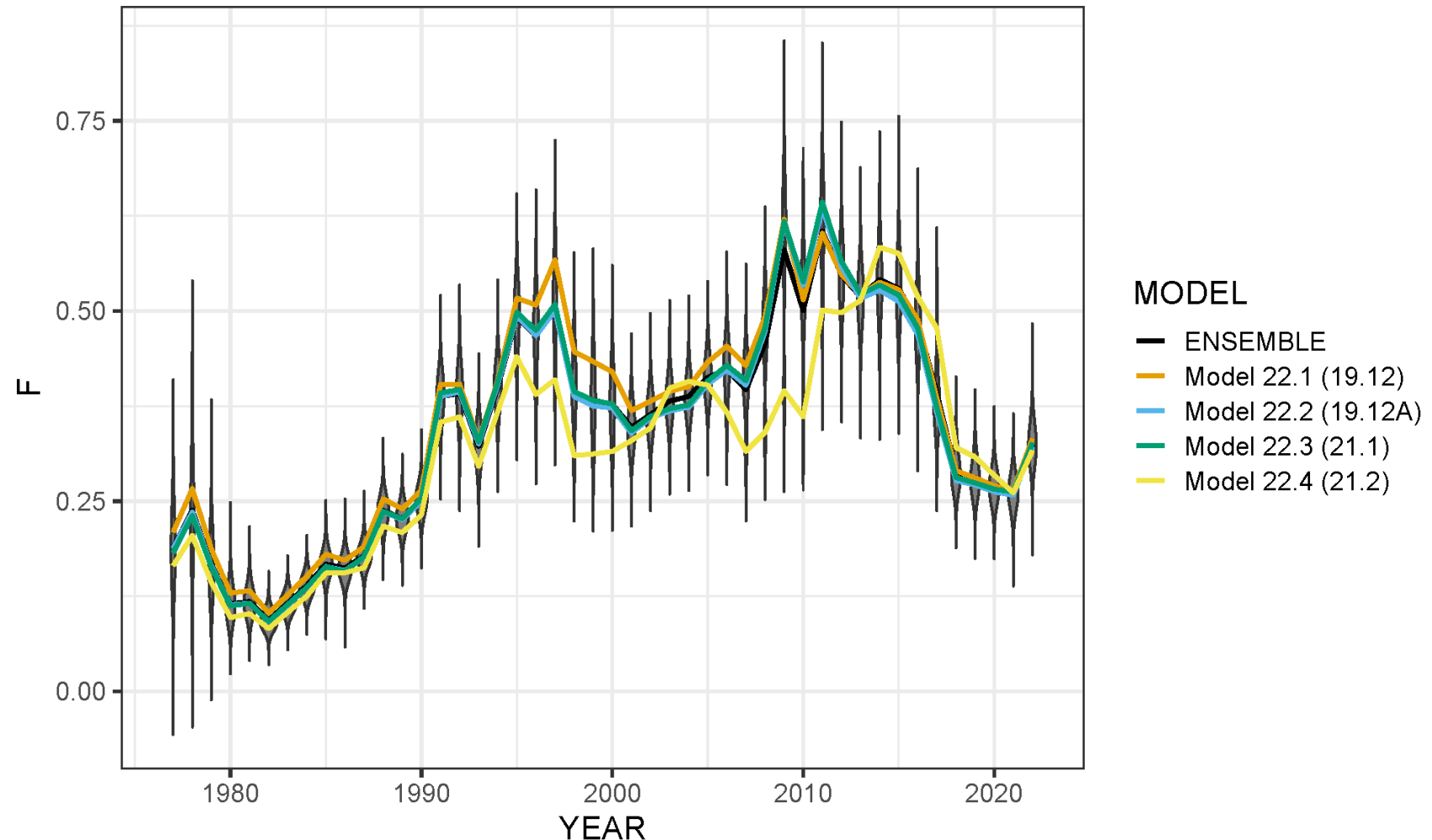
Phase Plane

- High fishing mortality from 2008-2016 with dome-shaped survey selectivity

- Drop in F 2017-2021 change to asymptotic survey selectivity.

- Increase in 2022 due again to change in model with ensemble
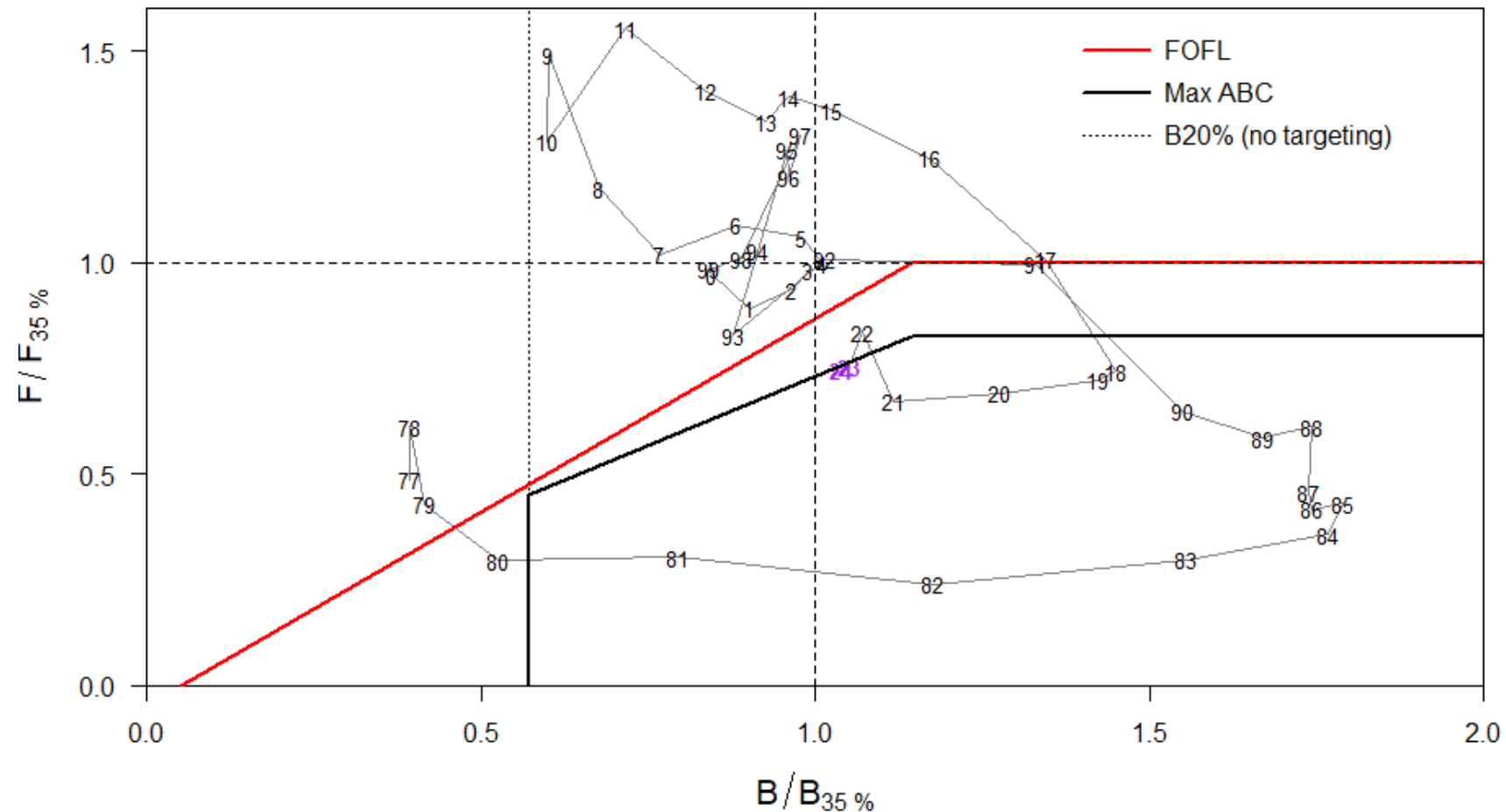
Risk Table

Assessment-related considerations	Population dynamics considerations	Environmental/ ecosystem considerations	Fishery Performance considerations
Level 1: Normal	**Level 1:** Normal	**Level 1:** Normal	**Level 1:** Normal

Assessment : No heightened concerns, autocorrelation in residuals for post-2007 suggests change in growth that may not be captured in current model

Pop. Dynamics: All concerns captured within the models and ensemble.

**Environment/Ecosystem:** Conditions near normal/average across the board, except ATF remains high.
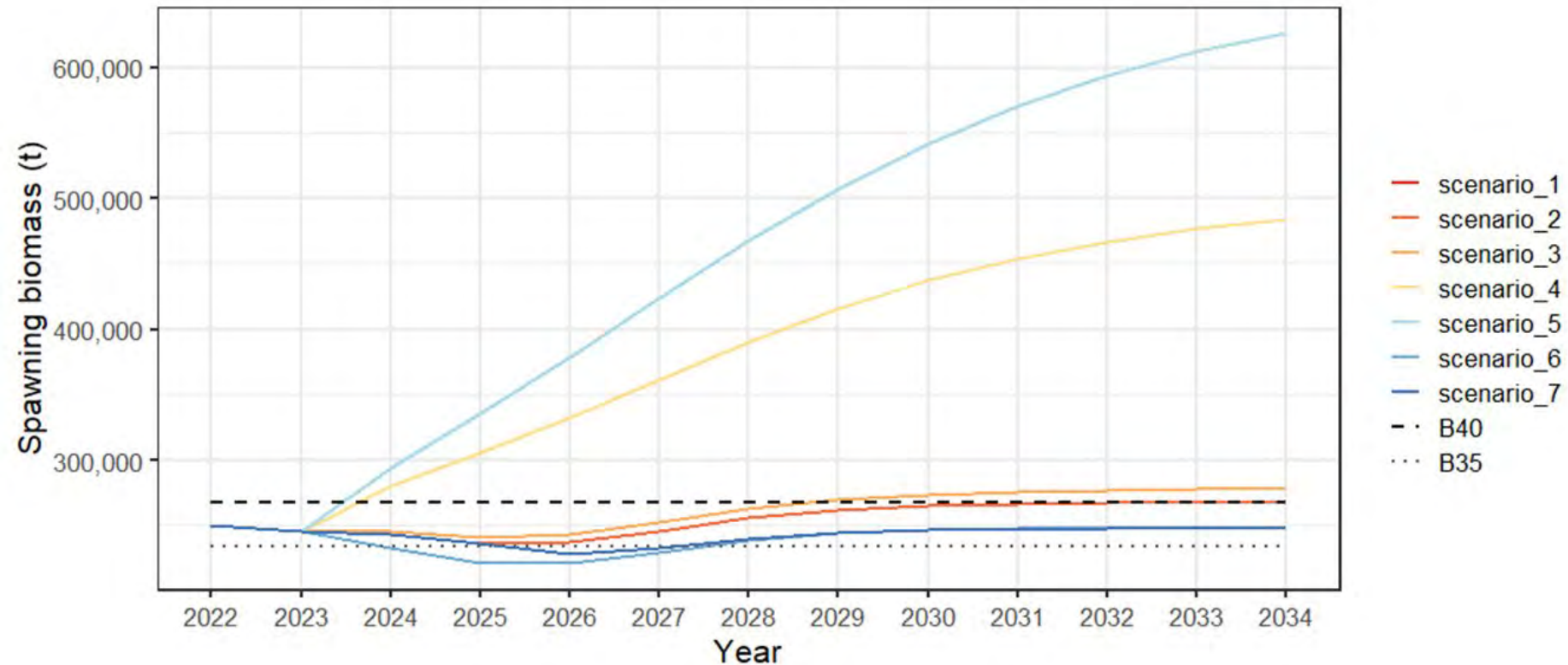
Fishery Performance: No heightened concerns, overall CPUE relatively stable for past 9 years, increase in winter longline fishery CPUE index in 2022. Average catch rates.

New Series ensemble – Projection scenarios

- Not overfishing
- Not overfished
- Not approaching an overfished condition

- With average recruitment projected decline through 2026

Harvest Recommendation

Unfished female spawning biomass (t)
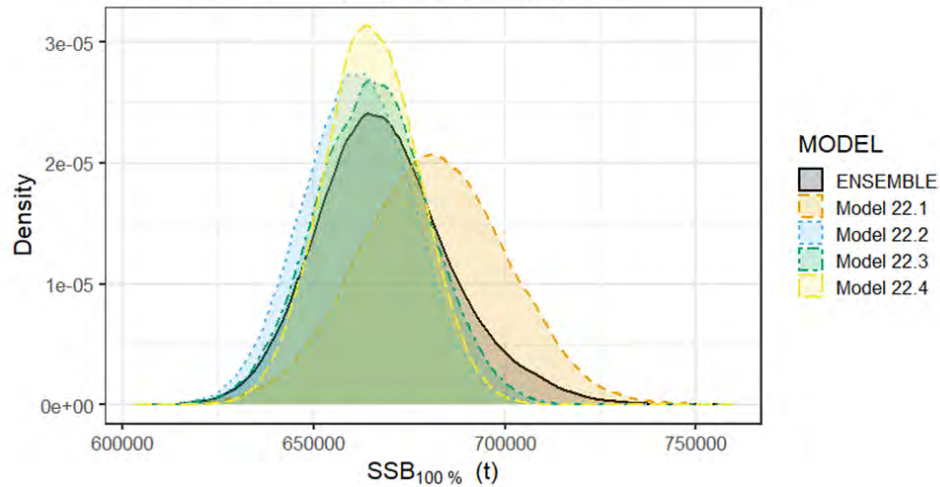
Year	Quantity	Last Year	New Series	Change
	$B_{100\%}$	686,761	668,477	-2.70%
2023	Tot Biom Age 0+	848,615	844,578	-0.50%
2023	B_{2023}	254,585	245,594	-3.50%
2023	$B_{\%}$	0.370	0.367	-0.80%
2023	maxF_{ABC}	0.310	0.293	-5.50%
2023	maxABC	151,709	144,834	-4.50%
2024	Tot biom Age 0+		831,566	
2024	B_{2024}		242,911	
2024	$B_{\%}$		0.364	
2024	maxF_{ABC}		0.29	
2024	maxABC		140,159	

Harvest Recommendation

2023 — $B_{37\%}$

2024 — $B_{36\%}$

2023 — 144.8 KT

2024 — 140.2 KT
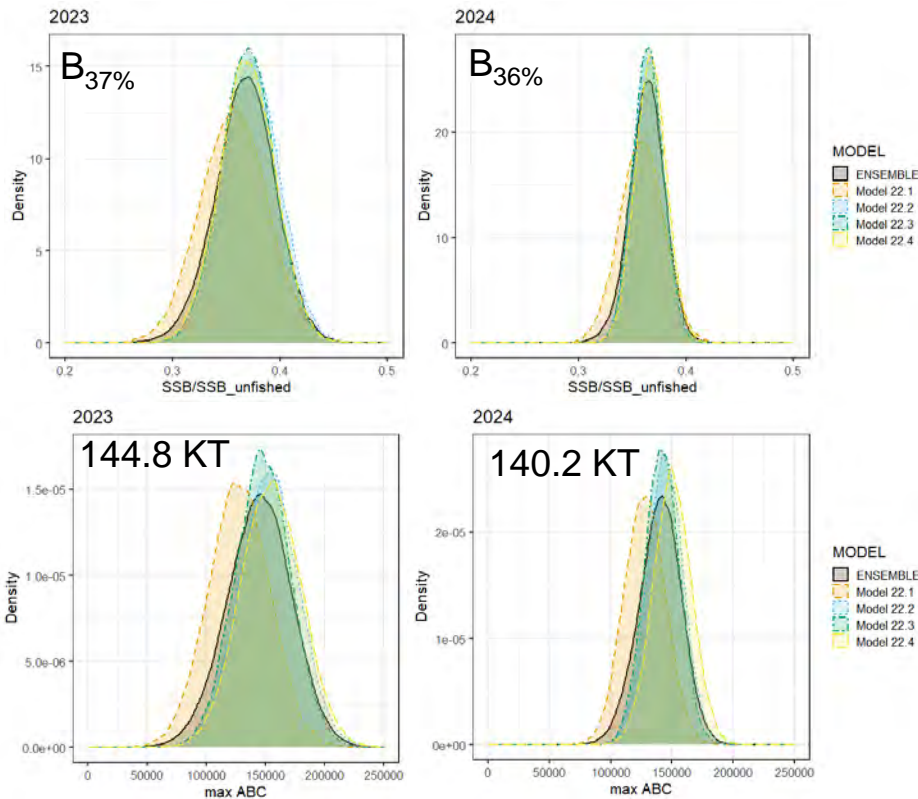
Quantity	As estimated or specified last year for:		As estimated or recommended this year for:	
	2022	2023	2023*	2024*
M (natural mortality rate)	0.34	0.34	0.34	0.34
Tier	3b	3b	3b	3b
Projected total (age 0+) biomass (t)	879,978	848,615	844,578	831,566
Projected female spawning biomass (t)	259,789	254,585	245,594	242,911
$B_{100\%}$	686,761		668,477	
$B_{40\%}$	274,704		267,391	
$B_{35\%}$	240,366		233,467	
F_{OFL}	0.38	0.37	0.36	0.35
$maxF_{ABC}$	0.31	0.31	0.29	0.29
F_{ABC}	0.31	0.31	0.29	0.29
OFL (t)	183,012	180,909	172,495	166,814
maxABC (t)	153,383	151,709	144,834	140,159
ABC (t)	153,383	151,709	144,834	140,159
Status	As determined last year for:		As determined this year for:	
	2020	2021	2021	2022
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 152,146 t, and 144,834 t in 2022 and 2023, respectively.

QUESTIONS?