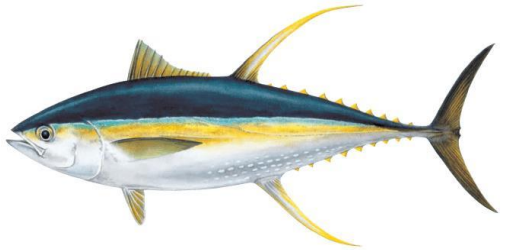
Stock assessment of yellowfin tuna (*Thunnus albacares*) in the WCPO

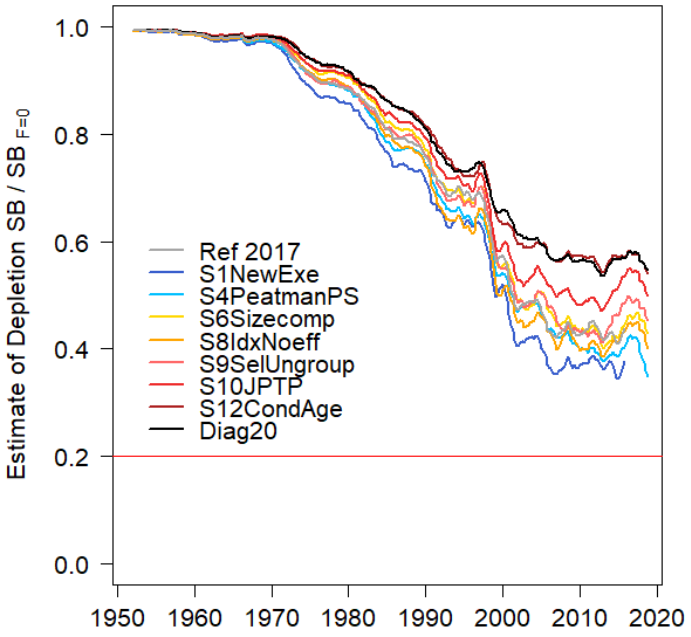
WCPFC-SC19-2023/SA-WP-04
August 2023

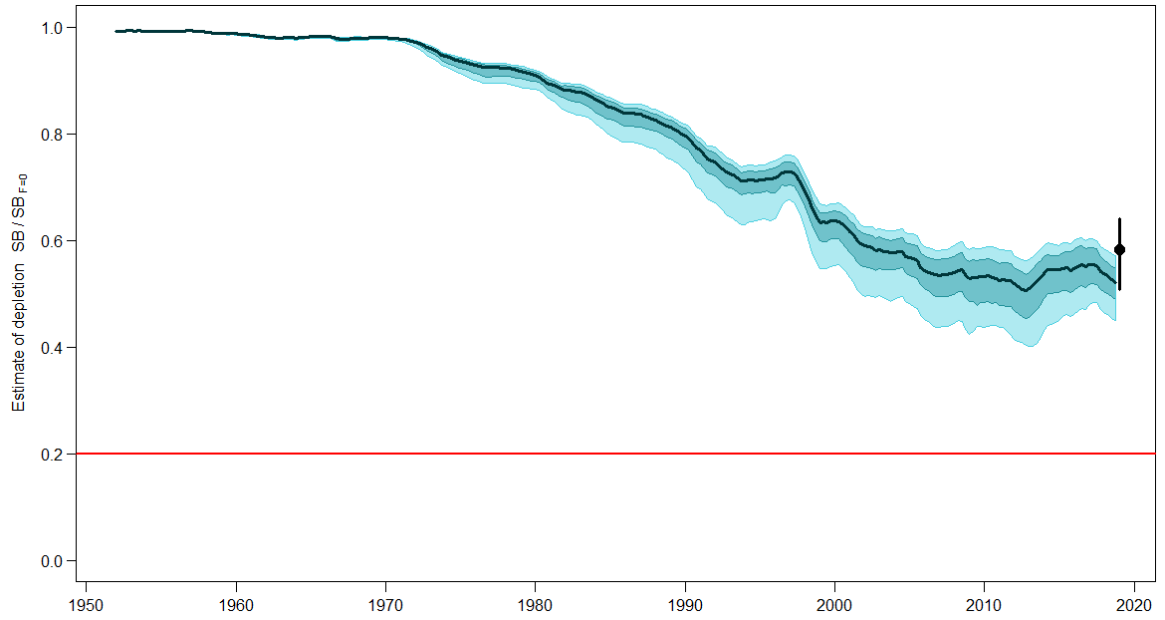


A. Magnusson[1], J. Day[1], T. Teears[1], J. Hampton[1], N. Davies[2], C. Castillo Jordán[1], T. Peatman[3], R. Scott[1], J. Scutt Phillips[1], S. McKechnie[1], F. Scott[1], N. Yao[1], R. Natadra[1], G. Pilling[1], P. Williams[1], P. Hamer[1]

1 Oceanic Fisheries Programme, the Pacific Community
2 Te Takina Ltd
3 Private Consultant

YFT 2020 in a Nutshell (Vincent et al. 2020)





	Median	10th percentile	90th percentile
$F_{\text{recent}}/F_{\text{MSY}}$	0.36	0.27	0.47
$SB_{\text{recent}}/SB_{F=0}$	0.58	0.51	0.64

Considerably more optimistic about current stock status than previous assessments

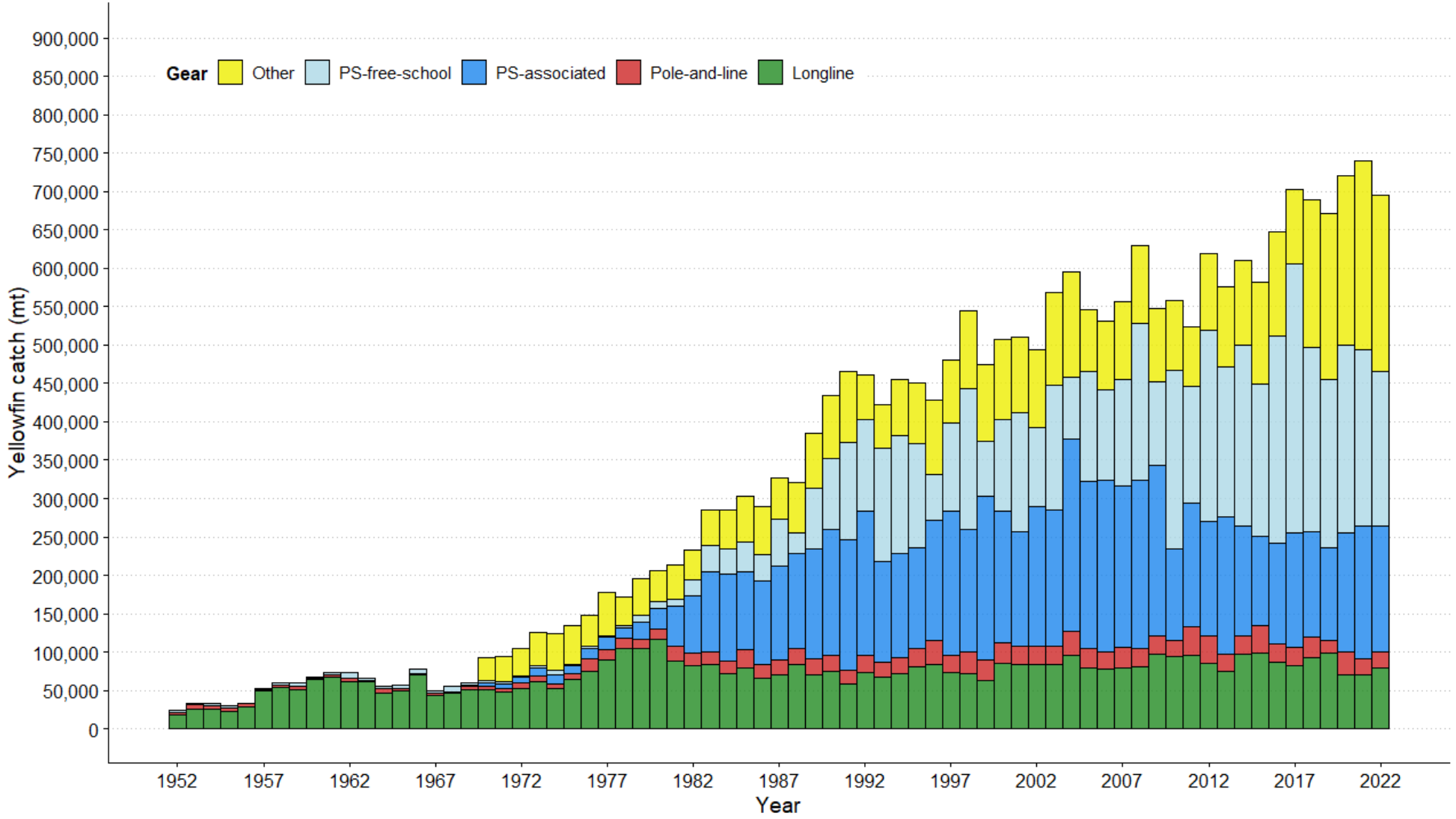
Stock not overfished, overfishing not occurring

Axis	Levels	Option 1	Option 2	Option 3	Option 4
Tag mixing (# quarters)	2	1	**2**		
Size data weighting divisor	4	20	**60**	200	500
Growth model	3	Modal estimate	External otolith	**Cond age-at-length**	
Steepness	3	0.65	**0.80**	0.95	

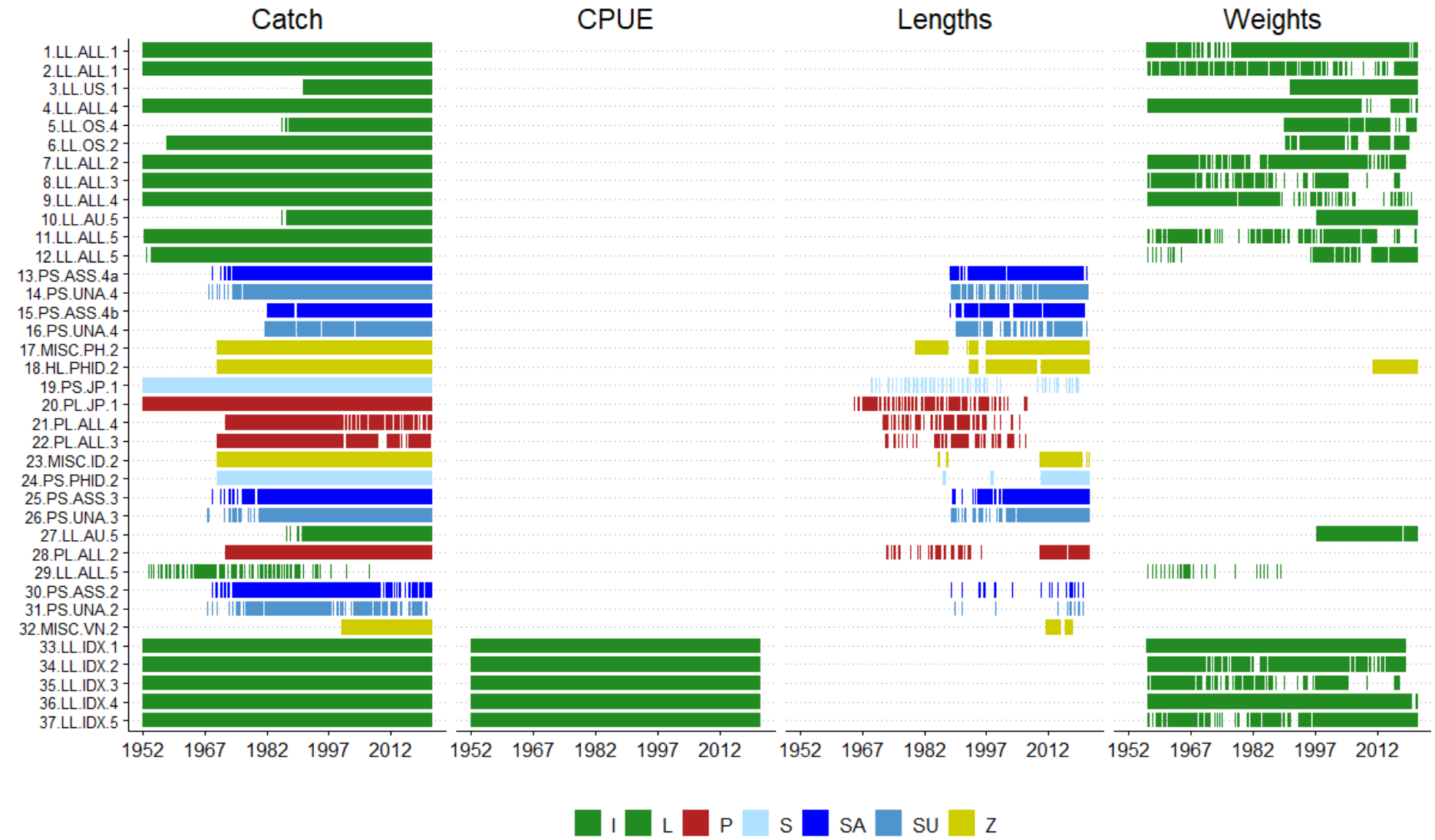
2023 YFT Assessment: Highlights and Key Changes

• Estimate Lorenzen M	(2023 CAPAM)
• Catch-conditioned model, CPUE likelihood	(2022 Review D.1)
• Simplified regional structure, 5 regions	(2022 Review B.5)
• Changes to data weighting: CPUE, CAAL, size comps	(2022 Review A.3, A.4)
• Statistically based CPUE CV, region-specific	(2020 SC Outcomes 70)
• Size composition filtering, tail compression	(2022 Review B.1)
• CPUE data preparation: sdmTMB, new covariates	(2022 Review A.5)
• Tagging data preparation: revised tagger effect	(2022 SPC workshop)
• Fully jittered grid, Hessian calculations	(2022 Review E.0)
• Incorporation of estimation uncertainty	(2022 Review B.4)
• MULTIFAN-CL version 2.2.x.0	(2023 Davies et al.)

Catch History

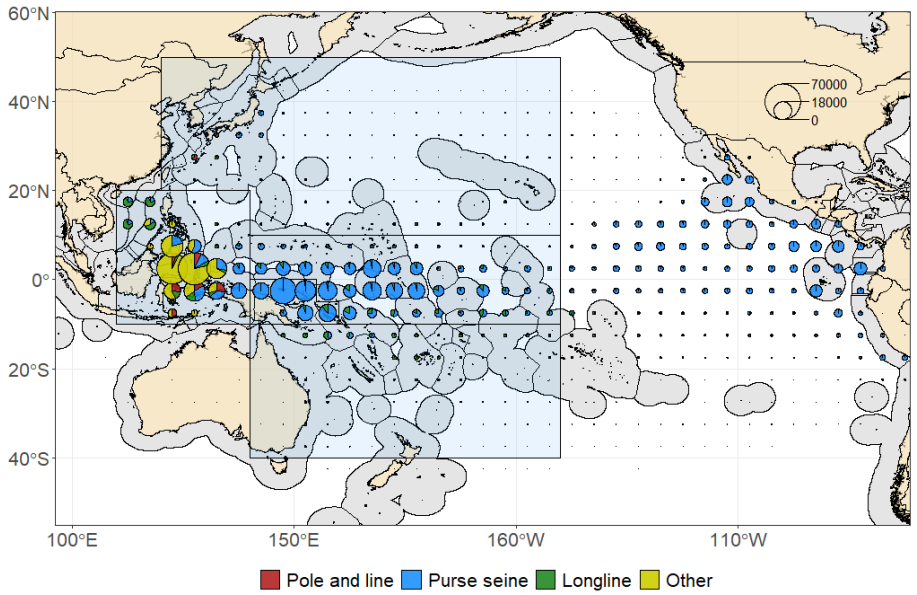


Data Overview: Catch, CPUE, Size Comps



Data Overview: Tags, Otoliths

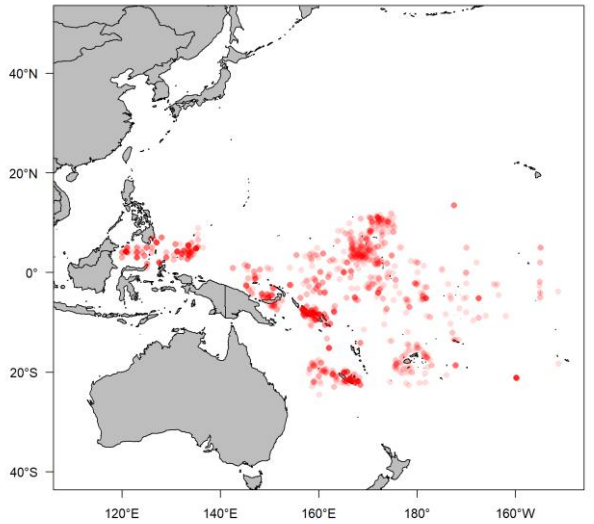
Catches

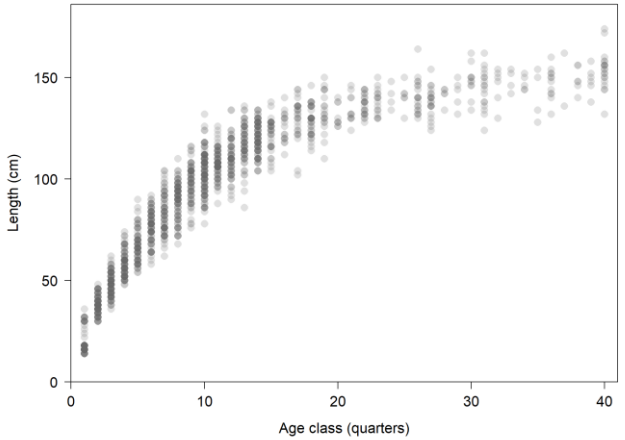


Tagging data

Program	Release years
JPTP	1997–2017
PTTP	2006–2020
RTTP	1989–1995

Conditional age-at-length (otoliths)





Problems with 9 Region Structure

Model complexity was too high

- Identified and discussed by 2022 Independent Review Panel, 2023 Pre-Assessment Workshop
- Recommendation to simplify model structure

Preventing model convergence

- Model had problems finding the best fit to the data
- Model could not achieve a positive definite Hessian

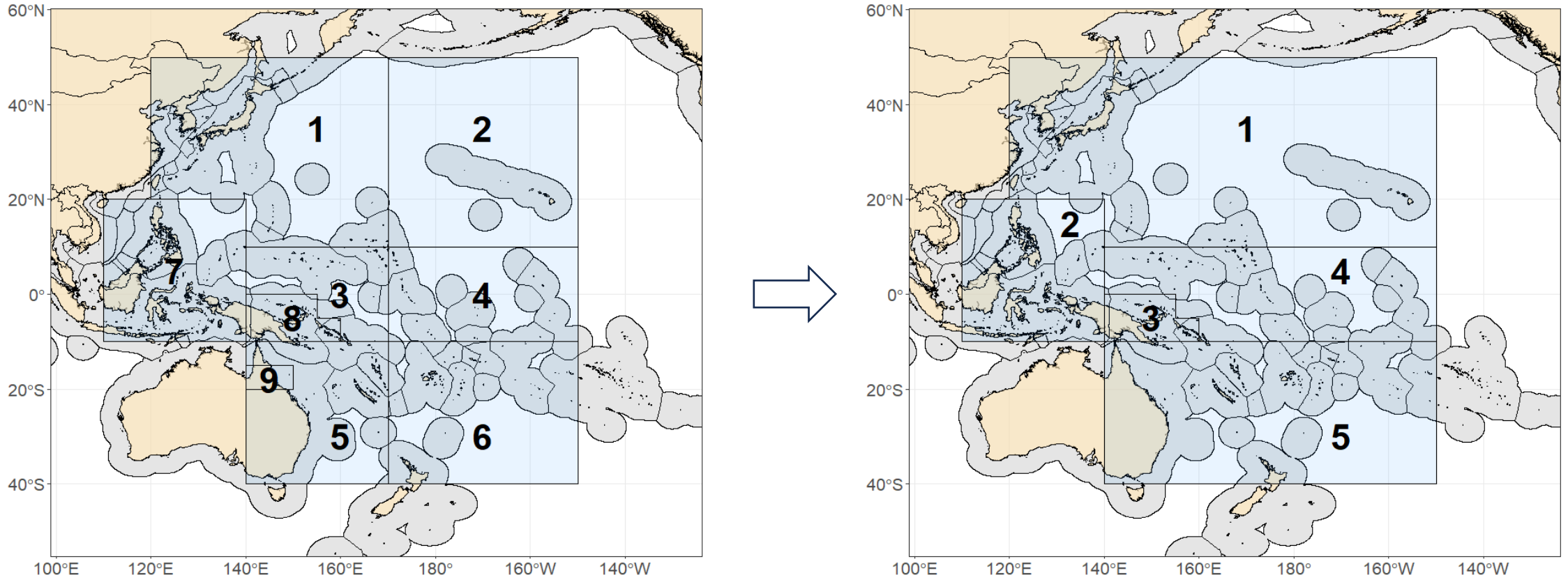
Estimating more complex dynamics than the information content in data allows

- Interaction between year × quarter × region recruitment and movement between regions
- Entire regions had zero estimated recruitment
- Estimate movement would sometimes be opposite of observed trends in tagging data

Simpler structure, fewer parameters helps with robustness

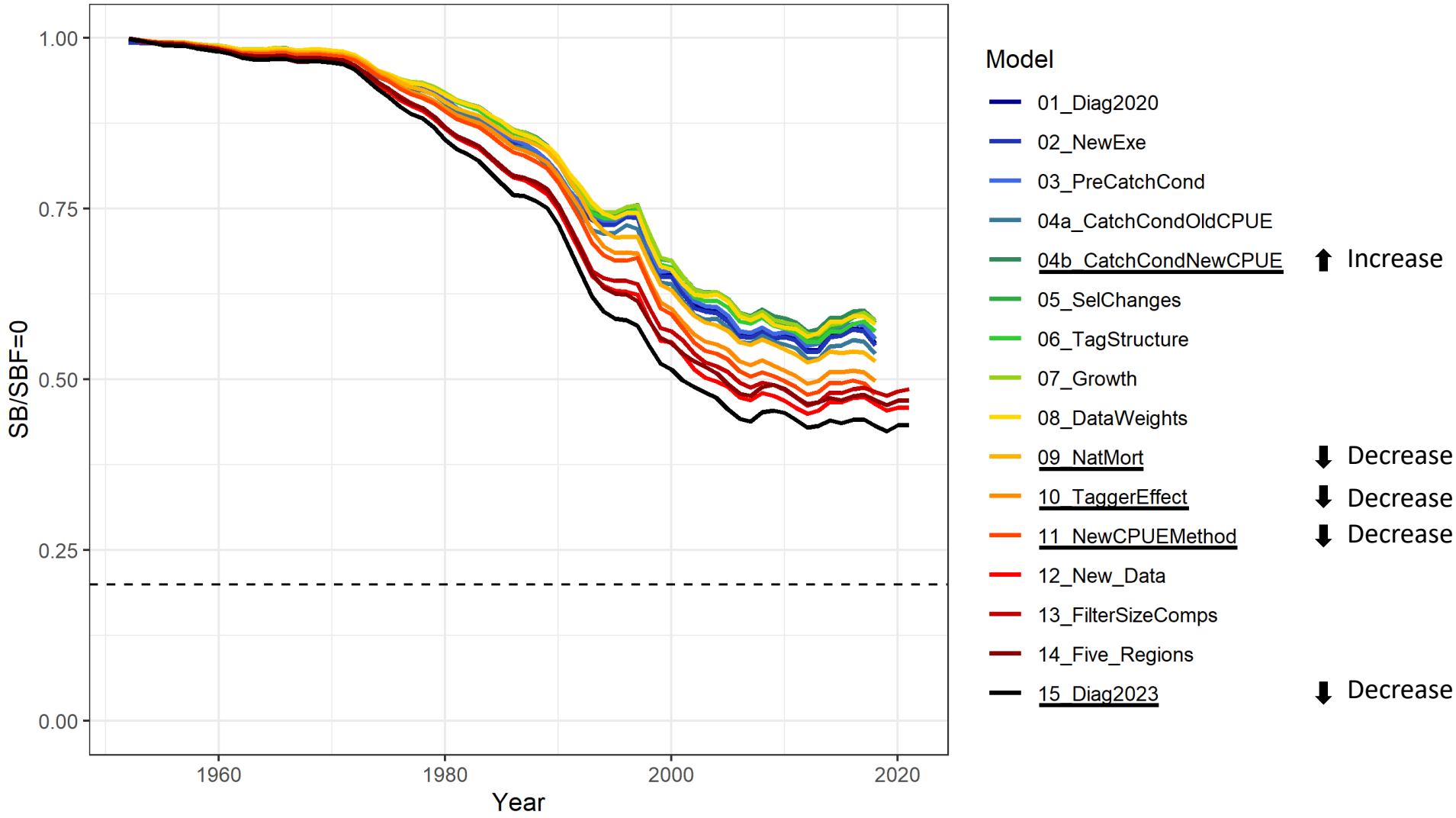
- Otherwise, tiny changes in model settings can result in large changes in estimated stock status
- Model parsimony is a general objective in all statistical modelling

Five Region Structure



"Everything should be made as simple as possible, but no simpler"

Stepwise Model Development



Model Overview

MULTIFAN-CL version 2.2.x.0

5 regions

1952–2021, quarterly time steps

32 fisheries + 5 CPUE indices

Internally estimated M, Lorenzen

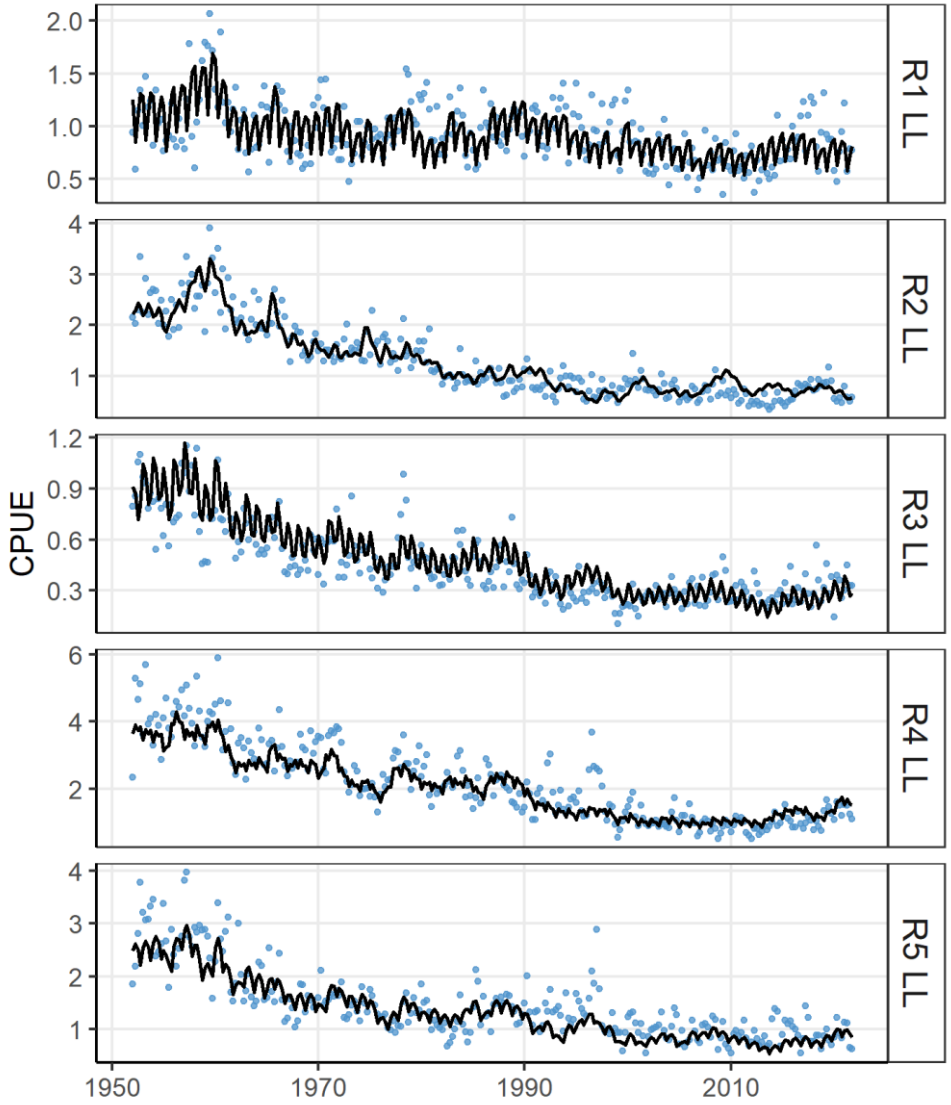
Internally estimated growth, von Bertalanffy

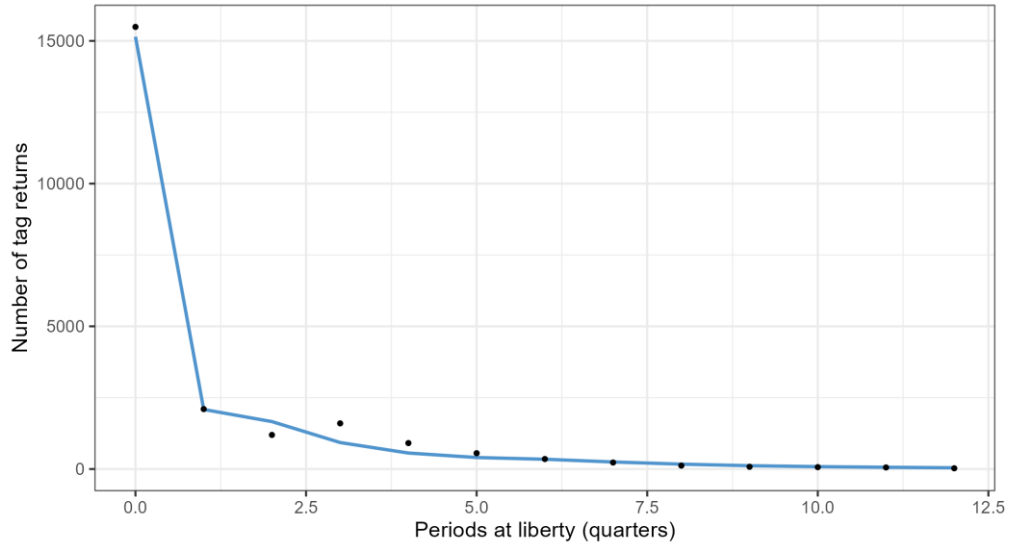
Major reduction of parameters 11,688 → 1,901

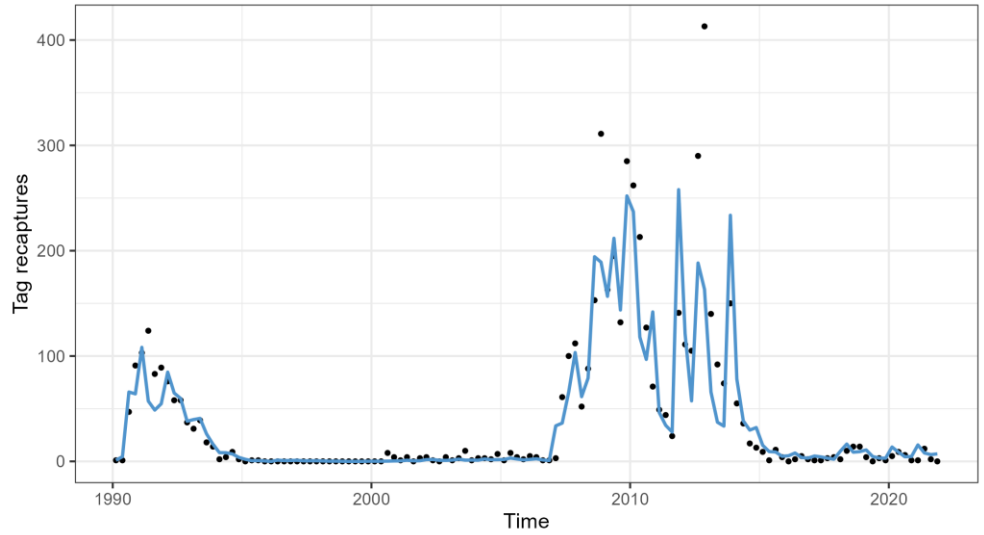
Likelihoods based on model fits to data

- Length comps
- CPUE
- CAAL (otoliths)
- Weight comps
- Tags

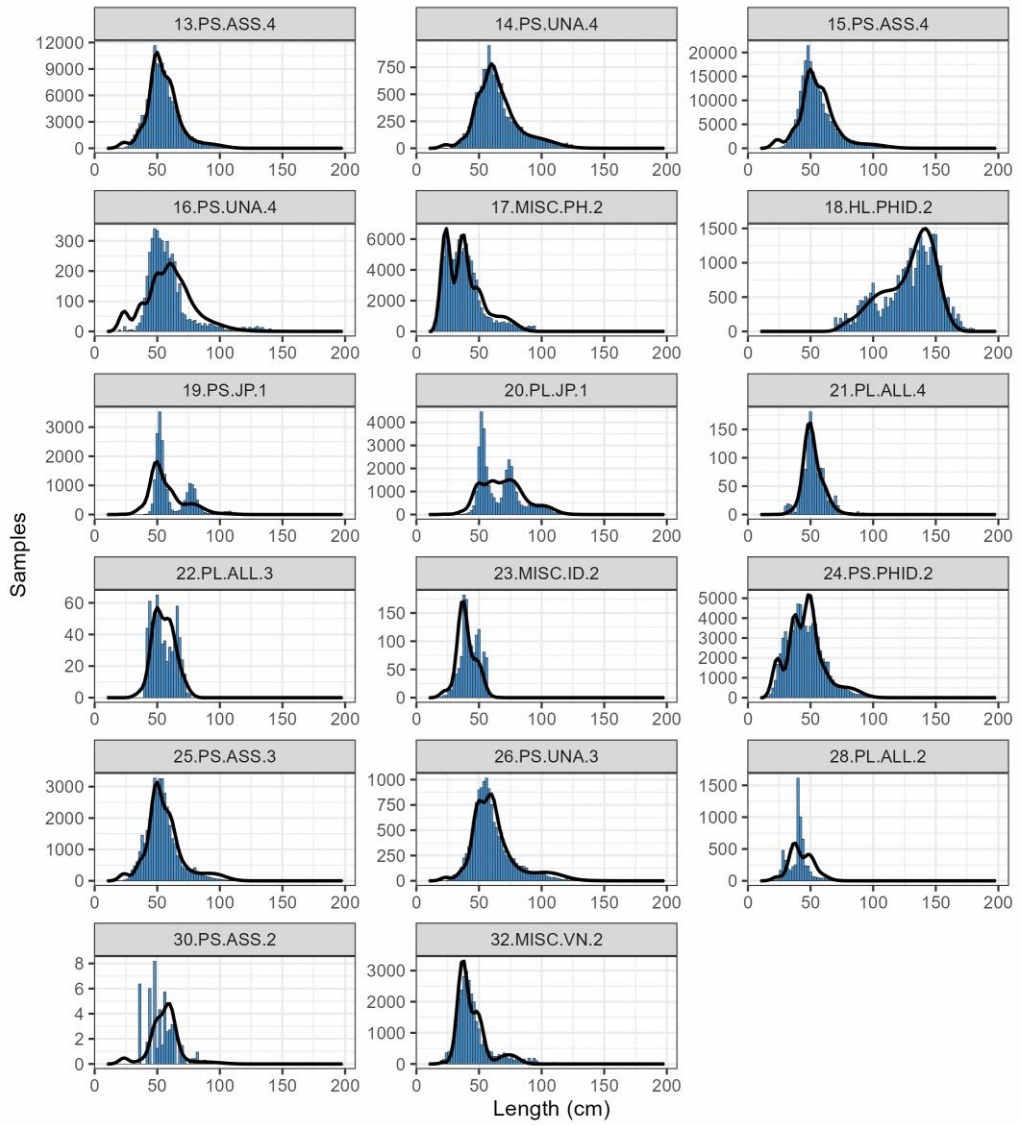
Fit to Data: CPUE and Tags

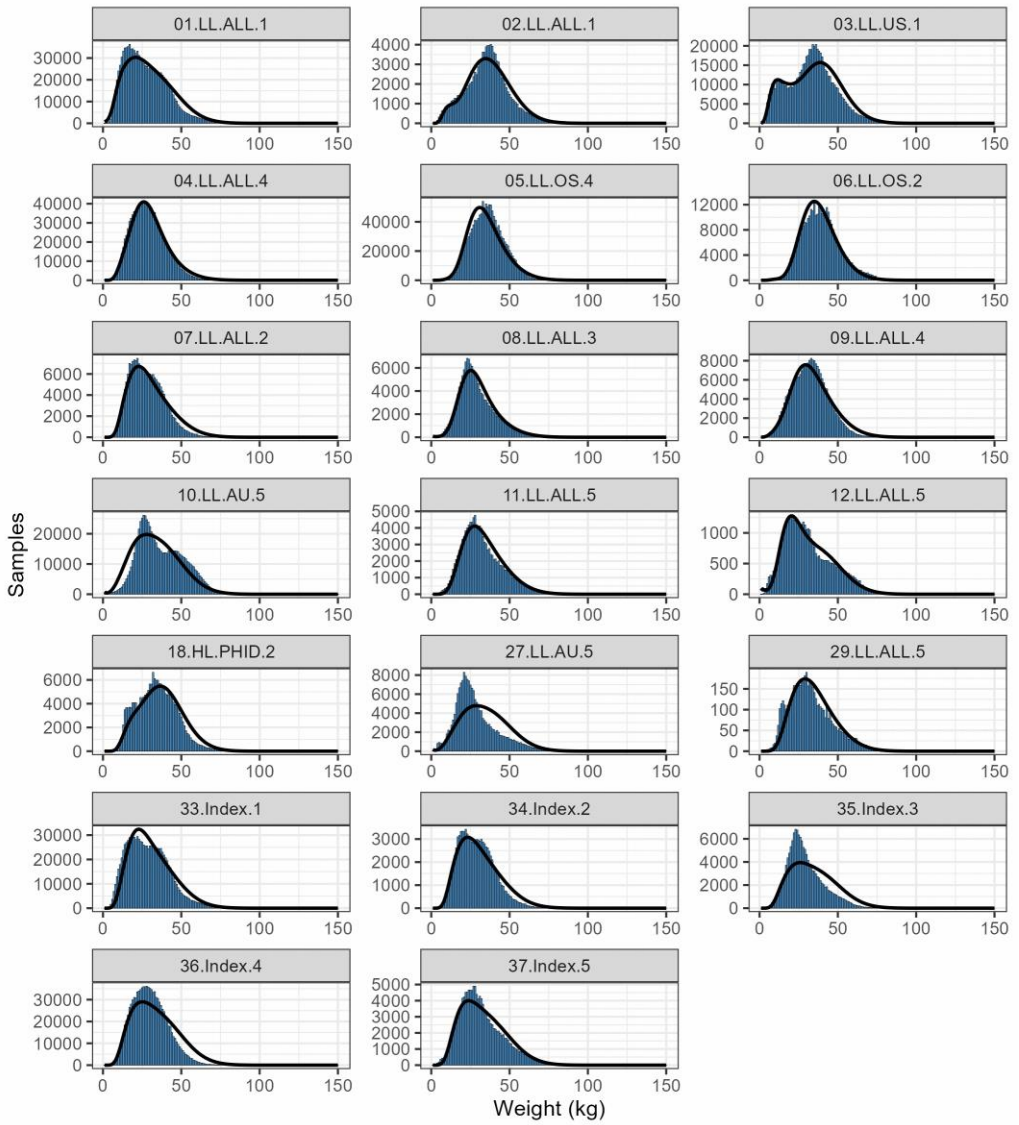




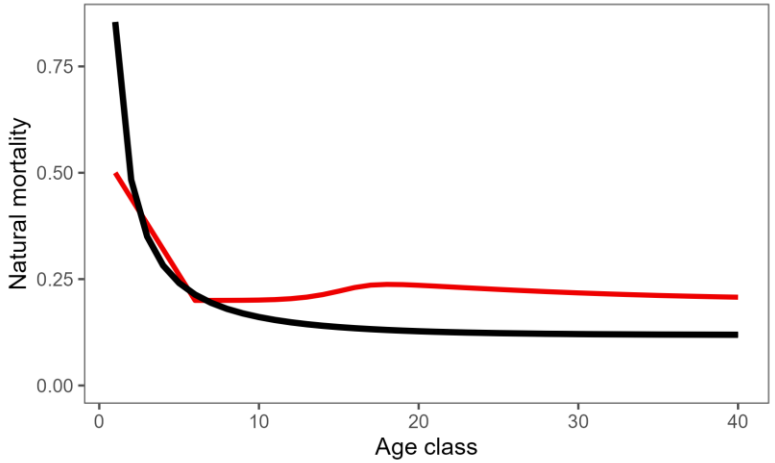


Fit to Data: Length Comps and Weight Comps



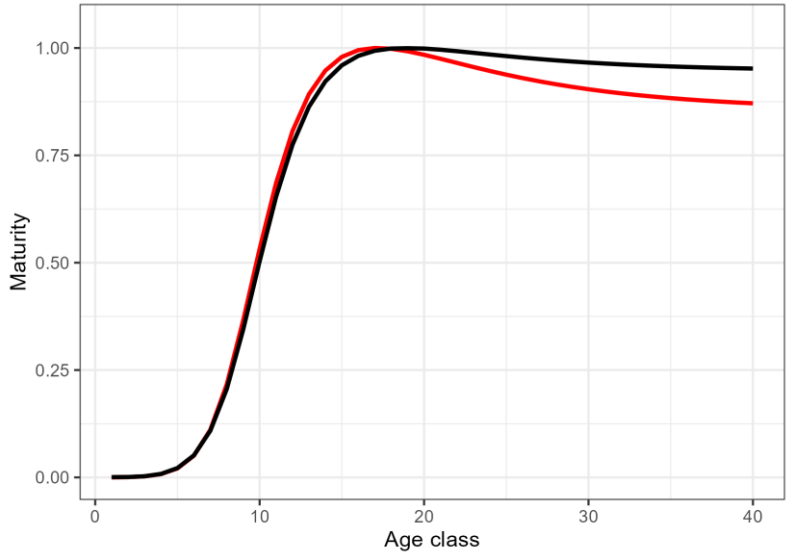


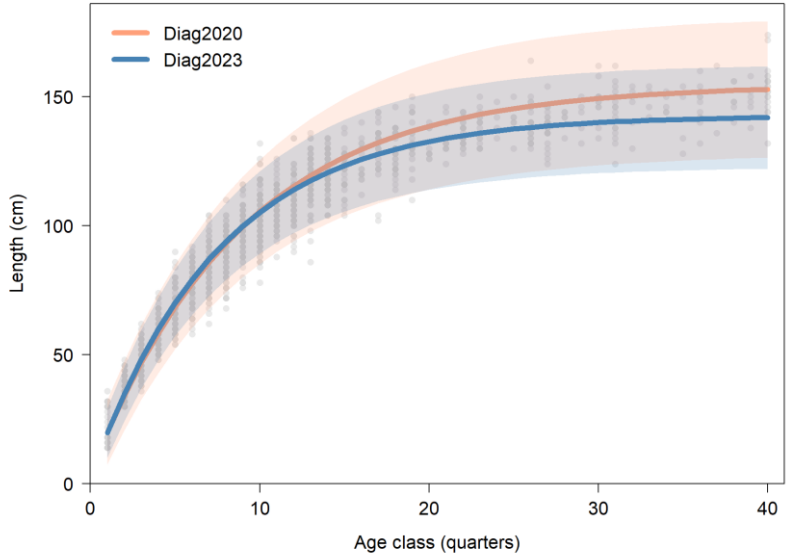
Life History: M, Growth, Maturity



Asymptotic M = 0.119 / quarter with 95% CI from 0.113 to 0.126 based on the Hessian

A 2020 meta analysis of literature and data indicated a 95% CI from 0.110 to 0.150

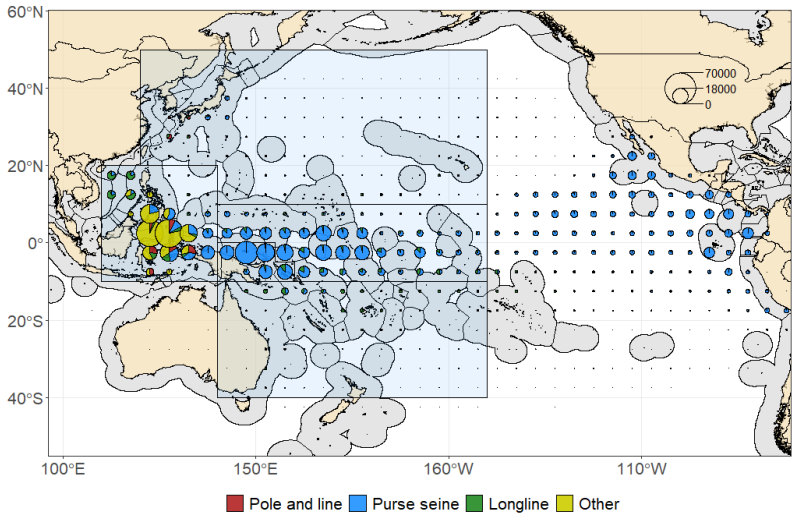


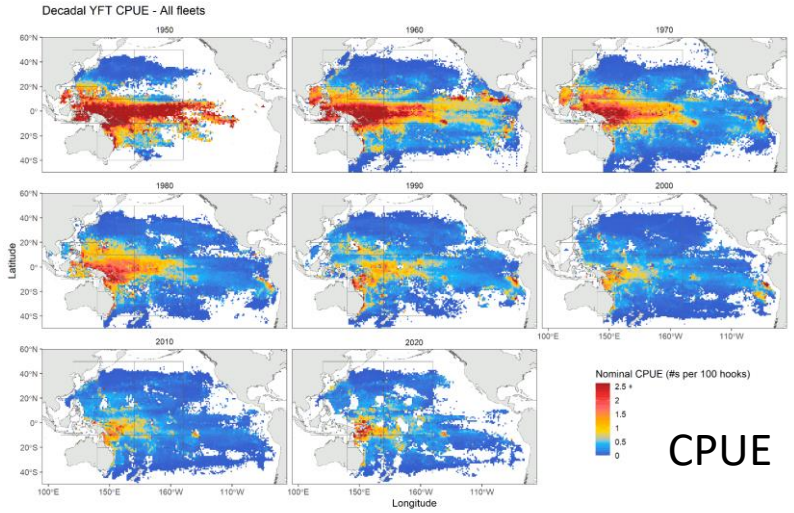


Yellowfin in Equatorial and Temperate Regions

Pacific Community
Communauté du Pacifique

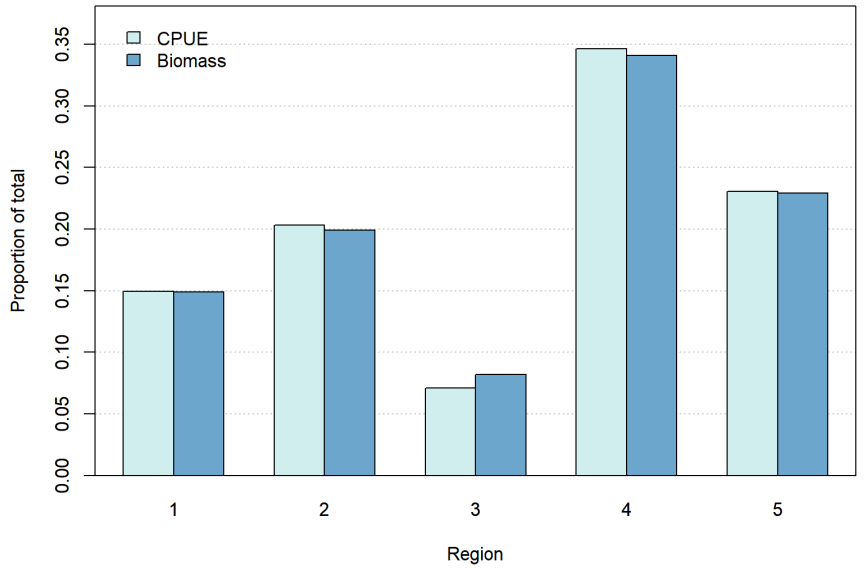
Catches



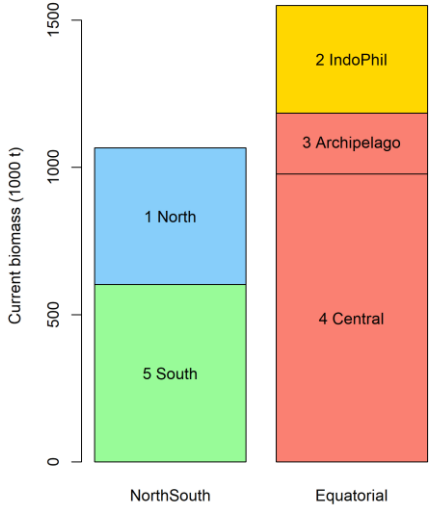


CPUE

CPUE and Biomass

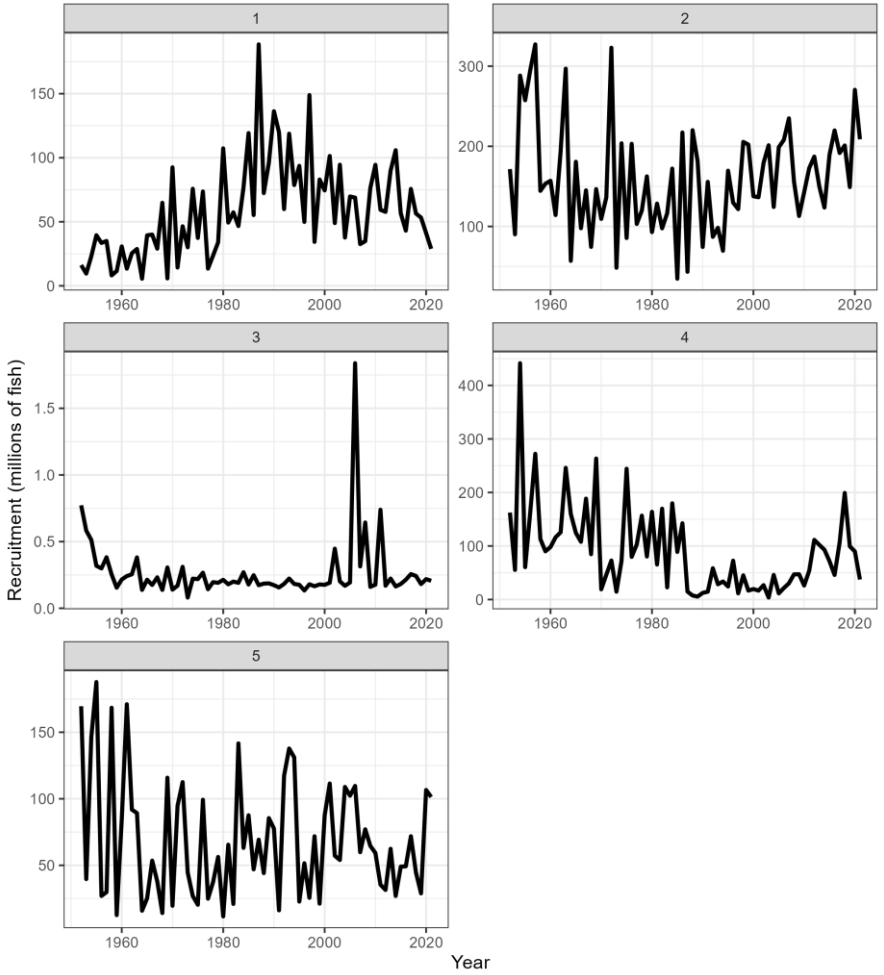


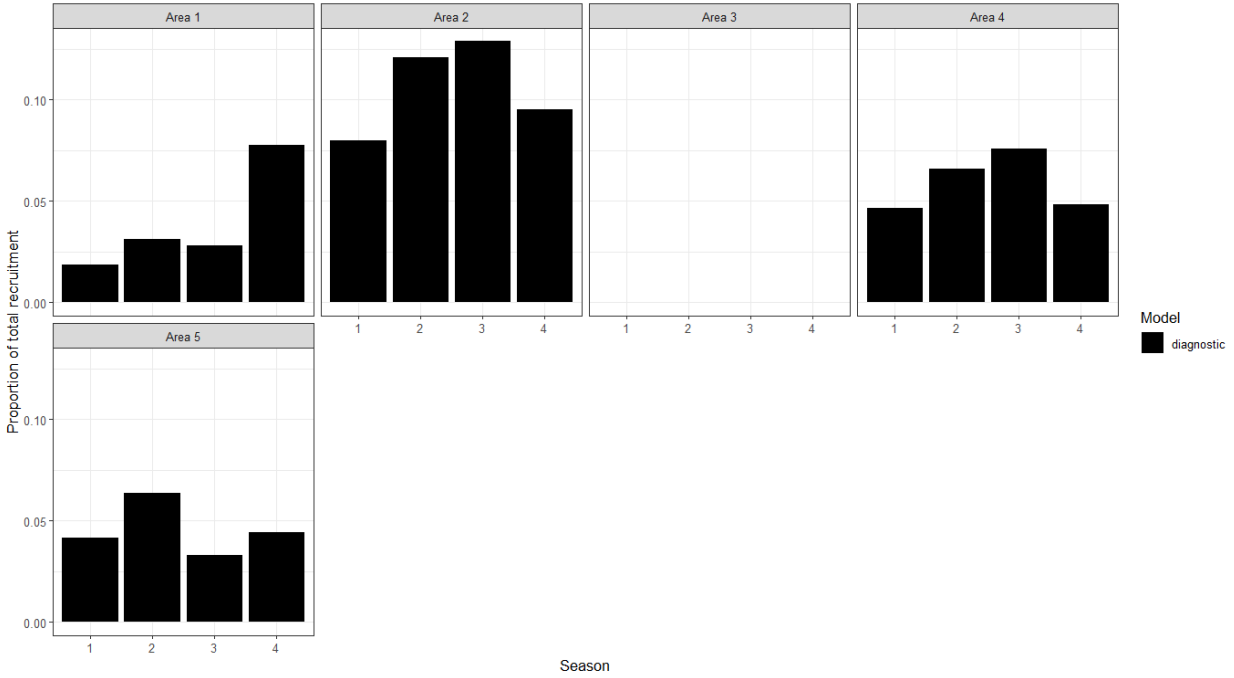
Biomass



Regions	Biomass		Catches	
Temperate	1066	(41%)	45	(6%)
Equatorial	1550	(59%)	707	(94%)

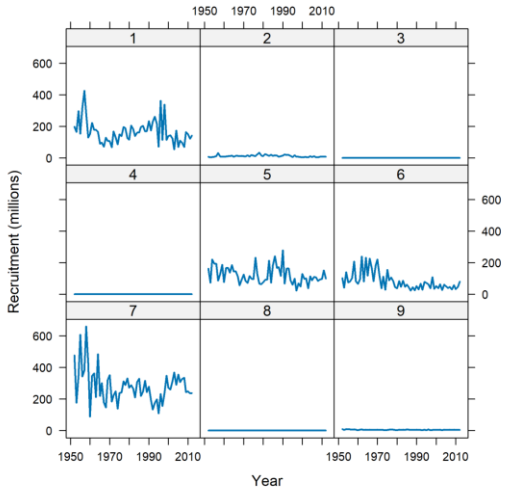
Zero Recruitment in Region 3





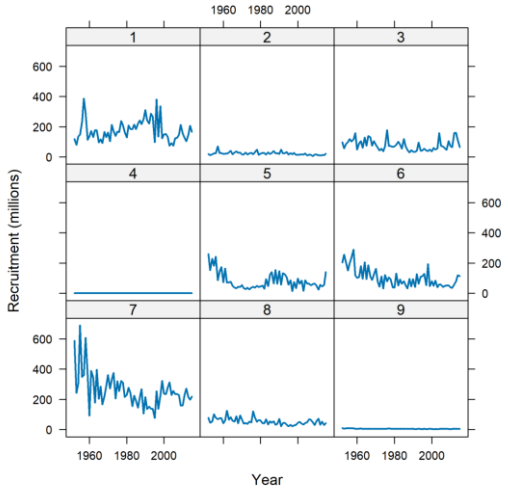
Zero Recruitment in Regions 3, 4, 5, 8 ...

2014 assessment



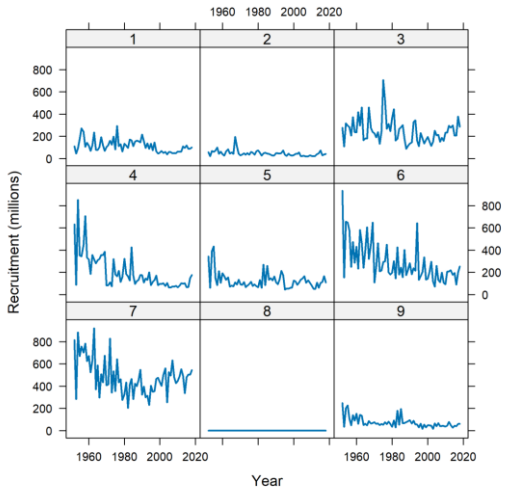
Empty 3, 4, 8

2017 assessment



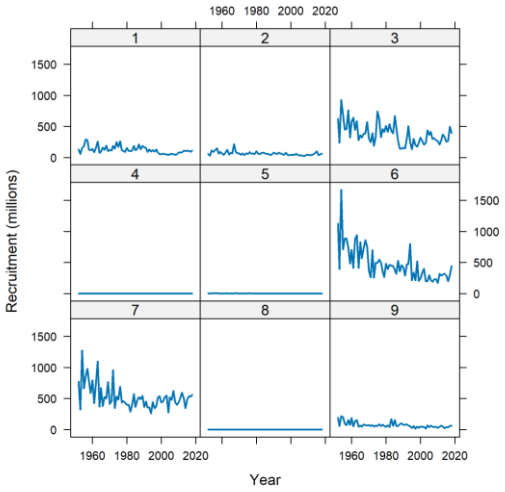
Empty 4

2020 assessment



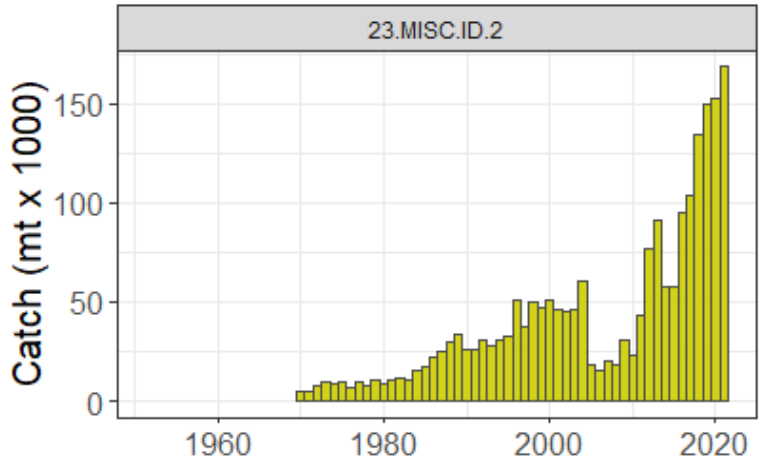
Empty 8

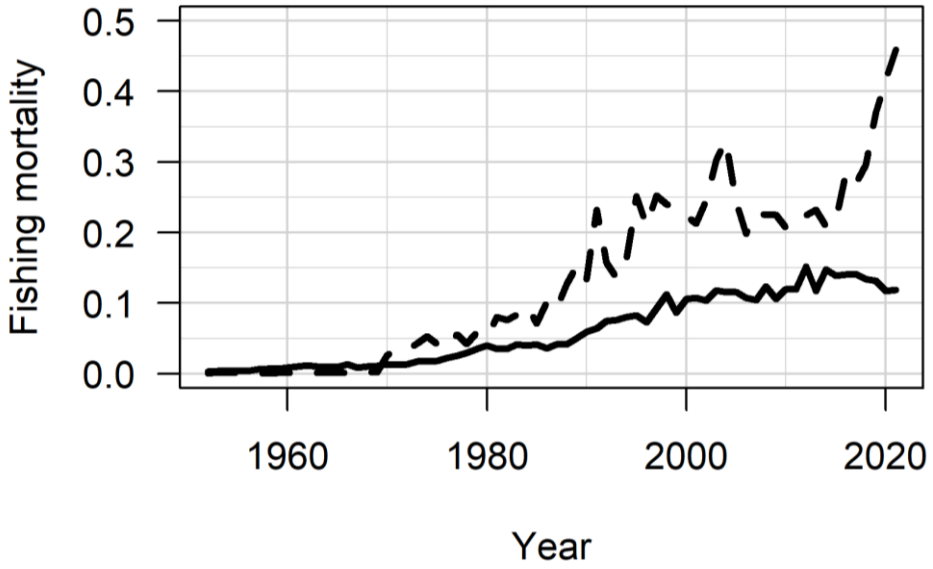
2023 stepwise 04b

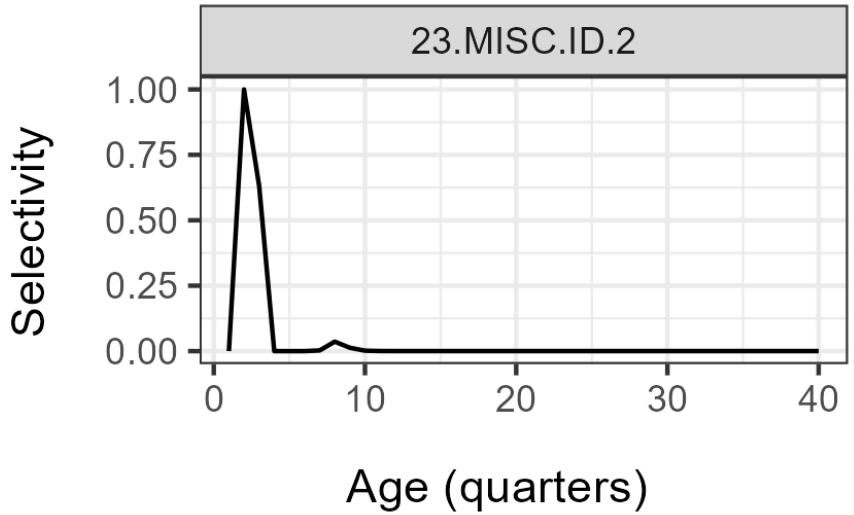


Empty 4, 5, 8

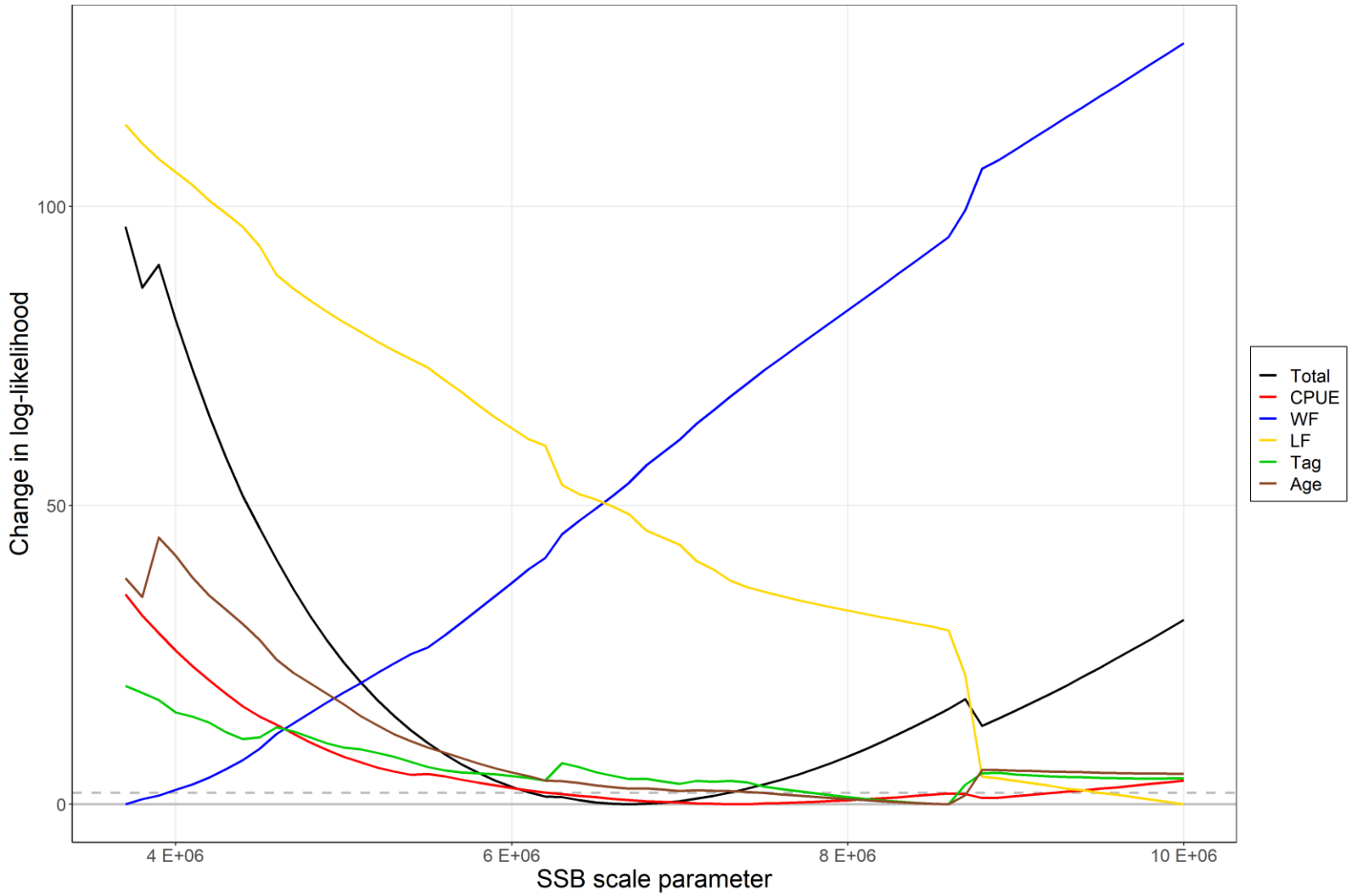
Catches in Region 2 and Juvenile Fishing Mortality



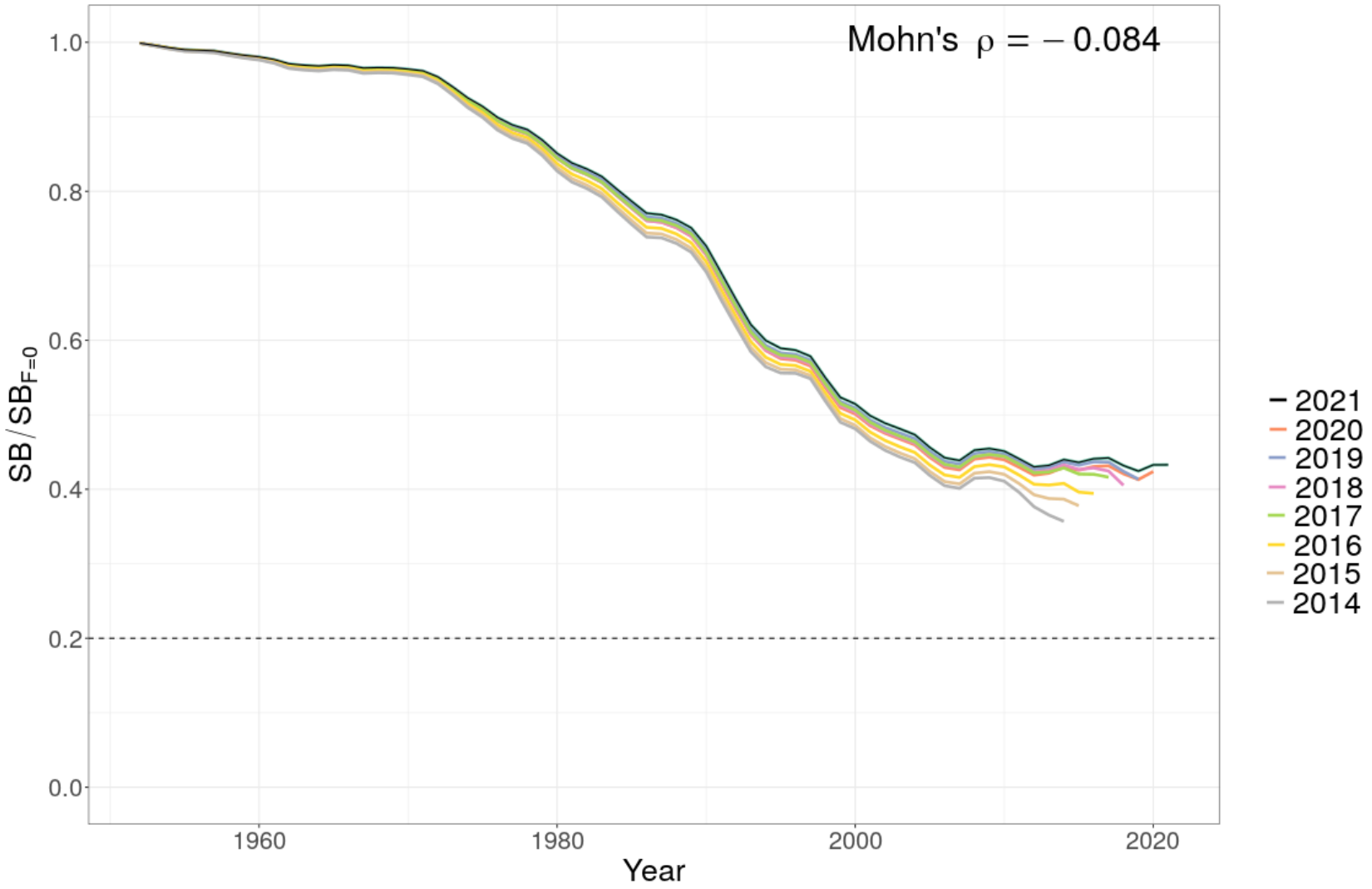




Likelihood Profile



Retrospective Analysis

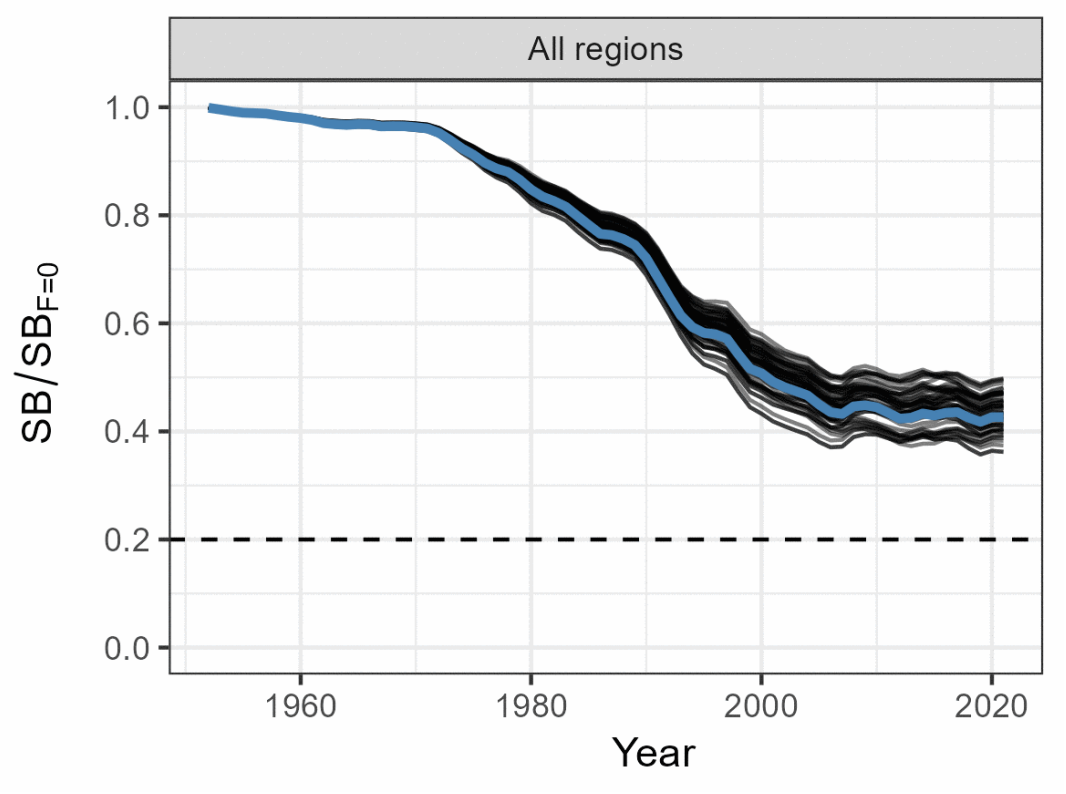


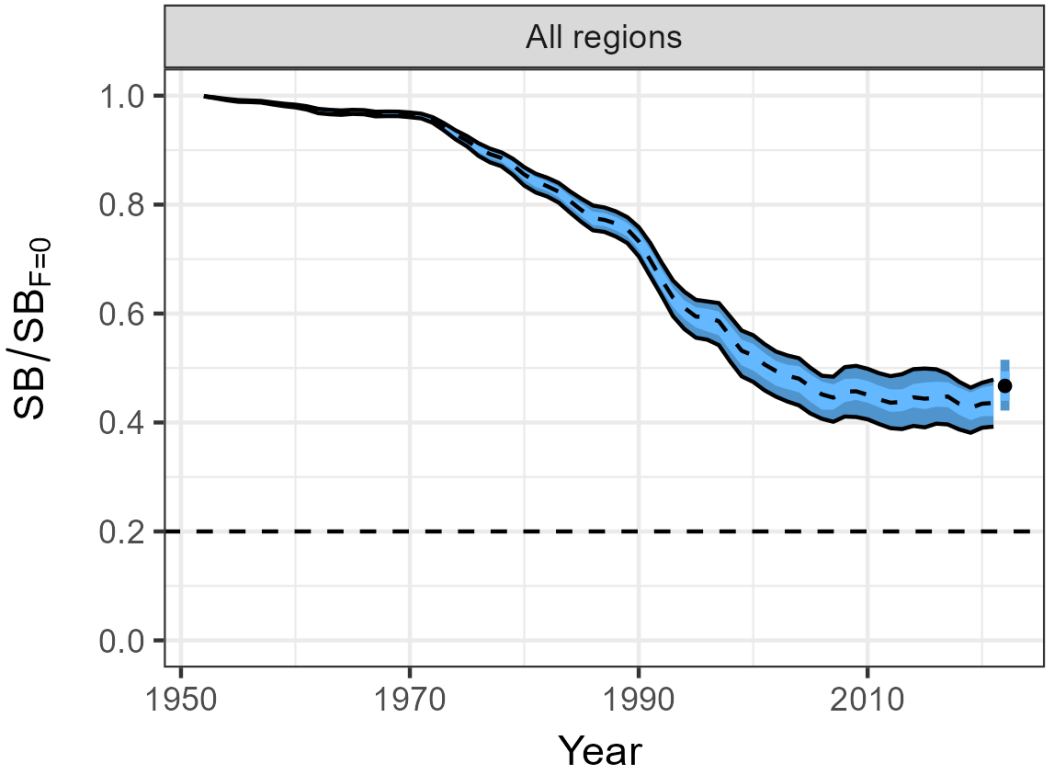
Structural Uncertainty Grid

Axis	Levels	Option 1	Option 2	Option 3
Steepness	3	0.65	**0.8**	0.95
Tag mixing (# quarters)	2	1	**2**	
Size data weighting divisor	3	10	**20**	40
Age data weighting	3	0.5	**0.75**	1

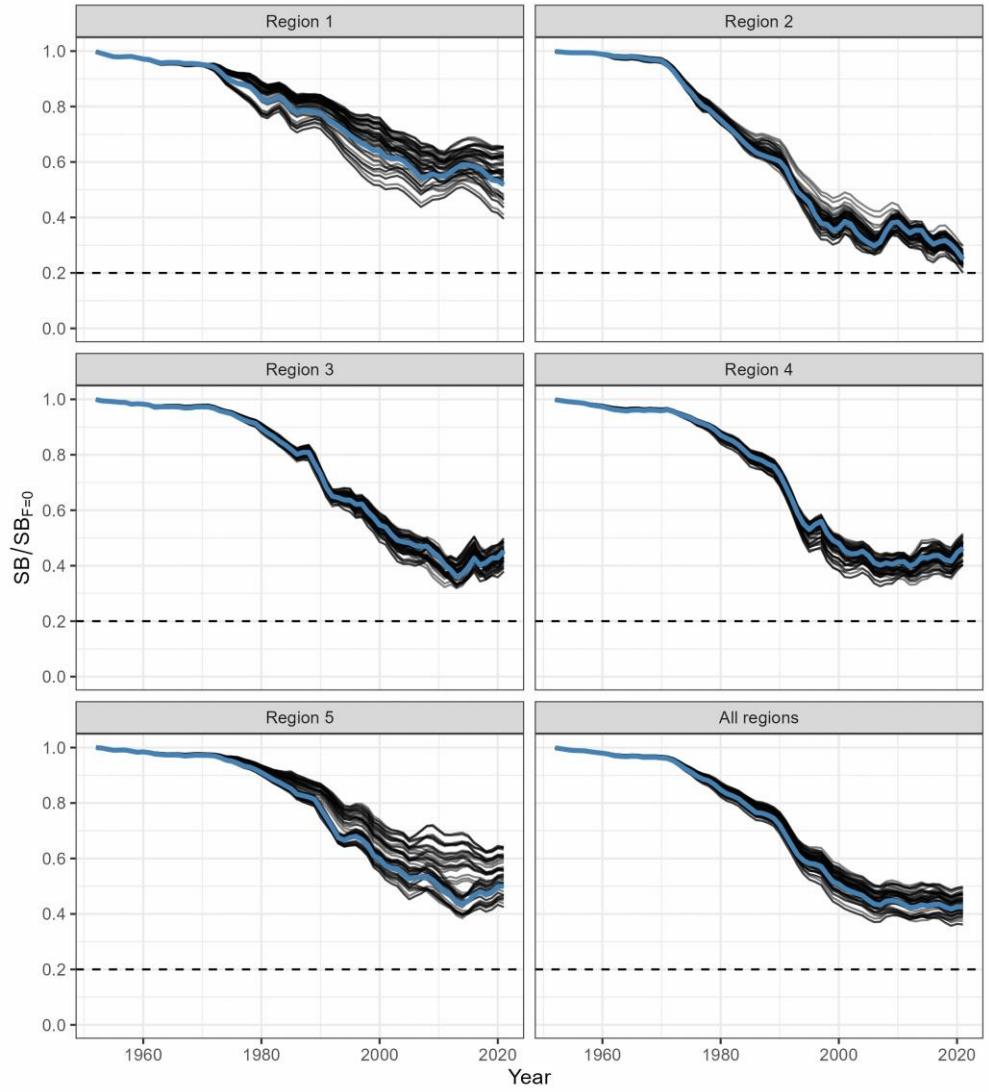
n = 54 grid members

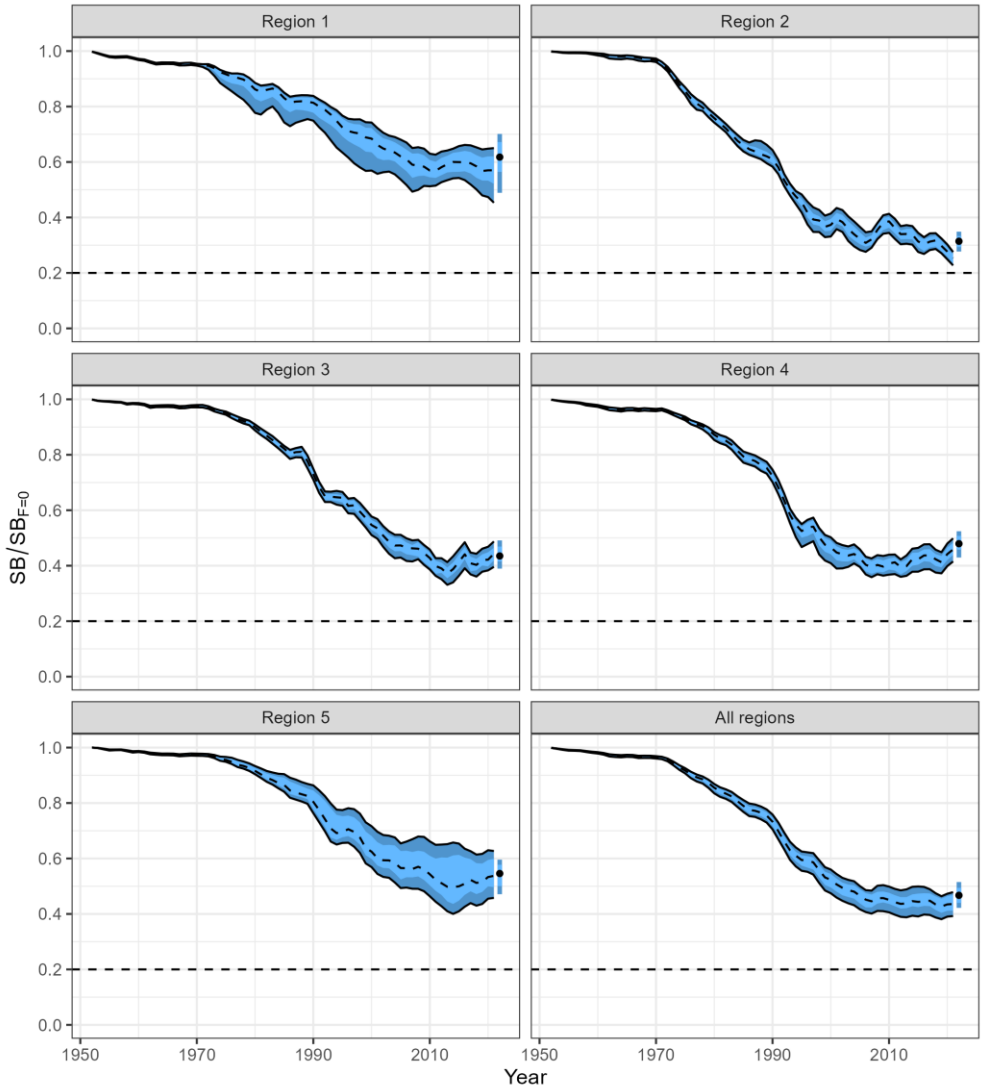
Depletion: All Regions Combined



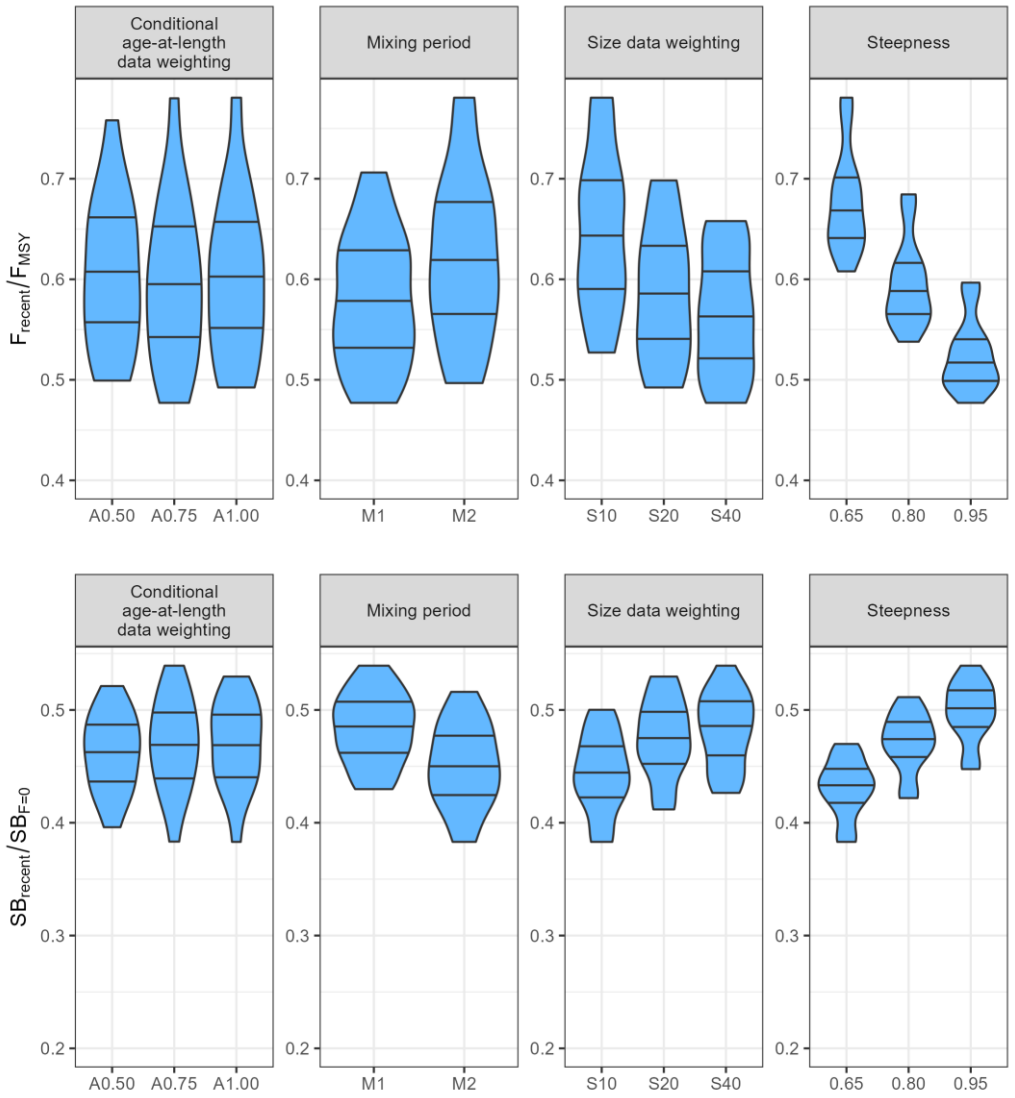


Depletion: Region Specific





Grid Axis Effects

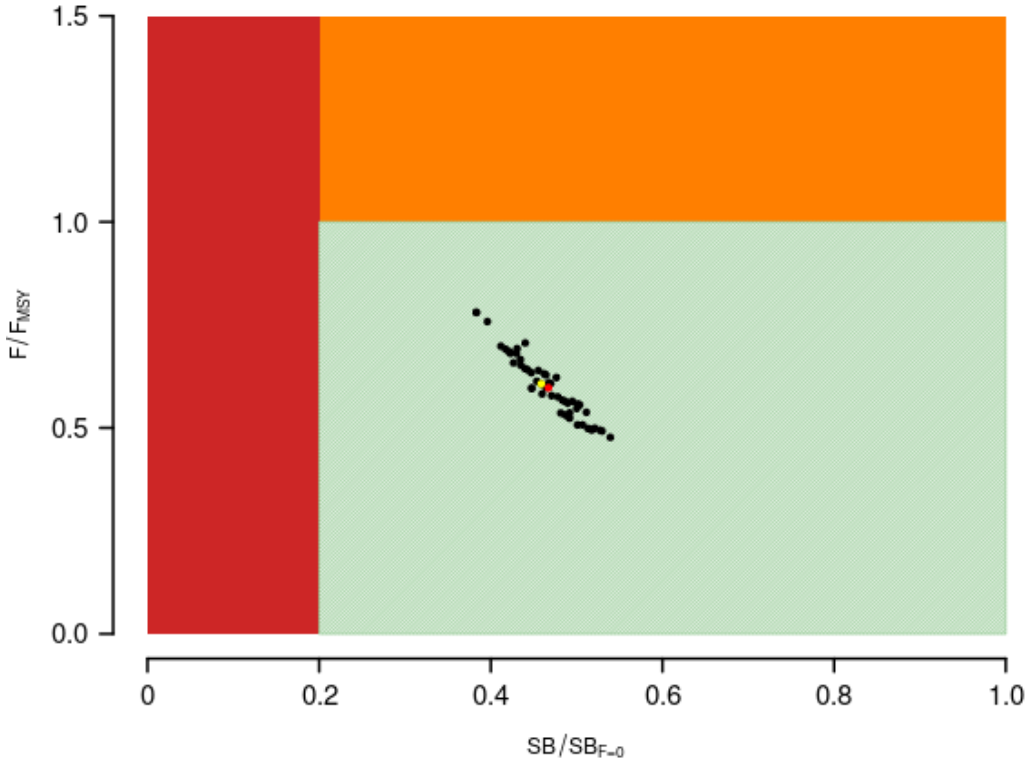


Steepness
has the greatest effect

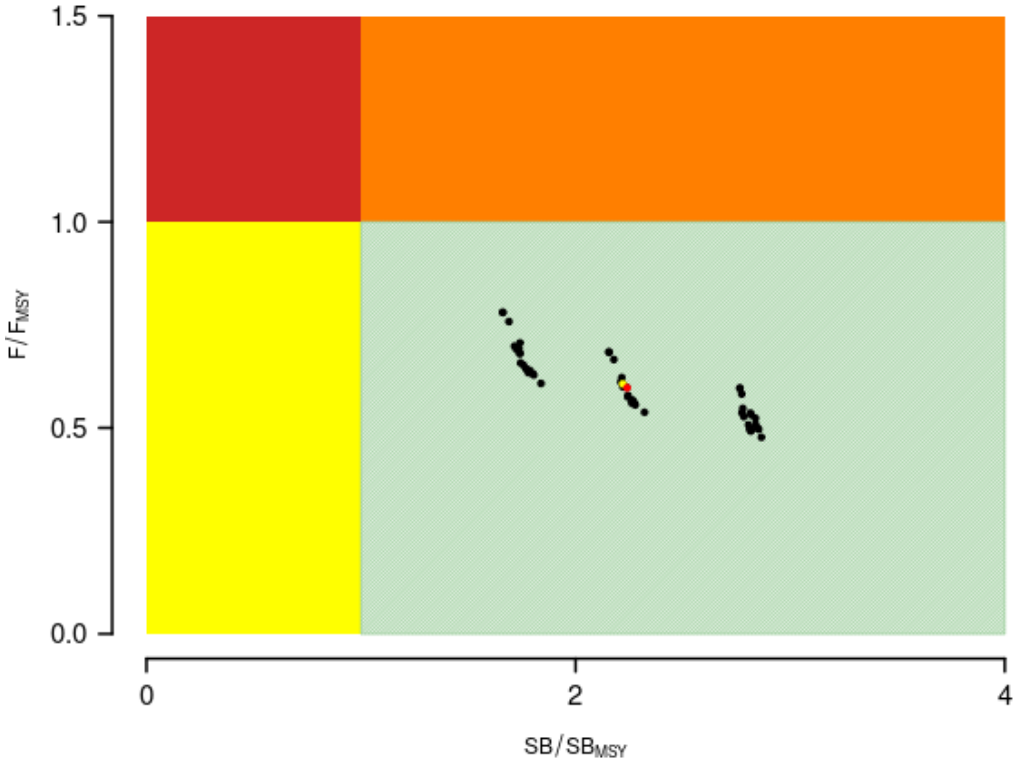
Age data weighting
has the least effect

Majuro and Kobe Plots

Majuro



Kobe

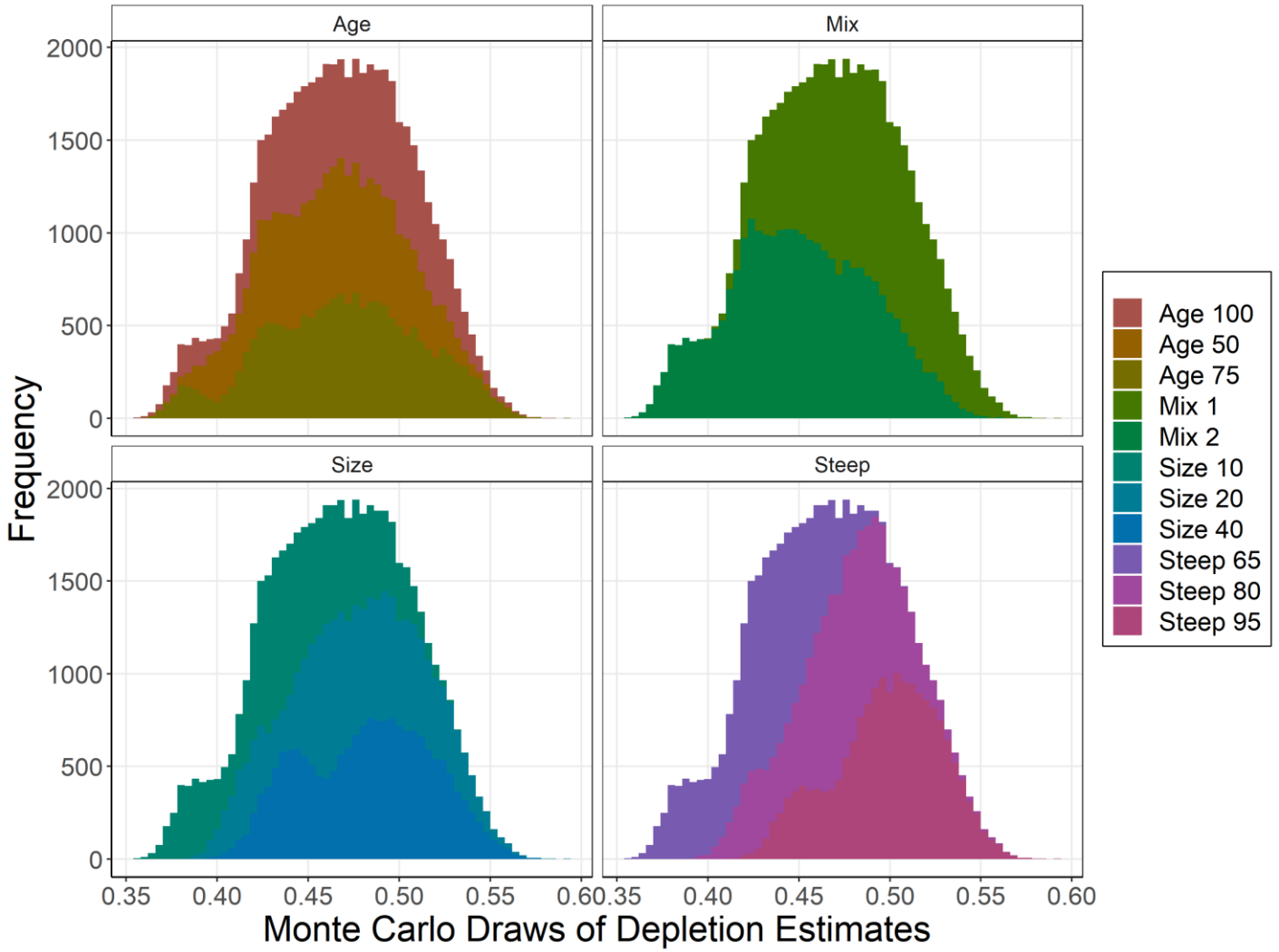


Incorporating Estimation Uncertainty

We calculate the estimation uncertainty for each grid member, $\sigma_{Depletion}$

Then we convert each grid member from a point estimate to a distribution of 1000 estimates

1000 random normal deviates using $\sigma_{Depletion}$



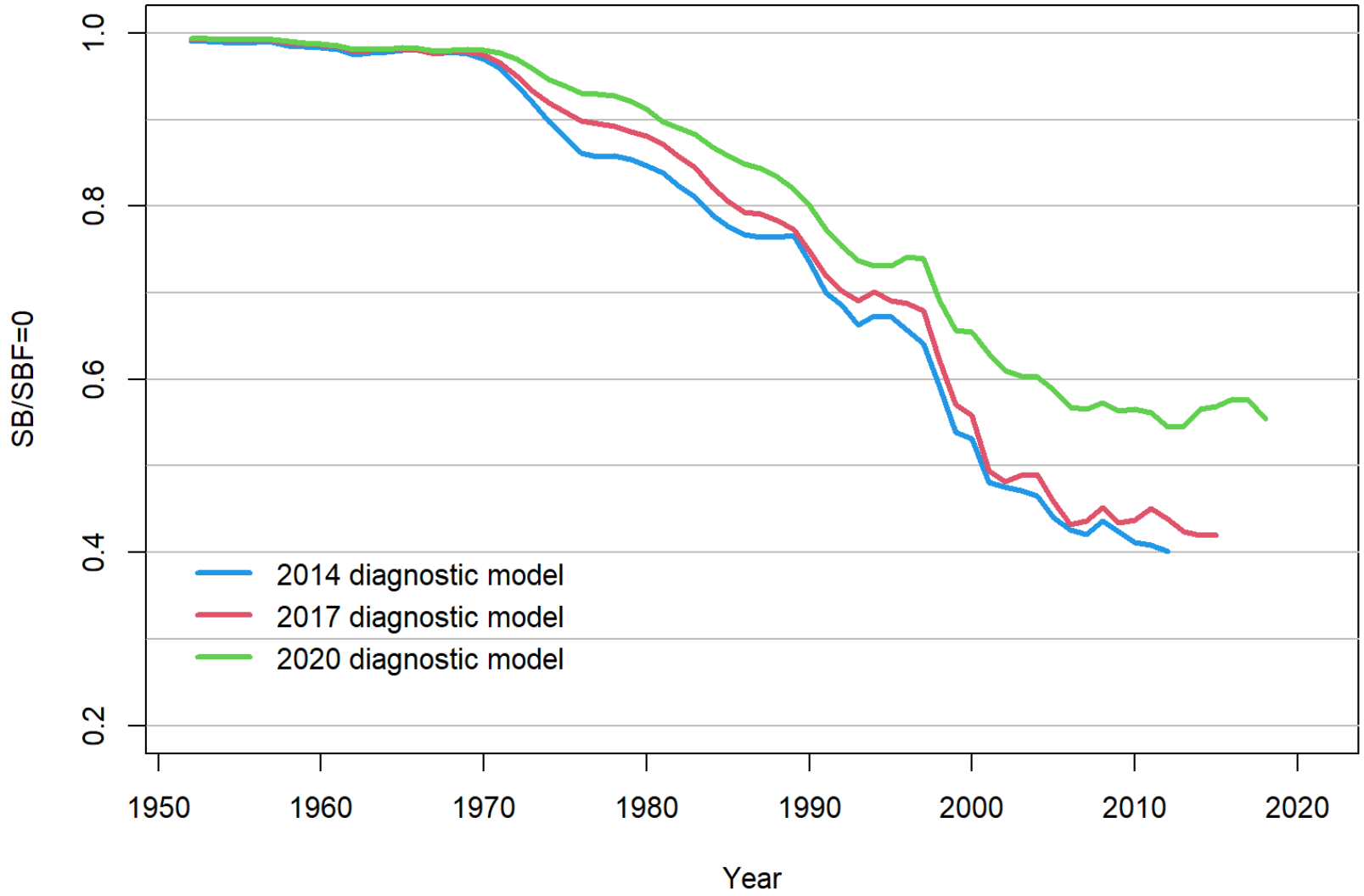
Reference Points

	mean	median	min	10%ile	90%ile	max	diagnostic model
C_{latest}	751657	751856	750785	750860	752268	752337	751908
F_{MSY}	0.07	0.07	0.06	0.06	0.09	0.09	0.07
$F_{\text{recent}}/F_{\text{MSY}}$	0.51	0.50	0.40	0.42	0.61	0.68	0.53
MSY	697874	700400	616800	644320	739560	771600	671600
SB_0	5761796	5729000	4455000	4817200	6640900	7279000	5216000
$SB_{F=0}$	5633743	5603267	4624645	4907798	6280841	6825888	5173954
SB_{latest}/SB_0	0.49	0.50	0.41	0.44	0.54	0.56	0.49
$SB_{\text{latest}}/SB_{F=0}$	0.50	0.50	0.41	0.45	0.55	0.58	0.49
$SB_{\text{latest}}/SB_{\text{MSY}}$	2.49	2.48	1.78	1.91	3.11	3.16	2.44
SB_{MSY}	1177733	1160500	740400	838260	1538200	1707000	1044000
SB_{MSY}/SB_0	0.20	0.20	0.17	0.17	0.23	0.24	0.20
$SB_{\text{MSY}}/SB_{F=0}$	0.21	0.21	0.16	0.17	0.24	0.25	0.20
$SB_{\text{recent}}/SB_{F=0}$	0.47	0.47	0.38	0.42	0.52	0.54	0.46
$SB_{\text{recent}}/SB_{\text{MSY}}$	2.31	2.30	1.68	1.77	2.89	2.94	2.27
$Y_{F_{\text{recent}}}$	157188	155300	141400	145150	172270	173300	152500

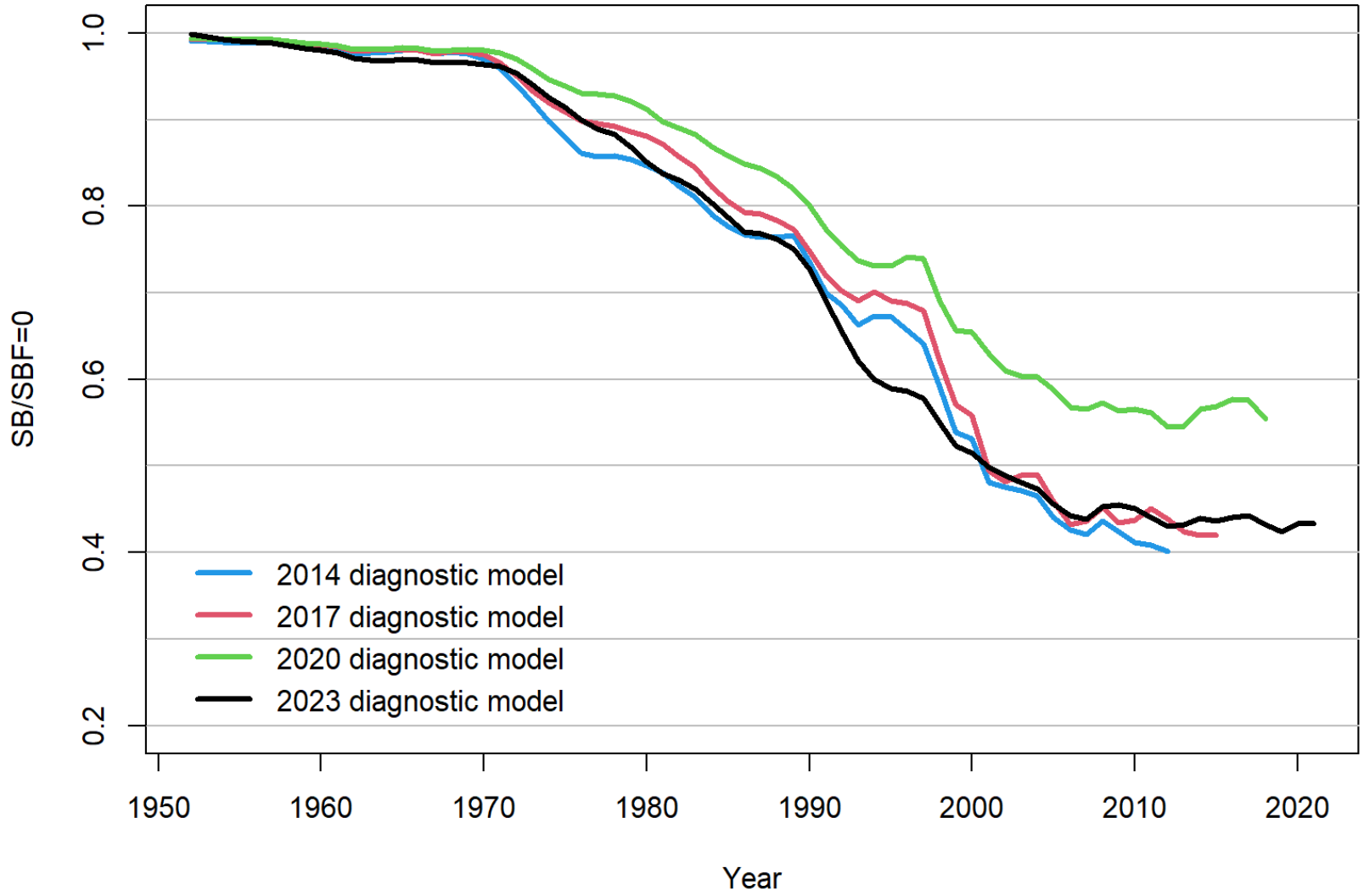
Including estimation uncertainty:

	mean	median	min	10%ile	90%ile	max
$SB_{\text{recent}}/SB_{F=0}$	0.47	0.47	0.36	0.42	0.52	0.59
$F_{\text{recent}}/F_{\text{MSY}}$	0.51	0.50	0.26	0.41	0.62	0.78
$SB_{\text{recent}}/SB_{\text{MSY}}$	2.31	2.28	0.93	1.73	2.95	3.59

Comparison with Previous Assessments



Comparison with Previous Assessments



Main Conclusions

Spawning depletion has been relatively stable from around 2005 to 2023, between 0.40 and 0.50

New 5 region structure improved the model in terms of Hessian diagnostics, robustness, parameter estimability, and shorter run time

Estimating *M* internally is an effective way to incorporate the full uncertainty, rather than fixing *M* and then using arbitrary grid levels

Convergence problems remain in the model, likelihood conflict between the length comps and weight comps

Comparable results from the 2023, 2017, and 2014 assessments; the 2020 assessment was an outlier

Recommendations for Further Work

1. Continued work examining appropriate approaches for **modeling *M*** for the WCPO yellowfin assessment
2. Further simplifying the assessment by **combining fisheries** within regions
3. Evaluation of **growth parameter settings**
4. Improved **sampling of biological data** across the WCPO region for yellowfin
5. **Succession planning** for MFCL
6. **Tropical focused model** investigation

Summary Outcome

Overall median spawning depletion 0.47 (80 percentile range 0.42 – 0.52)

No grid models below LRP

Median F / F_{MSY} = 0.50 (80 percentile range 0.41 – 0.62)

According to WCPFC reference points the yellowfin stock in the WCPO is not overfished, nor undergoing overfishing

CMM 2021-01 objective: maintain $SB/SB_{F=0}$ above $SB_{2012-2015}/SB_{F=0}$

$SB_{2012-2015}/SB_{F=0}$ = 0.44 (model grid only)

$SB_{recent}/SB_{F=0}$ = 0.47

objective has currently been met

Thank You

Calculation of CV for CPUE indices

New development in this year's assessments

Region-specific, calculated externally using maximum likelihood estimation

$$_{\text{MLE}}\hat{\sigma}_r = \sqrt{\frac{\sum_{t=1}^{T}\left(\log I_{t,r} - \log \hat{I}_{t,r}\right)^2}{T}}$$

Calculated once in each assessment, in the model development step where data weighting adjustments are made

This statistically based data weighting is an improvement from the last assessment, where σ = 0.2 in all regions

Three Variants of the Diagnostic Model

Same exact model, in terms of parametrization and data:

`14_Five_Regions`	the ancestor
`15_Diag2023`	the Diagnostic Model
`m2_s20_a075_h80`	the grid member

The best model fit occurs in a rough patch of likelihood surface

`14_Five_Regions` was the first one to be developed and run

`15_Diag2023` improved the initial parameter values and estimation phases to reach a better likelihood and achieve a positive definite Hessian

`m2_s20_a075_h80` is a double-jittered version of 15_Diag2023 that slightly improves the likelihood, but the Hessian is no longer positive definite

The Diagnostic Model and the grid member have essentially the same estimated stock status, but only the Diagnostic Model runs from a standard **`.ini`** file