Aleutian Islands Golden King Crab 2025 Proposed Models

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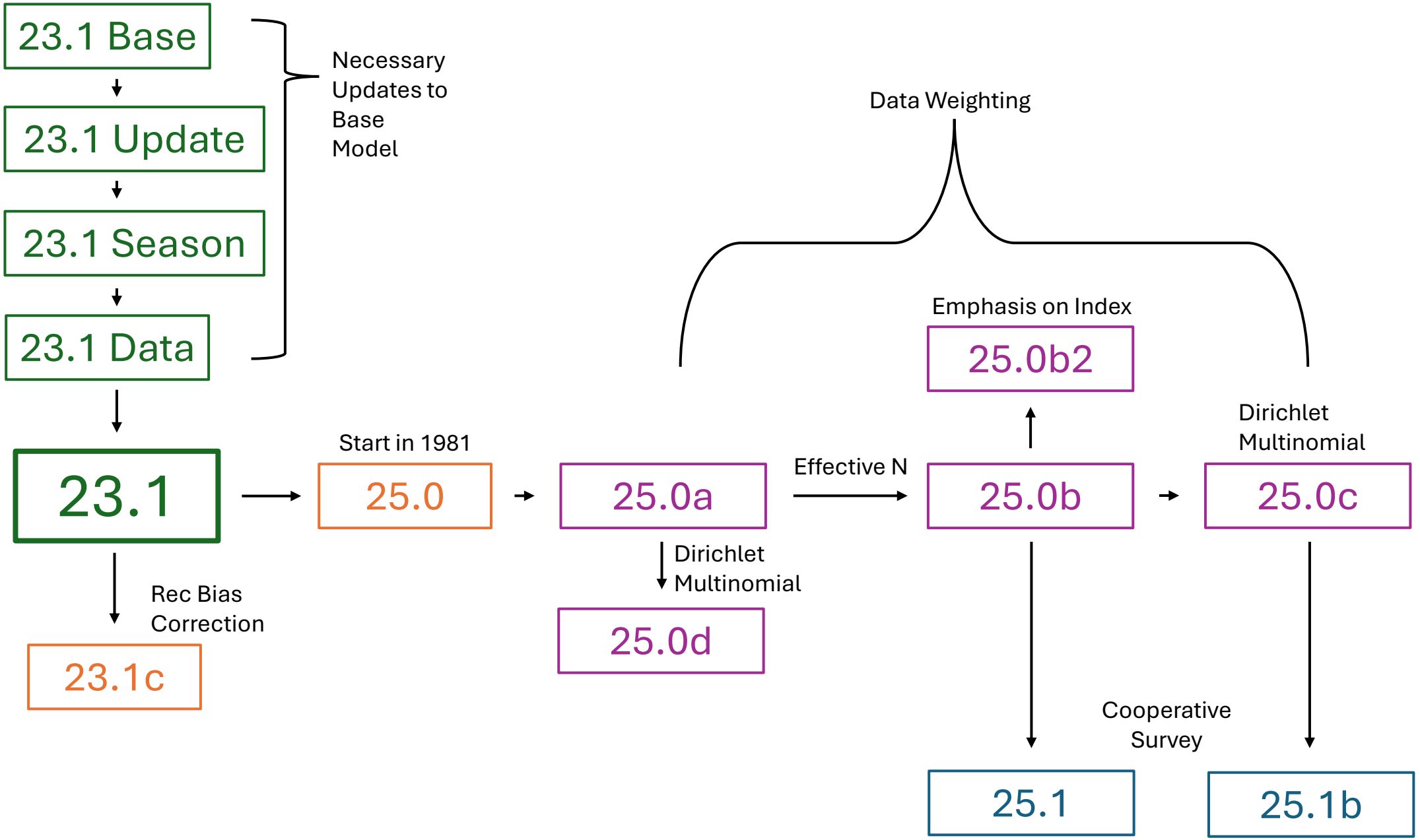
Sept 2024 CPT


23.1 Base
23.1 Update
23.1 Season
23.1 Data
Necessary Updates to Base Model
23.1
Rec Bias Correction
23.1c
Start in 1981
25.0
25.0a
Dirichlet Multinomial
25.0d
Effective N
Data Weighting
Emphasis on Index
25.0b2
25.0b
Dirichlet Multinomial
25.0c
Cooperative Survey
25.1
25.1b

Updates to 2024 Accepted Model

23.1 Base → **23.1 Update**

Update from GMACS 2.01.M.10 to 2.20.16

Updates to 2024 Accepted Model

23.1 Base → 23.1 Update → **23.1 Season**

	2024 Accepted Model			23.1 Season	
	Season	Duration	Process	Duration	Process
	1	Instantaneous	N at Size	Instantaneous	
	2	Jul 1 – Mid Fish	*M*	Jul 1 – Mid Fish	*M*
	3	Instantaneous	Dir Fishery / Bycatch	Instantaneous	Dir Fishery / Bycatch
	4	Mid Fish – Feb 15	*M*	Mid Fish – Feb 15	*M*
→	5	Instantaneous	Estimate MMB	Feb 15 – Jun 30	MMB, *M*, Growth, Rec
→	6	Feb 15 – Jun 30	*M*, Growth, Rec	Instantaneous	N at Size

Updates to 2024 Accepted Model

23.1 Base → 23.1 Update → 23.1 Season → **23.1 Data**

EAG 1993/94 Season

1. 1993/94 EAG (171° W) was open from Sept 1, 1993 – Mar 1, 1994. **There was no observer coverage.**
2. 1993/94 observer data here was actually from the (then) 1992/93 season in the WAG: Nov 1, 1992 – Aug 15, 1993
3. **These data were included in retained catch / size, but not total catch / size**

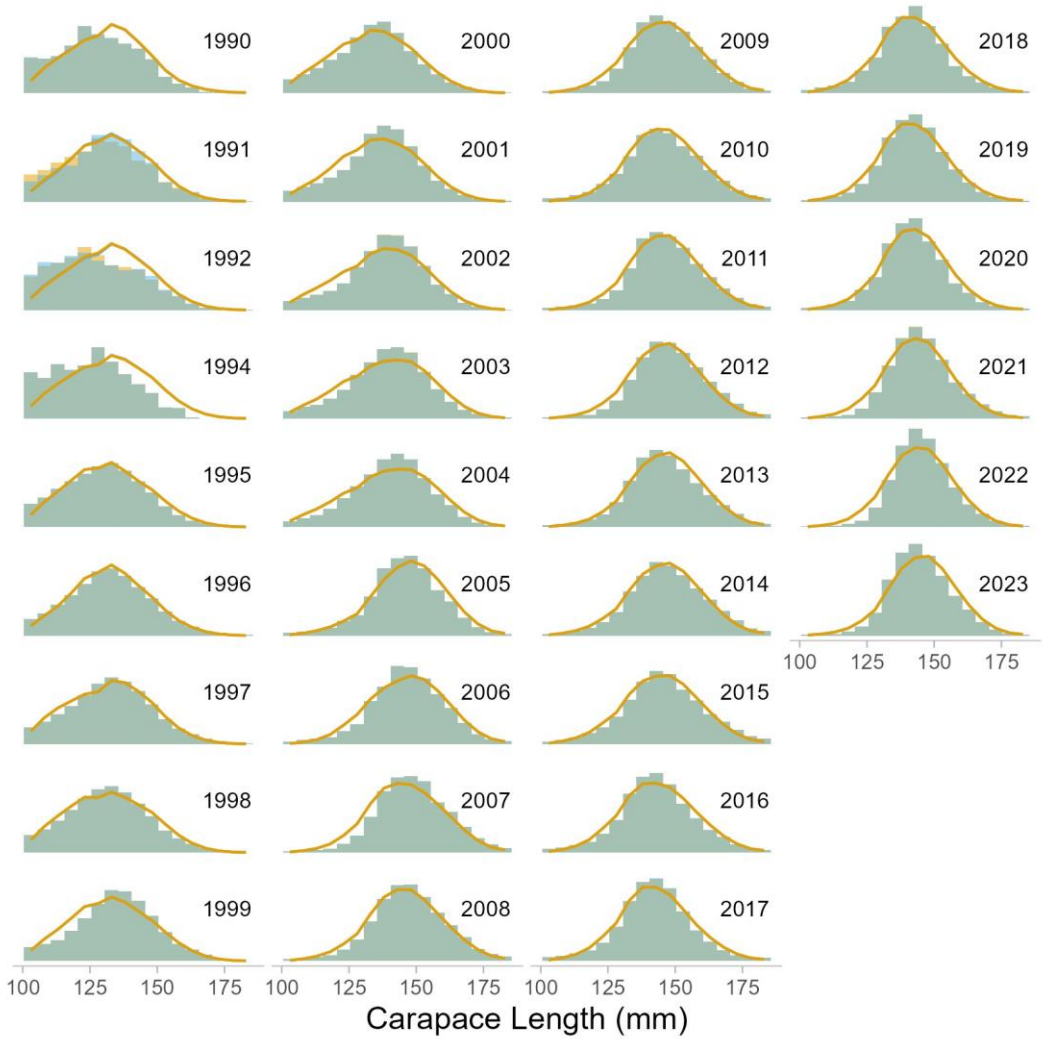
Updates to 2024 Accepted Model

23.1 Base → 23.1 Update → 23.1 Season → **23.1 Data**

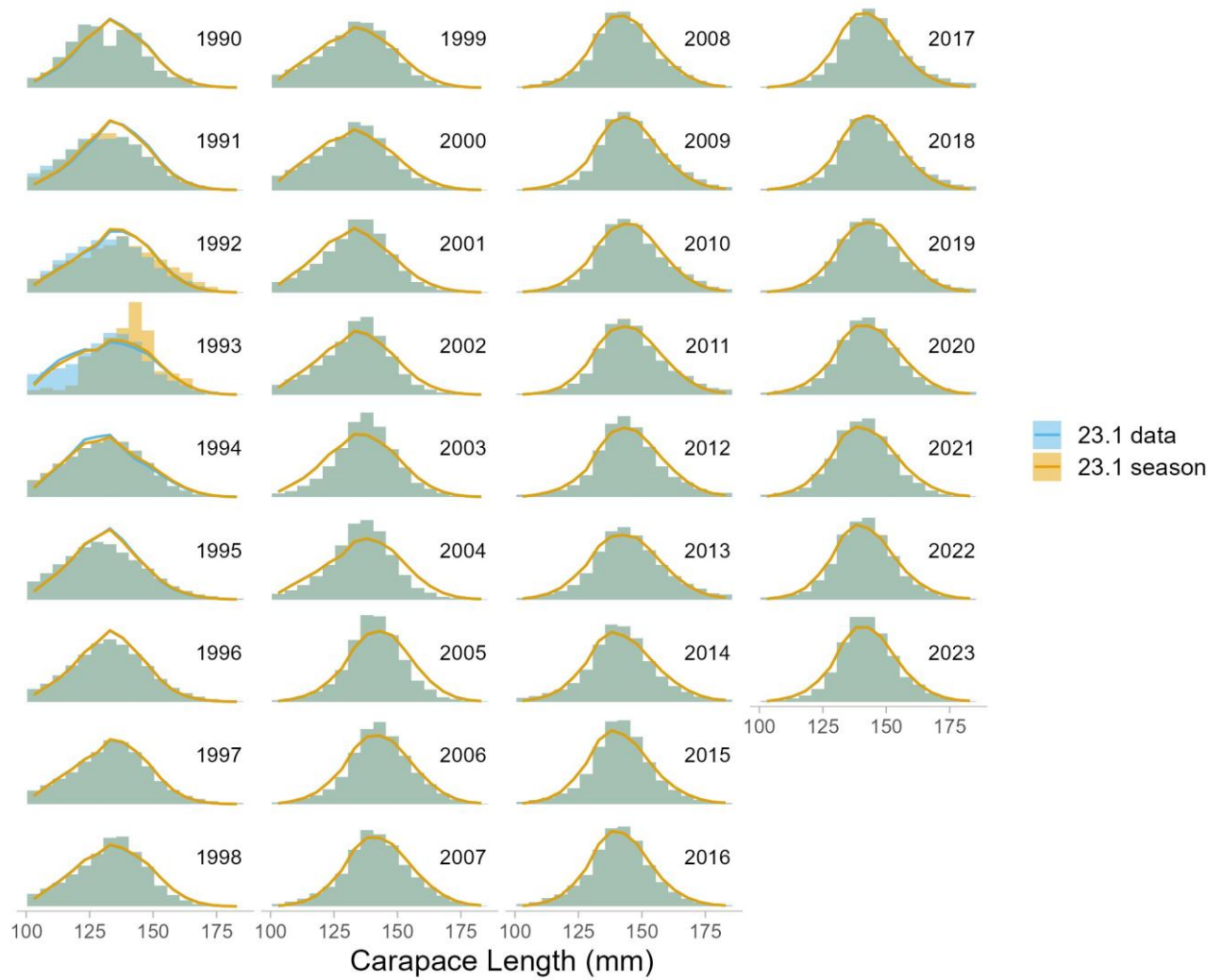
WAG 1993/94 Season

1. Exclusion of odd pots shapes and rectangular pots in the following dimensions: 9’x9’, 8.5’x8.5’, 9.5’x9.5’, 8’x9’, 8’x10’, 9’x10’, 7’x8’, or **unknown**.
2. Most (160/174) observer pots from 1993/94 are rectangular pots with unknown size
3. **Solution: Use all rectangular pots for size composition, status quo for CPUE**

EAG Observed Total Composition



WAG Observed Total Composition



Updates to 2024 Accepted Model

23.1 Base → 23.1 Update → 23.1 Season → 23.1 Data → **23.1**

Area	Model	MMB (t)	$B_{35\%}$ (t)	$\frac{MMB}{B_{35\%}}$	$\bar{R}_{1987-2017}$	$F_{35\%}$	F_{OFL}	OFL (t)
EAG	23.1 v2.01.M.10	7,551	6,905	1.09	2,781	0.55	0.55	2,825
EAG	23.1 v2.20.16	7,551	6,905	1.09	2,781	0.55	0.55	2,825
EAG	23.1 season	7,551	6,905	1.09	2,781	0.55	0.55	2,825
EAG	23.1 data	7,547	6,905	1.09	2,781	0.55	0.55	2,823
WAG	23.1 v2.01.M.10	3,837	4,638	0.83	1,866	0.54	0.44	900
WAG	23.1 v2.20.16	3,837	4,638	0.83	1,866	0.54	0.44	900
WAG	23.1 season	3,837	4,638	0.83	1,866	0.54	0.44	900
WAG	23.1 data	3,767	4,498	0.84	1,808	0.54	0.44	899

Initial Conditions

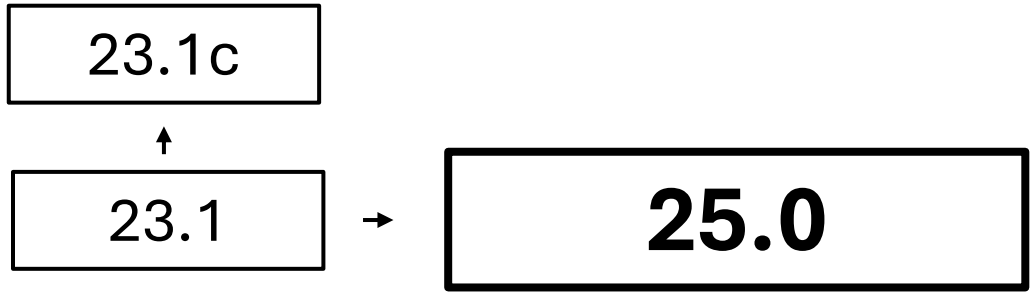
23.1 → **23.1c**

- Alternative bias correction on recruitment deviations from 1960 – 1980
- Model 23.1c implements bias correction as

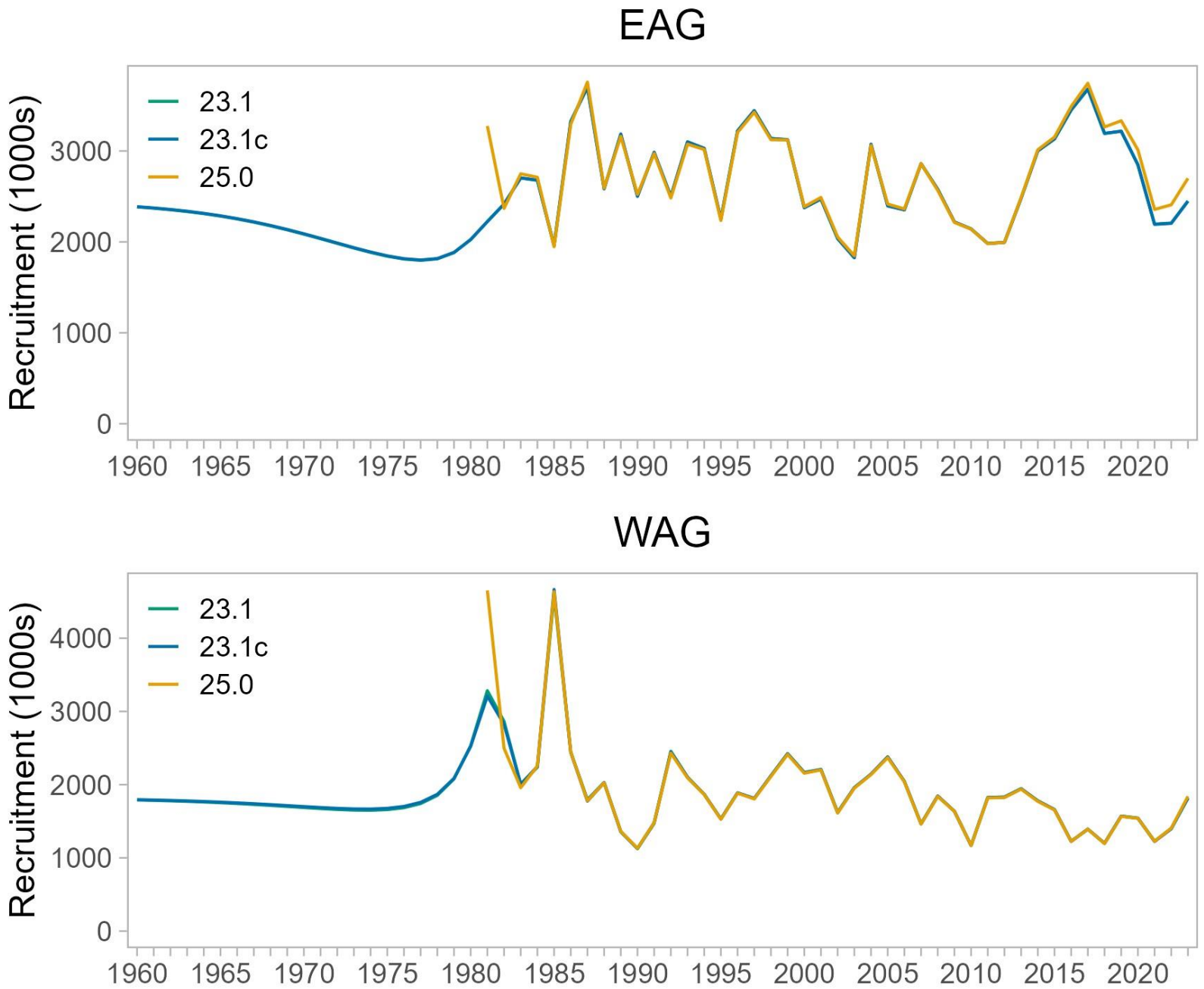
$$b_t e^{\frac{\sigma^2}{2}}$$

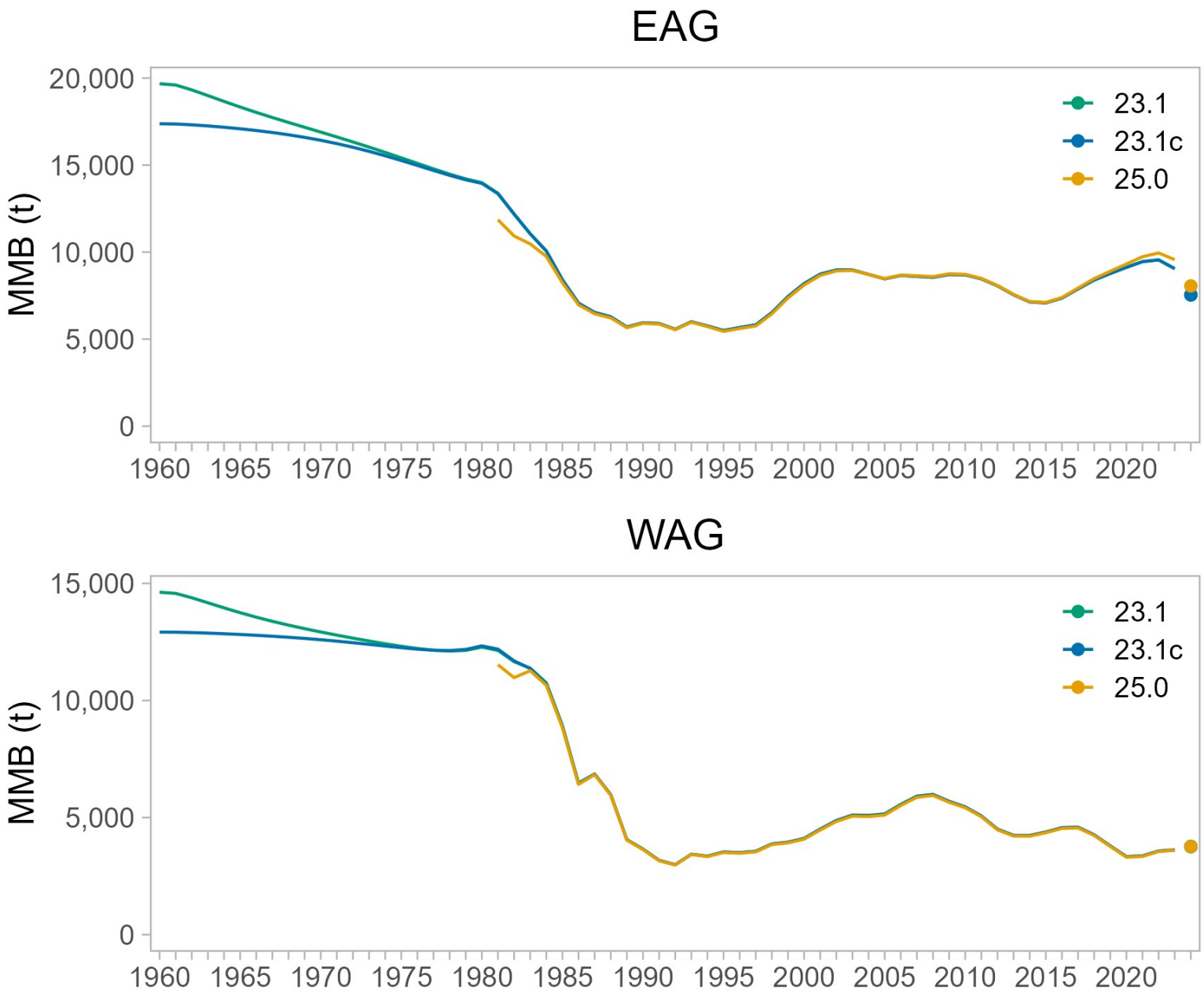
where b_t is a vector of 0 from 1960 – 1980 and 1 from 1981 - 2023

Initial Conditions



- Start model in non-equilibrium conditions in 1981
  - Remove 22 parameters for R_0 and 1960-1980 recruitment deviations
  - Add 18 parameters for R_{init}, N at size deviations, and $\bar{R}$
  - 136 – 140 mm CL as reference size class


EAG
Recruitment (1000s)
23.1
23.1c
25.0
0
1000
2000
3000
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
WAG
Recruitment (1000s)
23.1
23.1c
25.0
0
1000
2000
3000
4000
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020


EAG
20,000
15,000
10,000
5,000
0
MMB (t)
23.1
23.1c
25.0
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
WAG
15,000
10,000
5,000
0
MMB (t)
23.1
23.1c
25.0
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020

Data Weighting

SSC 2024 – "*The SSC recommends prioritizing further consideration of data weighting, as the Francis re-weighting continues to be an issue in this assessment.*"

CPT 2024 – "*Fit models that assume that the size-composition data are Dirichlet-multinomial distributed instead of Francis weighting the size-composition data.*

Current Data Weighting Scheme

- Retained catch CV = 0.0316, λ = 4
- Total catch CV is scaled number of observer pots with non-zero catches (0.04 – 0.5), λ = 2

$$cv_i = \sqrt{e^{\frac{1}{2\omega_i}} - 1}$$

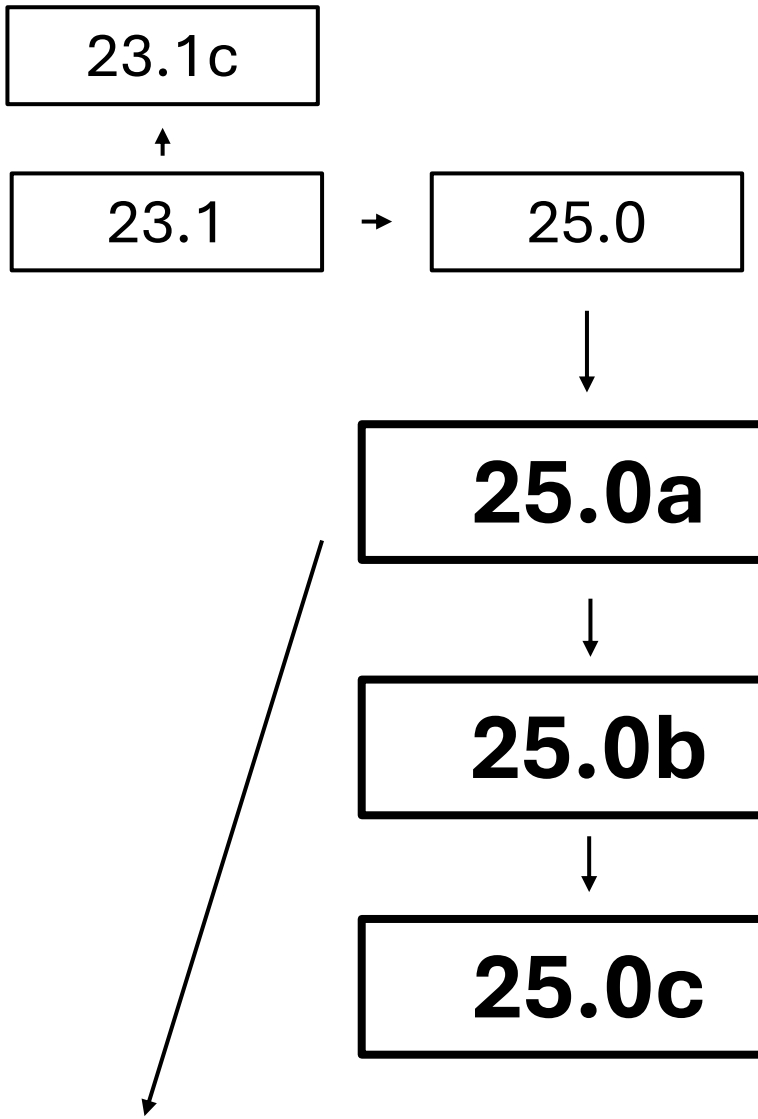
$$\omega_i = \frac{\max[\omega_i] m_{nz,i}}{\max[m_{nz,i}]} \qquad \max[\omega_i] = 250$$

Current Data Weighting Scheme

- Retained catch CV = 0.0316, λ = 4
- Total catch CV is scaled number of observer pots with non-zero catches (0.04 – 0.5 EAG; 0.09 – 0.3 WAG), λ = 2
- Bycatch CV = 1.3108, λ = 1
- Index data CV are extracted from standardization
  - FishTix 1985 – 1998 CV = 0.044 – 0.178 EAG; 0.038 – 0.093 WAG
  - Obs CV = 0.017 – 0.049 EAG; 0.019 – 0.059 WAG
  - Extra CV estimate for all three indices, λ = 1

Current Data Weighting Scheme

- Retained Size Comp – multinomial likelihood, stage 1 sample size is **number of vessel days** in directed fishery, tuned via Francis (2011)
  - Stage 1 N ~ 200 – 1000 in EAG; 100 – 1100 in WAG
  - Francis wts = 0.209 EAG; 0.143 WAG
  - λ = 1
- Total Size Comp – multinomial likelihood, stage 1 sample size is **number of observer days** in directed fishery, tuned via Francis (2011)
  - Stage 1 N ~ 44 – 1000 in EAG; 51 – 1100 in WAG
  - Francis wts = 0.432 EAG; 0.521 WAG
  - λ = 1
- Tagging – Sample sizes are actual tag return sample sizes, λ = 1



Model 25.0, with equal emphasis factors on all likelihood components

Model 25.0a, with bootstrap estimated stage 1 effective sample sizes for size comp and Francis (2011) weighting

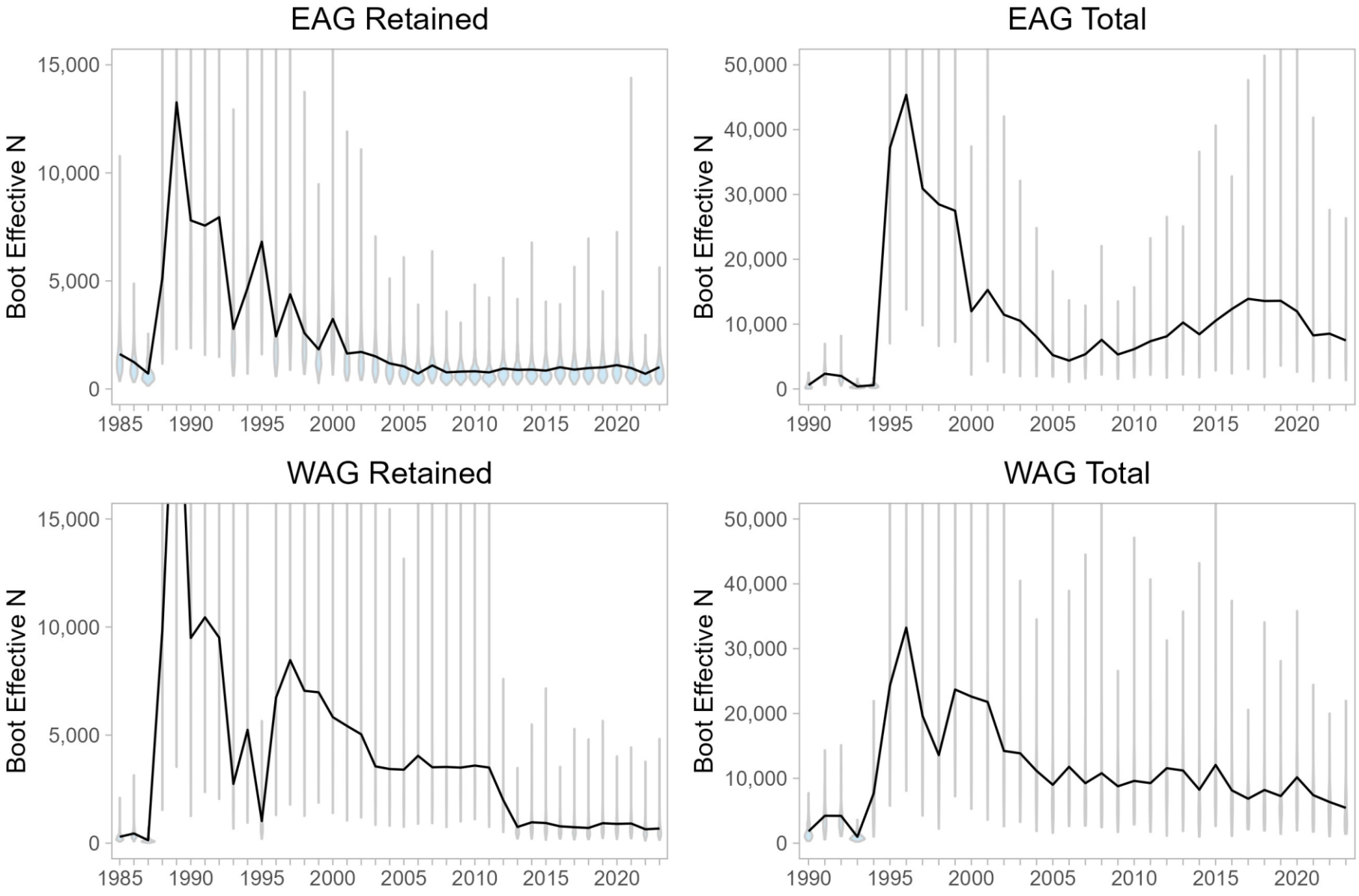
Model 25.0b, using the Dirichlet multinomial likelihood for size composition data

Model 25.0a, using the Dirichlet multinomial likelihood for size composition data

Bootstrap N_{eff} Estimation

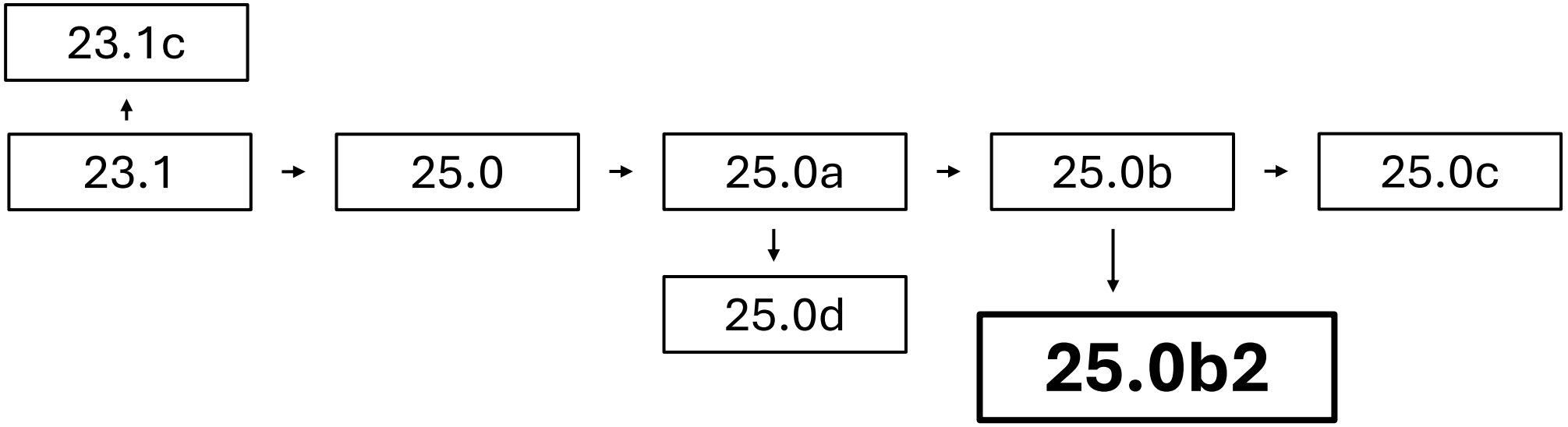
- Based on Stewart and Hamel (2014)
- Non-parametric, with replacement
- Two-stage approach
  1. Delivery (retained) or observer pot (total)
  2. Individual crab
- 500 replicates per year for retained catch, 100 for total catch (computation time)

$$N_{eff} = \frac{\sum_l P_l(1 - P_l)}{\sum_l (P_l - B_l)^2}$$



Very large. See Table 5-6.

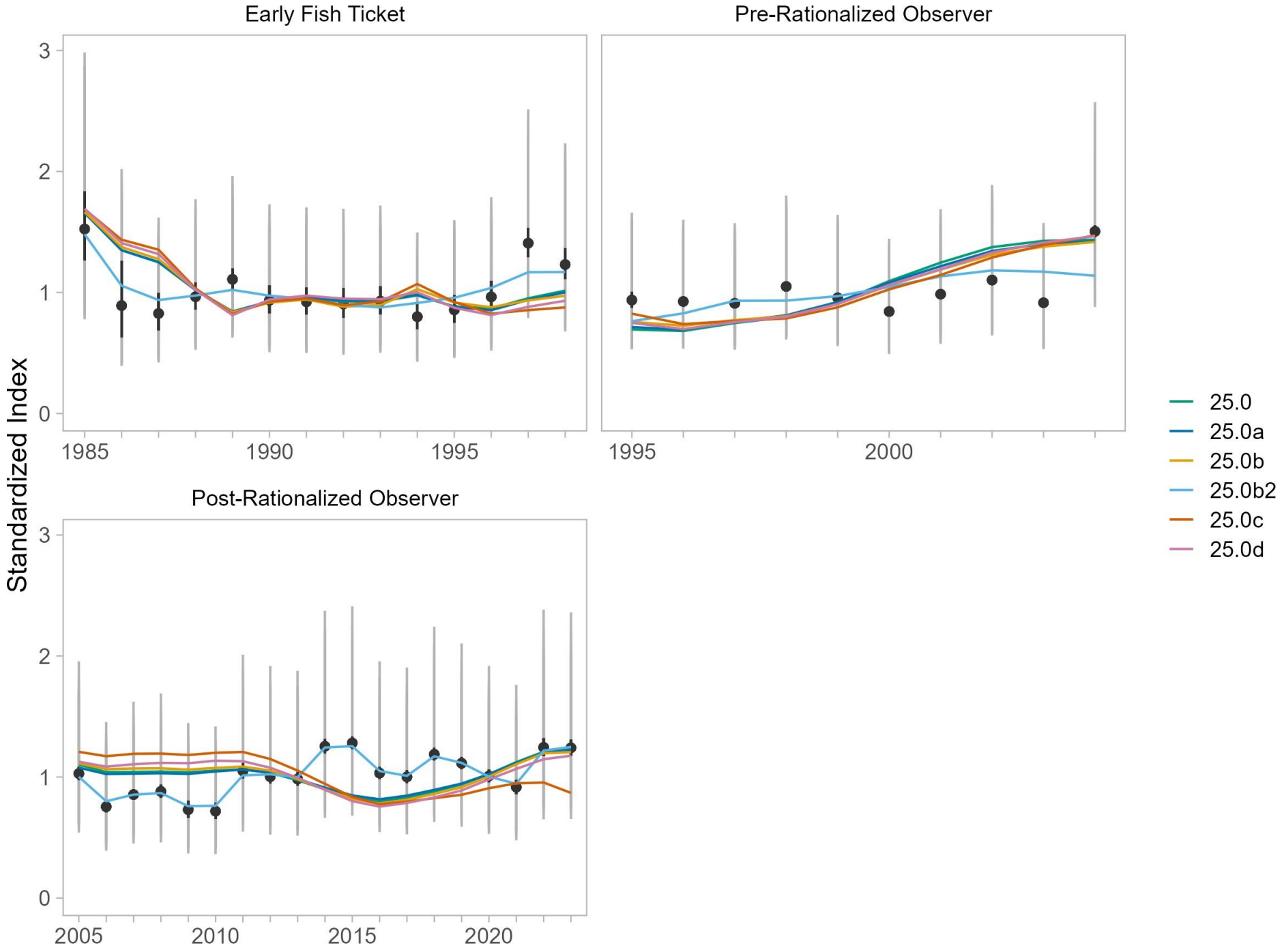
$$N'_{eff} = \min(2000, N_{eff})$$



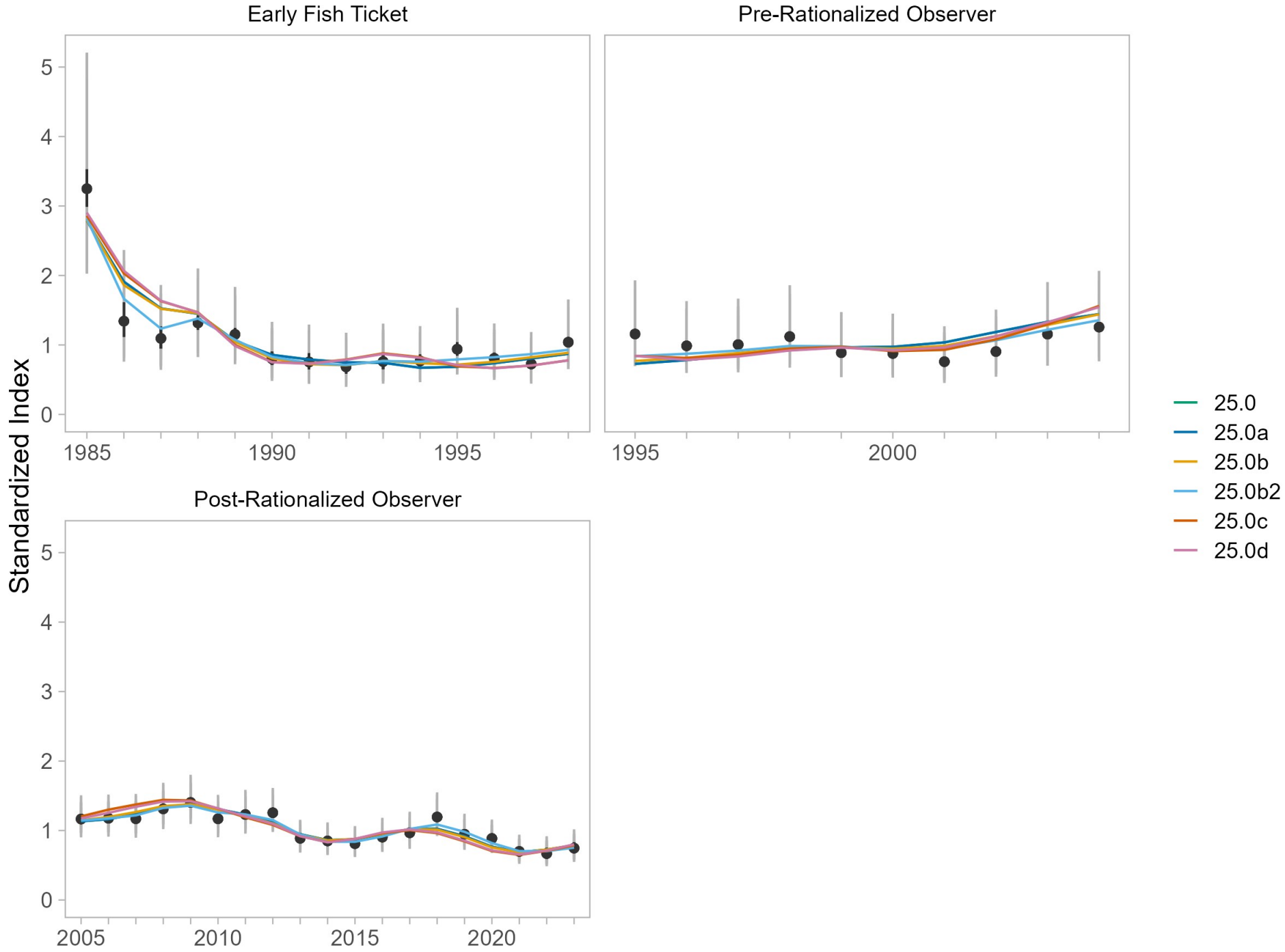
Increase emphasis on index data, $\lambda = 2$

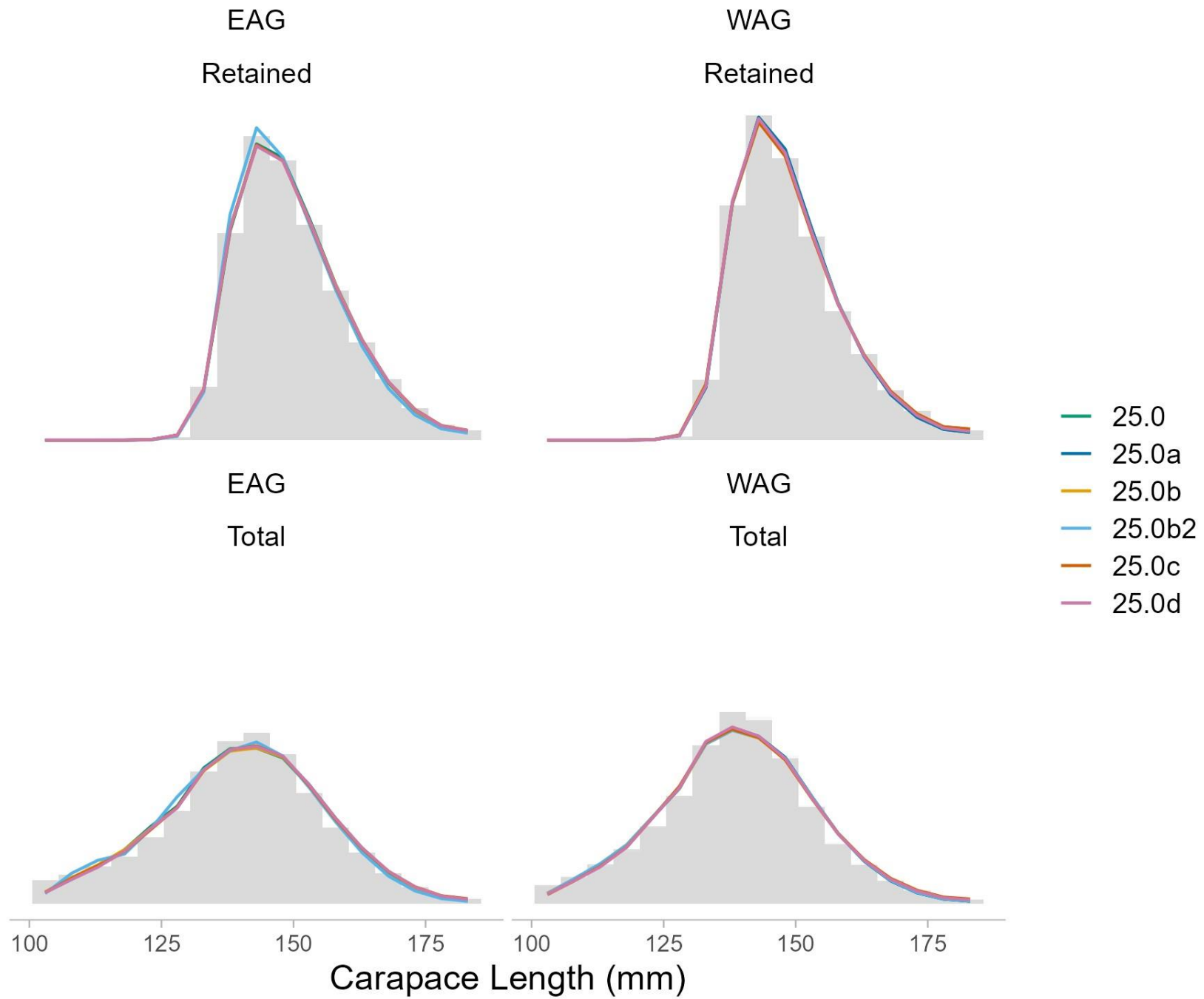
- Force better bit to index data
- Evaluate effects to other model processes and derived quantities
- Exploratory model not for final assessment
- Required increase to groundfish *F* penalty (0.1)

EAG


Early Fish Ticket
Pre-Rationalized Observer
Post-Rationalized Observer
Standardized Index
0
1
2
3
1985
1990
1995
2000
2005
2010
2015
2020
25.0
25.0a
25.0b
25.0b2
25.0c
25.0d

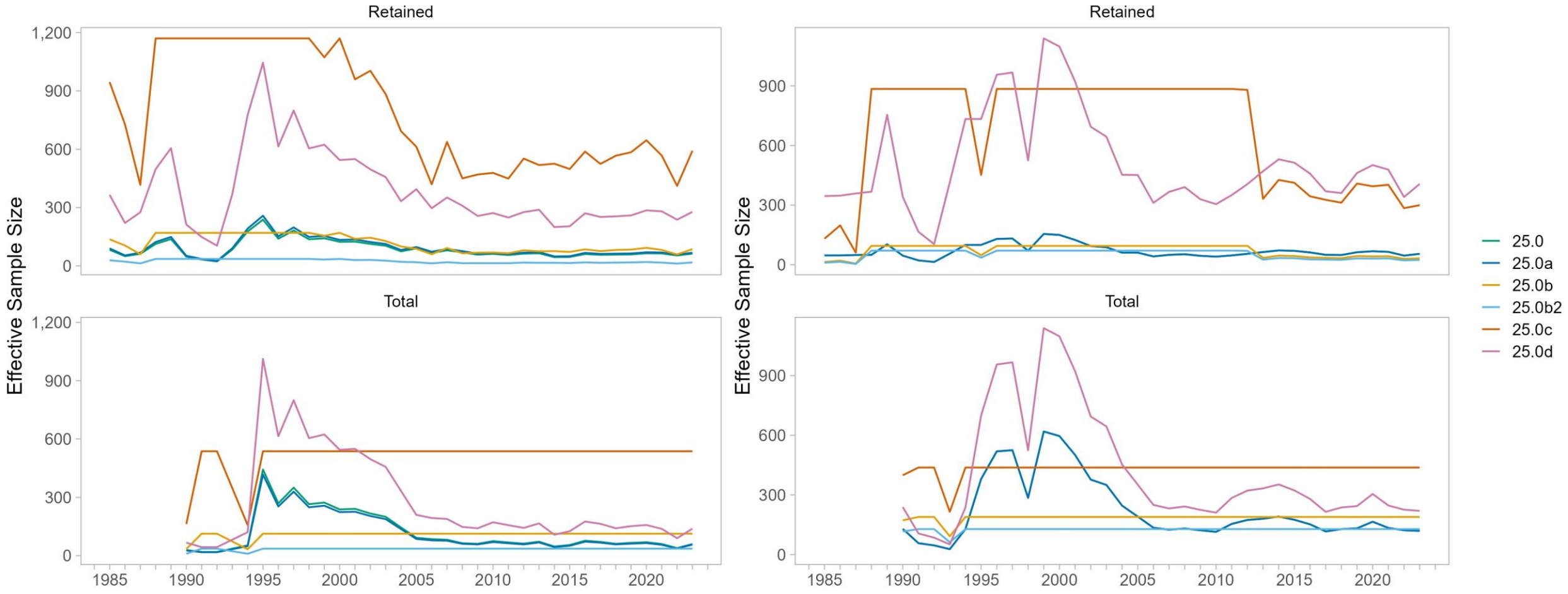
WAG


Early Fish Ticket
Pre-Rationalized Observer
Post-Rationalized Observer
Standardized Index
0
1
2
3
4
5
1985
1990
1995
2000
2005
2010
2015
2020
25.0
25.0a
25.0b
25.0b2
25.0c
25.0d

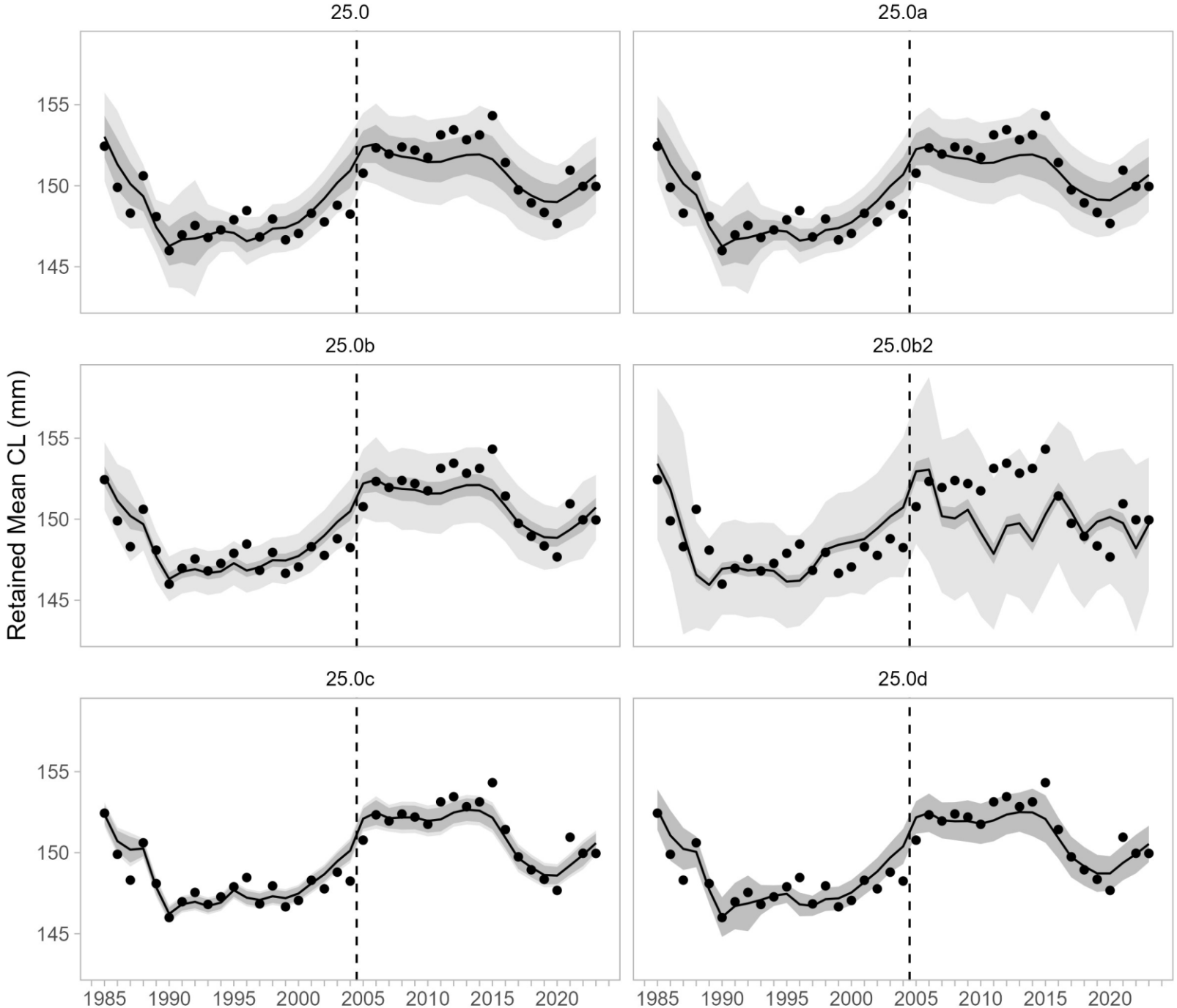

EAG
Retained
WAG
Retained
EAG
Total
WAG
Total
25.0
25.0a
25.0b
25.0b2
25.0c
25.0d
100
125
150
175
100
125
150
175
Carapace Length (mm)

EAG

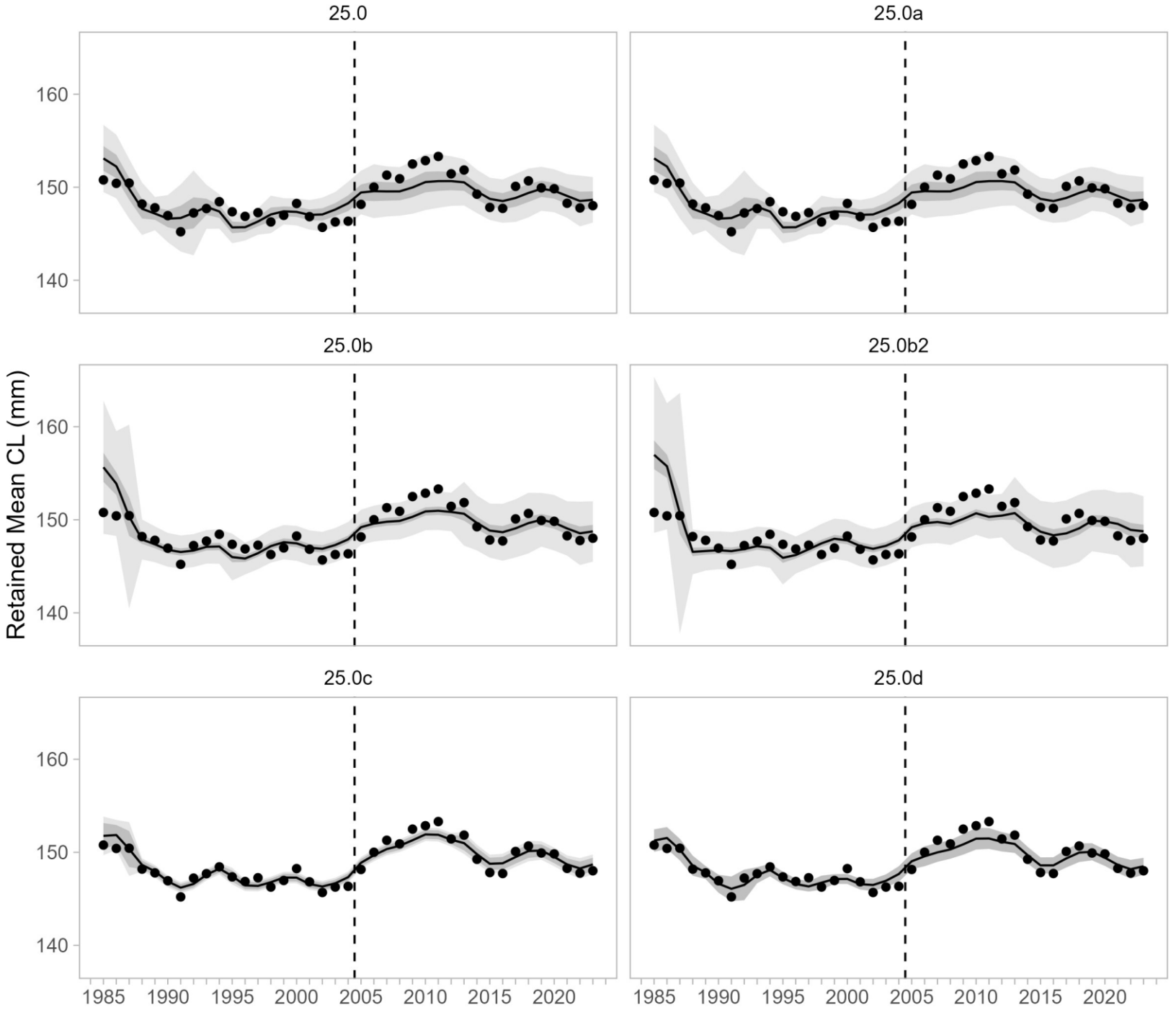
WAG


Retained
Total
Effective Sample Size
1,200
900
600
300
0
1985
1990
1995
2000
2005
2010
2015
2020
25.0
25.0a
25.0b
25.0b2
25.0c
25.0d

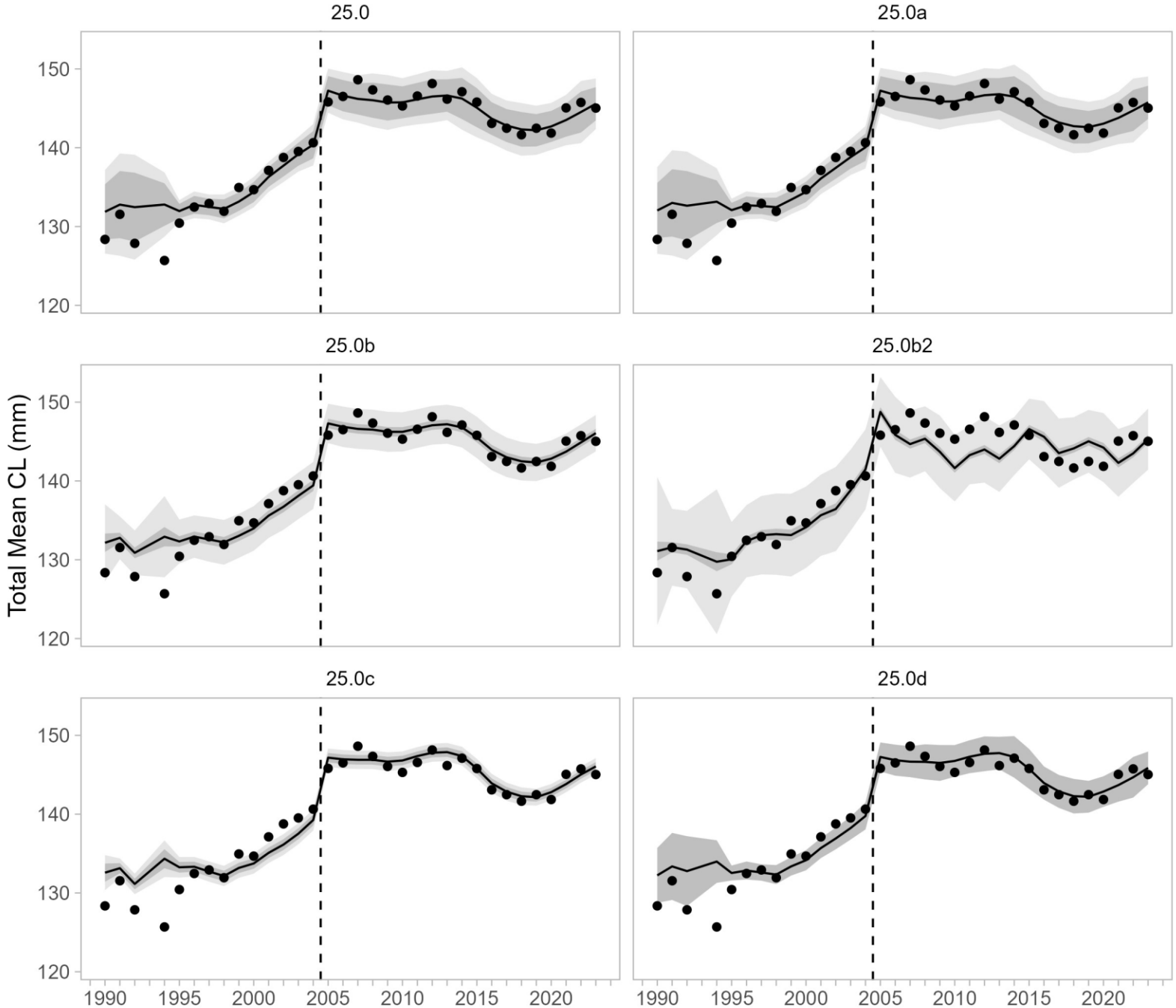
EAG


25.0
25.0a
25.0b
25.0b2
25.0c
25.0d
Retained Mean CL (mm)
155
150
145
1985
1990
1995
2000
2005
2010
2015
2020

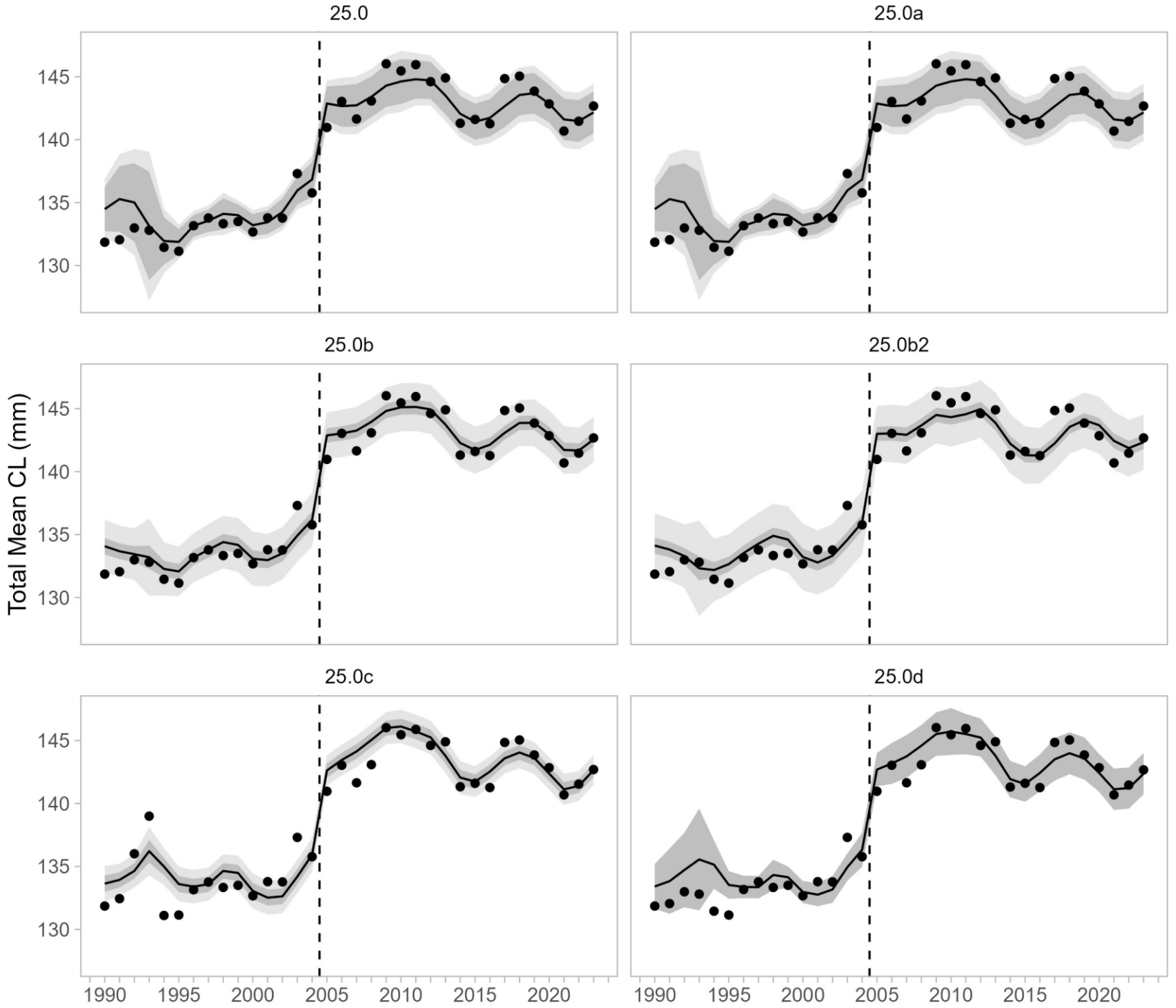
WAG

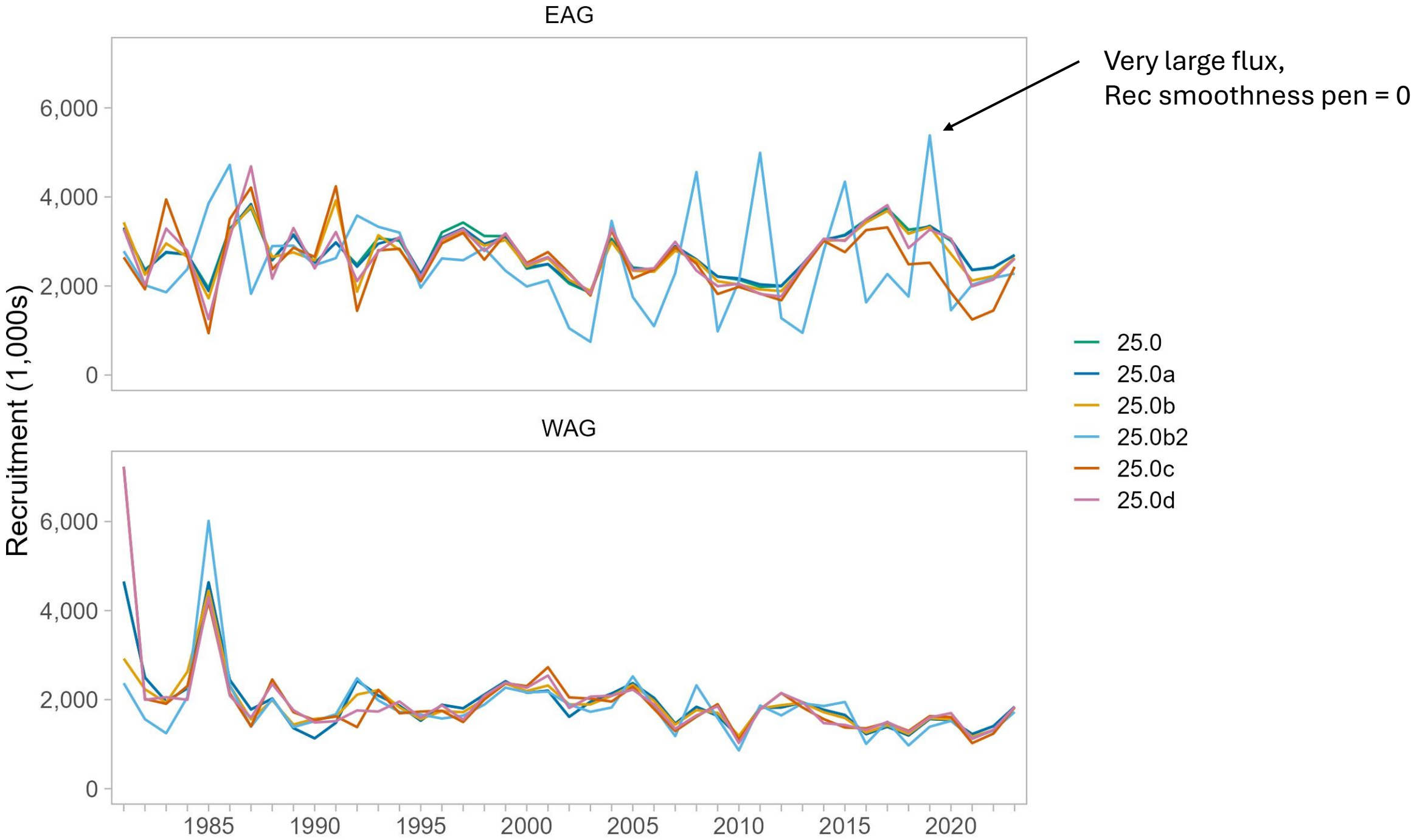

25.0
25.0a
25.0b
25.0b2
25.0c
25.0d
Retained Mean CL (mm)
160
150
140
1985
1990
1995
2000
2005
2010
2015
2020

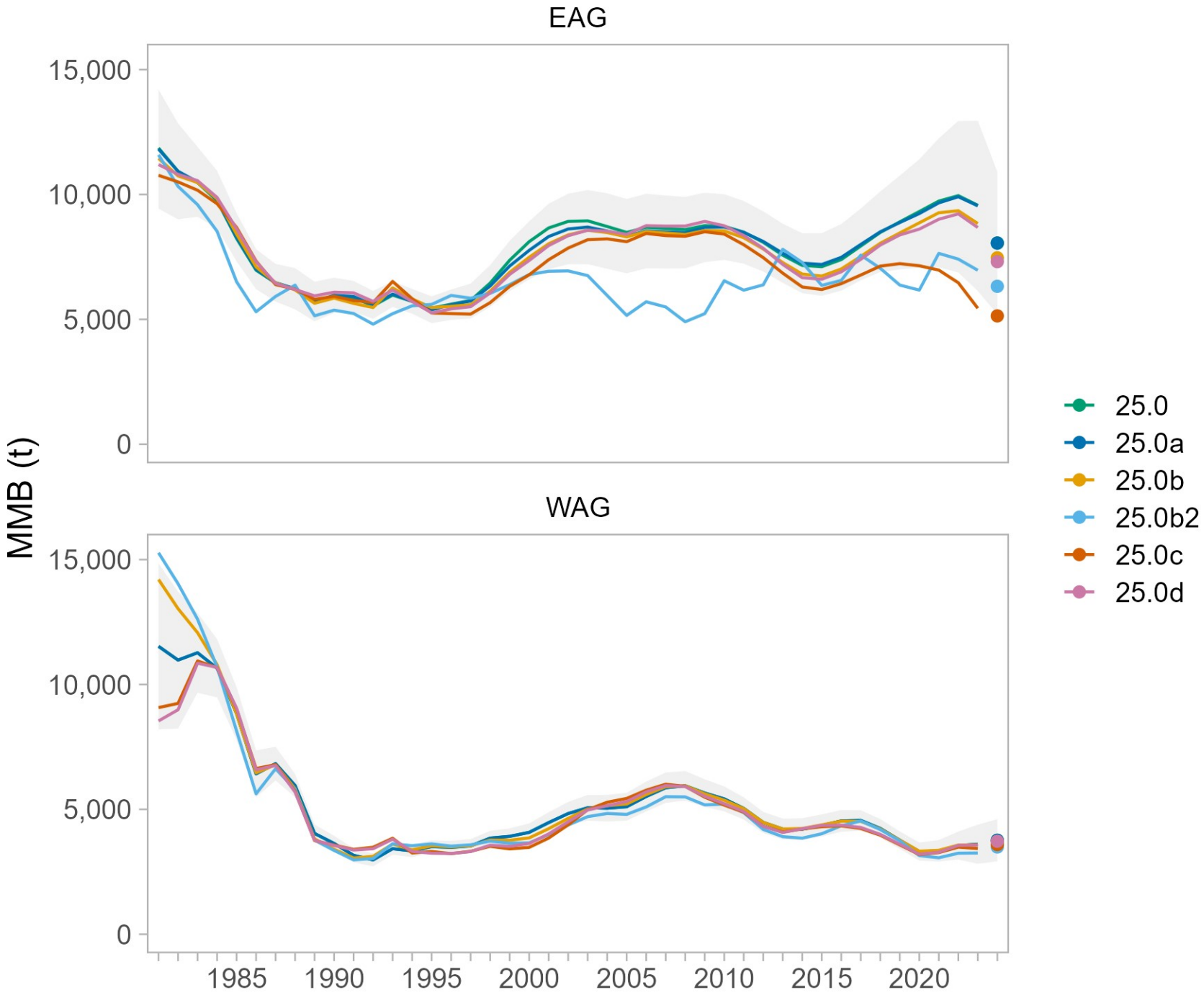
EAG


25.0
25.0a
25.0b
25.0b2
25.0c
25.0d
Total Mean CL (mm)
150
140
130
120
1990
1995
2000
2005
2010
2015
2020

WAG


25.0
25.0a
25.0b
25.0b2
25.0c
25.0d
Total Mean CL (mm)
145
140
135
130
1990
1995
2000
2005
2010
2015
2020


EAG
WAG
Recruitment (1,000s)
6,000
4,000
2,000
0
1985
1990
1995
2000
2005
2010
2015
2020
Very large flux,
Rec smoothness pen = 0
25.0
25.0a
25.0b
25.0b2
25.0c
25.0d


EAG
WAG
MMB (t)
15,000
10,000
5,000
0
1985
1990
1995
2000
2005
2010
2015
2020
25.0
25.0a
25.0b
25.0b2
25.0c
25.0d

Reference Points

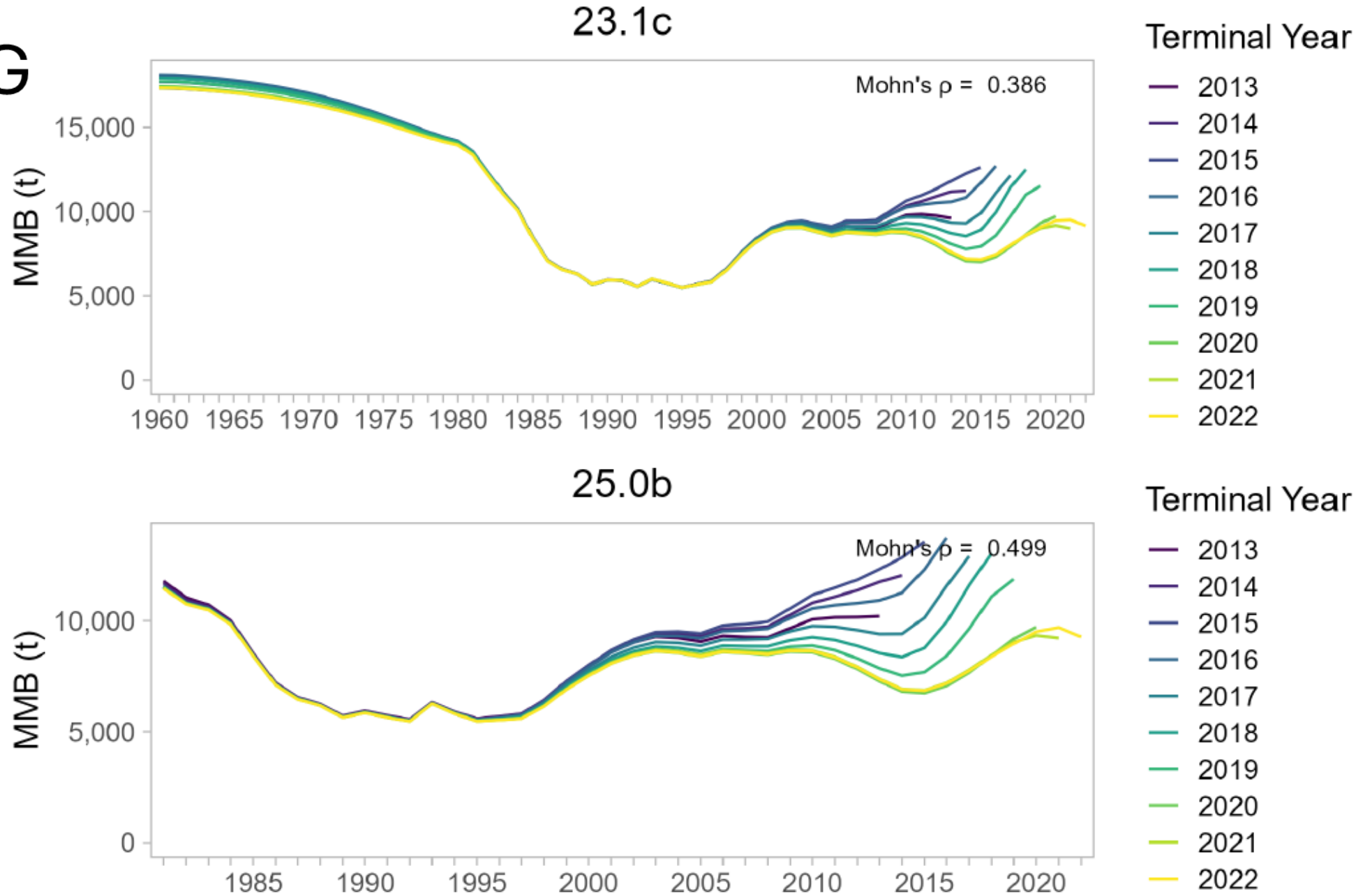
EAG

Model	MMB (t)	$B_{35\%}$ (t)	$\frac{MMB}{B_{35\%}}$	$\bar{R}_{1987-2020}$	$F_{35\%}$	F_{OFL}	OFL (t)
23.1	7,547	6,905	1.09	2,781	0.55	0.55	2,823
23.1c	7,539	6,904	1.09	2,781	0.55	0.55	2,822
25.0	8,058	6,939	1.16	2,789	0.54	0.54	2,973
25.0a	8,053	6,908	1.17	2,775	0.55	0.55	2,970
25.0b	7,464	6,846	1.09	2,743	0.55	0.55	2,755
25.0b2	6,324	6,439	0.98	2,573	0.51	0.50	2,096
25.0c	5,140	6,633	0.77	2,662	0.59	0.44	1,345
25.0d	7,311	6,846	1.07	2,752	0.58	0.58	2,710

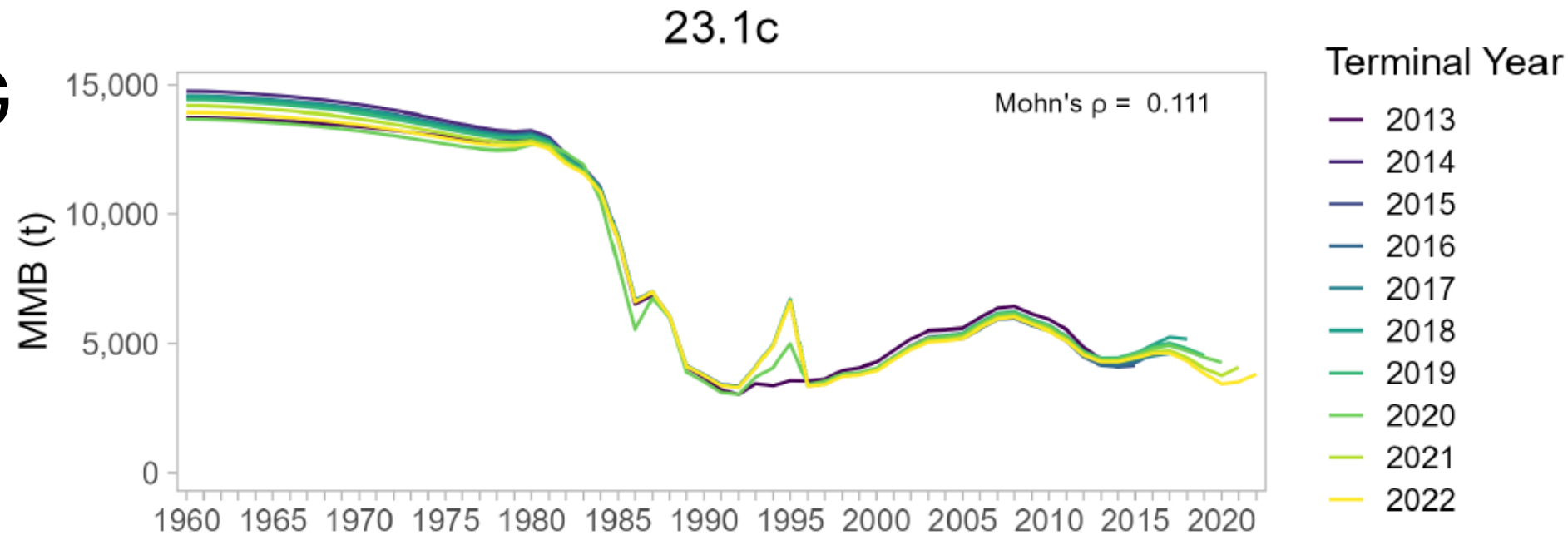
WAG

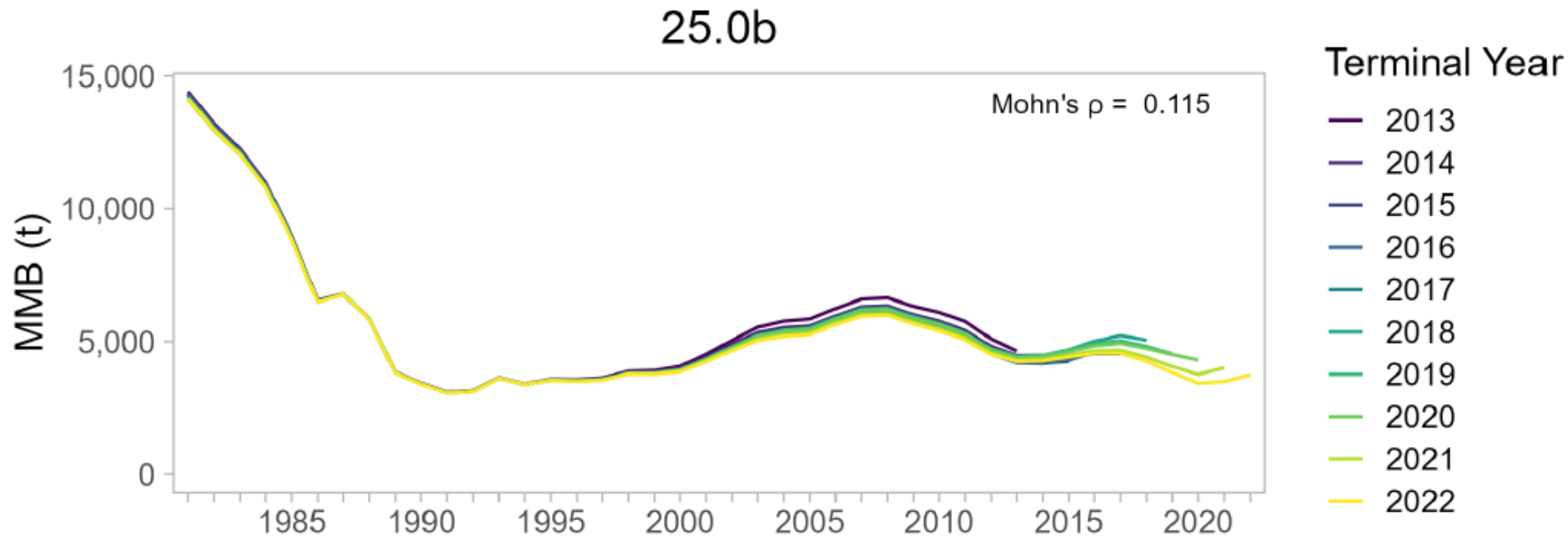
Model	MMB (t)	$B_{35\%}$ (t)	$\frac{MMB}{B_{35\%}}$	$\bar{R}_{1987-2020}$	$F_{35\%}$	F_{OFL}	OFL (t)
23.1	3,767	4,498	0.84	1,808	0.54	0.44	899
23.1c	3,757	4,494	0.84	1,807	0.55	0.45	894
25.0	3,762	4,491	0.84	1,803	0.54	0.45	892
25.0a	3,762	4,491	0.84	1,803	0.54	0.45	892
25.0b	3,705	4,504	0.82	1,800	0.54	0.44	872
25.0b2	3,493	4,417	0.79	1,757	0.54	0.41	754
25.0c	3,590	4,540	0.79	1,795	0.54	0.42	784
25.0d	3,722	4,522	0.82	1,793	0.54	0.43	849

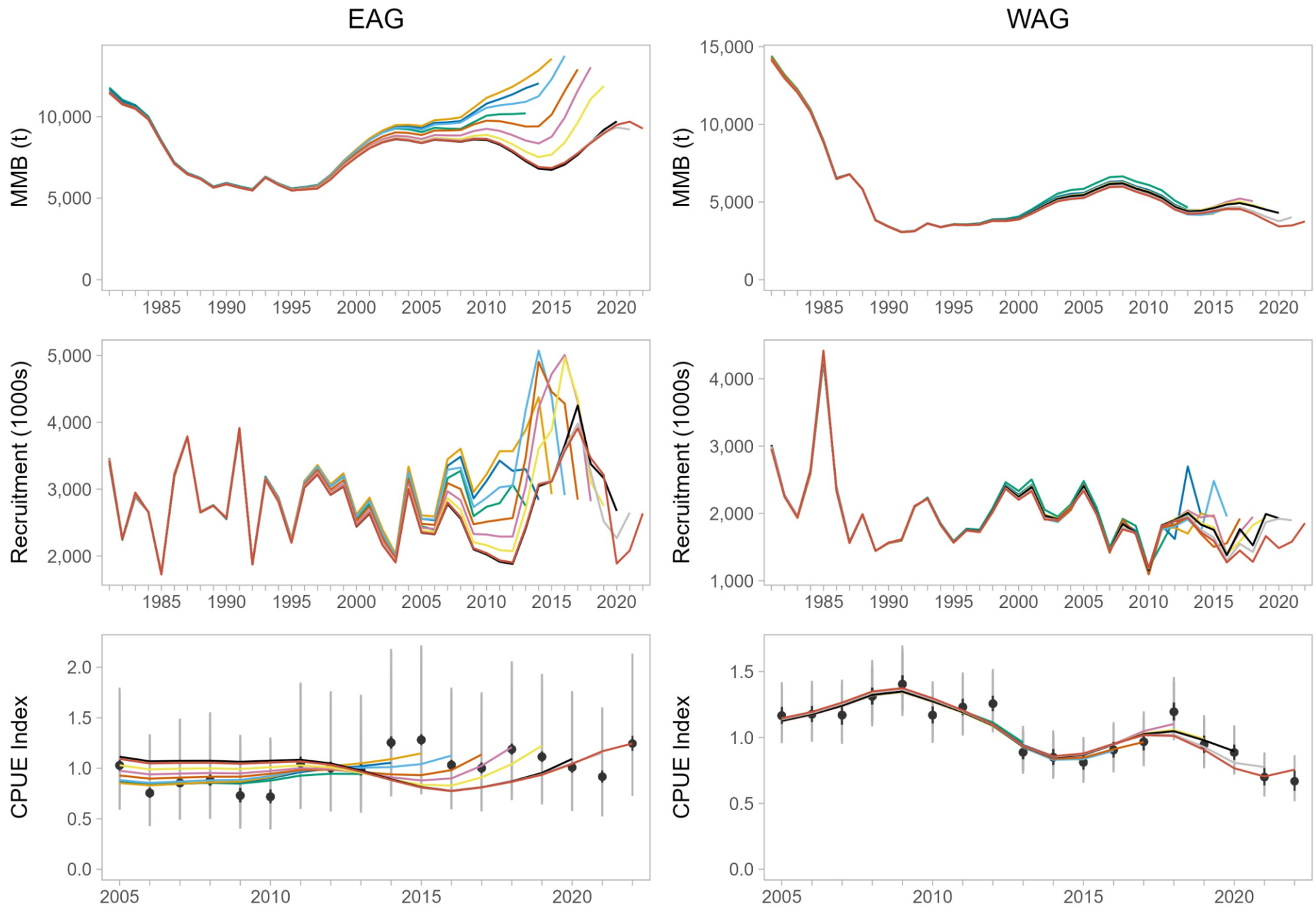
EAG


23.1c
Mohn's ρ = 0.386
MMB (t)
15,000
10,000
5,000
0
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
Terminal Year
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
25.0b
Mohn's ρ = 0.499
MMB (t)
10,000
5,000
0
1985 1990 1995 2000 2005 2010 2015 2020
Terminal Year
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022

WAG

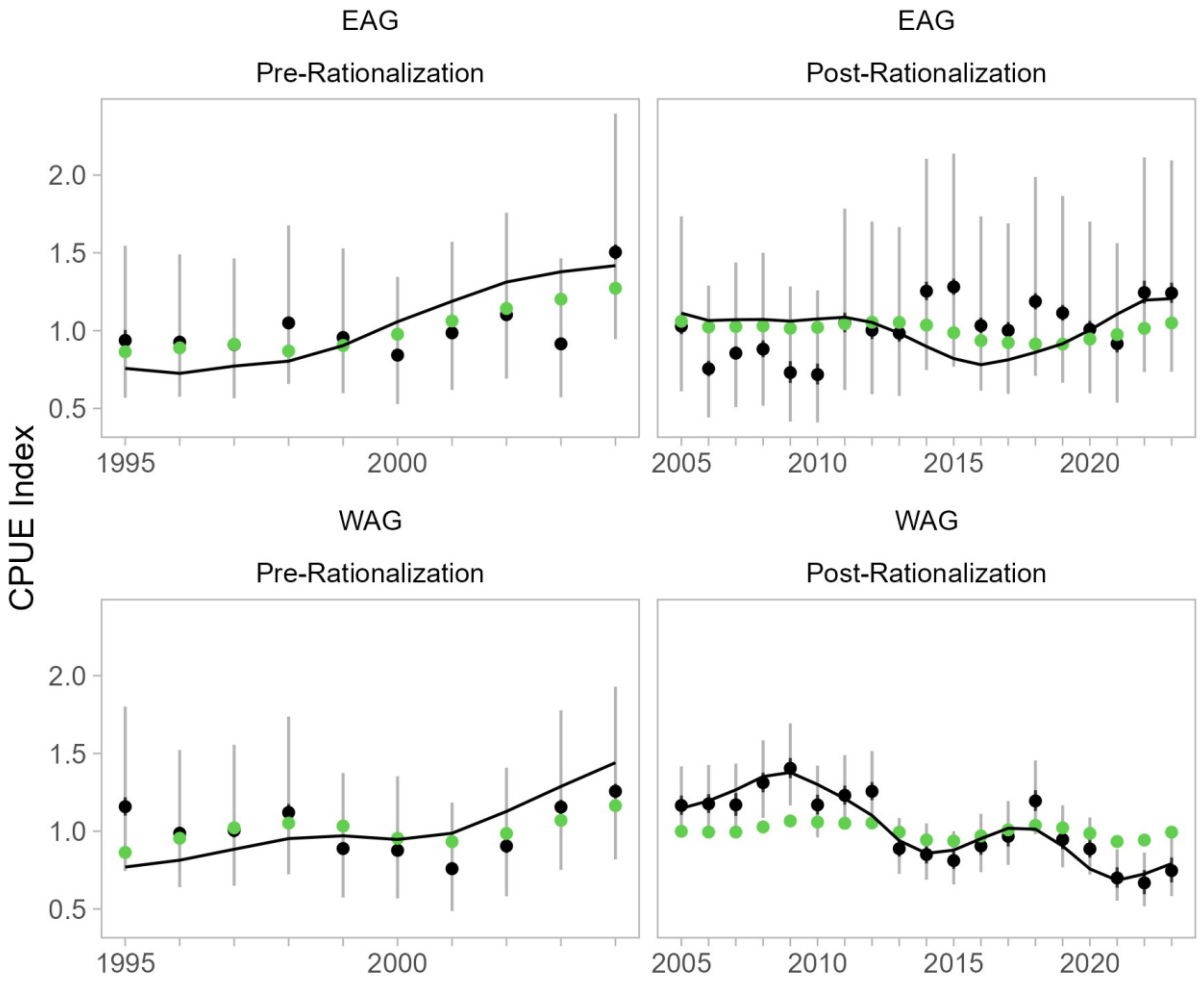

23.1c
Mohn's ρ = 0.111
MMB (t)
15,000
10,000
5,000
0
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
Terminal Year
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022

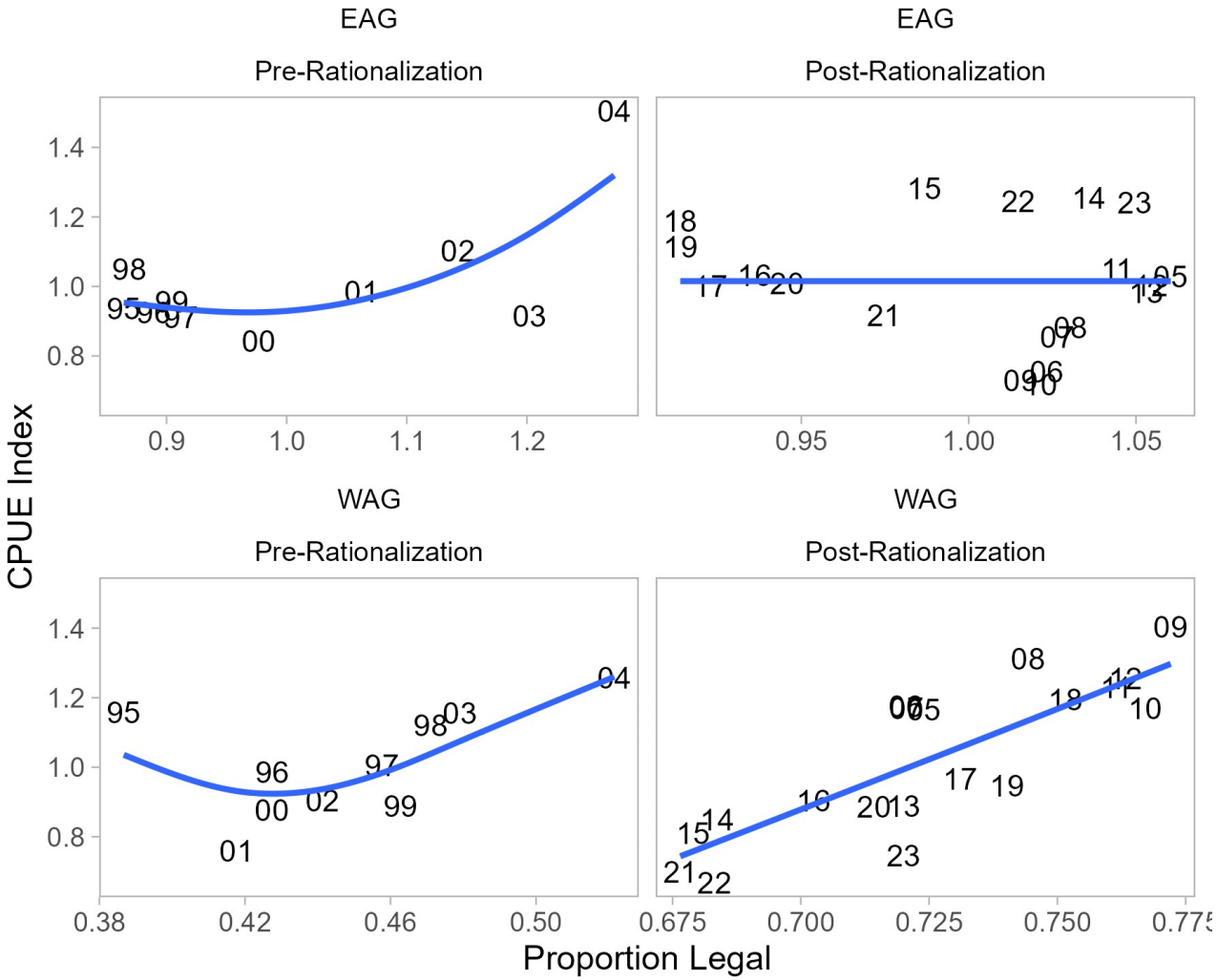

25.0b
Mohn's ρ = 0.115
MMB (t)
15,000
10,000
5,000
0
1985 1990 1995 2000 2005 2010 2015 2020
Terminal Year
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022


EAG
WAG
MMB (t)
Recruitment (1000s)
CPUE Index
0
5,000
10,000
15,000
1,000
2,000
3,000
4,000
0.0
0.5
1.0
1.5
2.0
1985
1990
1995
2000
2005
2010
2015
2020

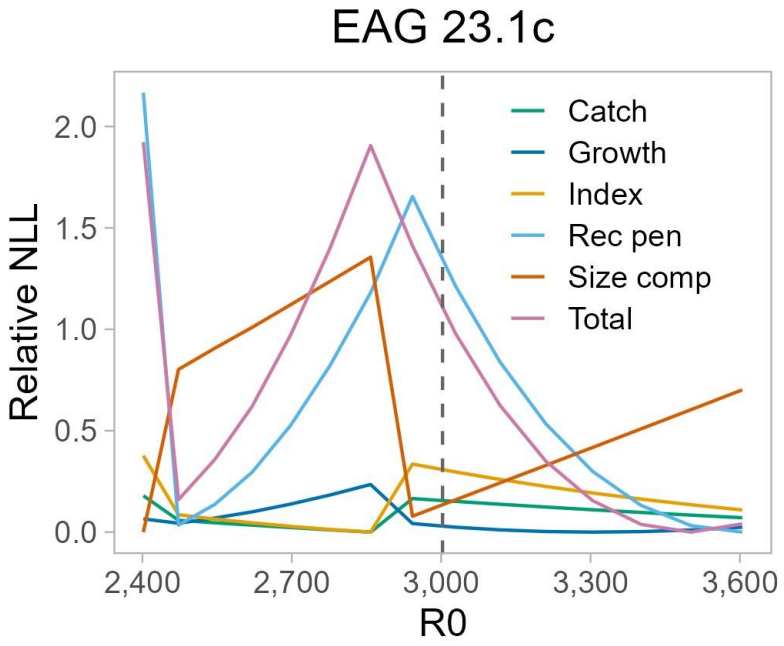
Data Weighting Conclusions

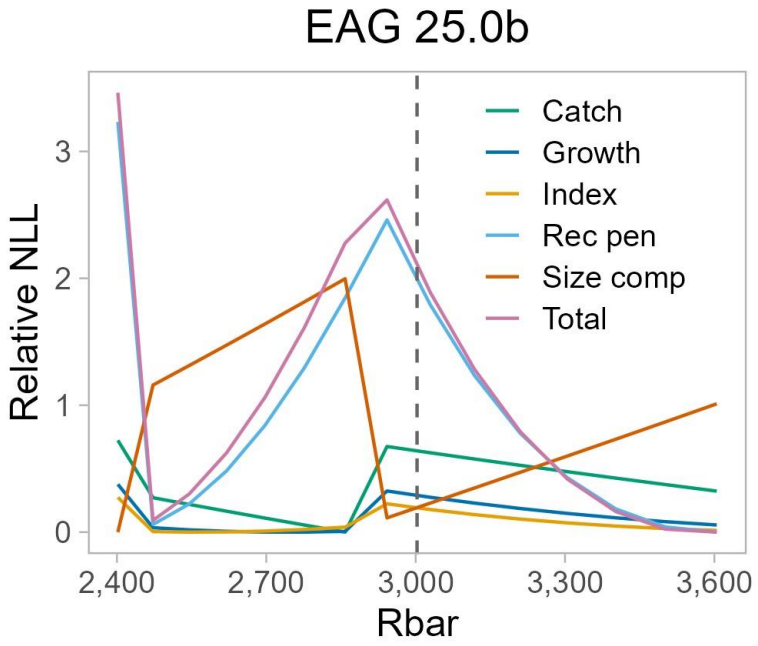
- EAG are more sensitive to data weighting than WAG
- Size composition data are overweighted relative to index data – Dirichlet doesn't resolve this
- Forcing fit to EAG index data results in implausible derived quantities, eg recruitment
- **Issue should not be resolved by data weighting**
- **Some time or spatial varying process in post-rationalized era is unaccounted for (eg catchability, selectivity, growth)**
- Unmodelled process error manifests as large estimated CV on index data, poor fit

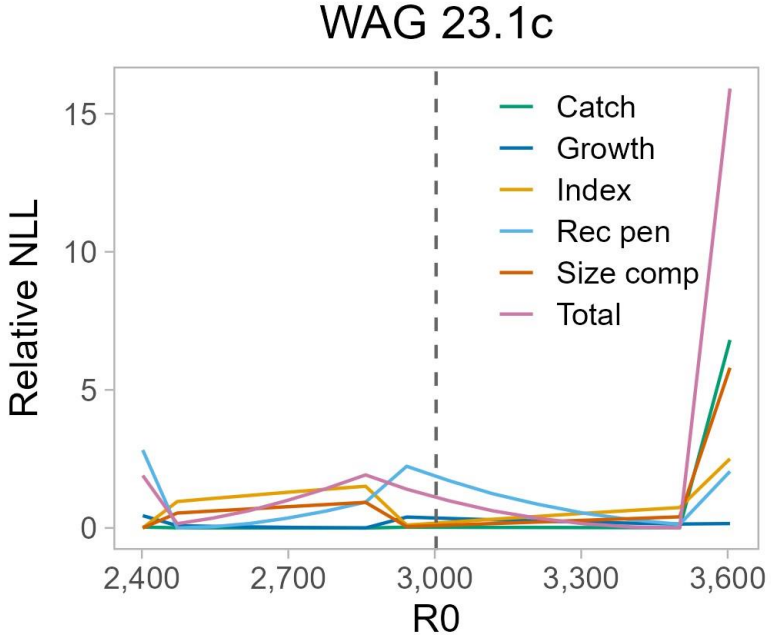


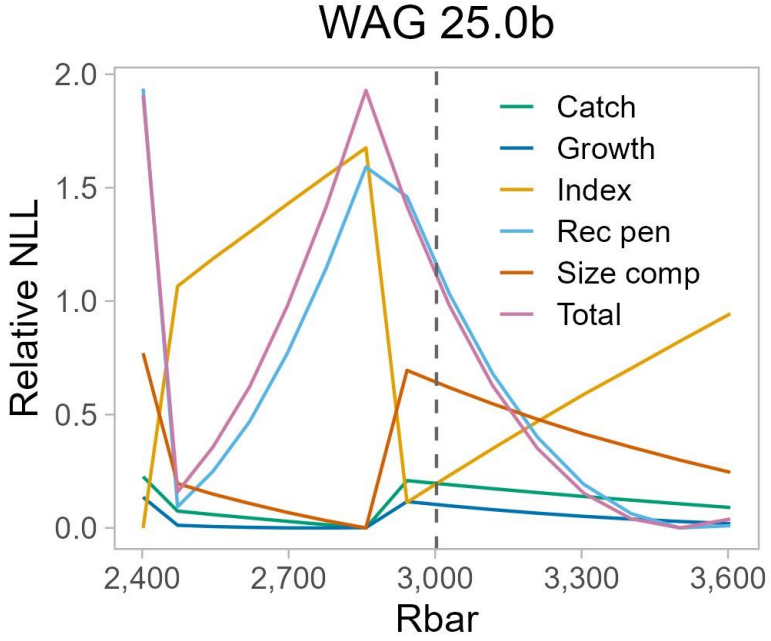


Model 25.0b, green dots are scaled proportion legal crab





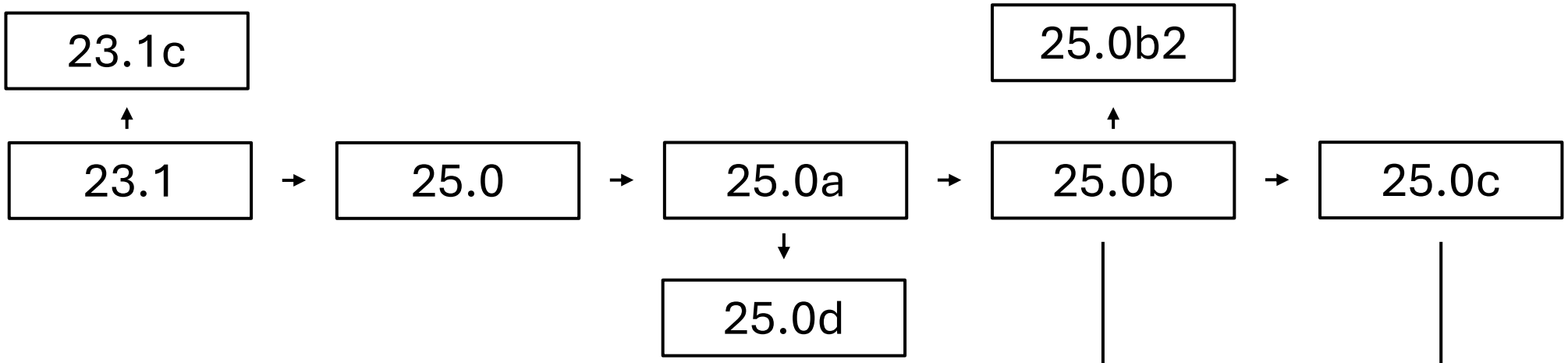




Messy, *but*

- Size Comp has larger gradient than index in EAG
- Opposite in WAG

Need to revisit with observed and simulated data



Cooperative survey as fleet

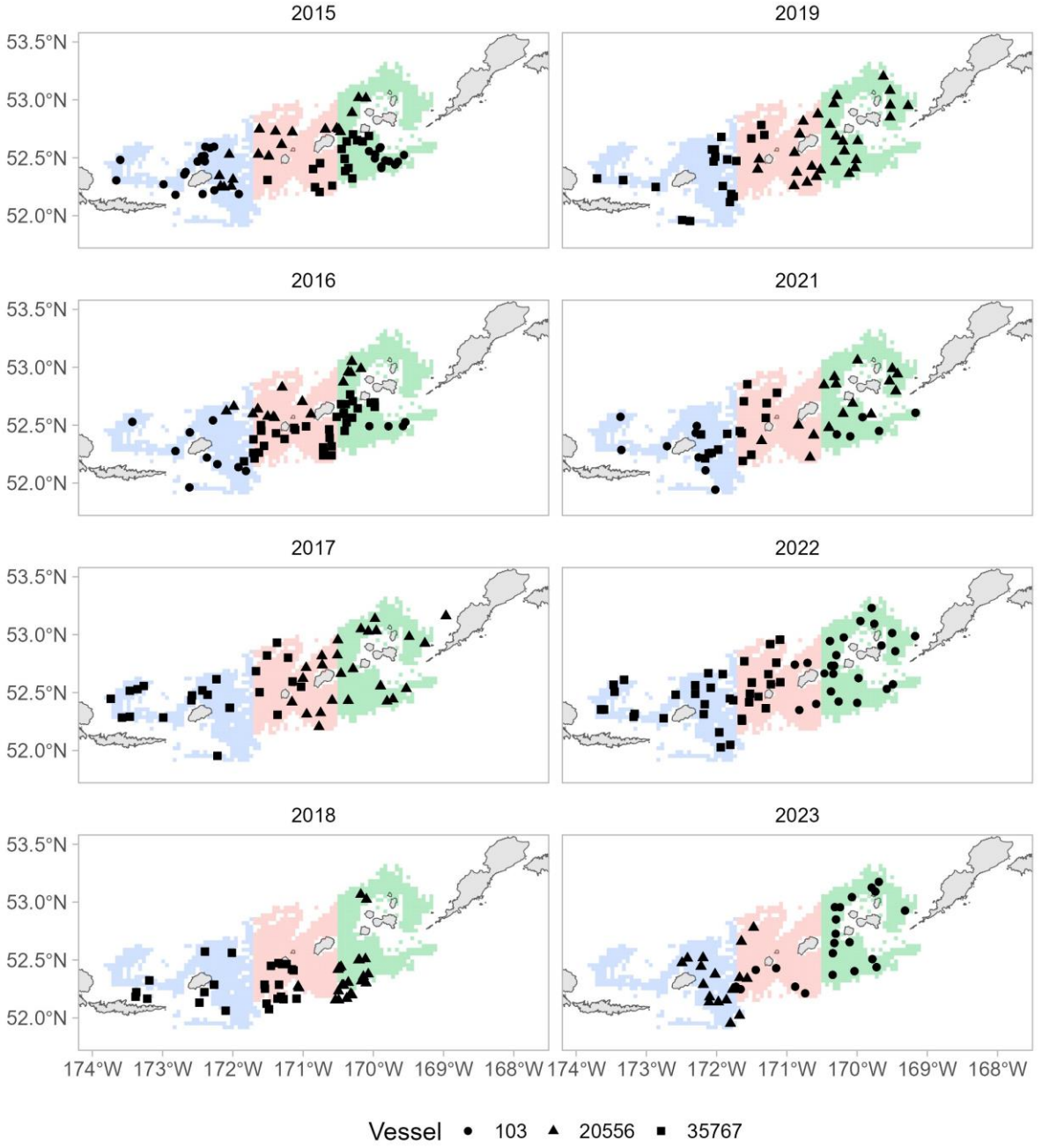
EAG Only

- Index, no extra CV
- Independent catchability
- Logistic selectivity
- No retention
- Size Comp, bootstrap N
  - Mult w/ Francis weighting (25.1) or Dirichlet Mult (25.1b)

25.1 **25.1b**

Appendix A – Cooperative Survey Data

- Vessels cover part of EAG, number of vessels vary by year
- 1 nmi x 1 nmi grid divided into 3 strata since 2022
- String set in each randomly selected grid cell
- Number of strings set has varied
- Not all strings set were hauled



- ADF&G staff sample 5-7 pots per string
  - Avoid 1st/last pot
  - Aim for systematic sample

- Some years saw over sampled strings, in 2019 oversampled strings had many 0s in EAG

- Measure subsample of crab
  - Legal males
  - Sublegal males
  - Females

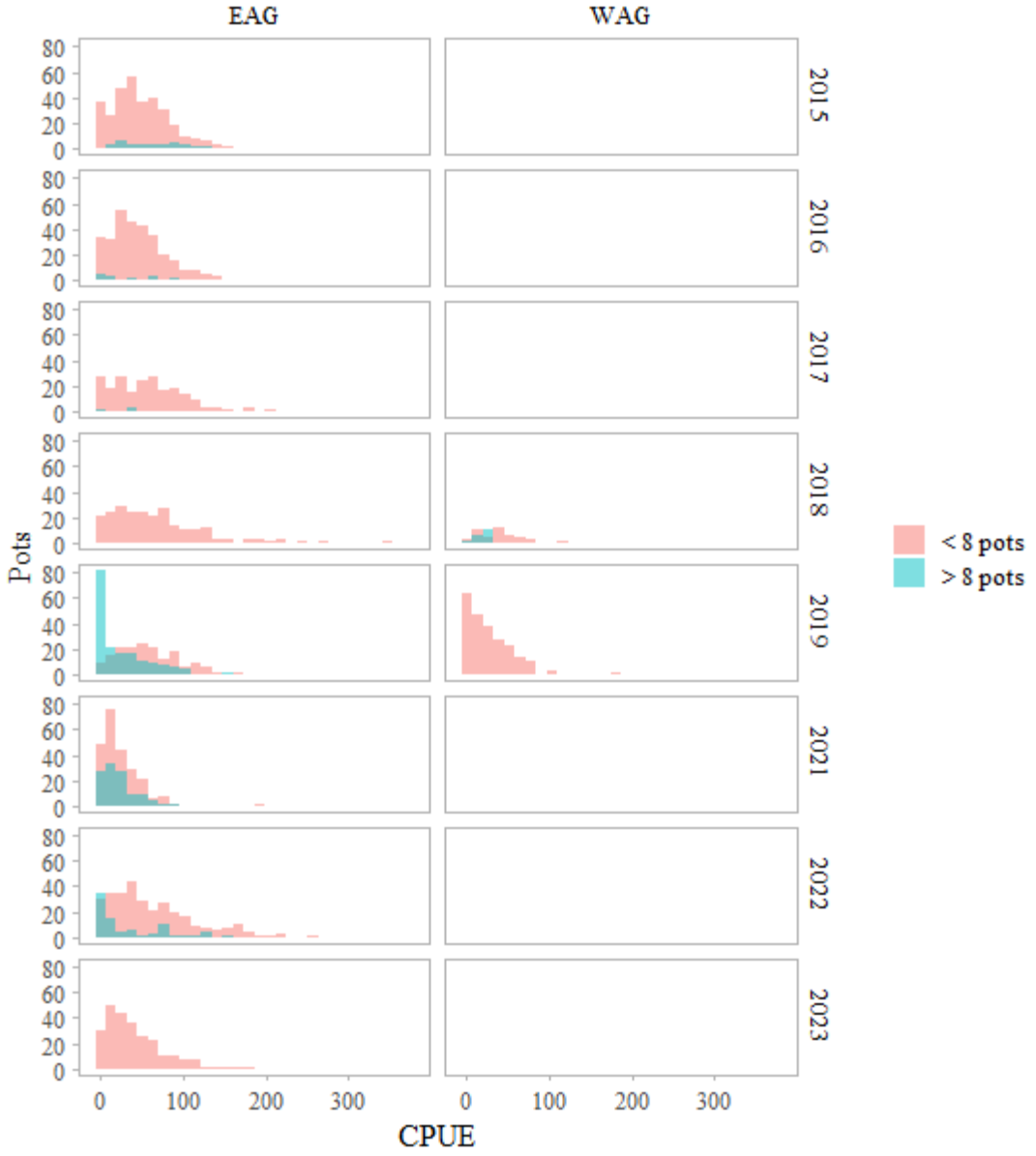


Table 1: Number of strings and pots sampled, and total number of male crab caught and measured by legal status.

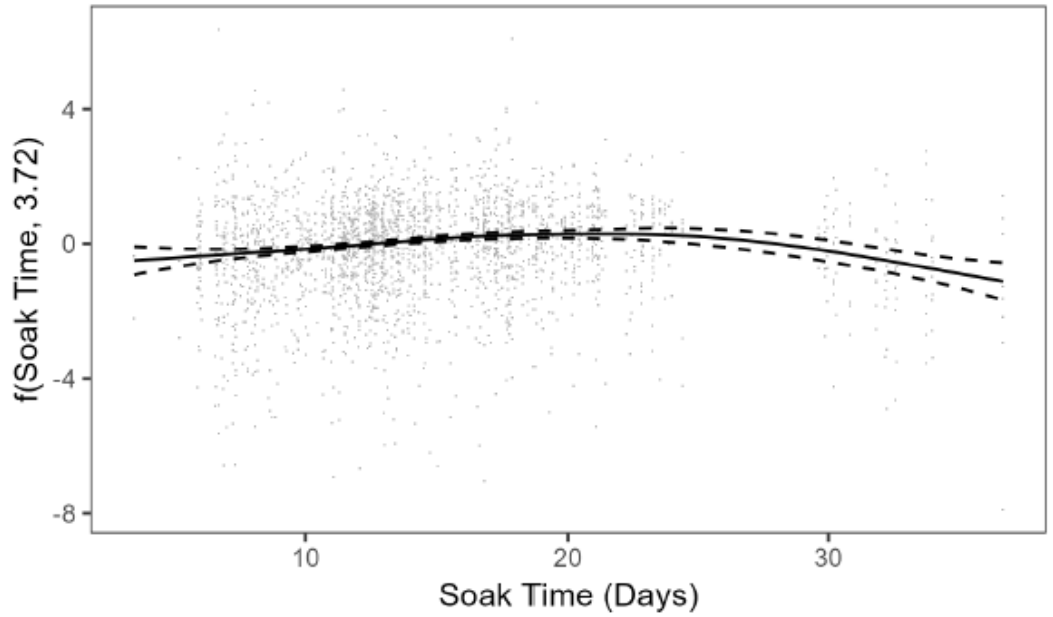
			Legal		Sublegal	
Survey Year	Strings Sampled	Pots Sampled	Caught	Measured	Caught	Measured
2015	65	361	14,290	3,630	4,746	1,459
2016	65	325	11,221	2,781	5,787	1,217
2017	48	224	9,308	2,682	4,669	1,167
2018	50	250	9,225	1,889	9,533	1,434
2019	47	352	9,582	3,870	6,195	2,320
2021	46	349	6,328	5,135	1,748	1,534
2022	43	263	19,352	8,101	4,619	2,175
2023	39	251	7,074	4,009	3,370	1,649

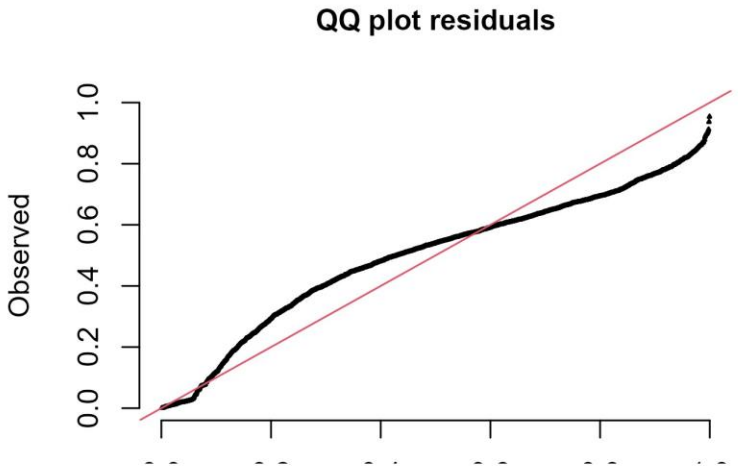
Survey Index Standardization

- Added zero catches to data, previously unavailable
- Model selection same as observer CPUE standardization

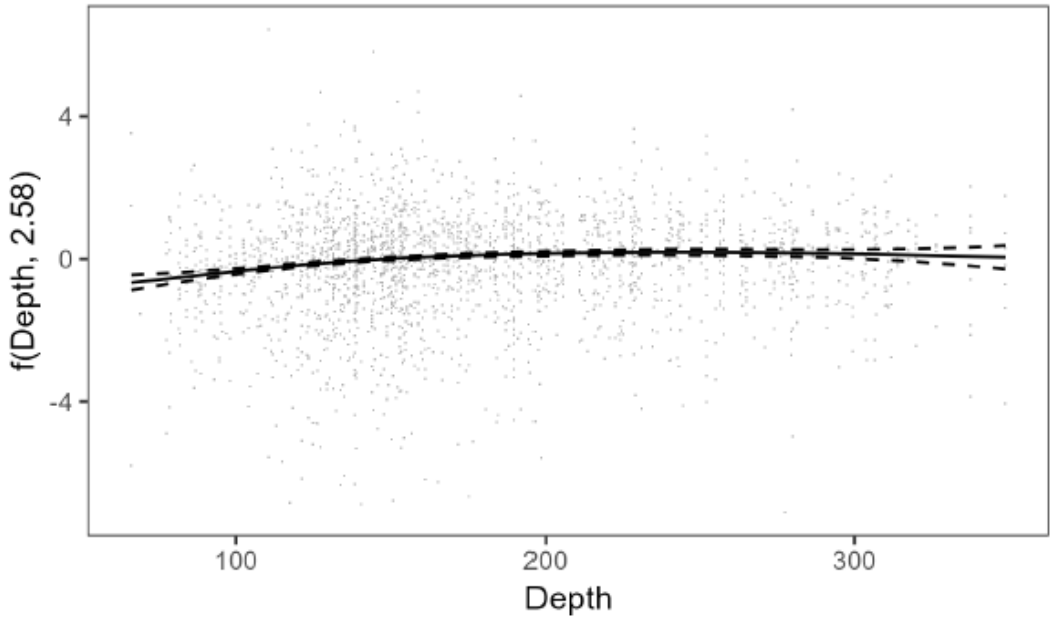
$$\ln(U_j) = \text{Year}_y + s(\text{soak time}) + s(\text{depth}) + (1|\text{Stratum}_h/\text{String}_{i,y}) + \epsilon$$

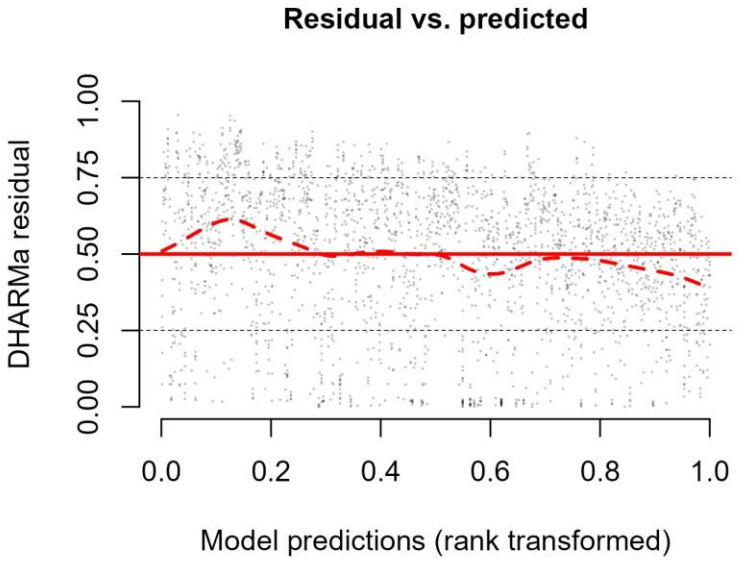
- Negative binomial GAMM with overdispersion estimated, *gamm4* (Wood and Scheipl 2020)
- Diagnose using DHARMa residuals

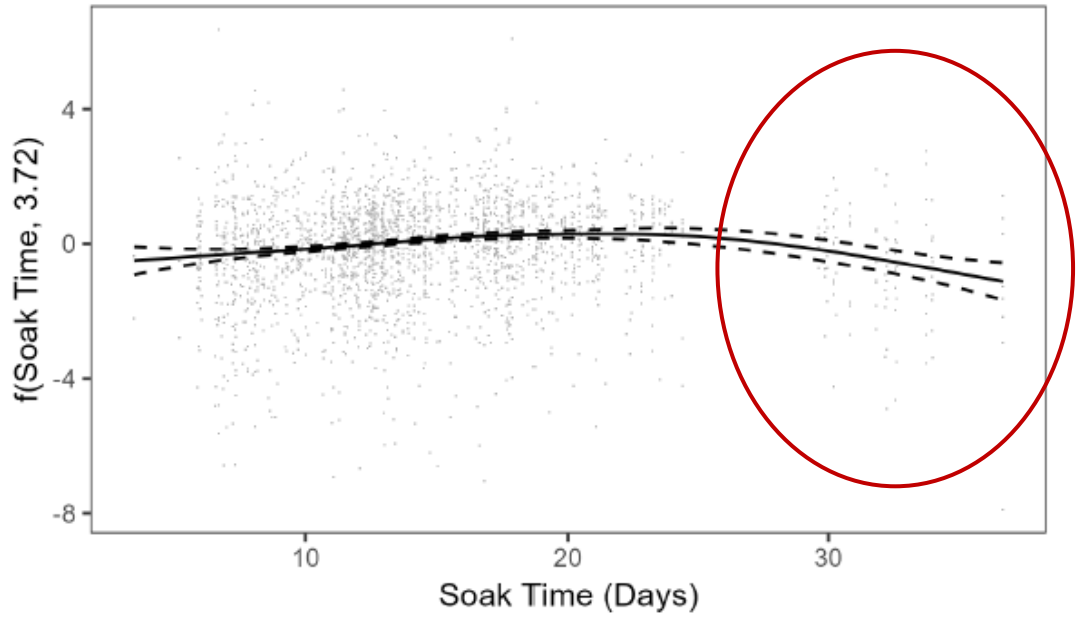


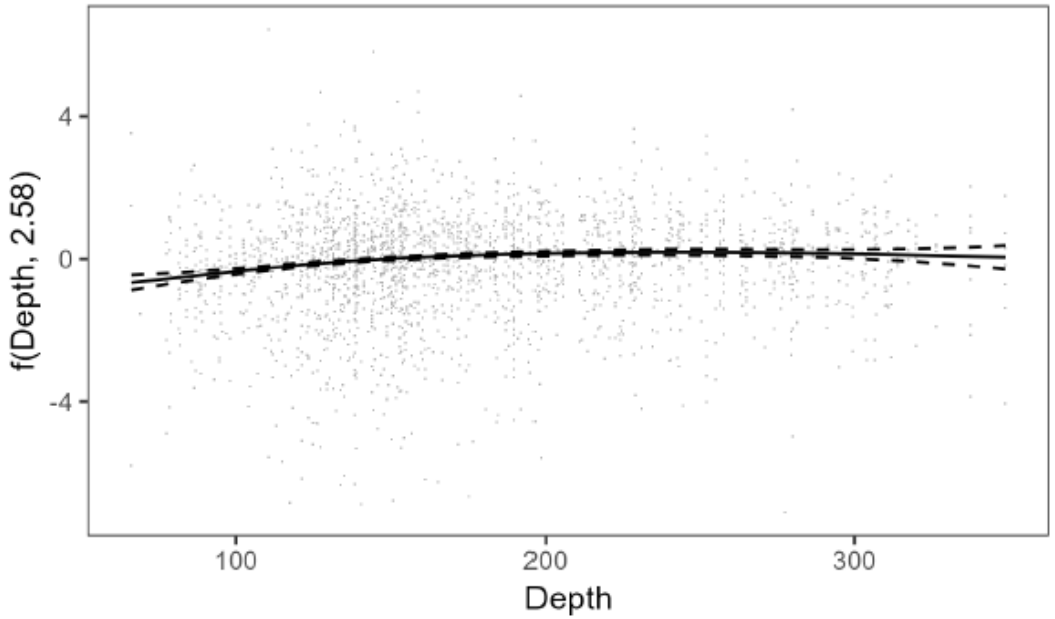


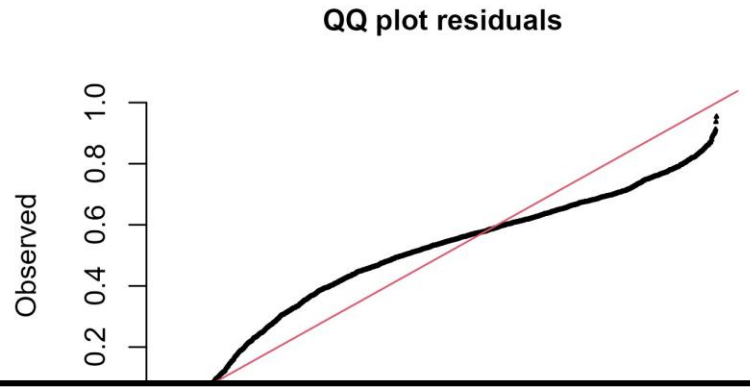
Neg Bin θ = 2.76



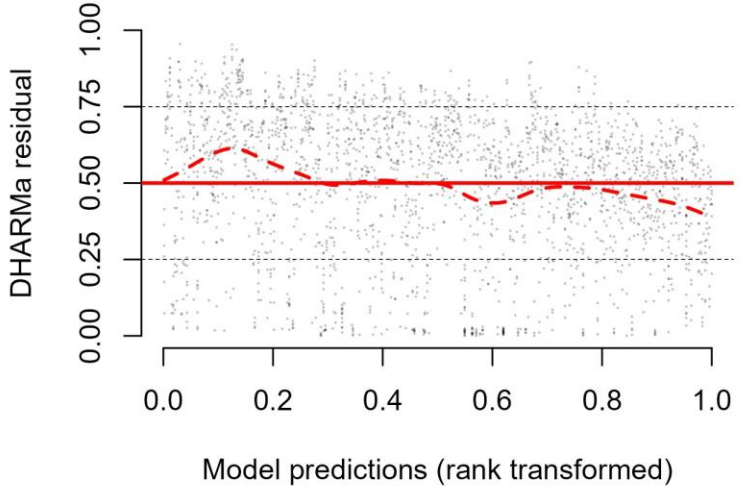


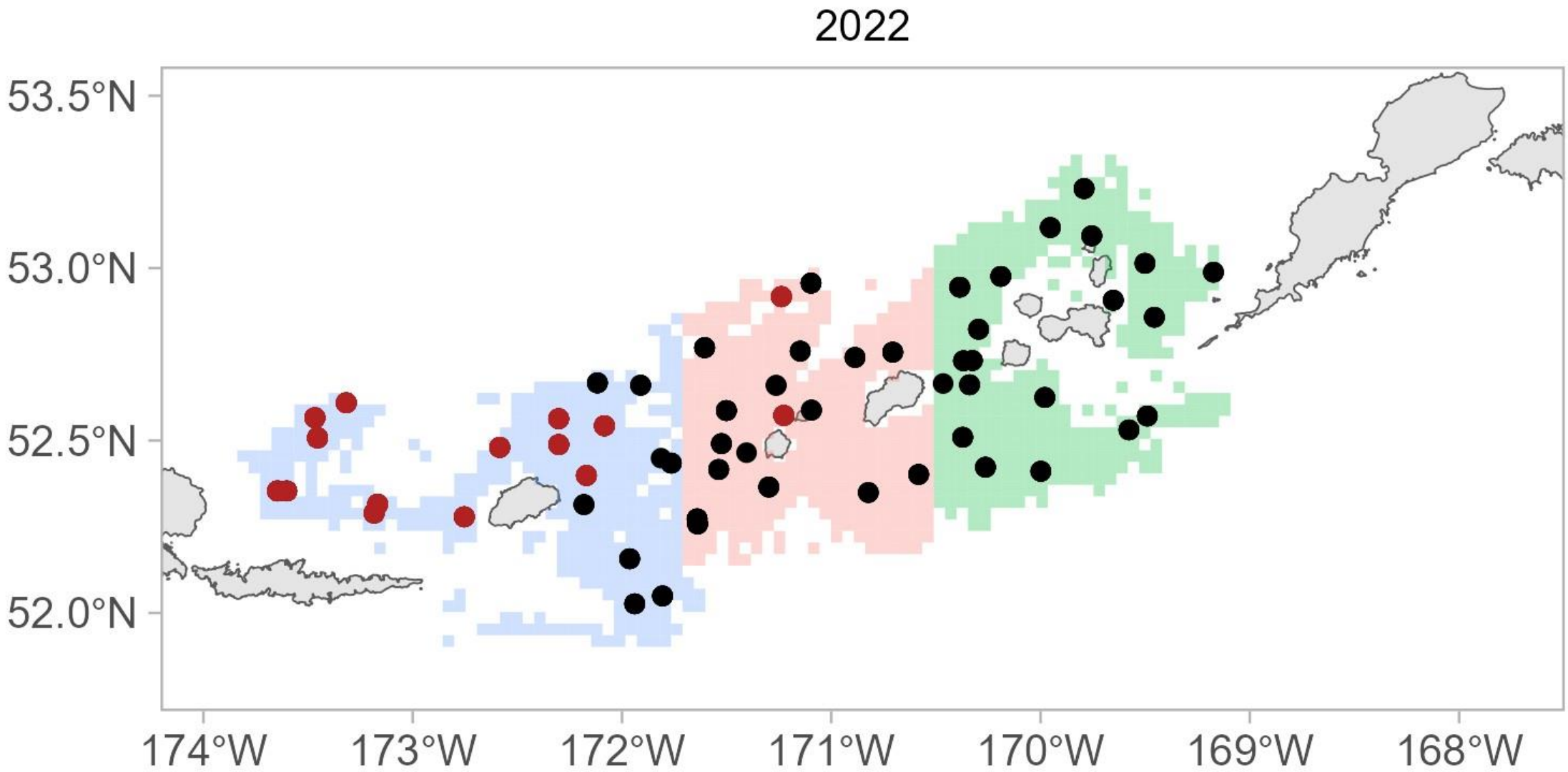


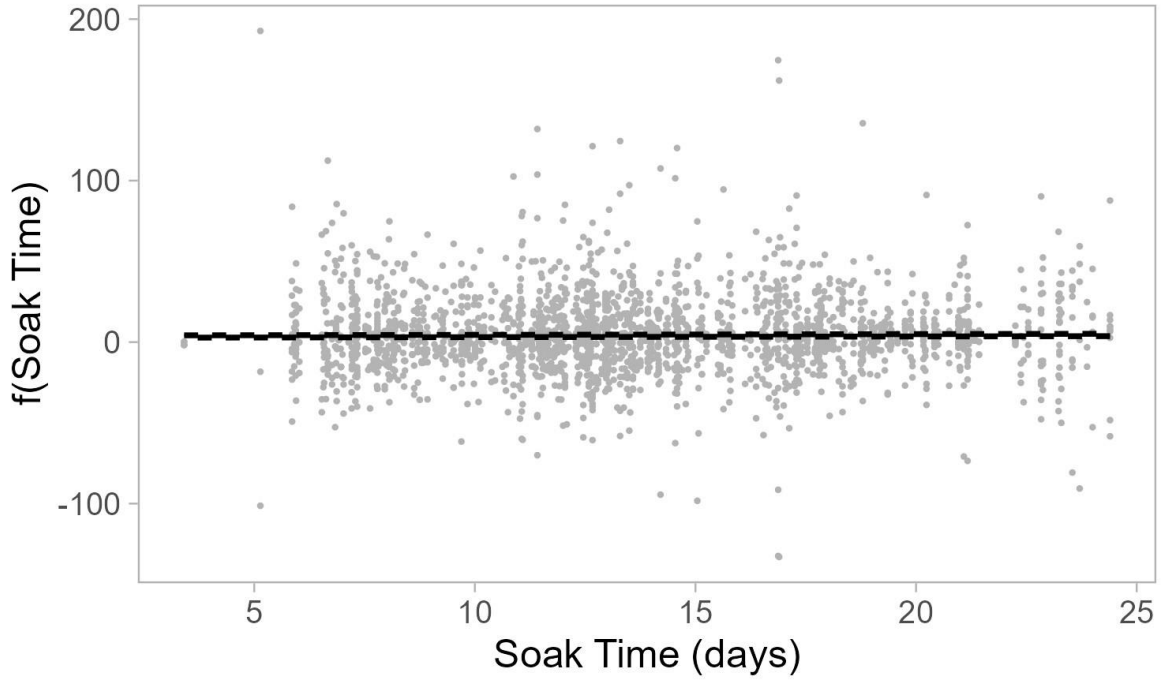


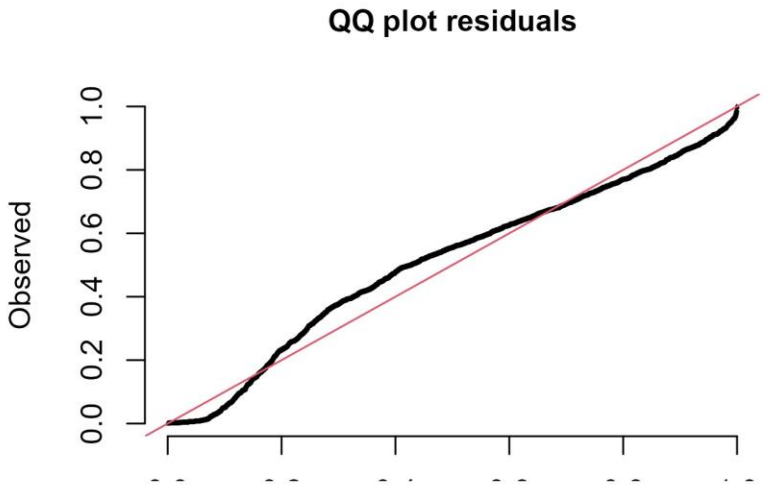


No formal bounds on soak time, > 30 days is long

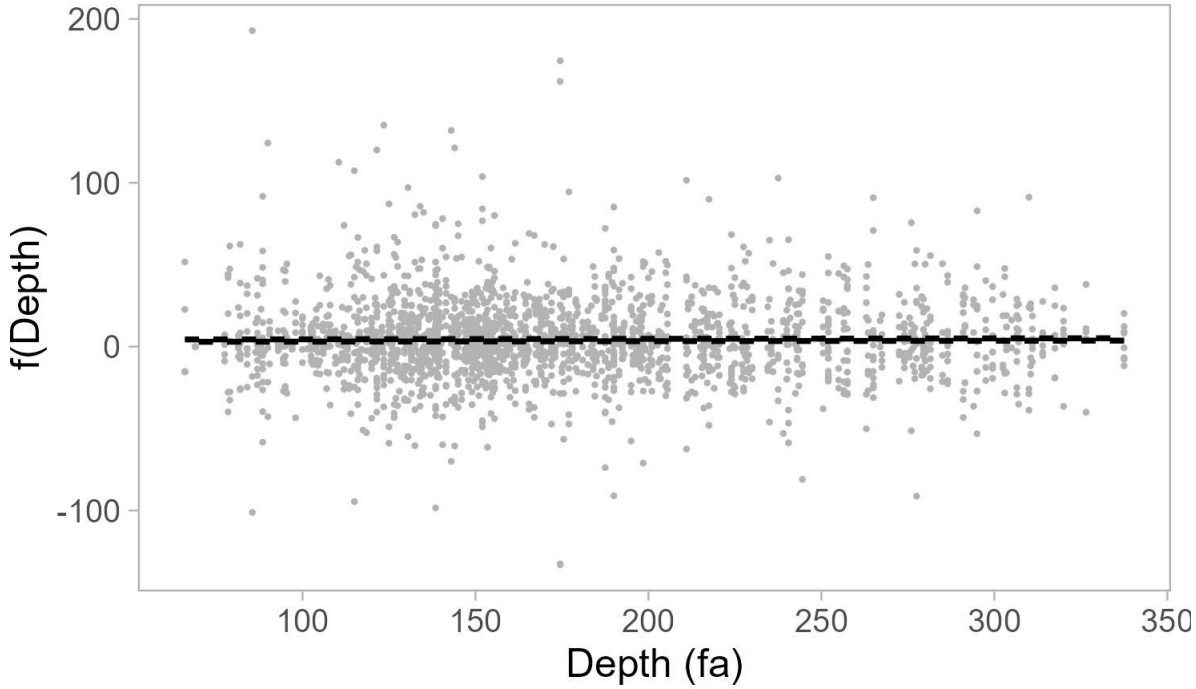


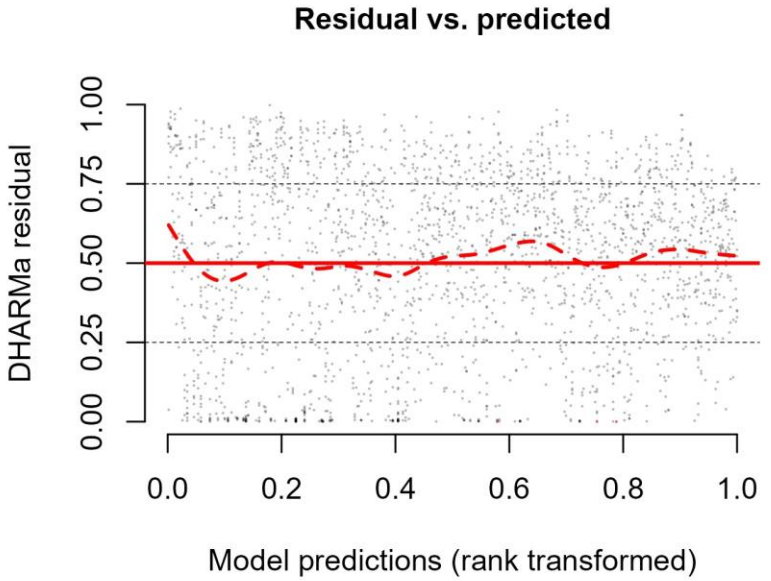

2022
53.5°N
53.0°N
52.5°N
52.0°N
174°W
173°W
172°W
171°W
170°W
169°W
168°W

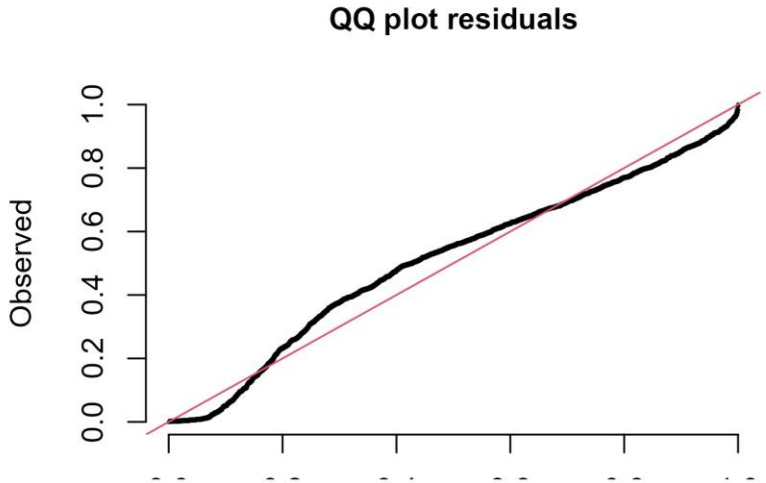




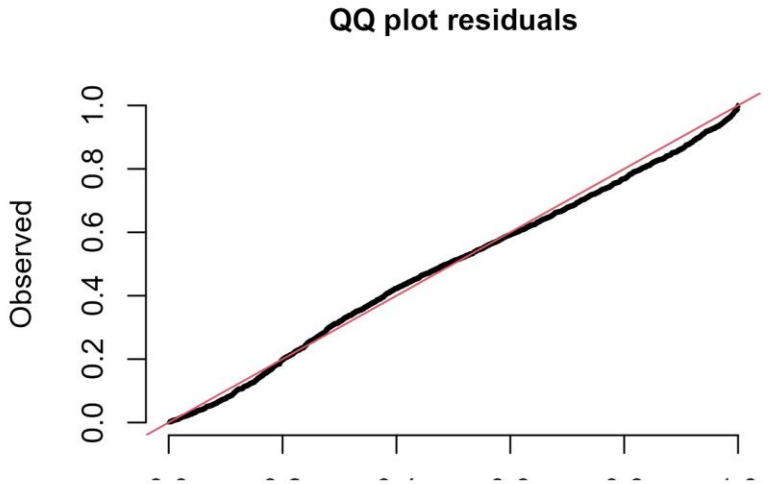
Neg Bin θ = 3.06



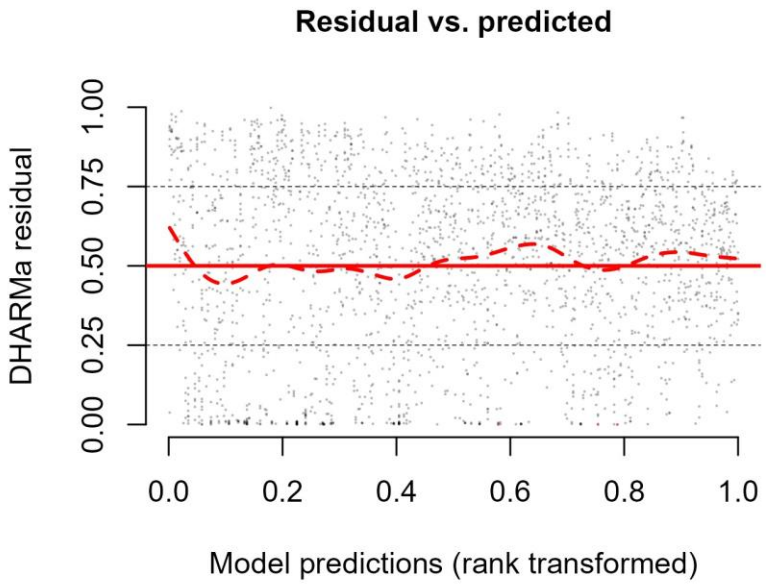




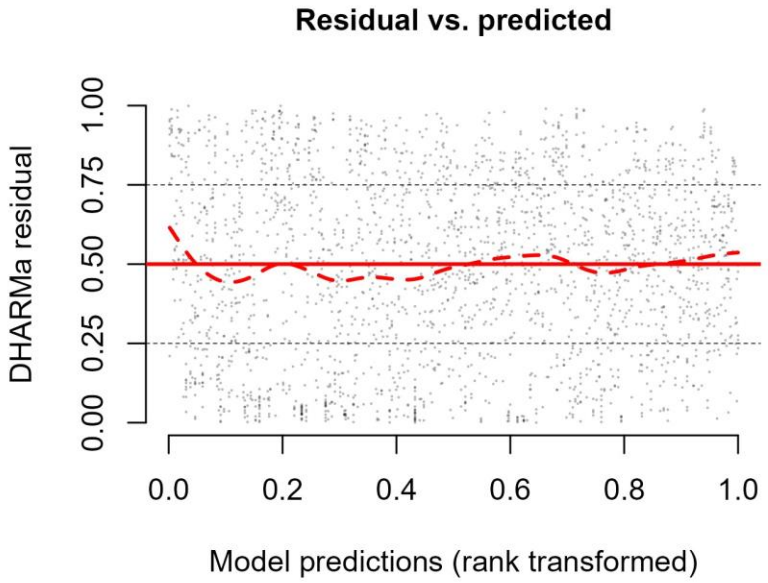
glmmTMB (Brooks et al. 2017)

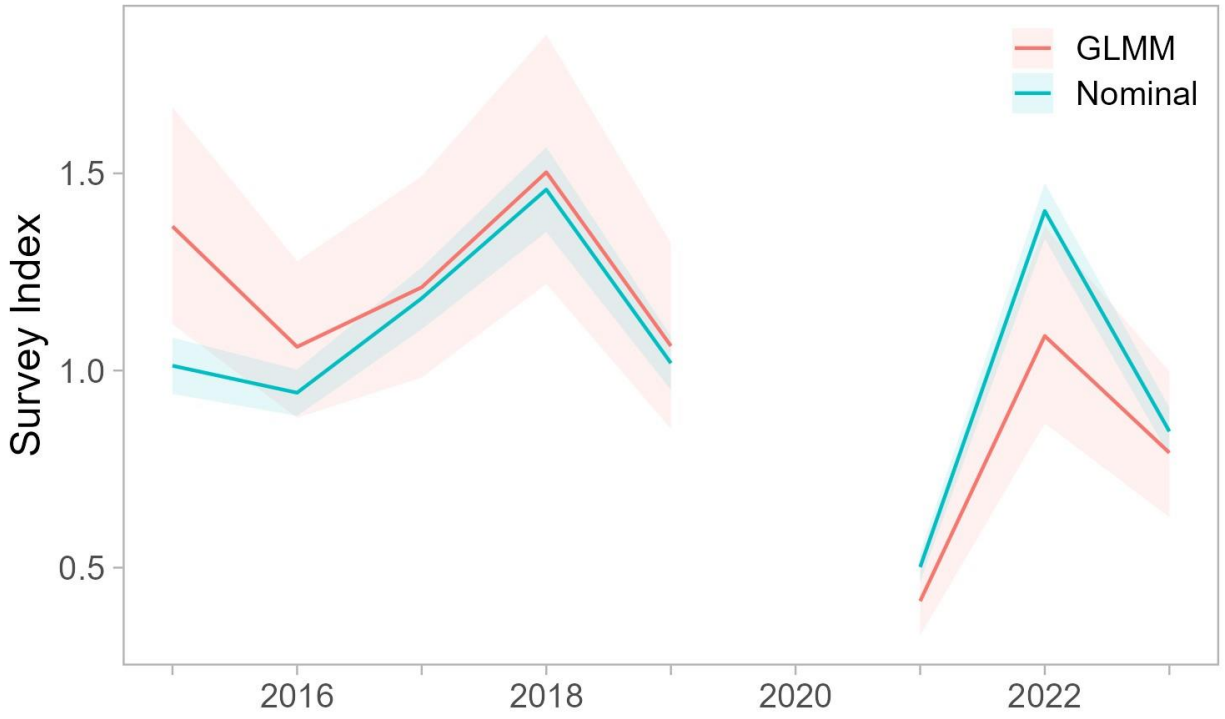


Neg Bin θ = 3.06

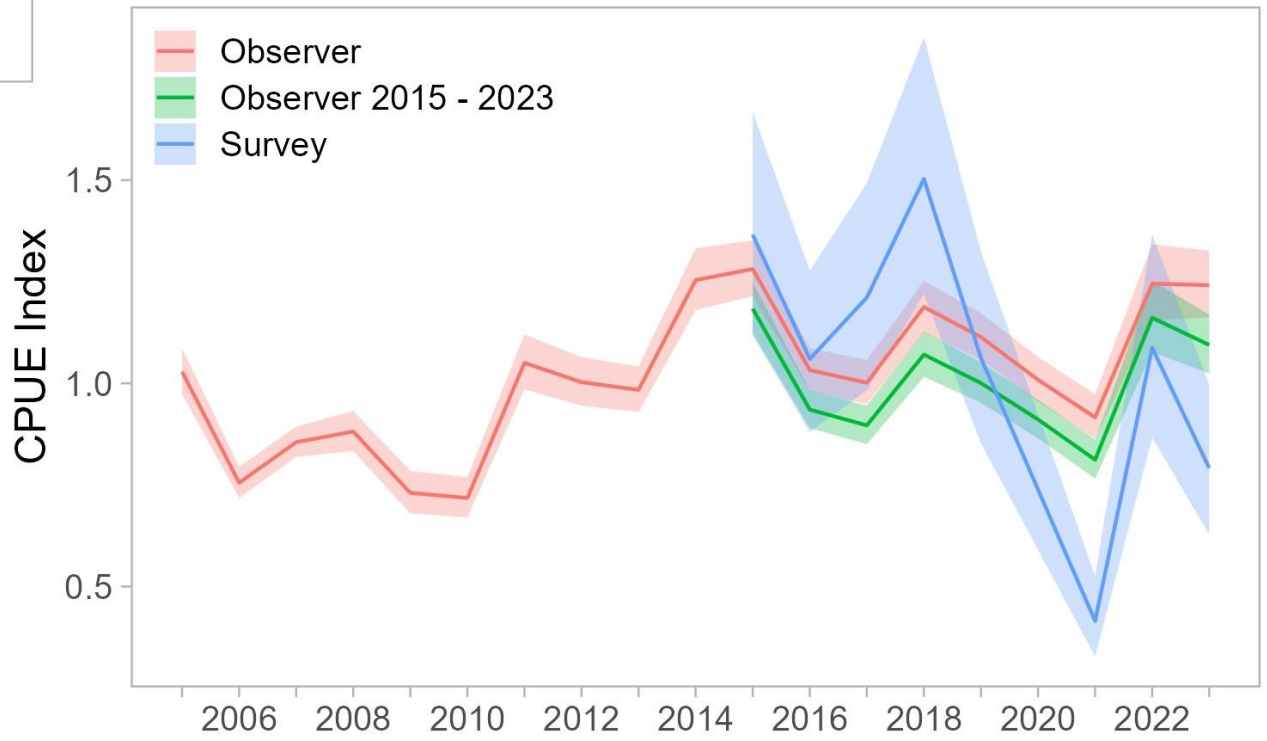


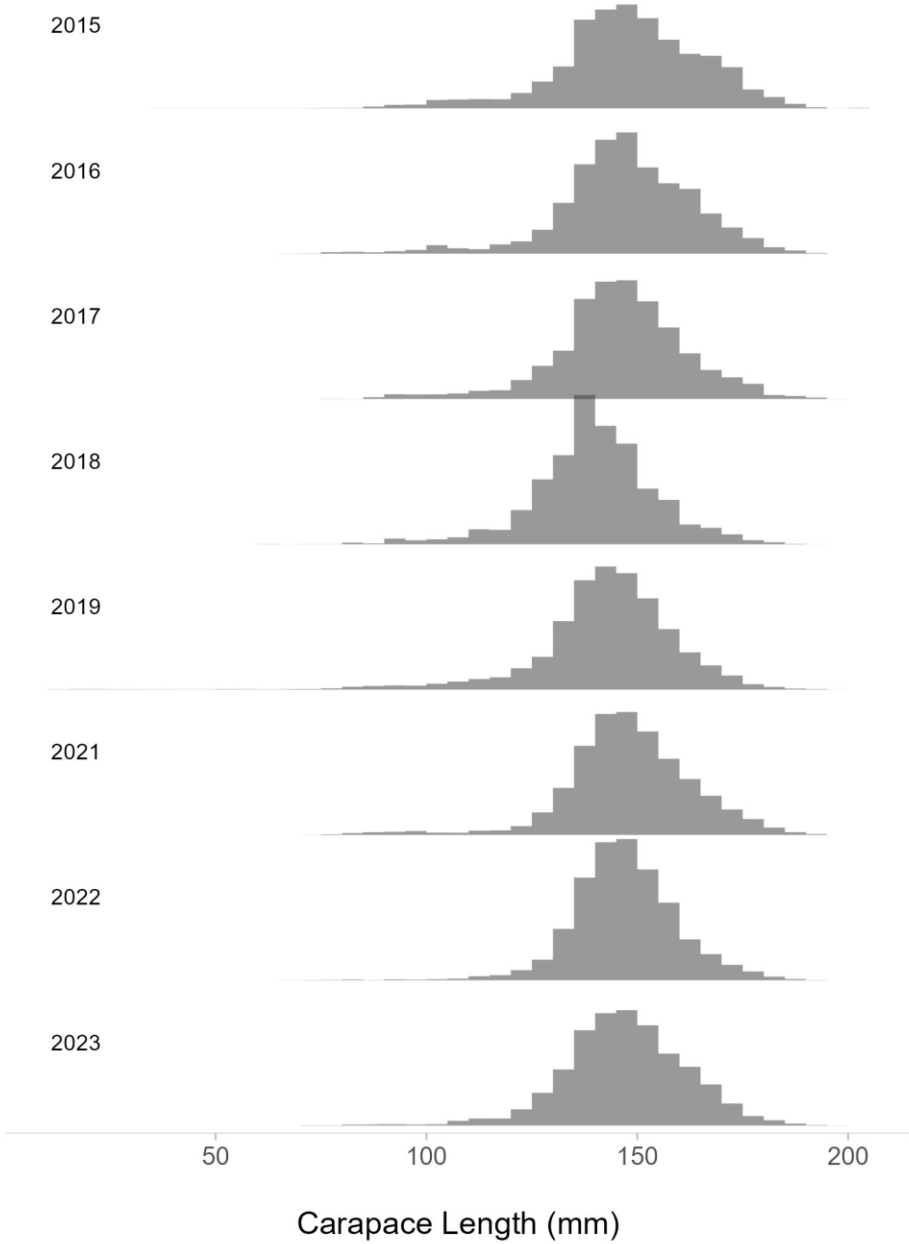
Tweedie p = 1.3





Mostly the same trend,
larger fluctuations,
more uncertainty




2015
2016
2017
2018
2019
2021
2022
2023
50
100
150
200
Carapace Length (mm)

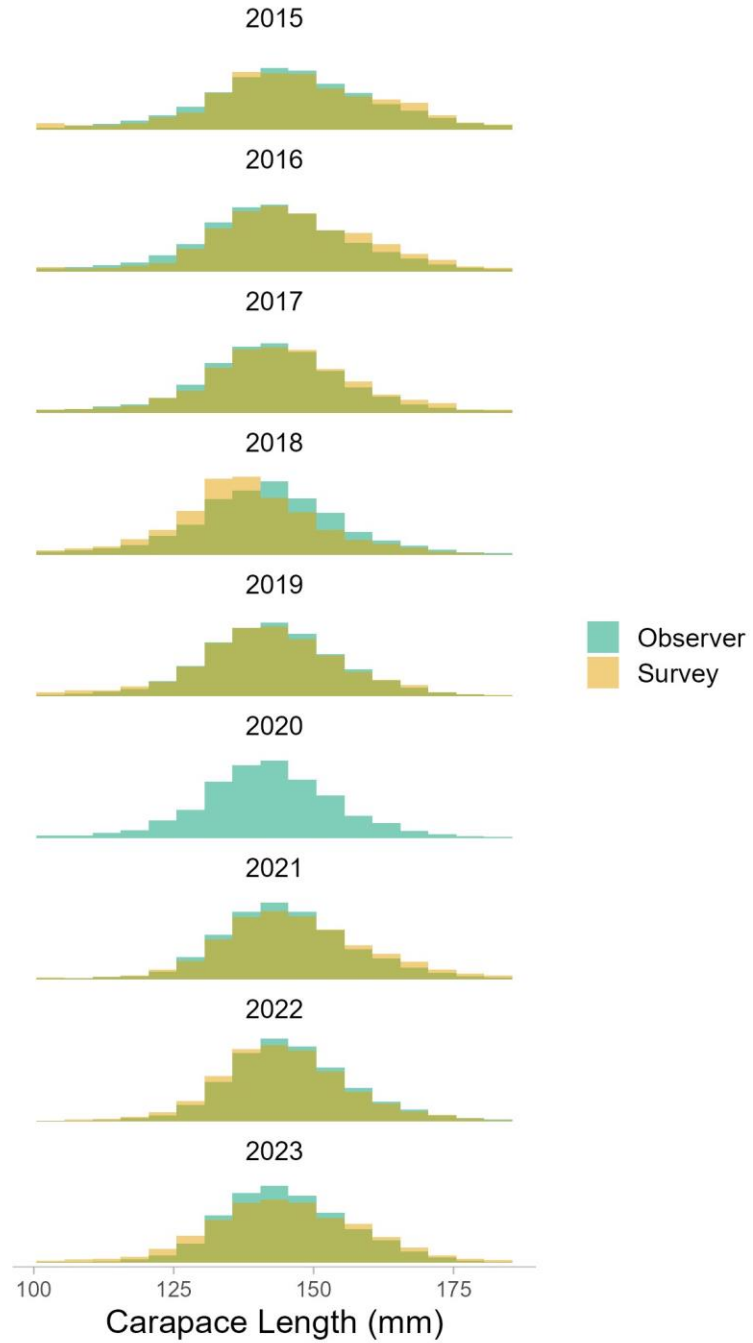
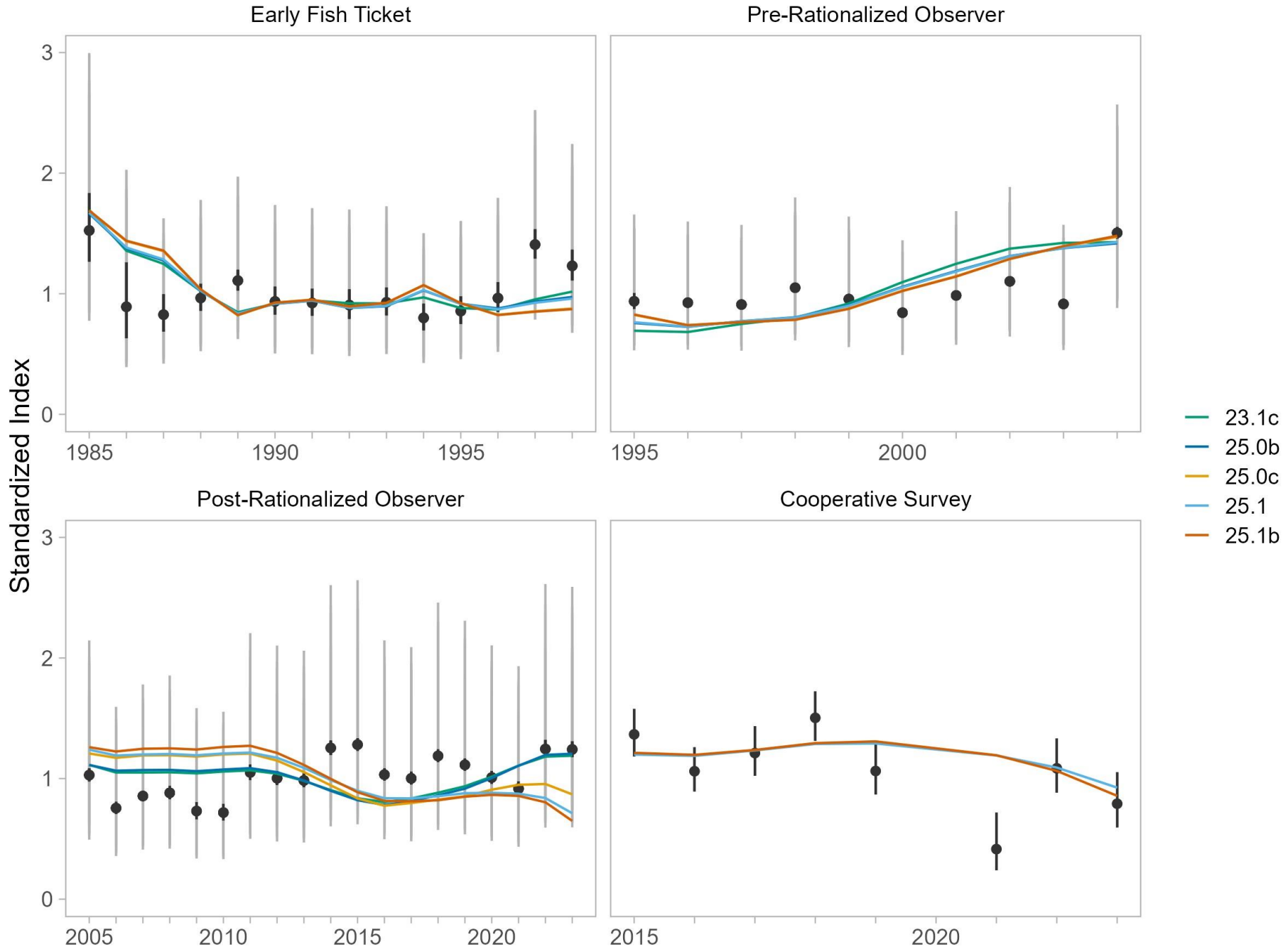
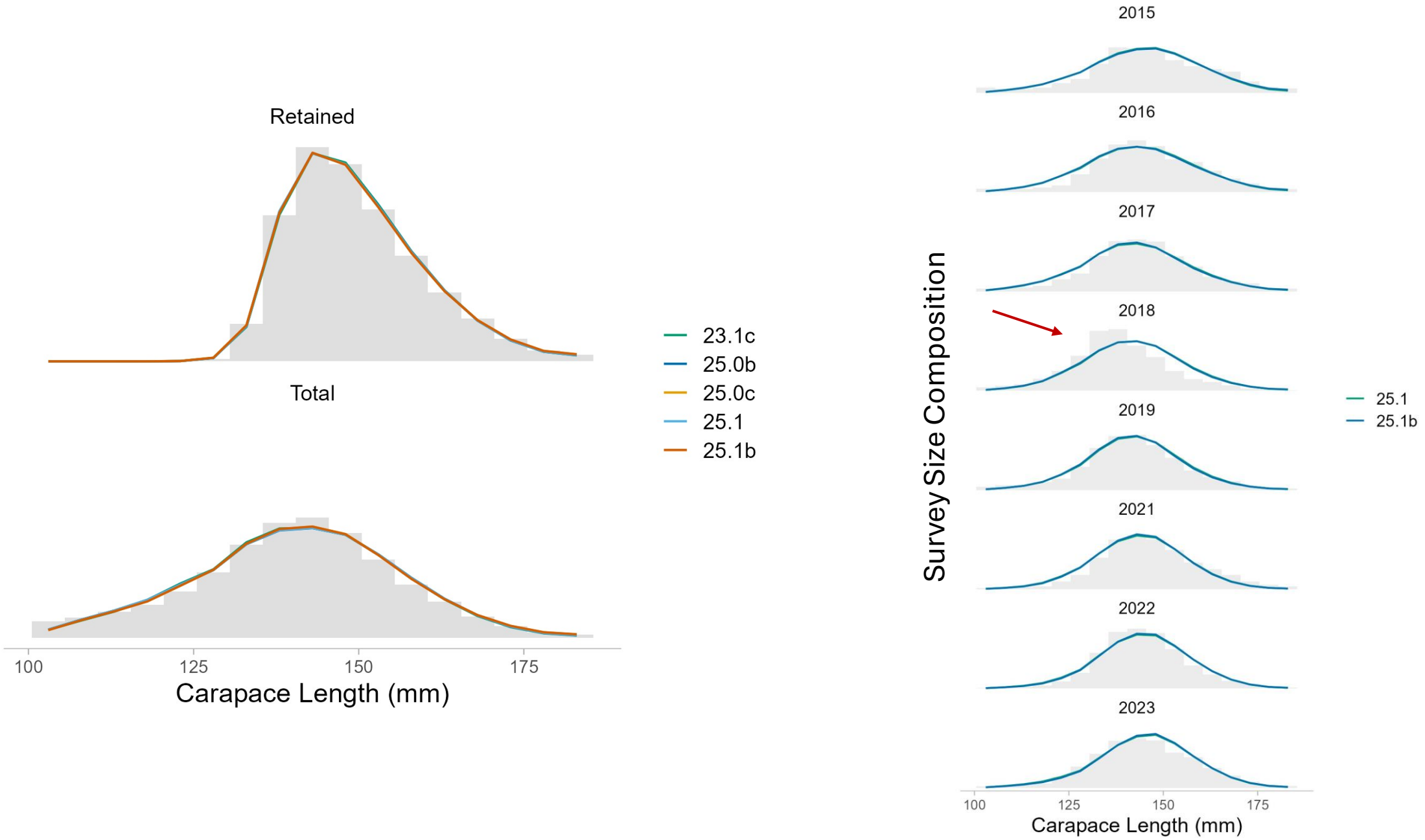
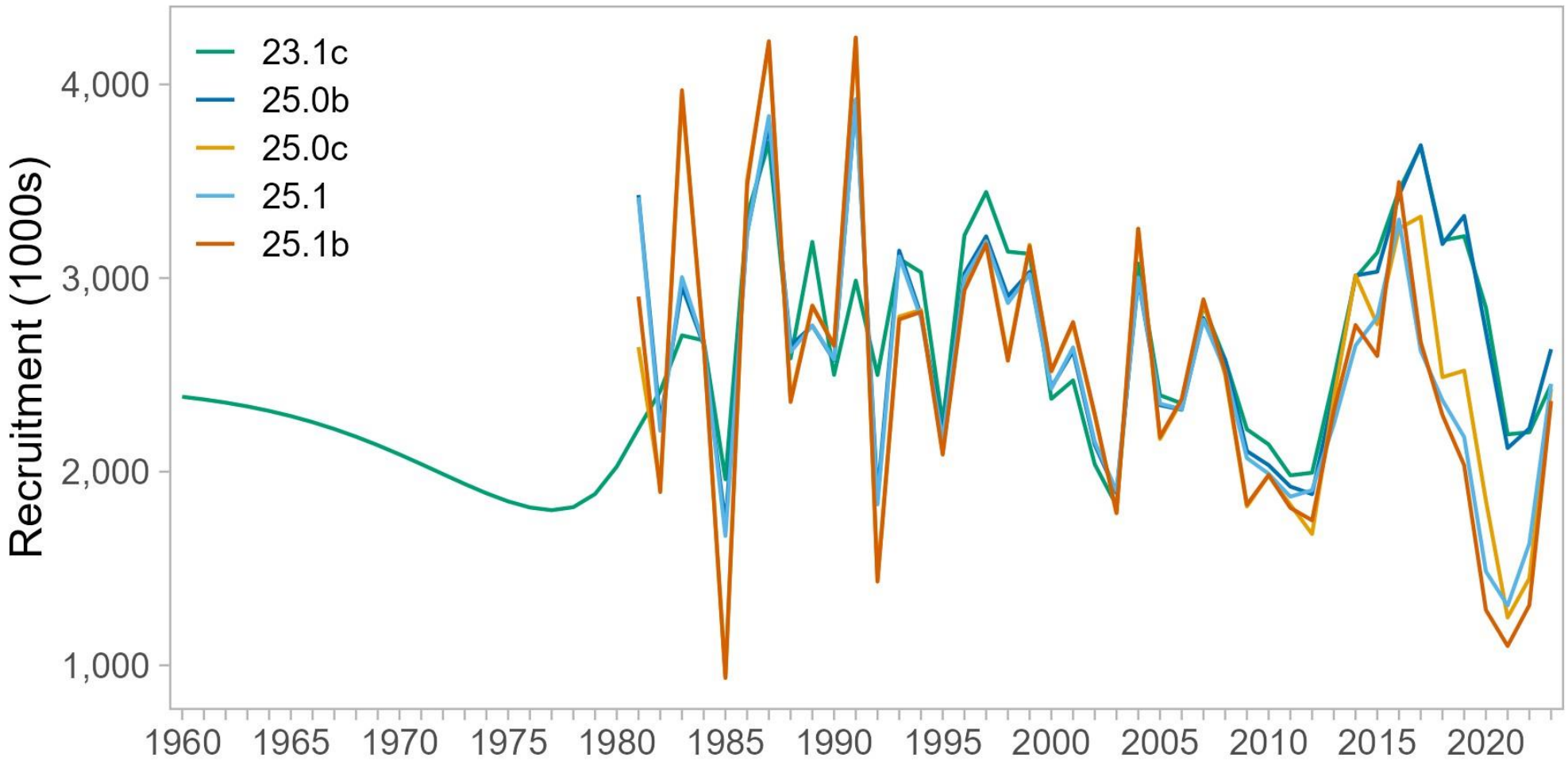

2015
2016
2017
2018
2019
2020
2021
2022
2023
Observer
Survey
100
125
150
175
Carapace Length (mm)

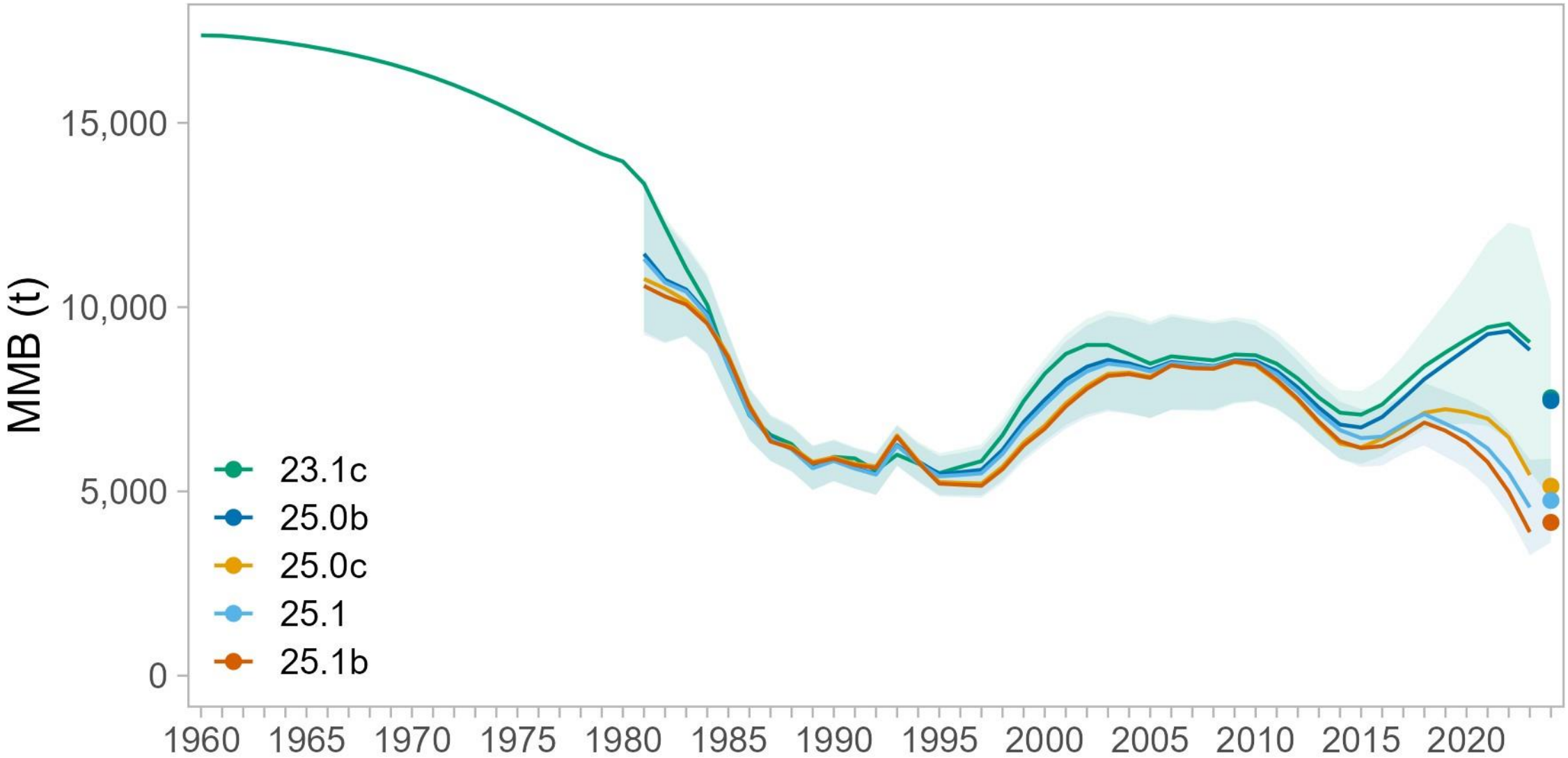
Table 3: Time series of number of crab measured (N) by the survey and bootstrap estimated effective sample size (N_{eff}). Number of crab measured is restricted to those $>$ 100 mm carapace length.

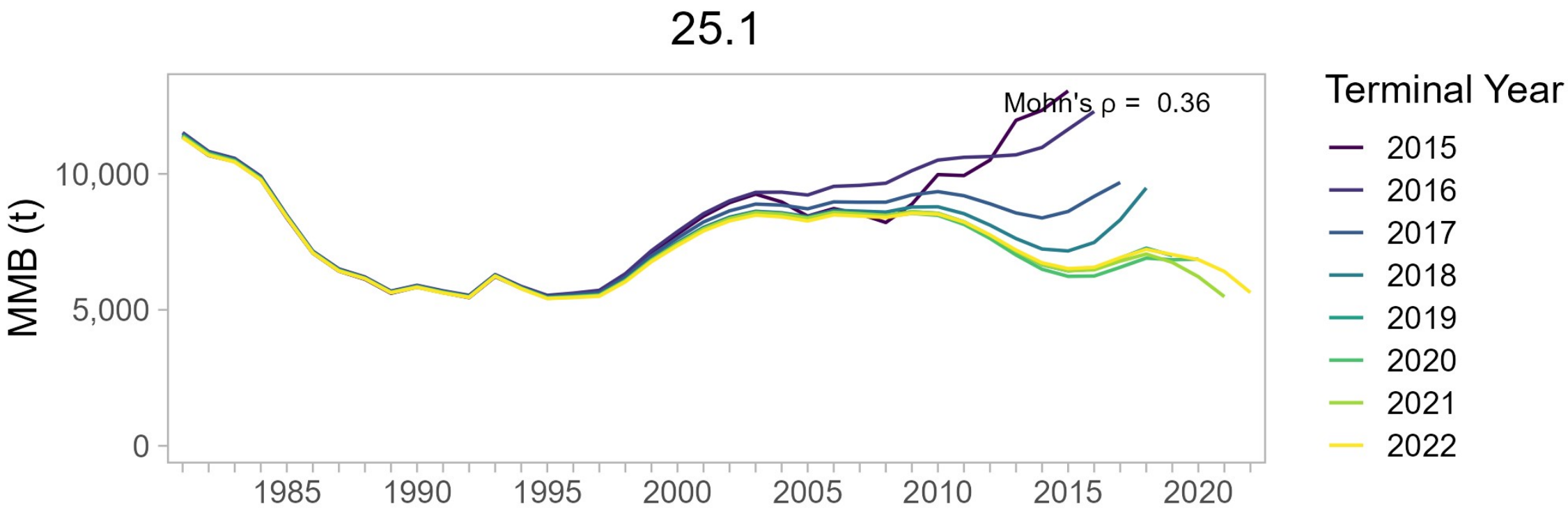
		Bootstrap N_{eff}		
Year	N	Min	Mean	Max
2015	4,987	136	408	1,305
2016	3,686	146	594	3,979
2017	3,655	241	834	5,555
2018	3,110	163	645	2,720
2019	5,876	206	837	3,327
2021	6,541	68	367	5,336
2022	7,022	238	1,364	7,206
2023	5,632	234	1,262	4,929


Early Fish Ticket
Pre-Rationalized Observer
Post-Rationalized Observer
Cooperative Survey
Standardized Index
0
1
2
3
1985
1990
1995
2000
2005
2010
2015
2020
23.1c
25.0b
25.0c
25.1
25.1b


Retained
Total
23.1c
25.0b
25.0c
25.1
25.1b
100
125
150
175
Carapace Length (mm)
2015
2016
2017
2018
2019
2021
2022
2023
Survey Size Composition
25.1
25.1b
100
125
150
175
Carapace Length (mm)


23.1c
25.0b
25.0c
25.1
25.1b
Recruitment (1000s)
4,000
3,000
2,000
1,000
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020


MMB (t)
15,000
10,000
5,000
0
23.1c
25.0b
25.0c
25.1
25.1b
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020

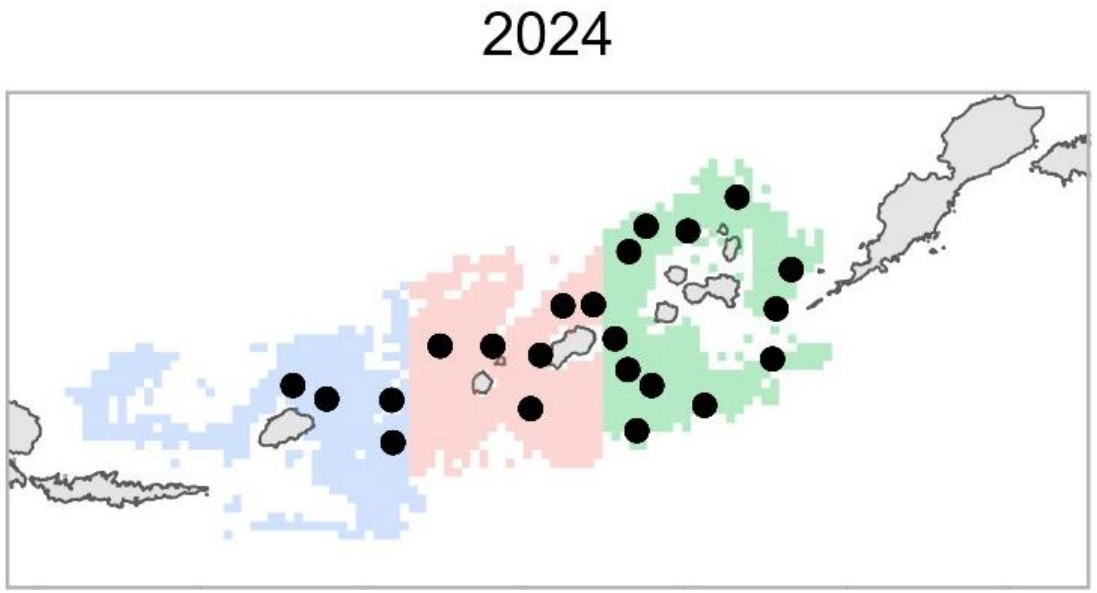

25.1
Mohn's ρ = 0.36
MMB (t)
10,000
5,000
0
1985
1990
1995
2000
2005
2010
2015
2020
Terminal Year
2015
2016
2017
2018
2019
2020
2021
2022

EAG Reference Points

Model	MMB (t)	$B_{35\%}$ (t)	$\frac{MMB}{B_{35\%}}$	$\bar{R}_{1987-2020}$	$F_{35\%}$	F_{OFL}	OFL (t)
23.1	7,547	6,905	1.09	2,781	0.55	0.55	2,823
23.1c	7,539	6,904	1.09	2,781	0.55	0.55	2,822
25.0	8,058	6,939	1.16	2,789	0.54	0.54	2,973
25.0a	8,053	6,908	1.17	2,775	0.55	0.55	2,970
25.0b	7,464	6,846	1.09	2,743	0.55	0.55	2,755
25.0b2	6,324	6,439	0.98	2,573	0.51	0.50	2,096
25.0c	5,140	6,633	0.77	2,662	0.59	0.44	1,345
25.0d	7,311	6,846	1.07	2,752	0.58	0.58	2,710
25.1	4,754	6,547	0.73	2,619	0.55	0.38	1,036
25.1b	4,158	6,528	0.64	2,615	0.58	0.35	774

Addition of Cooperative Survey

- Improvement from January 2024
- Several data quality issues need resolved
- 2024 survey had logistic issues, much fewer stations



Author Recommendation

- Model 23.1c as base model, preferred over 23.1

- Model 25.0b as alternative
  - Begins in 1981, non-equilibrium
  - Equal likelihood weighting
  - Size composition weights based on variability in data

- Model 25.1
  - **Unlikely to be selected as final model in May 2024 – *should resolve data conflict before adding complexity***
  - Would set back burner if necessary

Next Considerations

- Discuss simulation using GMACS at modelling workshop, *preferably before*
- Re-visit size at maturity
- Examine spatial / vessel effects in fishery data