NOAA FISHERIES

May 2021 CPT Report: Tanner Crab

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AFSC

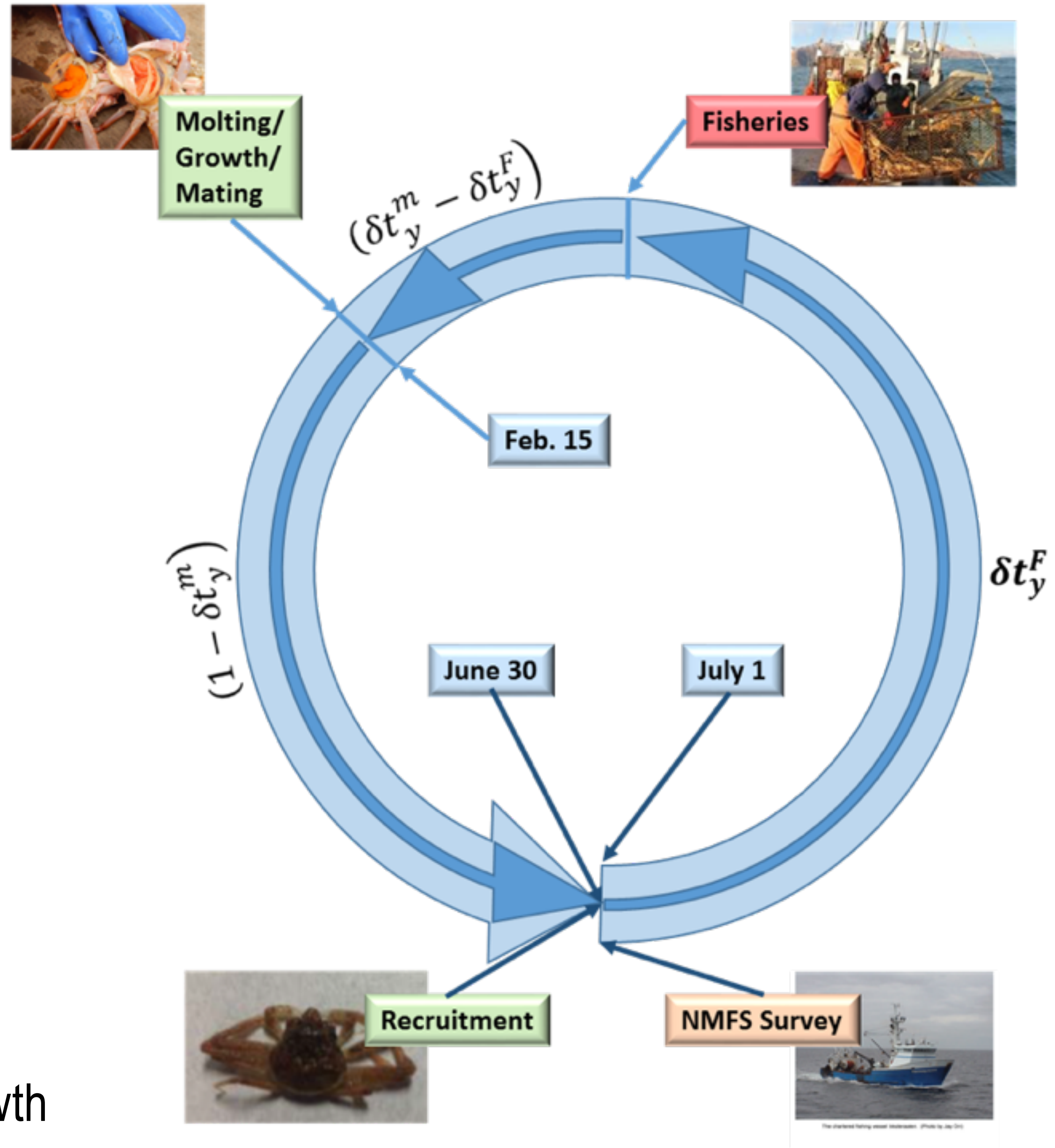
May 2021

Topics

- Using VAST estimates for survey biomass data
- Dealing with parameters at bounds
  - expand parameter bounds
  - change likelihoods
  - change selectivity functions
  - compress/truncate size distributions
  - truncate model size range
  - use Dirichlet-multinomial likelihood for size compositions
- Growth vs. terminal molt: Likelihood profiling
- Recommended models for September

Tier 3 stage/size-based population dynamics model

- model year runs July 1 to June 30
- sex, shell condition, maturity state, carapace width
- sex/stage-based natural mortality (2 time stanzas)
- trawl survey occurs July 1
- fisheries occur Feb. 15
    - directed fishery (retained and bycatch)
    - bycatch in snow crab fishery
    - bycatch in BBRKC fishery
    - bycatch in groundfish fisheries
- sex-specific growth & maturity (after fisheries)
    - pre-molt/post-molt size transition matrix
    - size-specific probability of terminal molt to maturity
- spawning stock (MMB) assessed at mating, before growth



Model runs

- 20 models
- 2 recommended (+ last year's)

model configuration	parent	additions	subtractions	label	number of parameters	number at bounds	objective function value	max gradient
20.07	--	--	--	2020 assessment model	349	11	3429.39	2.31E-04
* 21.00	20.07	NMFS VAST survey biomass estimates	NMFS design-based survey biomass estimates	VAST	349	12	4439.15	9.07E-05
* 21.00a	21.00	additional variance estimated for NMFS surveys		VAST+ExtraCVs	353	13	2964.76	4.98E-04
21.01	20.07	expanded limits on q's, fixed logit-scale retention parameters at upper limits		ExpandedQ's	346	7	3389.46	3.66E-04
21.03	20.07	lognormal fishery catch biomass likelihoods	"norm2" fishery catch biomass likelihoods	Lognormal	349	20	-1992.57	2.45E-03
21.04	21.01 + 21.03	lognormal fishery catch biomass likelihoods + SCF, RKF devs start in 1990	"norm2" fishery catch biomass likelihoods	Lognormal+ExpandedQ's	350	5	3165.74	1.08E-03
21.05	21.04	1/2-normal (ascnormal3) for NMFS female selectivity			350	5	3187.26	5.02E-04
21.06	21.05	tail compression in all size comp likelihoods		TailCompression	350	7	3049.36	3.86E-03
21.07	21.06	Switched to Dirichlet Multinomial likelihood for NMFS survey size comps	Dropped multinomial likelihoods for NMFS survey size comps	SurveyDMs	352	9	5600.78	2.10E-03
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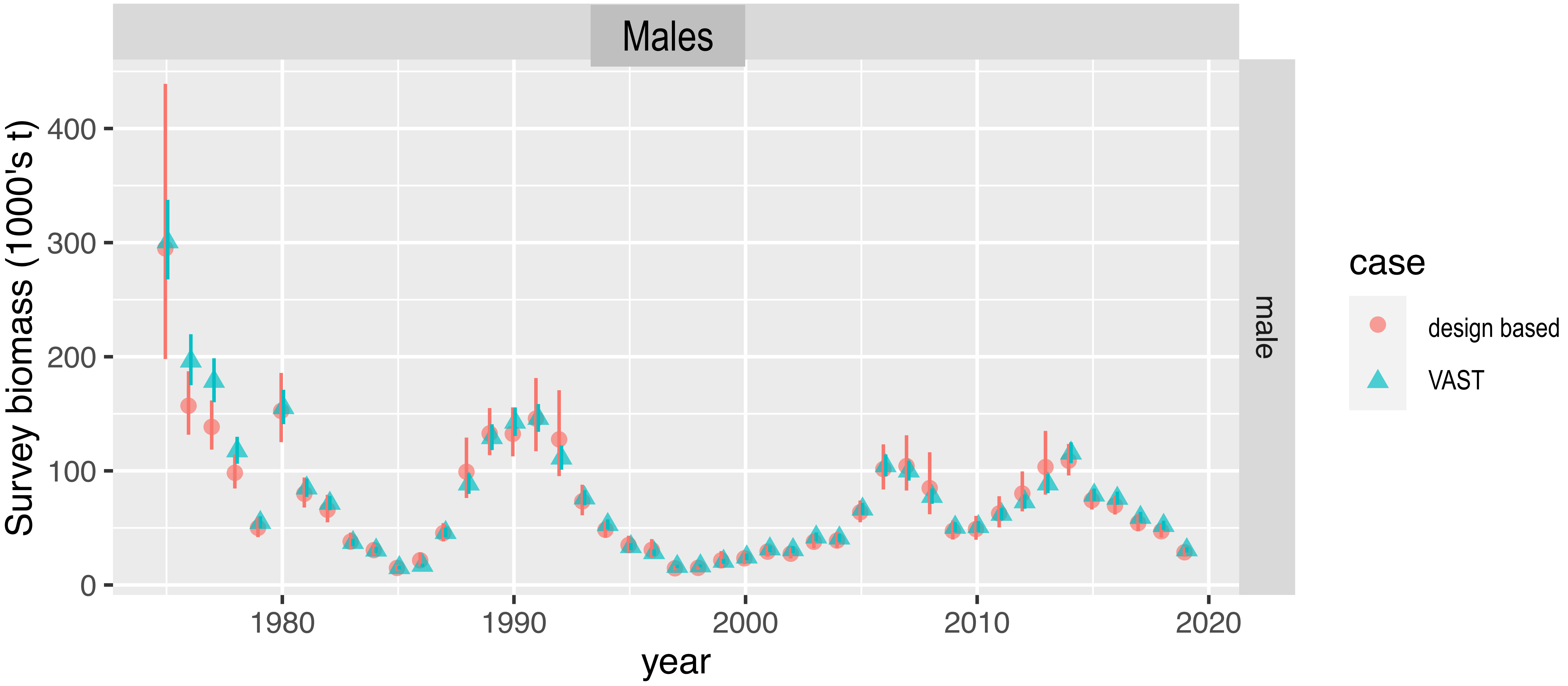
21.09	21.08	returned to multinomial likelihoods for NMFS survey and TCF, RKF, and GF fisheries		SomeDMs	355	8	6639.69	2.46E-02
21.10	21.09	Removed size comps with small sample sizes from likelihoods		NoSmallSSs	355	8	6639.44	2.53E-02
21.11	21.10	Imposed size limits on female growth		SizeLimits	355	8	6633.71	2.26E-02
21.12	21.11	1/2- normal (ascnormal) selectivity functions estimated for all RKF time periods	Ascending logistic selectivity functions for all RKF time periods	AscNrmRKF	355	9	6086.02	2.81E-02
21.13	21.12	Double normal selectivity functions estimated for male bycatch in SCF	double logistic selectivity functions	DblNrmSCF	355	9	6089.24	1.18E-02
21.14	21.13	Annual 1982+ NMFS survey catchability determined outside model, no fits to BSFSF data	2 catchability, 4 selectivity parameters	FixedSurveySels	343	7	6078.26	7.97E-02
21.15	21.14	mean growth parameters determined outside model	4 growth parameters	FixedSurveySels+FixedGrowth	339	7	6349.95	1.71E-02
* 21.21	21.04	modified so all estimated parameters are within bounds			347	0	3175.37	0.00E+00
* 21.22	21.13	modified so all estimated parameters are within bounds			347	0	6153.67	0.00E+00
21.23	21.15	modified so all estimated parameters are within bounds			329	0	6590.74	0.00E+00

NOAA FISHERIES

VAST Model Runs

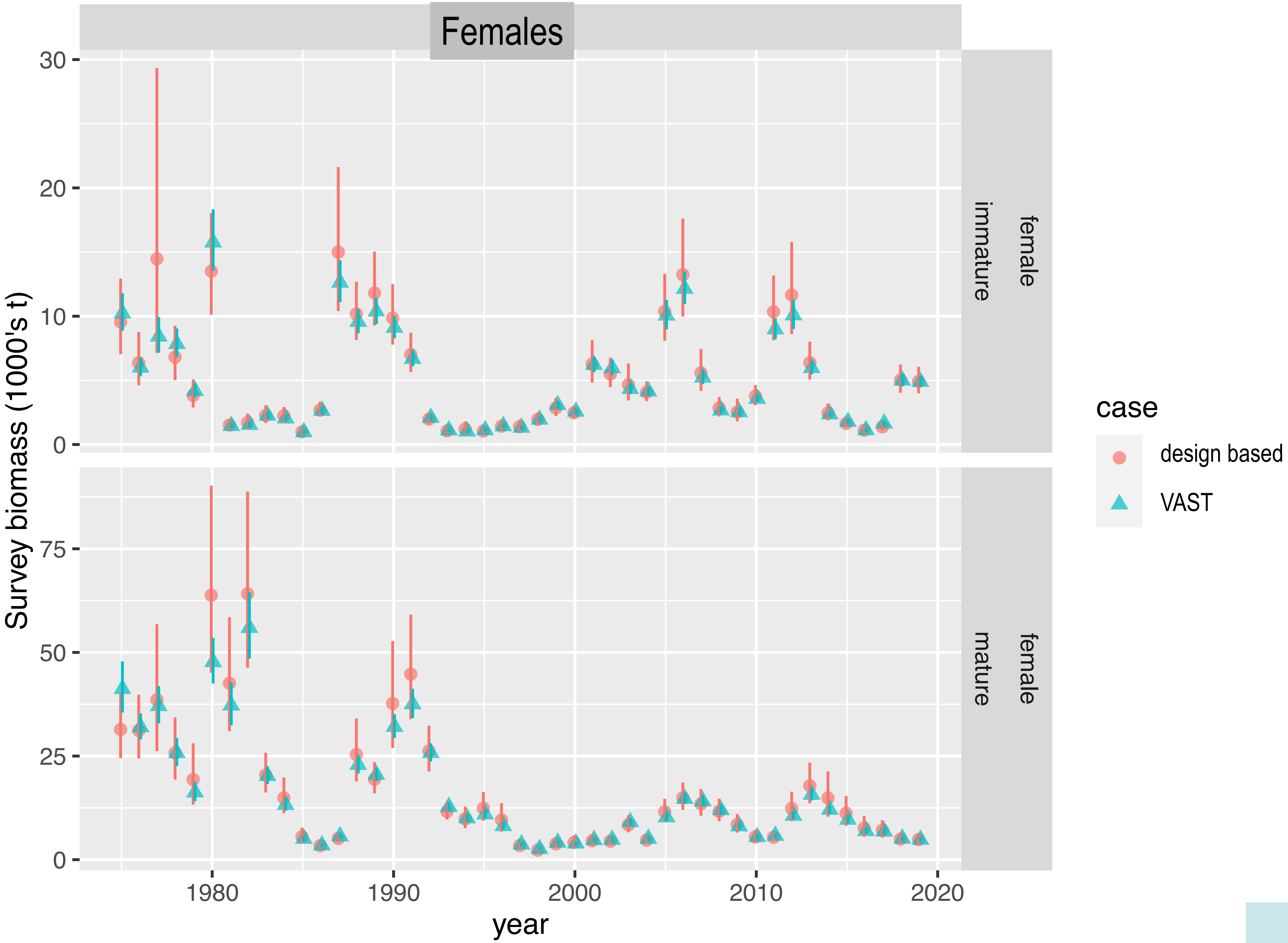
VAST Data

CV's reduced by ~50% using VAST



VAST Data

CV's reduced by ~40% using VAST



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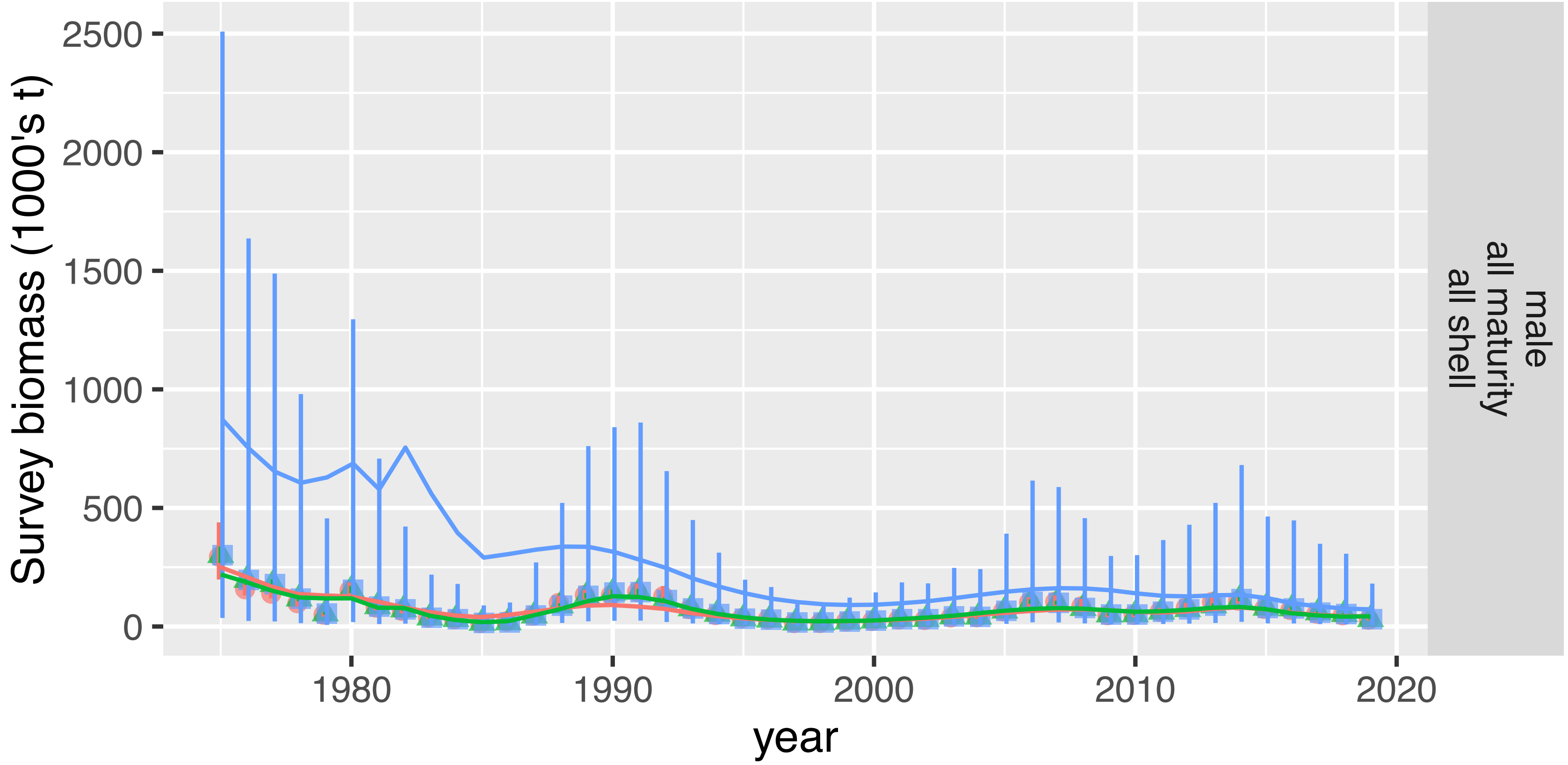
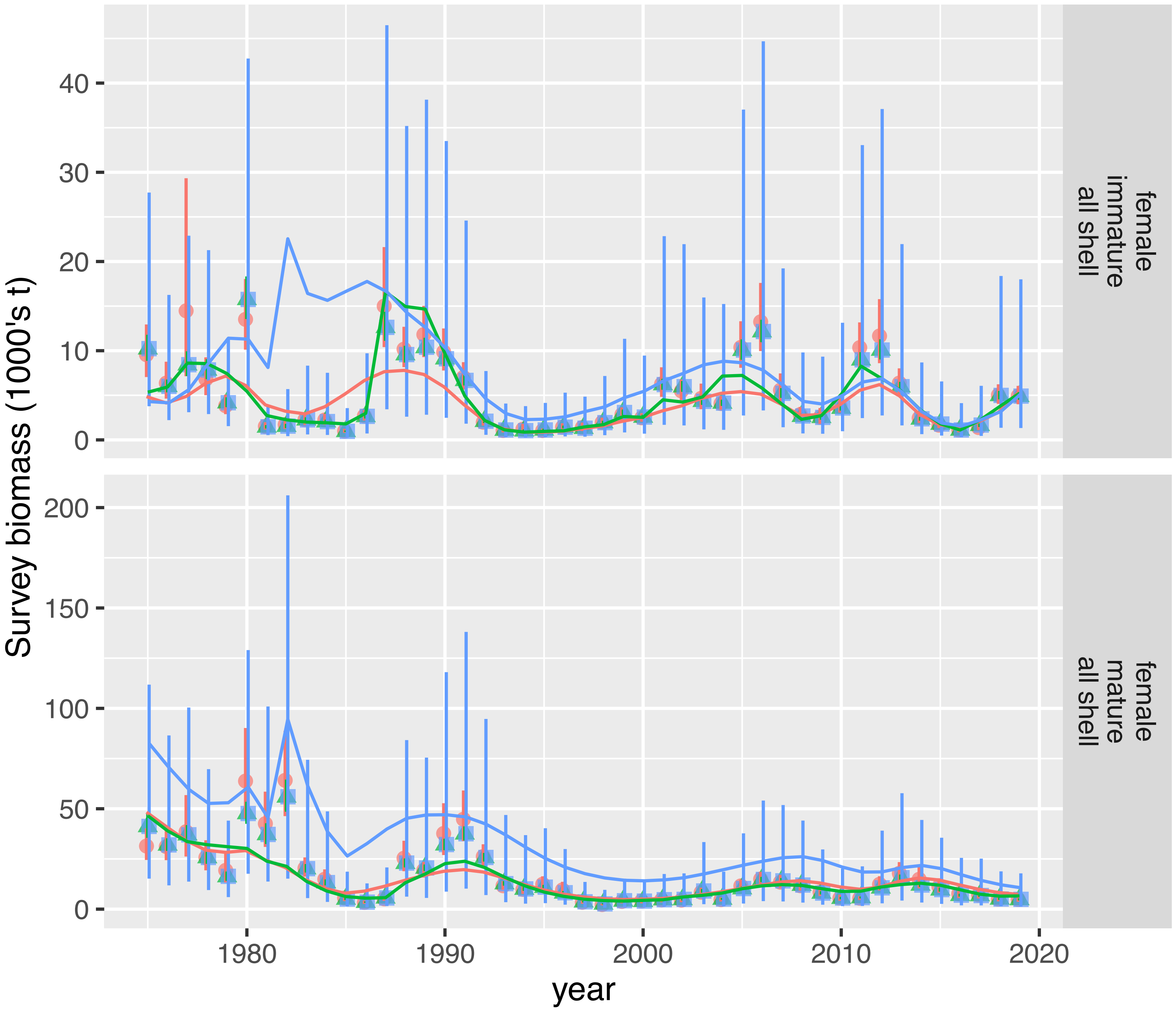
21.00a	21.00	additional variance estimated for NMFS surveys		VAST+ExtraCVs	353	13

case	average recruitment (millions)	B100 (1000's t)	Bmsy (1000's t)	current year MMB (1000's t)	Fmsy	MSY (1000's t)	Fofl
20.07	374.43	105.05	36.77	66.87	0.98	16.94	0.94
21.00	311.56	76.77	26.87	56.00	1.30	14.47	1.27
21.00a	477.66	134.75	47.16	63.02	1.37	19.21	1.00

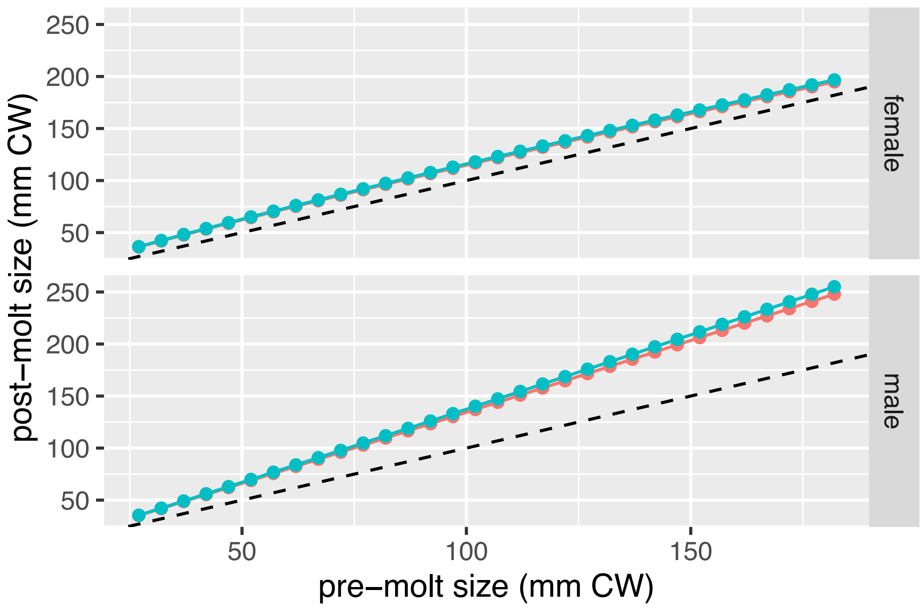
VAST Model Runs

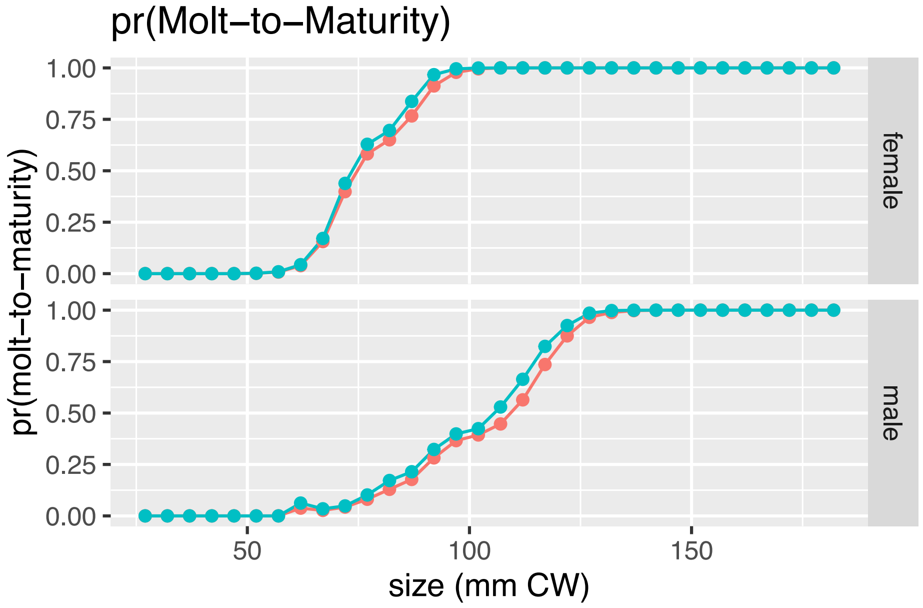


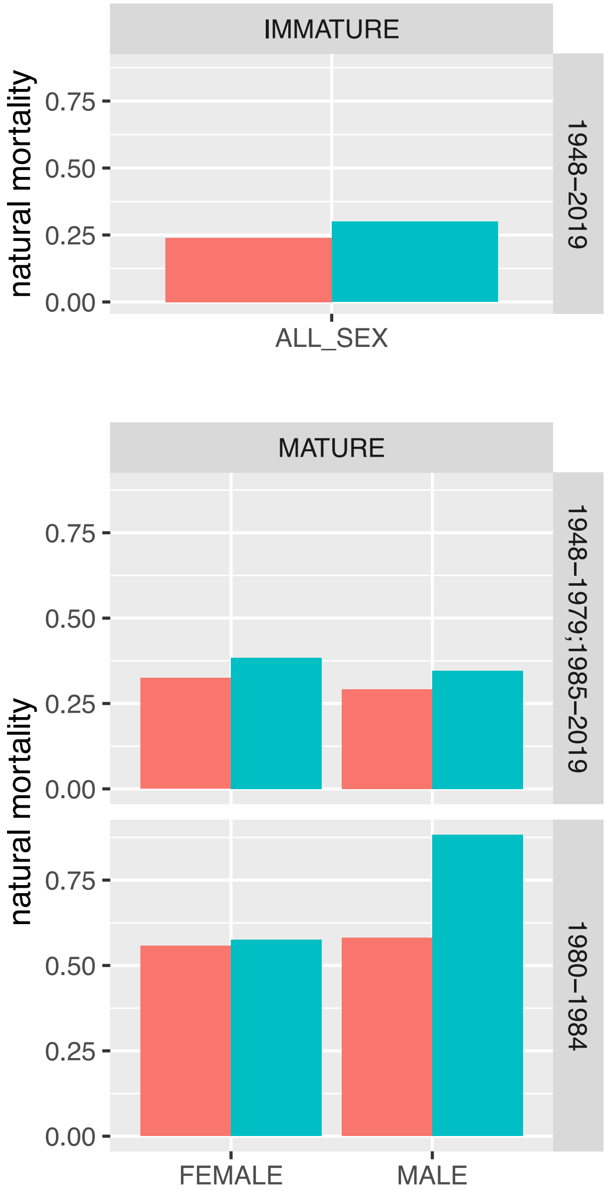


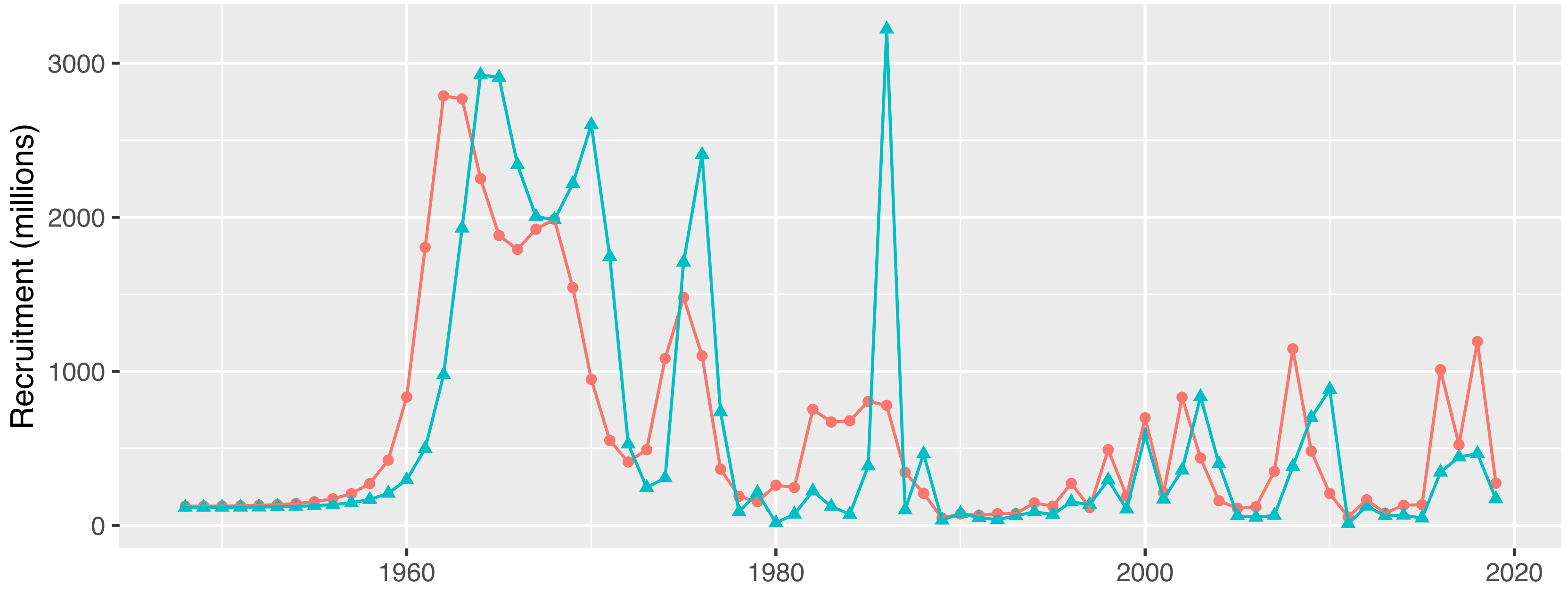
- 21.00a dropped (similar results last year)

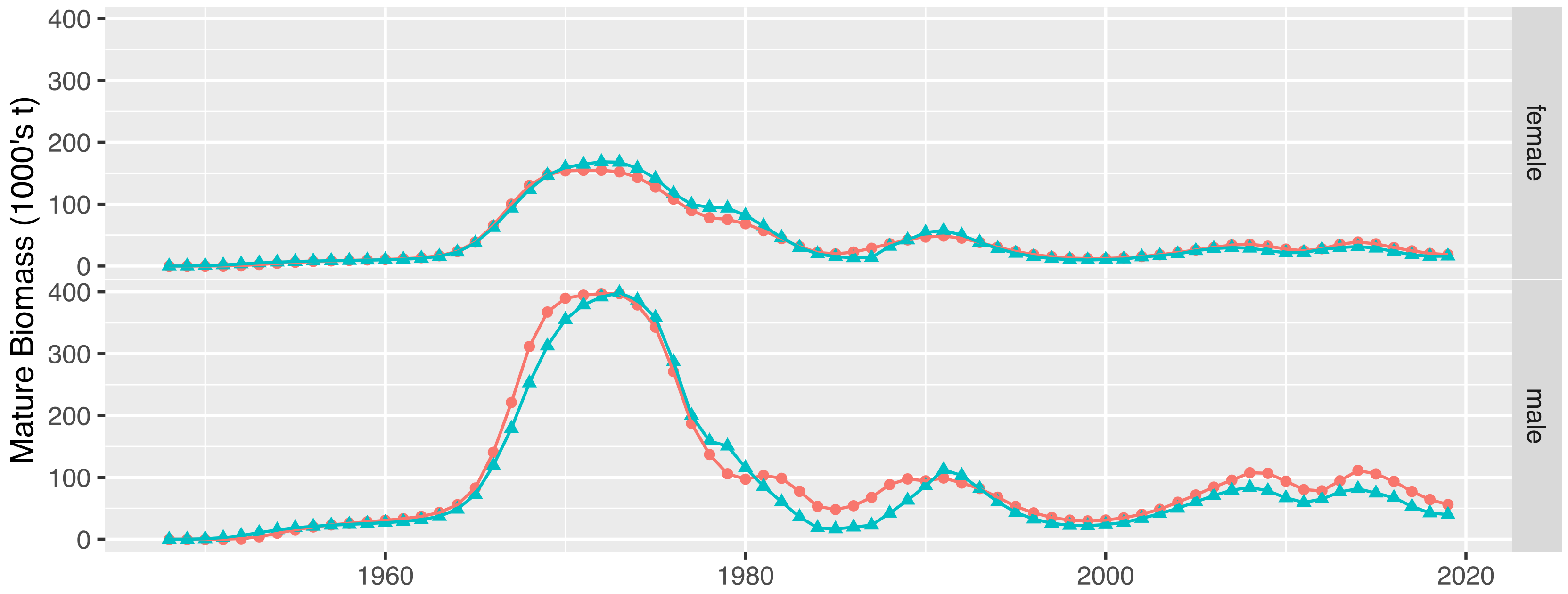
VAST Model Runs: Population Quantities



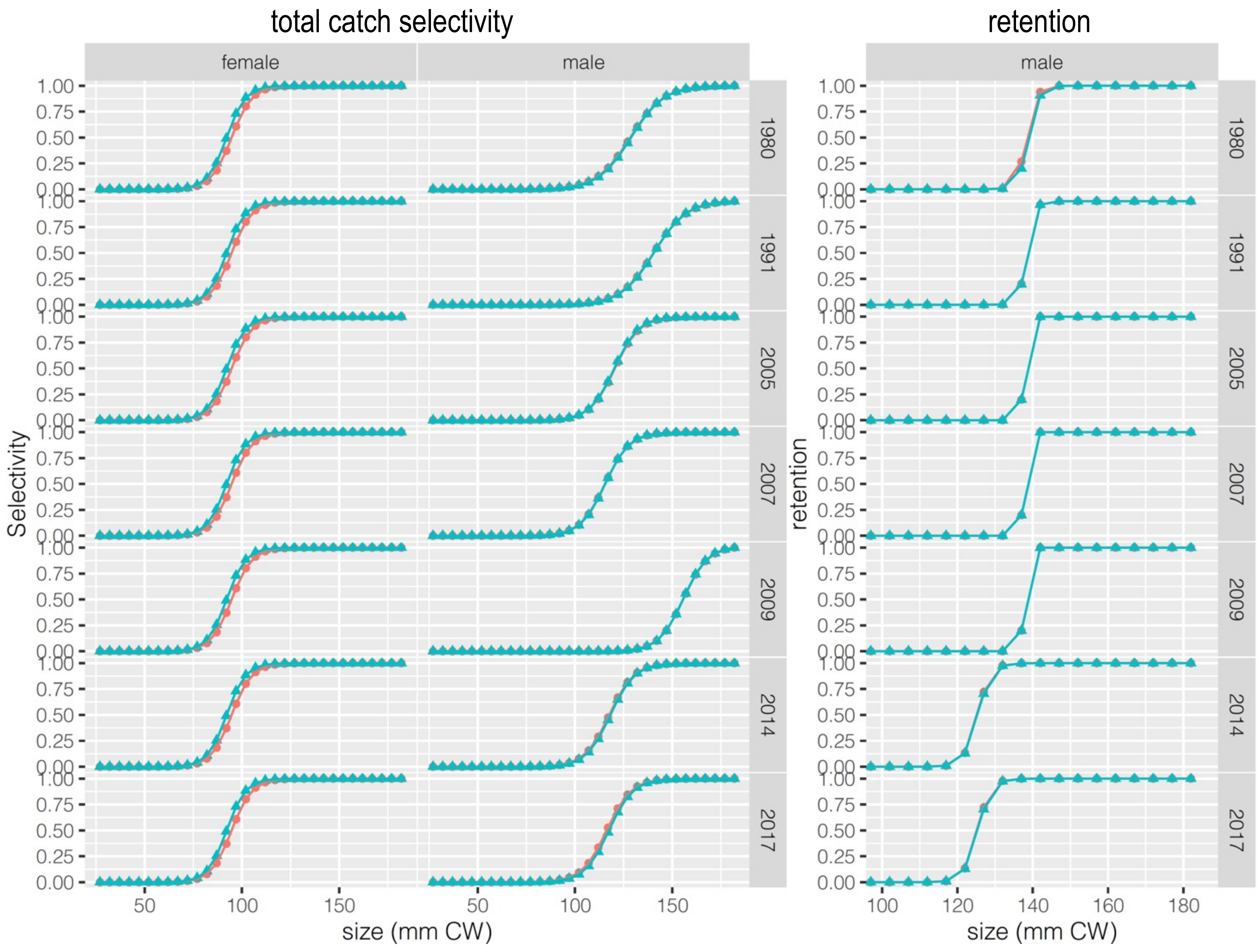


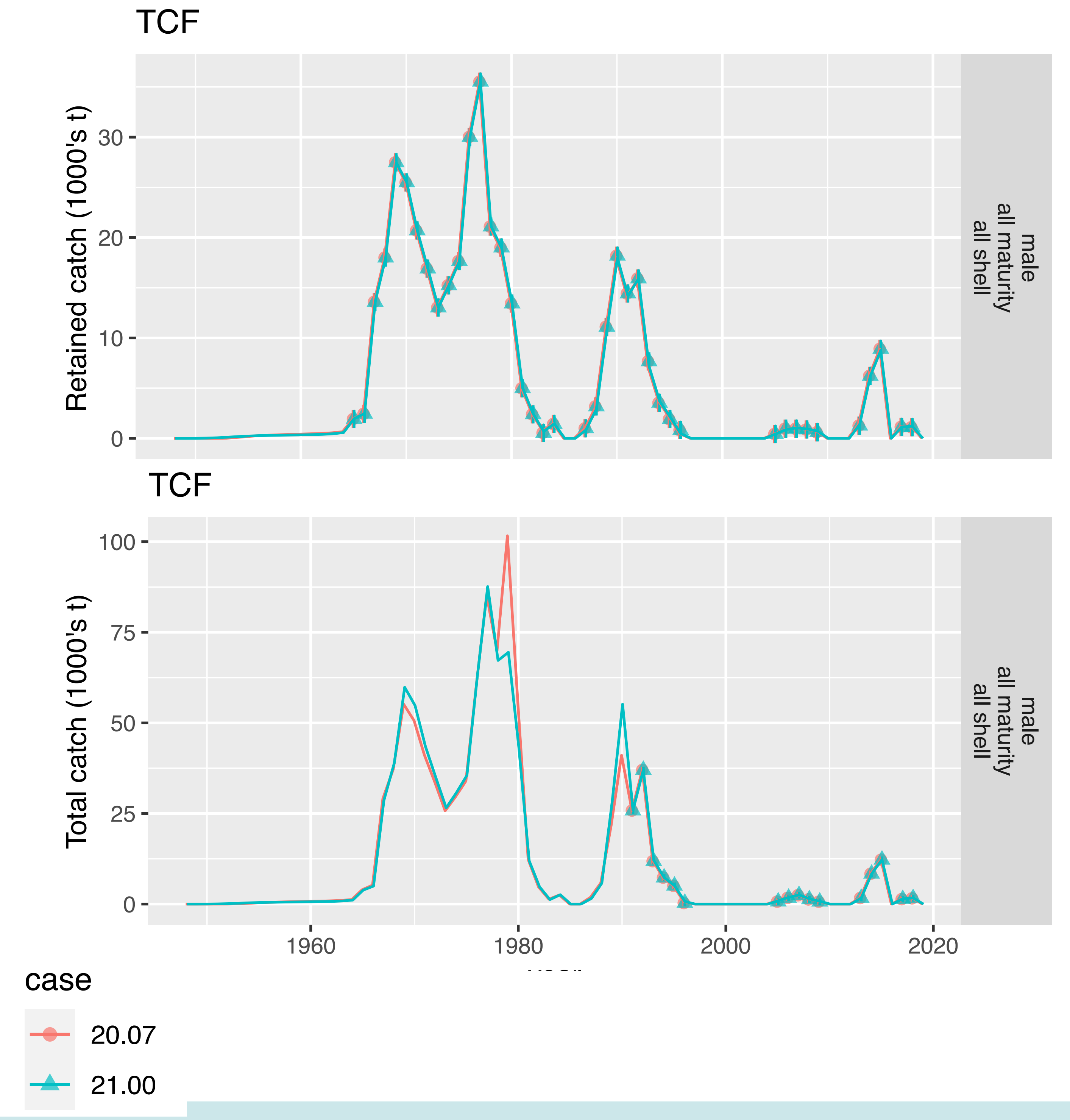




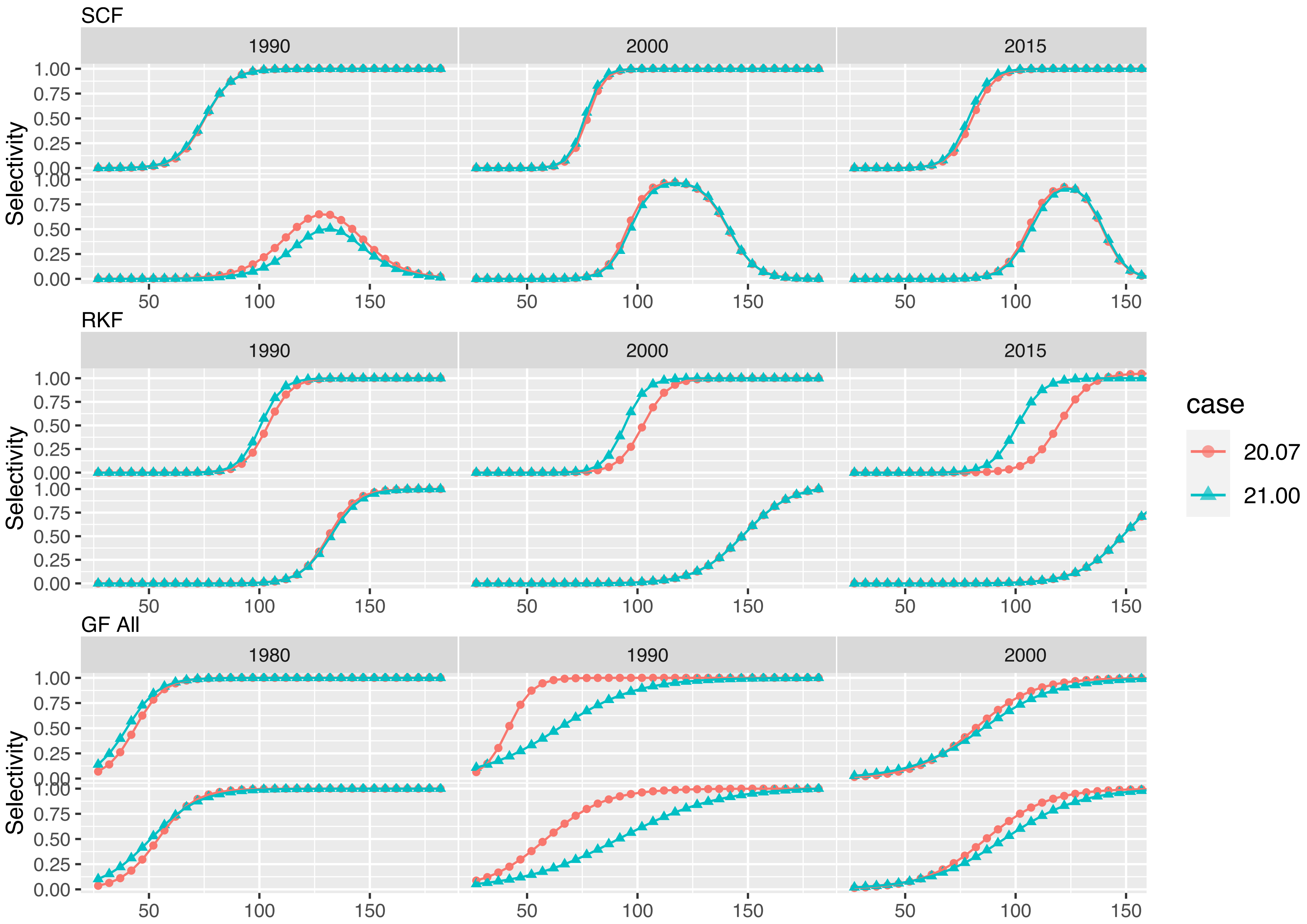


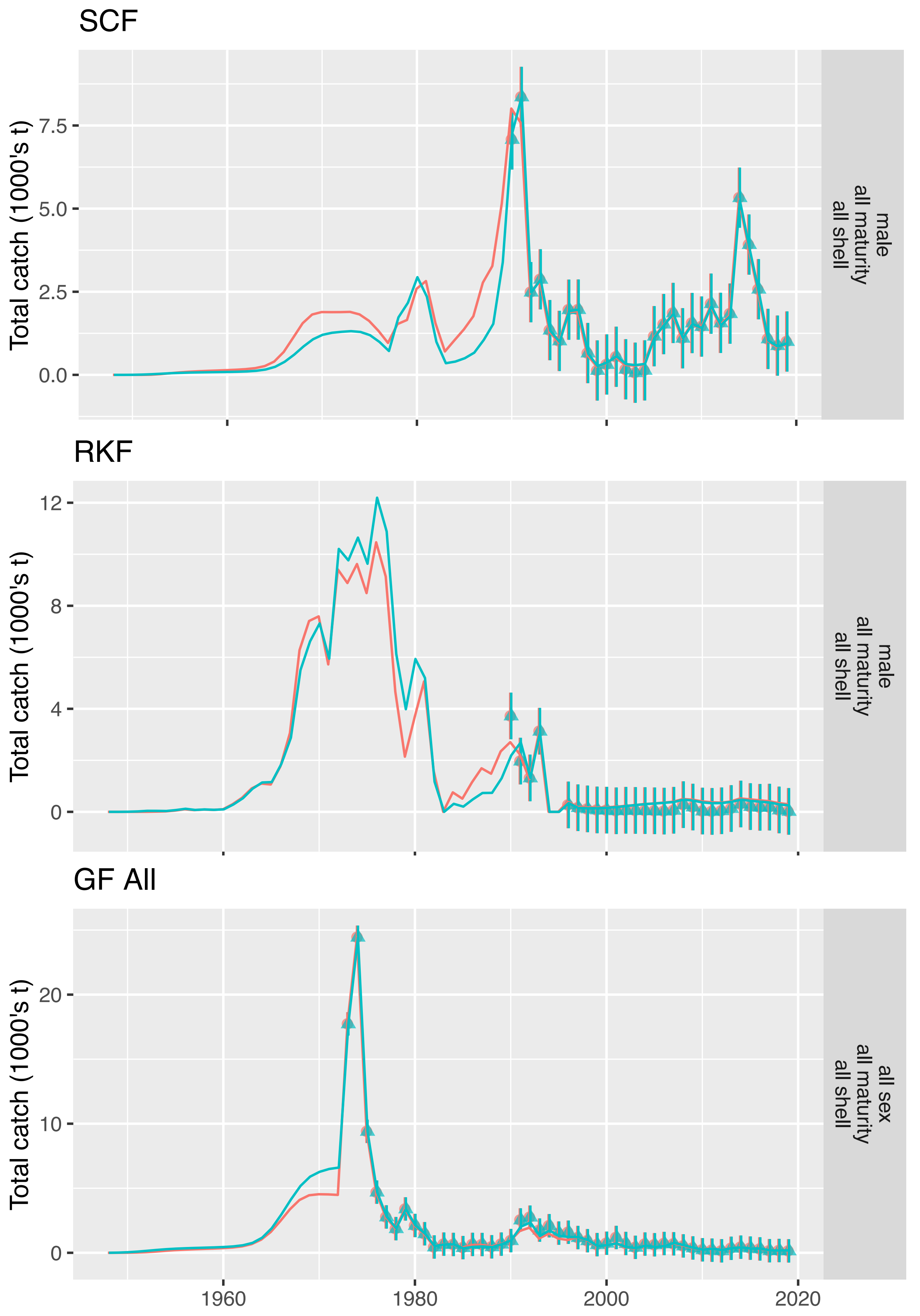
VAST Model Runs: Directed fishery



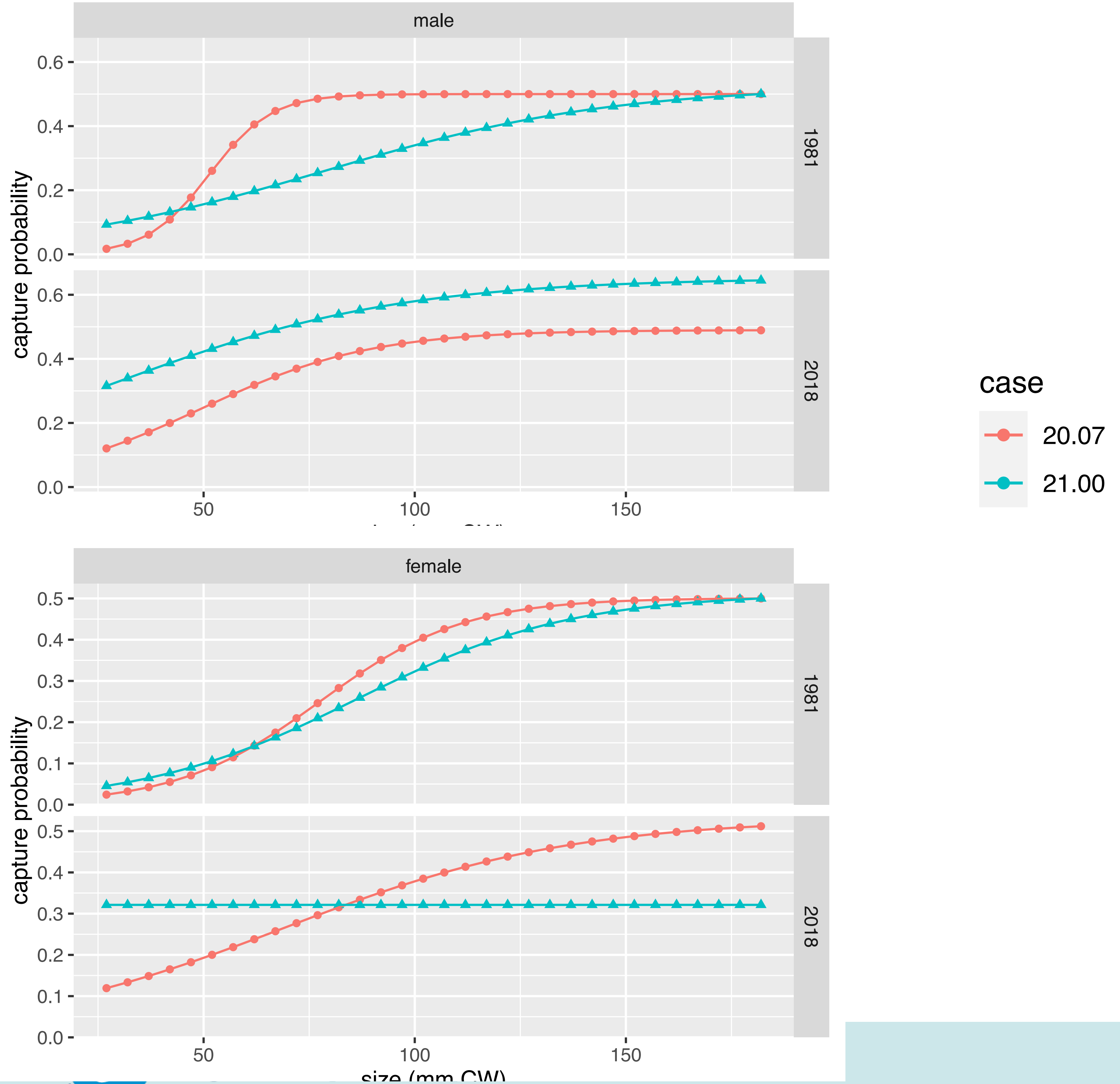


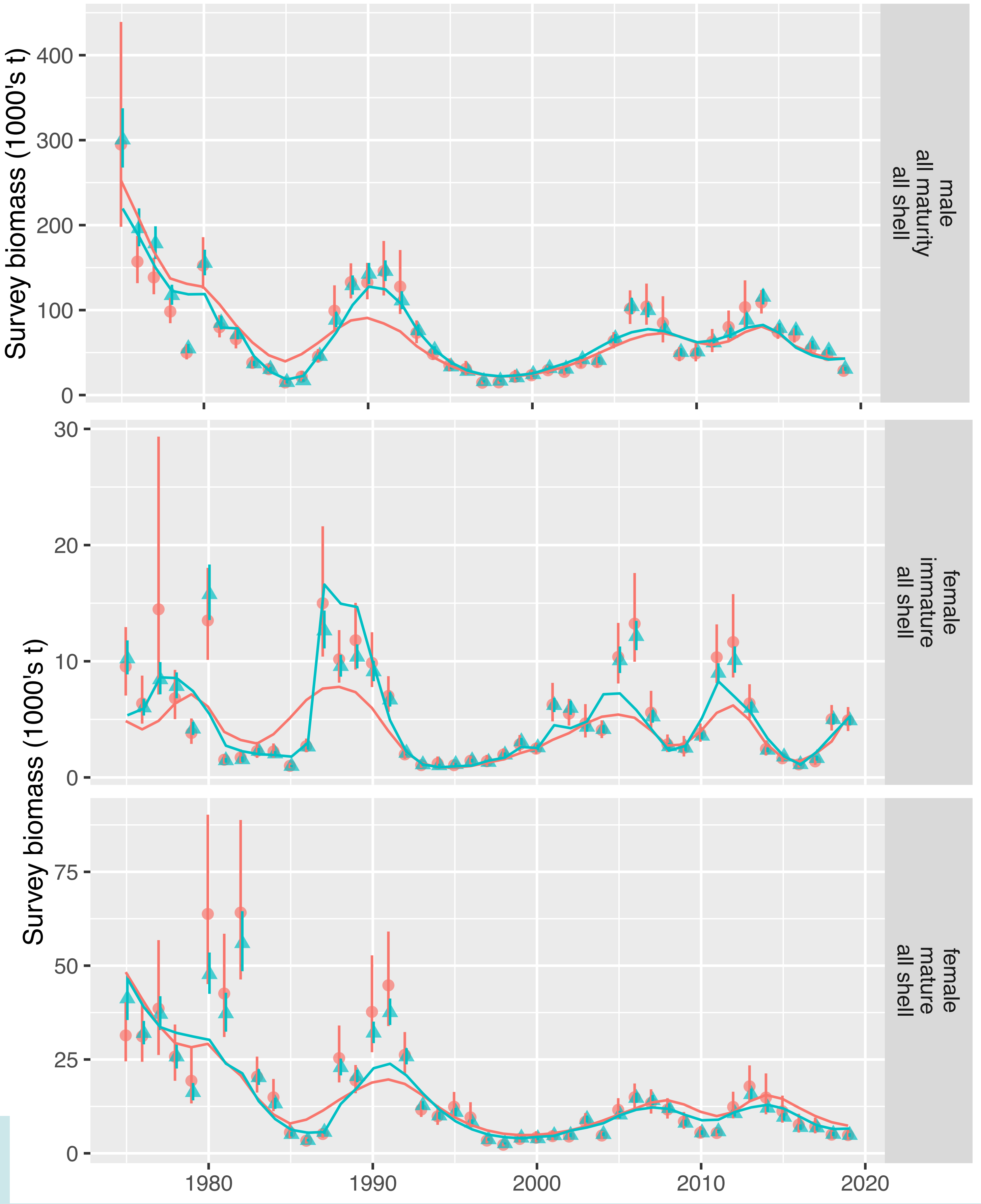
VAST Model Runs: Bycatch





VAST Model Runs: NMFS Survey Biomass





VAST Model Runs: Likelihood Values

category	fleet	catch.type	data.type	'20.07	'21.00
fisheries data	GF All	total catch	biomass	32.03	14.75
			n.at.z	538.82	648.19
	RKF	total catch	biomass	25.86	40.80
			n.at.z	73.55	71.45
	SCF	total catch	biomass	18.36	4.27
			n.at.z	134.22	159.45
	TCF	retained catc	biomass	8.13	8.51
			n.at.z	55.13	55.77
		total catch	biomass	12.97	11.58
			n.at.z	103.07	107.80
growth data	(blank)	(blank)	EBS_molt_increment_data	549.26	592.72
maturity ogive data	NMFS_M	(blank)	EBS_male_maturity_ogives	107.27	97.85
surveys data	NMFS F	index catch	biomass	139.92	467.05
			n.at.z	330.88	432.46
	NMFS M	index catch	biomass	65.33	115.14
			n.at.z	411.35	568.86
	SBS BSFRF fem	index catch	biomass	-6.64	-4.25
			n.at.z	146.29	198.33
	SBS BSFRF mal	index catch	biomass	-1.02	0.94
			n.at.z	153.24	205.17

The Parameters-At-Bounds Problem

SSC Comment (October 2010)

> Serious concerns remain about model convergence. A small percentage of models converge and it is not clear if the model is converging on a global minimum. This should remain a top priority for future work. Efforts should strive to reduce the number of parameters and minimize the number of parameters hitting bounds. Posterior correlations should be thoroughly examined to look for potential sources of the convergence issues.

The CPT has expressed similar concerns

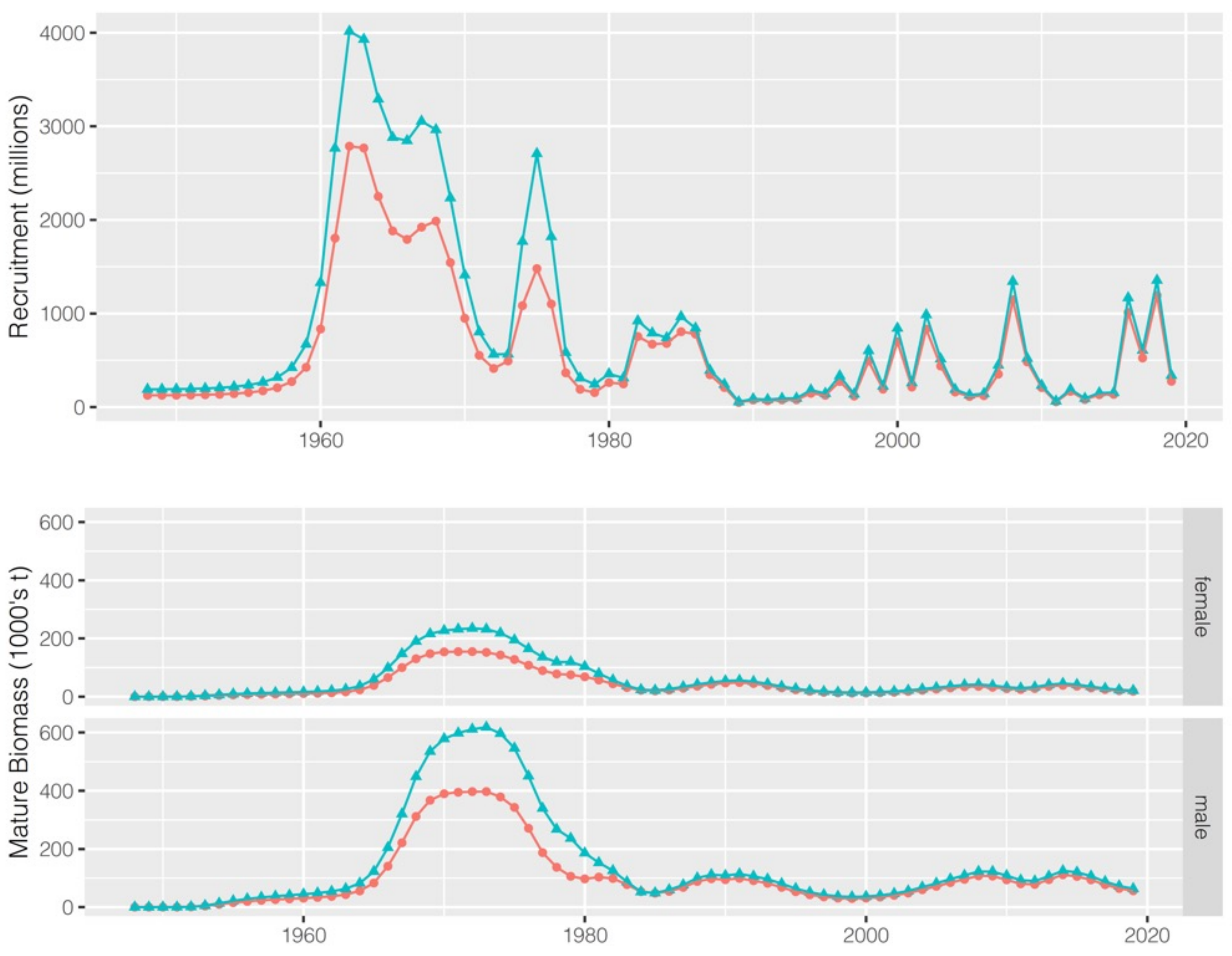
The Parameters-At-Bounds Problem: 20.07

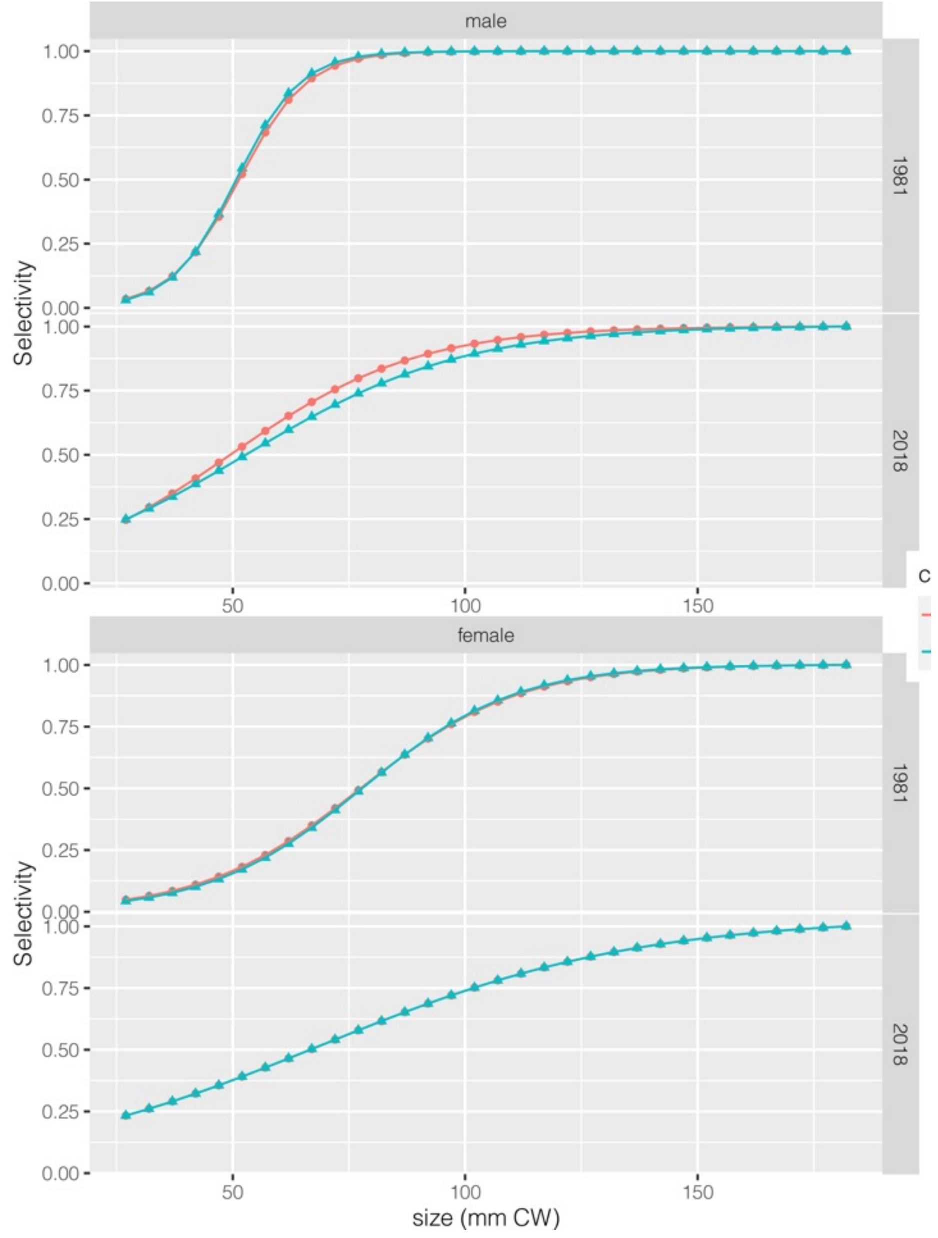
process	name	lower bound	upper bound	estimate	which bound?	description
growth	pGrBeta[1]	0.5	1	1.0000	at upper bound	scale parameter for growth gamma distributions
selectivity	pS1[4]	-50	69	69.0000	at upper bound	size at 50% selectivity for females in the NMFS survey
selectivity	pS1[23]	95	180	180.0000	at upper bound	size at 95% selected for males (1997-2004) by the RKF
selectivity	pS1[24]	95	180	180.0000	at upper bound	size at 95% selected for males (2005+) by the RKF
selectivity	pS1[27]	100	140	140.0000	at upper bound	size at 95% selected for females (2005+) by the RKF
selectivity	pS2[4]	0	100	100.0000	at upper bound	size difference between 50% and 95% selected females in the NMFS survey (1982+)
selectivity	pS2[10]	0.1	0.5	0.1000	at lower bound	ascending slope for SCF selectivity (males, pre-1997)
selectivity	pS4[1]	0.1	0.5	0.1000	at lower bound	descending slope for SCF selectivity (males, pre-1997)
fisheries	pLgtRet[1]	0	15	14.9989	at upper bound	TCF: logit-scale max retention (pre-1997)
surveys	pQ[1]	0.5	1.001	0.5000	at lower bound	ln-scale fully-serlected catchability, NMFS trawl survey: males, 1975-1981
surveys	pQ[3]	0.5	1.001	0.5000	at lower bound	ln-scale fully-serlected catchability, NMFS trawl survey: females, 1975-1981

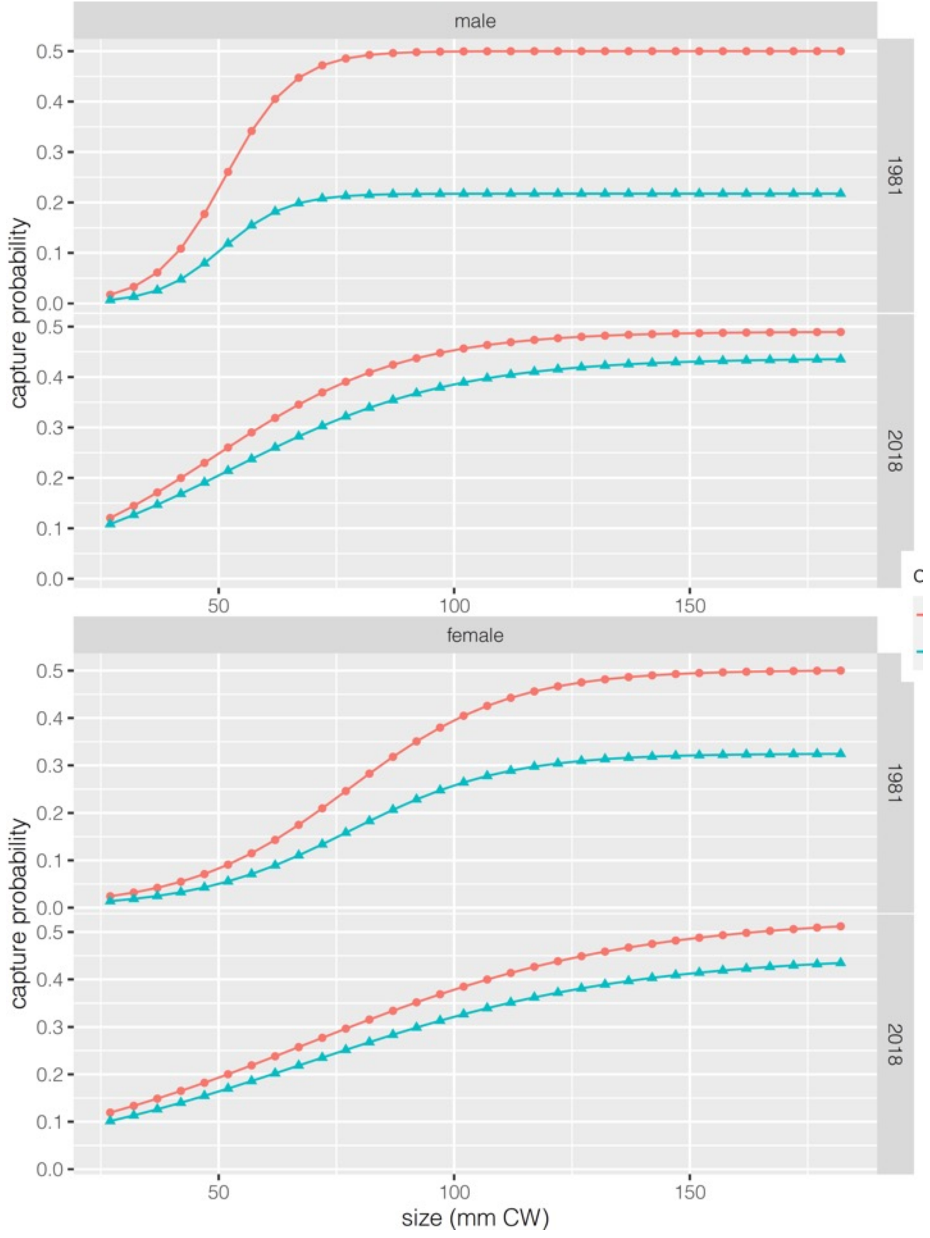
Approaches taken

- expand parameter bounds
- change likelihoods
- re-parameterize selectivity functions
- compress/truncate size distributions
- truncate model size range (females)
- use Dirichlet-multinomial likelihood for size compositions
- fix parameters at bounds when alternatives are exhausted

Model 21.01: Expanded bounds for NMFS survey q's







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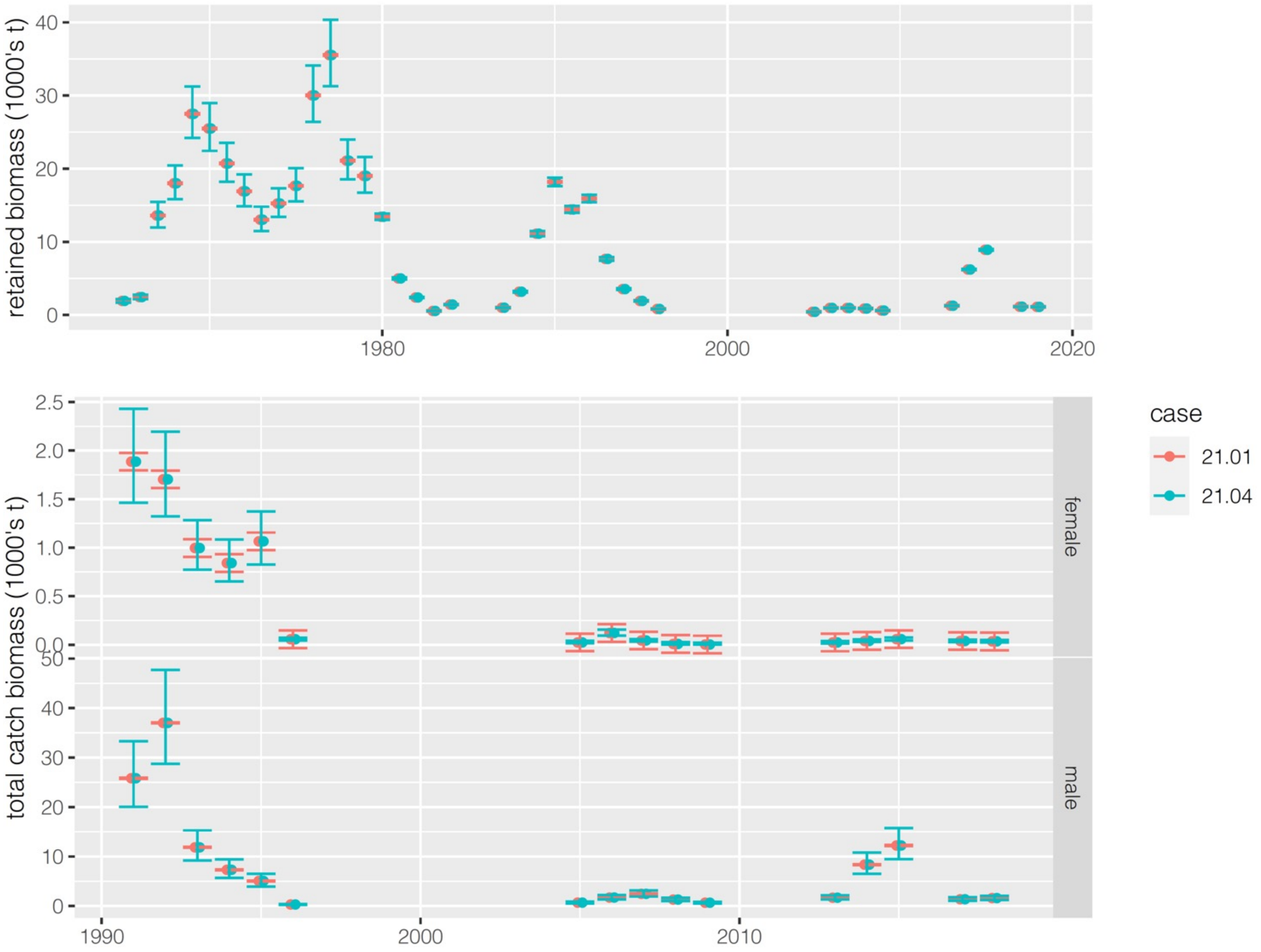
Lognormal Likelihoods for Fishery Catch Biomass

- current: normal likelihoods with assumed standard deviation of 100 t

- new: lognormal likelihoods with:
  - assumed cv
    - retained catch:
    - 1965-1979: 10%
    - 1980-1995: 2.5%
    - 1996+: 1%
    - total catch:
      - crab fisheries: 20% (1990+)
      - groundfish fisheries: 20% (1973+)
  - min. standard deviation: 10 t



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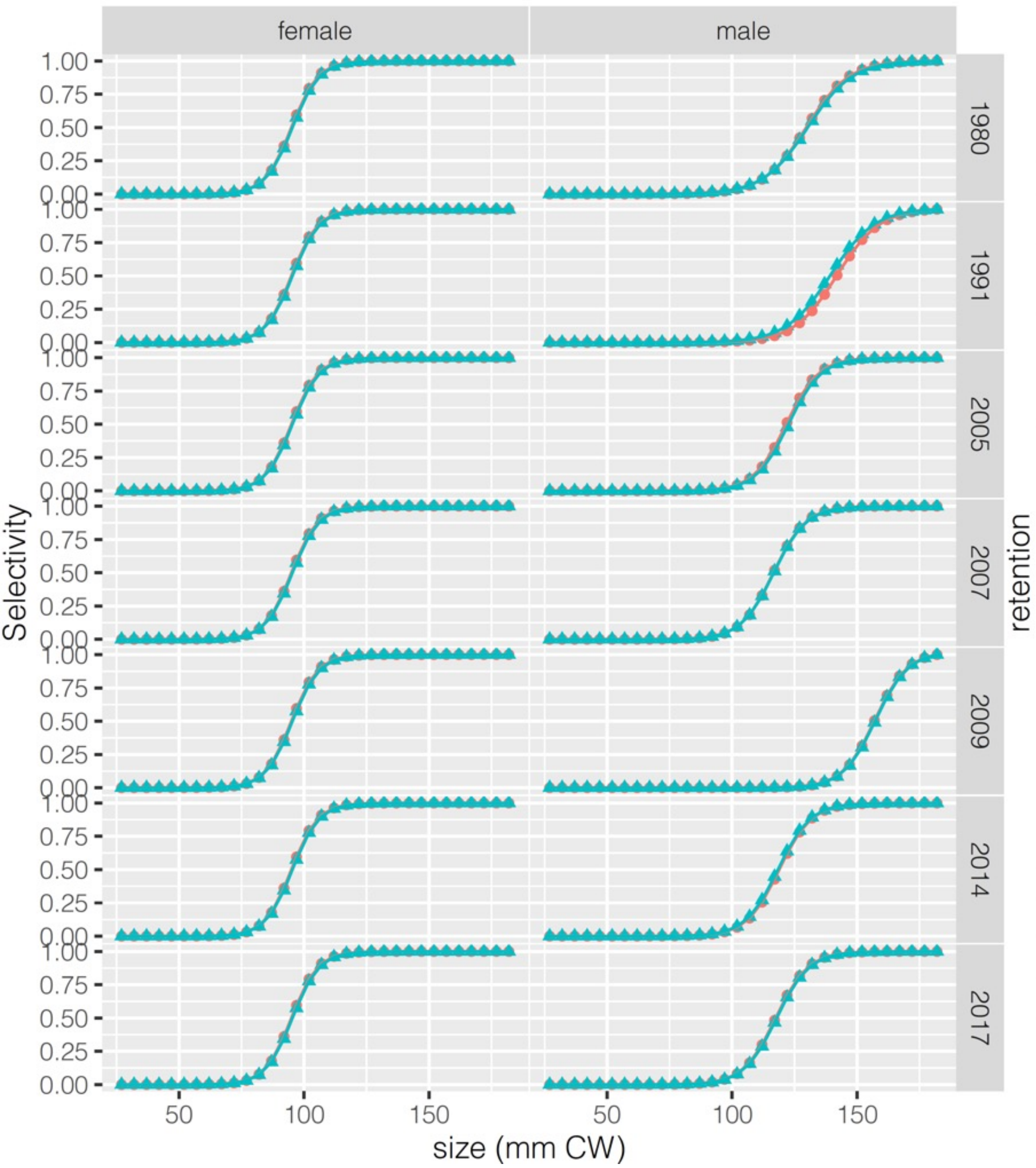
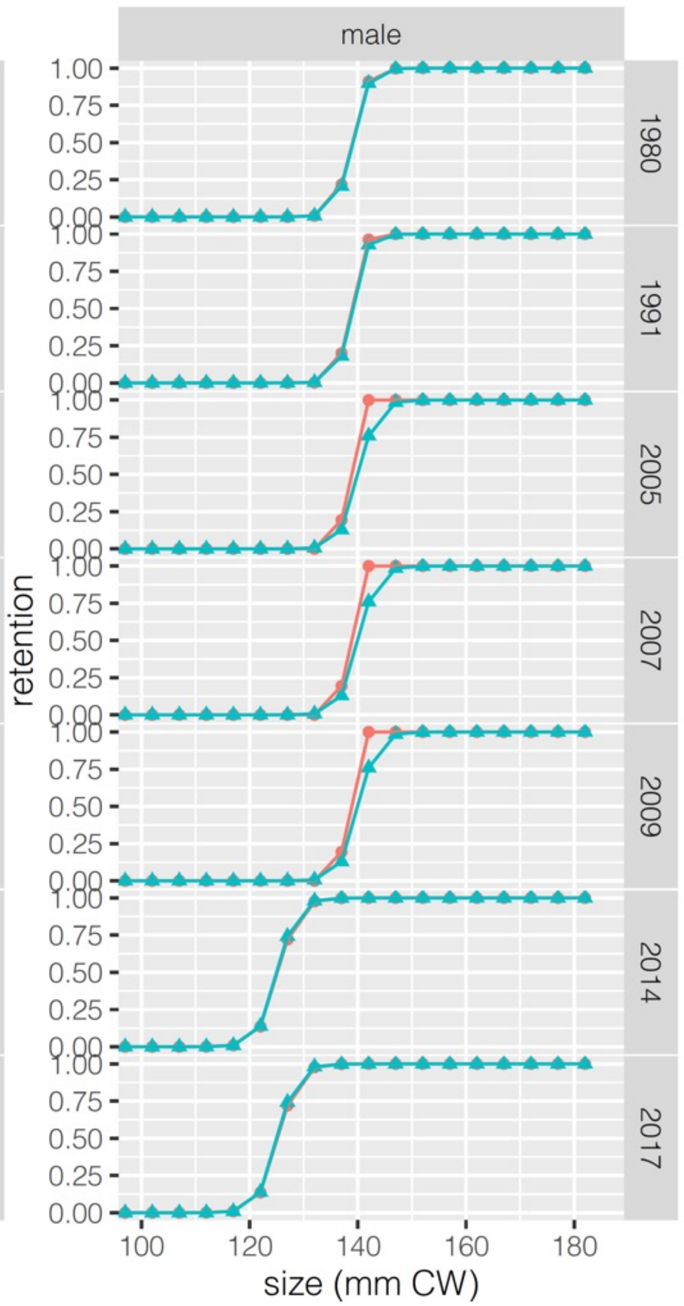
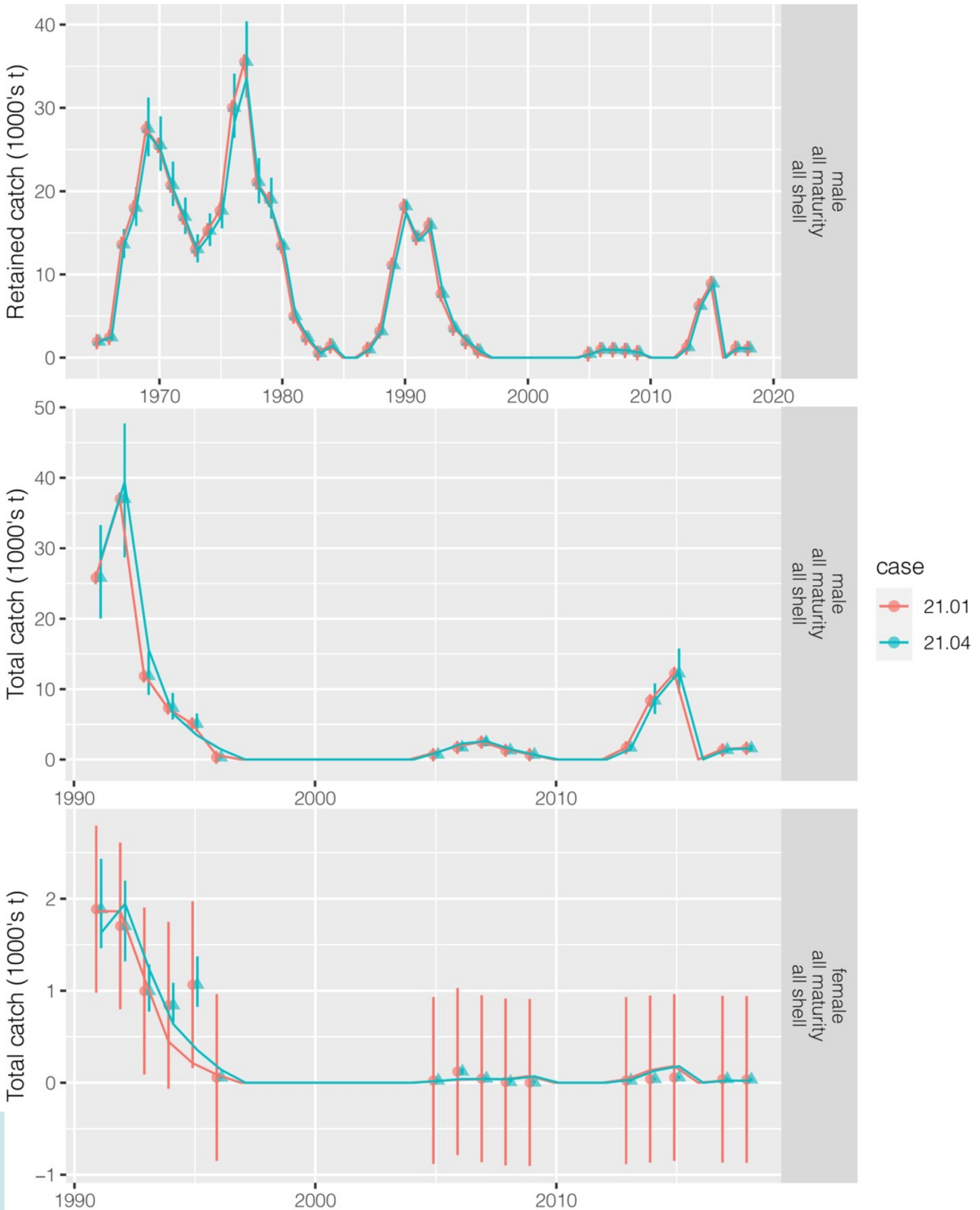
case	average recruitment (millions)	B100 (1000's t)	Bmsy (1000's t)	current year MMB (1000's t)	Fmsy	MSY (1000's t)	Fofl	OFL (1000's t)	projected MMB (1000's t)
20.07	374.43	105.05	36.77	66.87	0.98	16.94	0.94	21.13	35.33
21.01	436.93	116.66	40.83	74.58	1.13	18.77	1.07	24.35	38.61
21.04	424.93	115.23	40.33	73.90	1.12	18.39	1.06	24.11	38.40

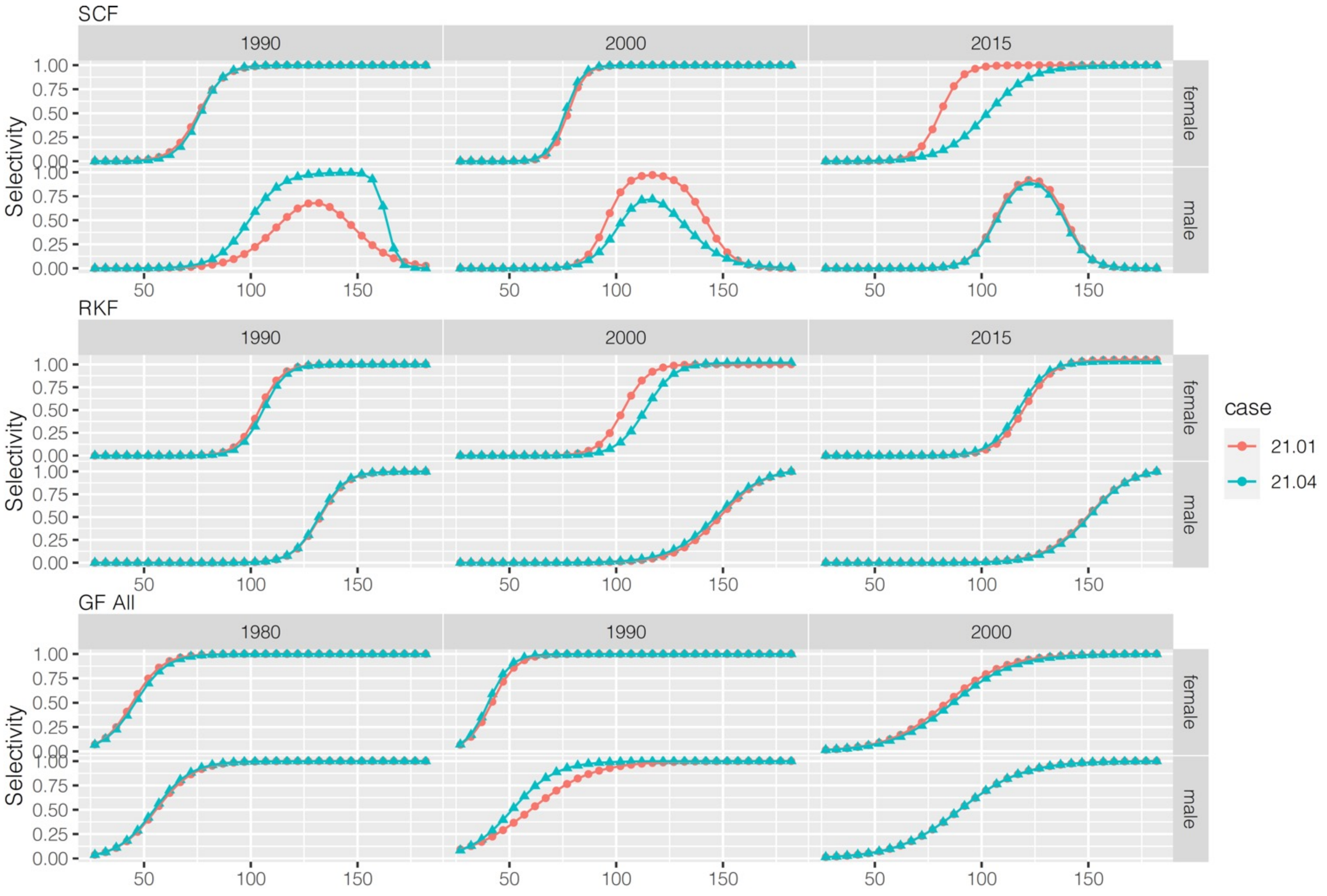
Fishery Likelihoods for Catch Biomass

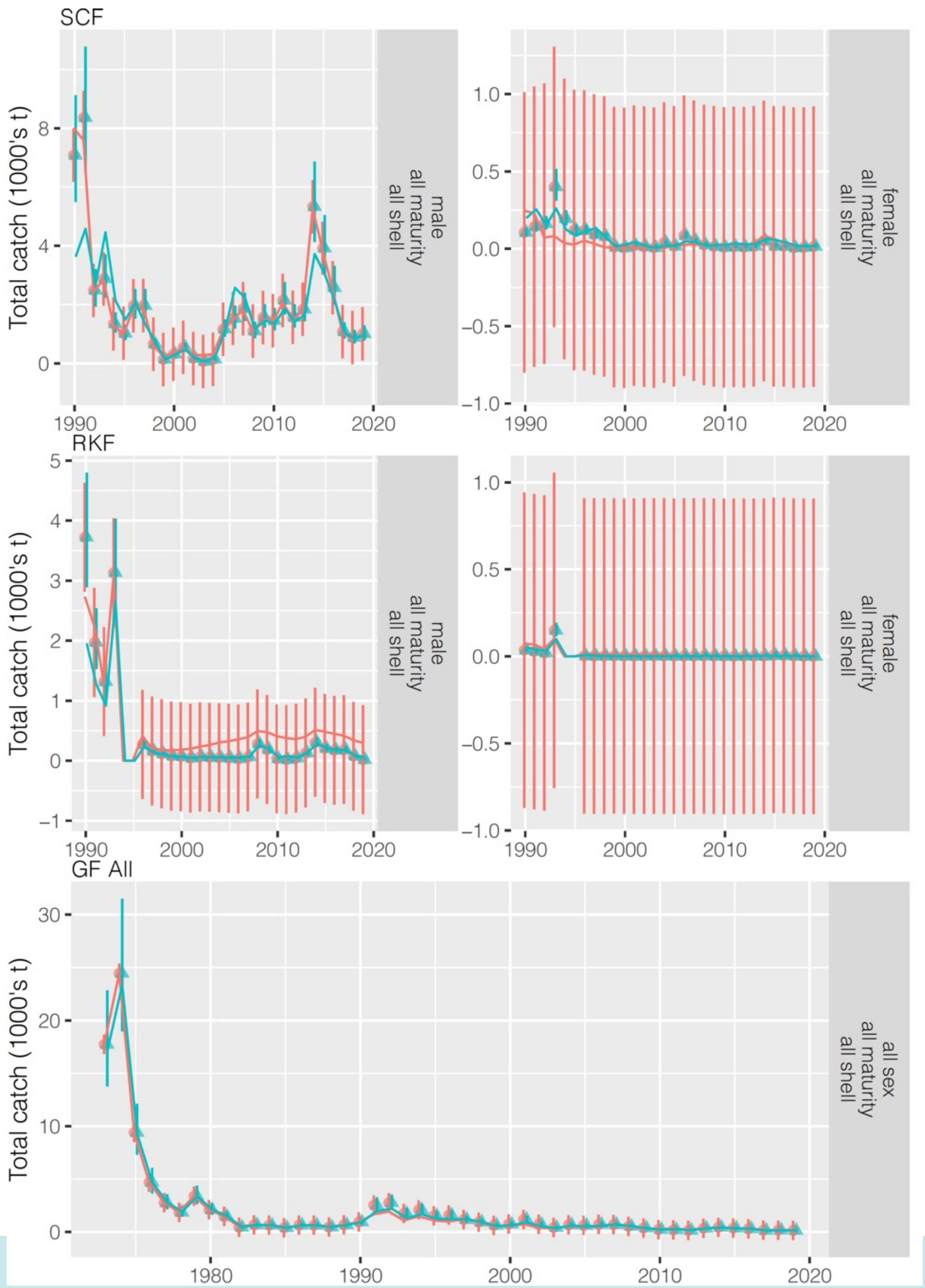






Fishery Likelihoods for Catch Biomass





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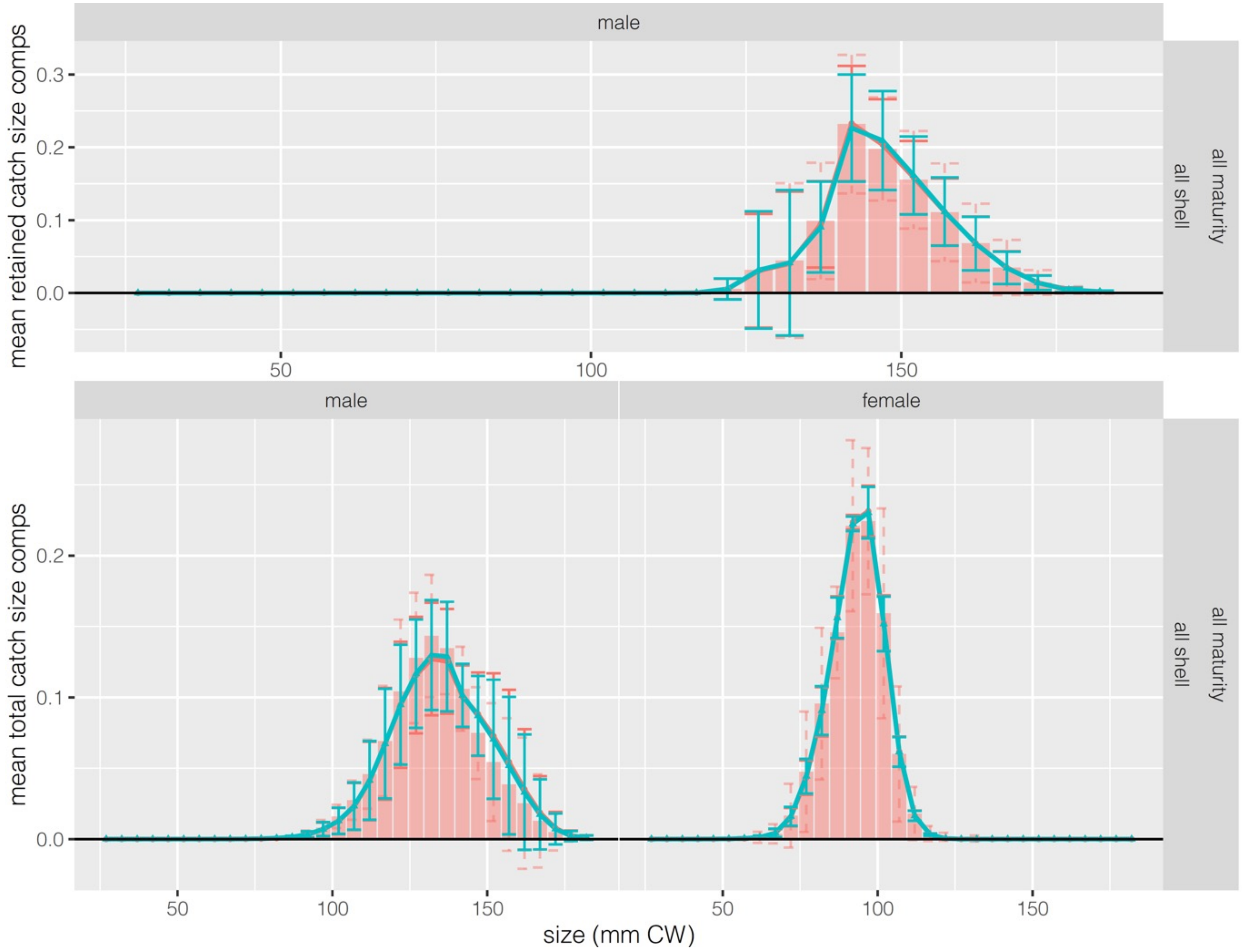
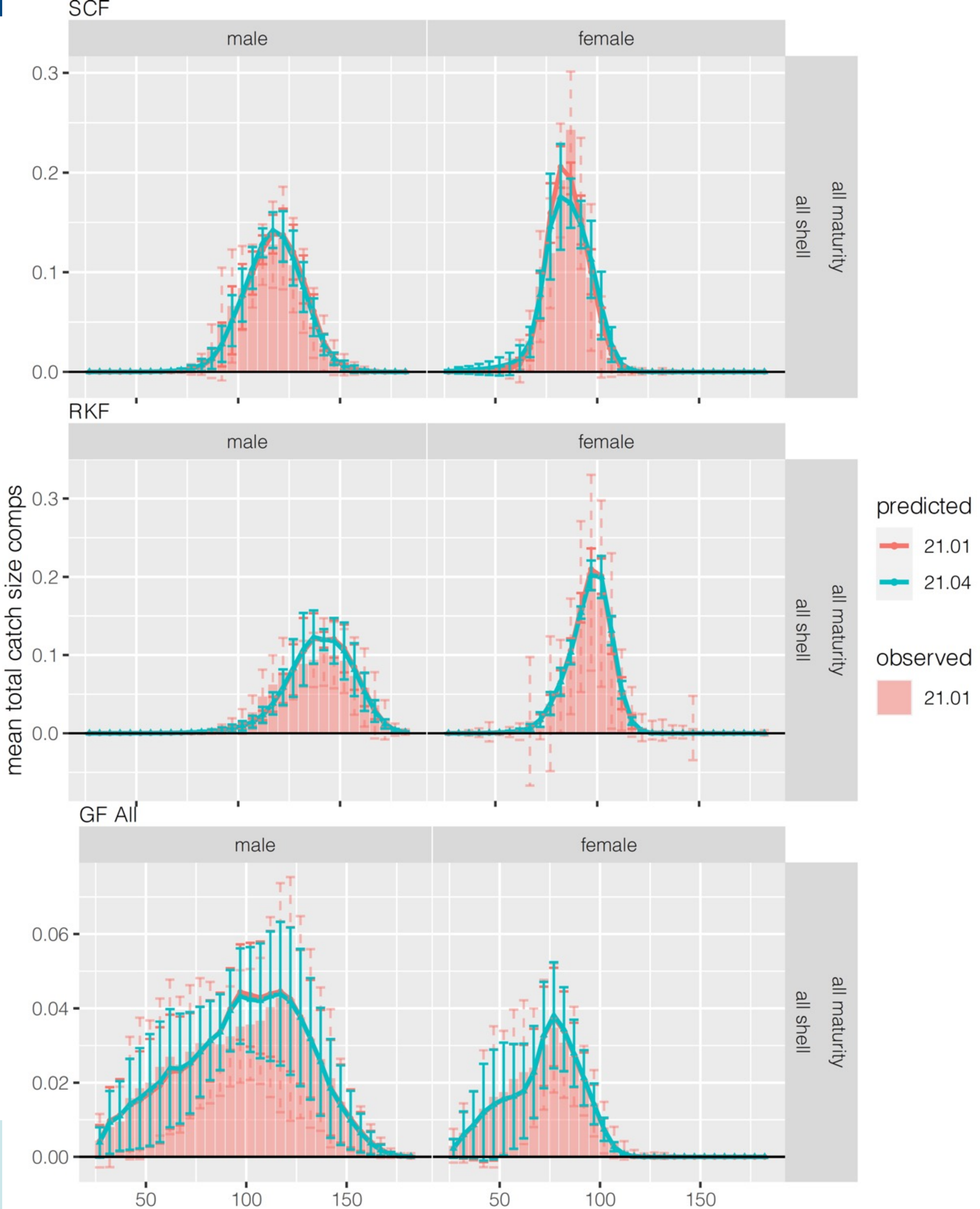
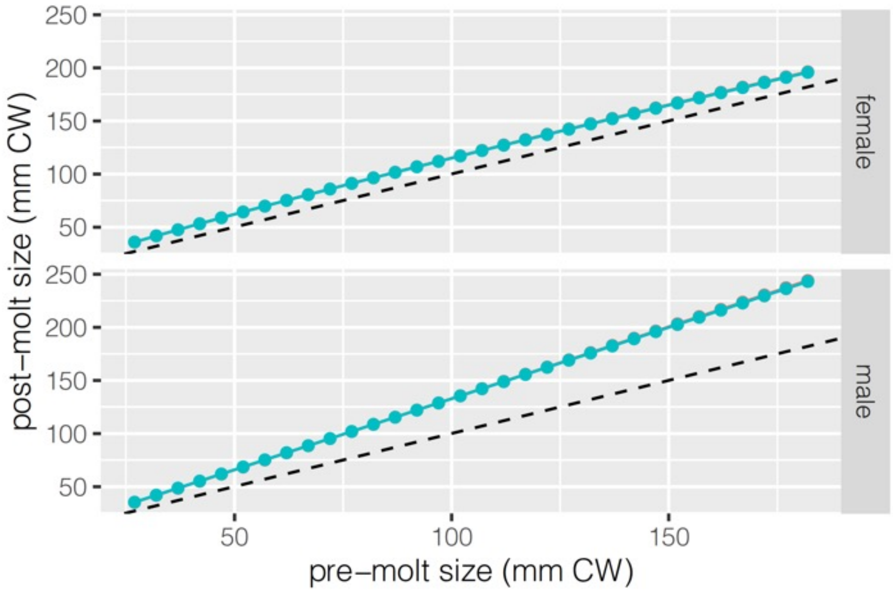
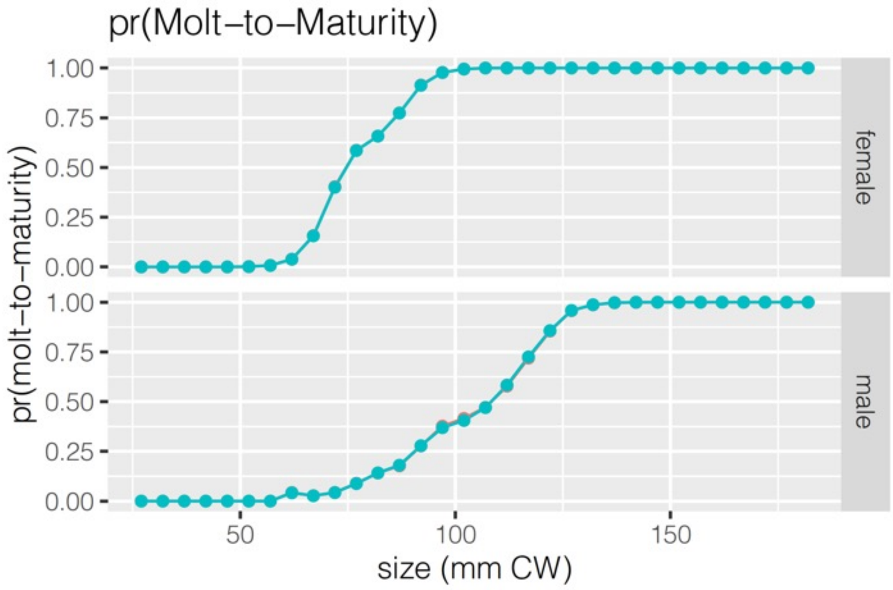
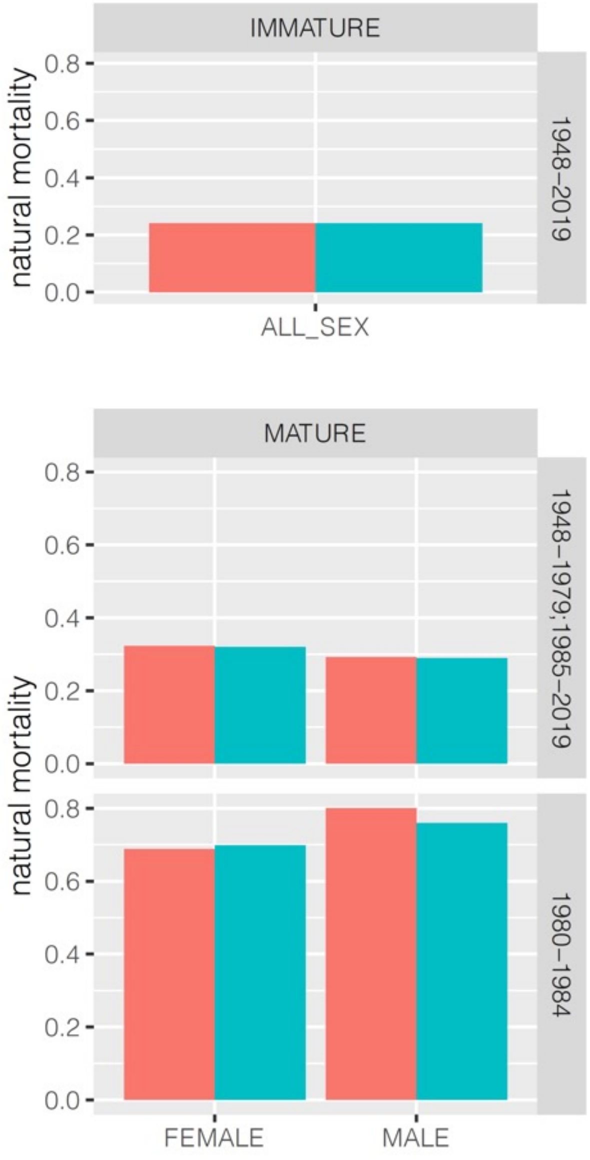


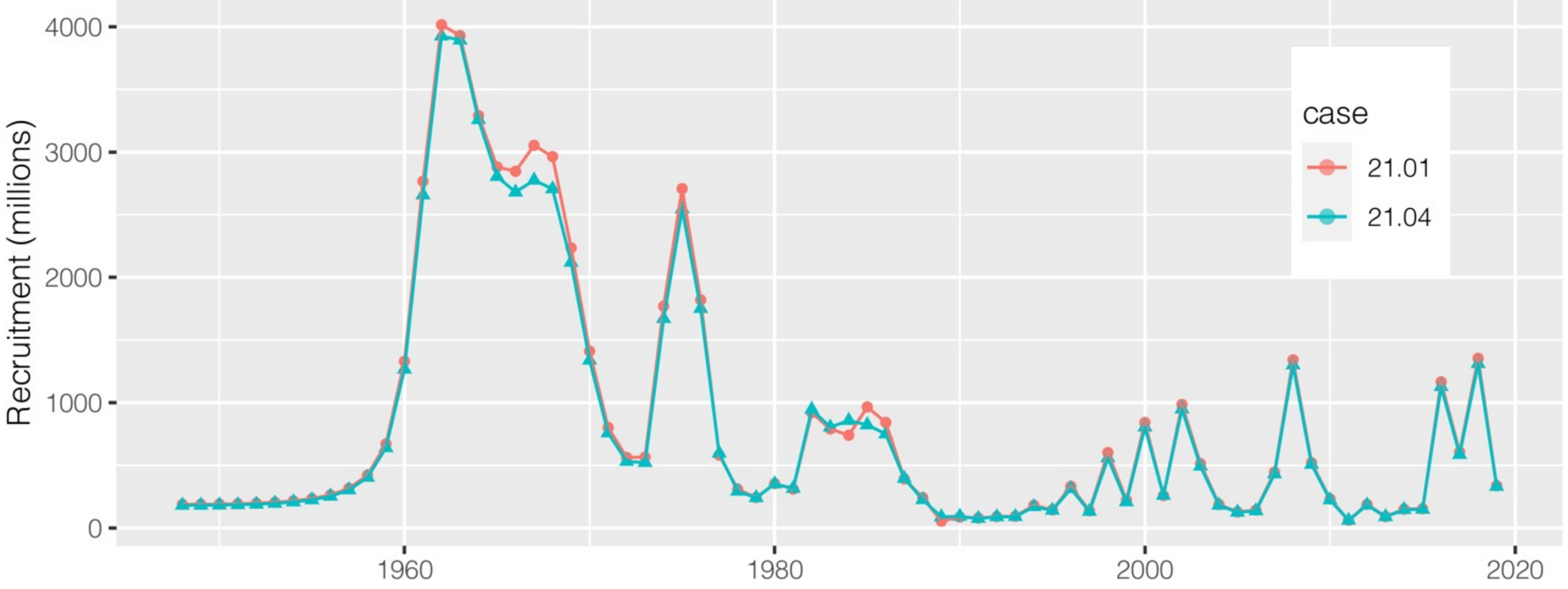


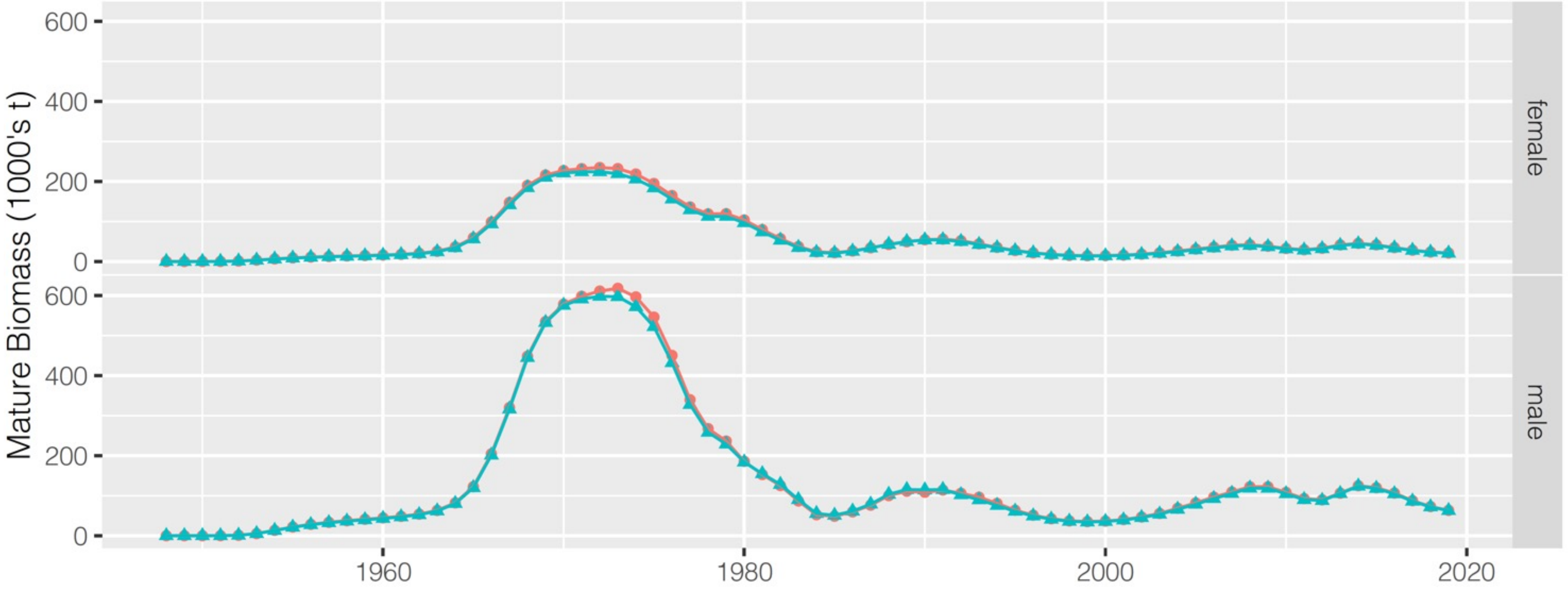
Lognormal Likelihoods for Fishery Catch Biomass











Lognormal Likelihoods for Fishery Catch Biomass

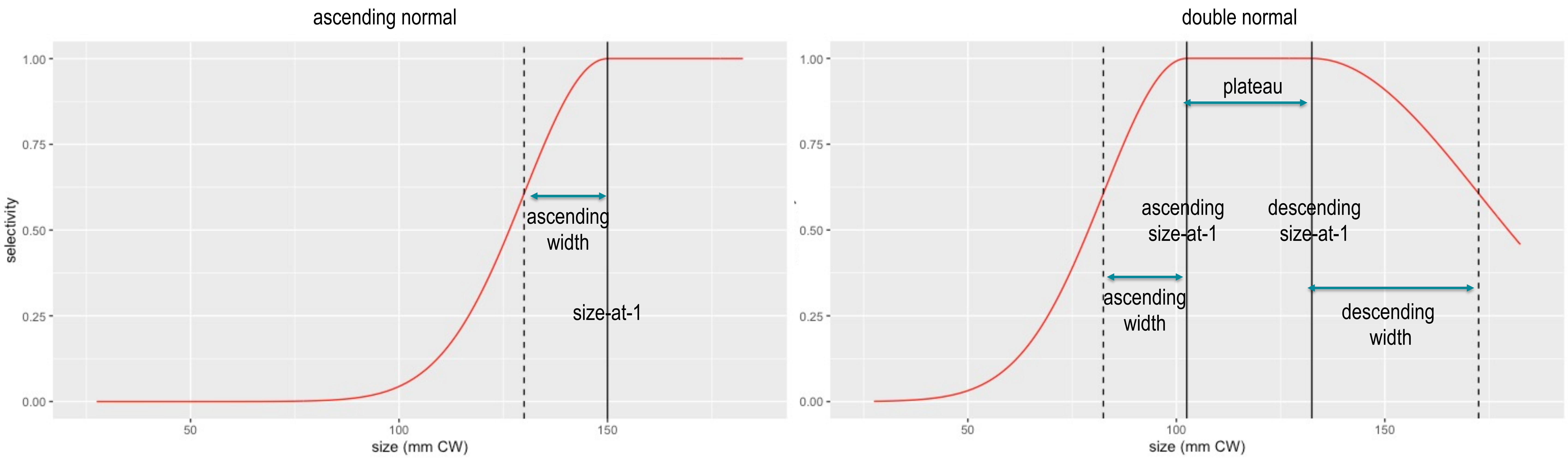
- Changing to lognormal likelihoods
  - tried unsuccessfully several years ago
  - results now seem reasonable
  - similar to what other assessments do

- Assumed CV's rather arbitrary
  - based on perceived accuracy
  - need minimum precision to keep tail from wagging dog

Other Approaches

- Alternative selectivity functions
  - logistic functions → normal functions
- Tail compression for size composition likelihoods
  - fishery size compositions have long tails
- Data censoring
  - don’t fit size compositions with small number of crab sampled
- Dirichlet-multinomial likelihoods
  - intrinsic data weighting

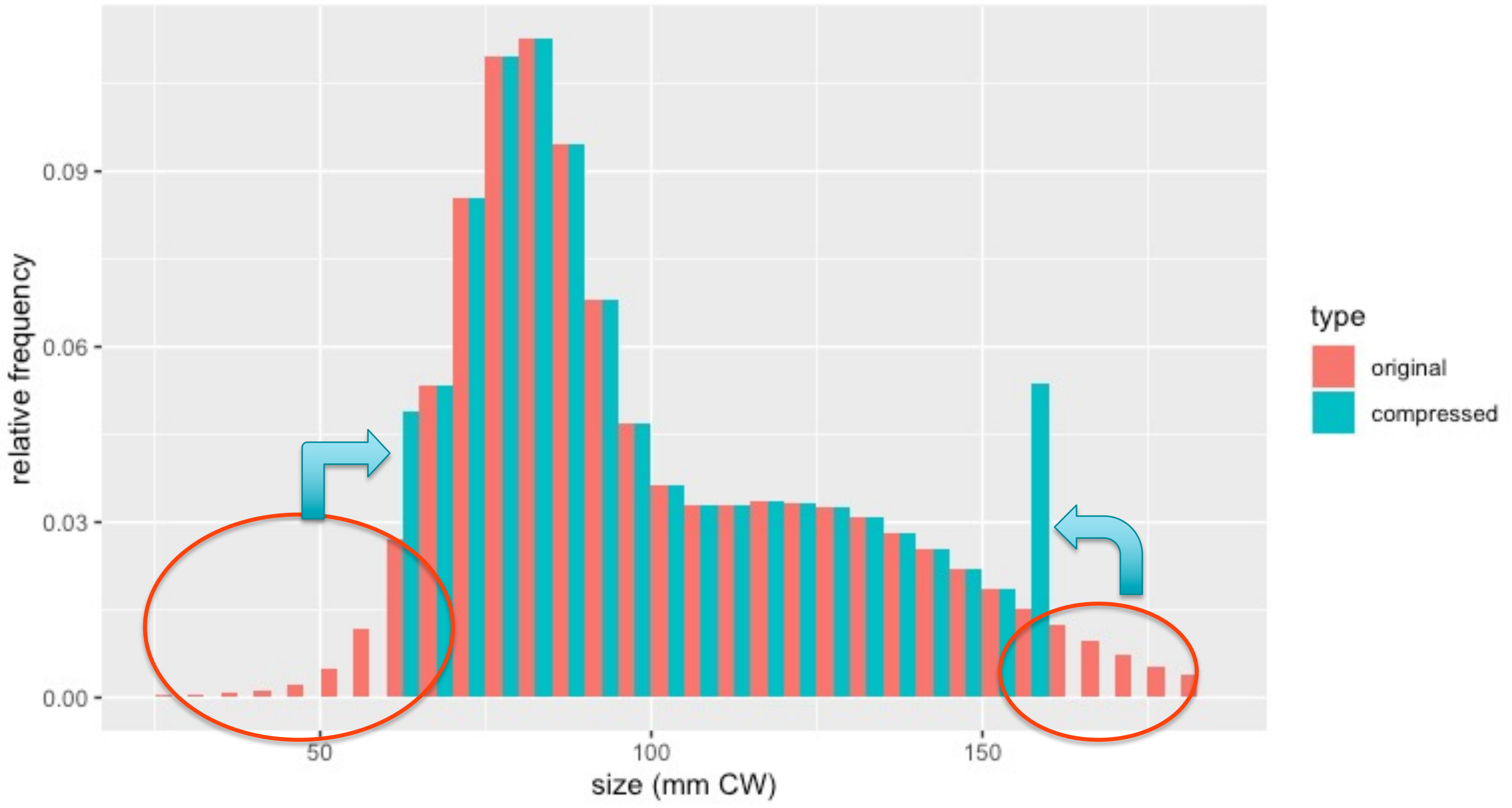
Other Approaches



- advantage over logistic functions:
  - always reaches 1
  - intrinsically normalized

Other Approaches: Tail Compression

can improve statistical stability fitting to size comps with long tails



Other Approaches

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Other Approaches

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21.04	424.93	115.23	40.33	73.90	1.12	18.39	1.06
21.05	497.90	120.06	42.02	76.45	1.12	19.05	1.05
21.06	477.22	114.82	40.19	74.30	1.08	18.27	1.03
21.07	475.67	114.96	40.24	74.73	1.07	18.27	1.02
21.08	470.22	121.35	42.47	81.65	0.98	18.80	0.98
21.09	455.33	117.07	40.97	78.69	0.98	18.18	0.98
21.10	455.33	117.07	40.97	78.69	0.98	18.18	0.98
21.11	462.11	116.35	40.72	78.28	1.00	18.11	1.00
21.12	355.36	107.92	37.77	74.14	0.94	16.76	0.94
21.13	359.13	107.91	37.77	74.12	0.95	16.85	0.95

Other Approaches: Dirichlet-multinomial likelihood

- Fits to size composition data based on multinomial likelihood frequently exhibit overdispersion
- uses mixed-effects modeling to replace McAllister-Ianelli-type tuning
- Marginal likelihood has a closed form solution

$$[\boldsymbol{\pi}_t^*] \sim \text{Dirichlet}(\beta \boldsymbol{\pi}_t)$$
$$[n_t \widetilde{\boldsymbol{\pi}}_t | \boldsymbol{\pi}_t^*] \sim \text{Multinomial}(\boldsymbol{\pi}_t^*, n_t)$$

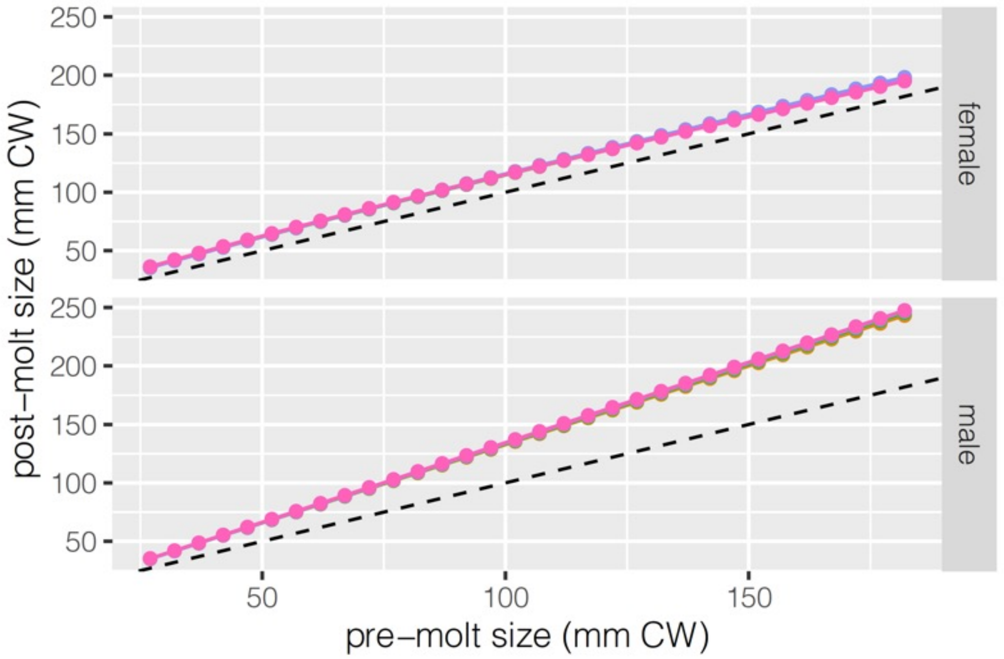
$$\mathcal{L}(\widetilde{\boldsymbol{\pi}}_t; \boldsymbol{\pi}_t, \theta, n_t) = \int \text{Multinomial}(n_t \widetilde{\boldsymbol{\pi}}_t | \boldsymbol{\pi}_t^*, n_t) \text{Dirichlet}(\boldsymbol{\pi}_t^* | \boldsymbol{\pi}_t, \theta) d\boldsymbol{\pi}_t^*$$
$$= \frac{\Gamma(n_t + 1)}{\prod_{i=1}^{n_i} \Gamma(n_t \widetilde{\pi}_{a,t} + 1)} \frac{\Gamma(\theta n_t)}{\Gamma(n_t + \theta n_t)} \prod_{a=1}^{n_a} \frac{\Gamma(n_t \pi_{a,t} + \theta n_t \pi_{a,t})}{\Gamma(\theta n_t \pi_{a,t})}$$

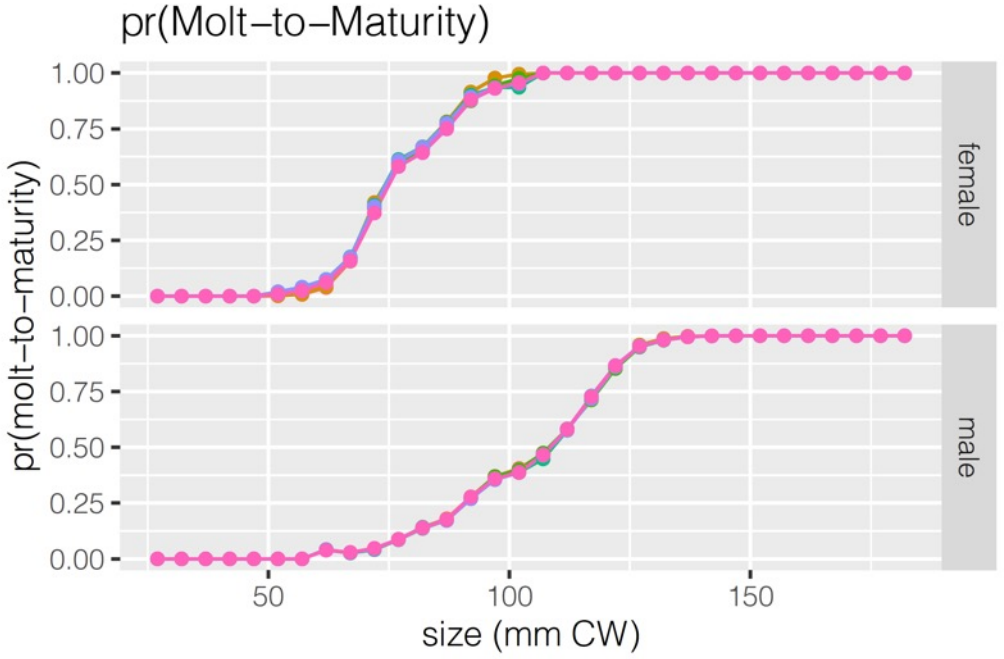
$$n_{effective} = \frac{1}{1+\theta} + n_t \frac{\theta}{1+\theta}$$

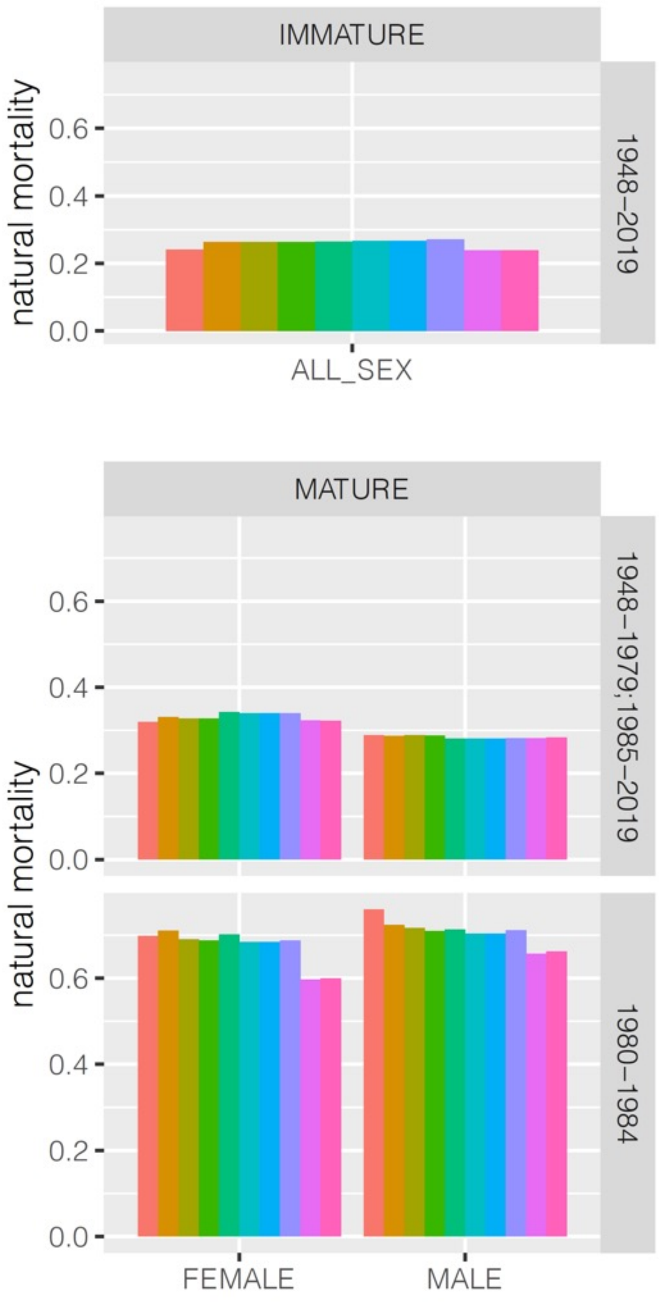
- scaling factor for effective sample size
  - hit upper bound for all size composition data except BSFRF survey data
  - results imply input sample sizes adequate for most data sources

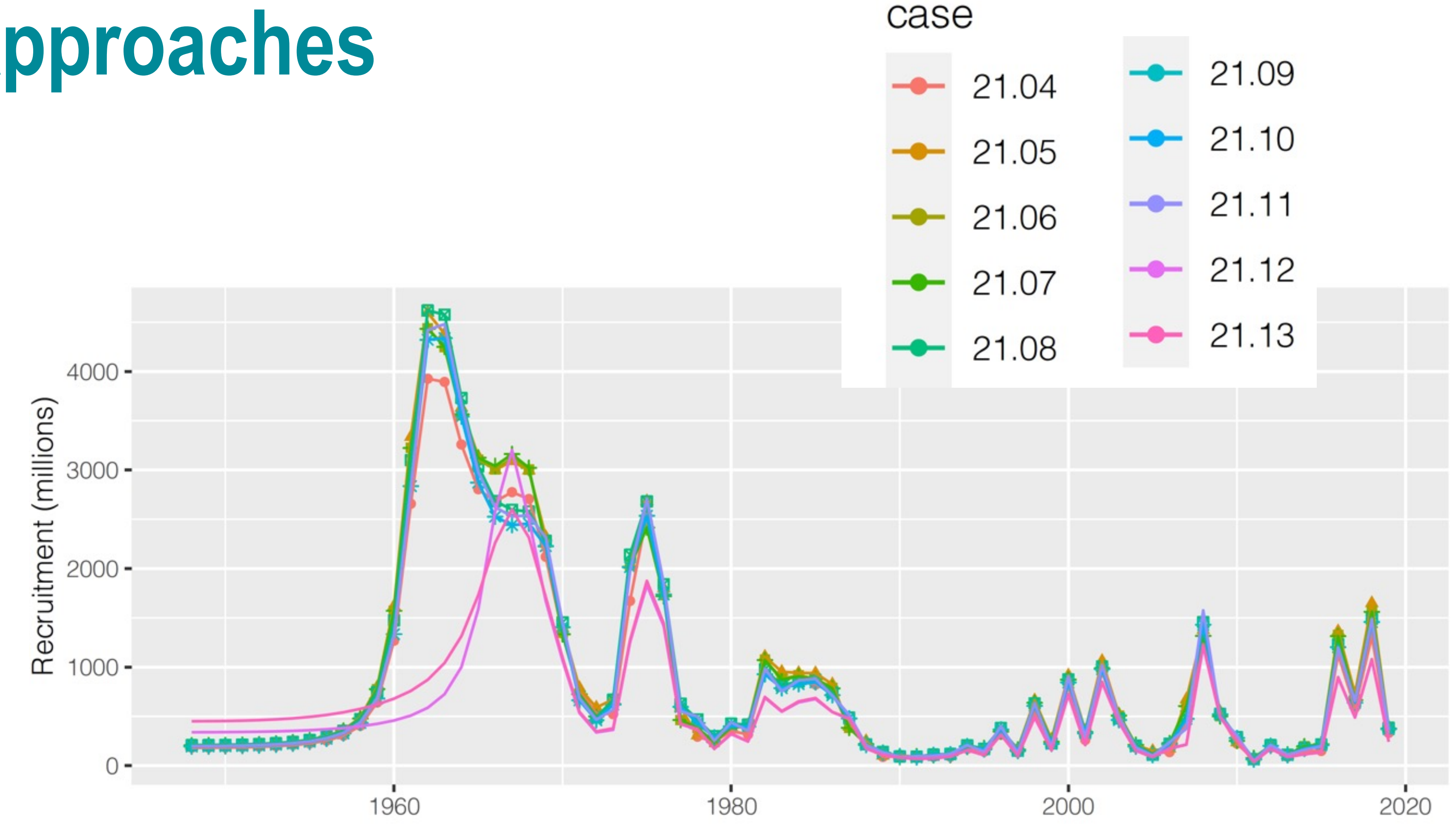
Thorson et al., 2017; Thorson 2019

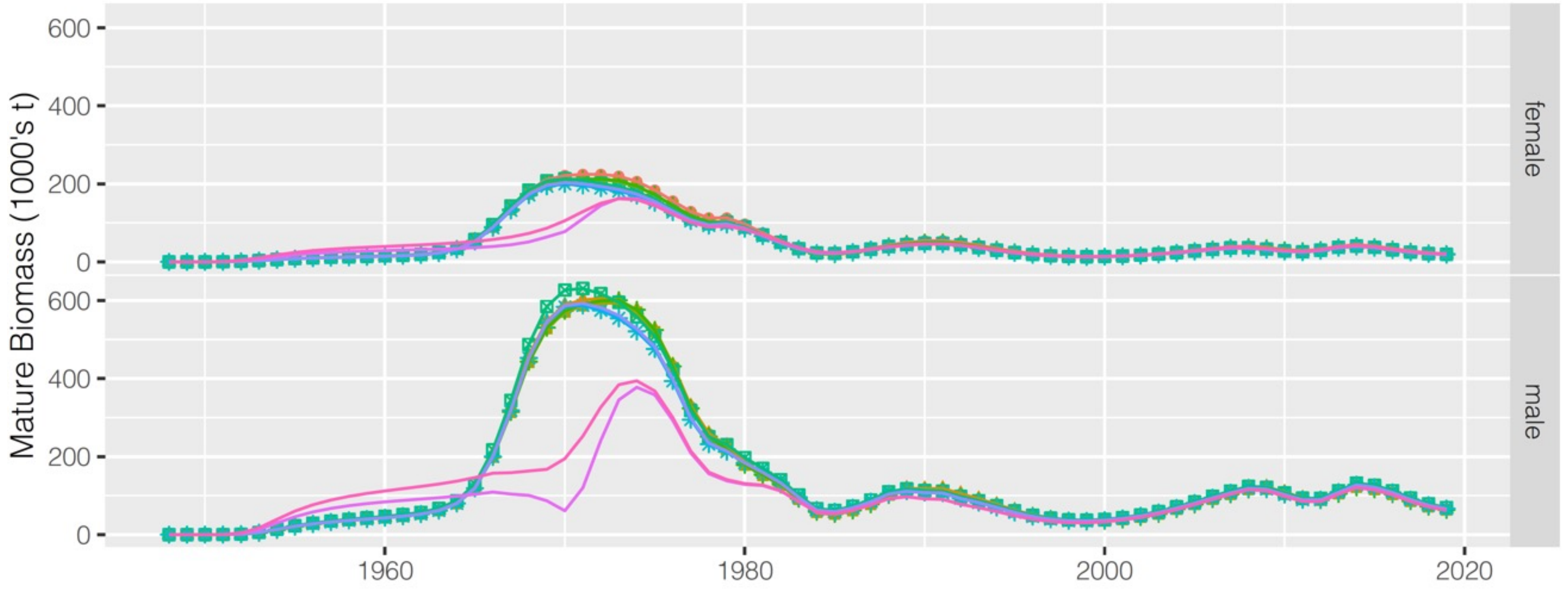
Other Approaches



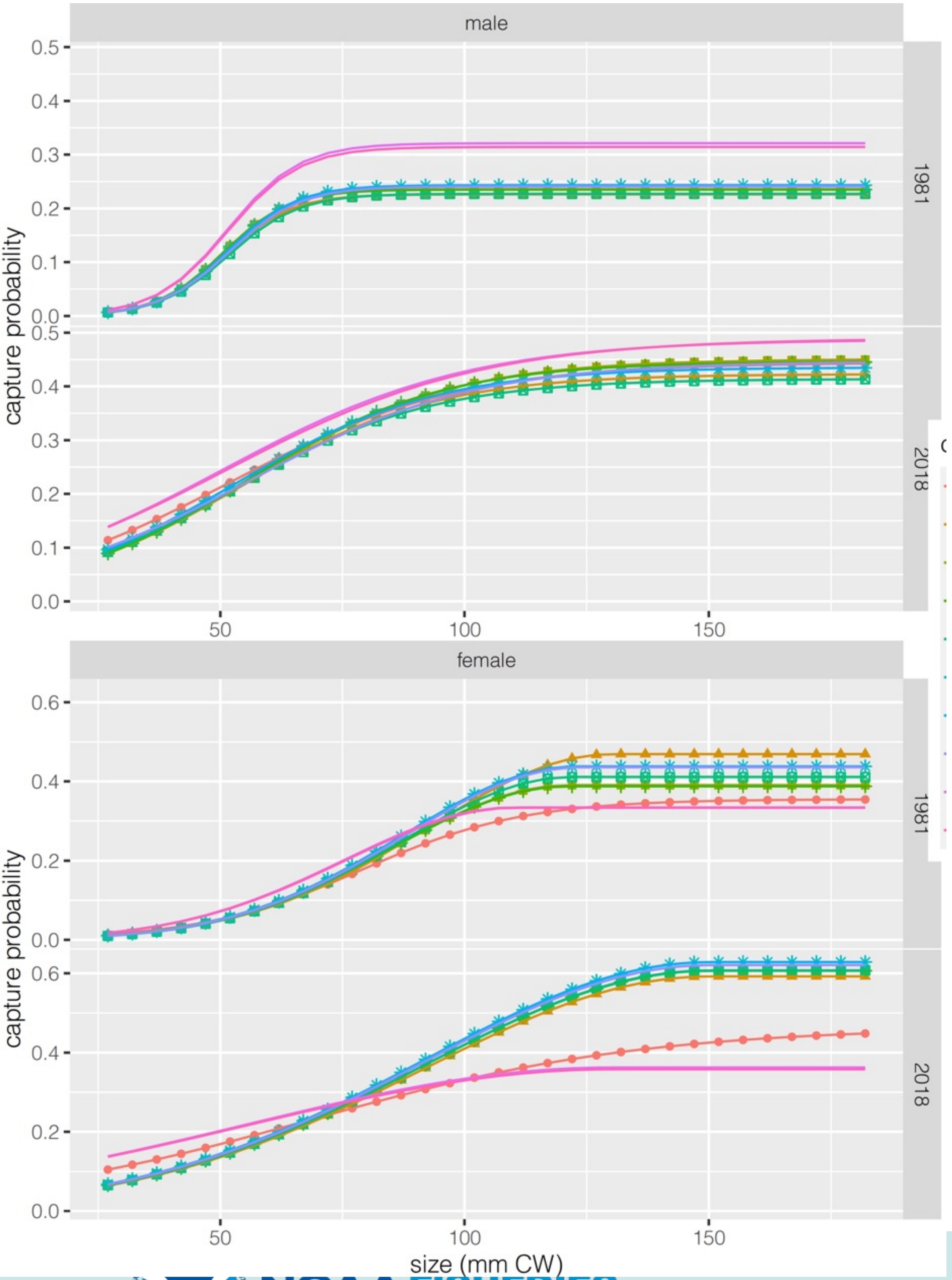


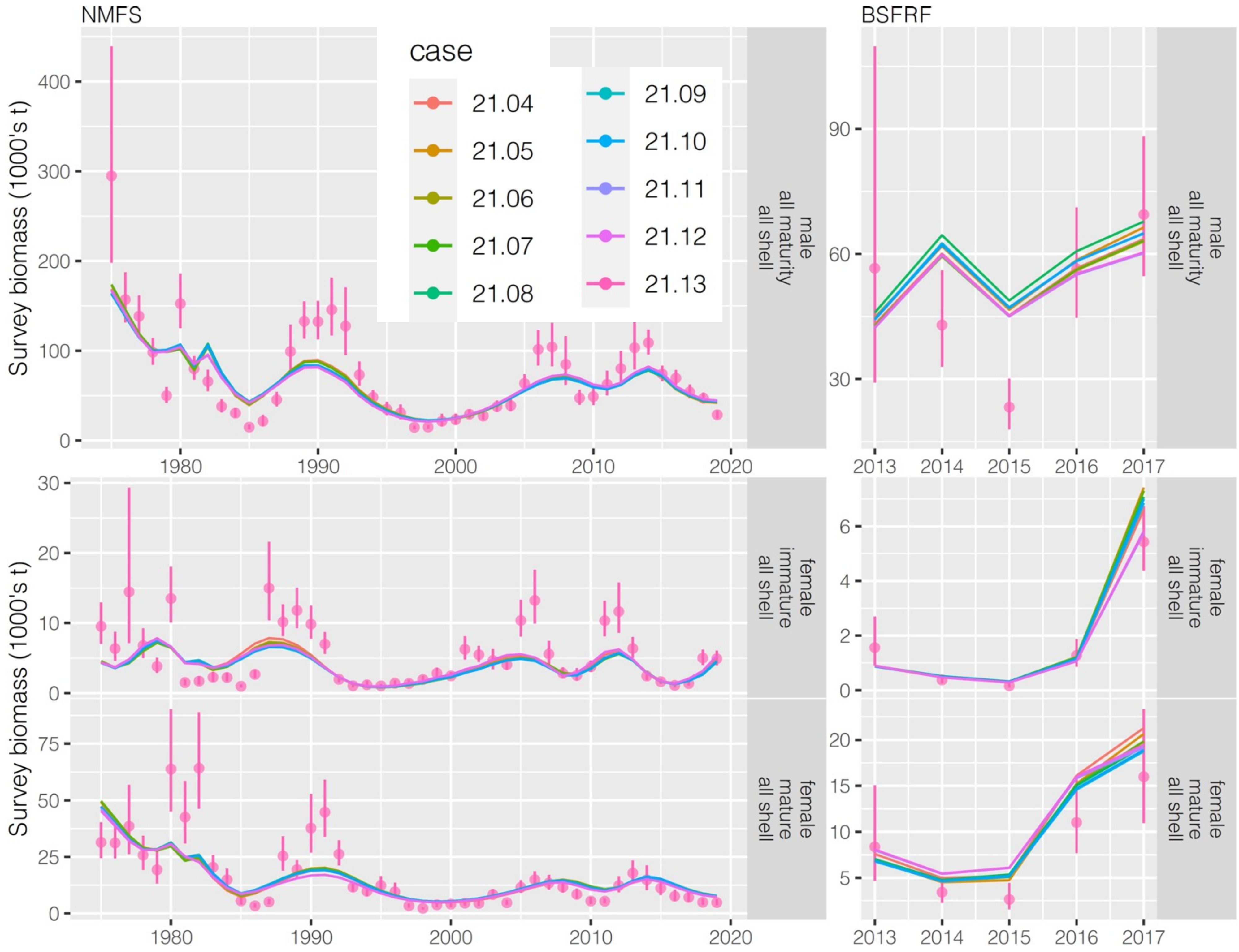




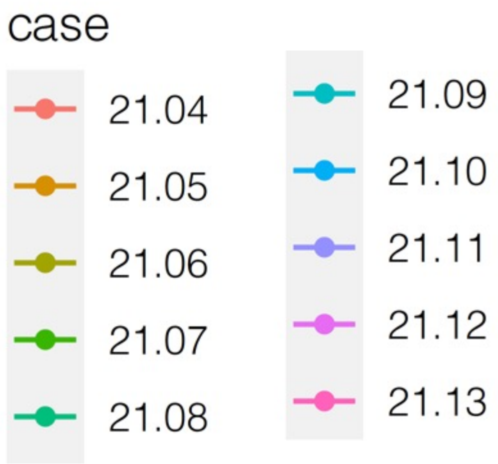


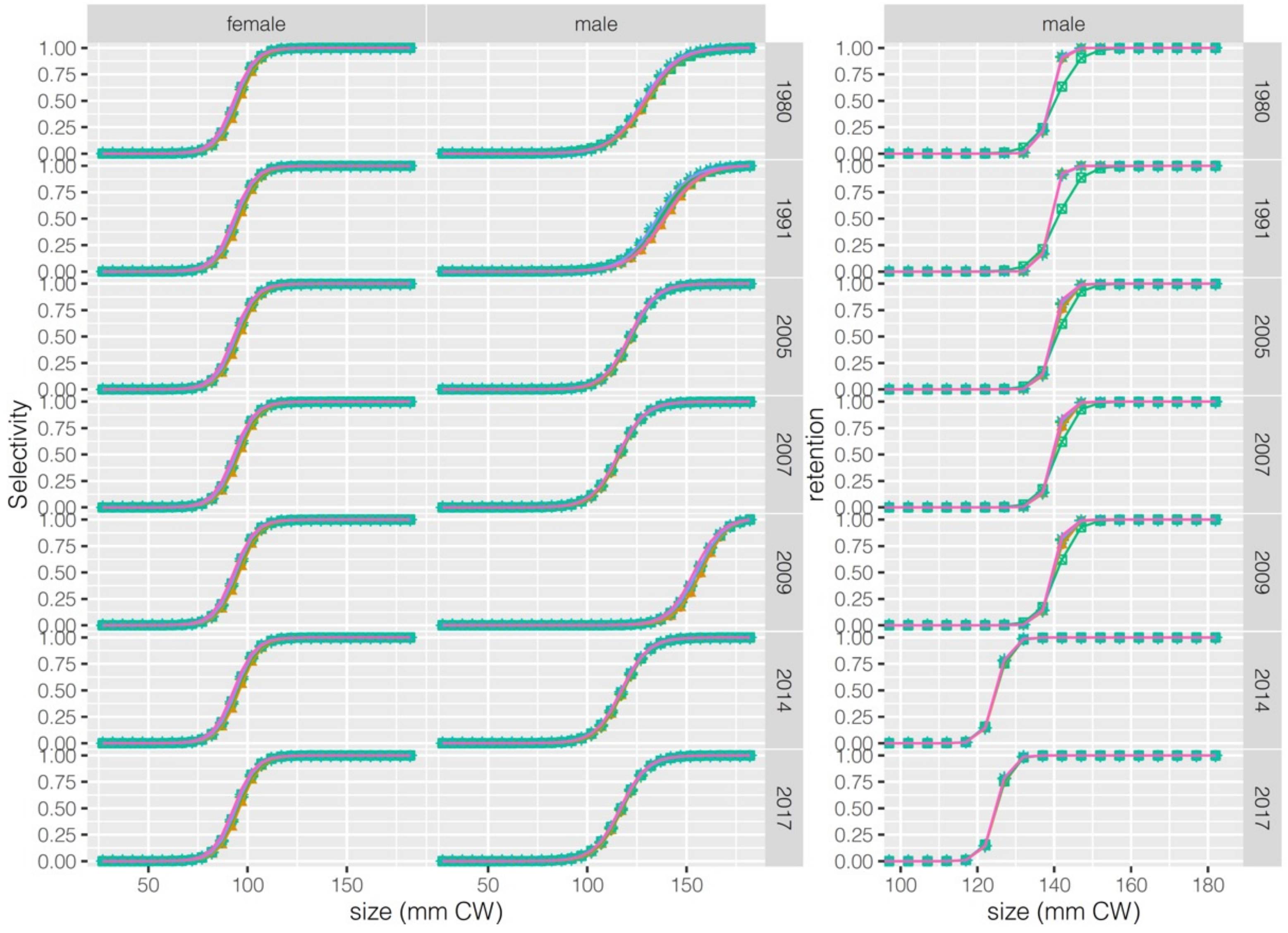
Other Approaches

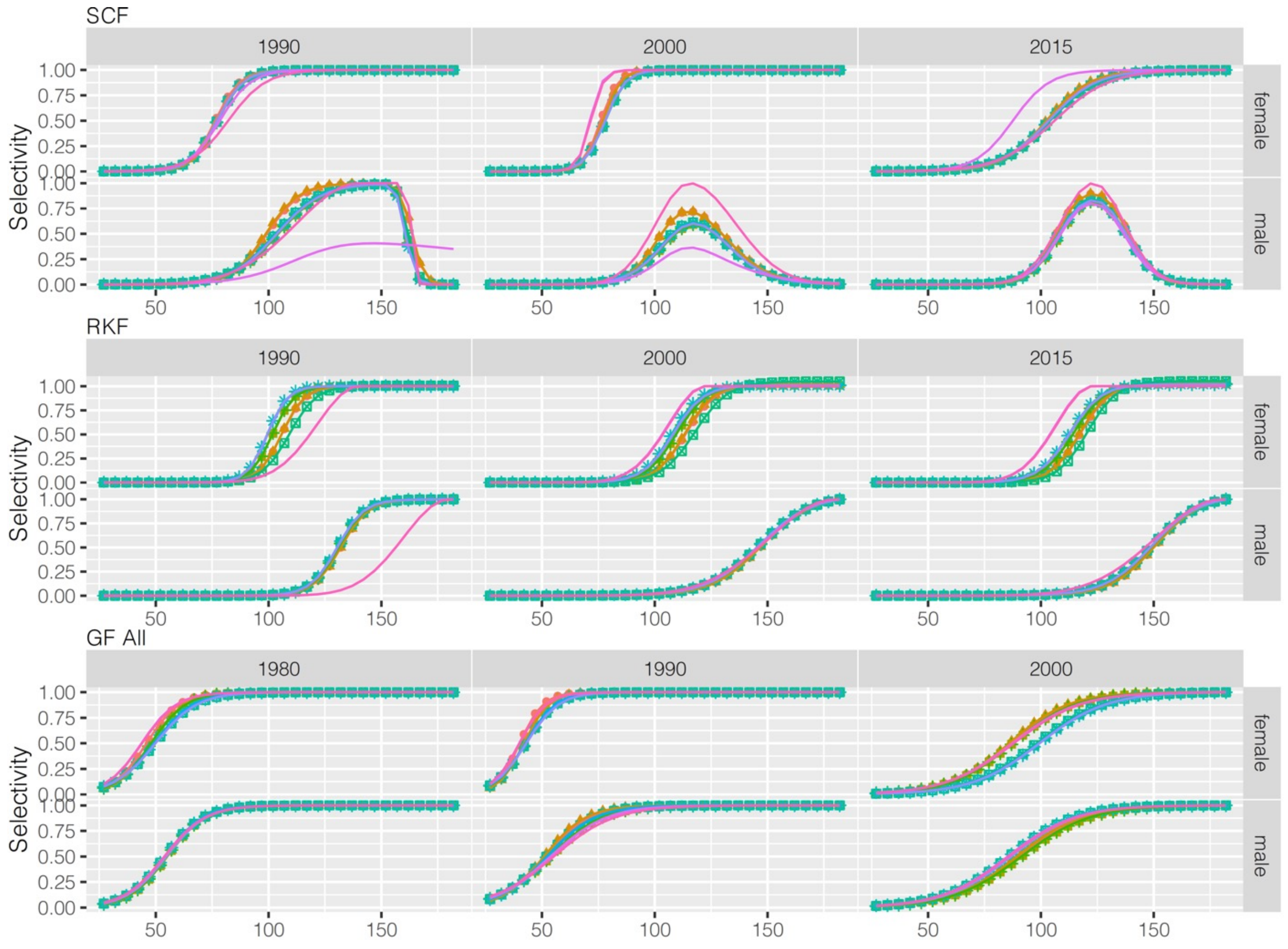




Other Approaches







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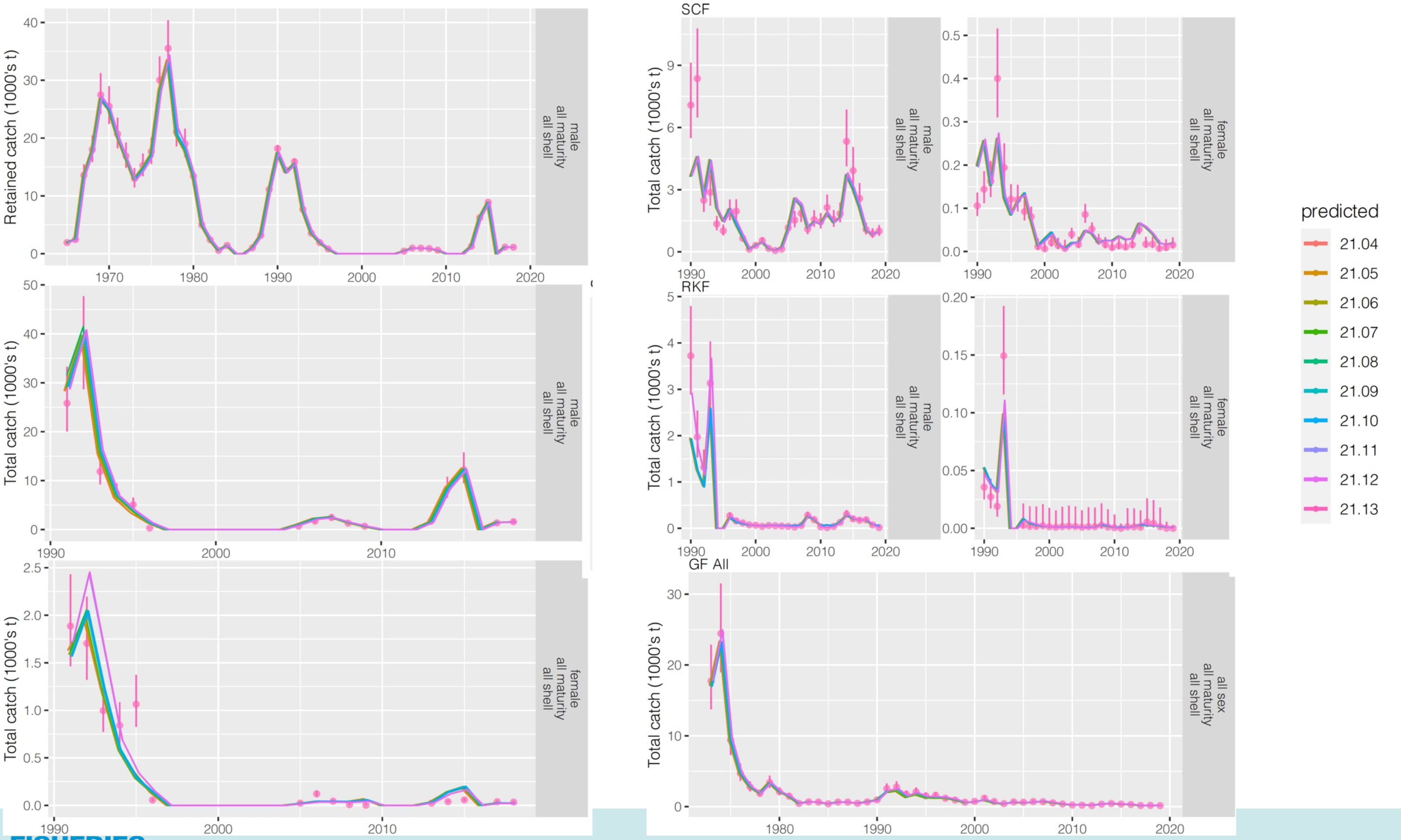

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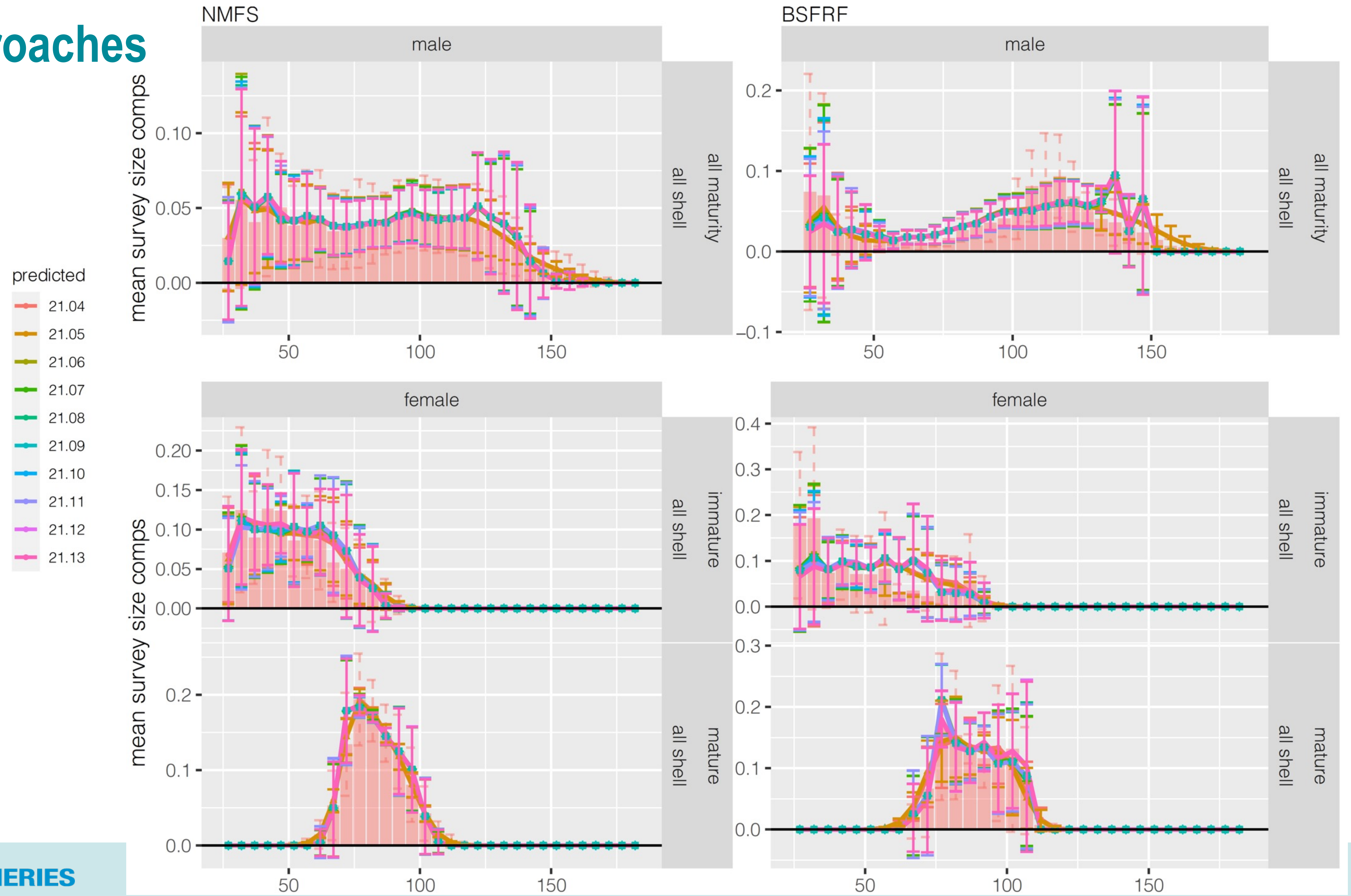
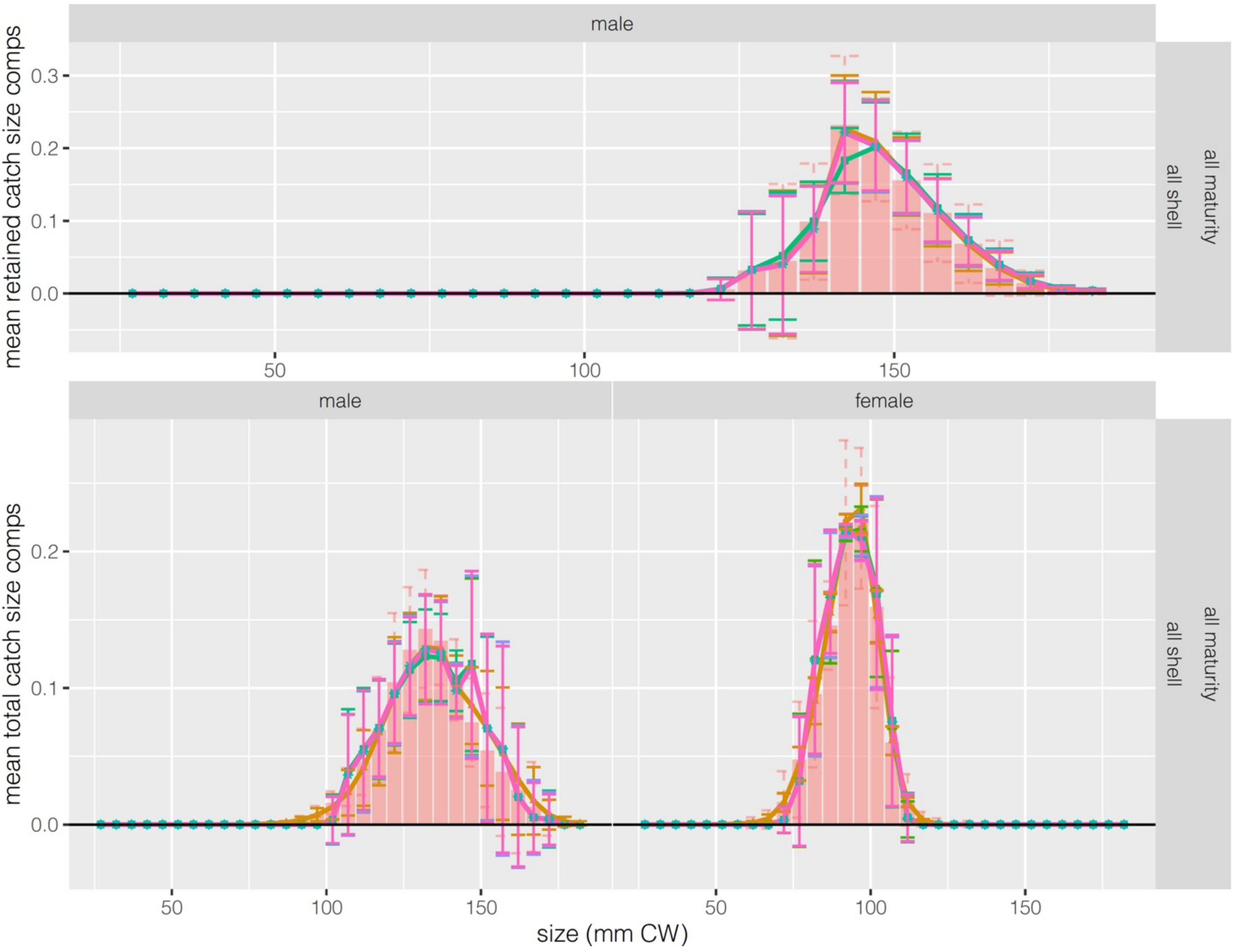
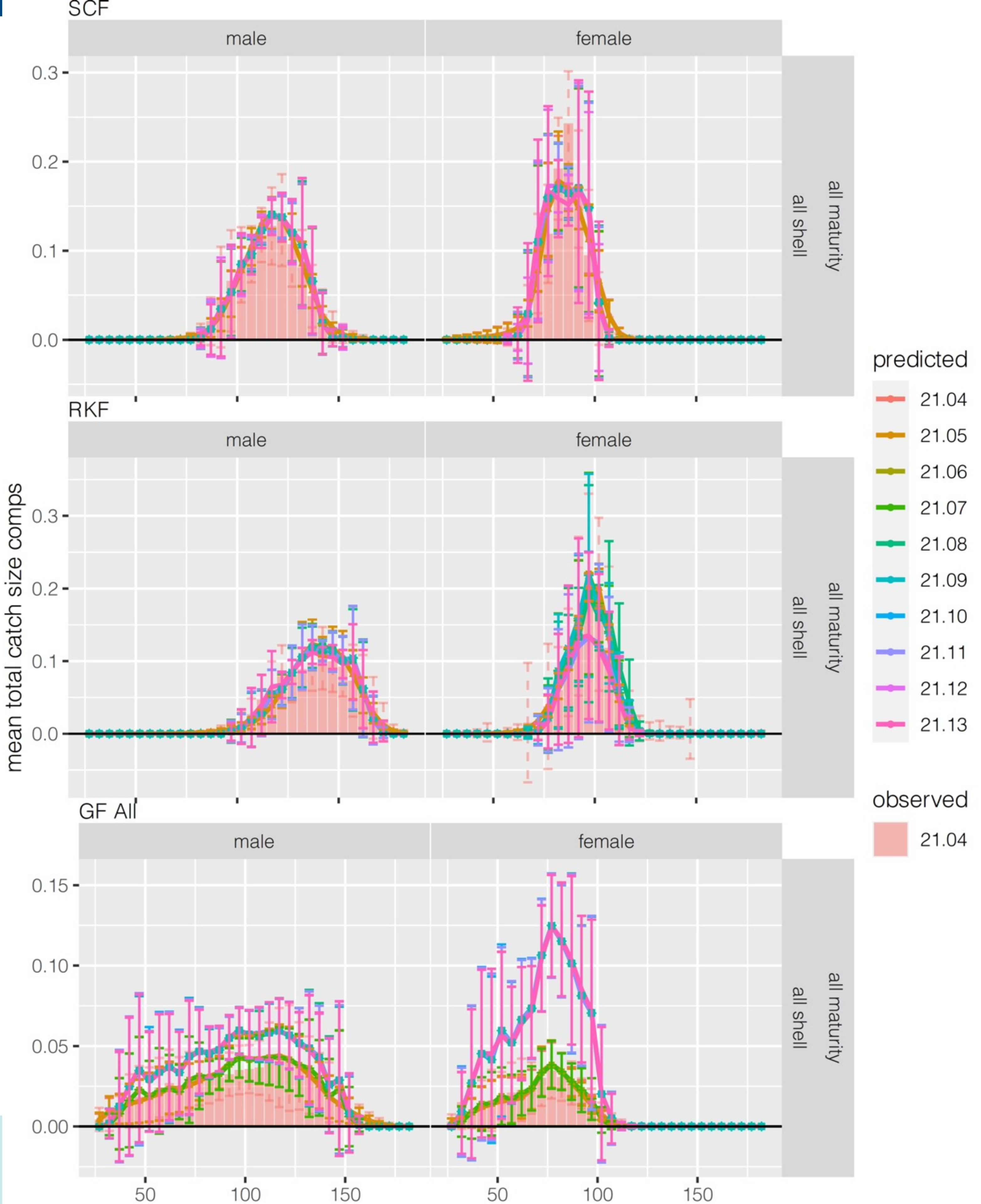


Other Approaches



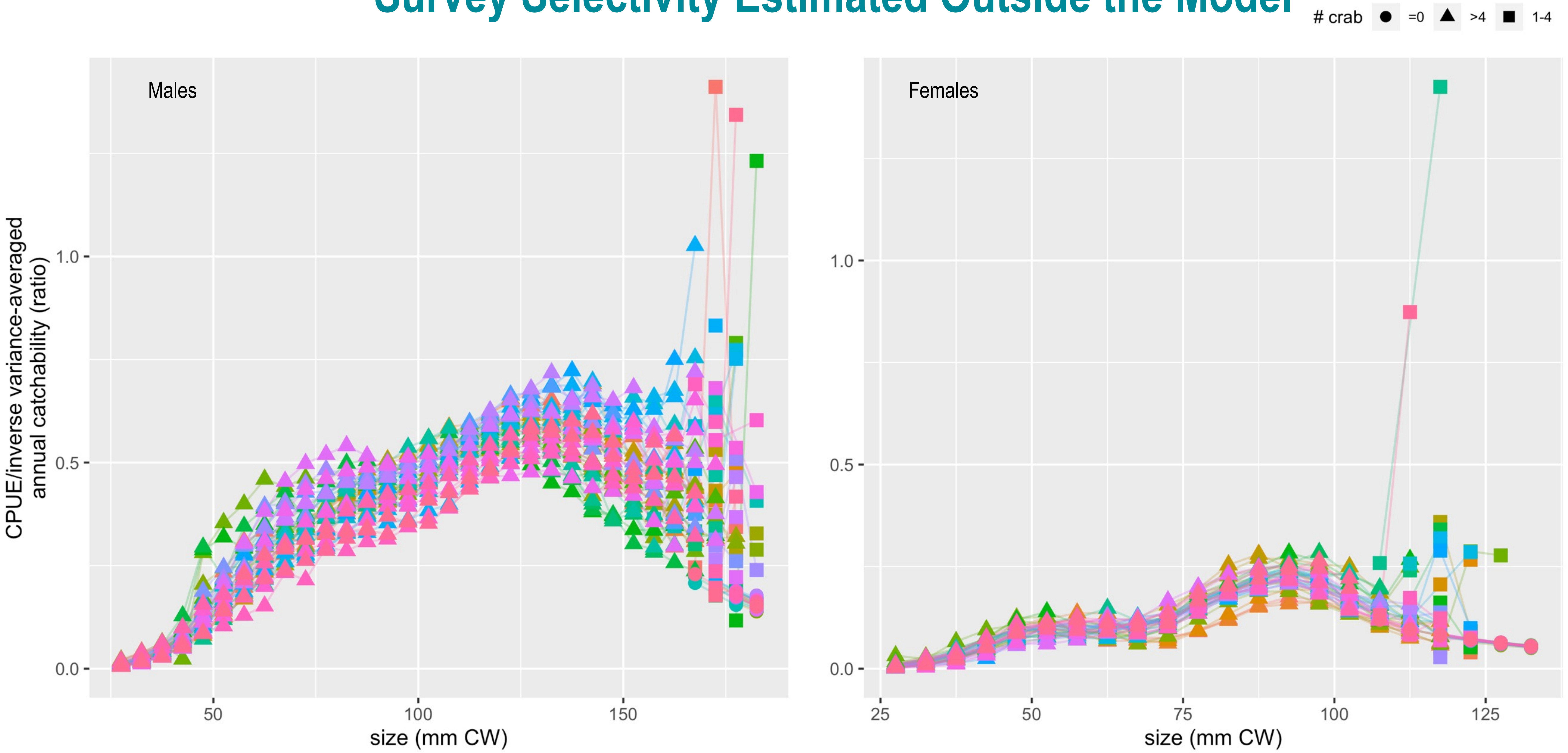


Survey Catchability Estimated Outside the Model

model configuration	parent	additions	subtractions	label	number of parameters	number at bounds	objective function value	max gradient
21.13	21.12	Double normal selectivity functions estimated for male bycatch in SCF	double logistic selectivity functions	DblNrmSCF	355	9	6089.24	1.18E-02
21.14	21.13	Annual 1982+ NMFS survey catchability determined outside model, no fits to BSFSF data	2 catchability, 4 selectivity parameters	FixedSurveySels	343	7	6078.26	7.97E-02
21.15	21.14	mean growth parameters determined outside model	4 growth parameters	FixedSurveySels+FixedGrowth	339	7	6349.95	1.71E-02

case	average recruitment (millions)	B100 (1000's t)	Bmsy (1000's t)	current year MMB (1000's t)	Fmsy	MSY (1000's t)	Fofl
21.13	359.13	107.91	37.77	74.12	0.95	16.85	0.95
21.14	1439.75	126.13	44.14	74.86	1.15	23.22	0.96
21.15	1409.54	124.67	43.63	72.21	1.20	20.70	0.99

Survey Selectivity Estimated Outside the Model



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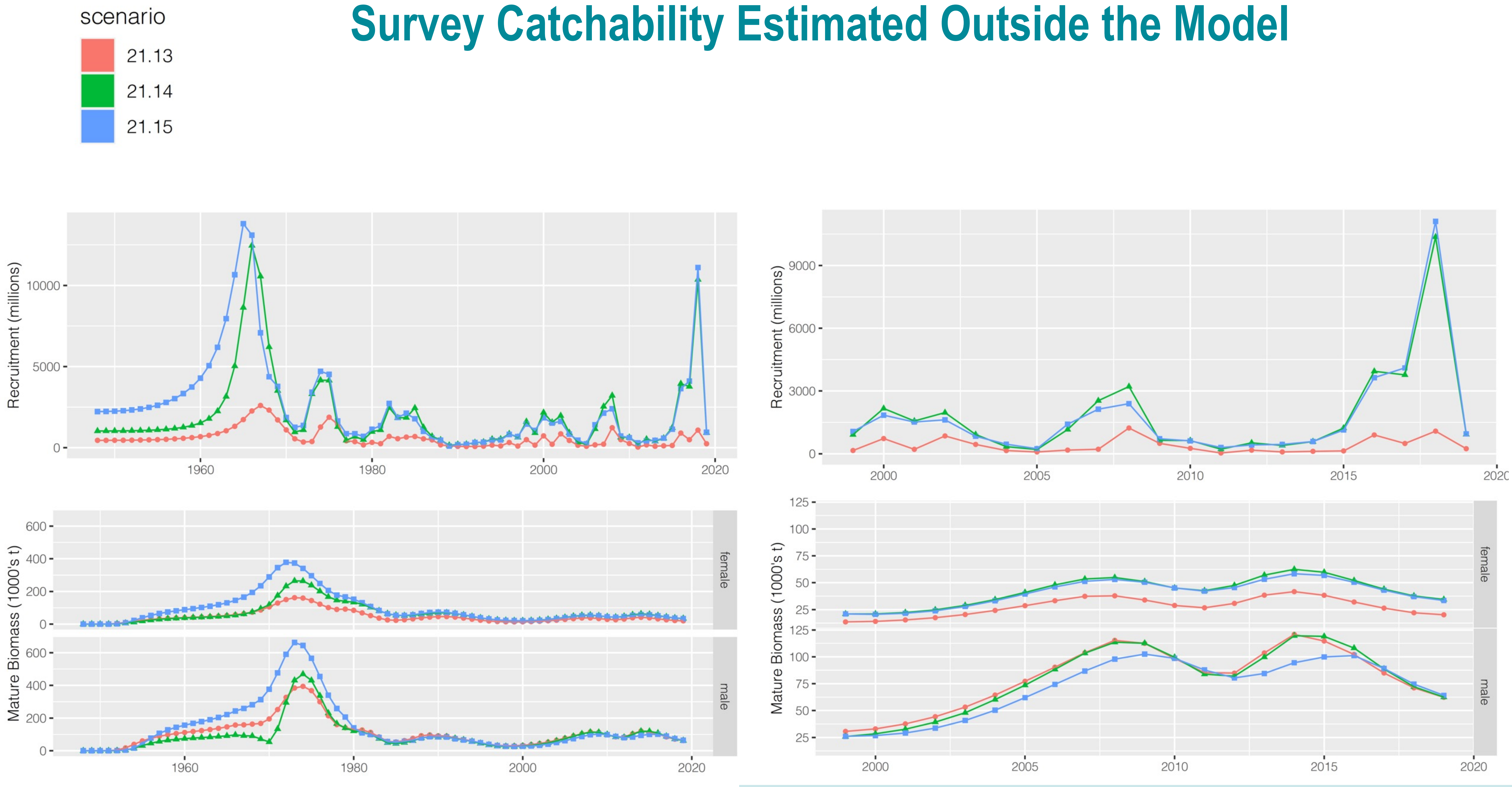
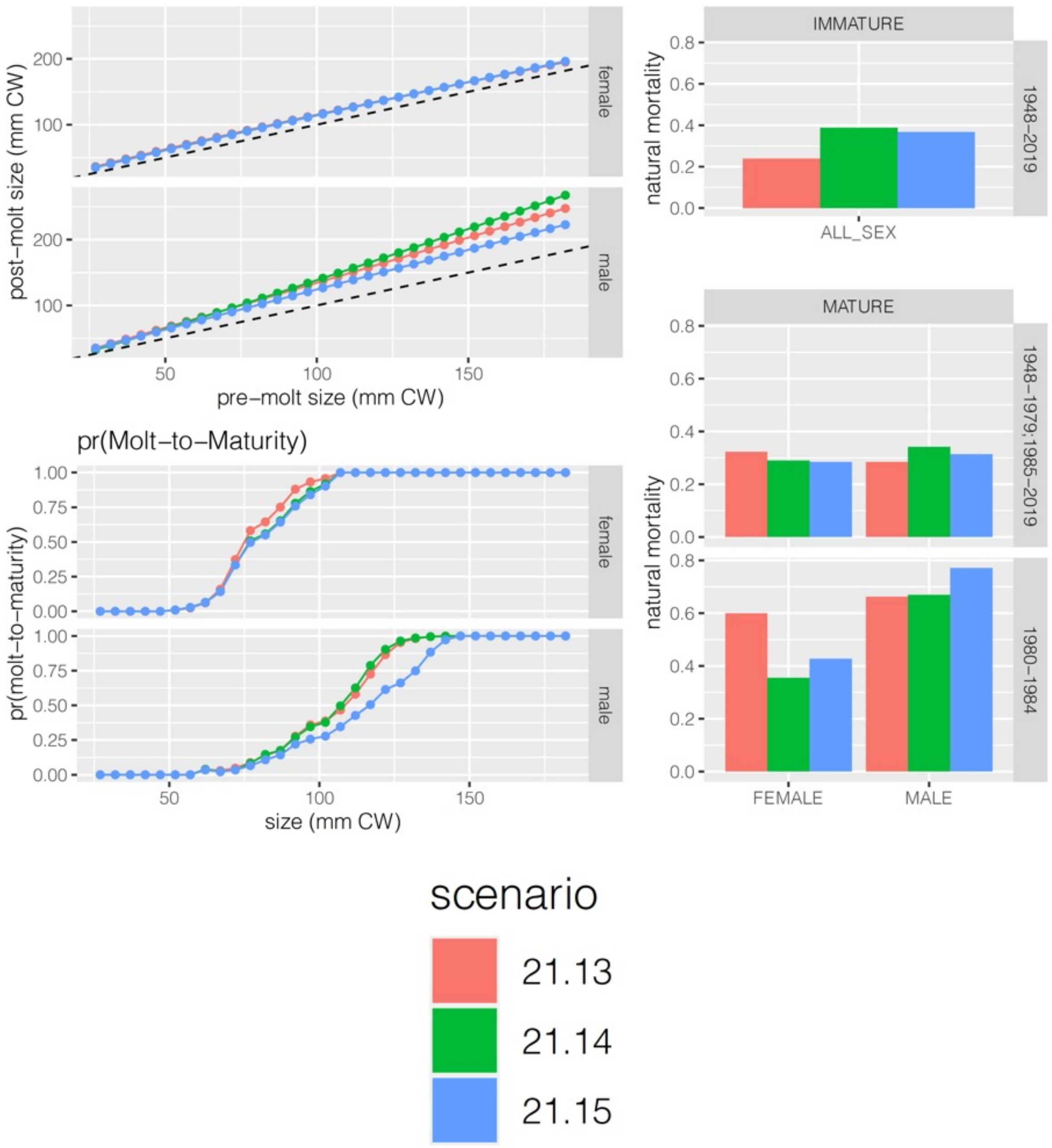
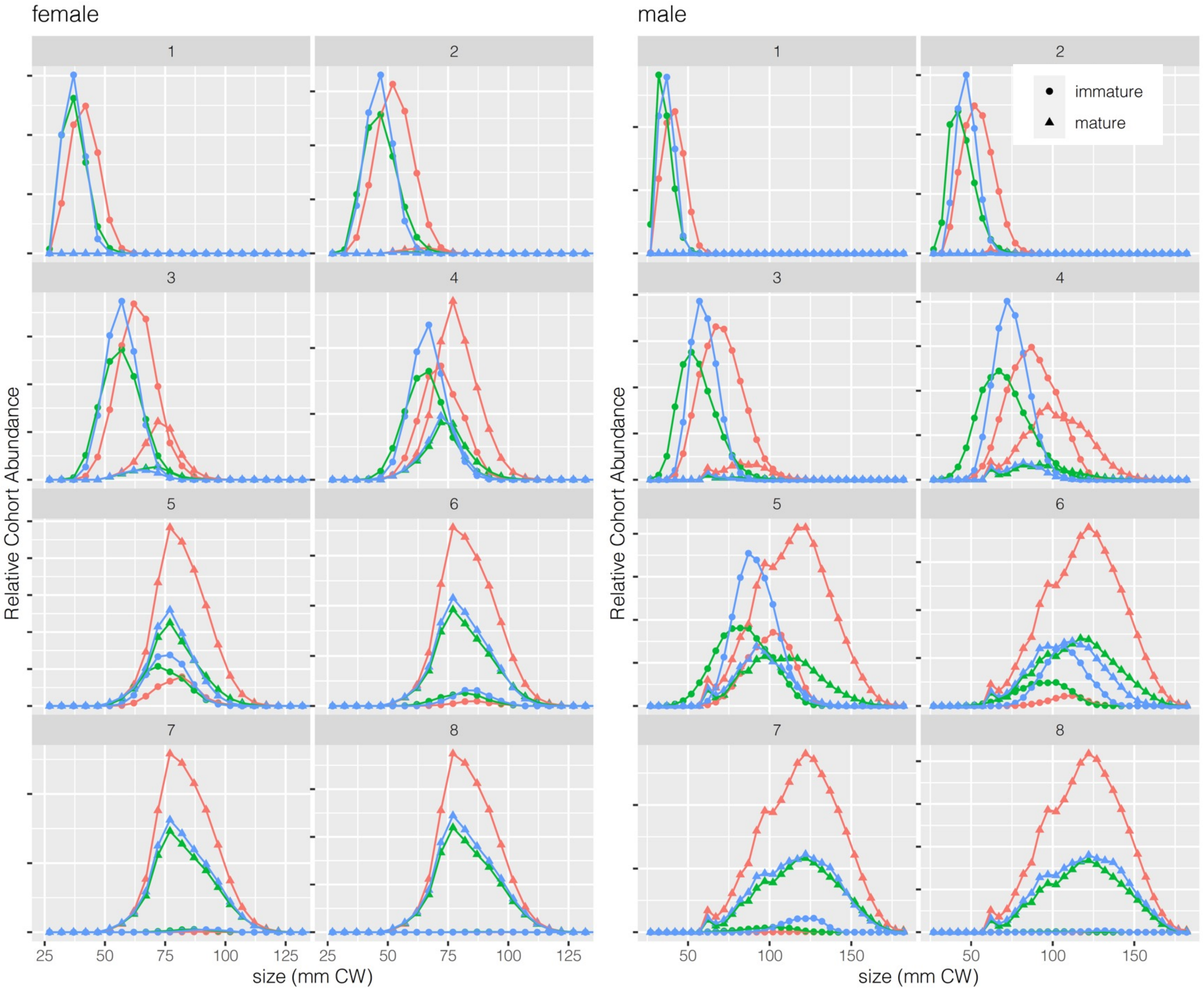


Survey Catchability Estimated Outside the Model





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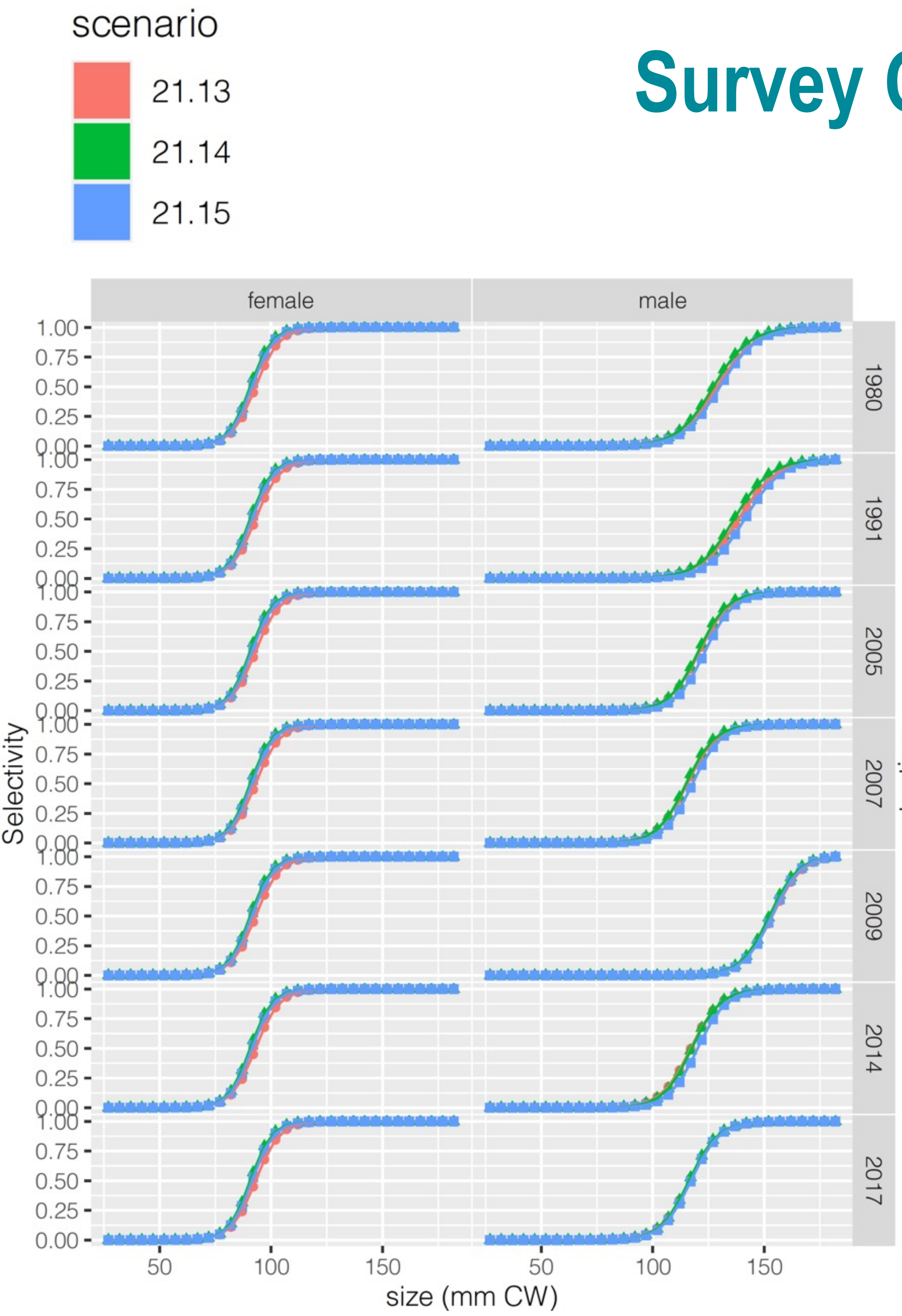
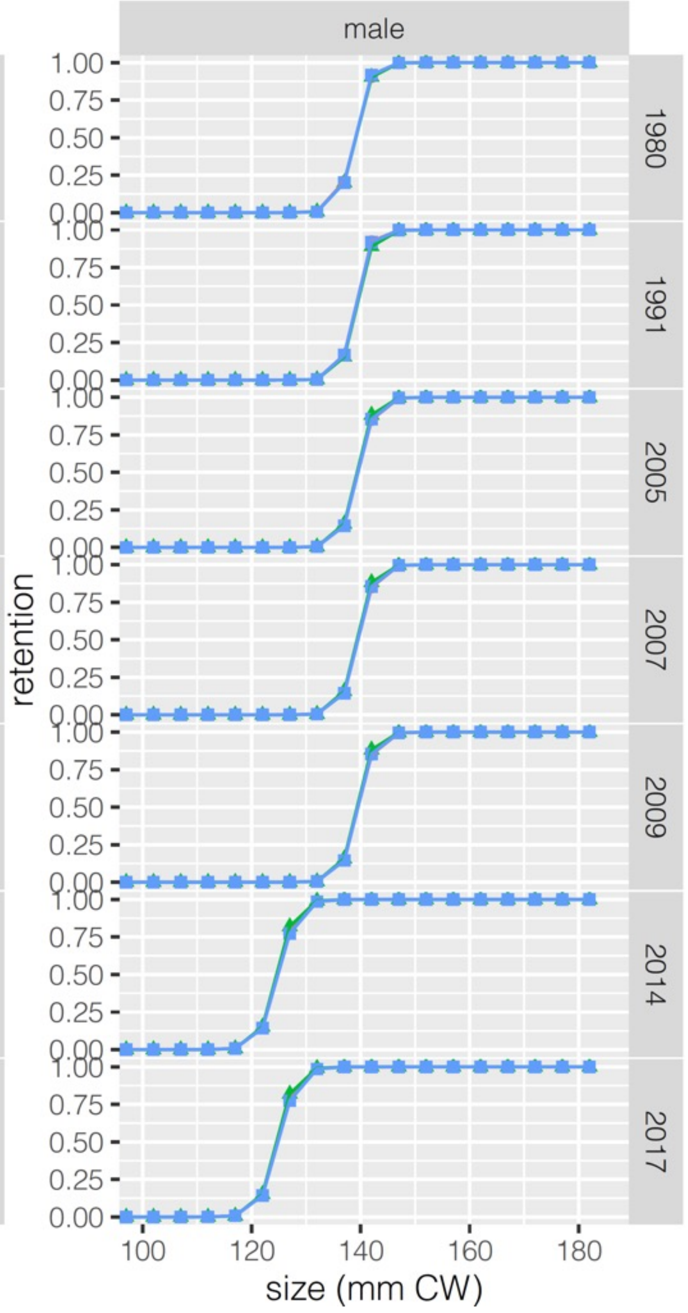
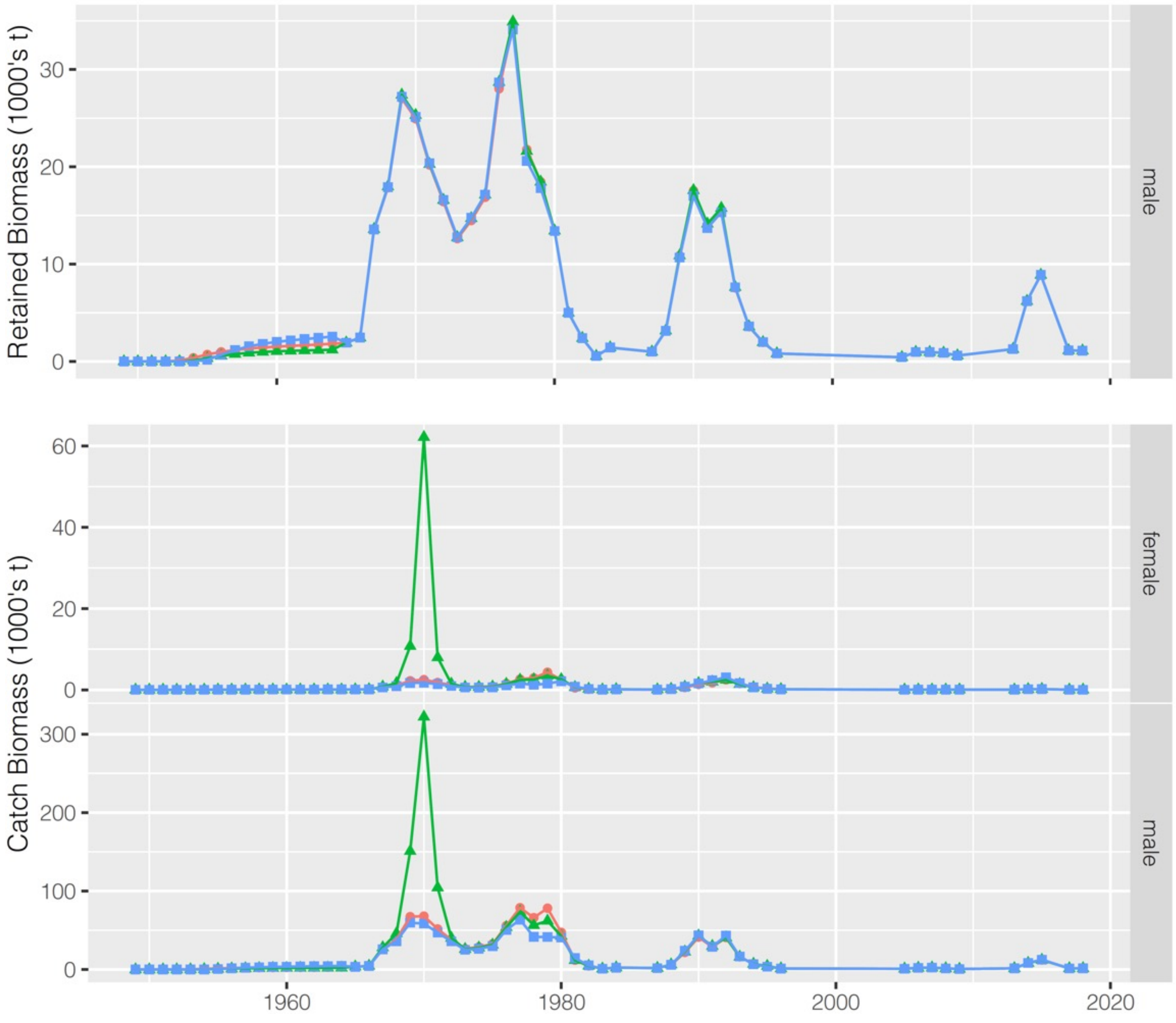
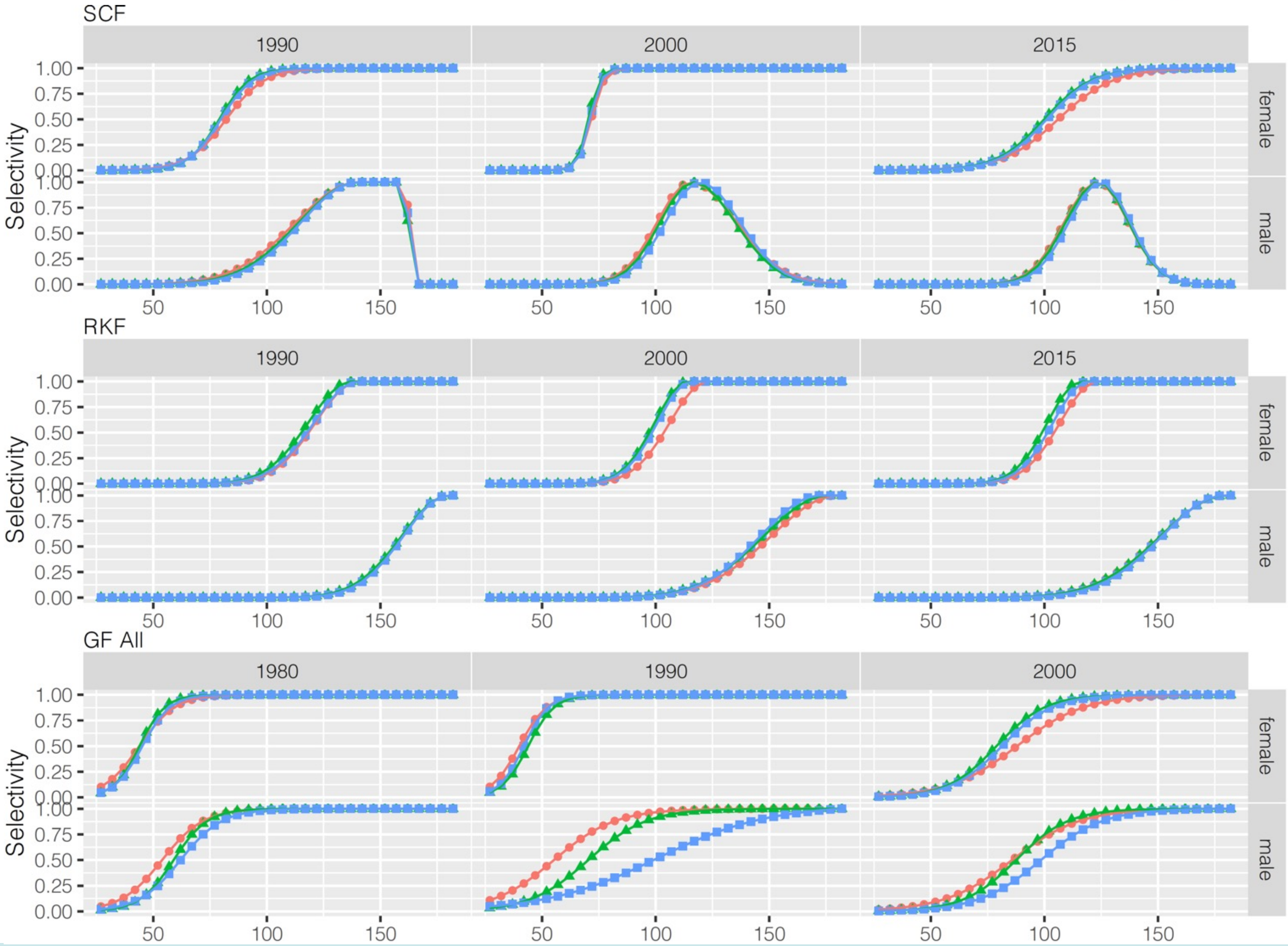


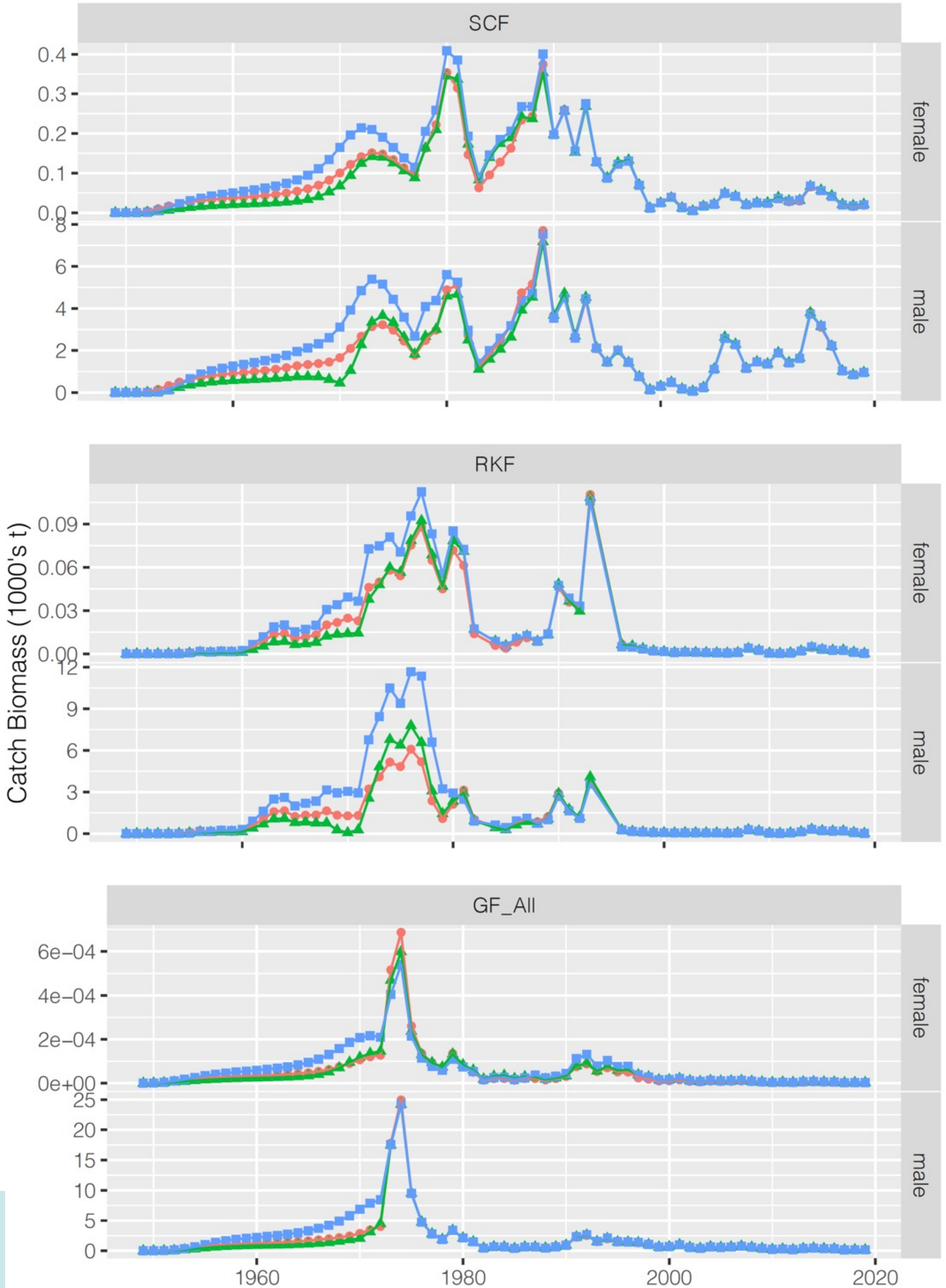




Survey Catchability Estimated Outside the Model

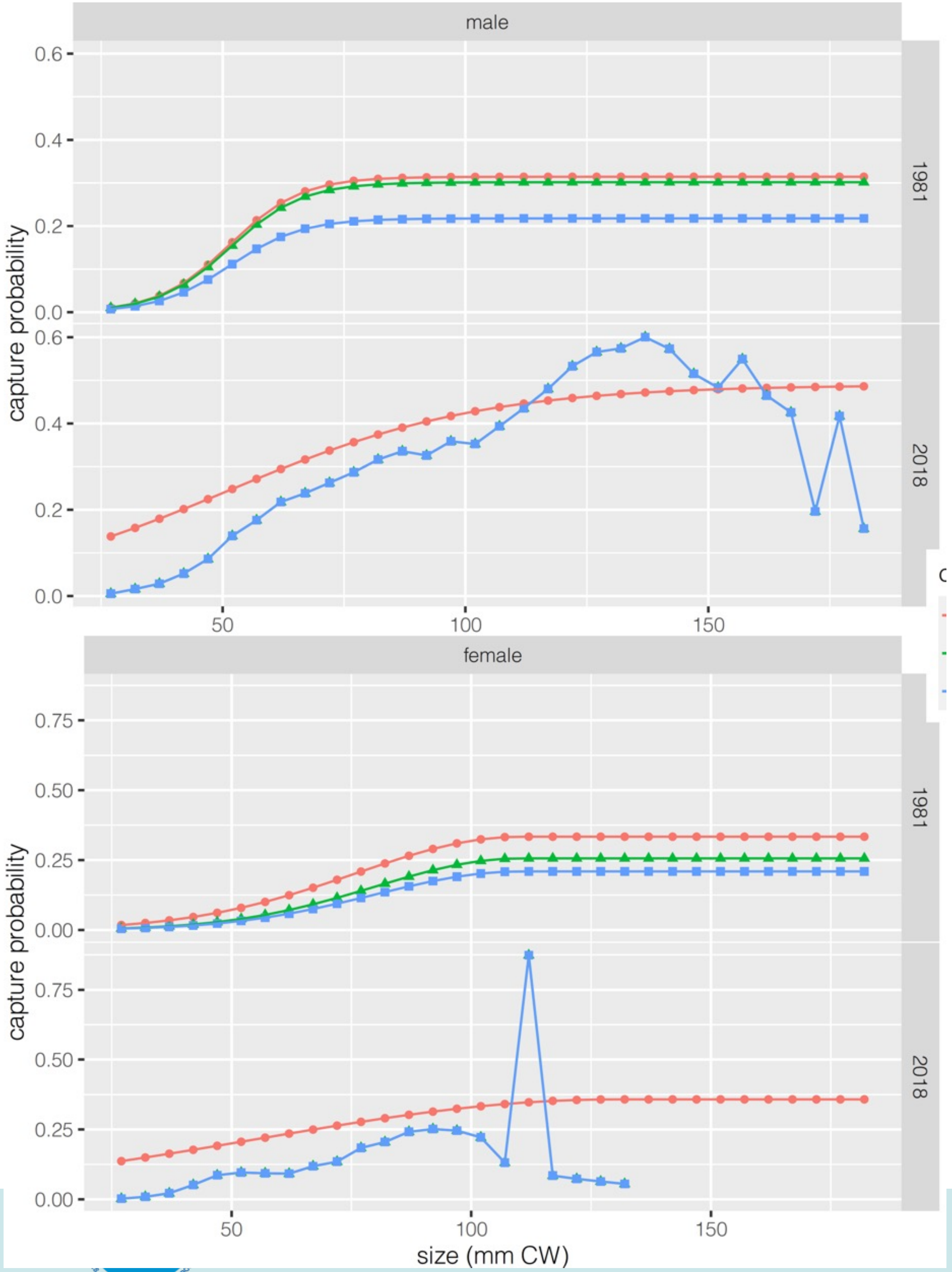
scenario
- 21.13
- 21.14
- 21.15





NOAA FISHERIES

Survey Catchability Estimated Outside the Model



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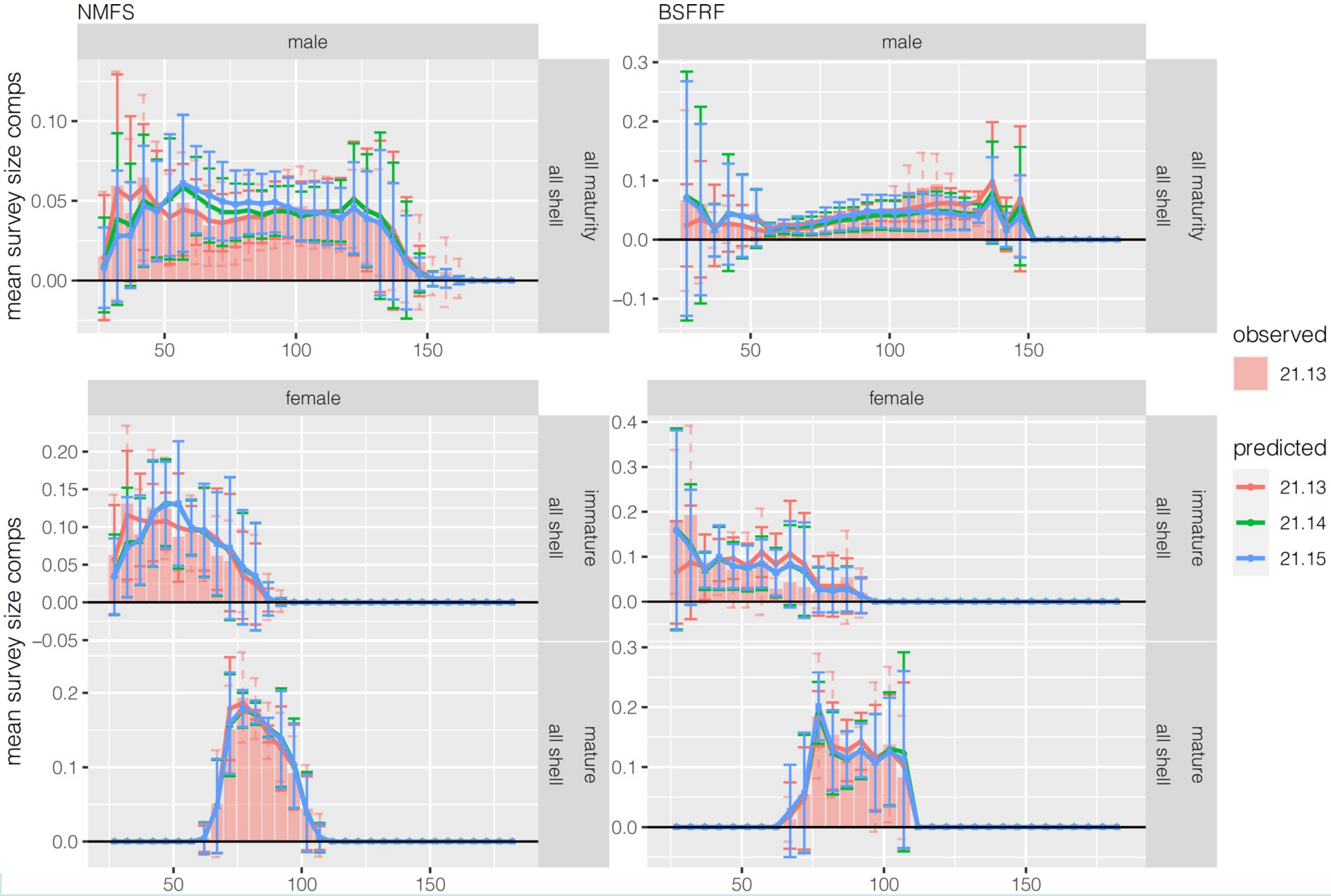

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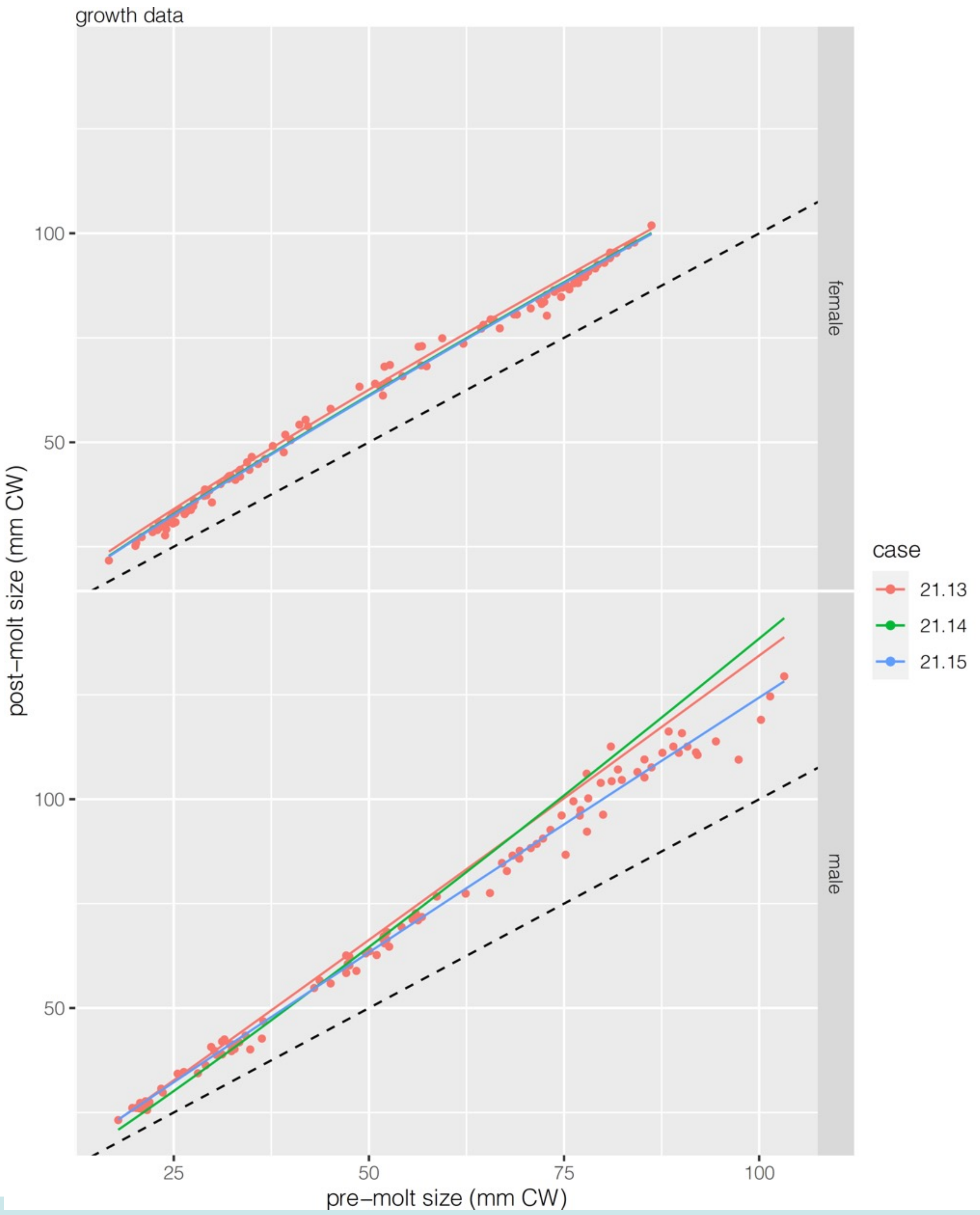
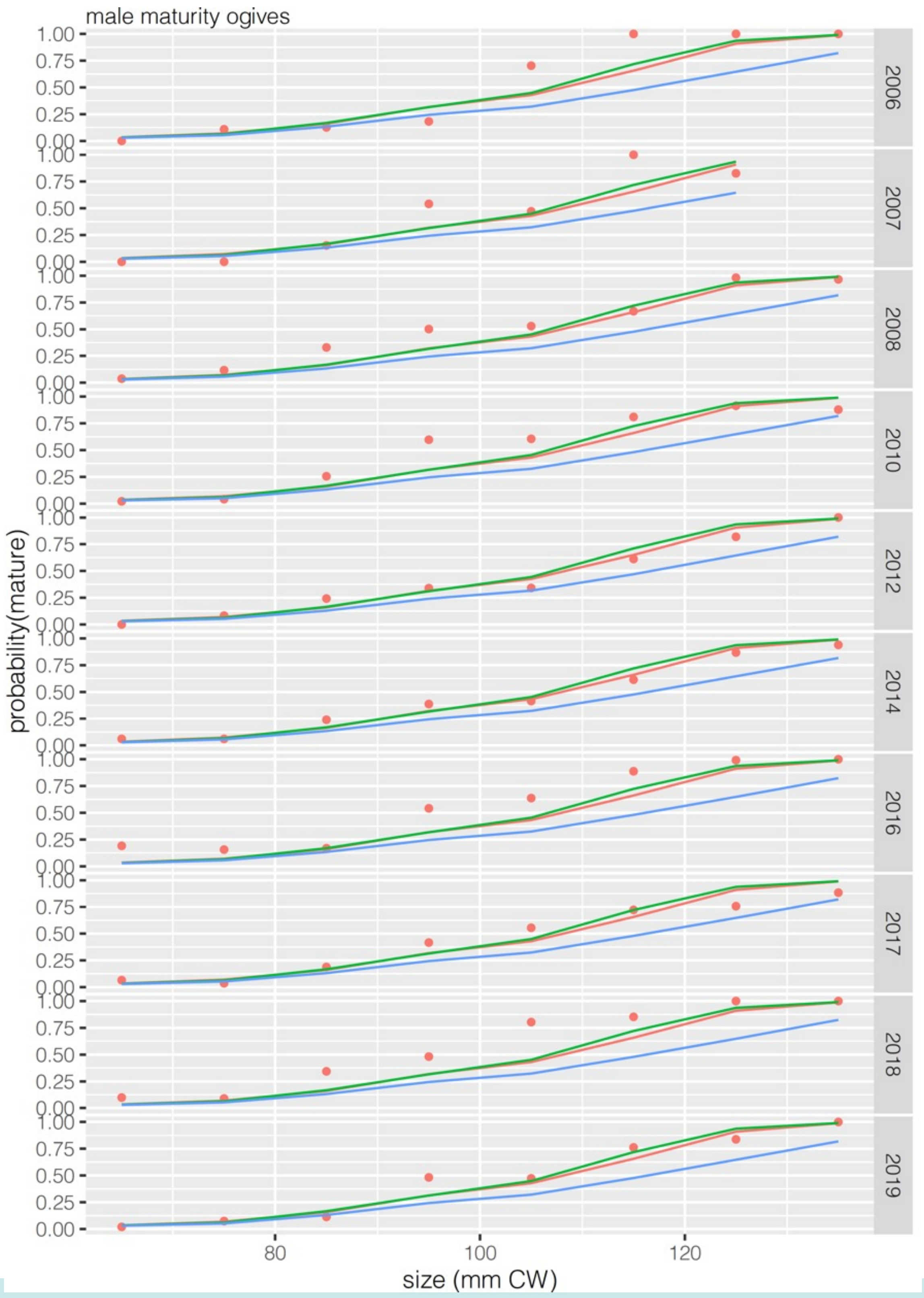
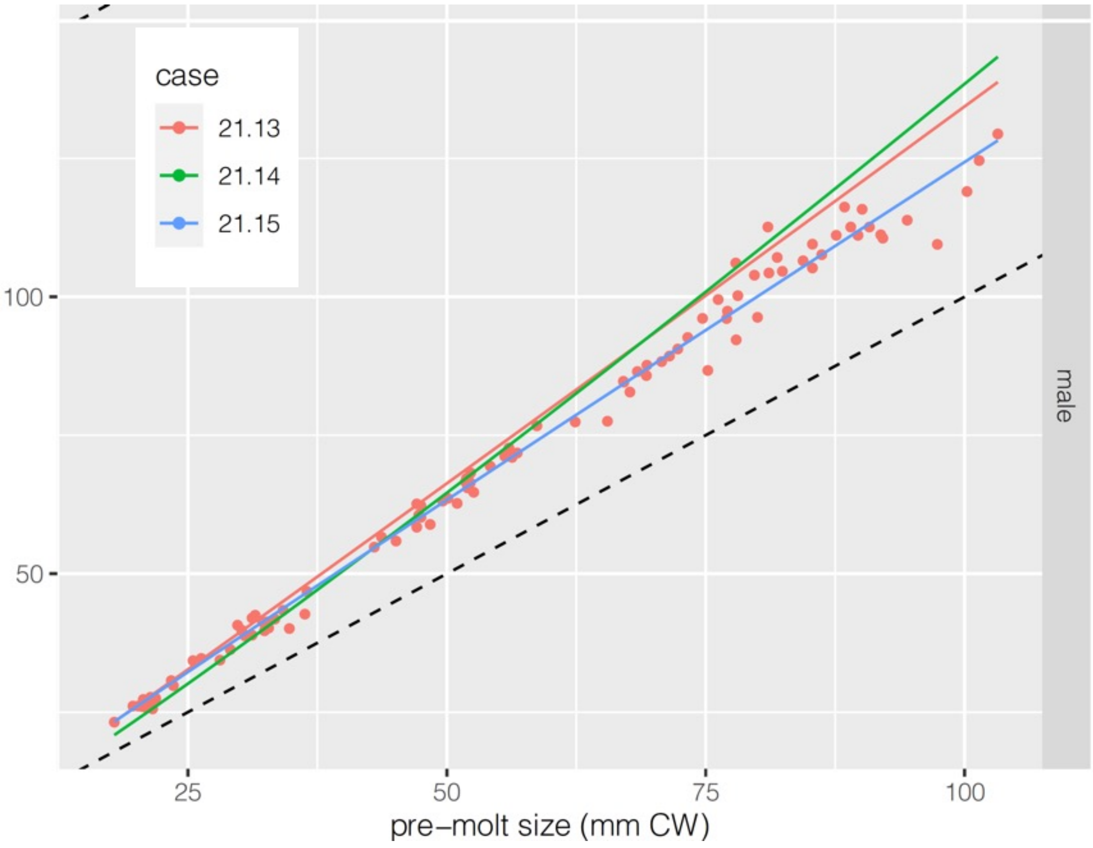
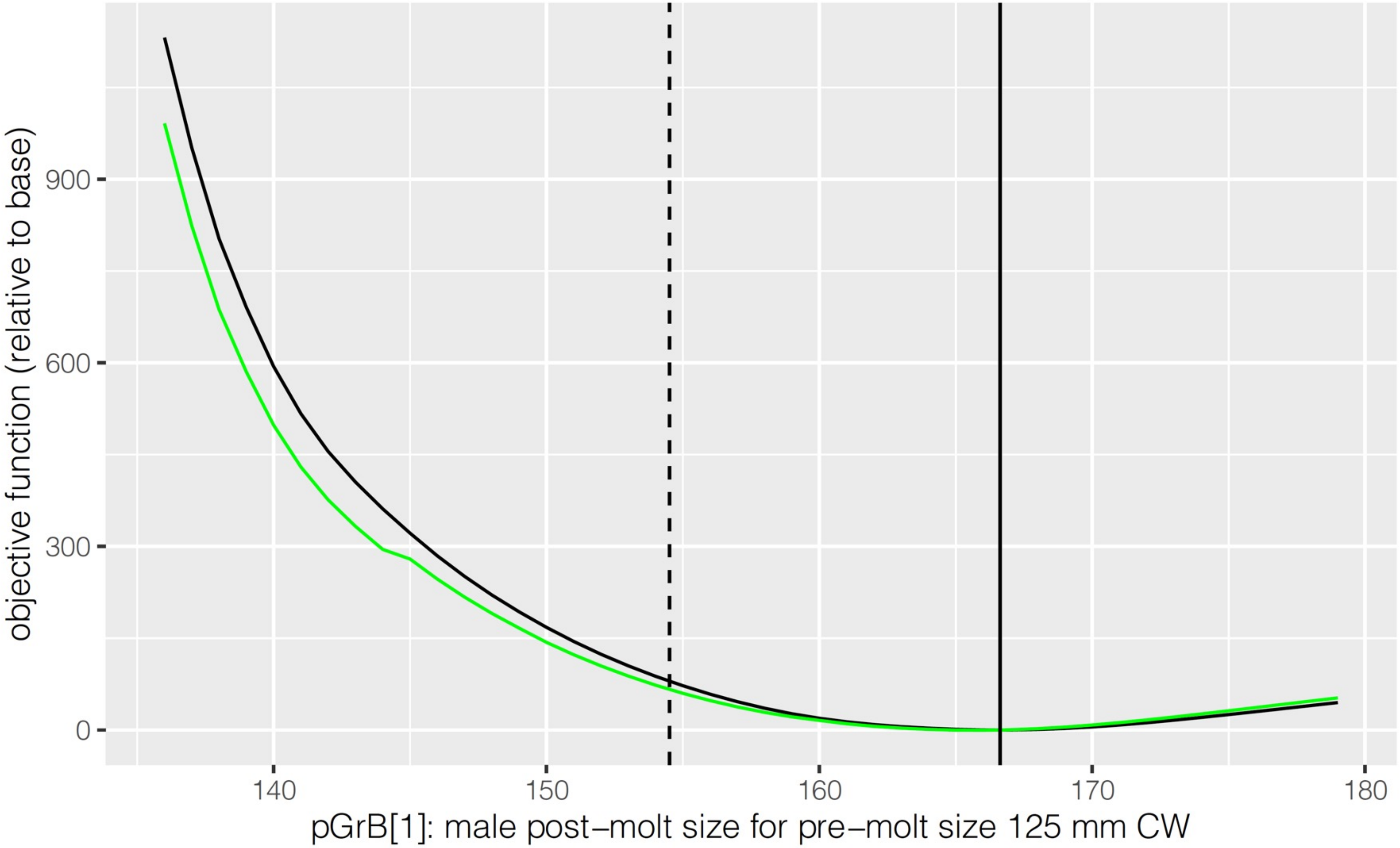




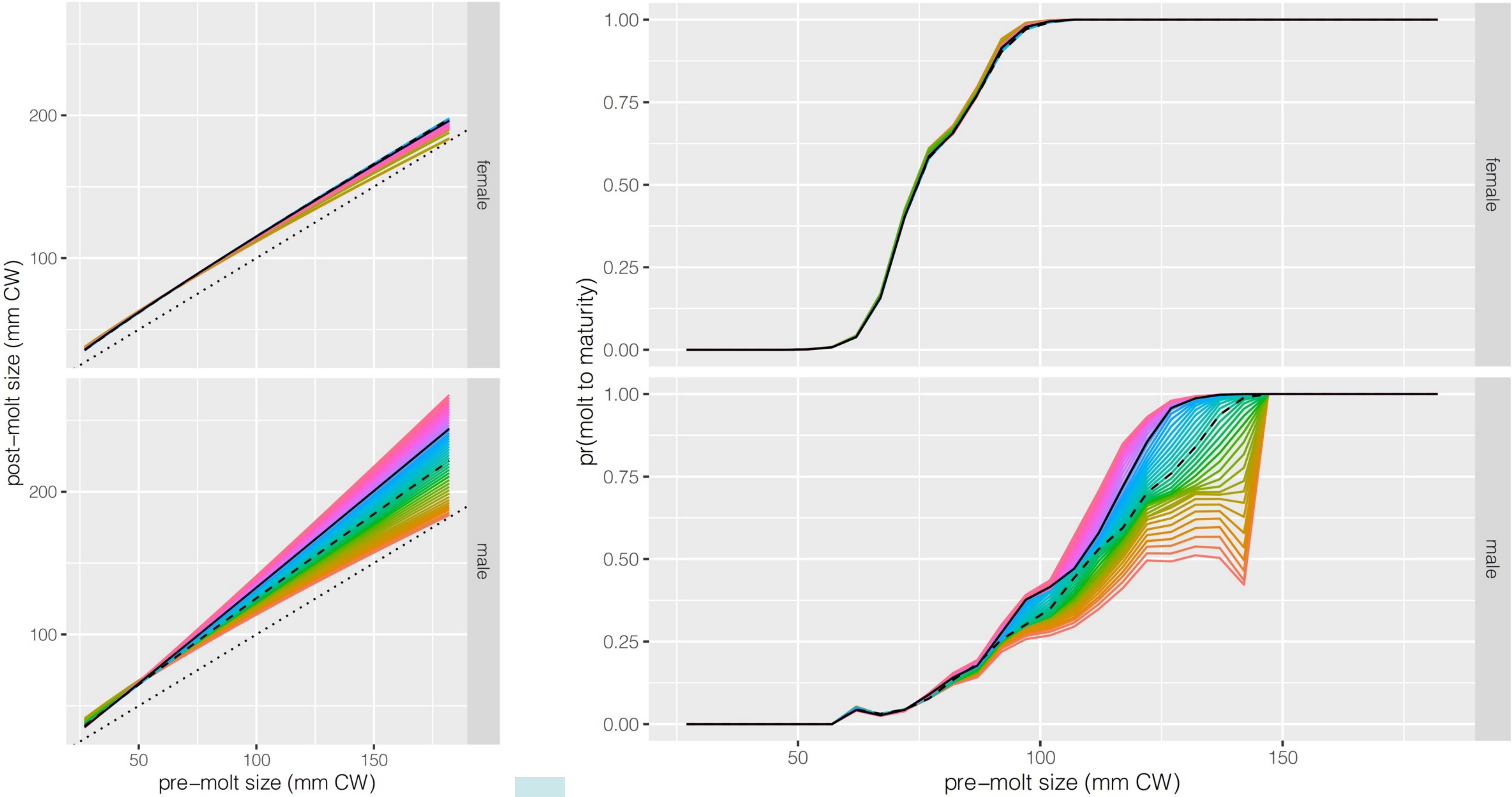
NOAA FISHERIES

Likelihood Profiling on Male Growth

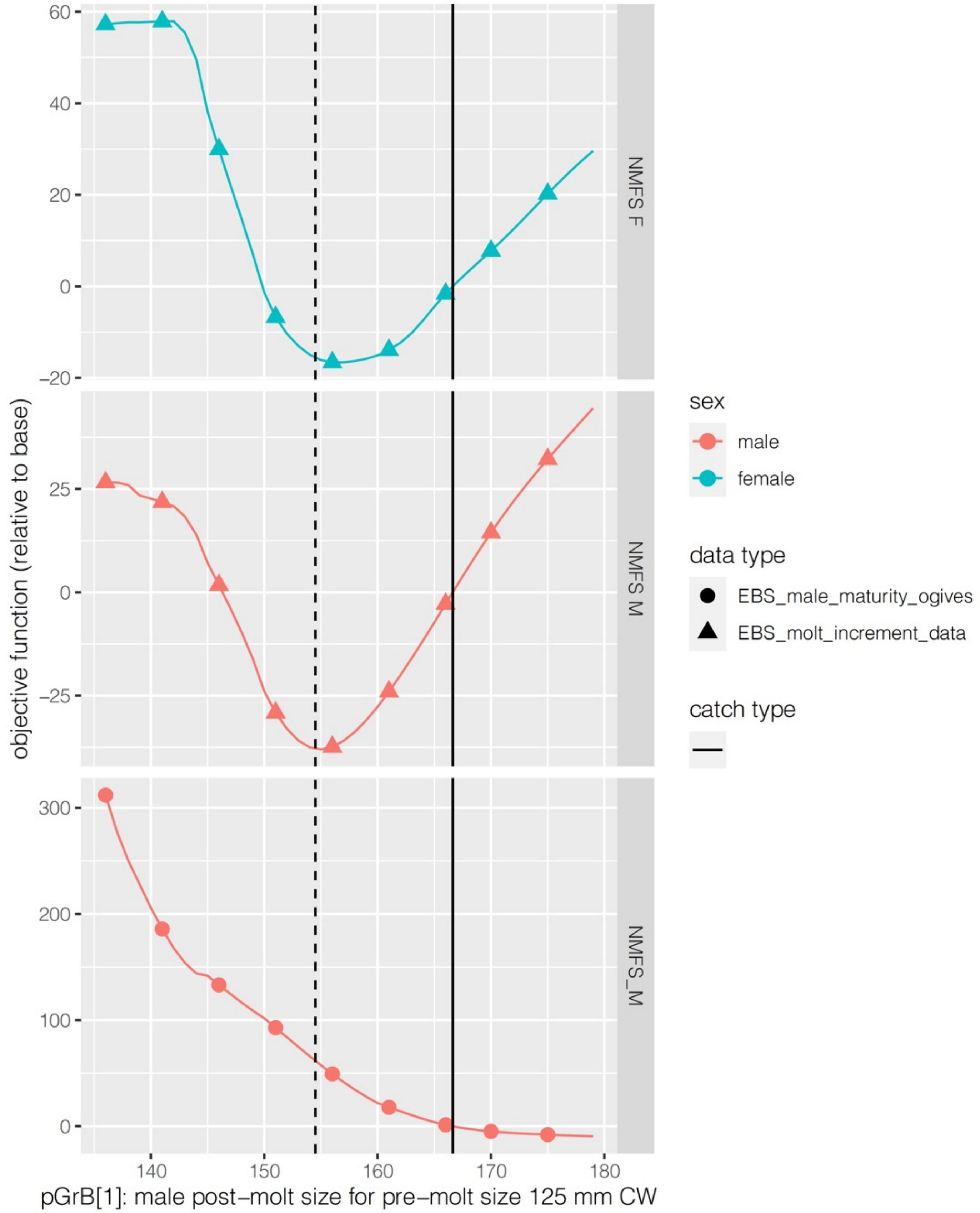




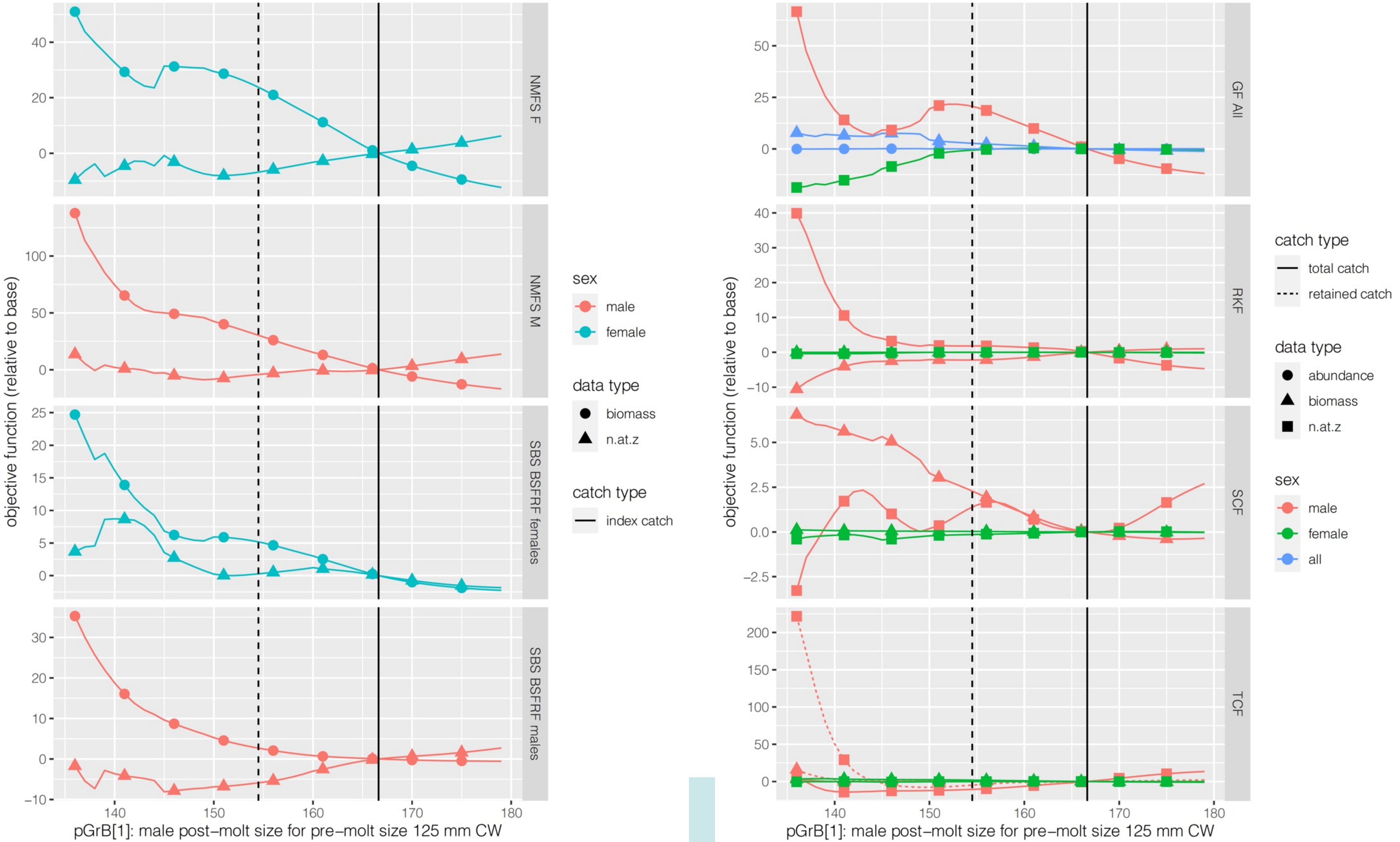
Likelihood Profiling on Male Growth



Likelihood Profiling on Male Growth



Likelihood Profiling on Male Growth



Likelihood Profiling on Male Growth

- Growth data seems easily fit outside assessment model
- Assessment model does not fit growth data well at all
- Definite tradeoff between molt increment size and probability of undergoing terminal molt
  - balances time to achieving maturity
  - processes are confounded
  - need correct weighting in objective function (or/and good data) to resolve conflicts
- What's going on?
  - male maturity/chela height data seems reasonably good
  - molt increment data seems good
  - correct data weighting?
  - missing biological processes?
    - maturity more function of age than size
    - tied to other factors?

Appendices: Capitulation!

- Achieve converged model with no parameters at bound
  - Do whatever it takes!
- Appendix A
  - Model 21.04 ⟶ Model 21.21
  - 5 parameters at bounds reduced to ZERO!
  - max gradient = ZERO!
- Appendix B
  - Model 21.13 ⟶ Model 21.22
  - 9 parameters at bounds reduced to ZERO!
  - max gradient = ZERO!
- Appendix C
  - Model 21.13 ⟶ Model 21.21
  - 7 parameters at bounds reduced to ZERO!
  - max gradient = ZERO!

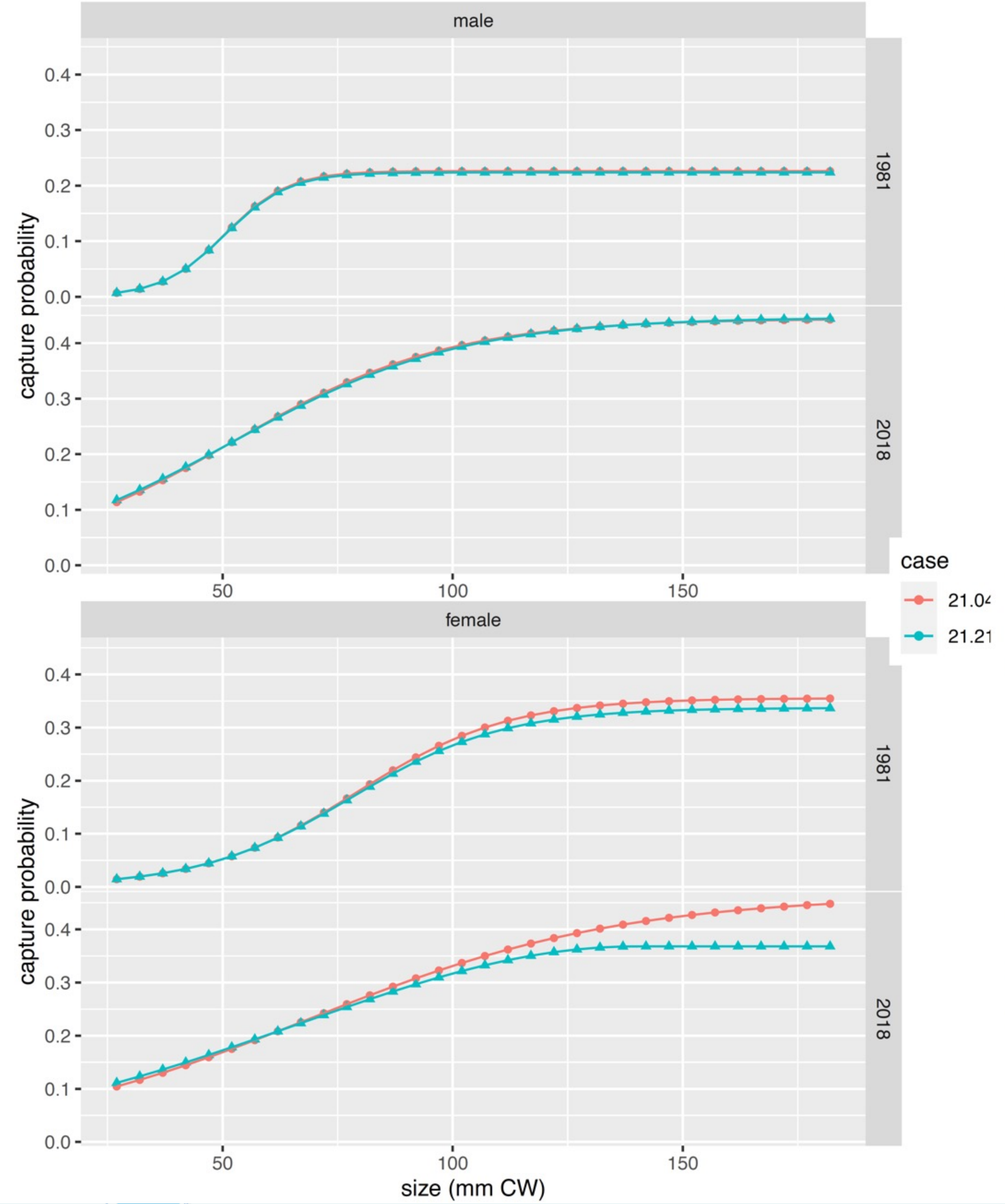
What it took: 21.04 → 21.21

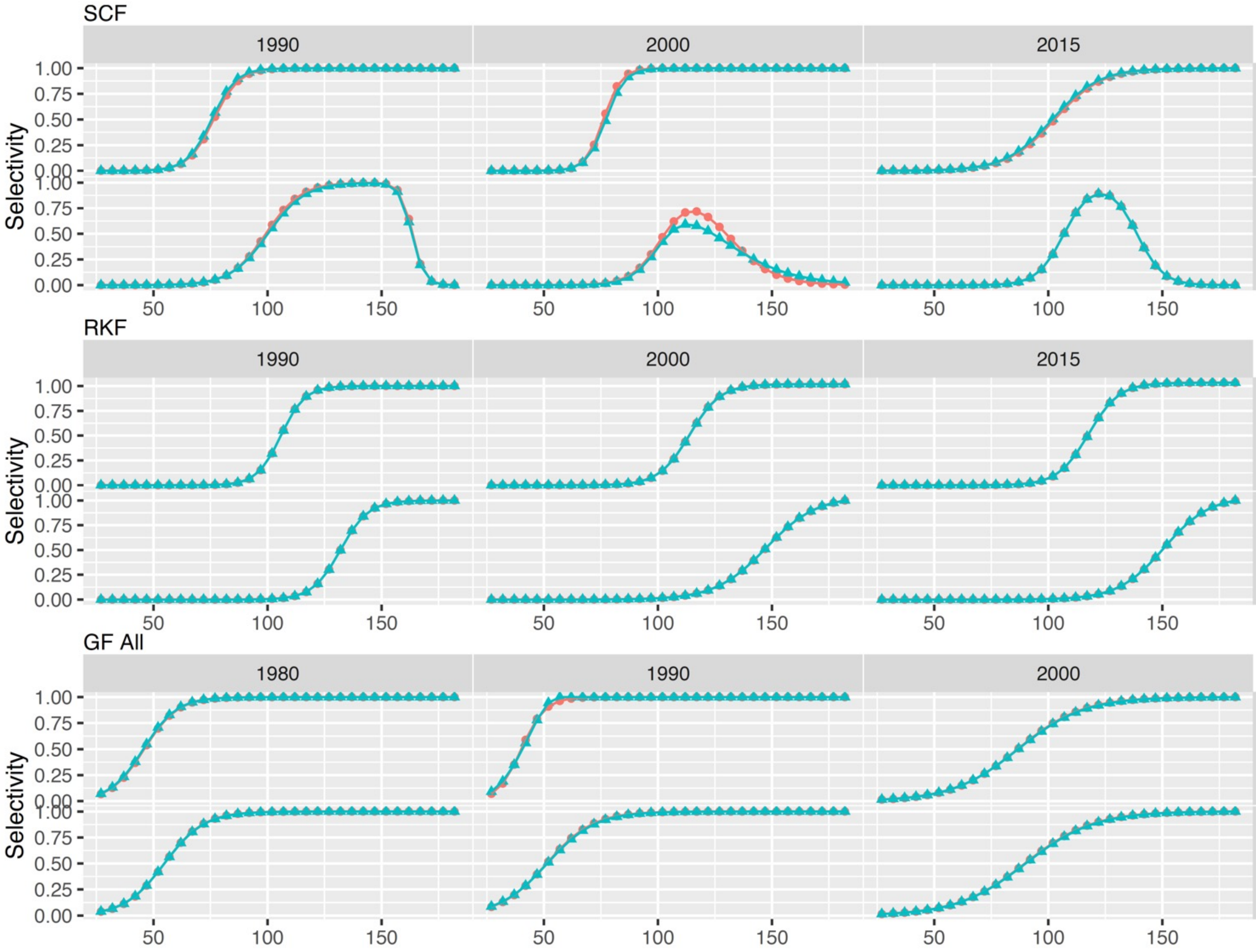
1. the selectivity function for the 1982+ NMFS survey for females was changed from an ascending logistic to an ascending normal function (parameterized with size-at-1 and width).
    a. the z-at-1 parameter was fixed at 139.9 mm CW.
2. pS1[23], the z95 parameter for the 1997-2004 RKF bycatch selectivity function for males, was fixed at 179.9 mm CW.
3. pS1[24], the z95 parameter for the 2005-present RKF bycatch selectivity for males, was fixed at 179.9 mm CW.
4. the bounds on pS4[1], the descending slope of the double logistic function for SCF male bycatch selectivity, were increased.
5. the selectivity function for 1987-1996 GF bycatch of females was changed from ascending logistic to an ascending normal.
    a. pS1[20], the size-at-1 parameter was fixed at 139.9 mm CW.

- All parameters fixed at bounds "made sense"

case	objective function	max gradient	avg recruitment	B100	Bmsy	current MMB	Fmsy	MSY	Fofl
21.04	3165.74	0.00108333	424.93	115.23	40.33	73.90	1.12	18.39	1.06
21.21	3175.37	0	419.61	115.17	40.31	74.00	1.13	18.40	1.07

21.04→21.21: what's the difference?





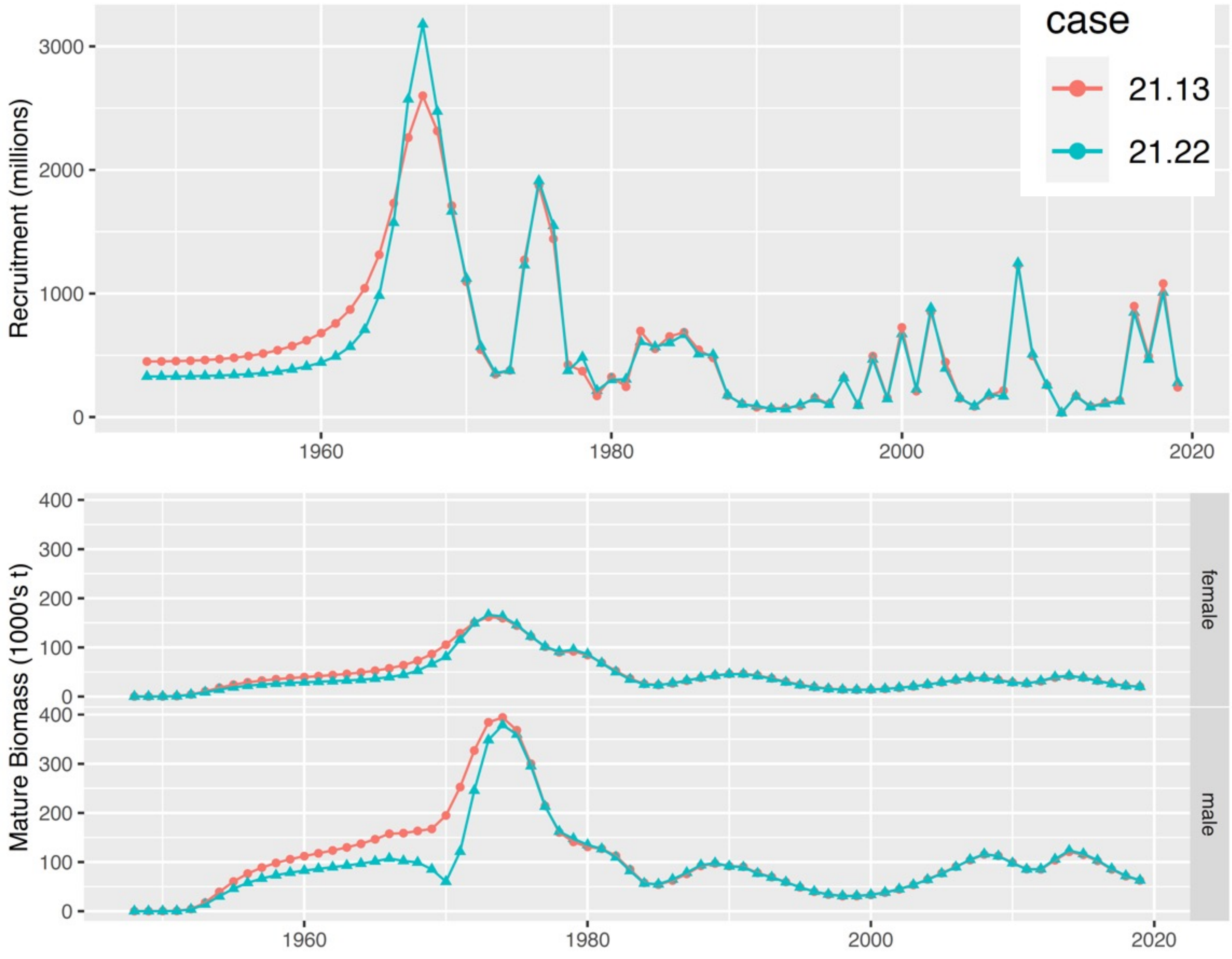
What it took: 21.13→ 21.22

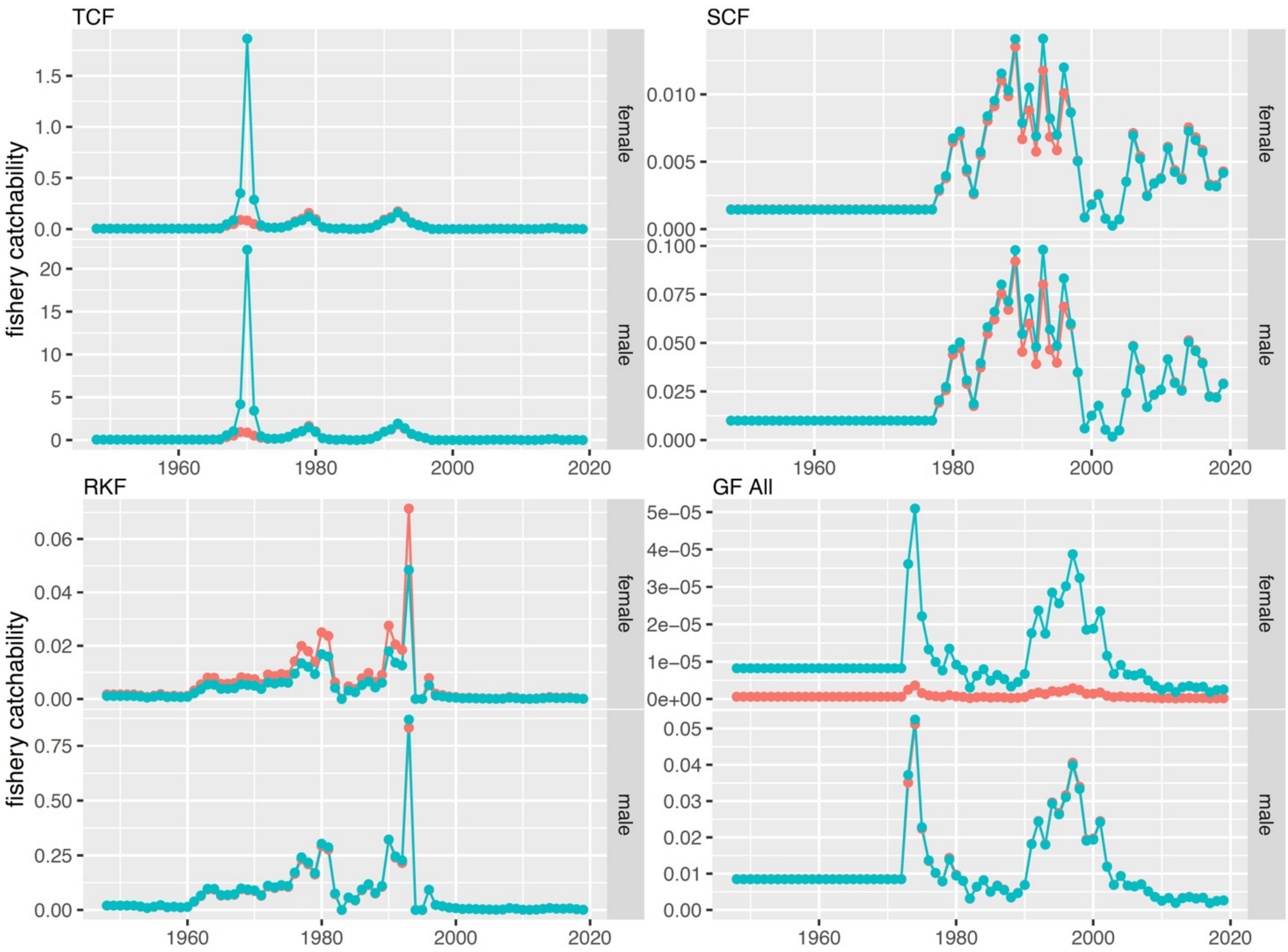
1. pS1[4]: fixed at 129.9
2. pS1[10]: upper bound increased from 140 to 180 mm CW
3. pS1[20]: lower bound decreased from 40 to 25 mm CW
4. pS1[22], pS1[23], and pS1[24] were all fixed at 179.9
5. pS3[2] and pS3[3] were fixed at 0.001
6. pLnDirMul[9] and pLnDirMul[13] were each fixed at 10 (on the ln-scale)

- All parameters fixed at bounds "made sense"

case	objective function	max gradient	avg recruitment	B100	Bmsy	current MMB	Fmsy	MSY	Fofl	OFL	projected MMB
21.13	6089.74	0.06988745	359.13	107.91	37.77	74.12	0.95	16.85	0.95	23.80	39.15
21.22	6153.67	0	349.48	107.76	37.72	74.91	0.94	16.75	0.94	24.01	39.67

21.13 → 21.22: what's the difference?





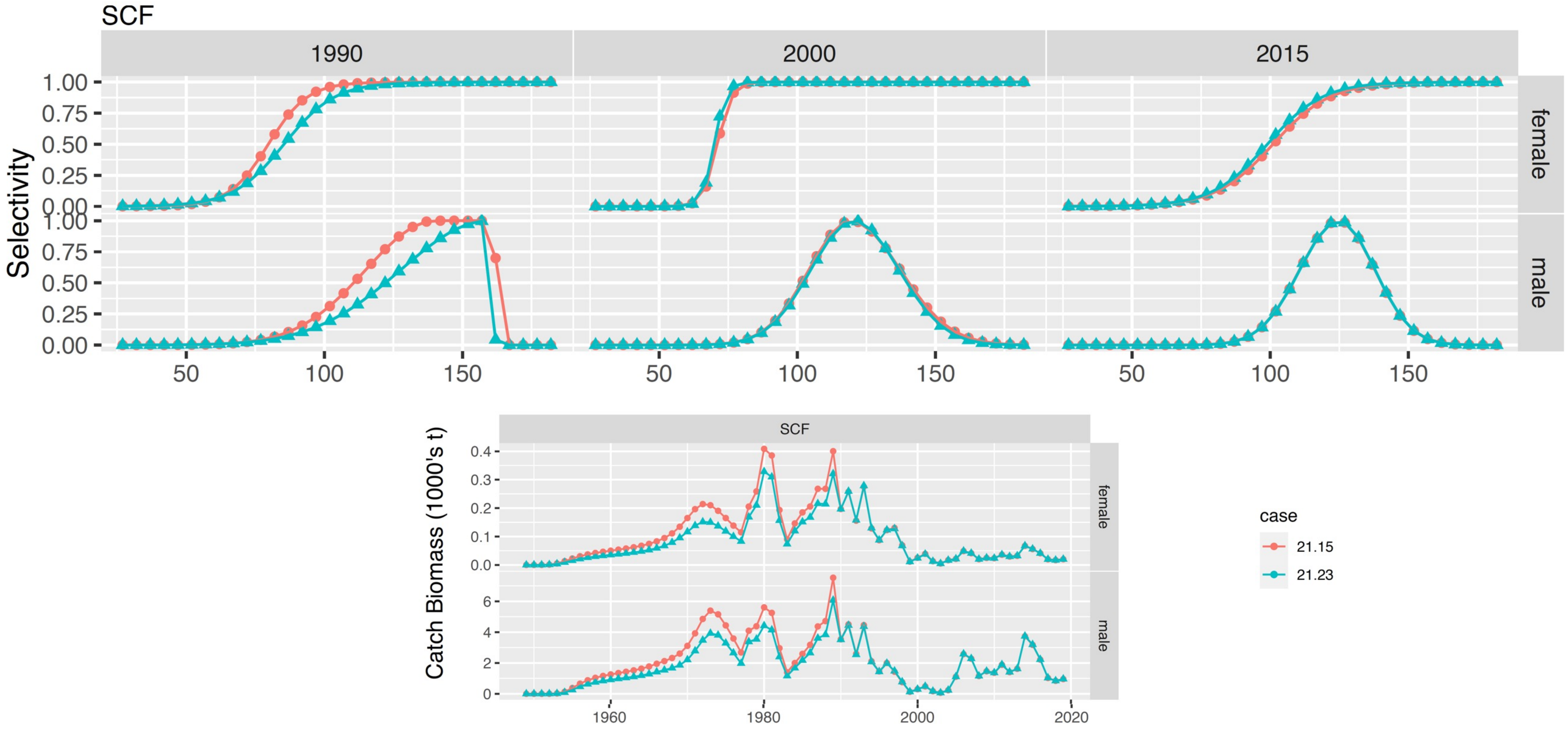
What it took: 21.15→ 21.23

1. pRb[1]: fixed at 0.00995 on the ln-scale (1.01 on the arithmetic scale) near its lower bound (0 on the ln-scale)
2. pS1[10]: upper bound increased from 140 to 180 mm CW
3. pS1[22] and pS1[24] were both fixed at 179.9 mm CW near their upper bounds (180)
4. pS1[25] was fixed at 139.9 mmCW near its upper bound (140)
5. pS3[1], pS3[2] and pS3[3] were fixed at 0.001 near their lower bounds
6. pS4[1] was fixed at 1.01 near its lower bound
7. pLnDirMul[9] and pLnDirMul[11] were each fixed at 10 (on the ln-scale)

- All parameters fixed at bounds "made sense"

case	objective function	max gradient	avg recruitment	B100	Bmsy	current MMB	Fmsy	MSY	Fofl
21.15	6349.95	0.01683371	1409.54	124.67	43.63	72.21	1.20	20.70	0.99
21.23	6590.74	0	1409.28	124.20	43.47	71.97	1.22	20.68	1.00

21.15→21.23: what's the difference?



Recommended Scenarios for Fall 2021

- 20.07 (the 2020 assessment model updated with 2020/2021 data)

- 21.21 (20.04 + modifications so no parameters at bounds)
  - lognormal fishery likelihoods, expanded bounds on survey *q*'s
  - ascending logistic functions with z95 fixed (179.9 mm CW) for
    - male bycatch in BBRKC fishery (1997-2004, 2005+)
  - ascending normal functions with fixed size-at-1 (139.9 mm CW) for
    - female NMFS survey selectivity
    - female bycatch in groundfish fisheries

- 21.22 (21.13 + modifications so no parameters at bounds)
  - 21.21 + tail compression + female size truncation + normal/double-normal selectivity functions replace all logistic/double-logistic functions + Dirichlet-normal likelihoods for size compositions
  - z-at-1 fixed at 179.9 mm CW for male bycatch selectivity functions in BBRKC fisheries, plateau widths set to minimum in double normal selectivity functions for male bycatch in snow crab fishery (1997-2004, 2005+)