2022 Tanner Crab Stock Assessment

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AFSC/NMFS/NOAA
Sept 14, 2022

Notes on SAFE Chapter

Converted to RMarkdown from Word

- no more cut-and-paste figures and tables
- about 85% successful
- need to improve
  - table sizing/fonts
  - units labelling (“thousands t”)

Summarizes model comparisons

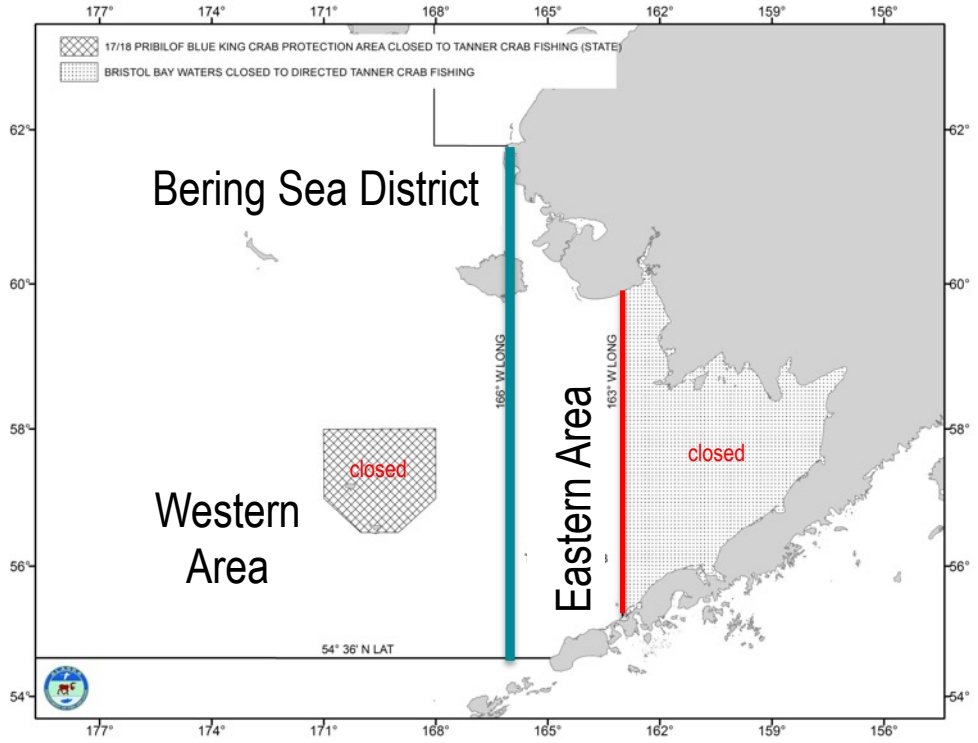
- focuses on base and preferred model

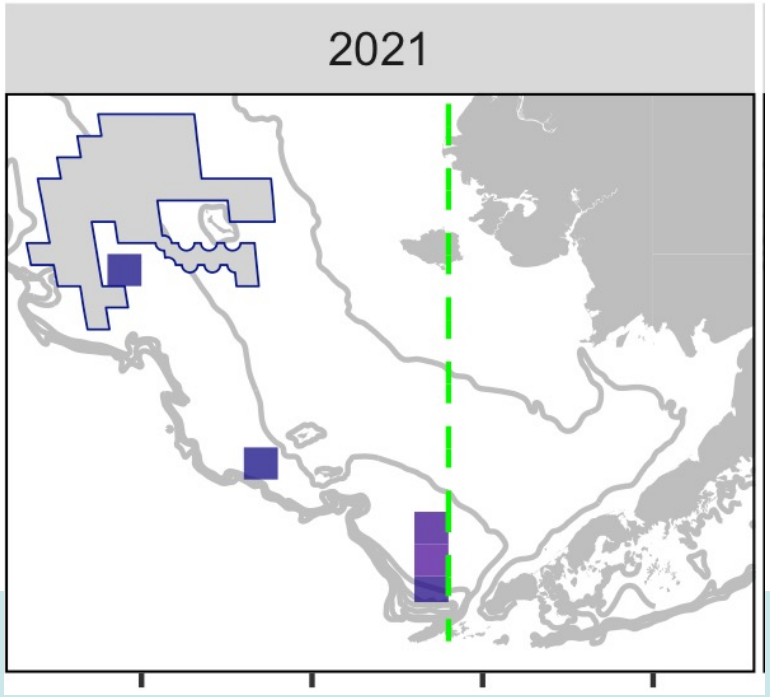
Comprehensive comparisons in Appendices

- D: Tables
- E: Figures
- G: Management Quantities

Overview:

- 2021/22 Federal management
  - OFL: 27,170 t
  - ABC: 21,740 t
  - Total catch mortality: 780 t (< OFL)
    - **overfishing did not occur**
    - mostly taken in directed fishery
  - 2021/22 MMB: 62,050 t (> MSST = 17,370 t)
    - **stock is not overfished**
- ADFG management
  - Eastern Area closed
    - MMB failed to meet threshold
  - Western Area
    - TAC: 499 t
    - Retained catch: 494 t
    - 19,252 potlifts
    - CPUE: 26 kg/pot (+25%)





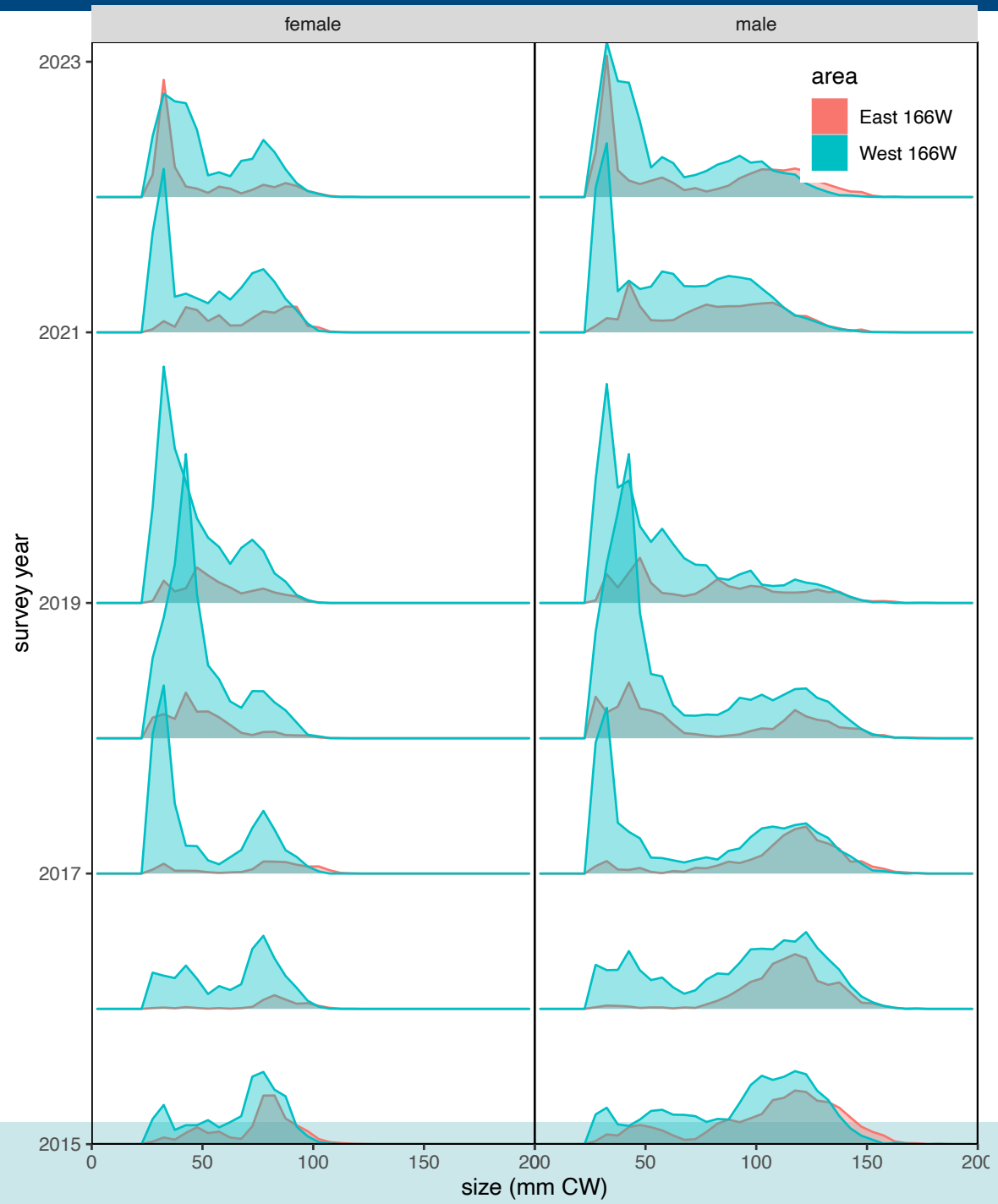
Overview:

Surveys

- 2022 NMFS EBS Shelf Survey Biomass
  - 29,254 t male biomass (+7%)
  - 6,252 t industry-preferred males (-3% [-21%W])
  - 9,232 t female biomass (+10%)
- Concern:
  - evidence for recent recruitment
  - not moving into larger size classes

2022/23 Management

- Based on preferred model (20.03)
  - Tier 3a ($B>B_{MSY}$; not overfished)
  - OFL: 32,810 t (+21%)
  - ABC: 24,610 t (25% buffer)



Outline

- SSC & CPT Comments
- Recent Fishery & Survey Trends
- Model Description & Scenarios
- Model Evaluation
- Status Determination & OFL Calculation
- Final Remarks

2021: Moving forward

- Looking for prioritization on:
  - implement projection capabilities in TCSAM02 √
  - implement delta approximation in TCSAM02 √
  - transition to GMACS

- finish BSFRF/NMFS SBS survey selectivity analysis
  - would be helpful to have 2018 BSFRF survey data

- continue exploring ways to simplify model structure
  - start model in 1982 √
  - drop fits to small-catch bycatch data

- investigate nonparametric approaches to selectivity

- develop model that better reflects State management structure √

SSC & CPT Comments

CPT Comment: Four models are requested by the CPT for the September CPT meeting: 1) Model 22.01: Base model from last year updated with new data; 2) Model 22.03: updated bycatch estimates for the groundfish fisheries, and fitting to fishery aggregate biomass; 3) modified model 22.06a: Initial size composition in 1982 with a smoothing weight of 0.1, and initial composition parameters estimated on a logit scale, but also including the features of model 22.03; and 4) modified model 22.06a as described above plus bootstrap estimates of input sample sizes.

Response (9/22): All requested models were implemented and results are provided in this assessment. The latter two models were numbered as 22.07 and 22.08 because they differ from models presented in May.

SSC Comment: the SSC commends the authors for proposing two models (22.01 and 22.03) with no parameters hitting bounds and the remaining models having only two or three parameters at bounds (depending on smoothing). The SSC recommends continued efforts to examine and address the remaining parameters that are still estimated at their bounds.

Response (9/22): The author appreciates the SSC comment and notes that remaining parameters at bounds involve limits on selectivity-related parameters reflecting knife-edge like selectivity patterns (e.g., retention functions) or full selected sizes that would go beyond observed sizes in the data. Implementation of a well-behaved bounding function is an area of active (although incomplete) research.

SSC & CPT Comments

SSC Comment: Even though the estimation of input sample sizes did not perform as expected (it produced even higher sample sizes than default values in the base model), the SSC supports the CPT recommendation to revisit this approach with the revised start date (1982).

Response: Model 22.08 addresses this request, but results remained problematic. The author notes that multinomial likelihoods were used in fitting this model and that it should be reconsidered using the Dirichlet-multinomial likelihood.

SSC Comment: The SSC reiterates its suggestion from October 2020 to prioritize development of a projection model for crab that doesn't assume the entire OFL is removed, which is especially important for the EBS Tanner crab stock where exploitation is routinely below the OFL.

Response (9/22): A projection model of the type described has been implemented. 20-year projections at 0, 0.25, 0.5, 0.75, 1, and 1.25 times F_{OFL} for the directed fishery have been included in the assessment for the base and author-preferred models.

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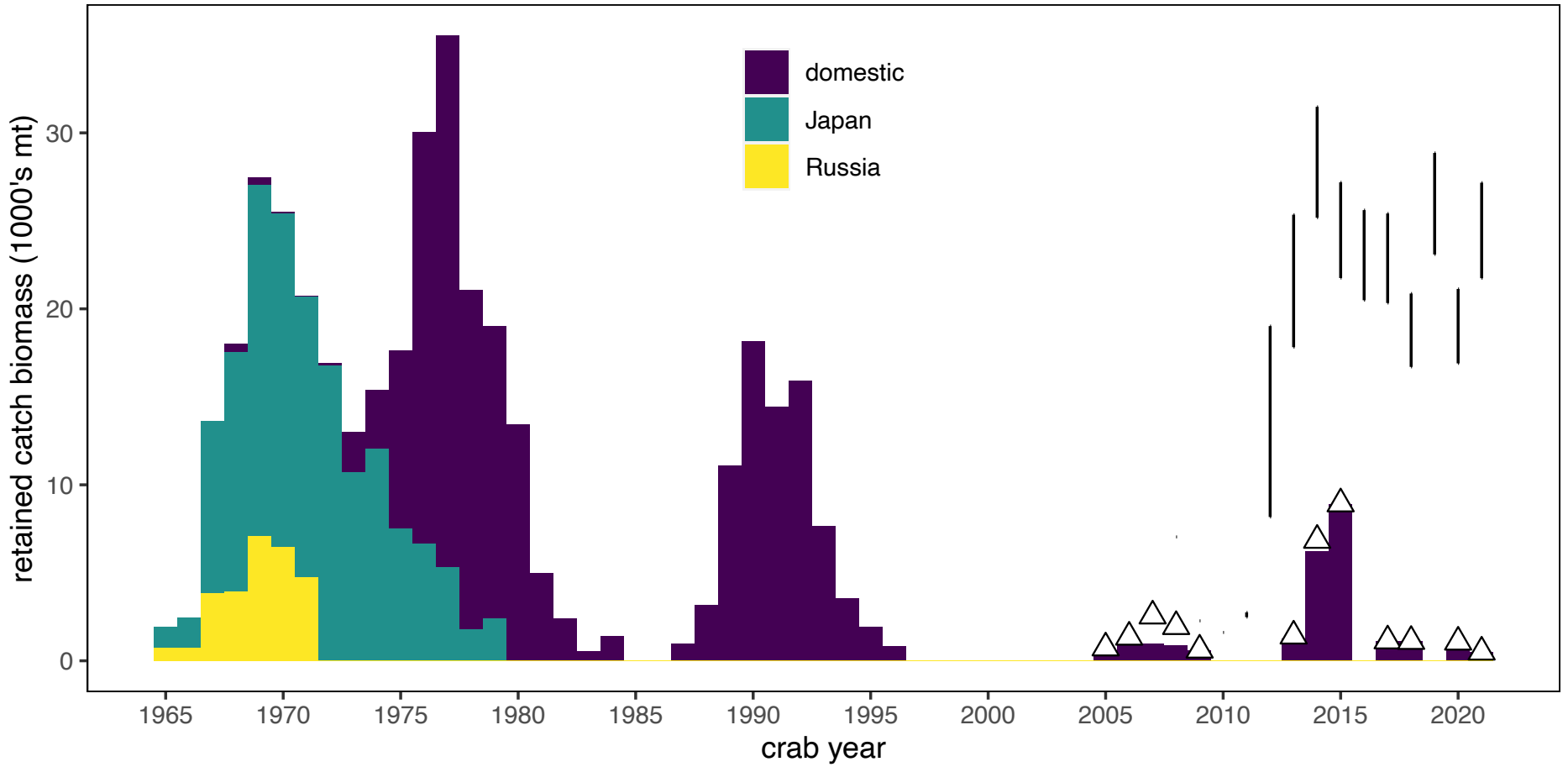
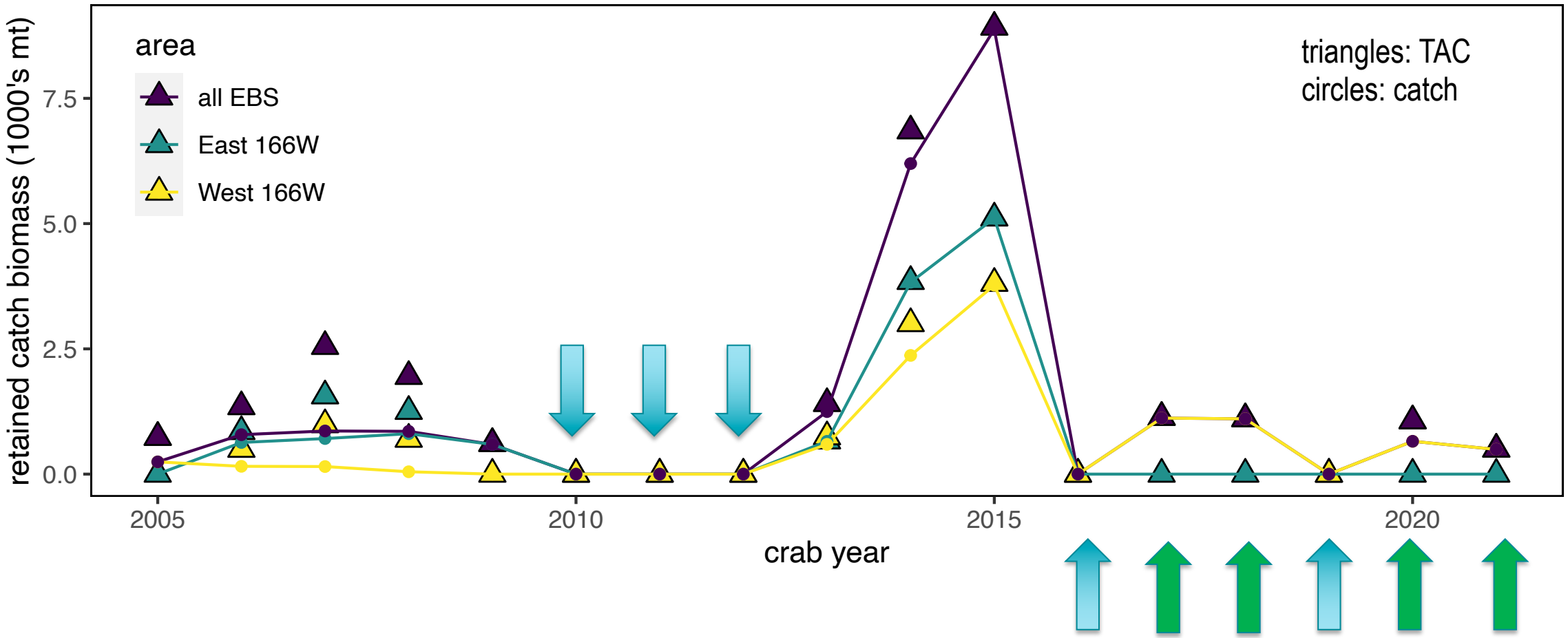
Retained catch



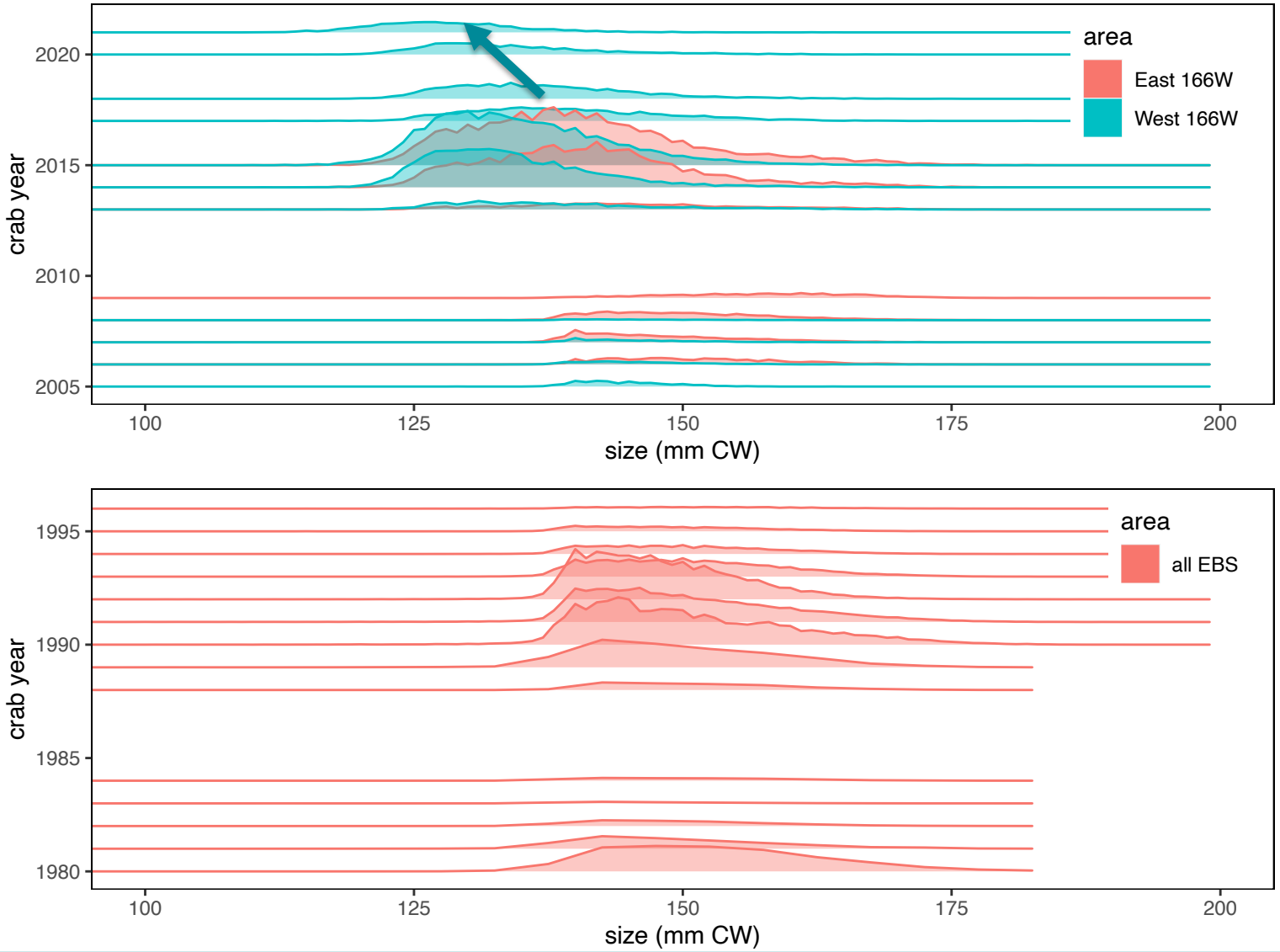
Tier 3
bars: OFL/ABC

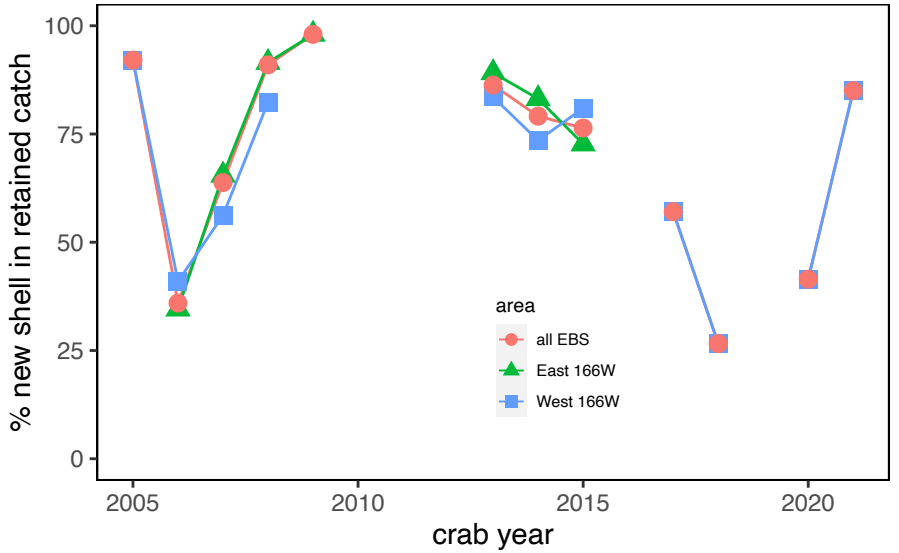
triangles: TAC

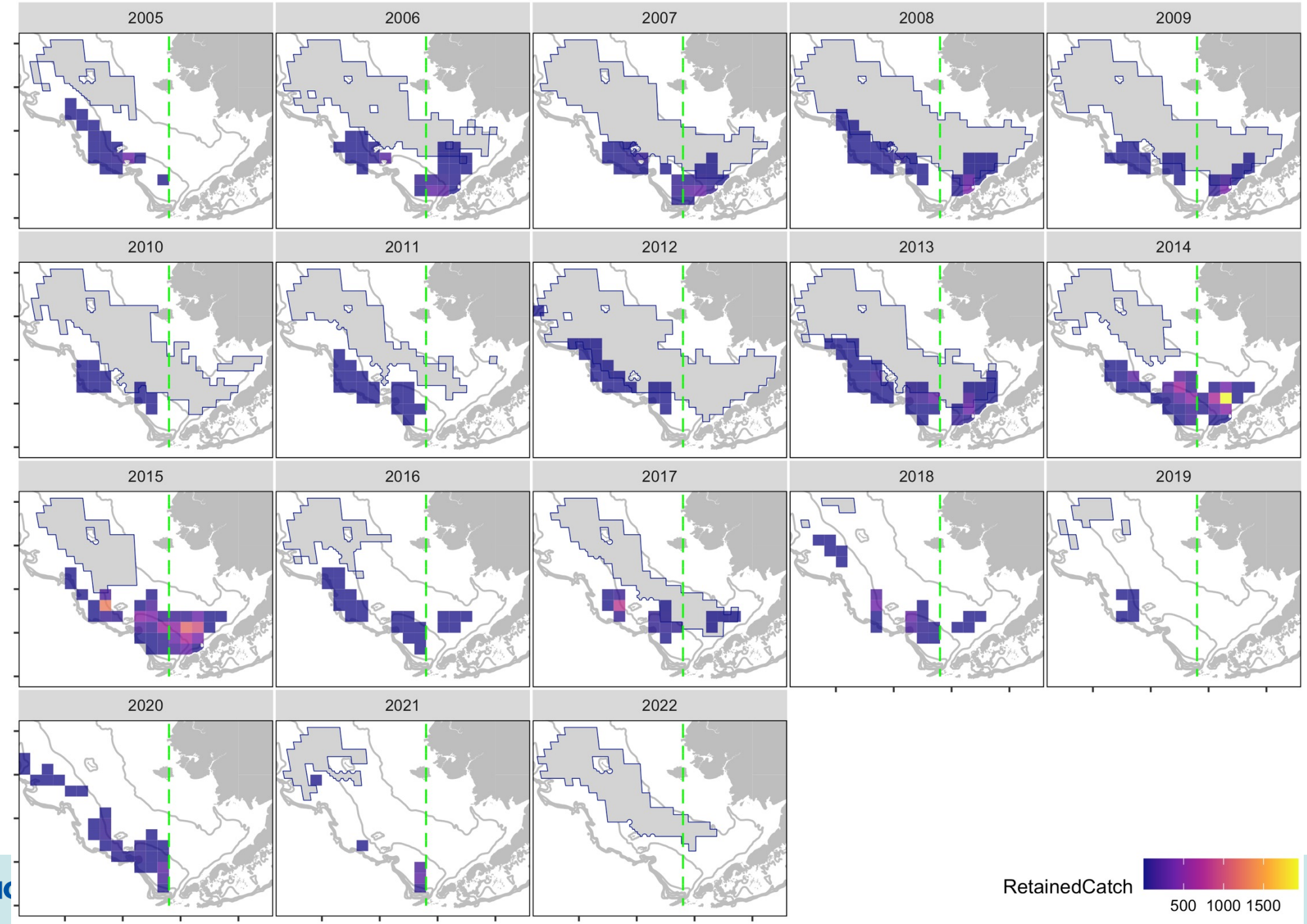
Retained catch



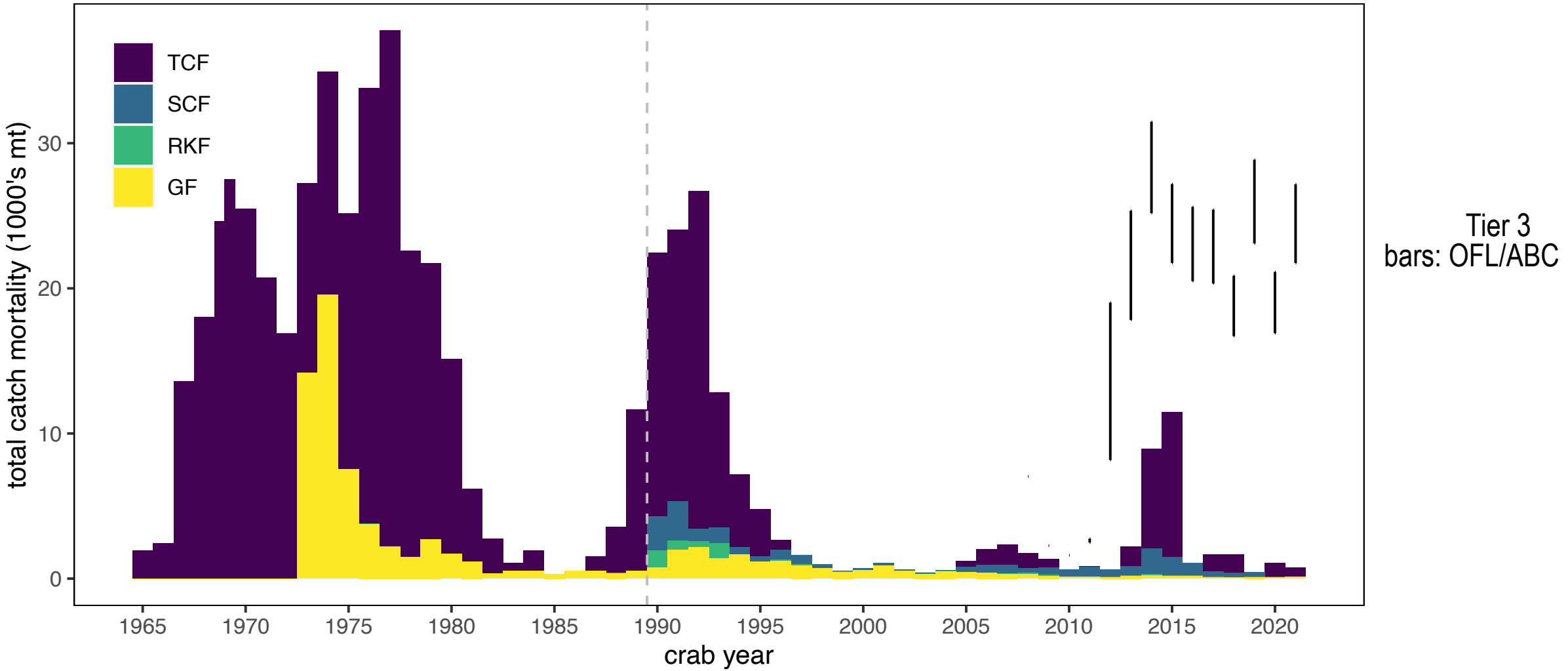
Retained catch



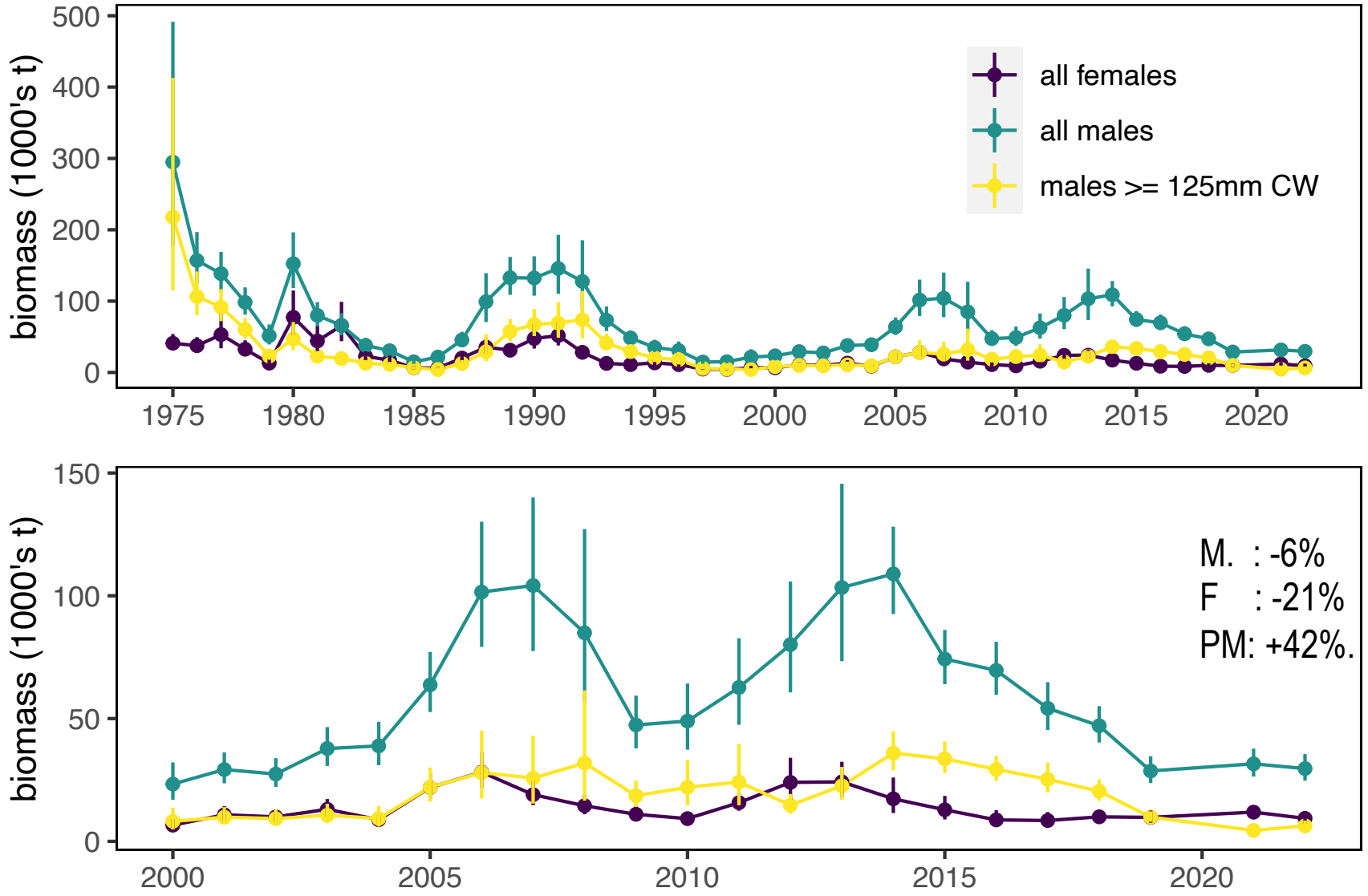



2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
RetainedCatch
500 1000 1500

Total catch mortality

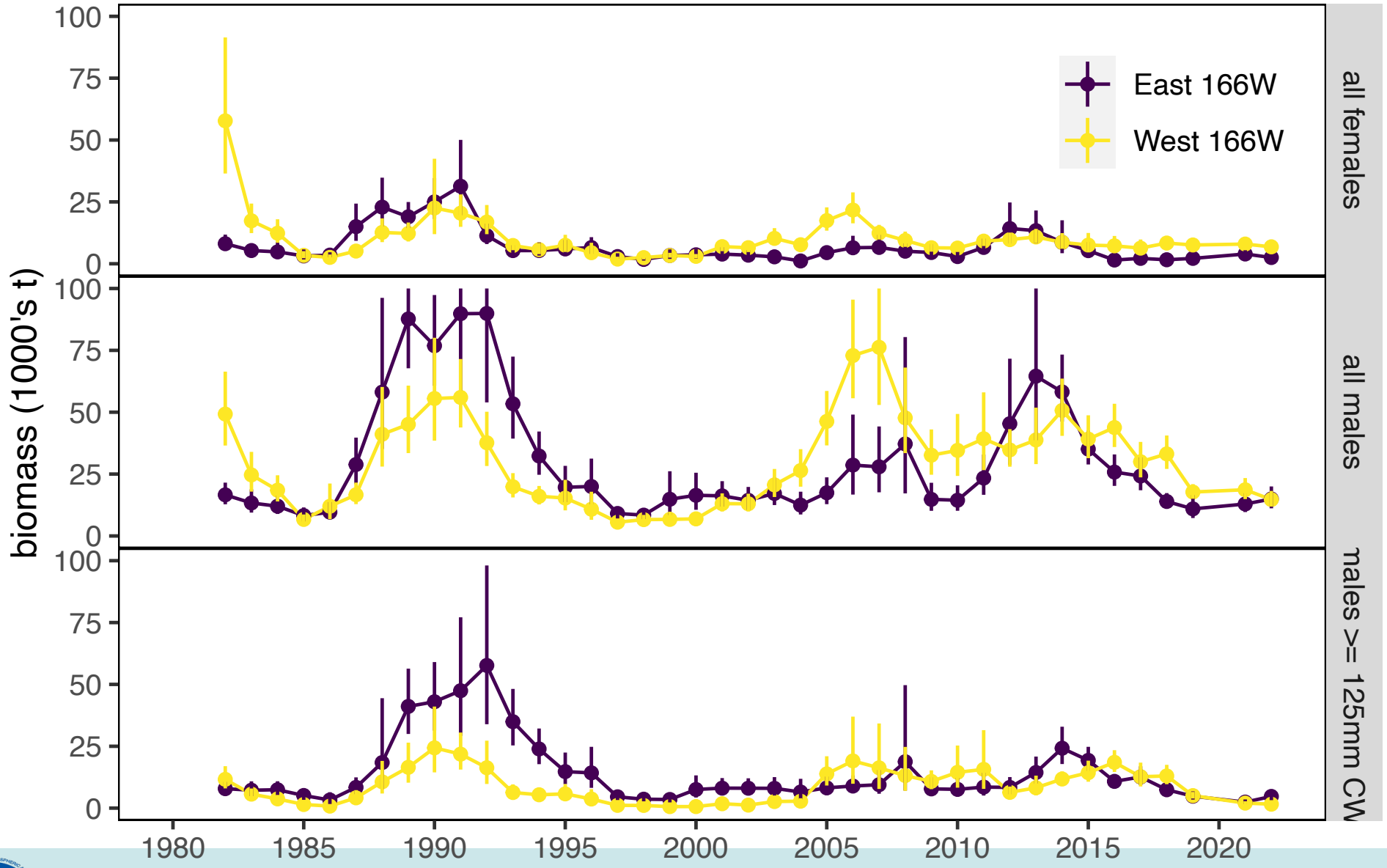


NMFS EBS Survey Data



(+142% NS)

By Management Region



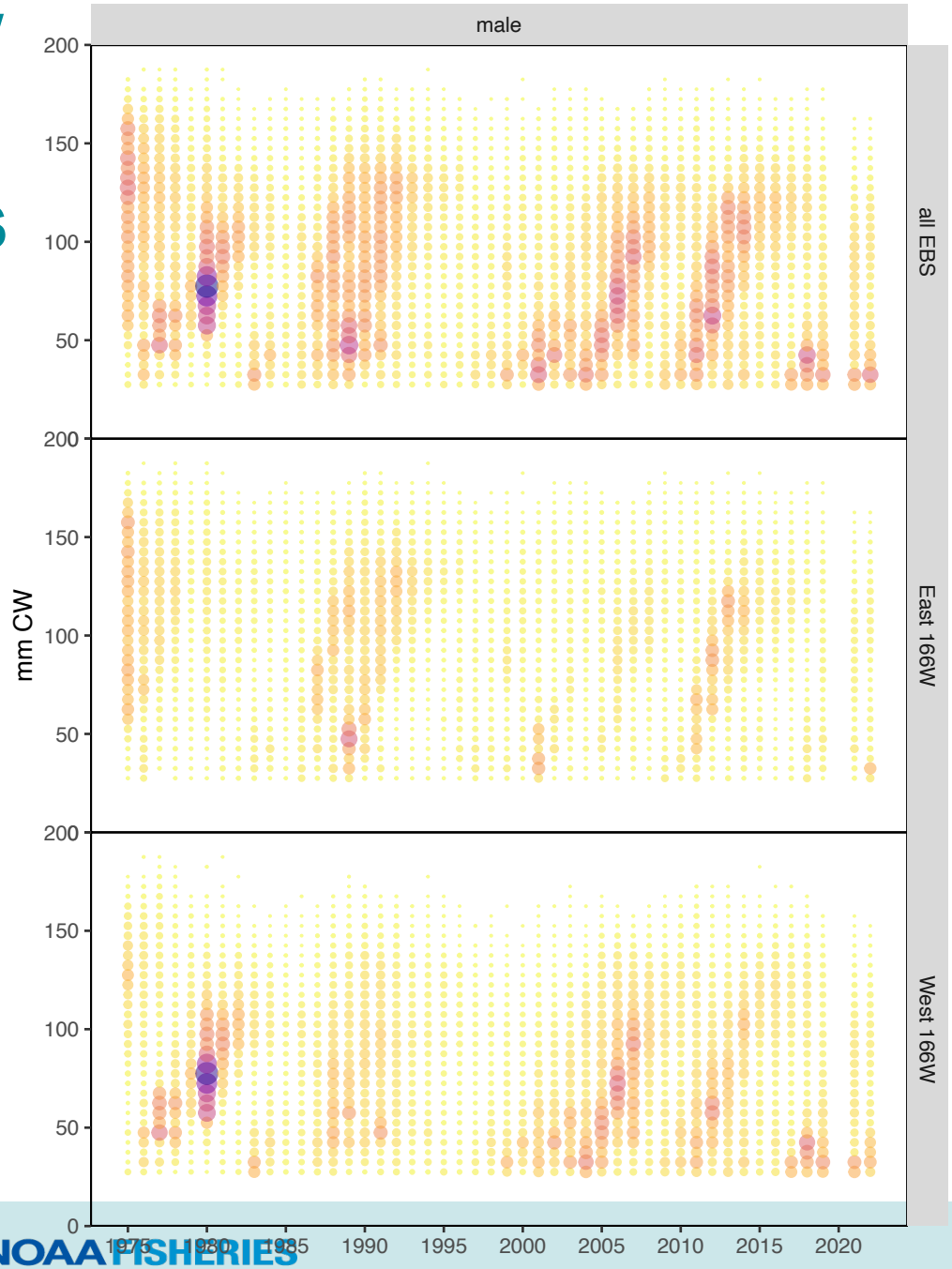
E: -35%
W: -14%

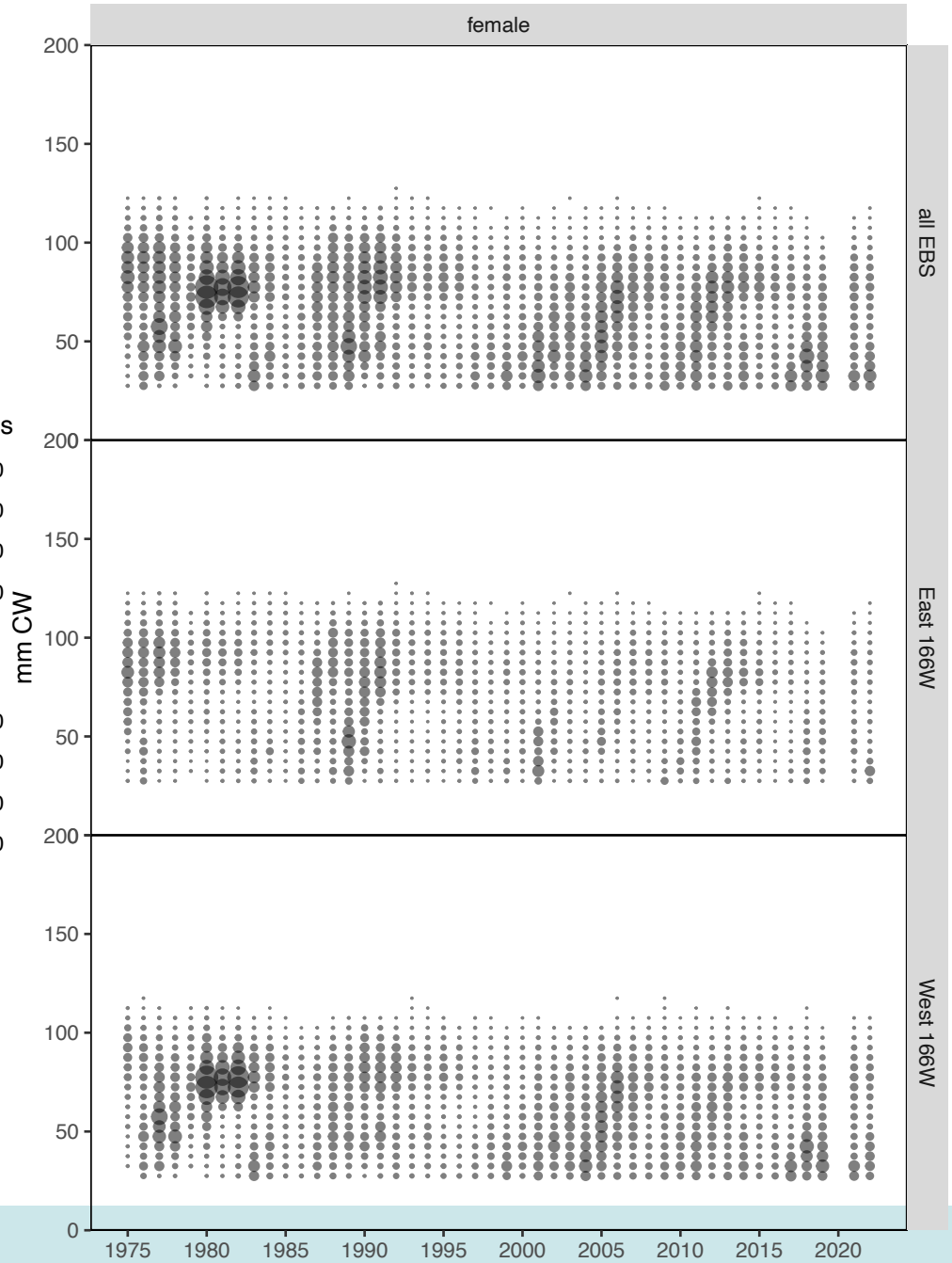
E: +16%
W: -21%

NS

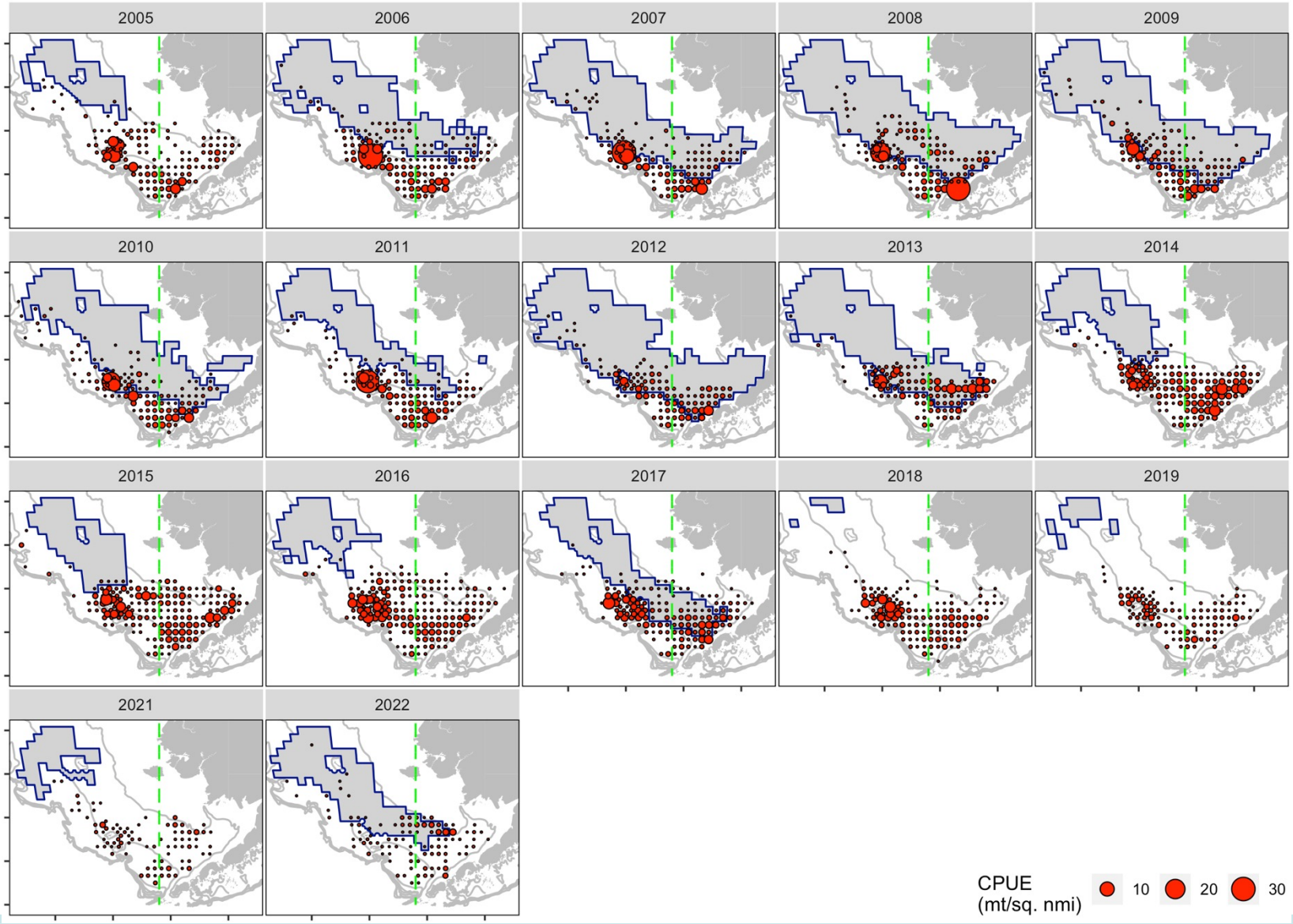
E: +95%. +160%
W: -21%. + 80%

Survey Size Comps





Survey Spatial Distributions: Preferred Males



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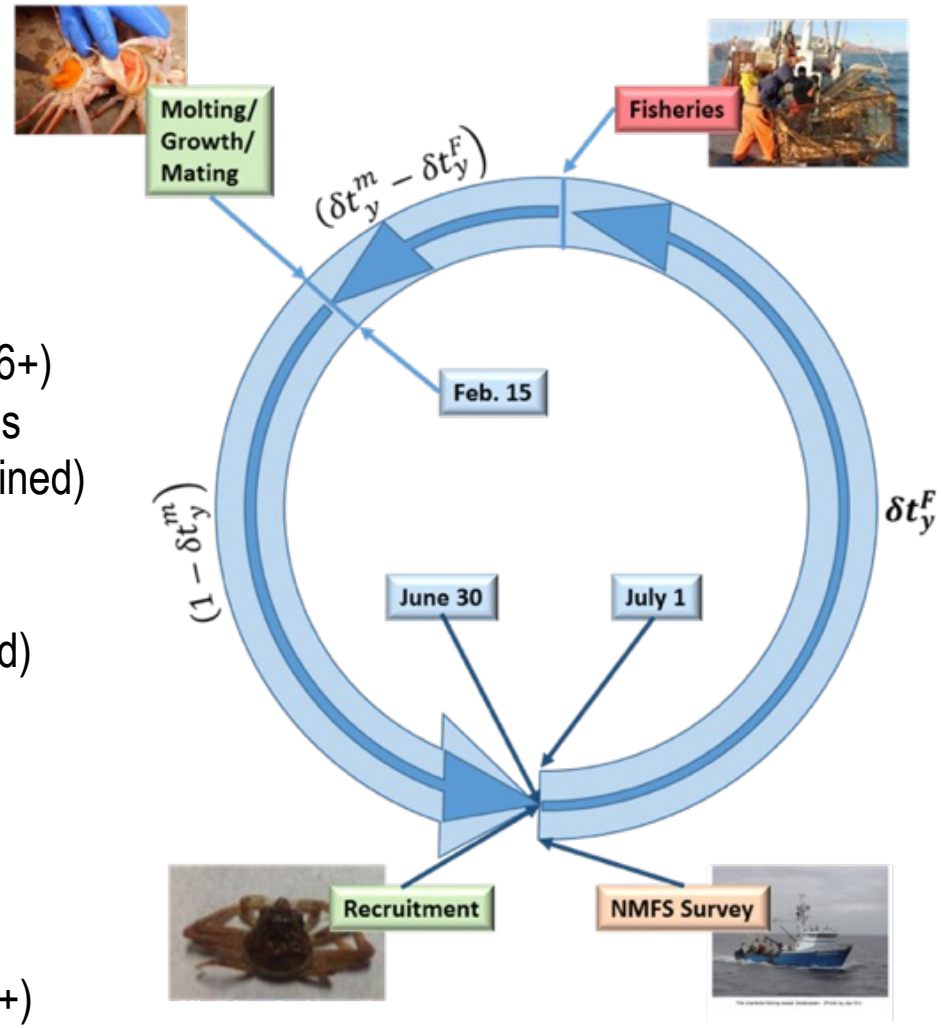
Assessment: Tier 3 size-structured model

Fits to

- Survey data
  - biomass, size comps
  - NMFS EBS shelf survey
    - 1975-present (no 2020)
    - male maturity ogives (2006+)
  - BSFRF side-by-side haul studies
    - 2013-2017 (2018 not obtained)
- Molt increment data
- Fishery data (biomass, size comps)
  - directed fishery (areas combined)
    - retained catch (1965+)
    - total catch (1991+)
  - bycatch in
    - snow crab fishery (1990+)
    - BBRKC fishery (1990+)
    - groundfish fisheries (1973+)



Model estimates

- Natural mortality (M)
- growth (molt increment)
- probability of molt to maturity
- initial abundance
- recruitment
- fully-selected capture rates
- size-specific fishery selectivity
- size-specific retention
- NMFS survey catchability
- NMFS survey selectivity

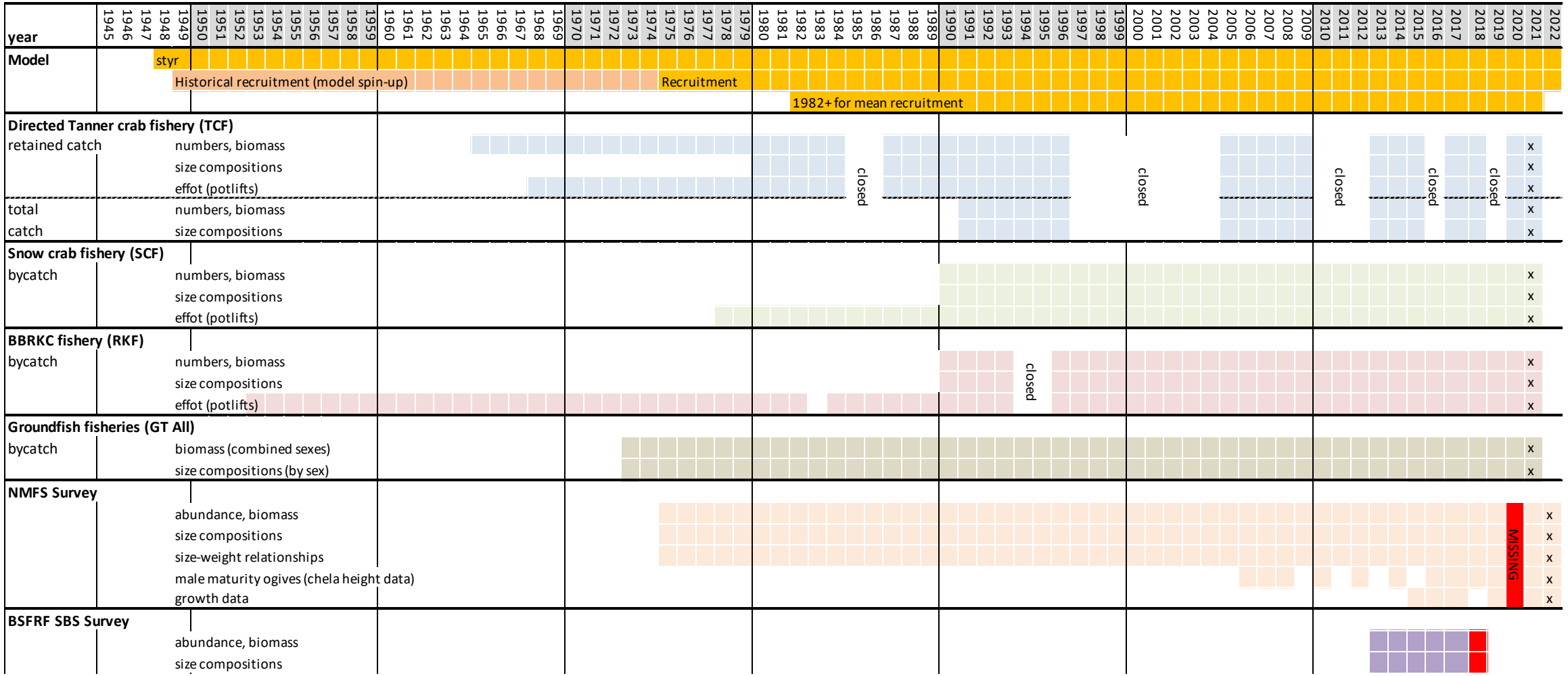
Fixed parameters

- weight-at-size
- handling mortality rates
- availability to BSFRF survey
- fully-selected sizes

Determines

- Avg. Rec., F_{msy}, B_{msy},
- F_{OFL}, OFL, ABC

Model time frames and data



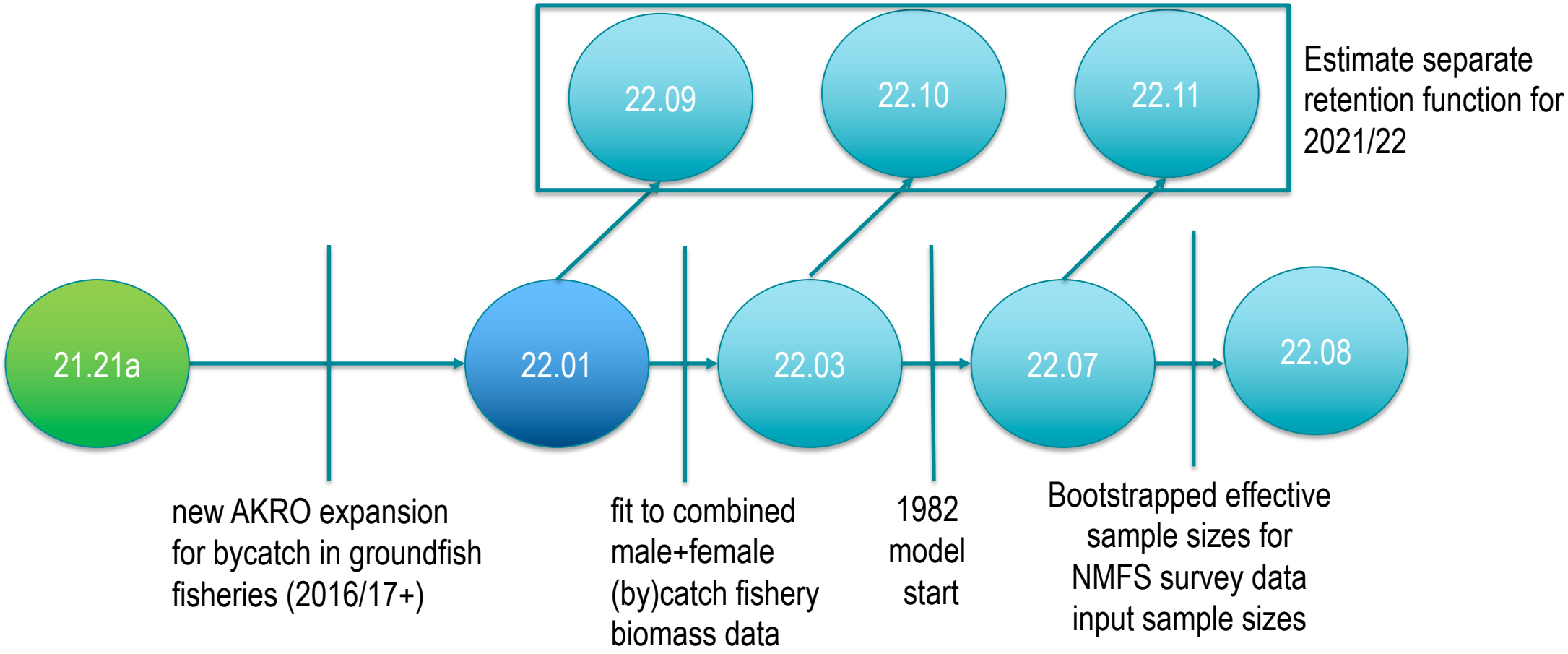
Fisheries: Directed Fishery

Fishery/process	time blocks	22.01 description
TCF	directed Tanner crab fishery	
capture rates	pre-1965	male nominal rate
	1965+	male ln-scale mean + annual devs
	1949+	ln-scale female offset
male selectivity	1949-1990	ascending logistic
	1991-1996	annually-varying ascending logistic
	2005+	annually-varying ascending logistic
female selectivity	1949+	ascending logistic
male retention	1949-1990; 1991-1996; 2005-2009; 2013+	ascending logistic
max % retained	pre-1988	fixed at 100%
	1991-1996	fixed at 100%
	2005-2009	fixed at 100%
	2013+	fixed at 100%

Likelihoods

Model	Component	Type	included in optimization	Fits	Likelihood distribution
22.01	TCF: retained catch	biomass	yes	males only	lognormal
		size comp.s	yes	males only	multinomial
	TCF: total catch	biomass	yes	by sex	lognormal
		size comp.s	yes	by sex	multinomial
	SCF: total catch	biomass	yes	by sex	lognormal
		size comp.s	yes	by sex	multinomial
	RKF: total catch	biomass	yes	by sex	lognormal
		size comp.s	yes	by sex	multinomial
	GF All: total catch	abundance	yes	by sex	lognormal
		biomass	yes	by sex	lognormal
		size comp.s	yes	by sex	multinomial
	NMFS "M" survey (males only, no maturity)	biomass	yes	males only	lognormal
		size comp.s	yes	males only	multinomial
	NMFS "F" survey (females only, w/ maturity)	biomass	yes	by maturity classification	lognormal
		size comp.s	yes	by maturity classification	multinomial
	BSFRF "M" survey (males only, no maturity)	biomass	yes	males only	lognormal
		size comp.s	yes	males only	D-M
	BSFRF "F" survey (females only, w/ maturity)	biomass	yes	by maturity classification	lognormal
		size comp.s	yes	by maturity classification	D-M
	growth data	EBS only	yes	by sex	gamma
	male maturity ogive data	EBS only	yes	males only	binomial

Model Scenarios



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Model Evaluation

	model configuration	parent	changes	number of parameters	no. of jitter runs	no. converged to MLE	no. of param.s at bounds	objective function value	max gradient	invertible for std. devs?
	21.22a	--	--	346	--	--	0	3014	5.92E-04	yes
	22.01	21.22a	using updated bycatch estimates for the groundfish fisheries used in place of old versions; new fishery and survey data for 2021/22	351	800	731	0	3077	1.98E-03	yes
	22.03	22.01	fits to fishery catch data changed from sex-specific to aggregated, corresponding fits to size composition data changed to extended versions	351	800	710	1	3045	2.92E-03	yes
	22.07	22.03	Starting model in 1982, estimating initial population size using individual parameters on logistic scale, minimal smoothing on parameters, all data prior to 1982 dropped	409	800	537	1	2943	2.69E-03	yes
X	22.08	22.07	using effective sample sizes estimated by bootstrapping as input sample sizes for NMFS survey data	409	800	772	3	3602	6.22E-04	yes
	22.09	22.01	added 2021/22 as new time block for retention functions in the directed fishery	353	800	788	0	3072	1.39E-03	yes
	22.10	22.03	added 2021/22 as new time block for retention functions in the directed fishery	353	800	794	1	3039	8.65E-03	yes
	22.11	22.07	added 2021/22 as new time block for retention functions in the directed fishery	411	800	522	1	2938	2.49E-03	yes

Model Evaluation: Parameters at a Bound

name	label	22.01	22.03	22.07	22.08	22.09	22.10	22.11
pS2[2]	width for NMFS survey selectivity (females, 1982+)	–	–	–	1	–	–	–
pS2[28]	slope for TCF retention (2005-2009)	–	1	–	–	–	1	–
pS2[3]	slope for TCF retention (pre-1991)	–	–	1	1	–	–	1
pS2[4]	slope for TCF retention (1997+)	–	–	–	1	–	–	–

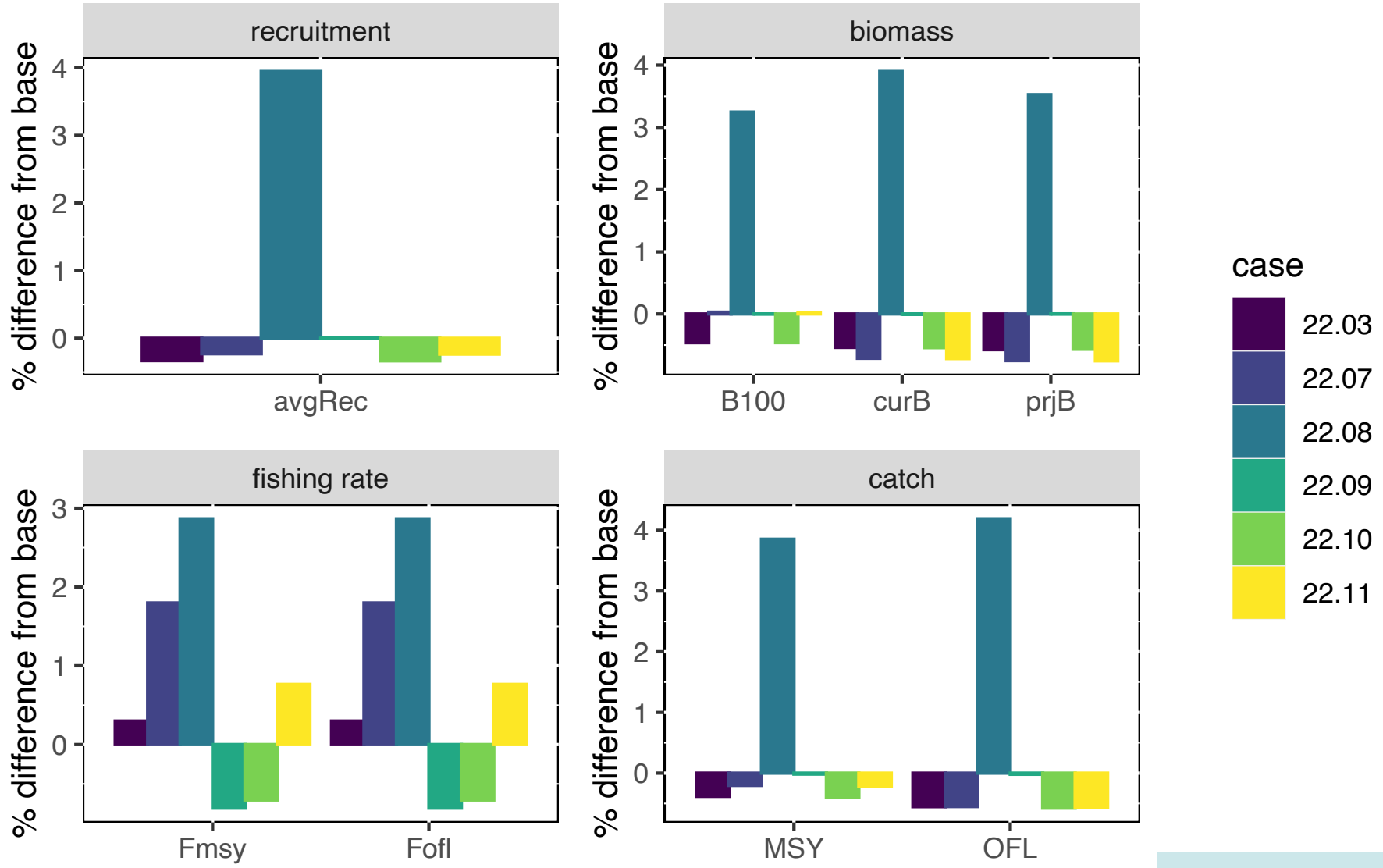
Model Evaluation

category	fleet	catch type	data type	22.01	22.03	22.07	22.08	22.09	22.10	22.11
surveys data	NMFS F	index catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	166.995	163.916	124.999	152.696	167.055	163.965	125.037
			n at z	296.833	298.183	247.086	535.371	296.824	298.183	247.092
	NMFS M	index catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	72.358	70.699	69.814	97.698	72.402	70.745	69.861
			n at z	410.411	411.493	297.002	540.856	410.282	411.380	296.963
	SBS BSFRF F	index catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	− 1.288	− 1.622	− 2.384	4.853	− 1.291	− 1.628	− 2.392
			n at z	231.853	231.943	231.698	233.783	231.849	231.946	231.696
	SBS BSFRF M	index catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	− 0.940	− 1.151	− 1.636	0.189	− 0.943	− 1.154	− 1.639
			n at z	290.361	290.992	288.384	288.166	290.362	290.999	288.393
	SBS NMFS F	index catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			n at z	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	SBS NMFS M	index catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			n at z	0.000	0.000	0.000	0.000	0.000	0.000	0.000
fisheries data	GF All	total catch	abundance	− 37.753	− 37.835	− 38.441	− 38.390	− 37.752	− 37.834	− 38.440
			biomass	− 68.870	− 68.910	− 54.993	− 54.652	− 68.870	− 68.909	− 54.992
			n at z	517.780	515.465	453.651	474.820	517.714	515.429	453.625
	RKF	total catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	− 22.073	− 37.093	− 37.181	− 37.174	− 22.071	− 37.092	− 37.180
			n at z	36.229	38.550	39.625	39.352	36.208	38.528	39.600
	SCF	total catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	− 10.935	− 52.237	− 52.262	− 52.148	− 10.930	− 52.234	− 52.260
			n at z	105.035	132.502	132.483	131.645	104.880	132.355	132.340
	TCF	retained catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	−142.002	−143.049	−101.160	−100.700	−141.993	−143.043	−101.154
			n at z	63.997	64.684	52.851	50.305	58.855	59.371	47.621
		total catch	abundance	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			biomass	73.588	6.586	7.921	7.546	74.235	6.971	8.265
			n at z	106.764	172.717	165.630	158.233	106.726	172.708	165.583
growth data	not appl	not appl	EBS molt increment data	525.929	526.605	521.958	528.229	525.823	526.514	521.874
maturity ogive data	NMFS M	not appl	EBS mature male ratios	211.944	211.641	208.534	214.404	211.970	211.674	208.566

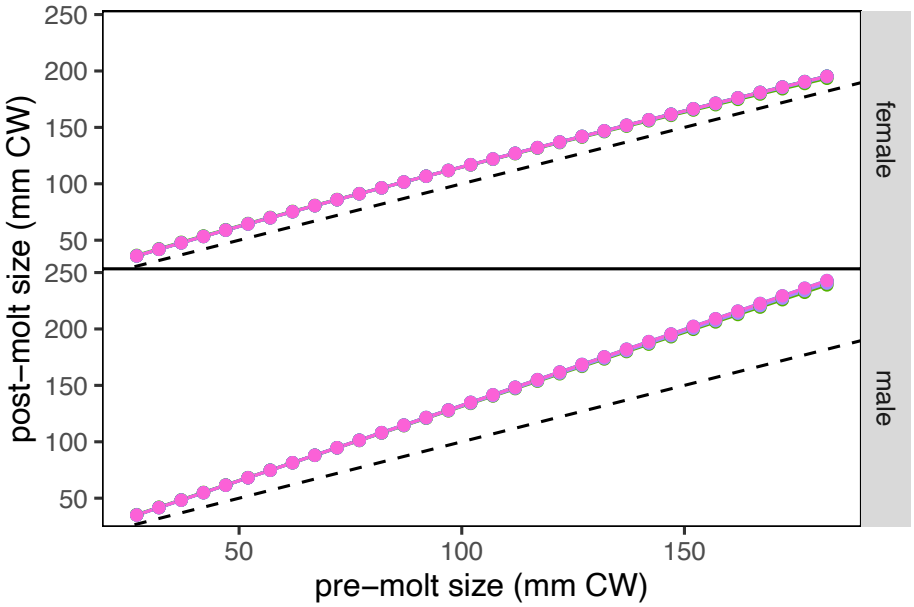
Model Evaluation

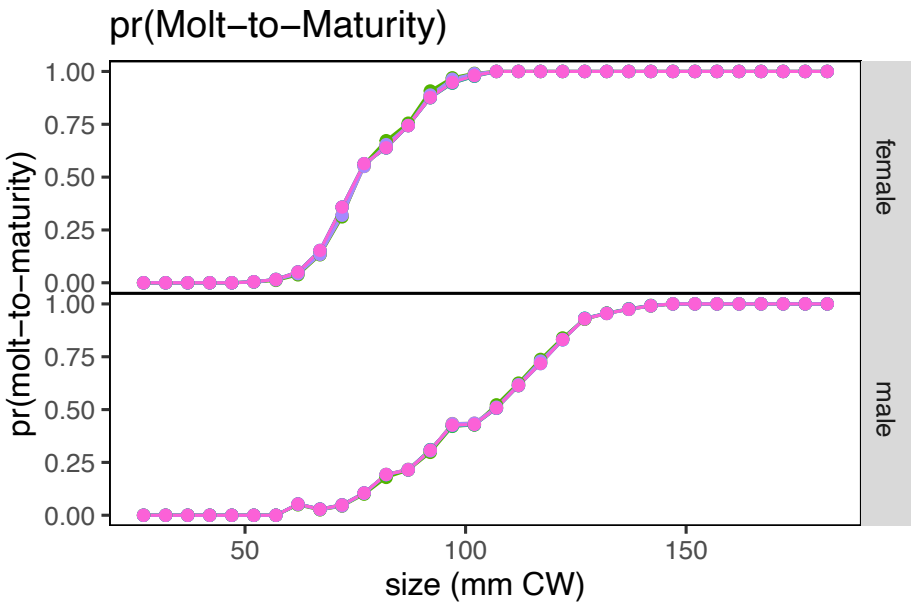
category	type	element	22.01	22.03	22.07	22.08	22.09	22.10	22.11
penalties	devsSumSq	pDevsS1	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001
	initNatZs	sumTo1	0.0000	0.0000	0.0011	0.0011	0.0000	0.0000	0.0011
	maturity	smoothness	2.0125	2.0656	2.2106	2.3352	2.0368	2.0917	2.2316
priors	initNs	pvLnInitNatZ	0.0000	0.0000	198.7802	203.7045	0.0000	0.0000	198.7815
	natural mortality	pDM1	36.3664	37.9890	38.4204	40.3521	36.2953	37.9068	38.3524
	recruitment	pDevsLnR	113.0504	113.1919	53.4687	52.6919	113.0556	113.1945	53.4709
	surveys	pQ	99.4911	97.2863	96.4674	127.9939	99.4815	97.2604	96.4217

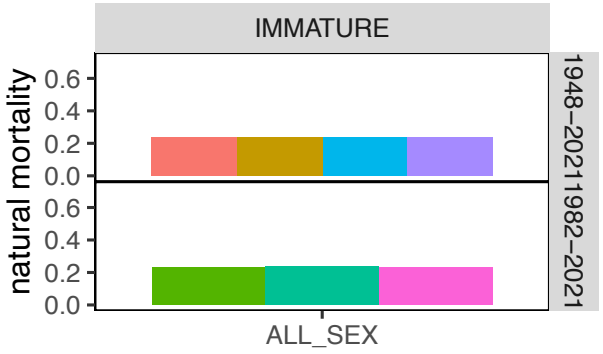
Model Evaluation

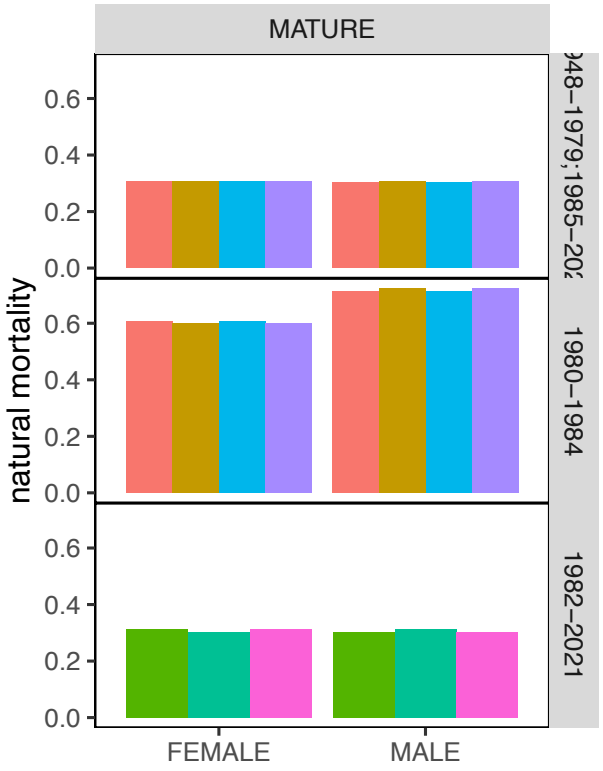


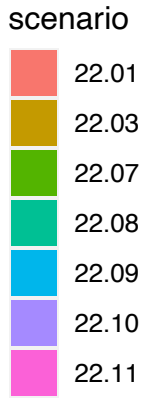
Population Results



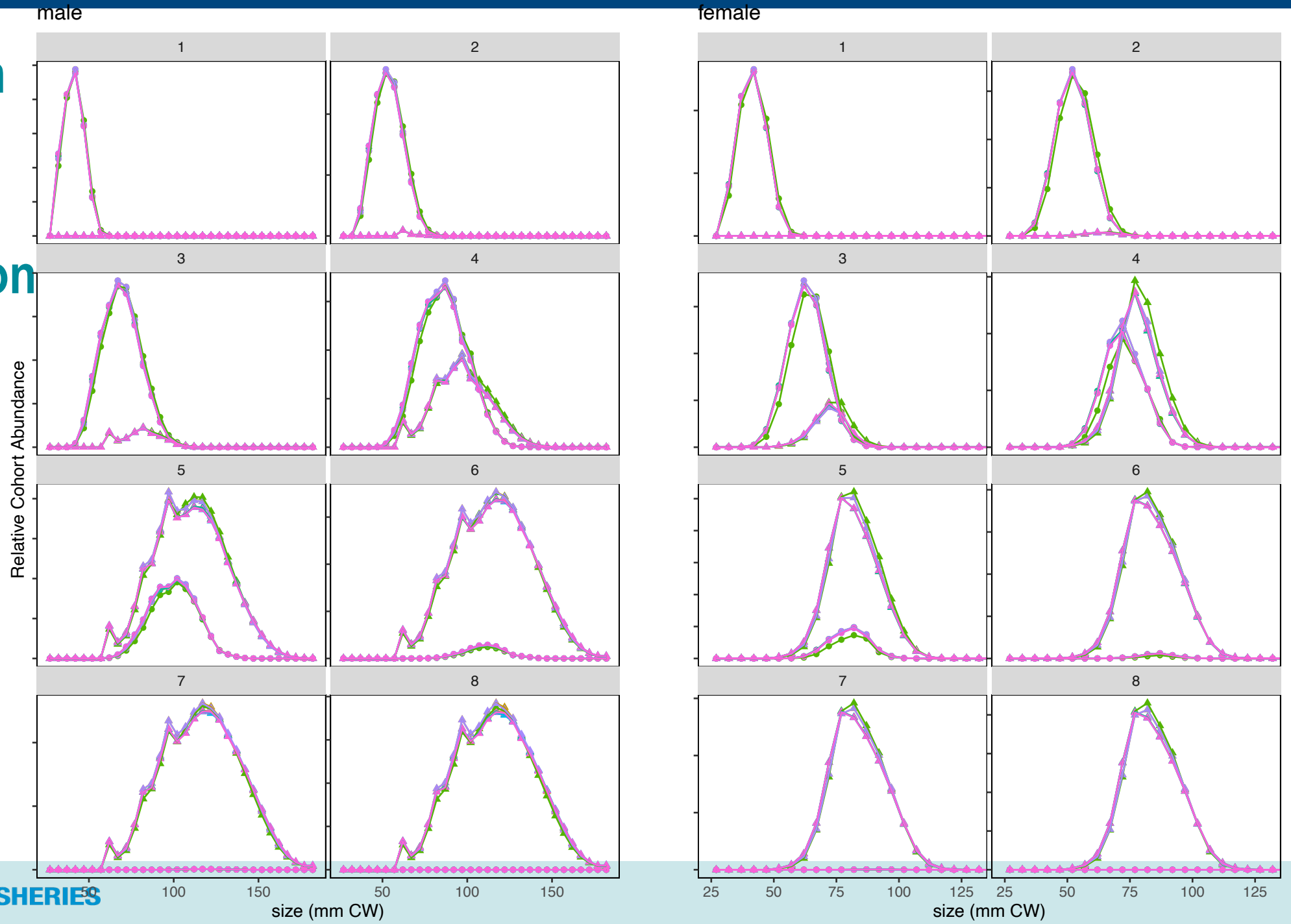




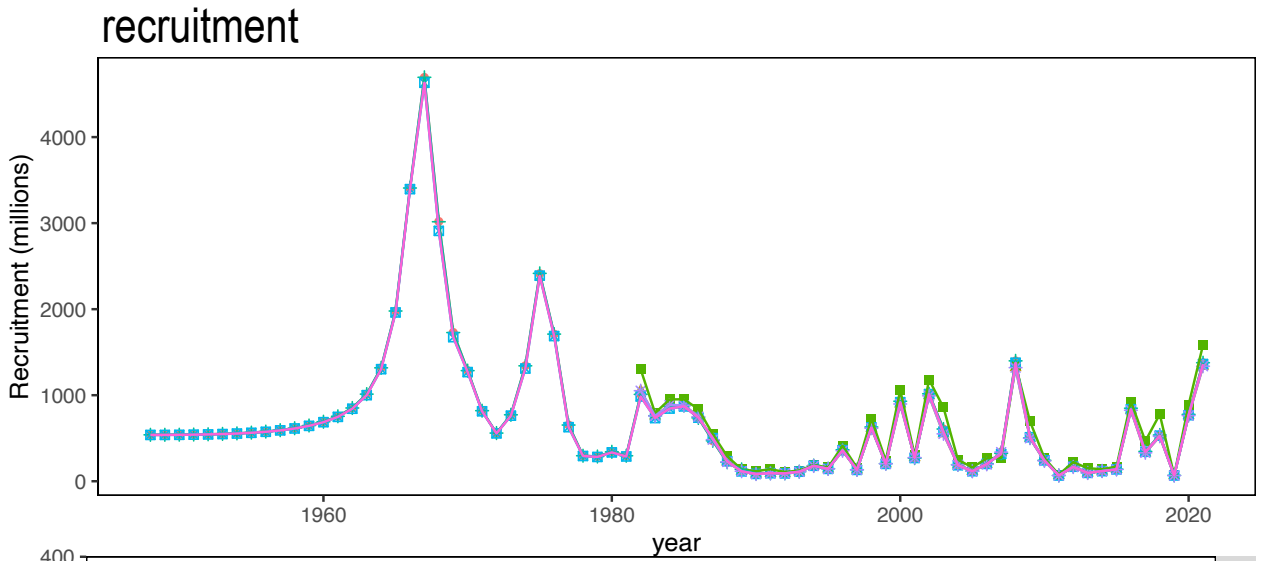


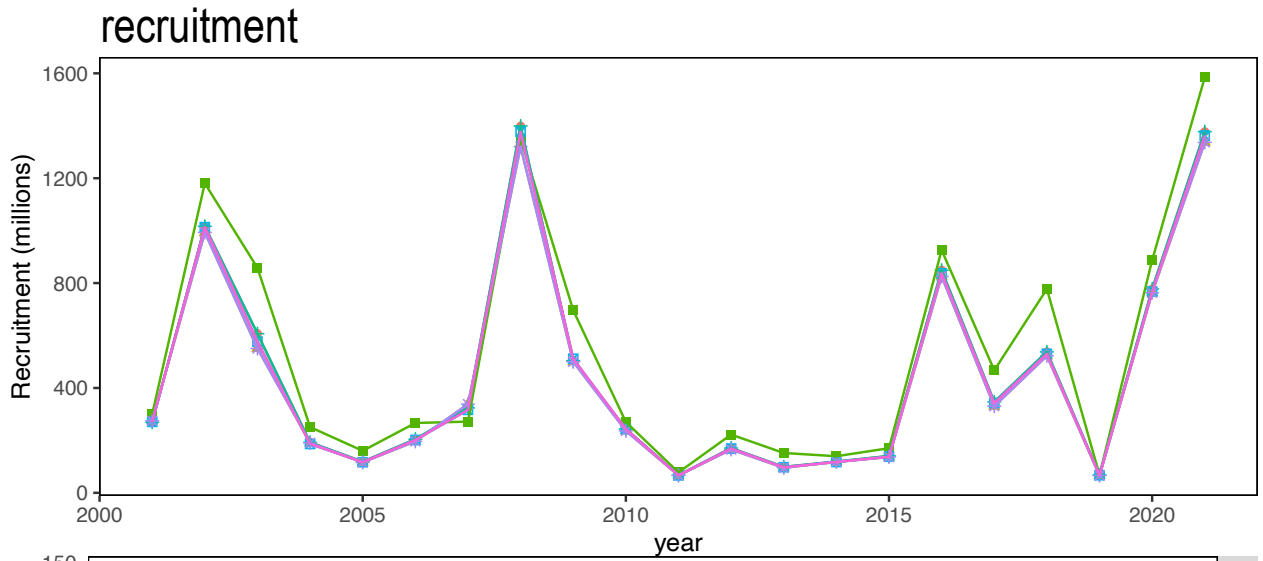


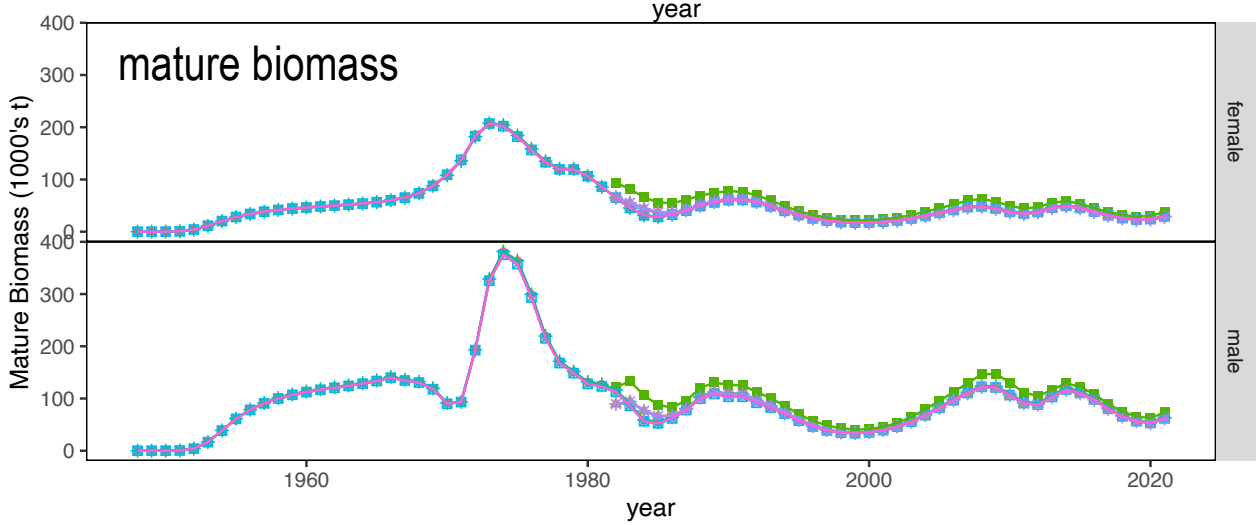
Population Results: Cohort Progression

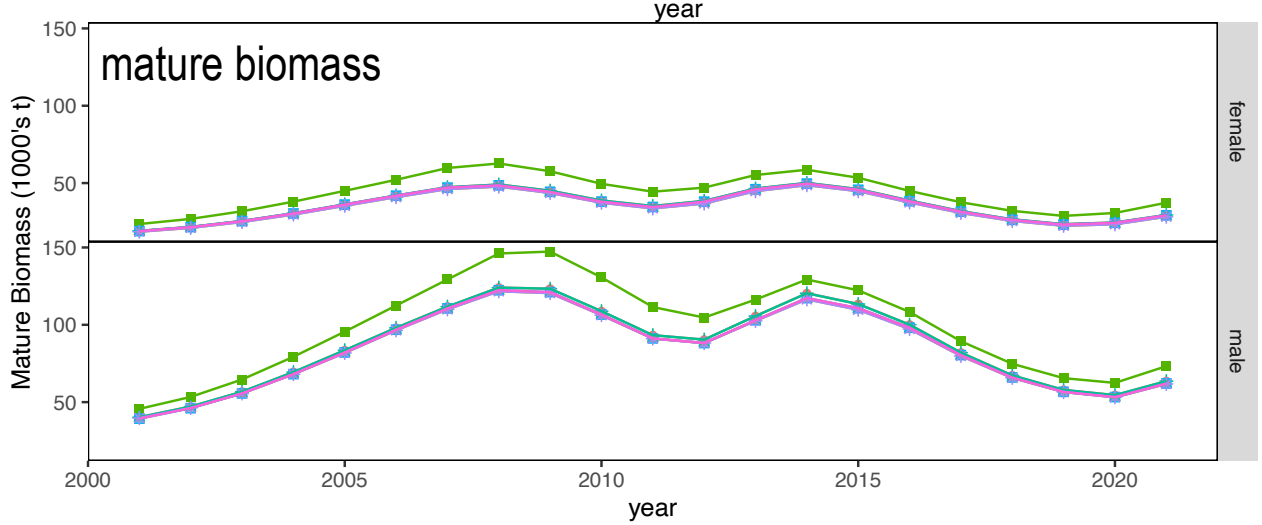


Population Results: Recruitment and MMB

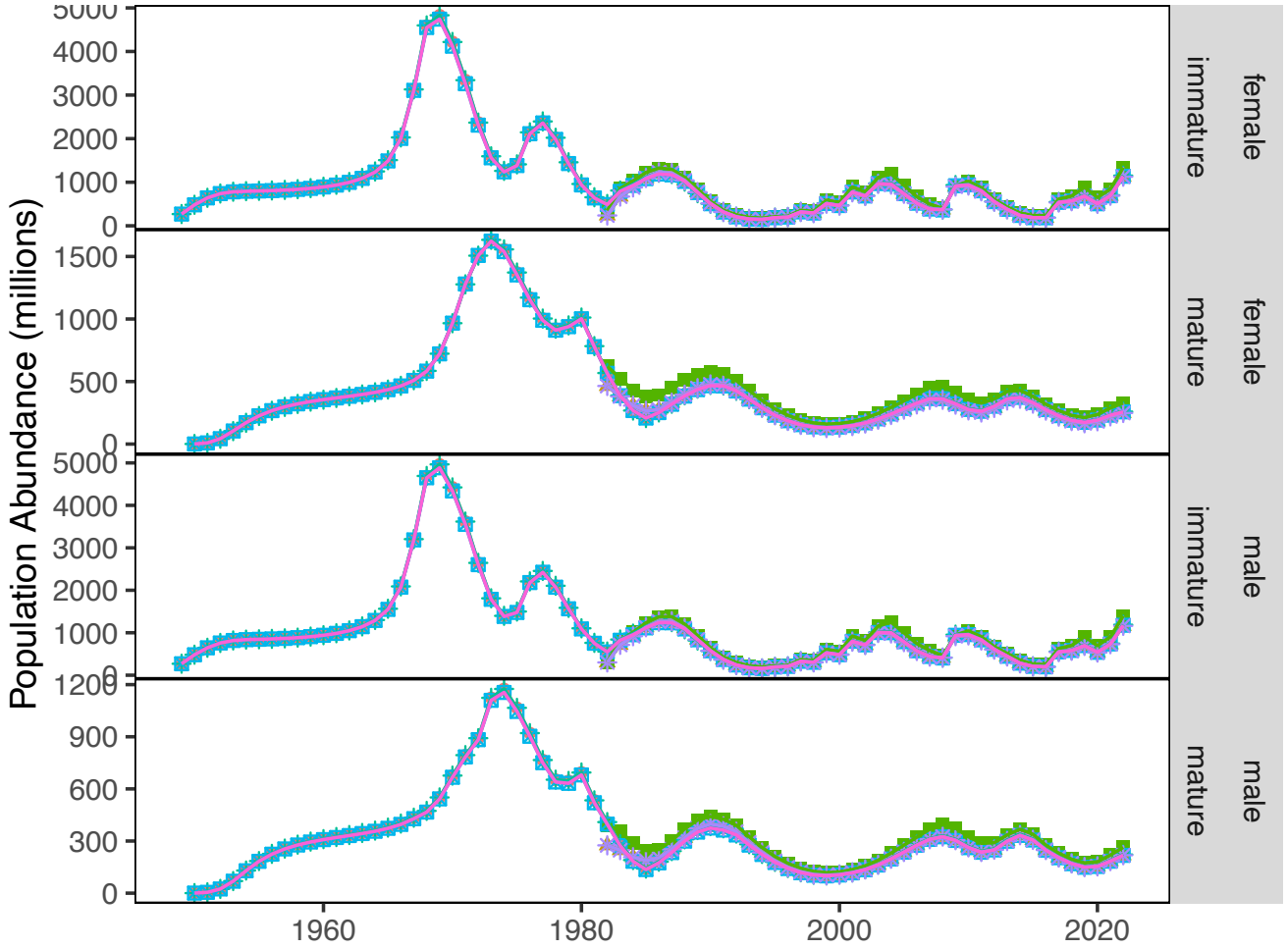


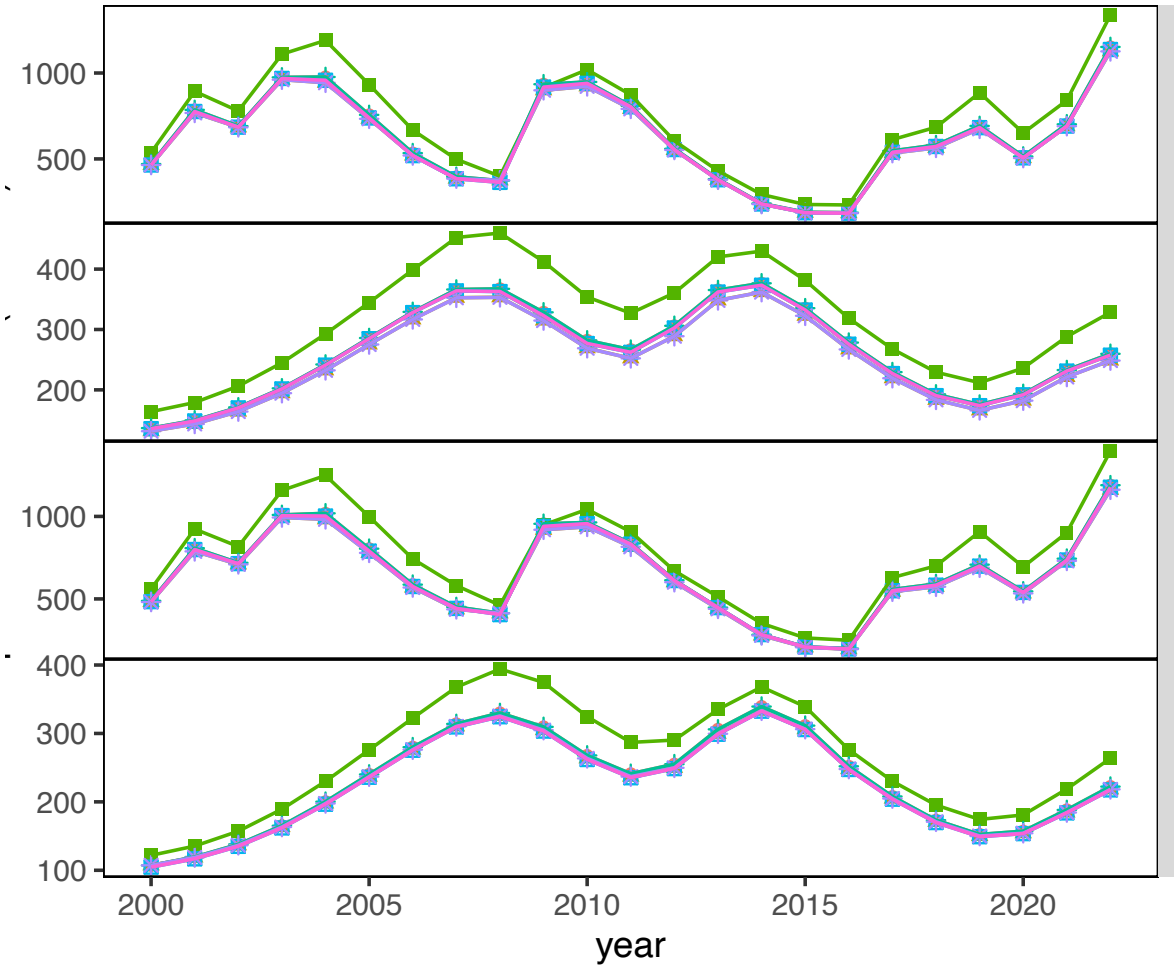




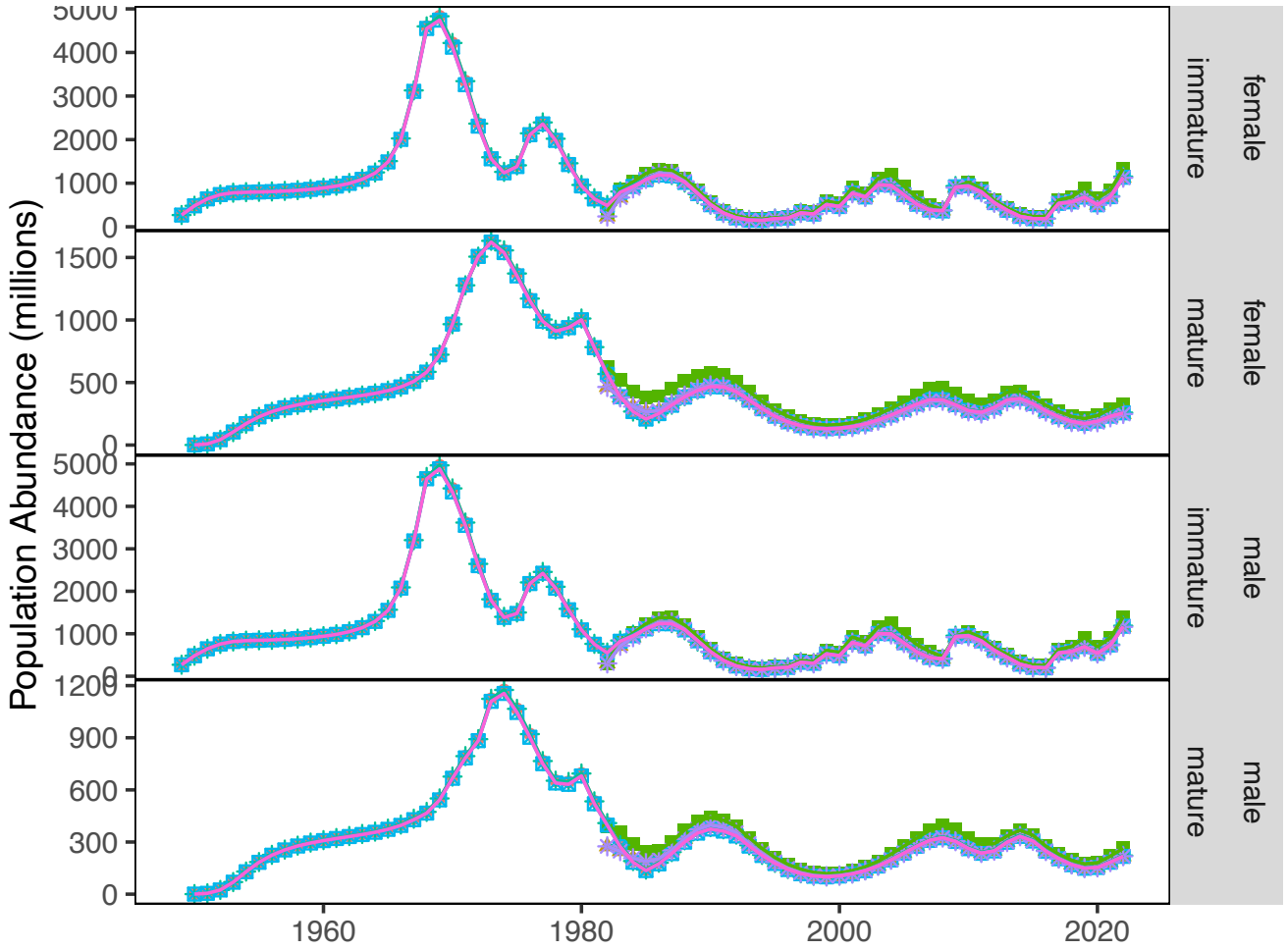


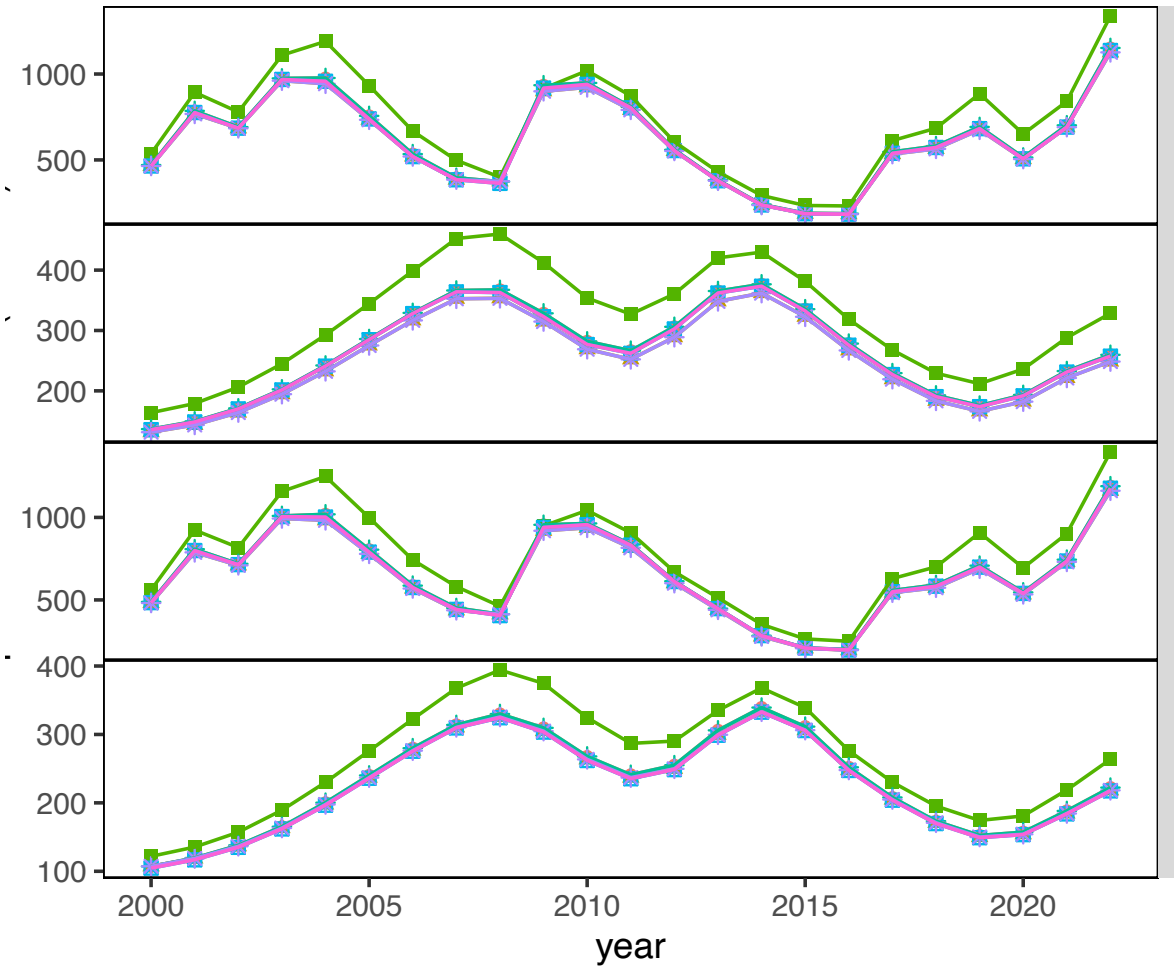
Population Results: Biomass



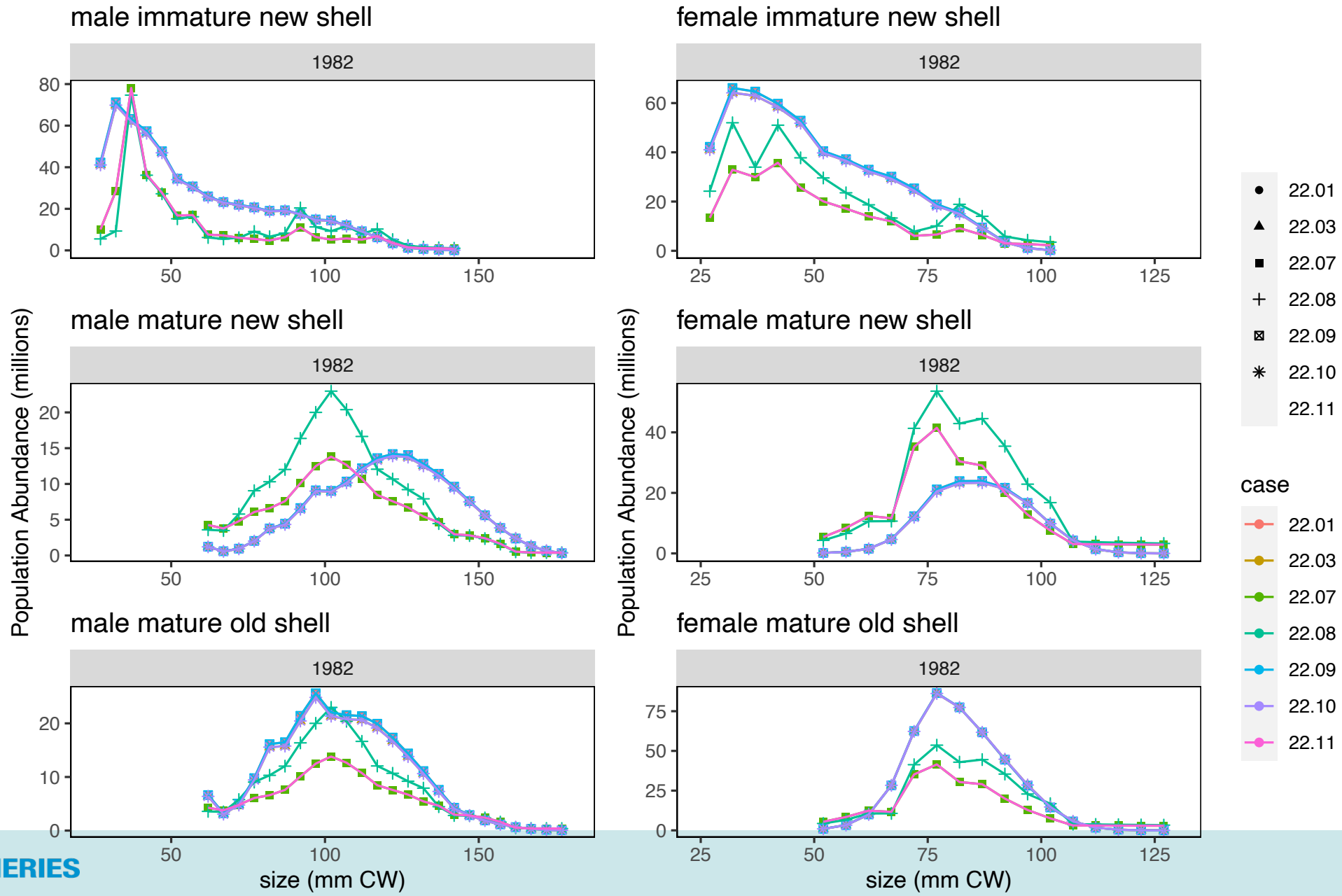


Population Results: Abundance



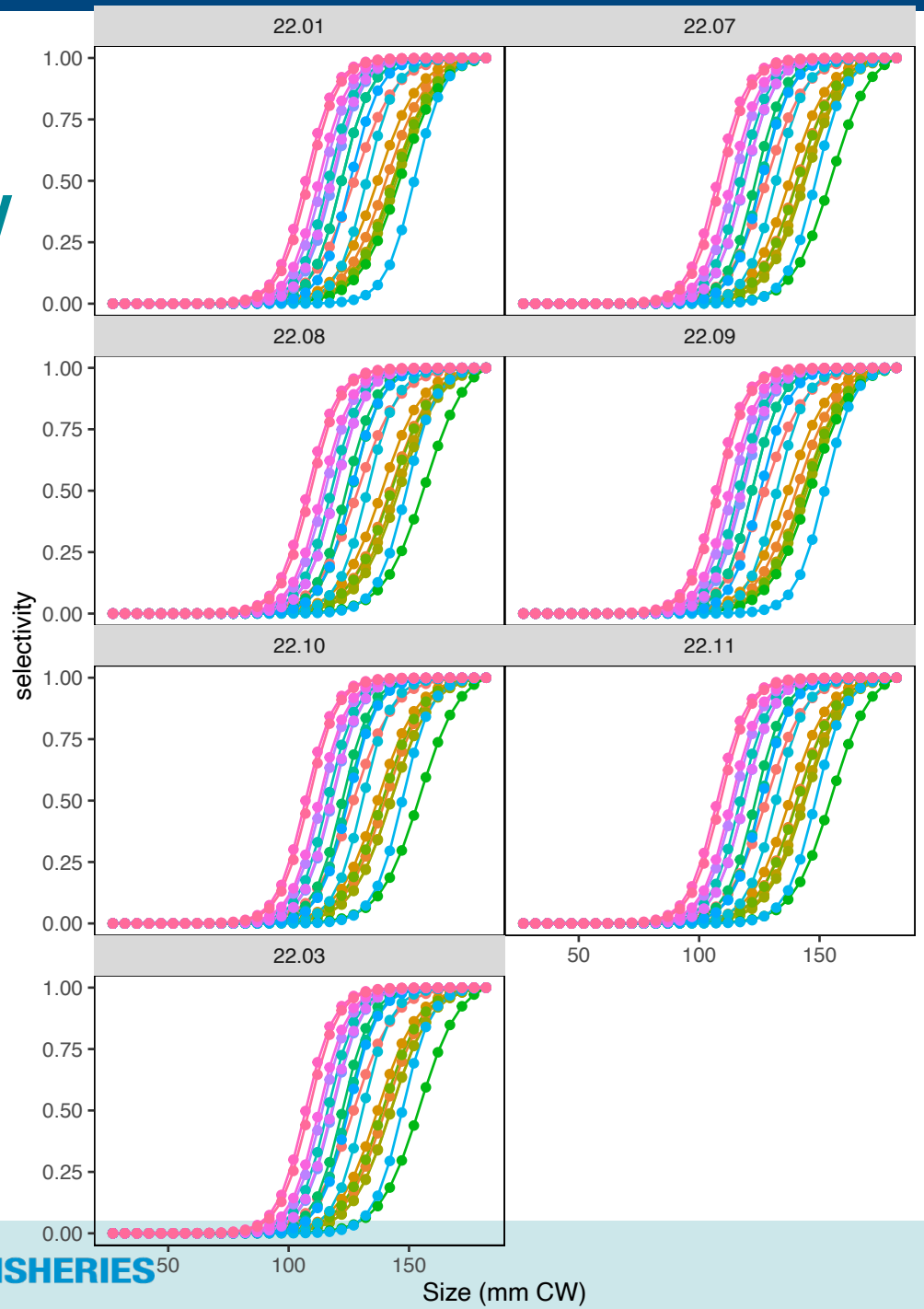


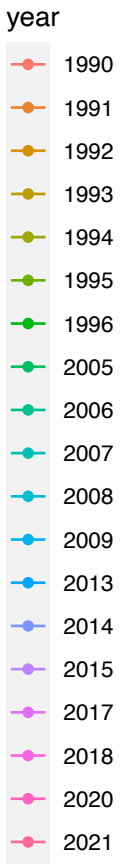
Population Results: 1982 Abundance-at-Size

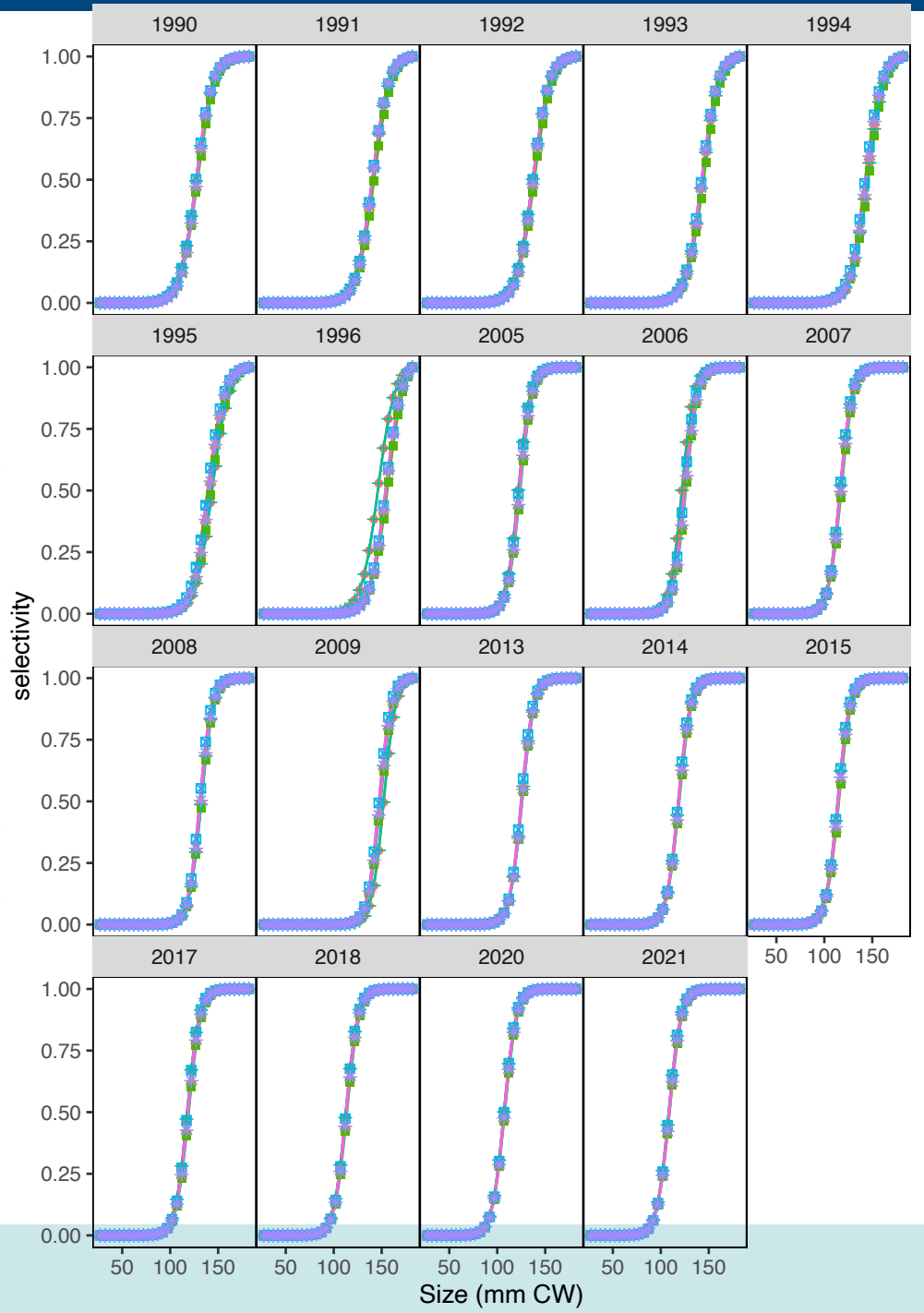


Fishery Selectivity

Directed Fishery



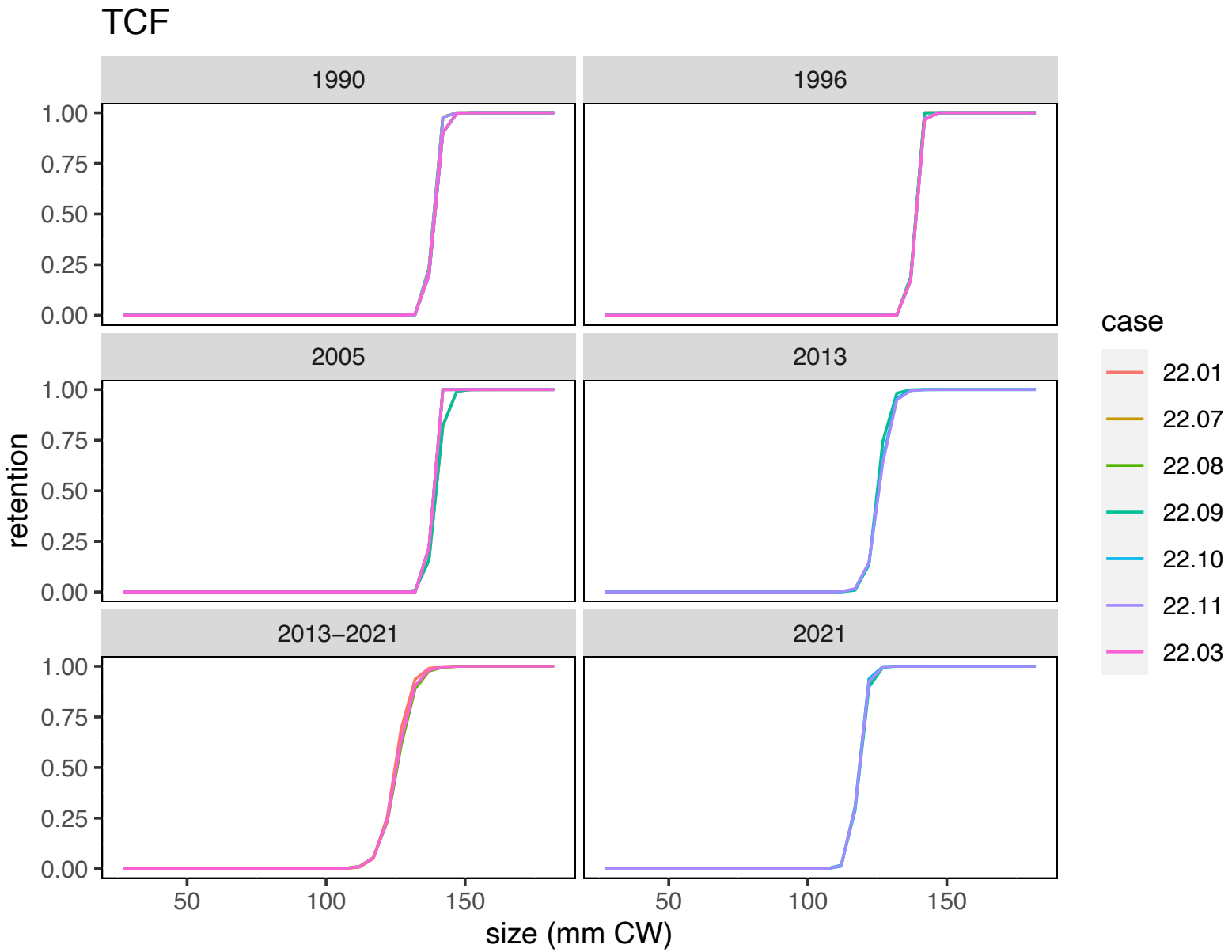




NOAA FISHERIES

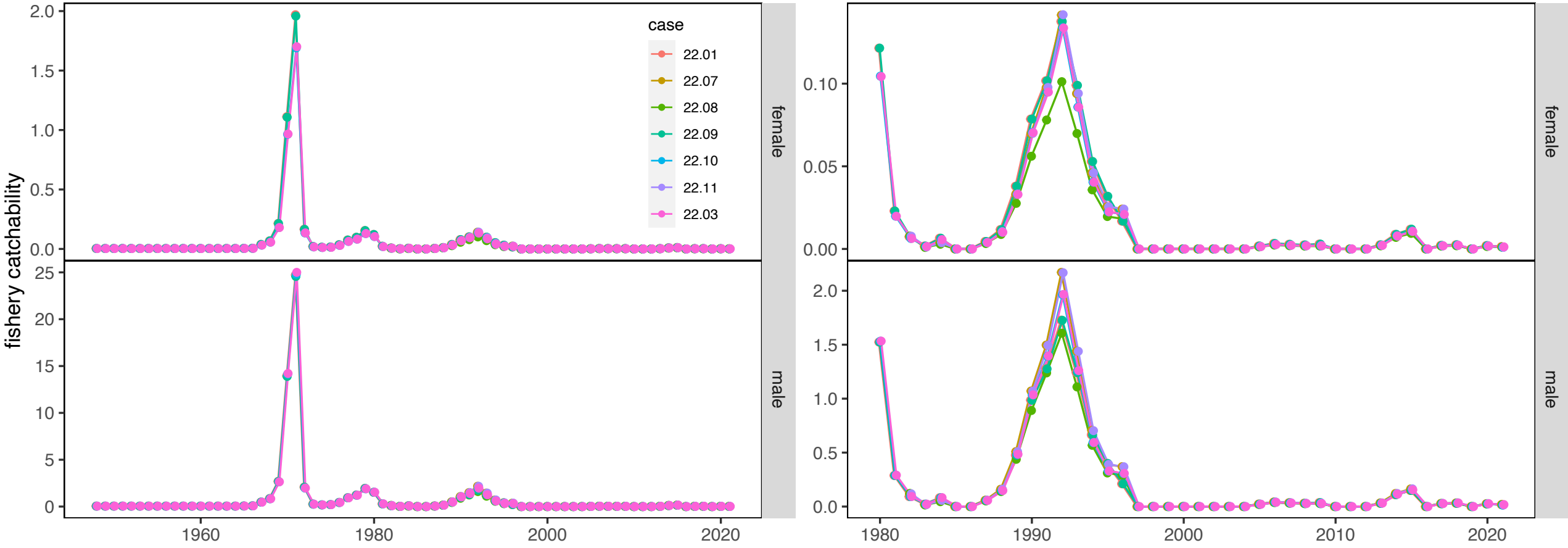
Fishery Retention

Directed Fishery

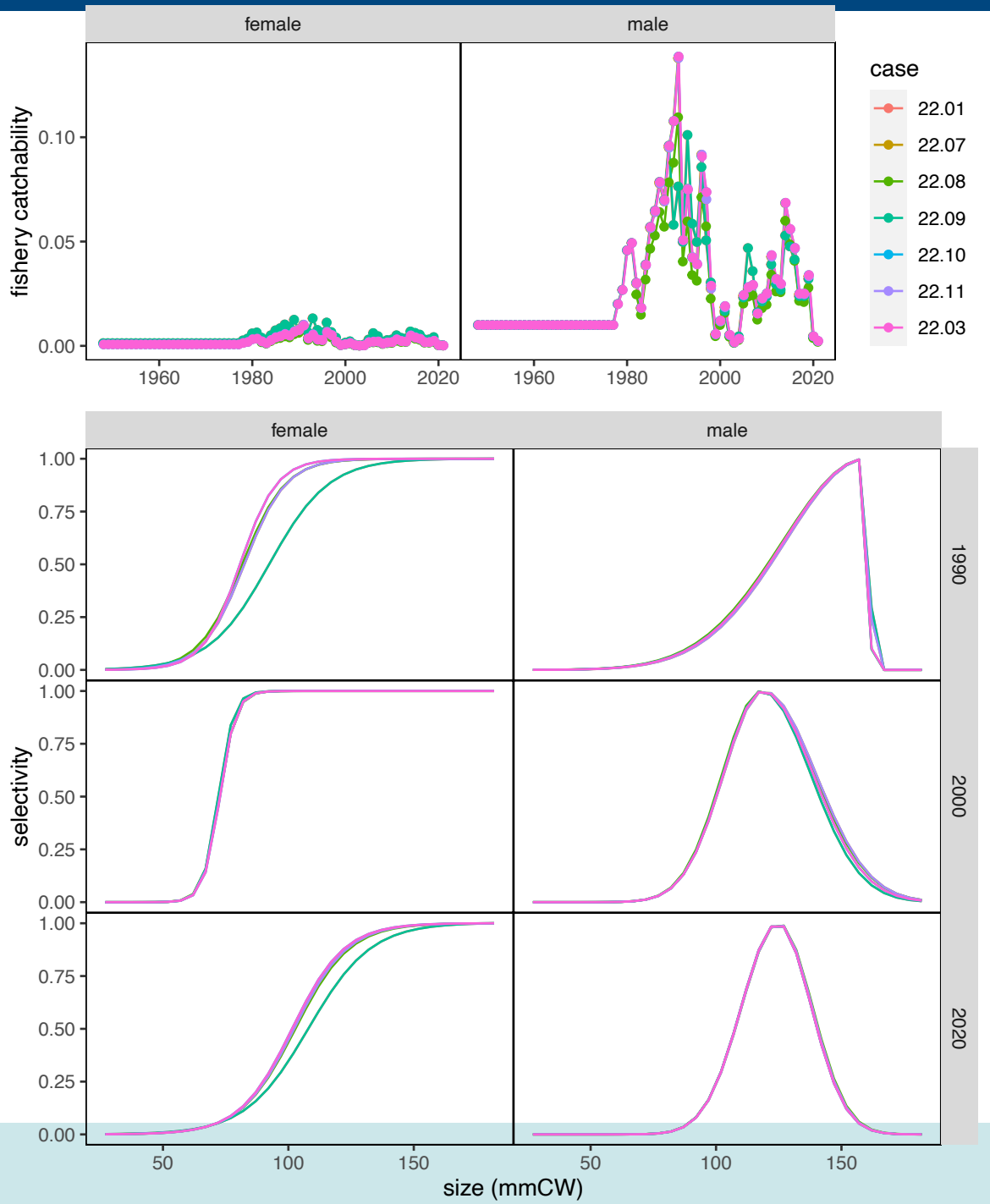


Fully-selected fishing catchability (mortality)

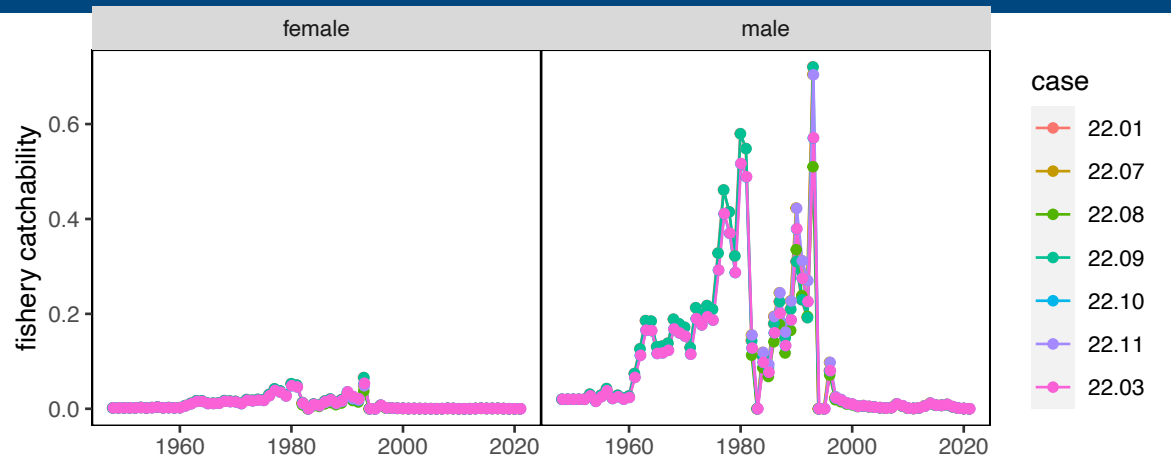
Directed Fishery

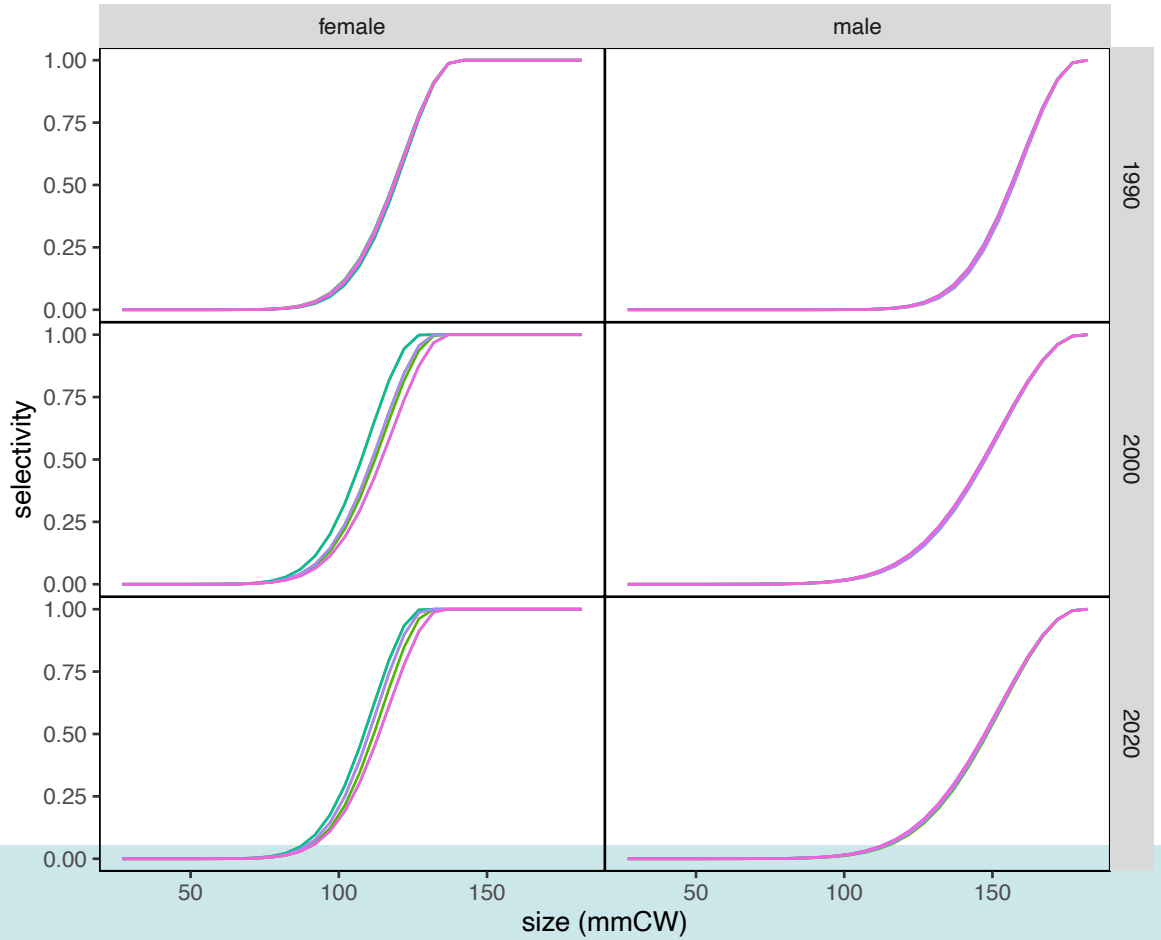


Fishery characteristics: snow crab fishery

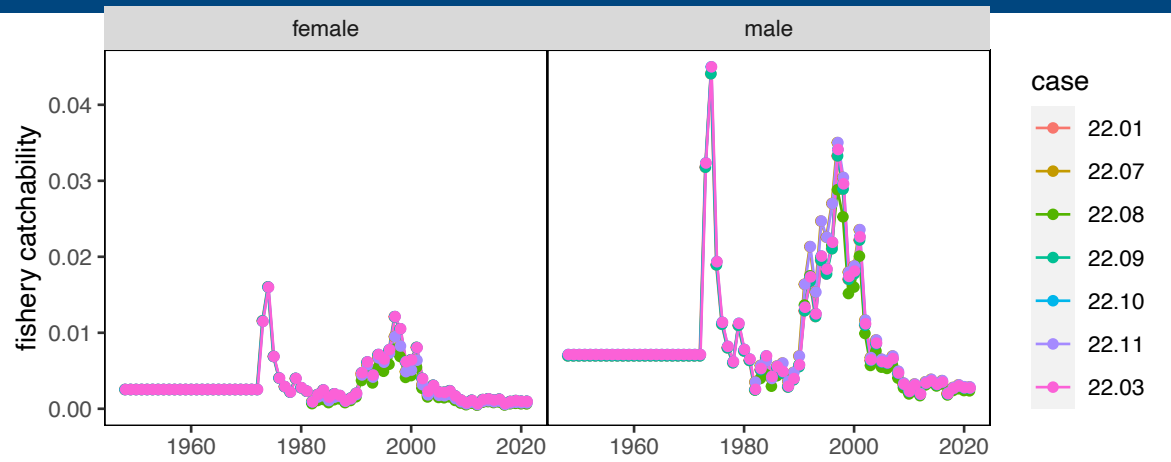


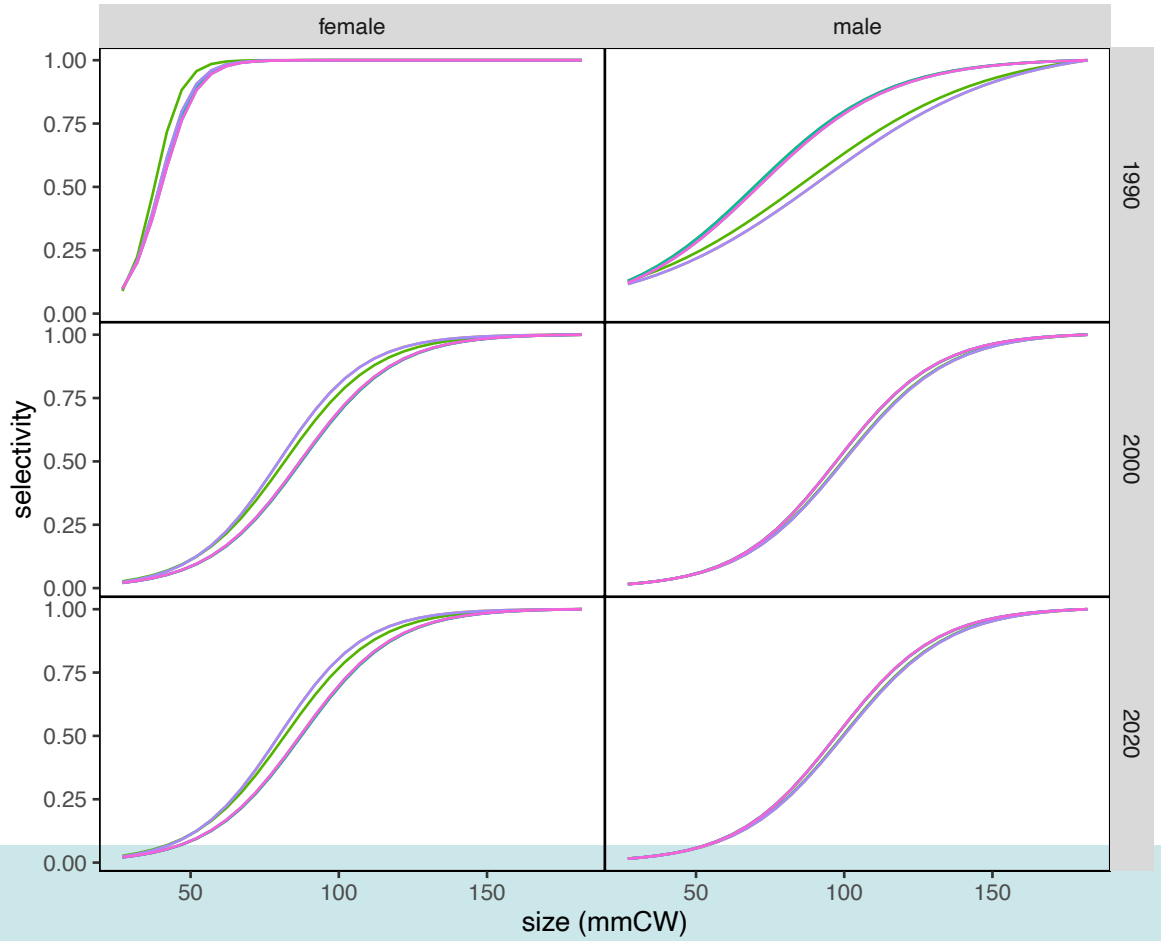
Fishery characteristics: BBRKC



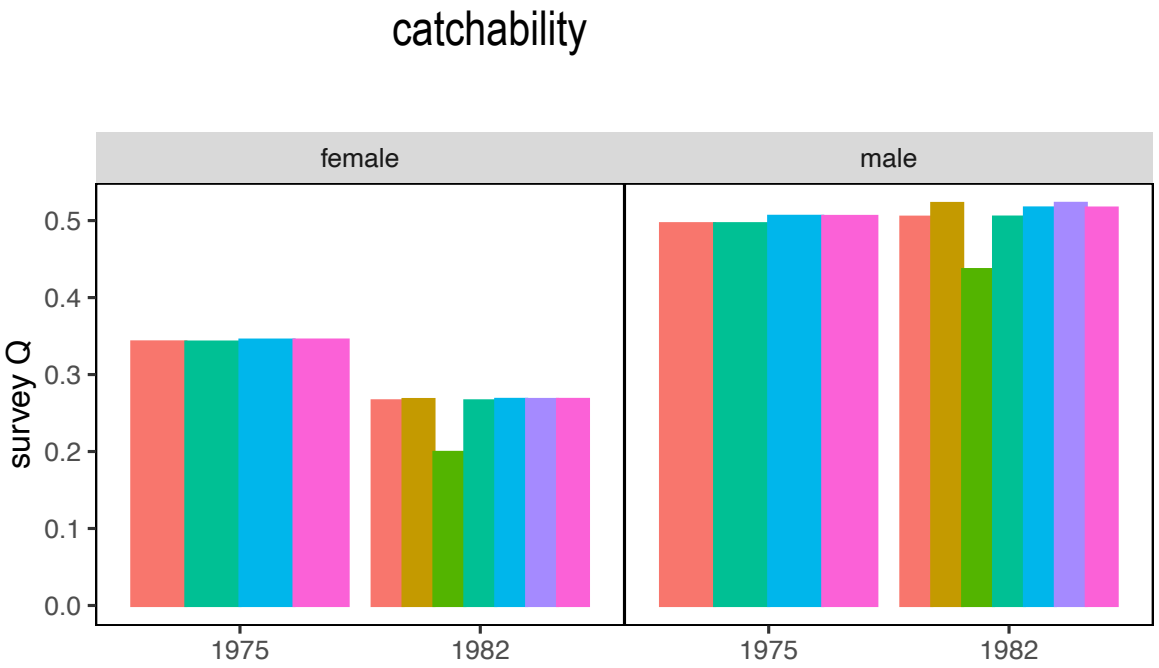


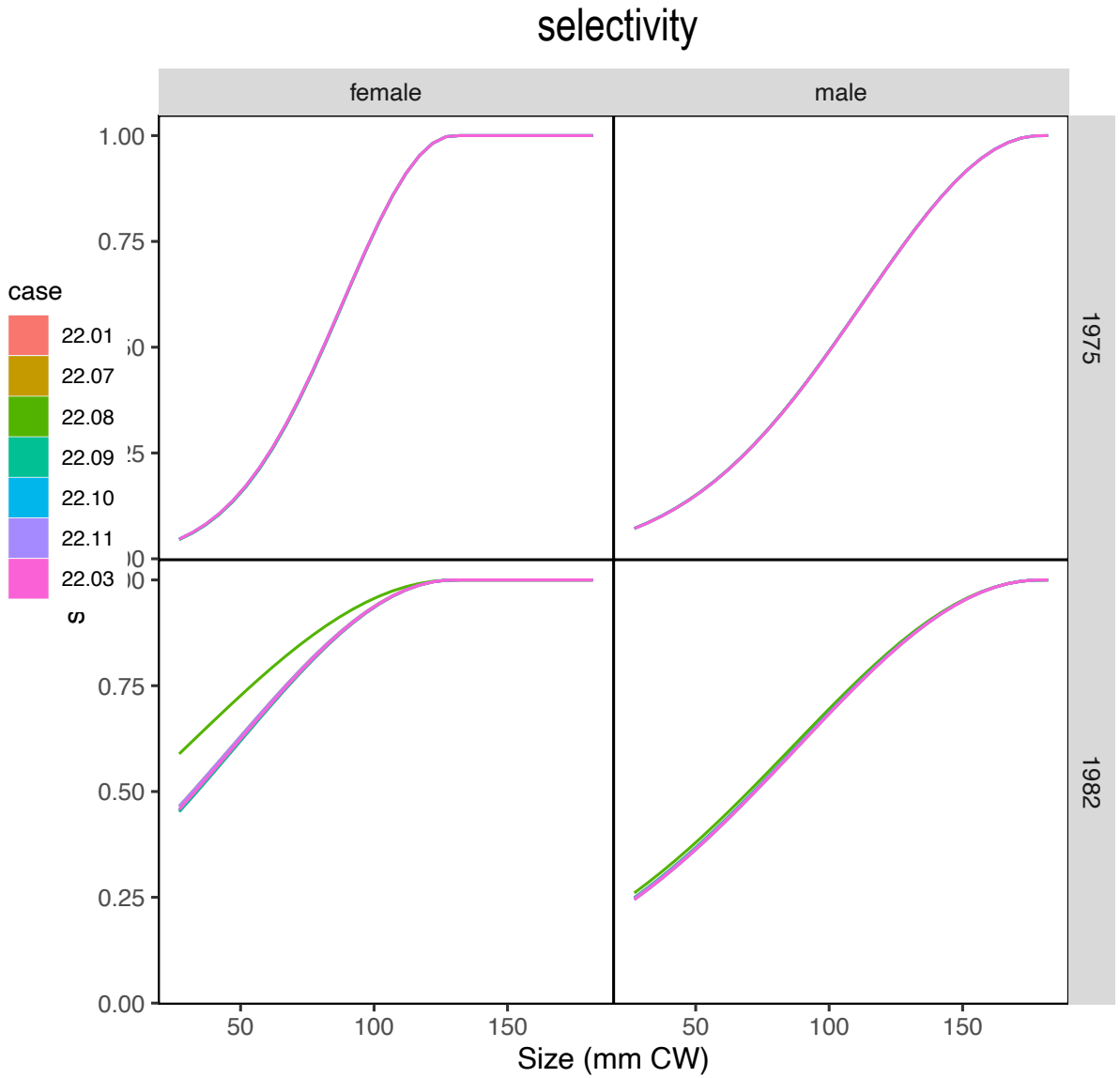
Fishery characteristics: groundfish fisheries





Survey Estimates





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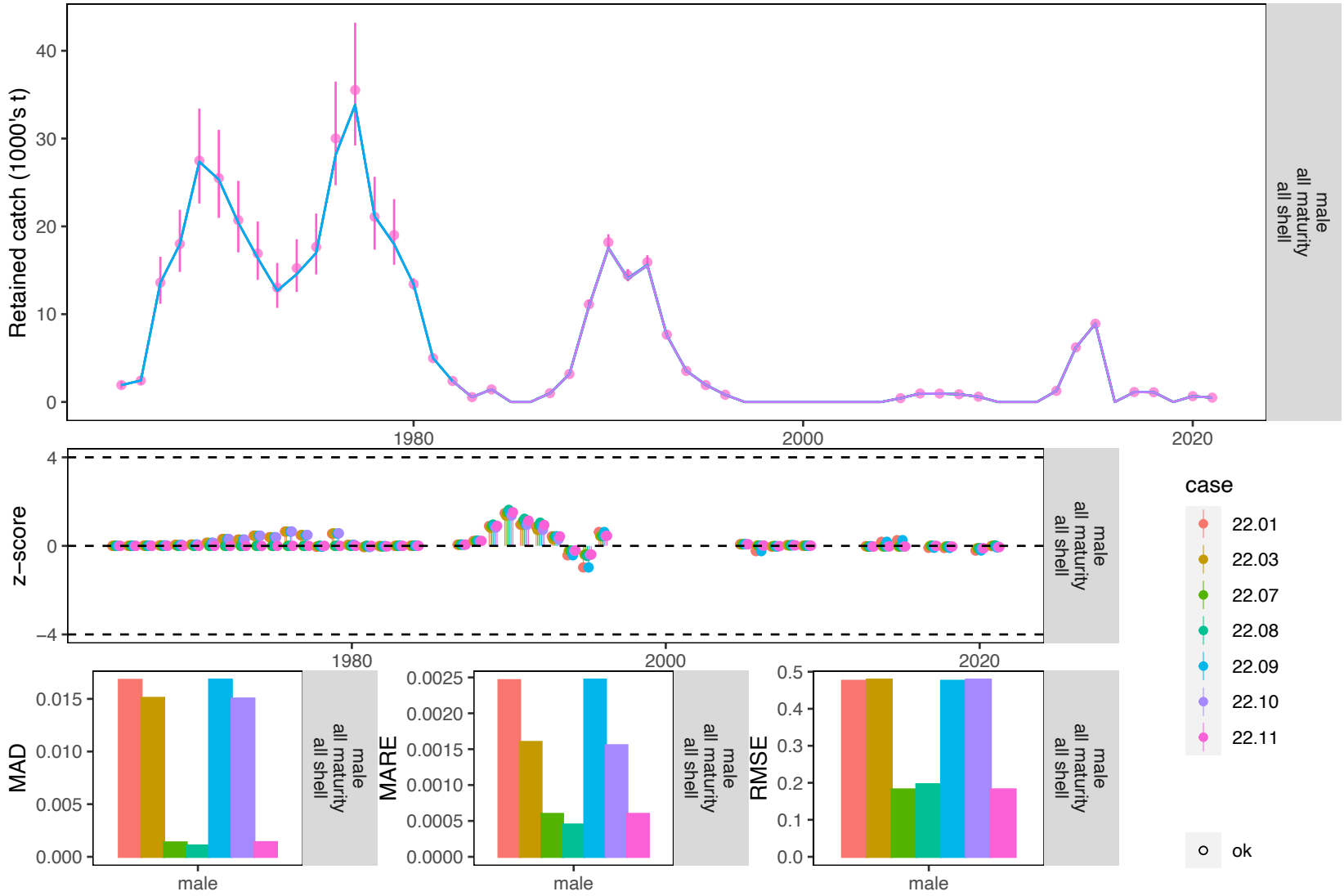
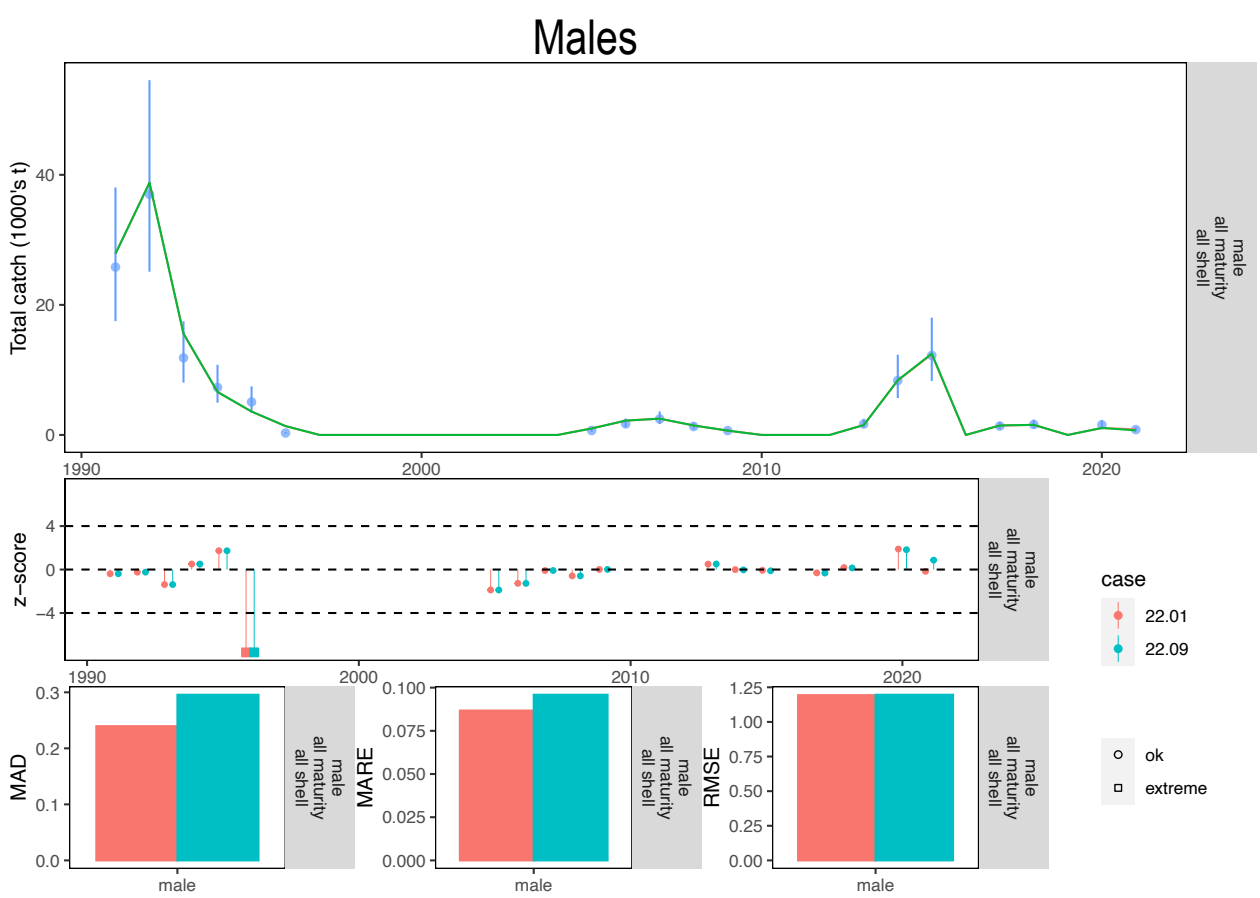
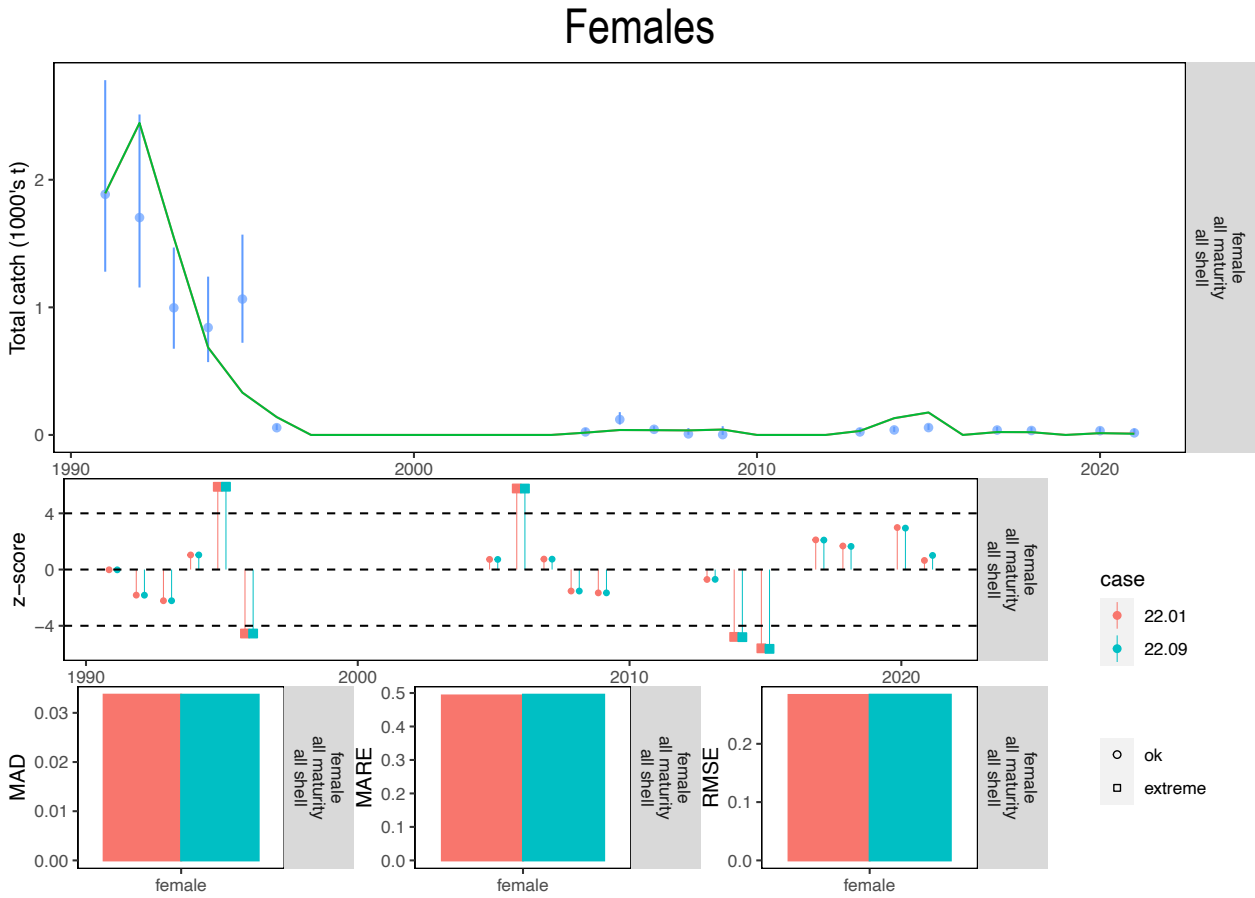
Fits to Data: Retained Catch

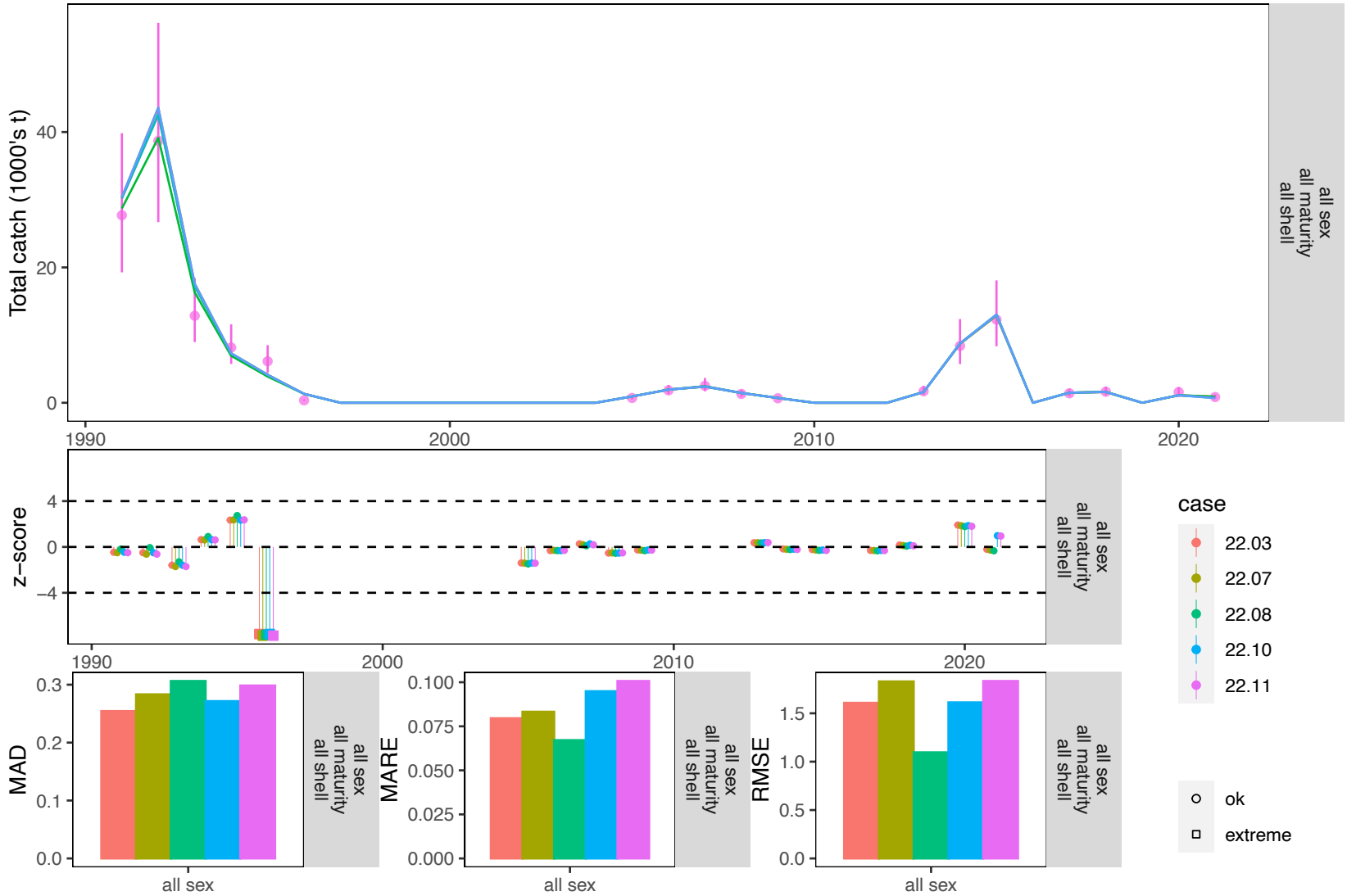


Fits to Data: Directed Fishery Total Catch (22.01, 22.09)

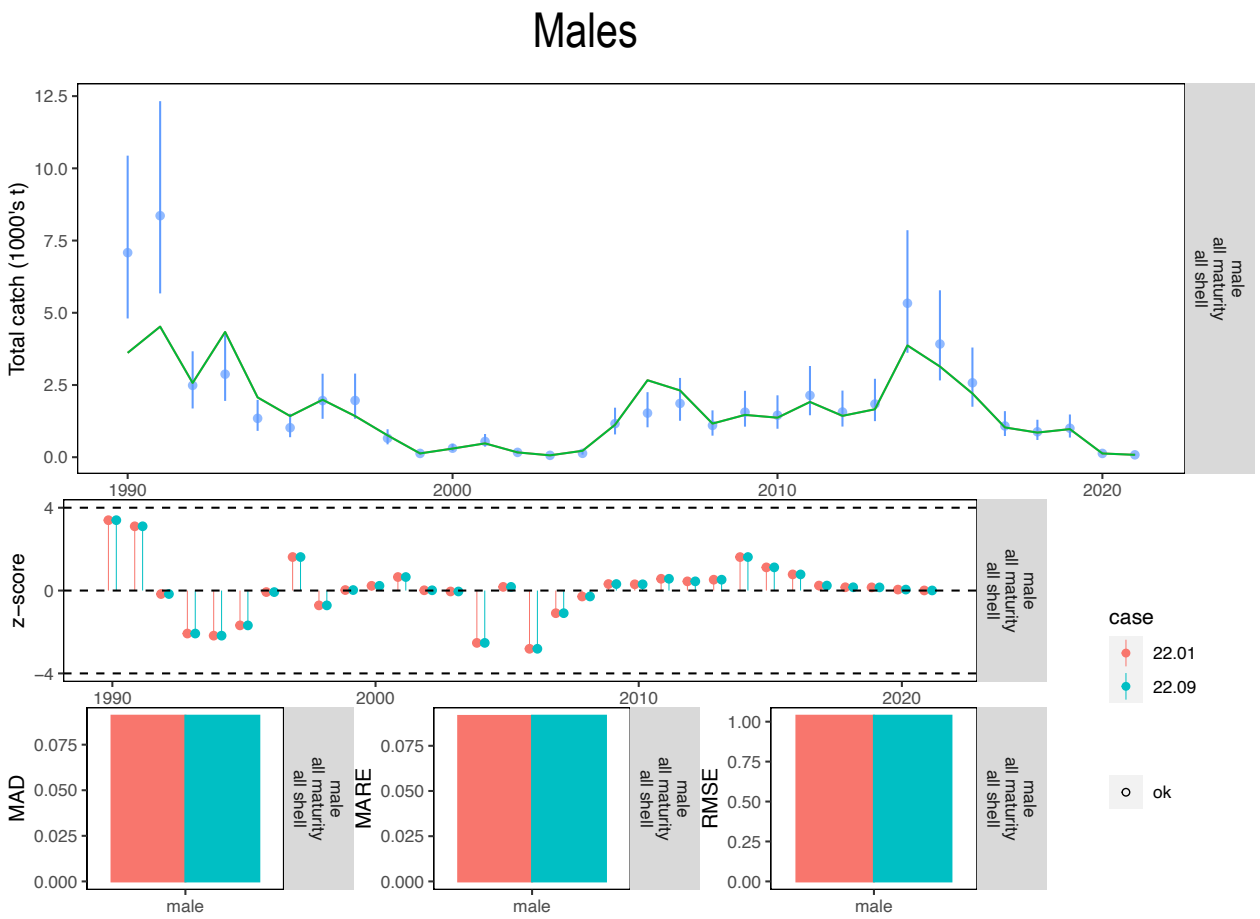


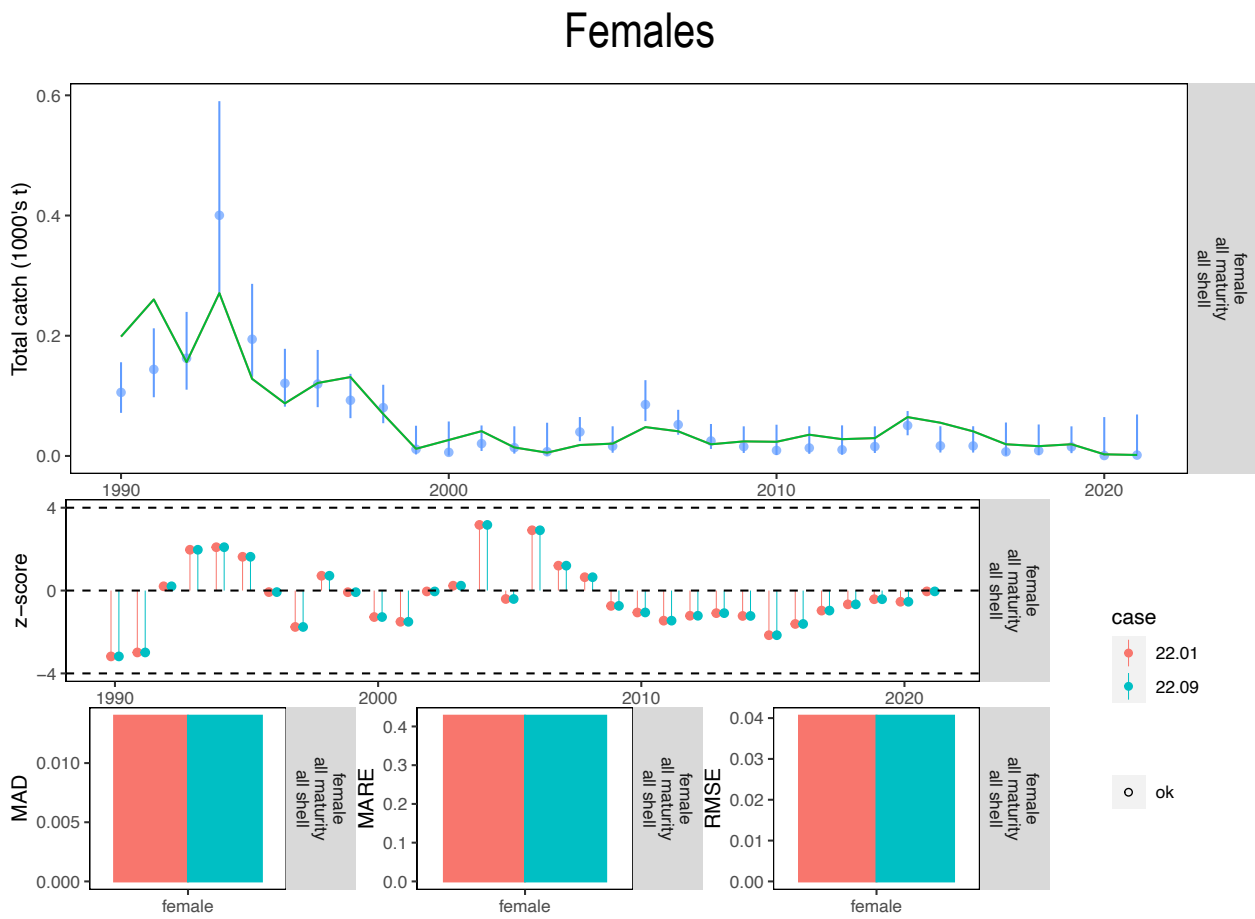


Fits to Data: Directed Fishery Total Catch (other models)

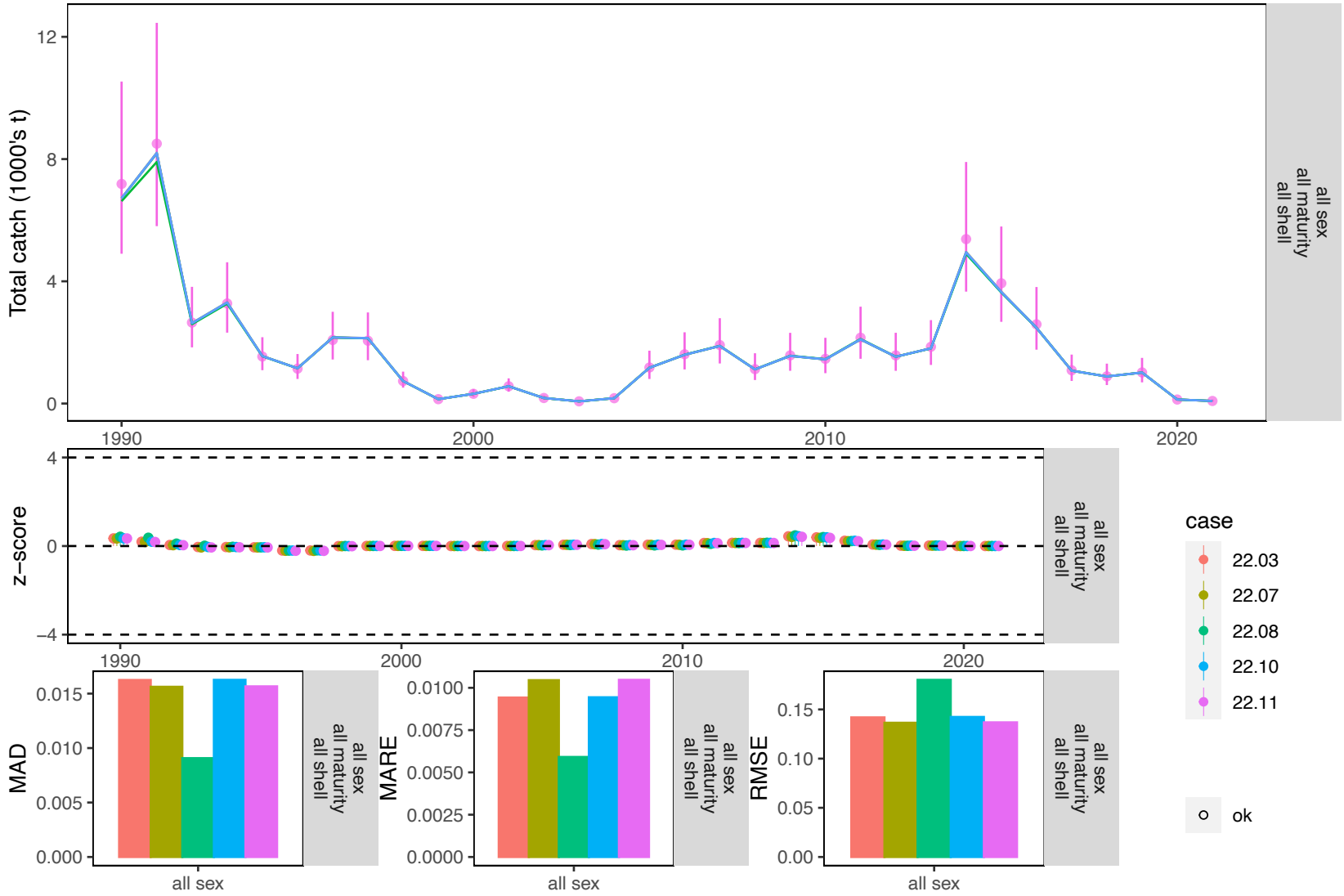


Fits to Data: Bycatch in Snow Crab Fishery (22.01, 22.09)

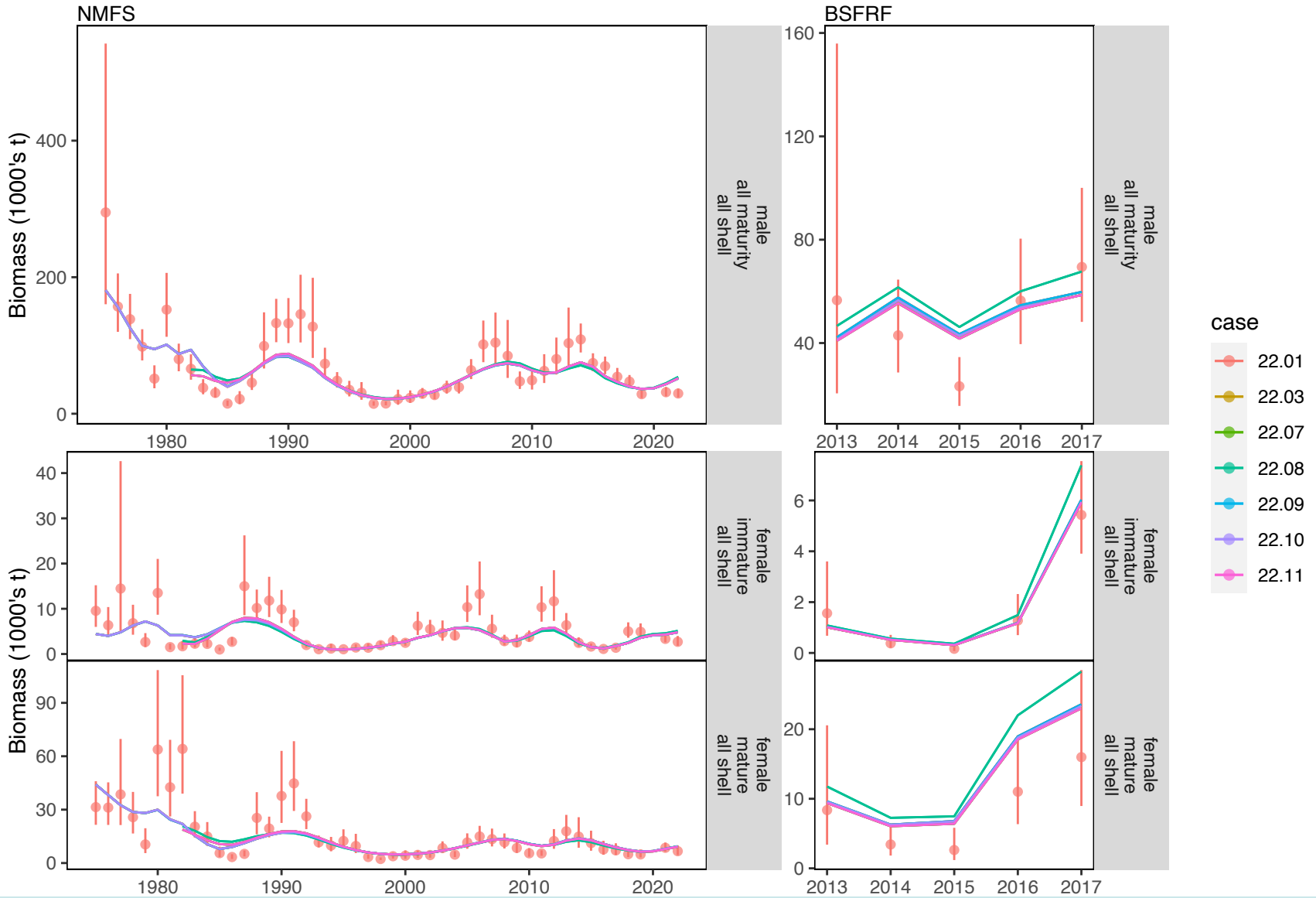




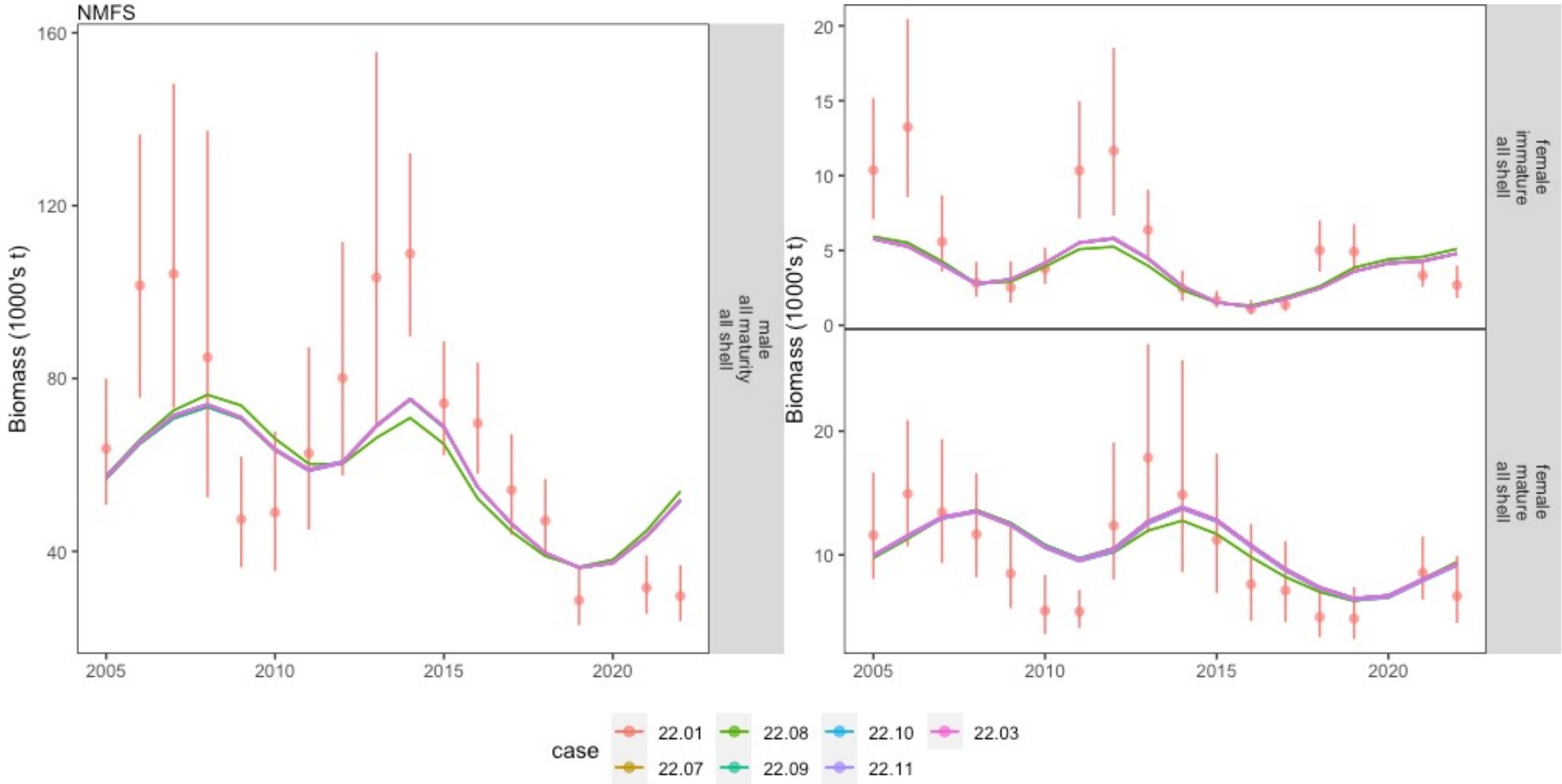
Fits to Data: Bycatch in Snow Crab Fishery (other models)



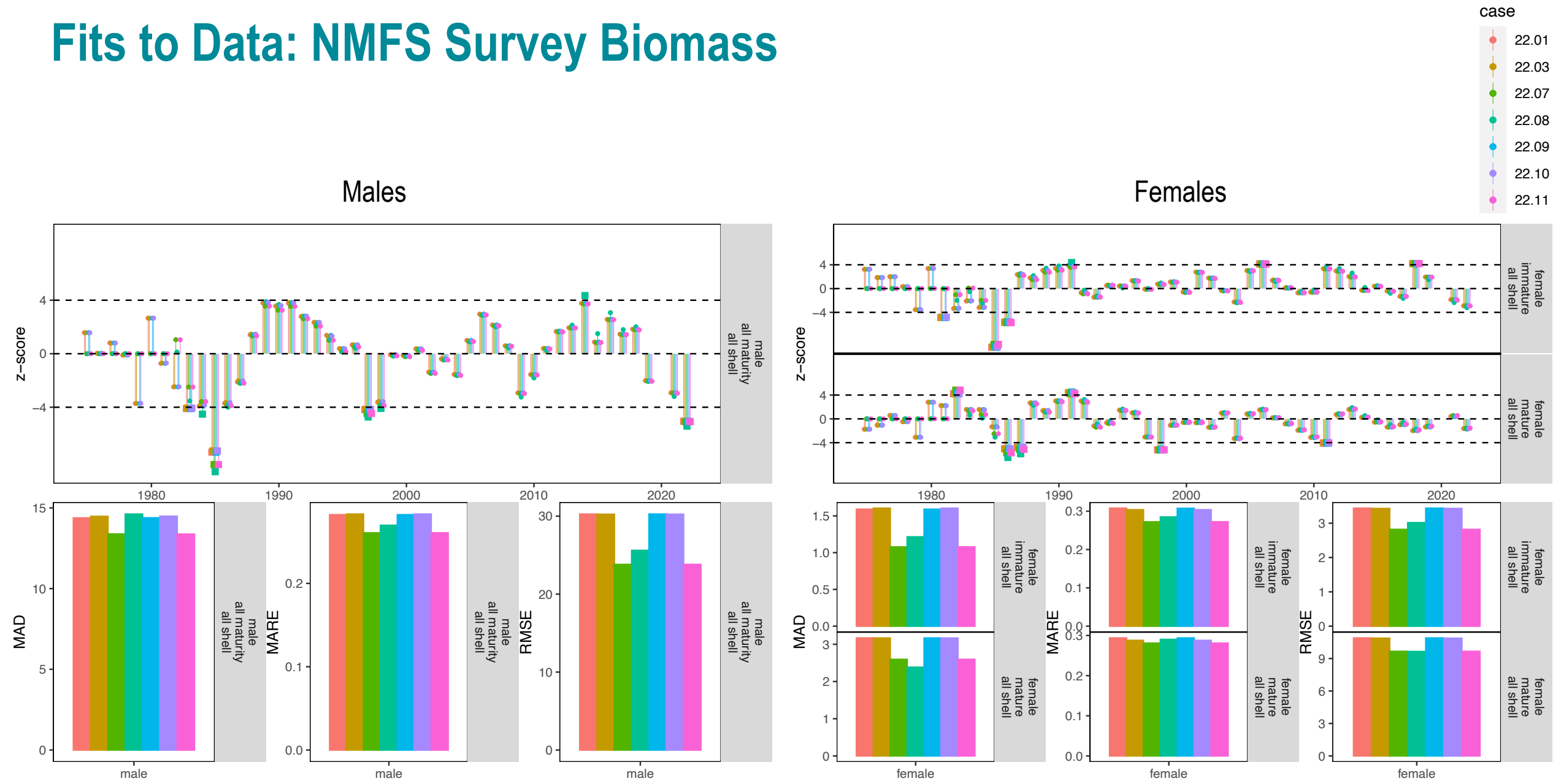
Fits to Data: Survey Biomass



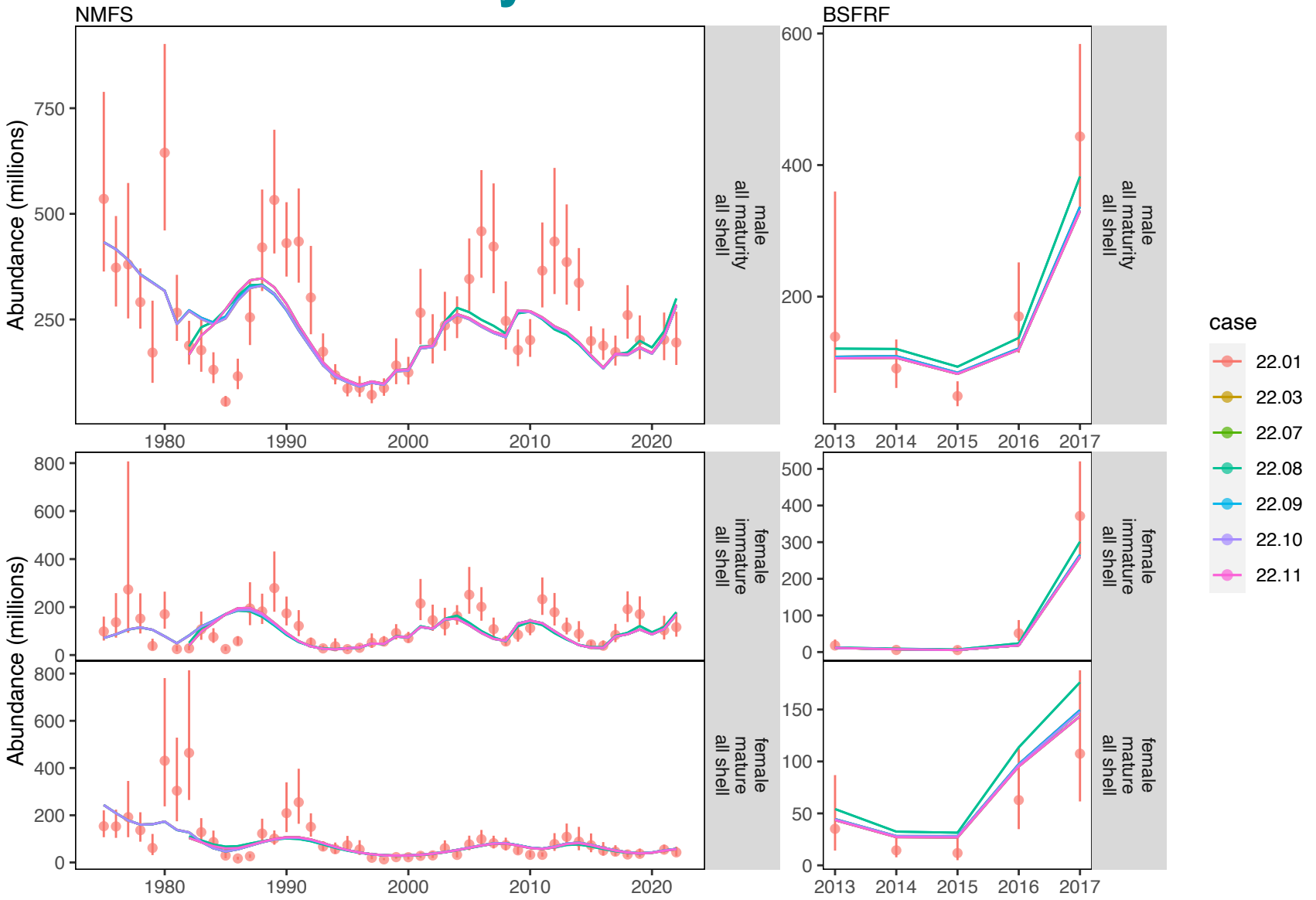
Fits to Data: Survey Biomass



Fits to Data: NMFS Survey Biomass



Diagnostic fits to NMFS Survey Abundance



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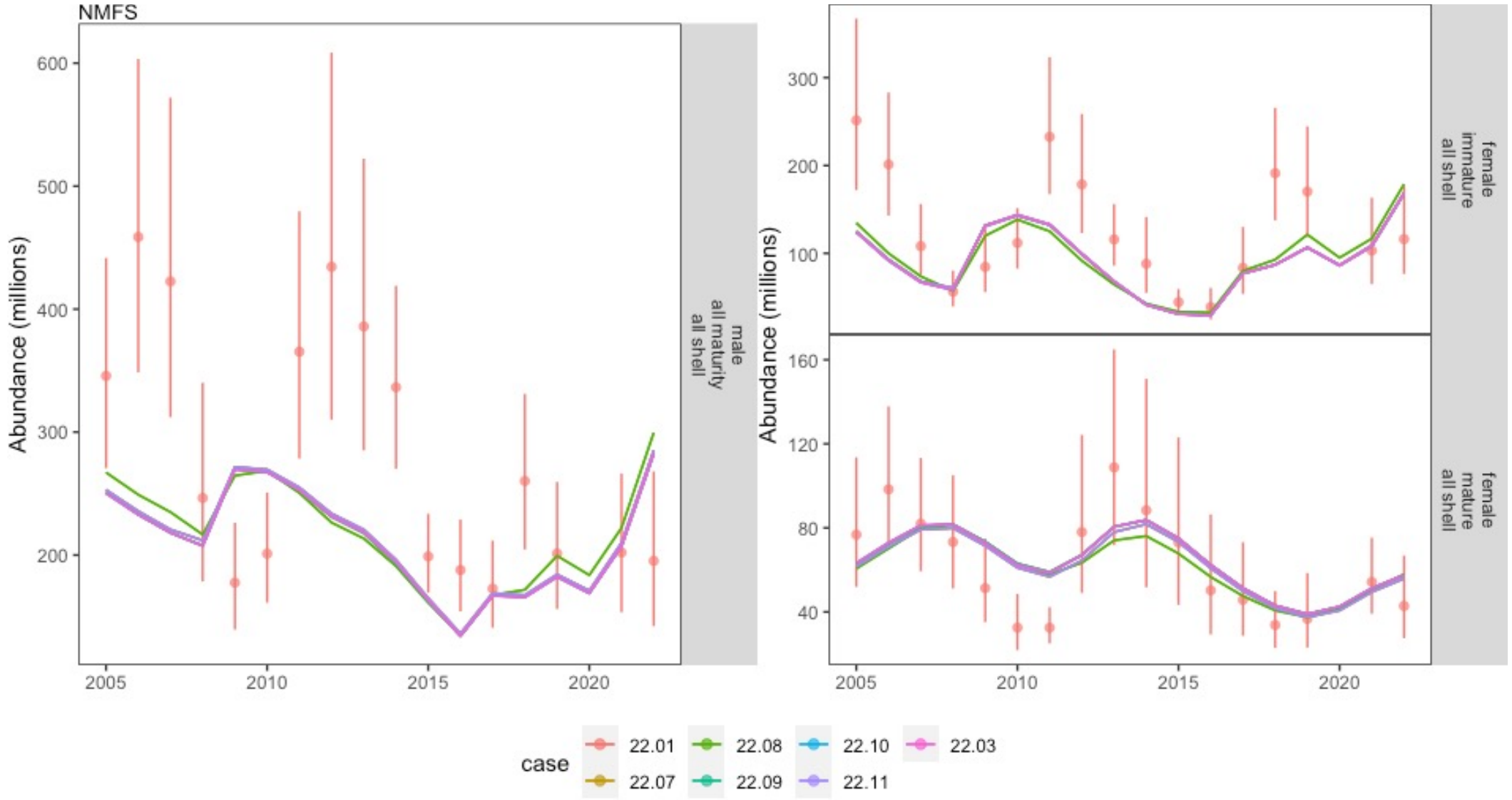

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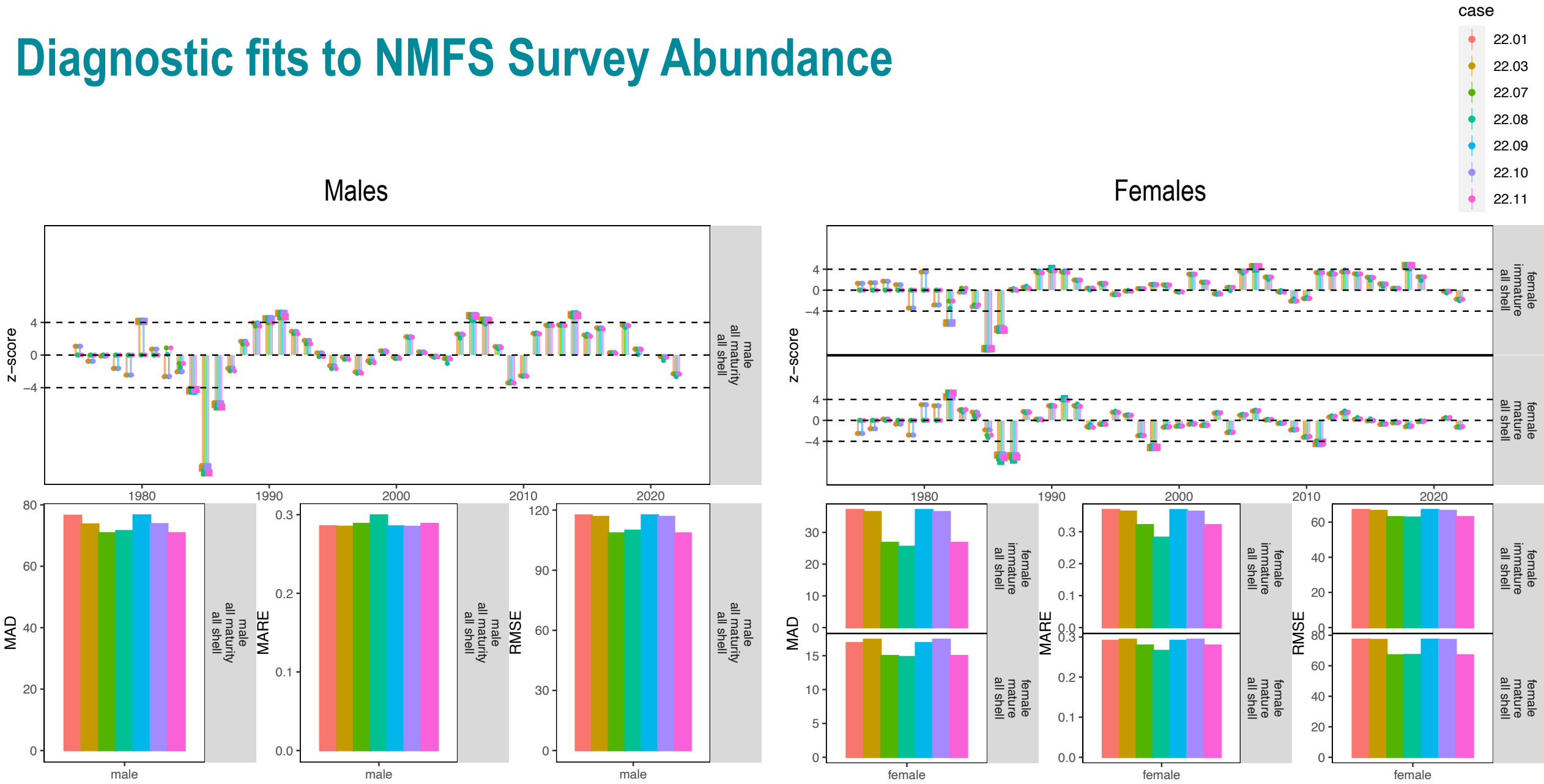
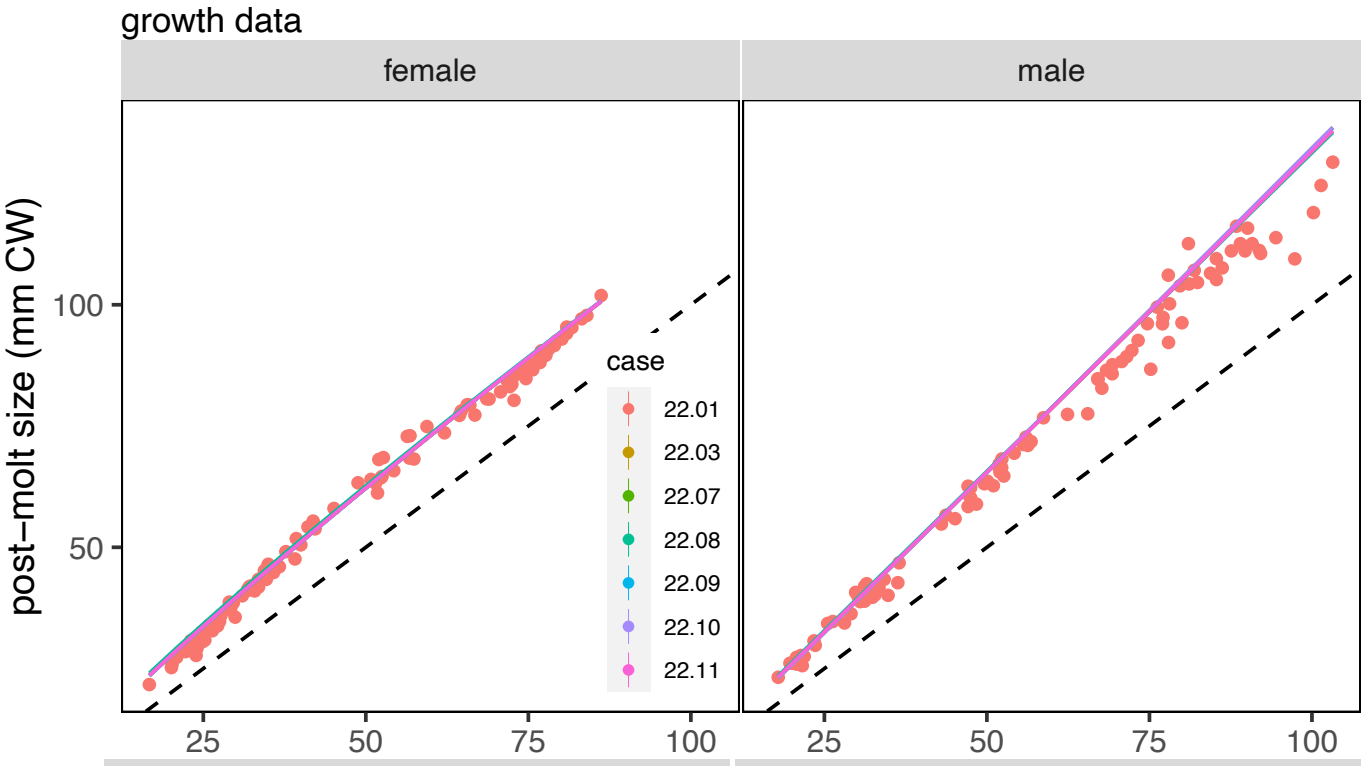
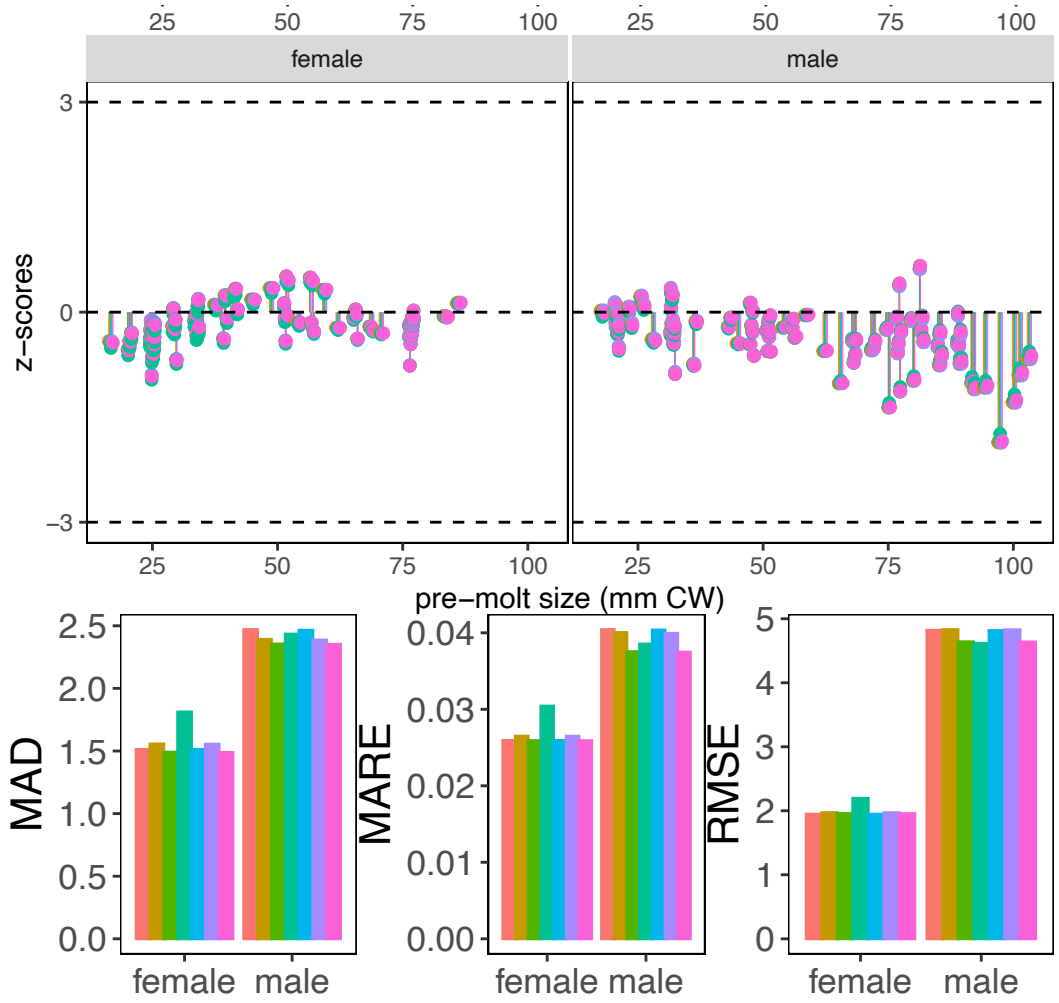
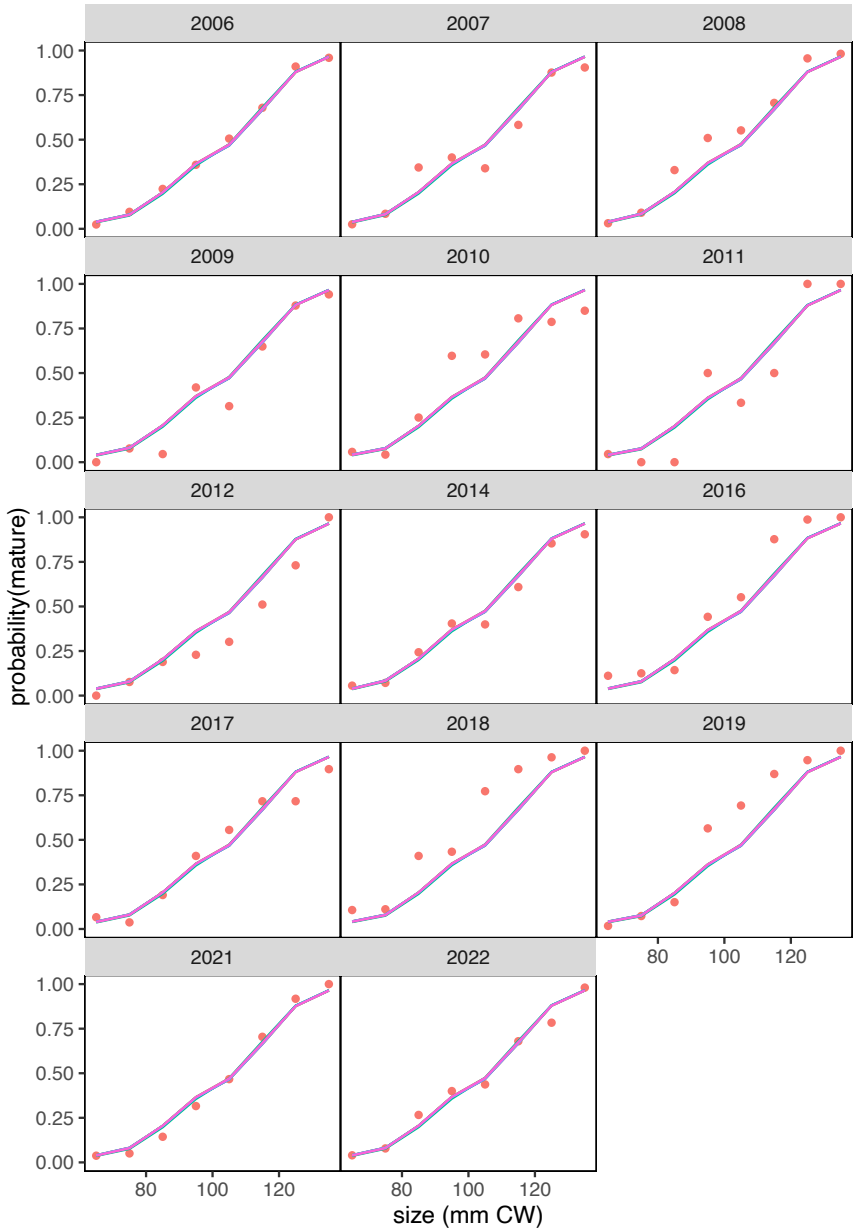


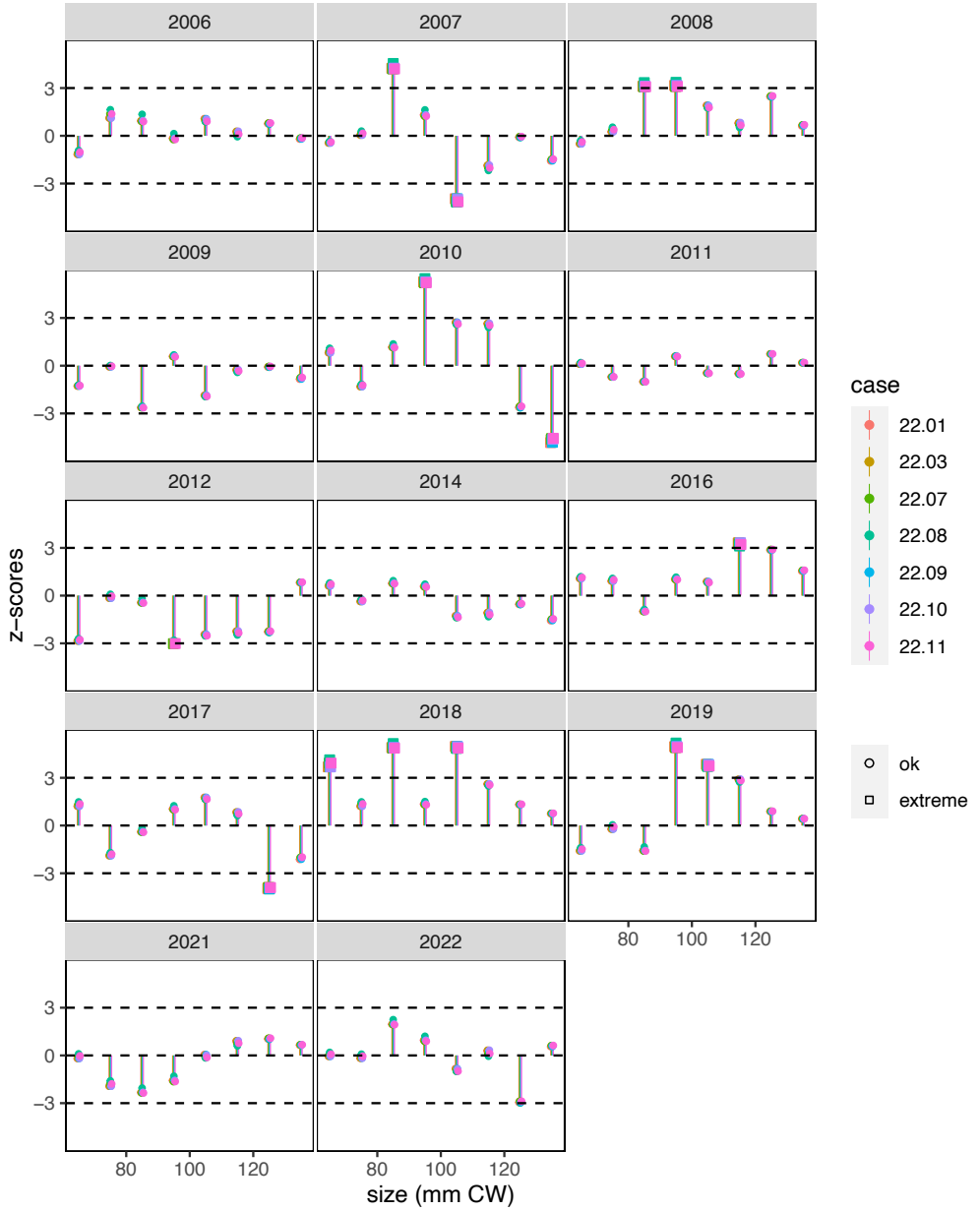
Fits to Data: Molt Increment Data



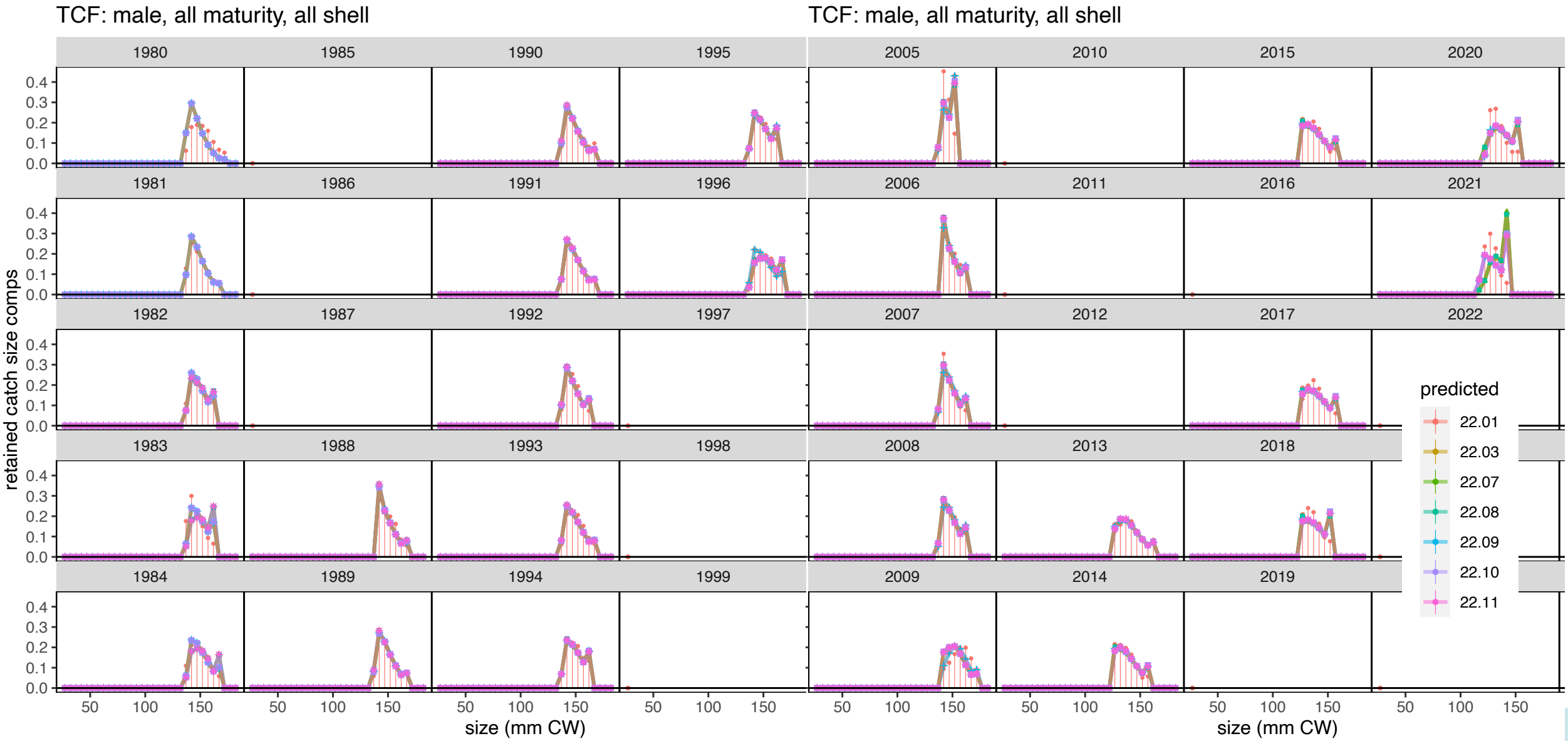


Fits to Data: Male Maturity Ogive Data

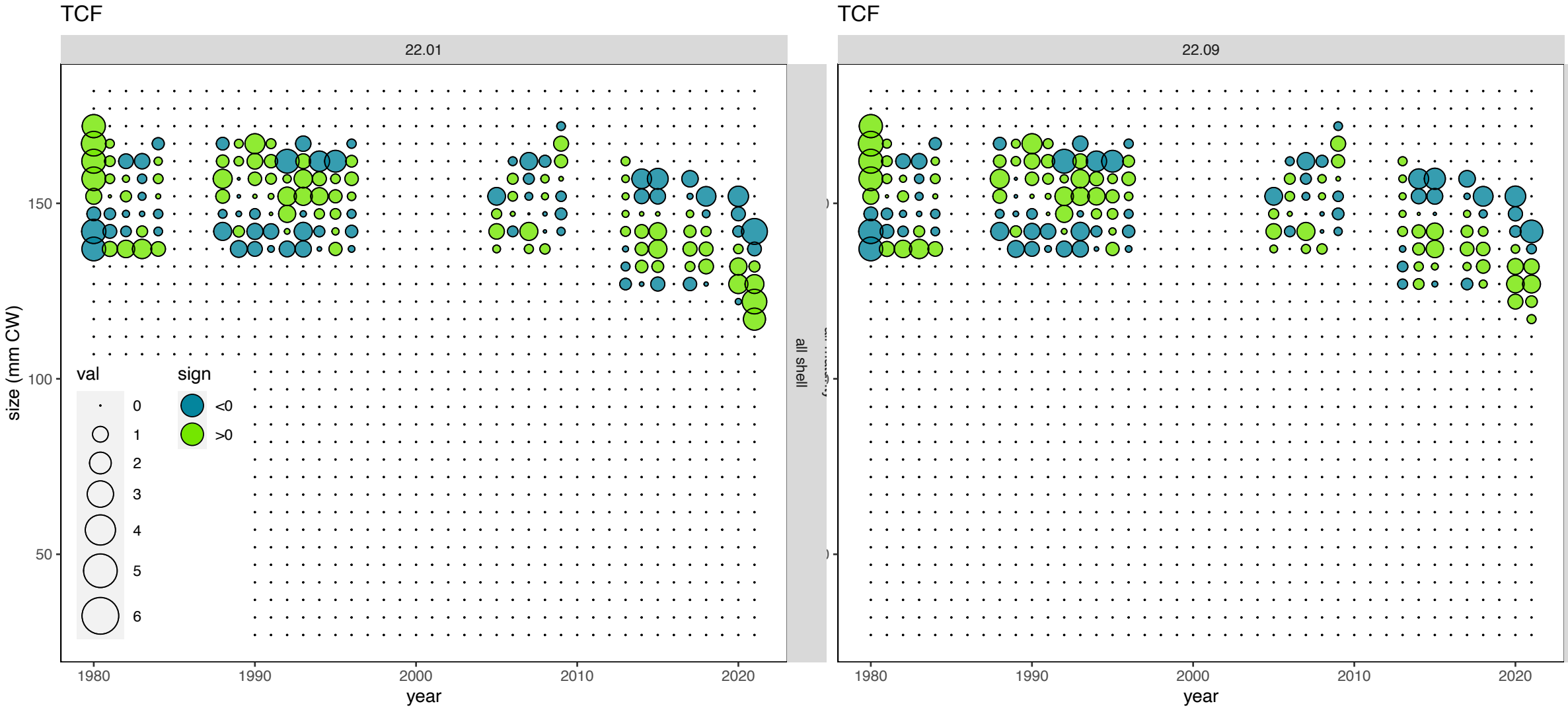




Fits to Data: Retained catch



Fits to Data: Retained catch size comps



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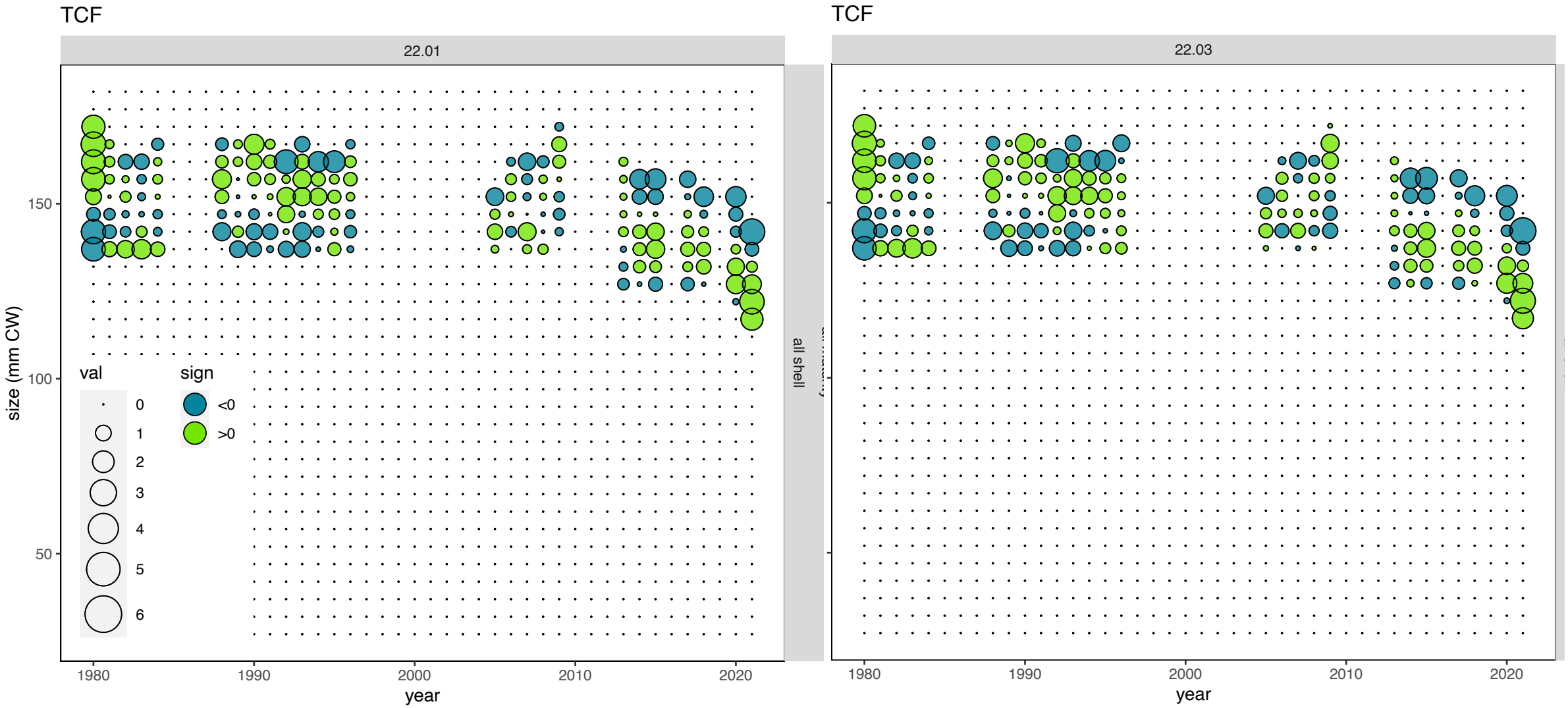
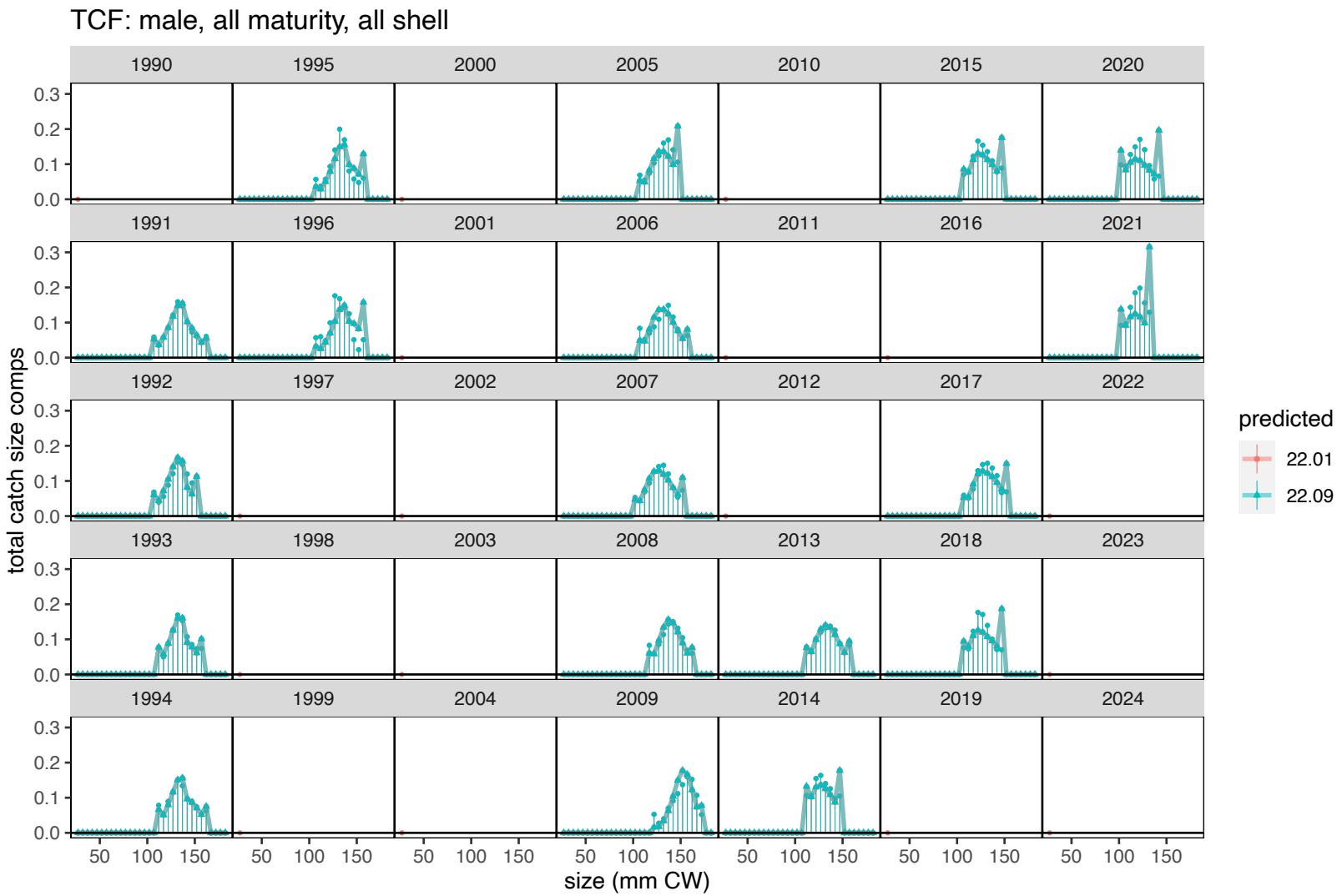


Fits to Data: Total catch in Directed Fishery



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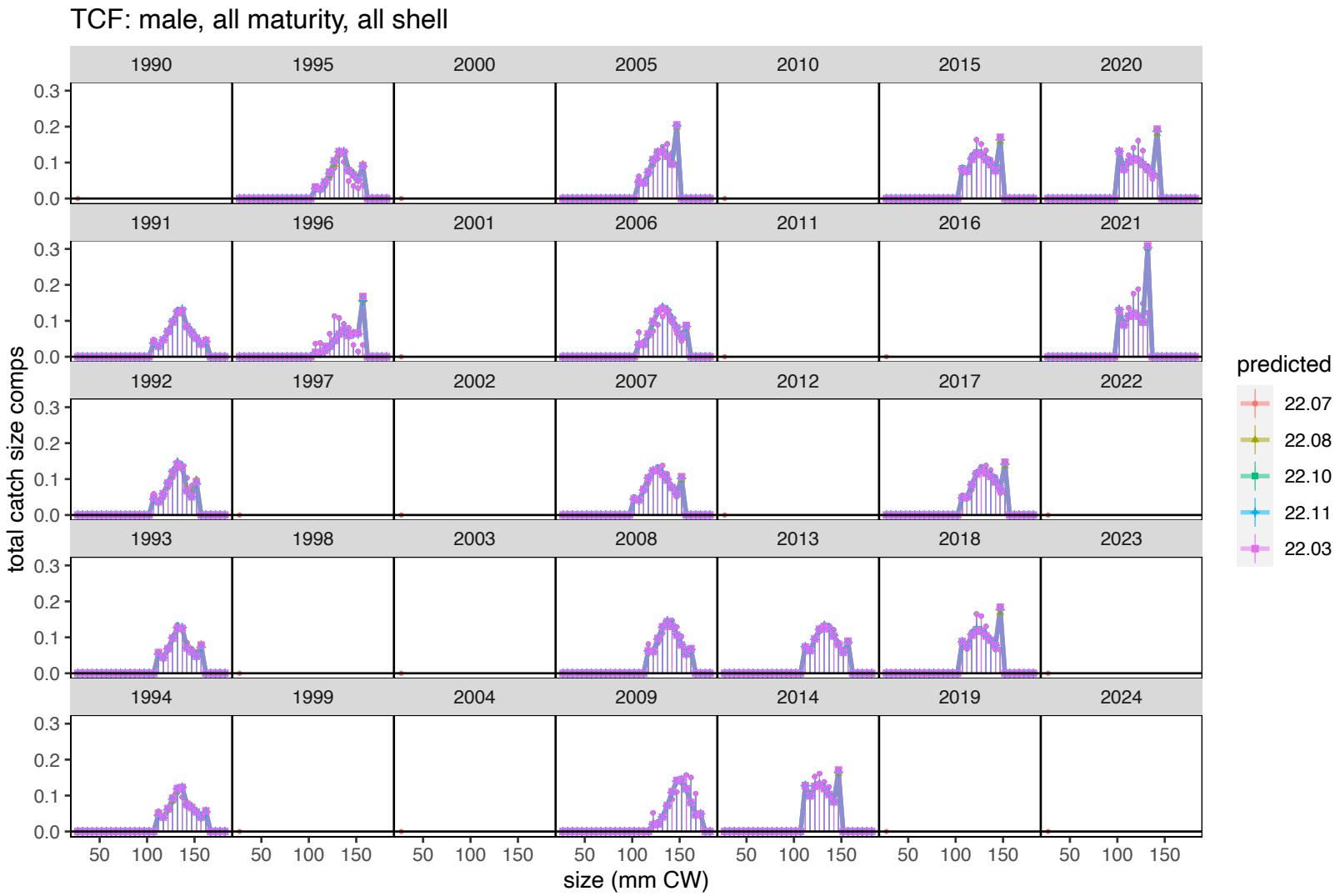
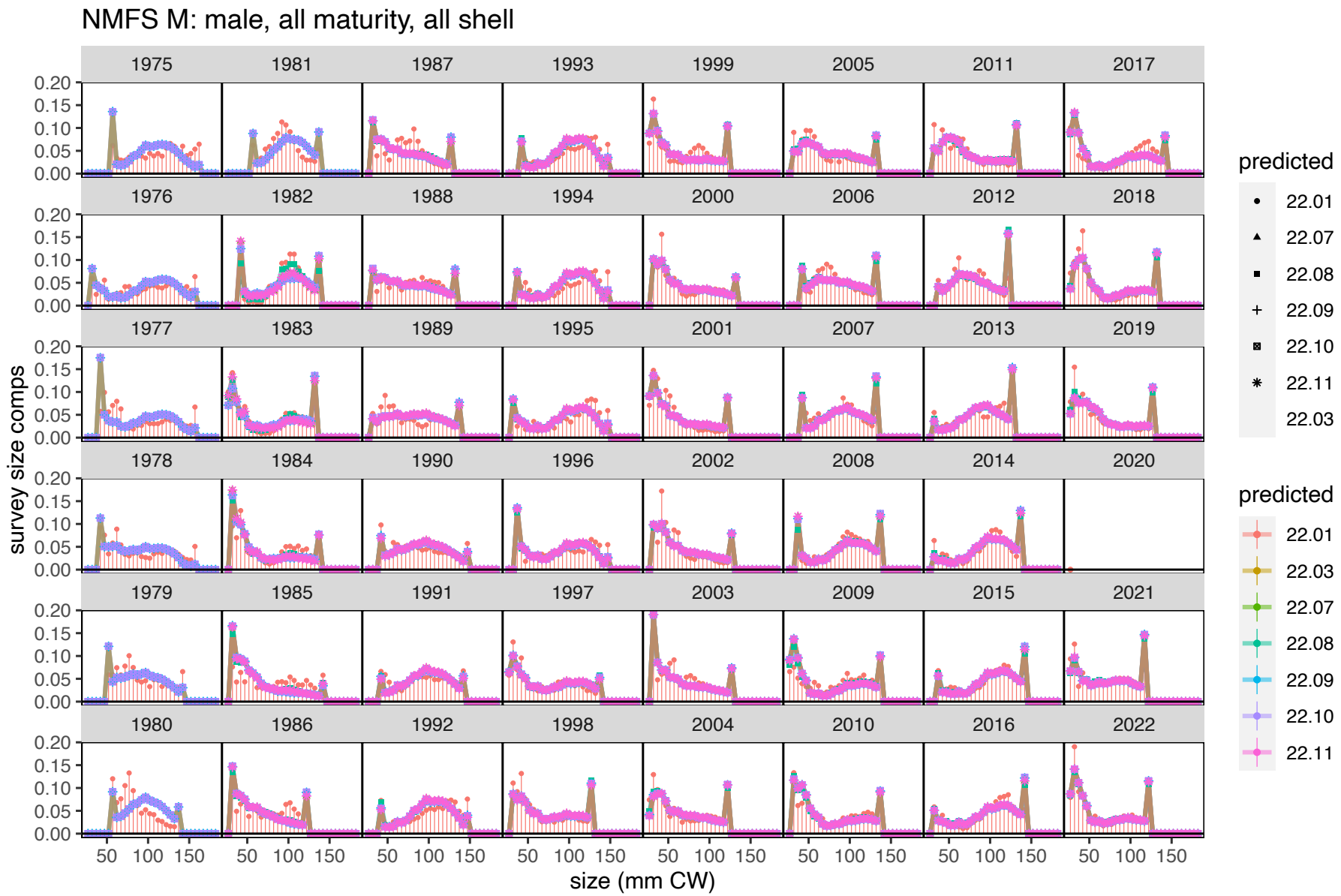


Fits to Data: Total catch (males) in the Directed Fishery

Fits to Data: NMFS Survey Male Size Comps



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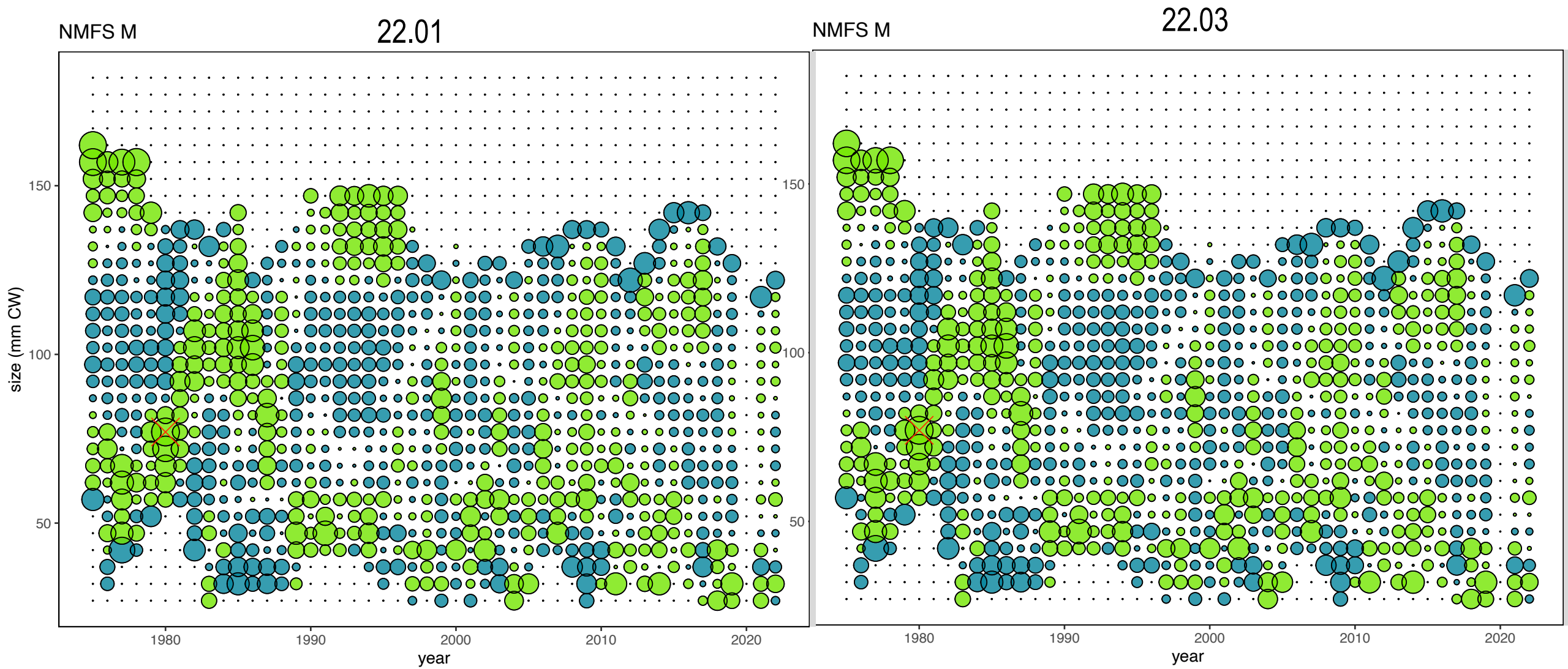
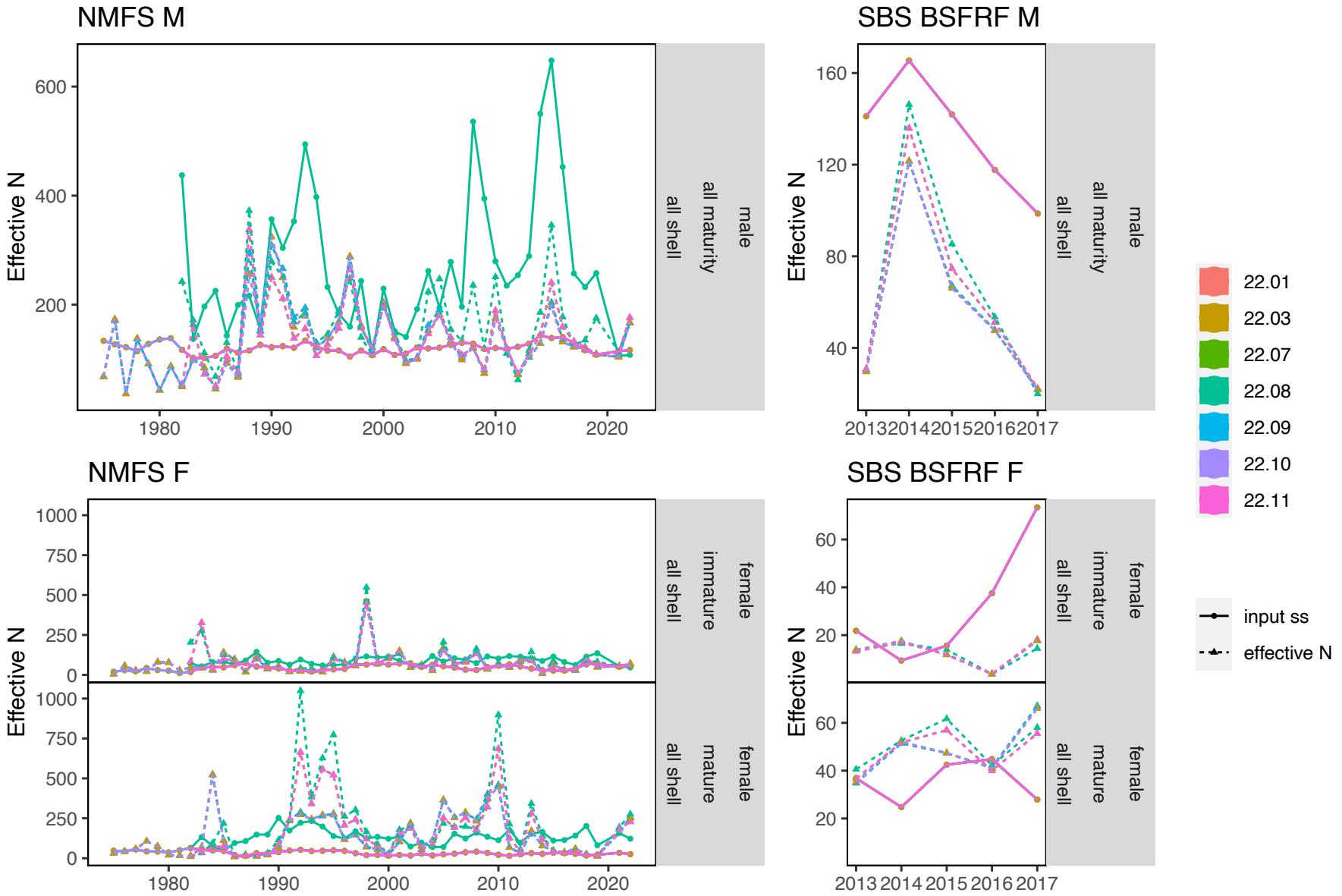
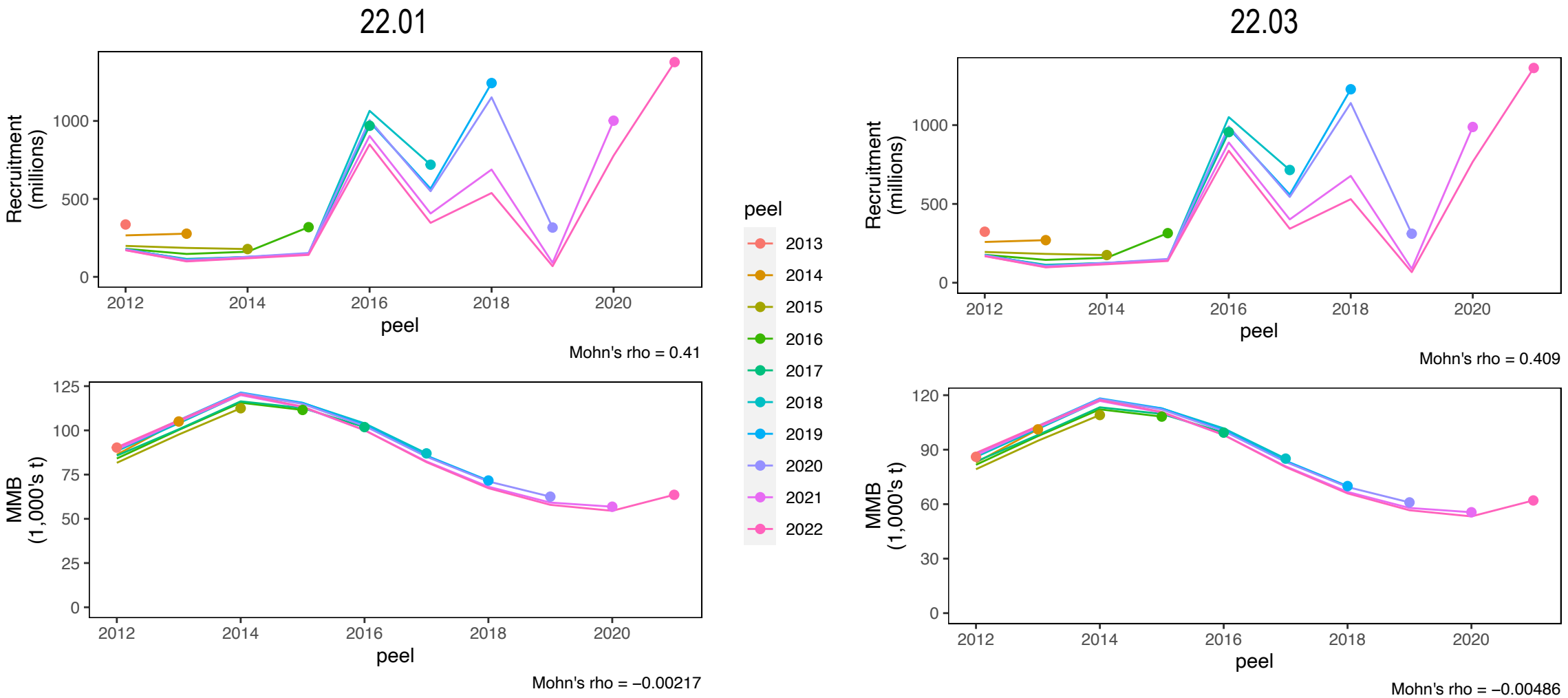


Fits to Data: NMFS Survey Mature Female Size Comps



Retrospective Analysis



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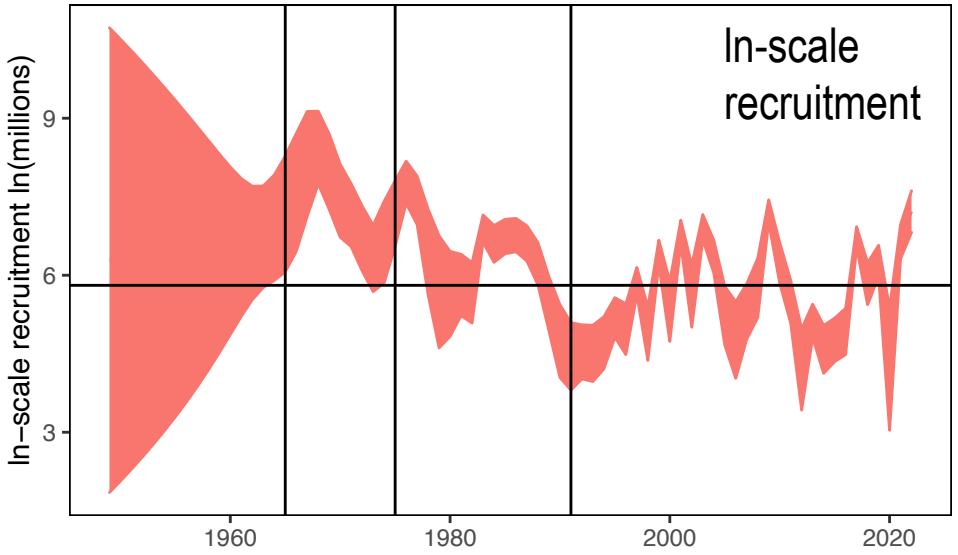
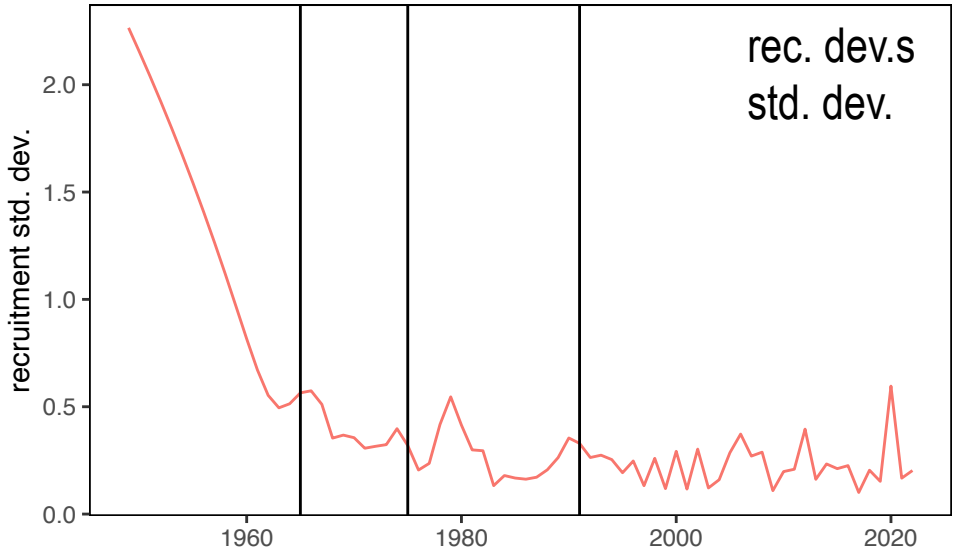
- Recent Fishery & Survey Trends
- Model Description & Scenarios
- Model Evaluation
- Status Determination & OFL Calculation
- Final Remarks

OFL Calculation: Average Recruitment Timeframe (22.03)

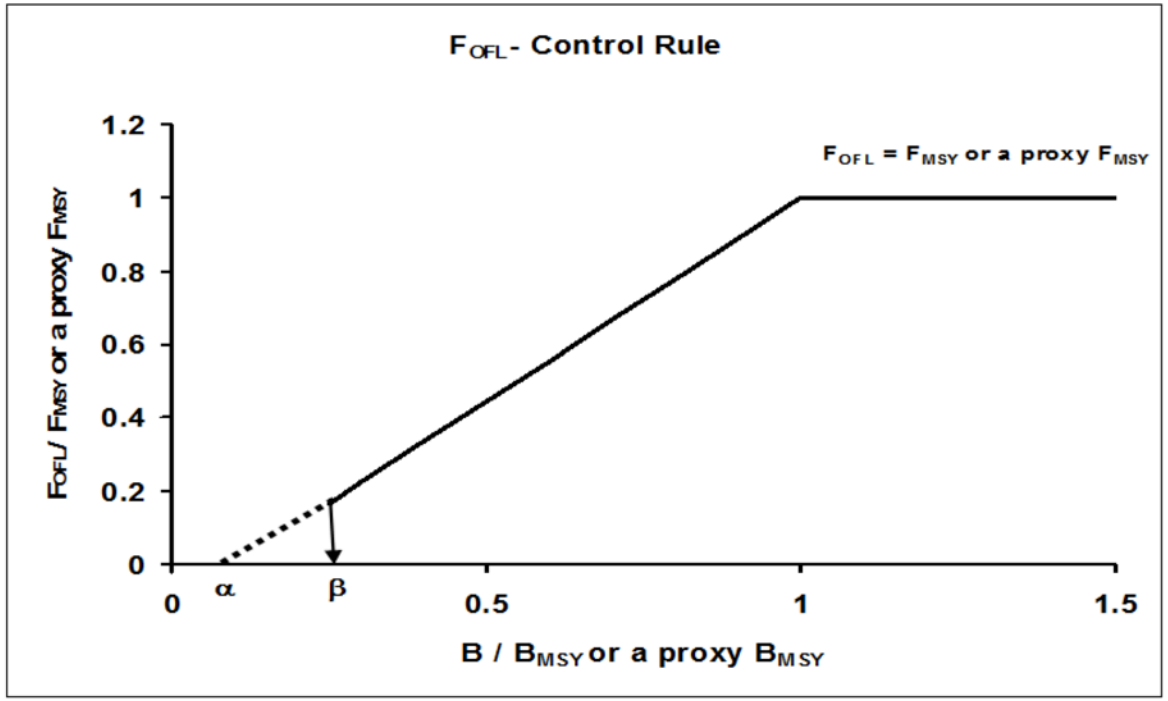




- 1982-2021 (terminal year-1; same as last year)
- 2019 recruitment very low, but fairly consistent with 2021 survey size compositions
- higher recruitment in 2021 supported by survey results

- Avg Rec. = 396 million

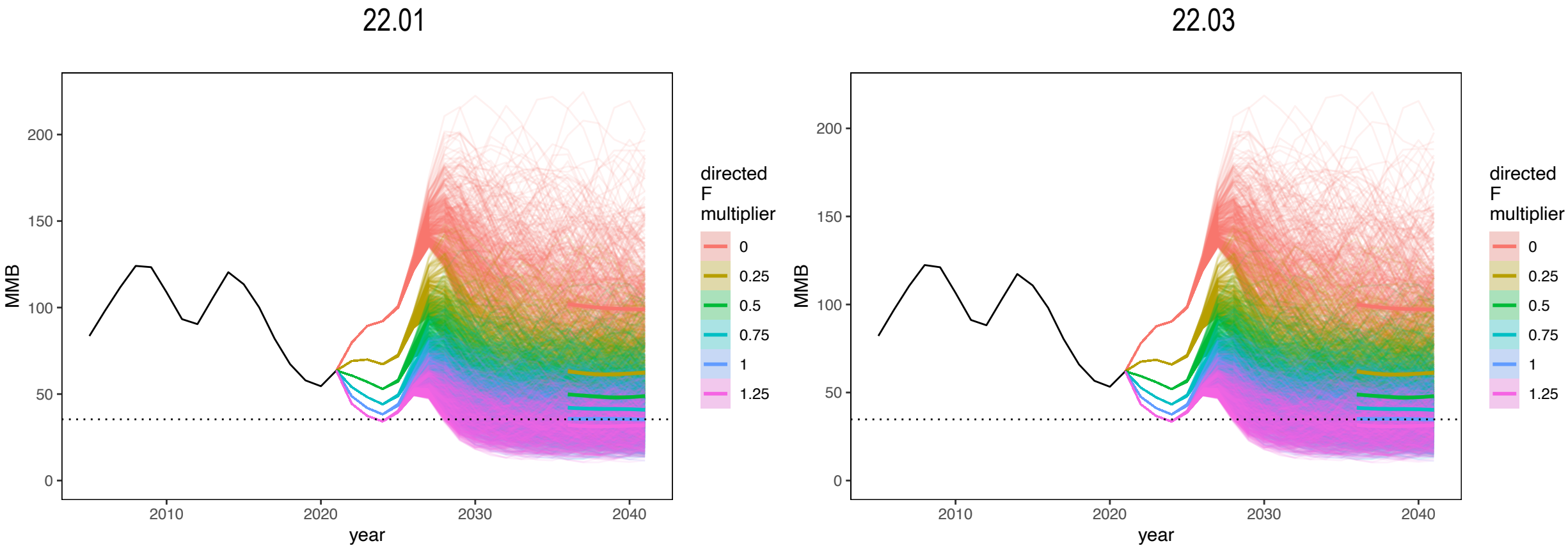
OFL Calculation: 22.03



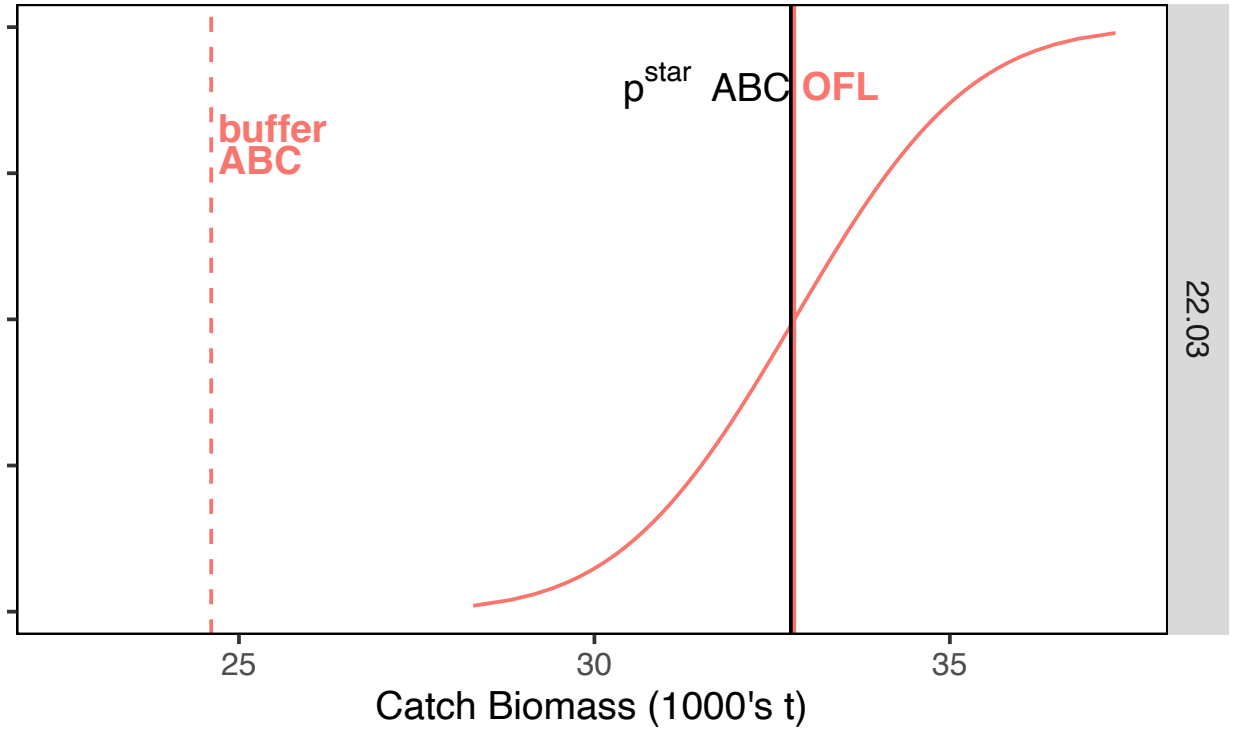
MLE Results (22.03)

- $MMB_{2021/22}$= 62.05 kt
- Avg Rec. = 396 million
- $B_{MSY.}$ = 34.73 kt
- F_{MSY} = 1.17 yr^{-1}
- F_{OFL} = 1.17 yr^{-1}
- OFL = 32.80 kt
- $MMB_{2022/23}$= 47.58 kt
- Tier 3a

Projections



ABC Determination (22.03)



MLE Results

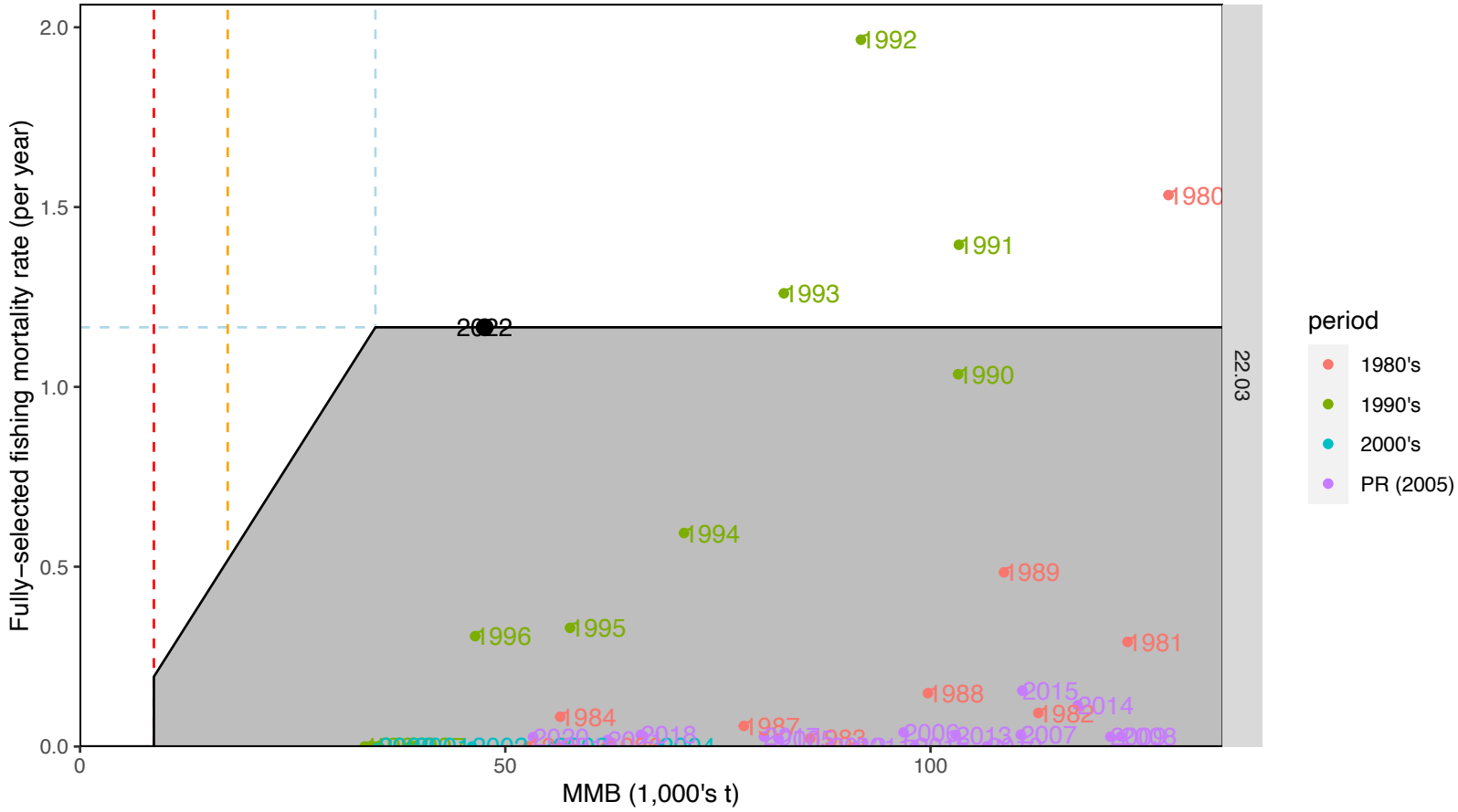
- OFL = 32.81 kt
- p-star ABC = 32.76 kt

Buffer recommendation: 25%

- increase from last year (+5%)
- missing 2020 survey continues to affect results
- smaller survey q estimates
- overestimating large crab
- overestimating terminal year survey biomass
- disappearing recruitment

buffer ABC = 24.61 kt (25%)

Stock Status (22.03)



Stock Status (22.03)

- Tier 3a
- Not overfished
- No overfishing

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2017/18	15.15	64.09	1.13	1.13	2.37	25.42	20.33
2018/19	20.54	82.61	1.11	1.11	1.90	20.87	16.70
2019/20	18.31	56.15	0.00	0.00	0.54	28.86	23.09
2020/21	17.97	56.34	1.07	0.66	0.96	21.13	16.90
2021/22	17.37	62.05	0.50	0.49	0.78	27.17	21.74
2022/23	NA	47.58	NA	NA	NA	32.81	24.61

Year	Tier	Bmsy	Projected MMB	B/Bmsy	Fofl	Years to Define Bmsy	
2017/18	3a	29.17	47.04	1.49	0.75	1982-2017	
2018/19	3a	21.87	23.53	1.08	0.93	1982-2018	
2019/20	3b	41.07	39.55	0.96	1.08	1982-2019	
2020/21	3b	36.62	35.31	0.96	0.93	1982-2019	
2021/22	3a	35.94	42.57	1.18	1.17	1982-2020	
2022/23	3a	34.73	47.58	1.37	1.17	1982-2021	*

M: immature: 0.24, females: 0.31, males: 0.31 (Table 52, p. 132)

Outline

- SSC & CPT Comments
- Recent Fishery & Survey Trends
- Model Description & Scenarios
- Model Evaluation
- Status Determination & OFL Calculation
- Final Remarks

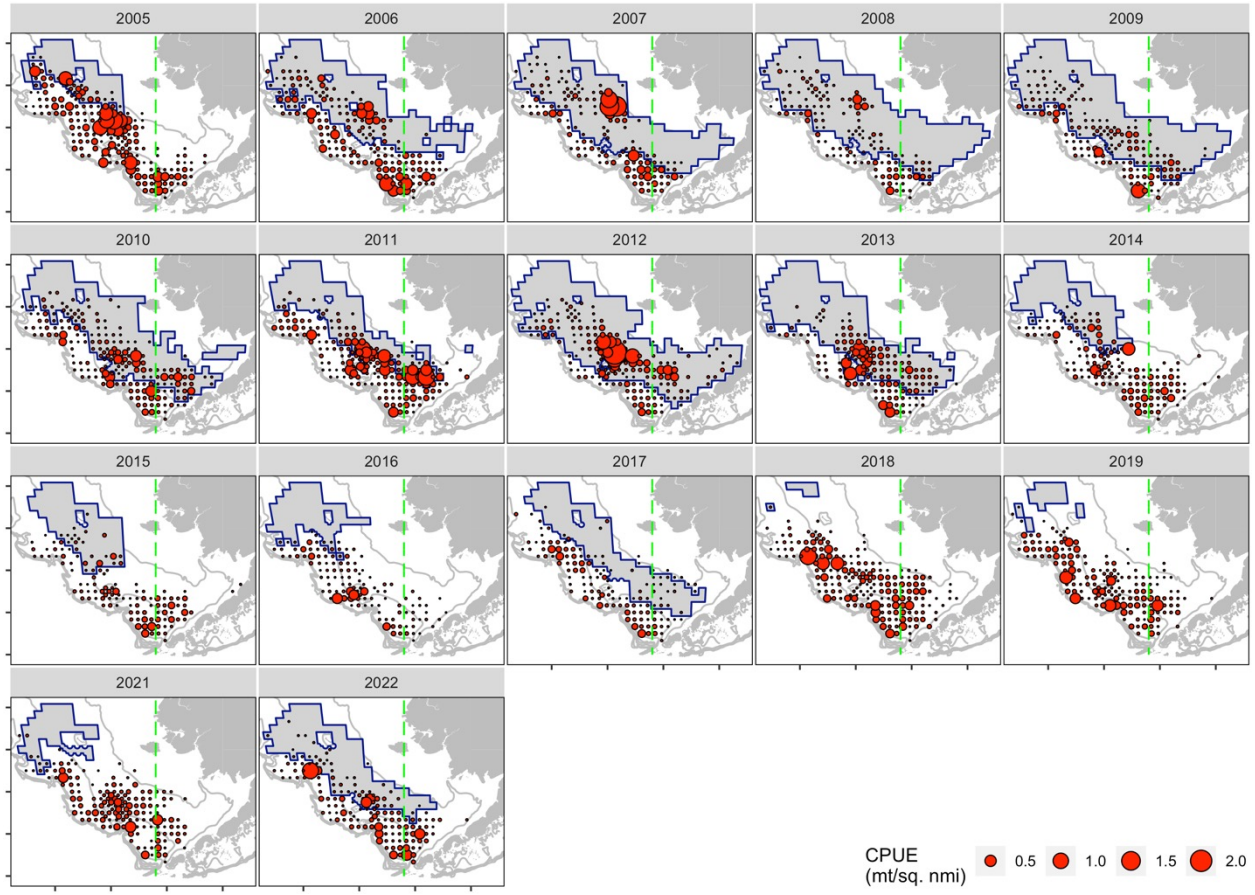
2022: Moving forward

- transition to GMACS
- finish BSFRF/NMFS SBS survey selectivity analysis
  - would be helpful to have 2018 BSFRF survey data
- explore temporally-varying natural mortality
- investigate nonparametric approaches to selectivity
- revisit
  - model that better reflects State management structure
  - model that starts in 1982 (drops uncertain historical data)

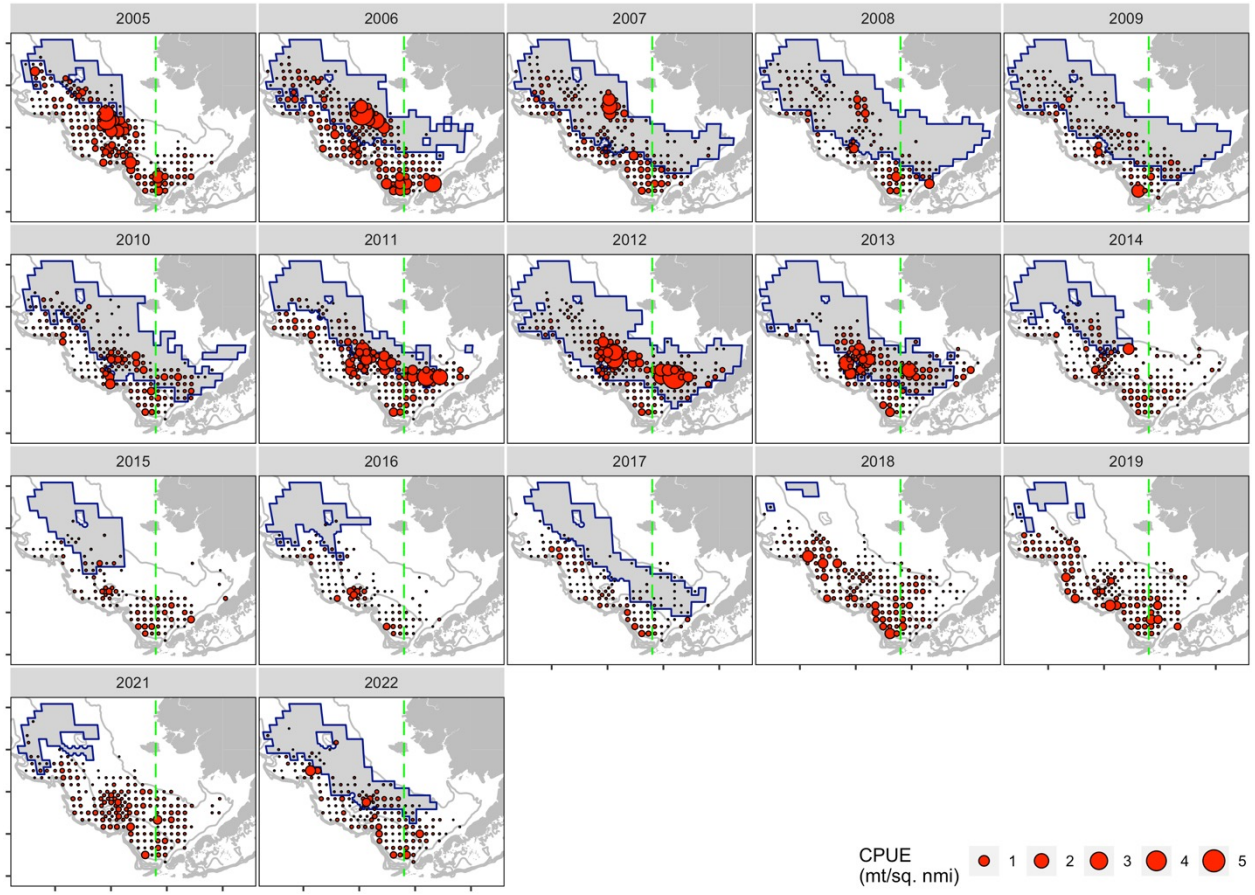
Blank

Survey Spatial Distributions

small males (< 60 mm CW)

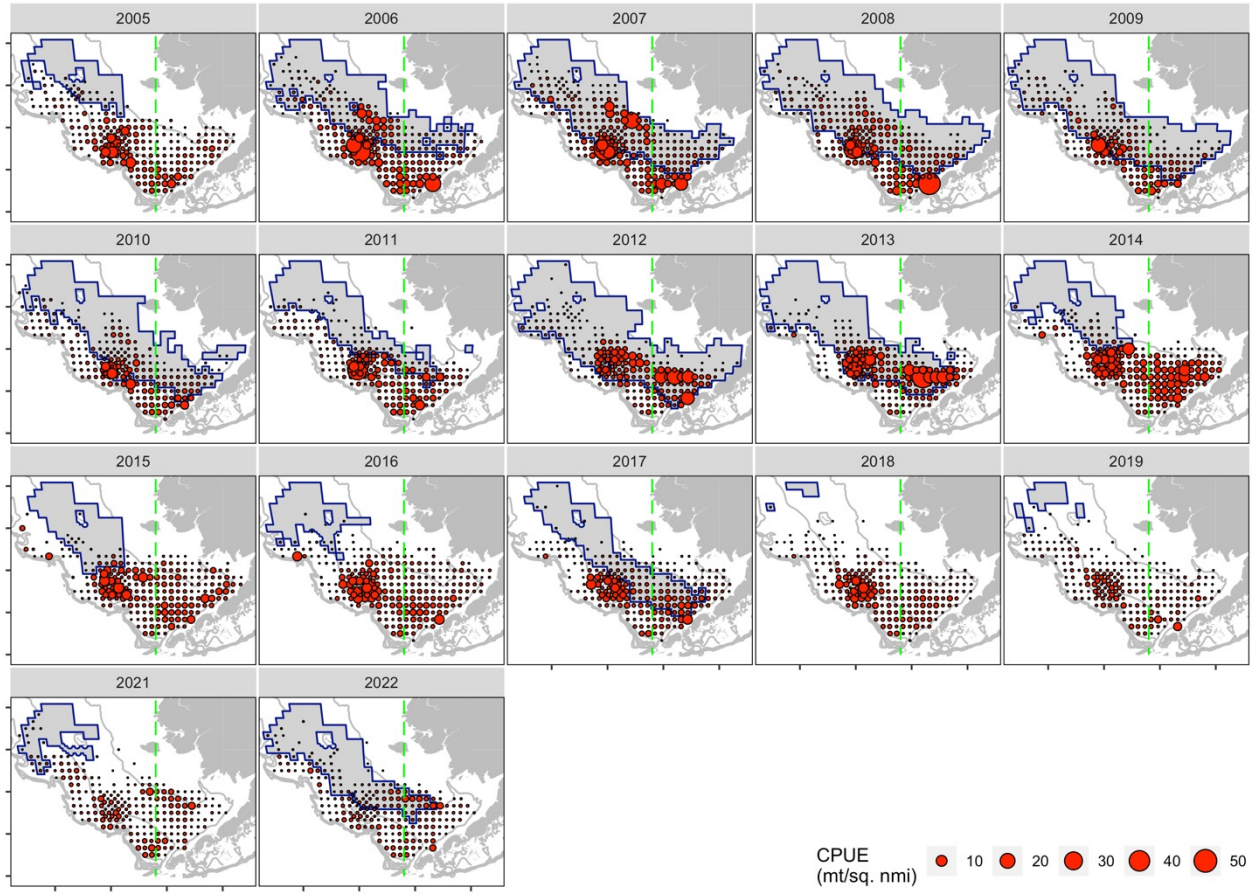


immature females

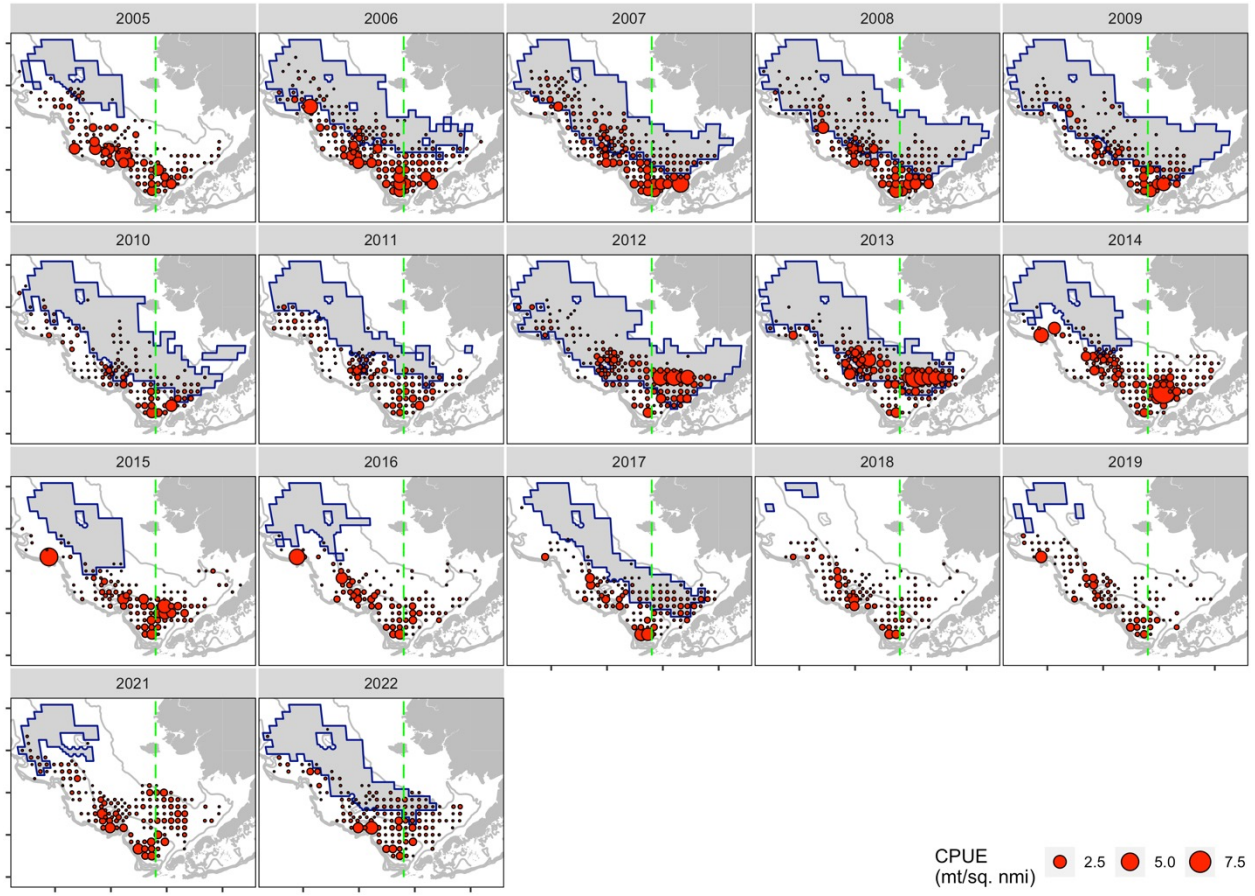


Survey Spatial Distributions

larger males (> 60 mm CW)



mature females



Model Processes

process	time blocks	22.01 description
Population rates and quantities		
Population built from annual recruitment		
Recruitment	1949-1974	ln-scale mean + annual devs constrained as AR1 process
	1975+	ln-scale mean + annual devs
	1949+	sigma-R fixed, sex ratio fixed at 1:1
Growth	1949+	sex-specific
		mean post-molt size: power function of pre-molt size
		post-molt size: gamma distribution conditioned on pre-molt size
Maturity	1949+	sex-specific
		size-specific probability of terminal molt
		logit-scale parameterization
Natural mortalty	1949-1979,	estimated sex/maturity state-specific multipliers on base rate
	1985+	priors on multipliers based on uncertainty in max age
	1980-1984	estimated "enhanced mortality" period multipliers

Fisheries: Snow Crab Fishery

Fishery/process	time blocks	22.01 description
SCF	bycatch in snow crab fishery	
capture rates	pre-1978	nominal rate on males
	1979-1991	extrapolated from effort
	1992+	male ln-scale mean + annual devs
	1949+	ln-scale female offset
male selectivity	1949-1996	dome-shaped (double normal)
		--plateau width fixed to 0
		--descending limb width fixed to 1
	1997-2004	dome-shaped (double normal)
	2005+	dome-shaped (double normal)
female selectivity	1949-1996	ascending logistic
	1997-2004	ascending logistic
	2005+	ascending logistic

Fisheries: Other

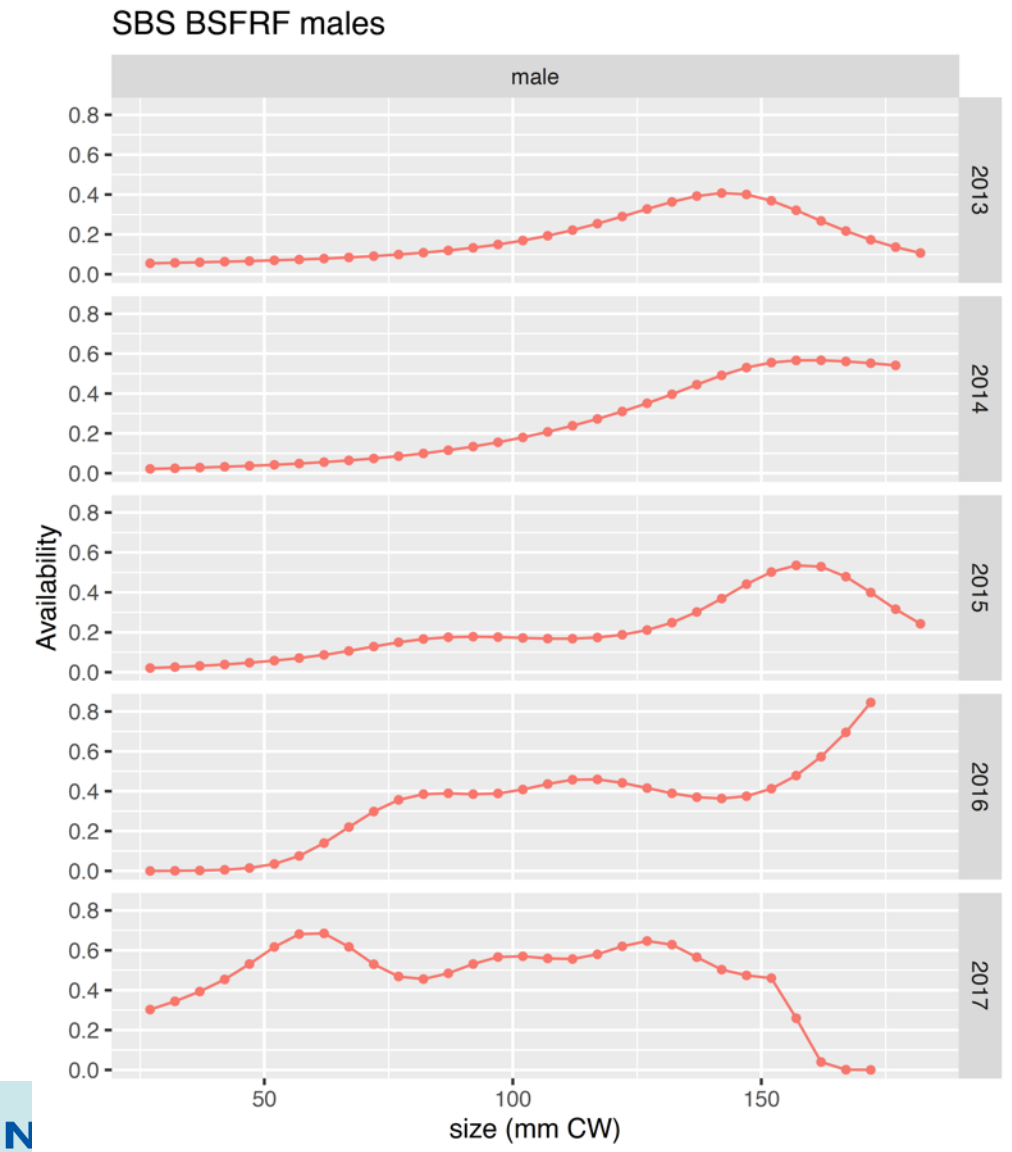
Fishery/process	time blocks	22.01 description
RKF	bycatch in BBRKC fishery	
capture rates	pre-1952	nominal rate on males
	1953-1991	extrapolated from effort
	1992+	male ln-scale mean + annual devs
	1949+	ln-scale female offset
male selectivity	1949-1996	ascending normal, asymptote fixed
	1997-2004	ascending normal, asymptote fixed
	2005+	ascending normal, asymptote fixed
female selectivity	1949-1996	ascending normal, asymptote fixed
	1997-2004	ascending normal
	2005+	ascending normal
GTF	bycatch in groundfish fisheries	
capture rates	pre-1973	male ln-scale mean from 1973+
	1973+	male ln-scale mean + annual devs
	1973+	ln-scale female offset
male selectivity	1949-1986	ascending logistic
	1987-1996	ascending logistic
	1997+	ascending logistic
female selectivity	1949-1986	ascending logistic
	1987-1996	ascending logistic
	1997+	ascending logistic

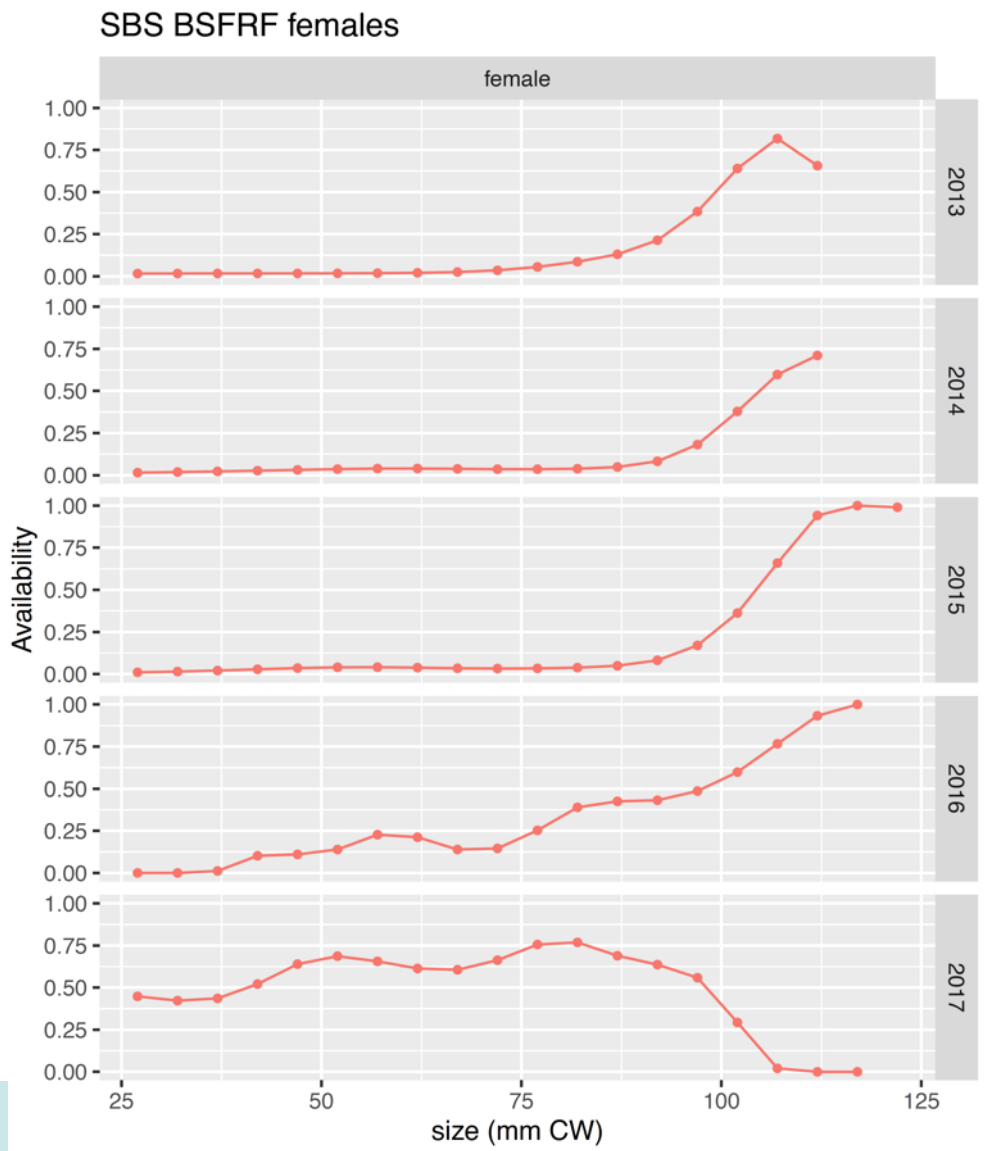
Surveys

Survey/process	time blocks	22.01 description
NMFS EBS trawl survey		
male survey q	1975-1981	ln-scale
	1982+	ln-scale w/ prior based on Somerton's underbag experiment
female survey q	1975-1981	ln-scale
	1982+	ln-scale w/ prior based on Somerton's underbag experiment
male selectivity	1975-1981	ascending normal, fixed fully-selected size at 180
	1982+	ascending normal, fixed fully-selected size at 180
female selectivity	1975-1981	ascending normal, fixed fully-selected size at 130
	1982+	ascending normal, fixed fully-selected size at 130
BSFRF SBS trawl surveys		
male catchability	2016-2017	fixed at 1 for all sizes
male availability	2016-2017	empirically-determined outside the model
female catchability	2016-2017	fixed at 1 for all sizes
female availability	2016-2017	empirically-determined outside the model

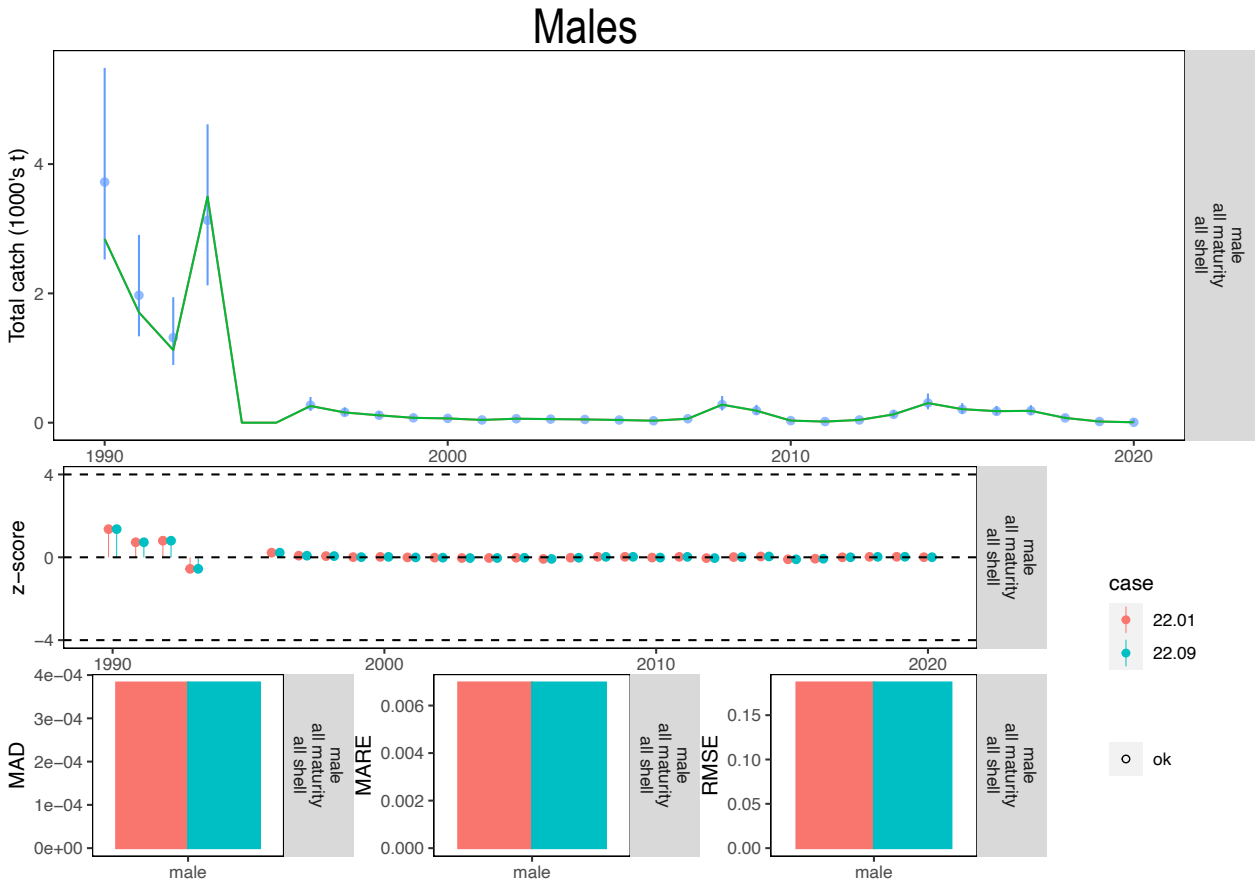
Empirical availability

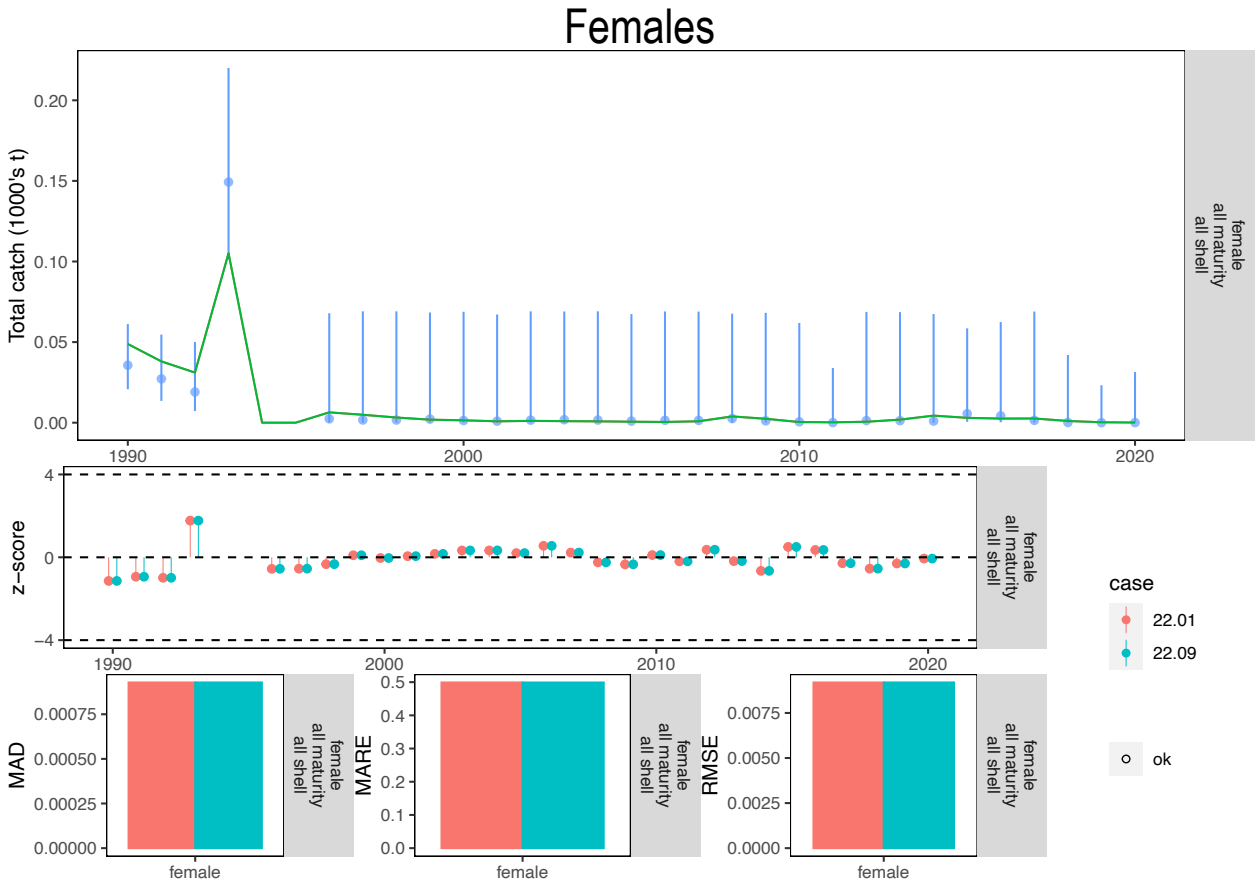
$$A_z^{SBS} = \frac{N_z^{NMFS\ SBS}}{N_z^{NMFS\ EBS}}$$



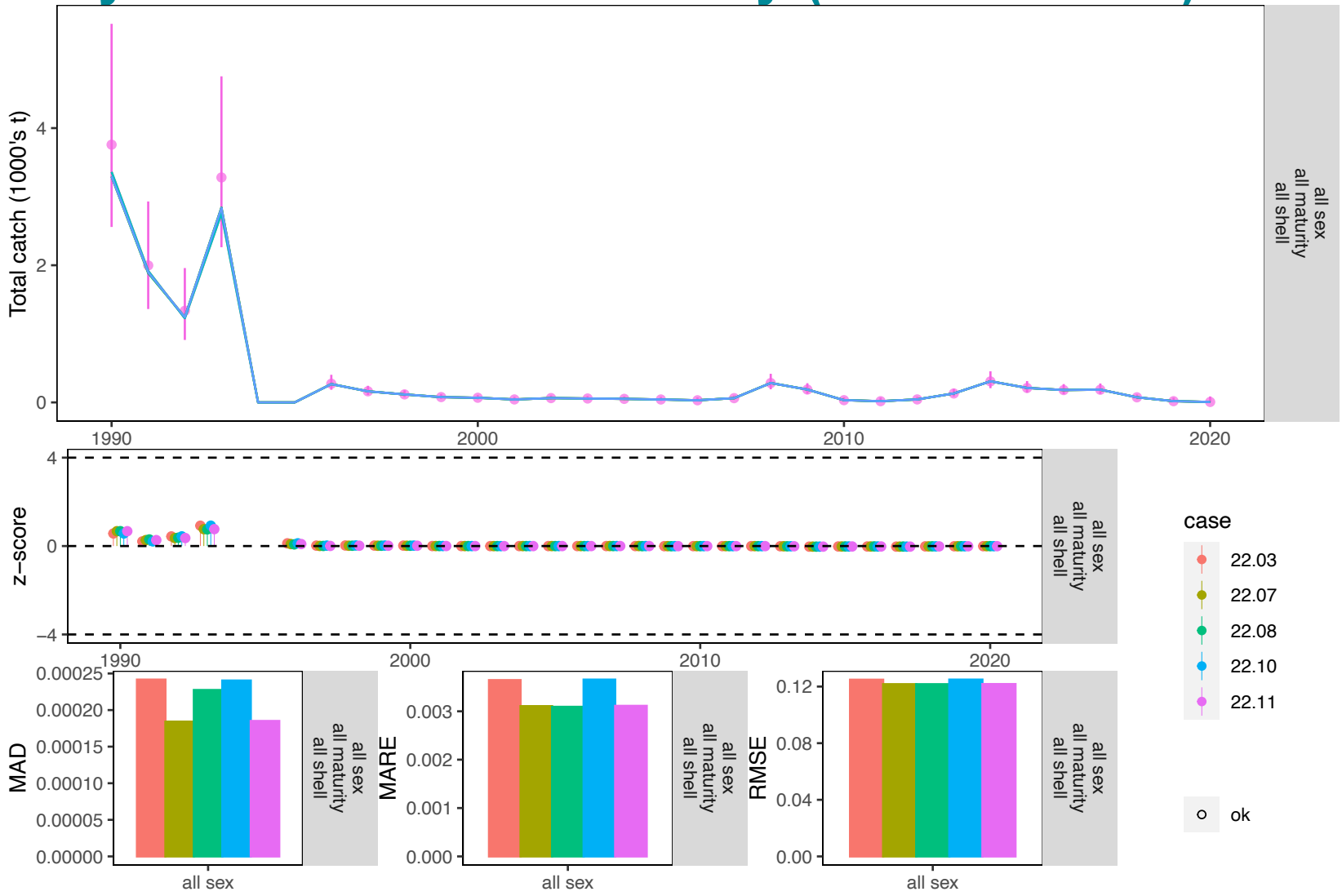


Fits to Data: Bycatch in BBRKC Fishery (22.01, 22.09)

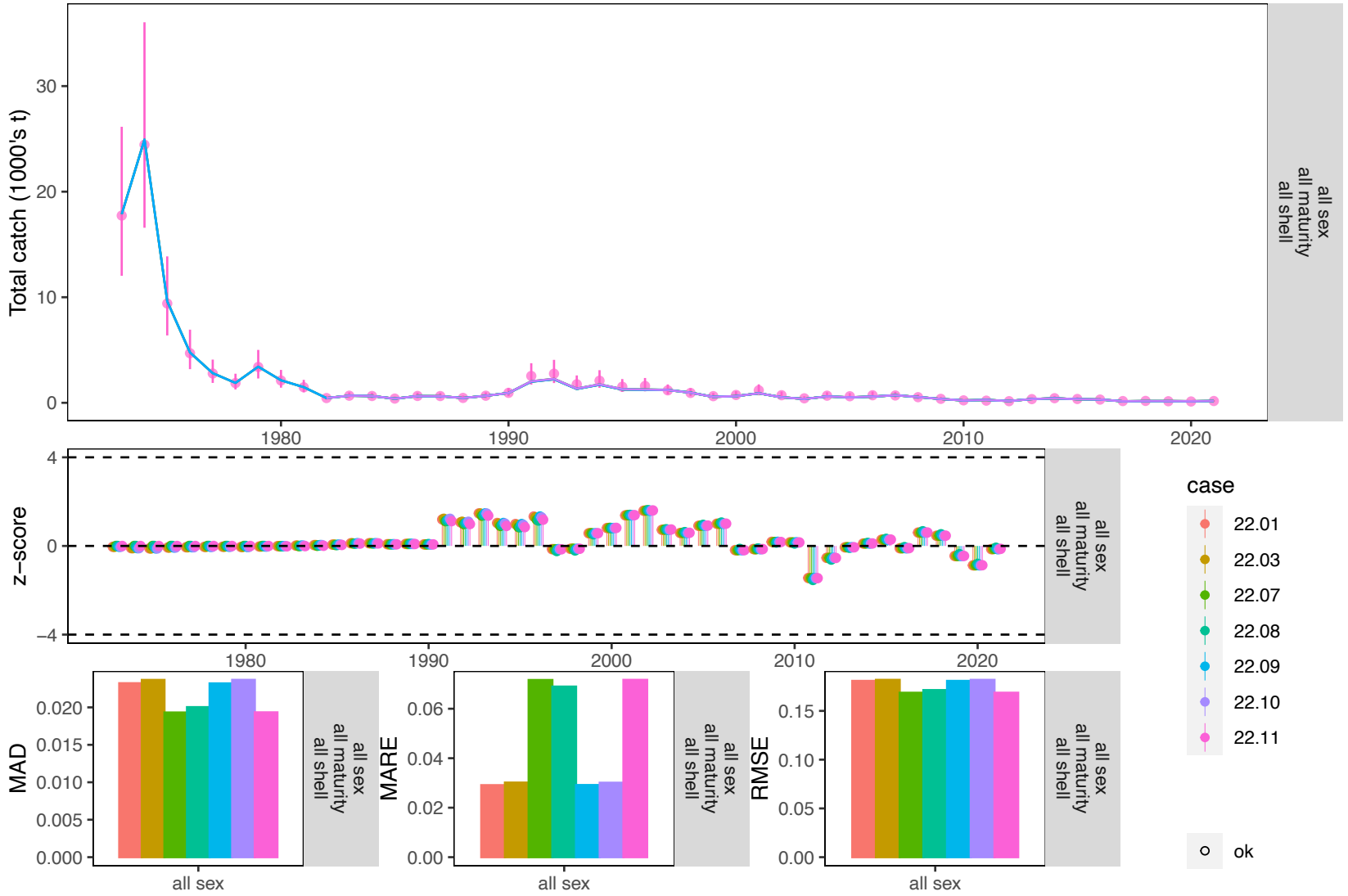




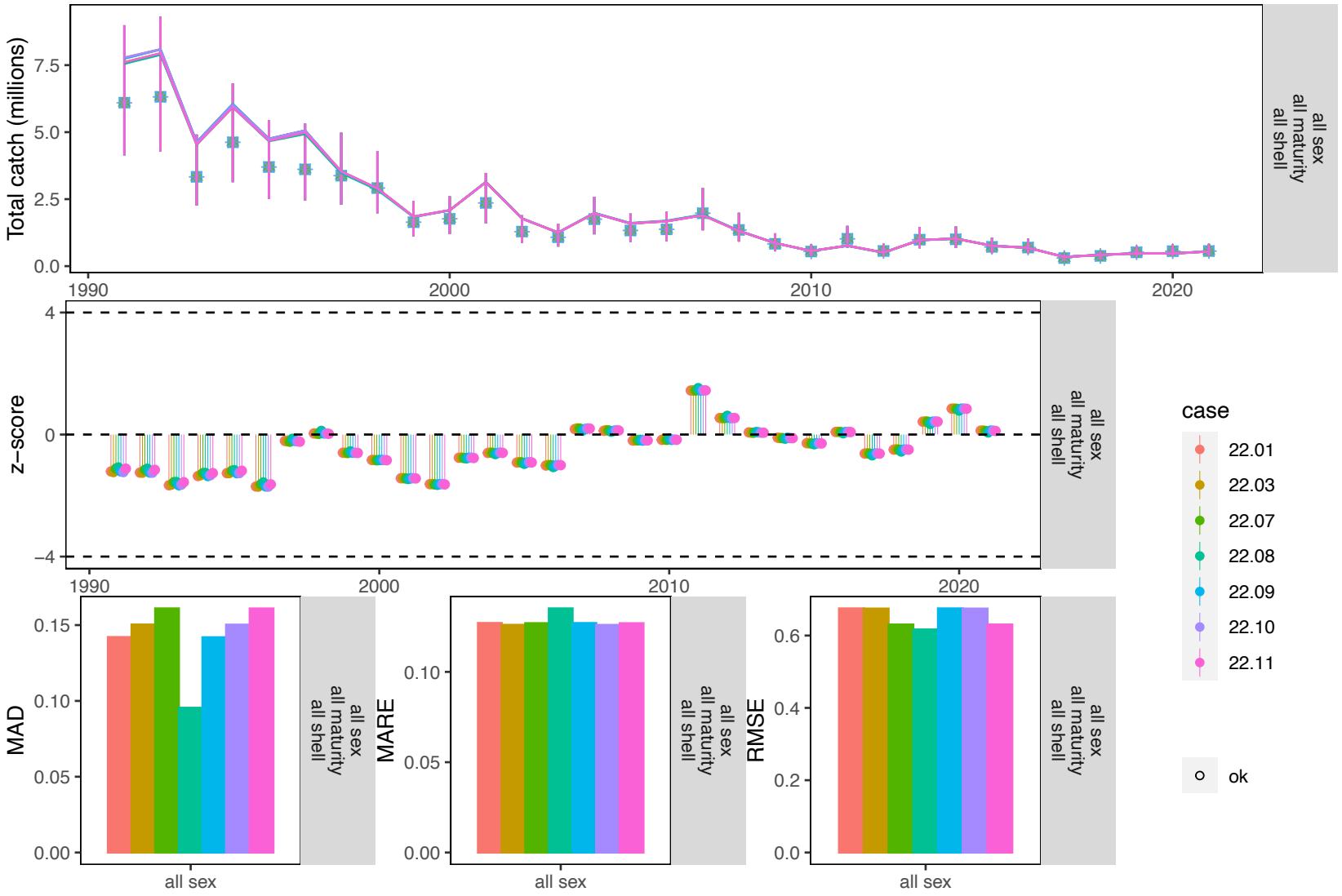
Fits to Data: Bycatch in BBRKC Fishery (other models)



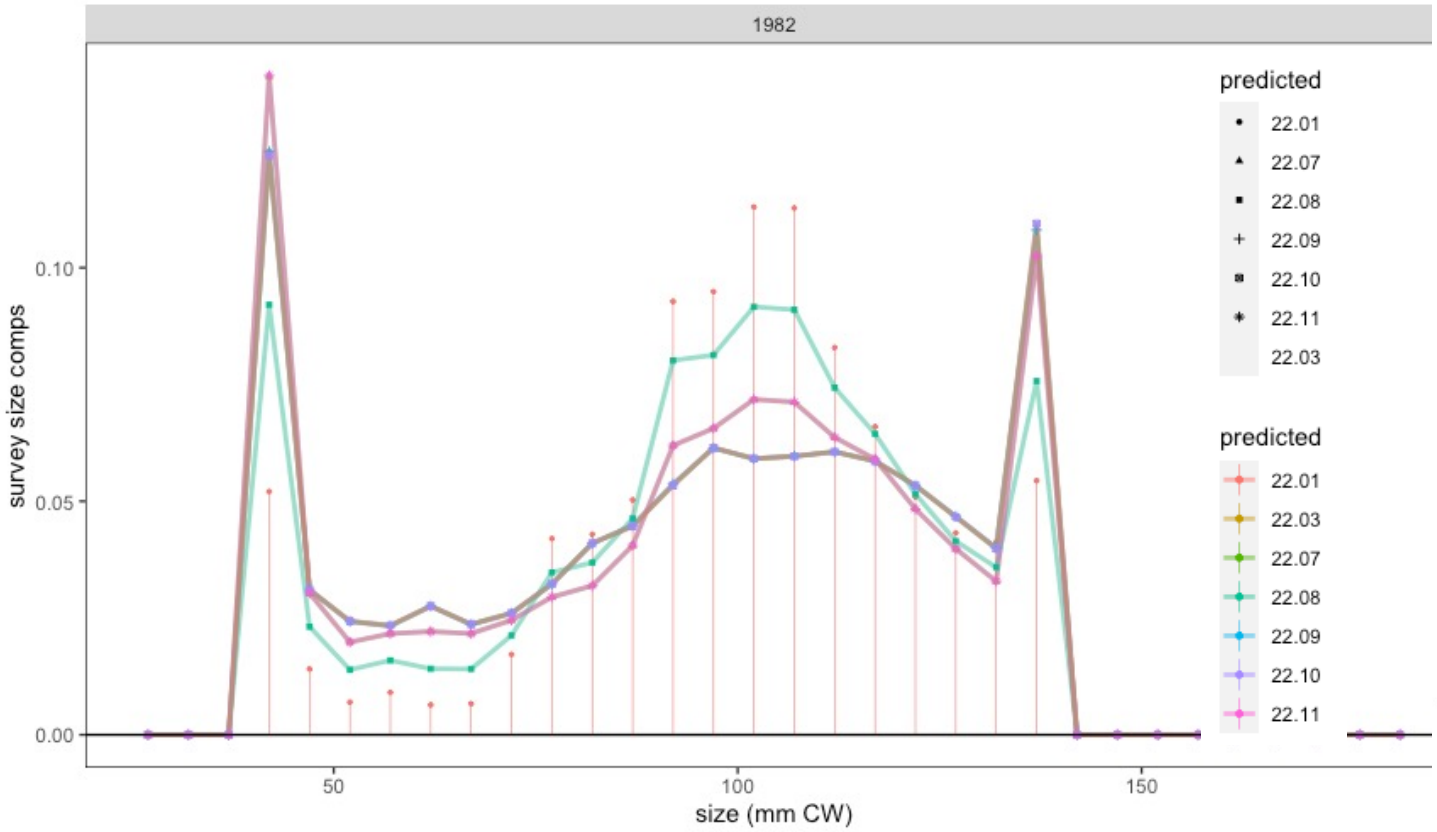
Fits to Data: Bycatch in Groundfish Fisheries (Biomass)

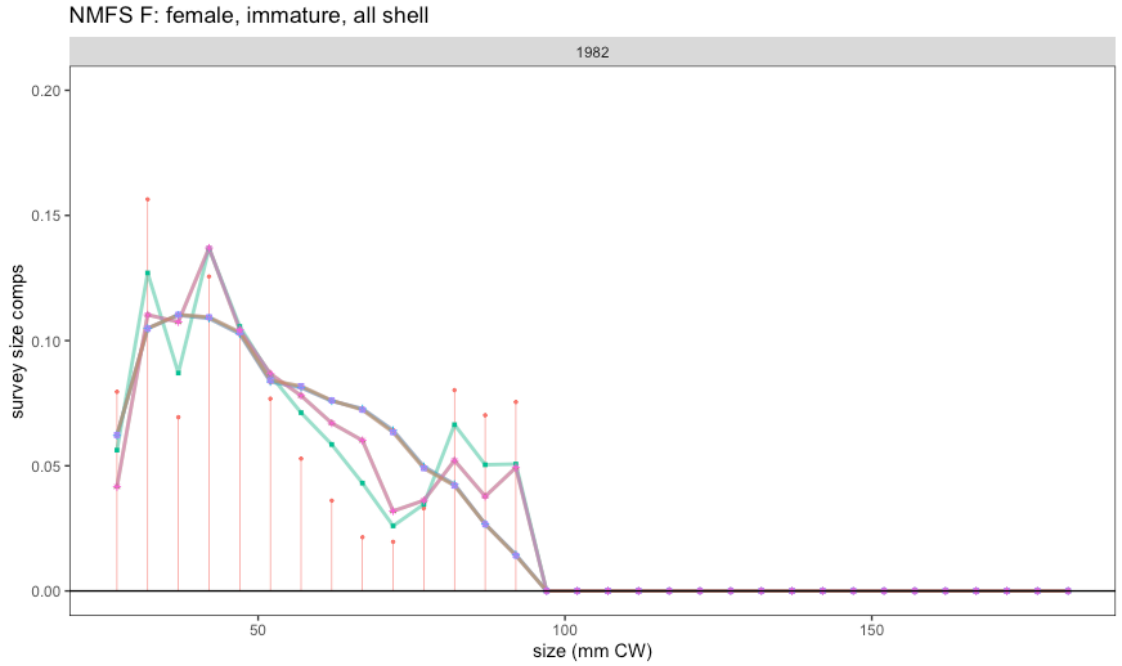


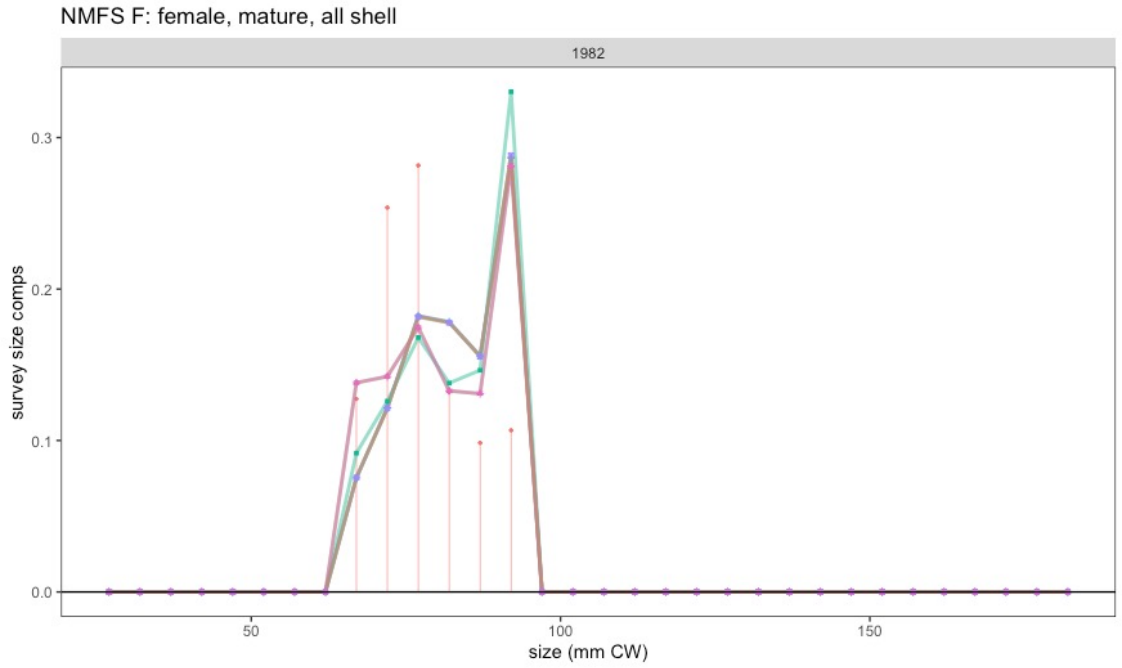
Fits to Data: Bycatch in Groundfish Fisheries. (Abundance)



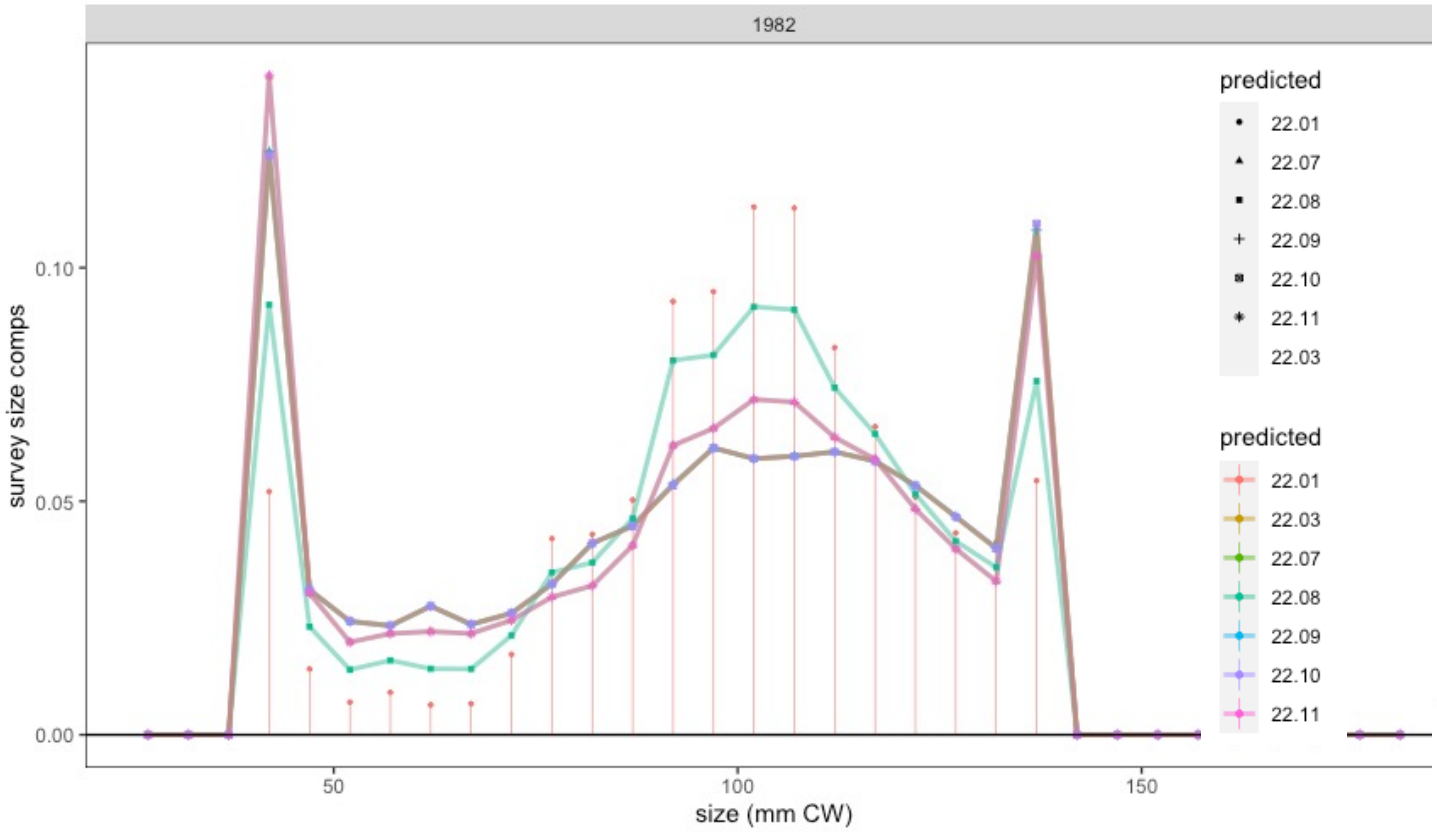
Fits to 1982 NMFS survey size comps

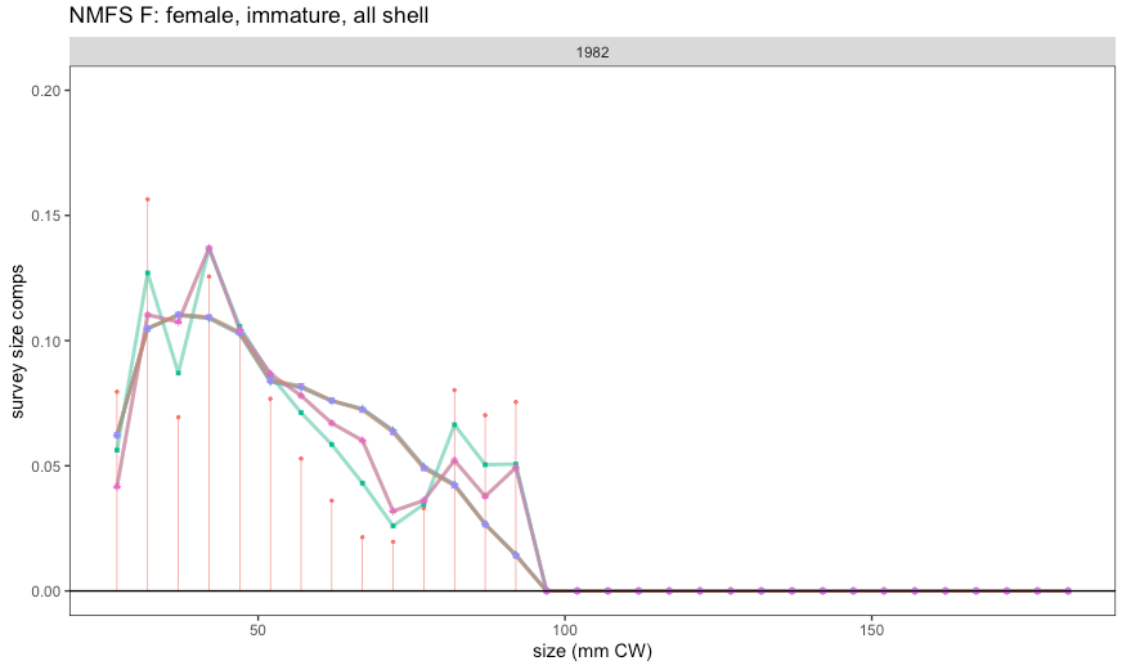


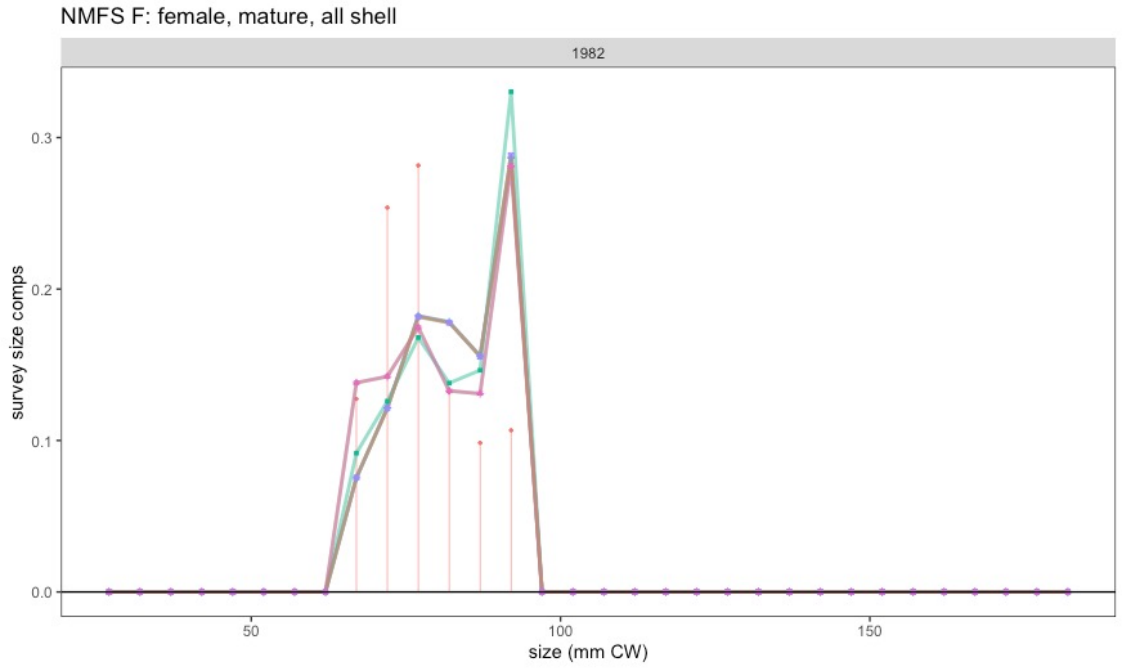




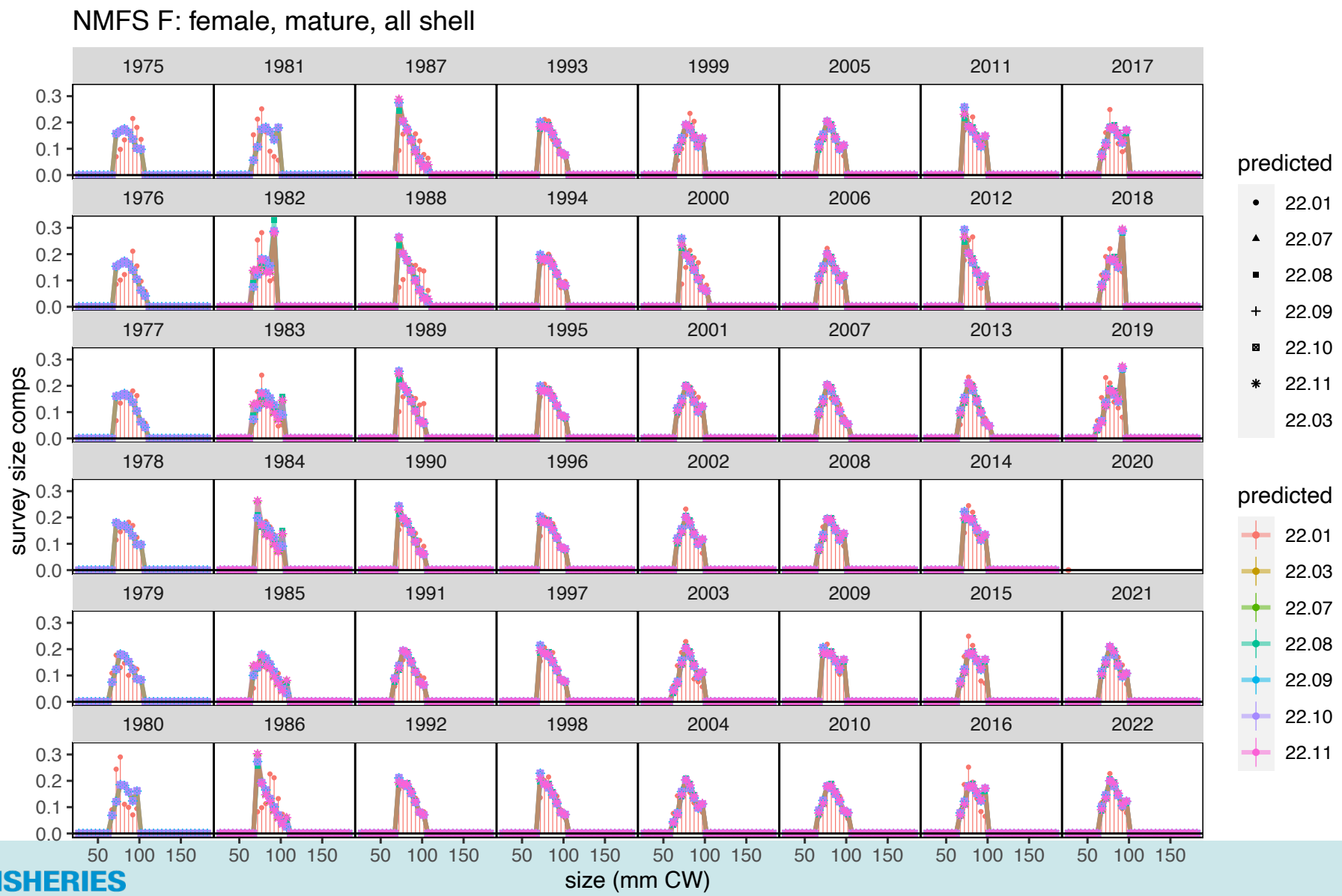
Fits to 1982 NMFS survey size comps



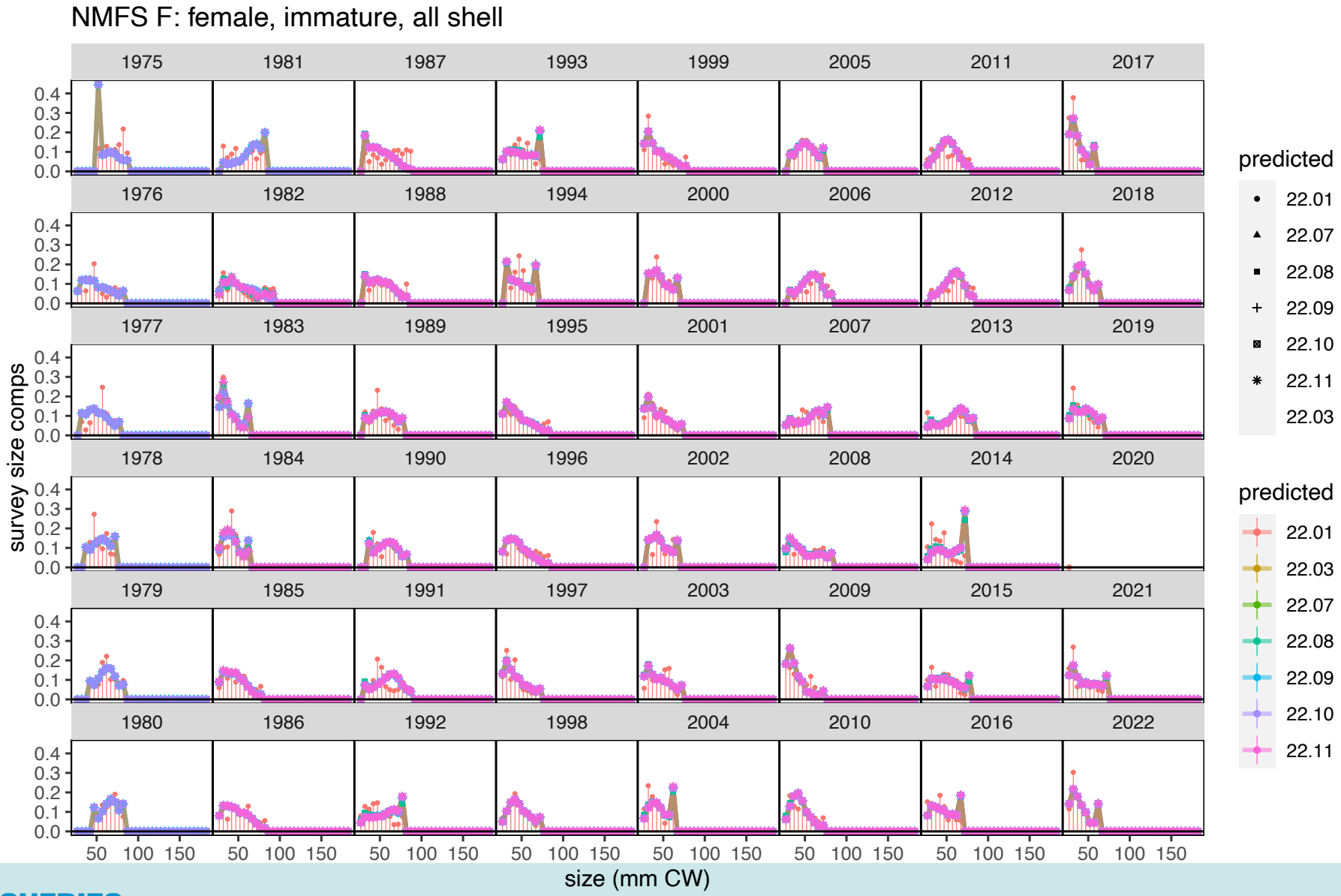




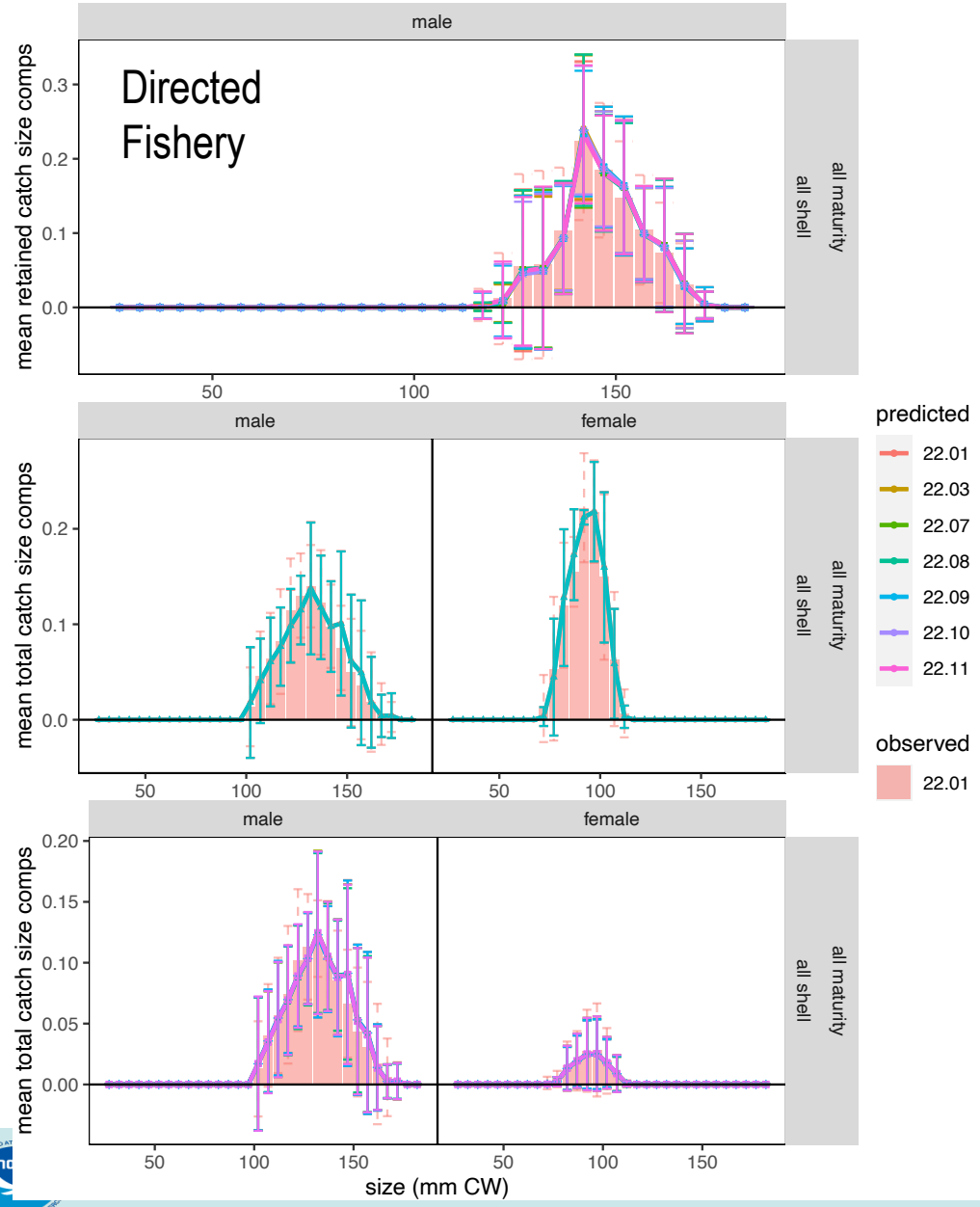
Fits to Data: NMFS Survey Mature Female Size Comps

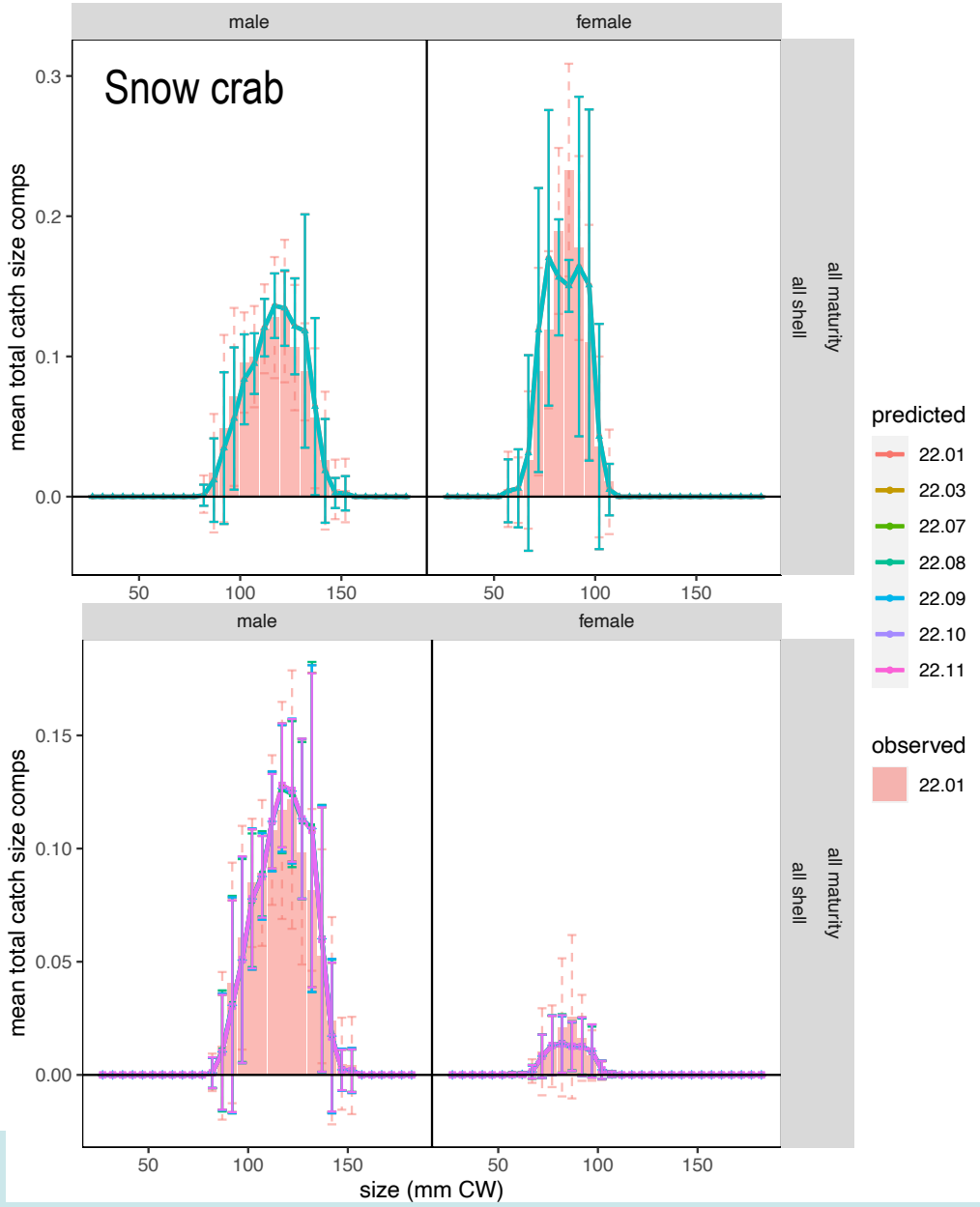


Fits to Data: NMFS Survey Immature Female Size Comps

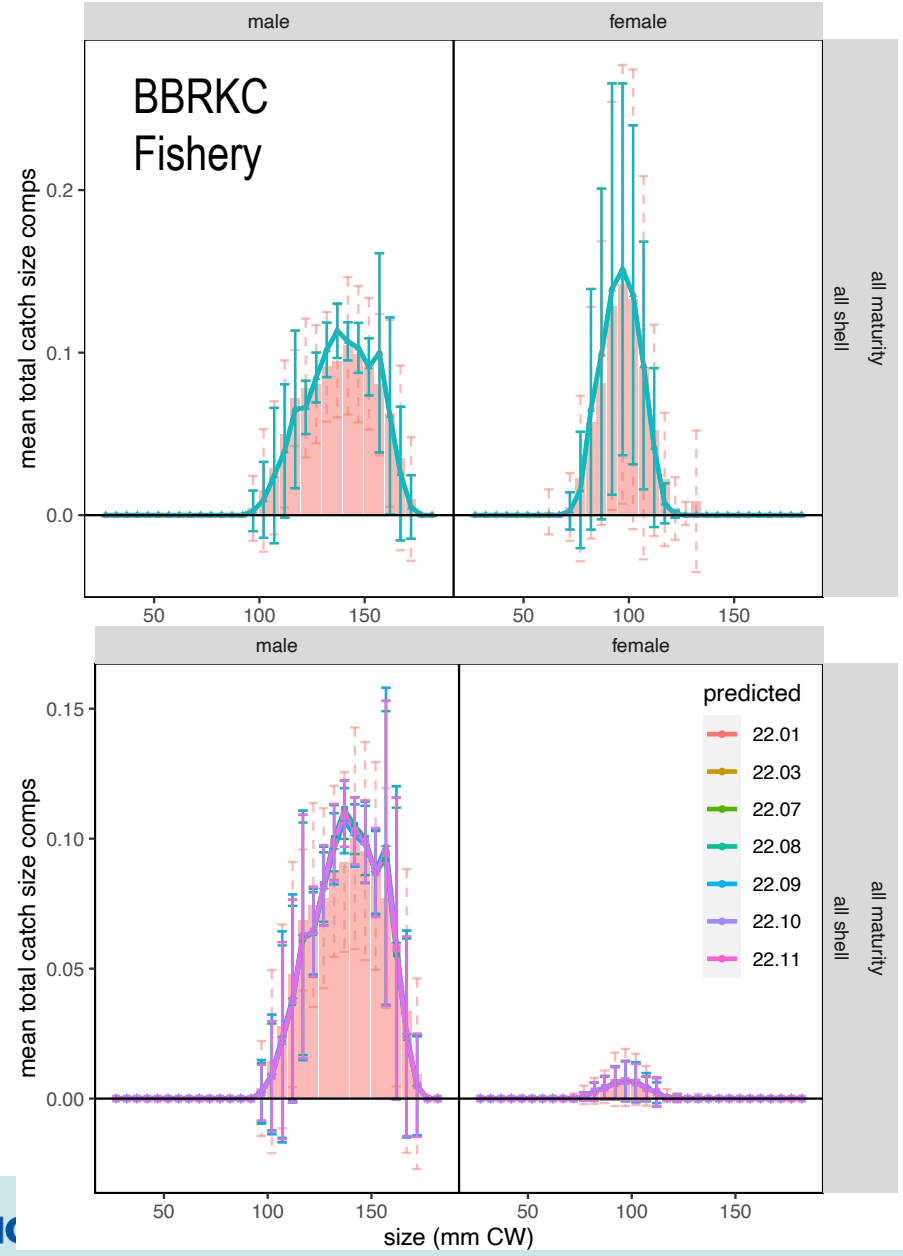


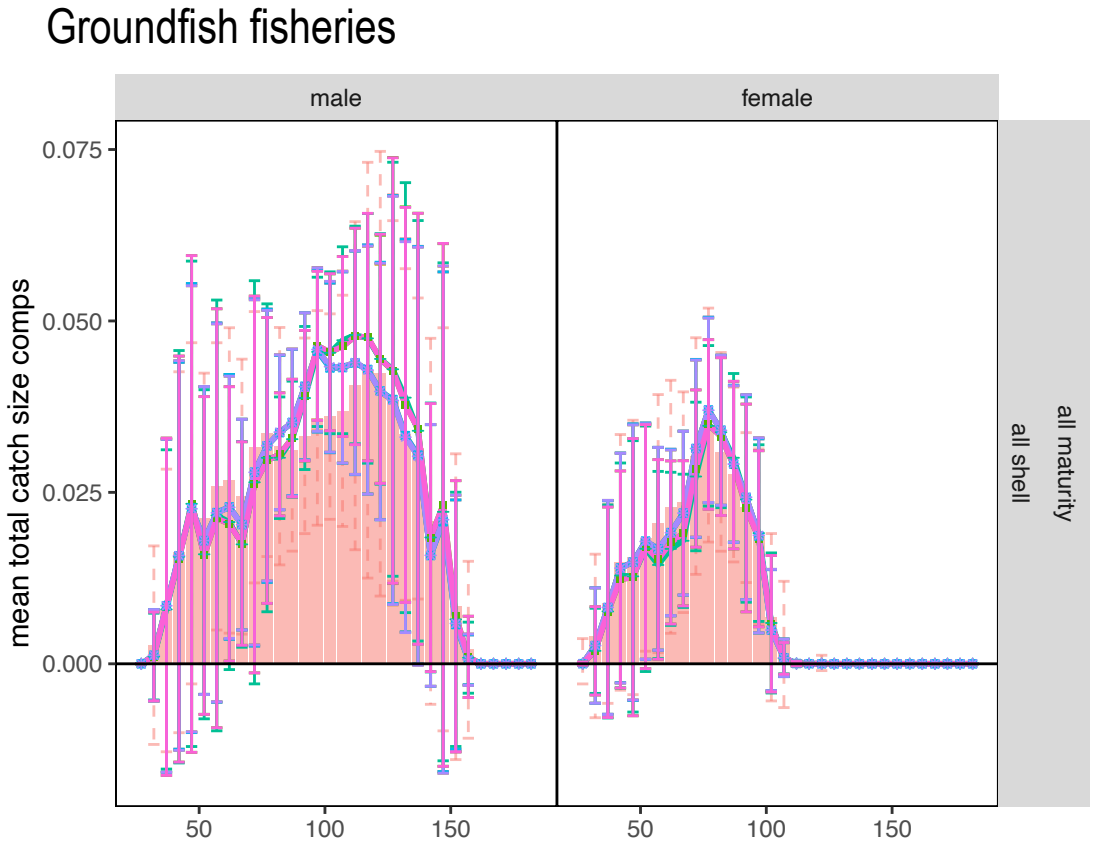
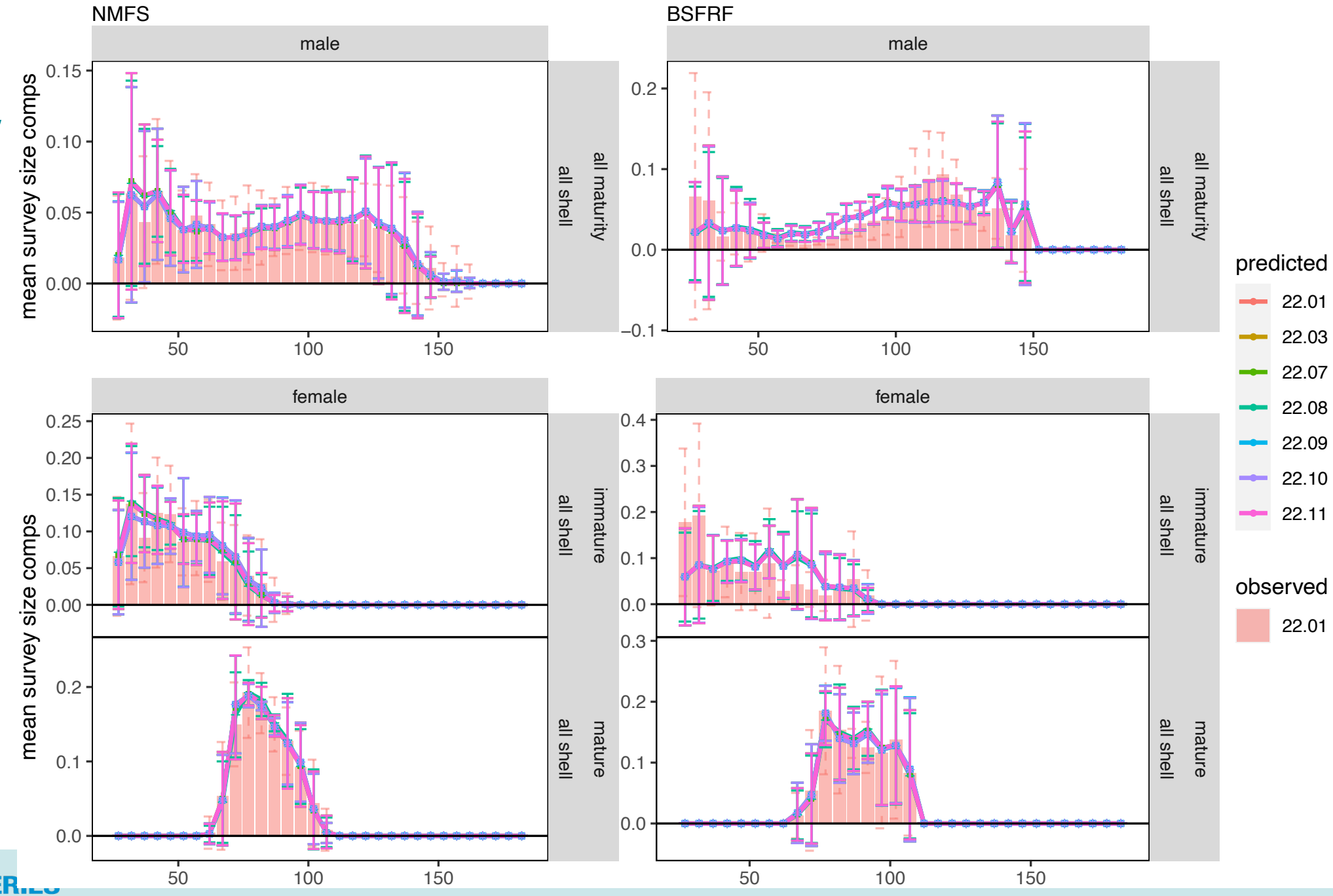
Fits to Data: Mean Fishery Catch Size Comps





Fits to Data: Mean Fishery Catch Size Comps





Fits to Data: Mean Survey Size Comps