

# 2024-05 Tanner Crab Report

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# Outline

- New Data and Analysis
- Proposed Models
  - TCSAM02 models
  - GMACS models
- Summary



# SSC/CPT Requests Addressed

- Develop GMACS model with simplified dynamics
- Incorporate 2018 BSFRF data
- Evaluate inclusion of VAST model-based survey indices
- Initiated research into GOA Tanner crab fisheries and stock dynamics
- Results from a Tier 4 model were included in the 2023 assessment
  - will be updated for 2024



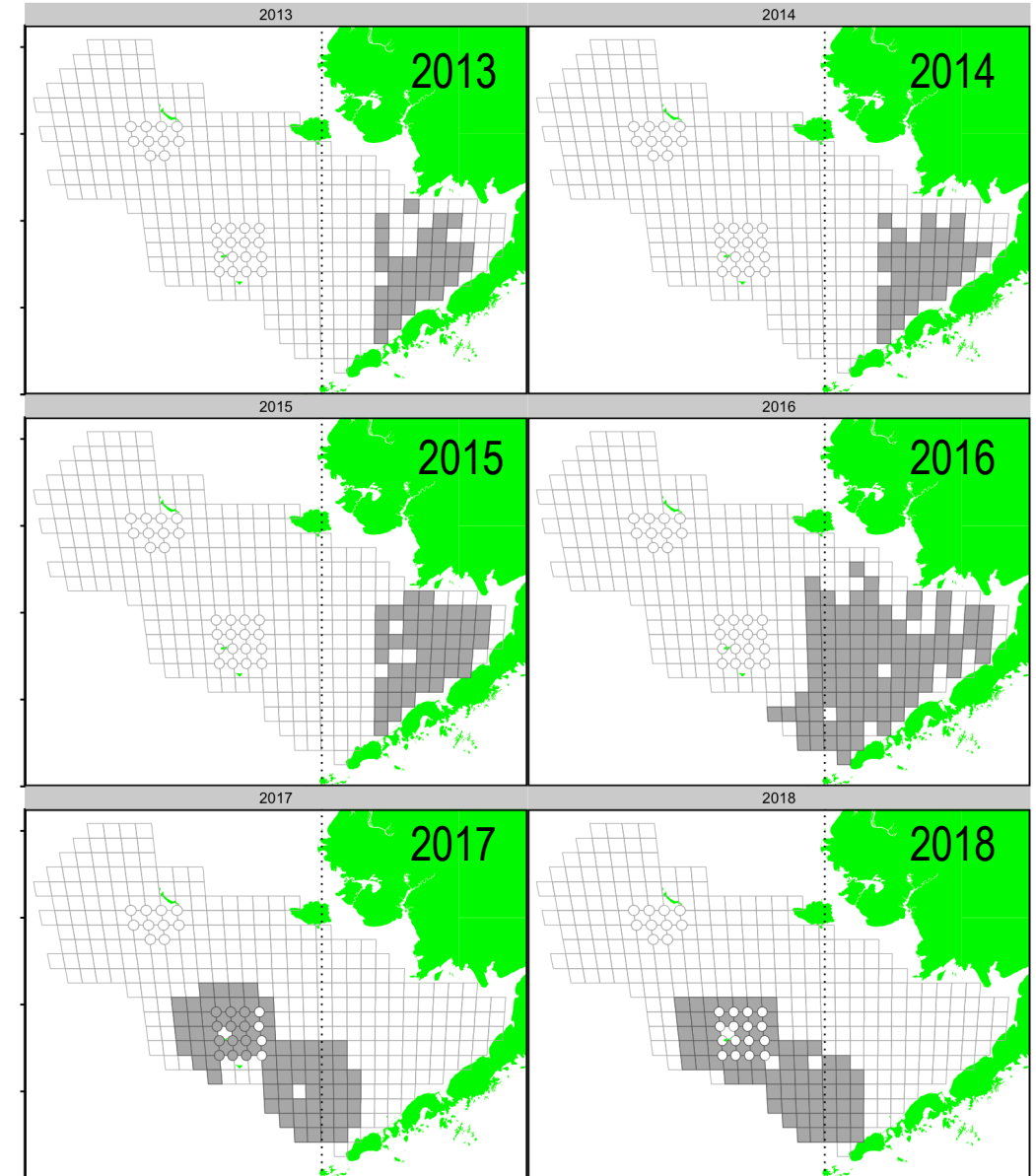
# New Data and Analysis

- Updated 2013-2017 + **new 2018** BSFRF SBS data
  - Updated/new BSFRF biomass estimates and size comps
  - Updated/new empirical availability curves
- New SBS selectivity analysis
- Empirical probability of terminal molt
- VAST (model-based) indices
- GOA Tanner crab trends
  - Kodiak large mesh survey
  - Harvest data



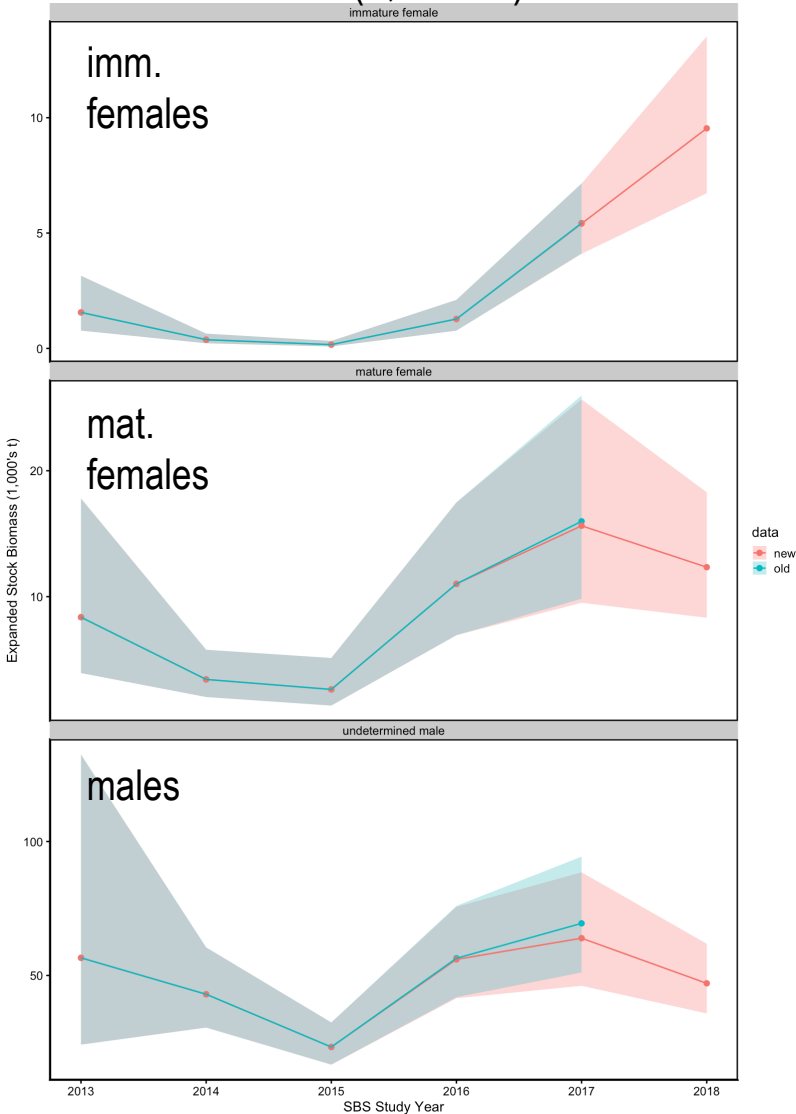
# 2013-2018 BSFRF SBS Data

- BSFRF-NMFS collaborative studies to estimate NMFS survey selectivity for BBRKC, Tanner crab
- Side-by-side (SBS) hauls allow estimates of
  - *relative* NMFS haul-level selectivity
- BSFRF nephrops gear assumed to catch all crab in area swept; allows estimates of
  - *absolute* NMFS haul-level selectivity
- Scale up to NMFS survey-level selectivity by
  - estimating haul-level covariate effects
  - weighting haul-level estimates by observed abundance-at-size

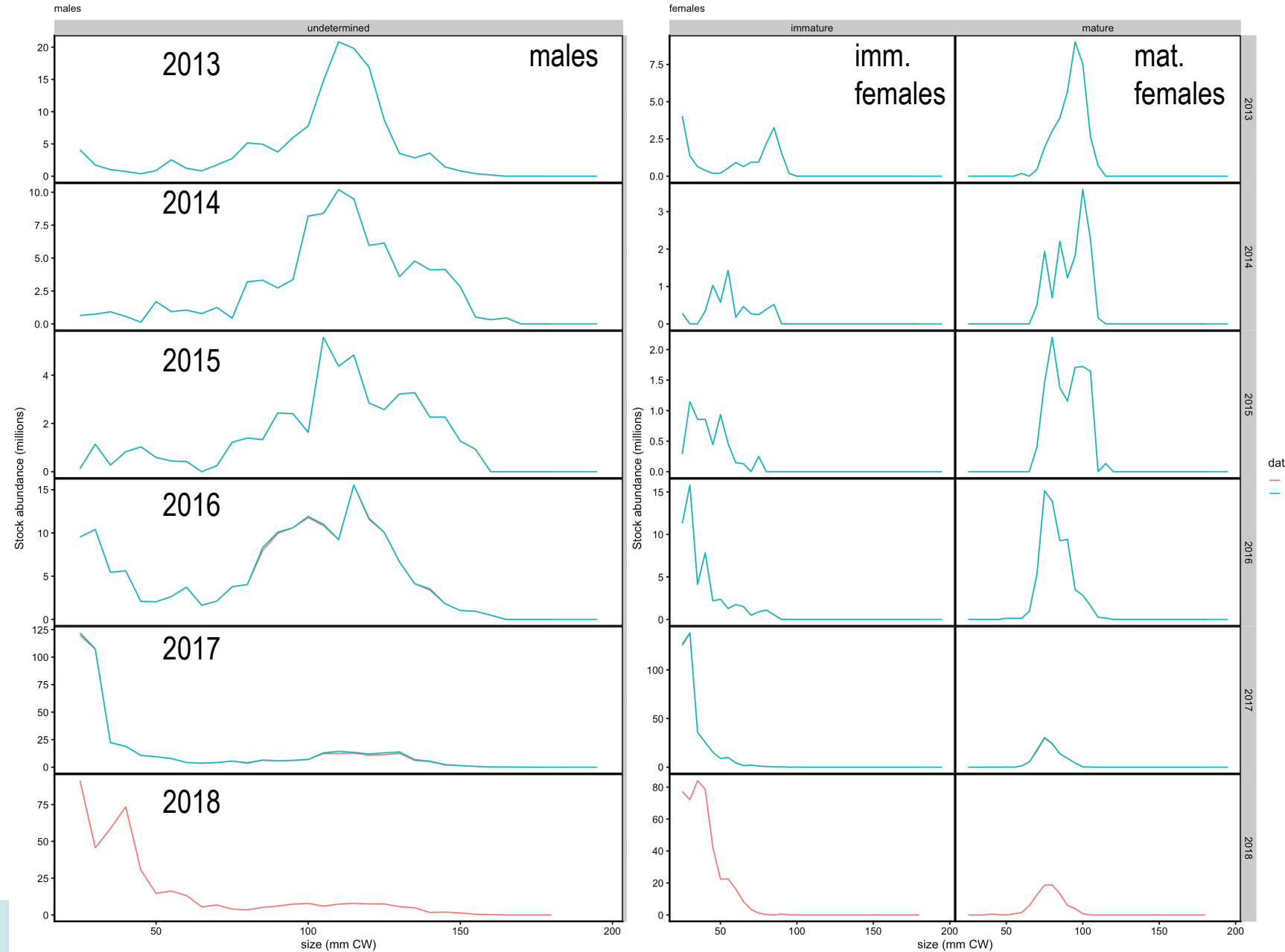


# BSFRF Estimates

## Biomass (1,000's t)



## Abundance-at-size (millions)



# Empirical Availability

Raw estimates

$$A_x(z) = \frac{N_x^a(z)}{N_x^t(z)}$$

2013-2017 Analysis

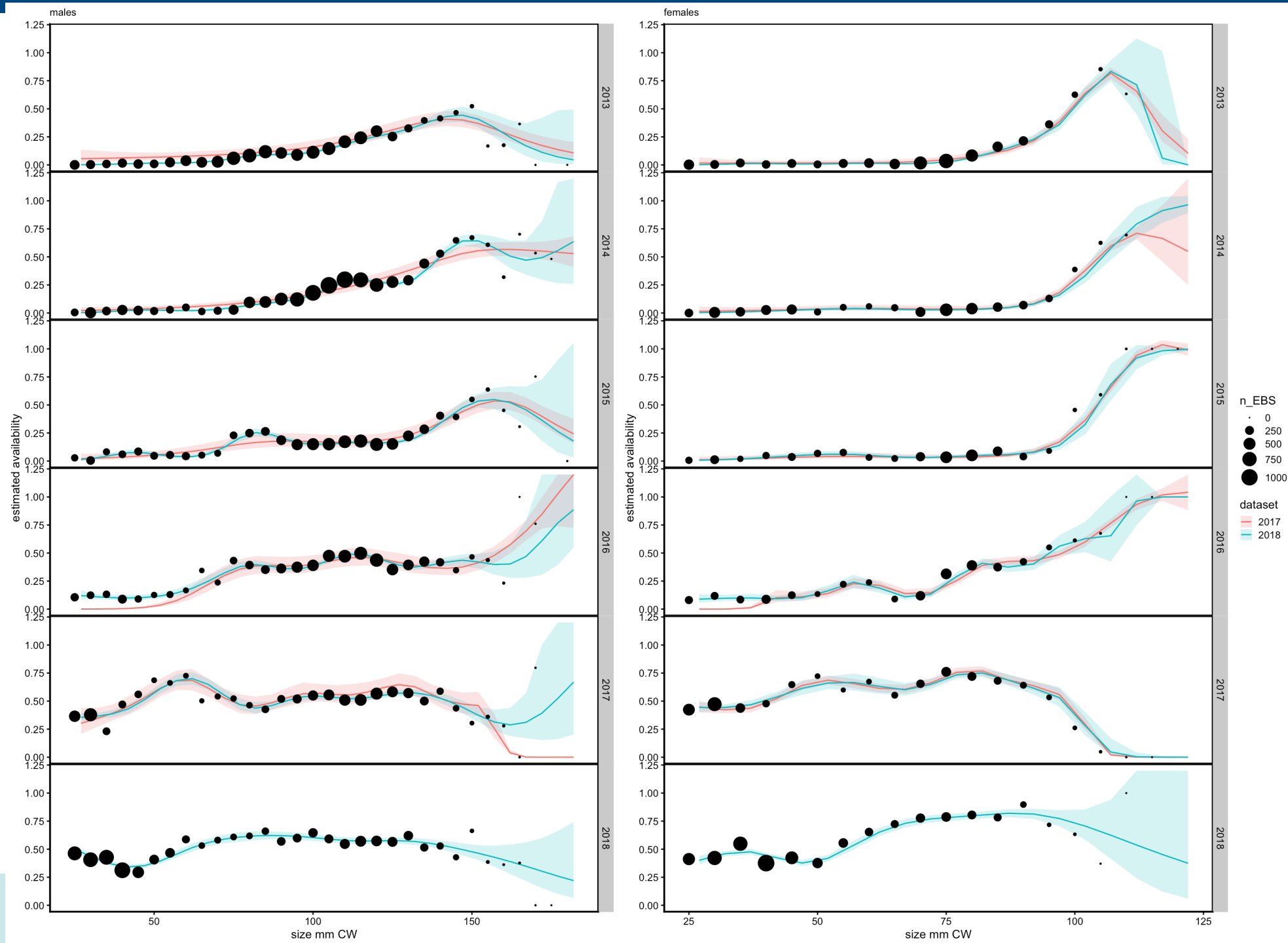
GAM using normal error dist.

$$\log(A_{y,z}) = s(z, by = y)$$

2013-2018 Analysis

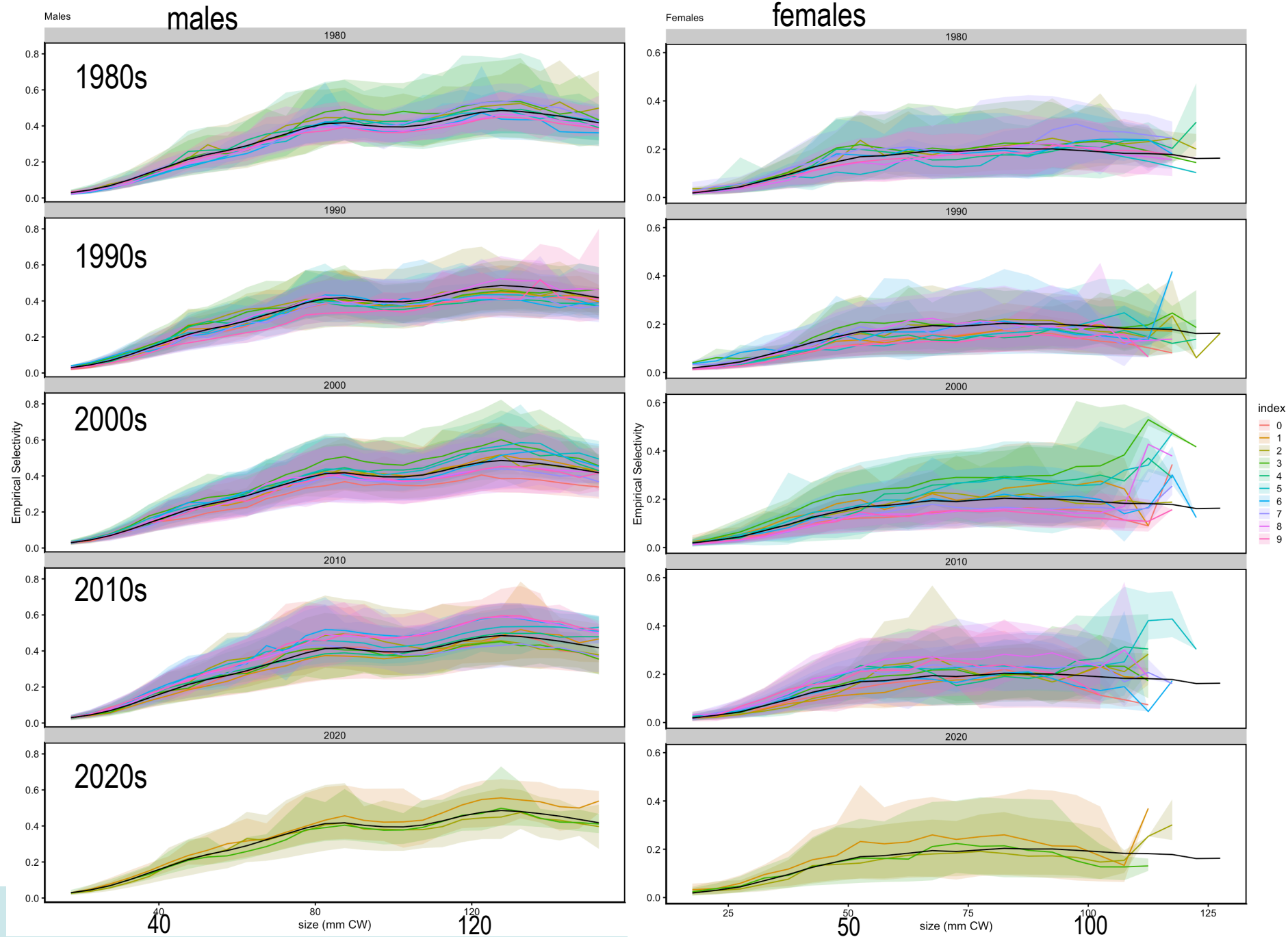
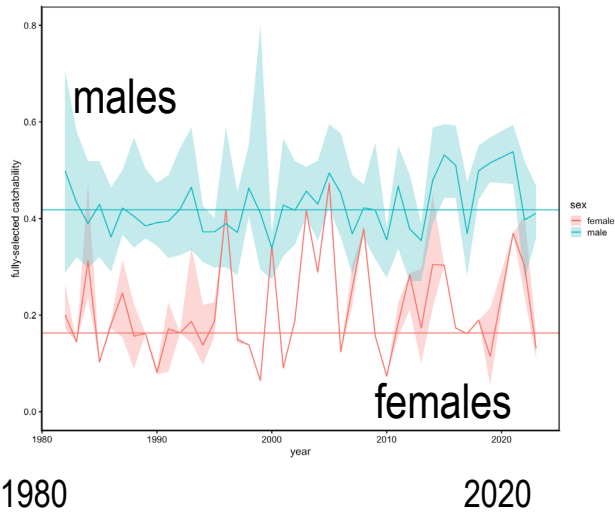
GAM using binomial error dist.

$$\frac{\log(A_{y,z})}{\log(1 - A_{y,z})} = c_y + s(z, by = y)$$



# Estimated Annual Survey Selectivity

fully-selected catchability

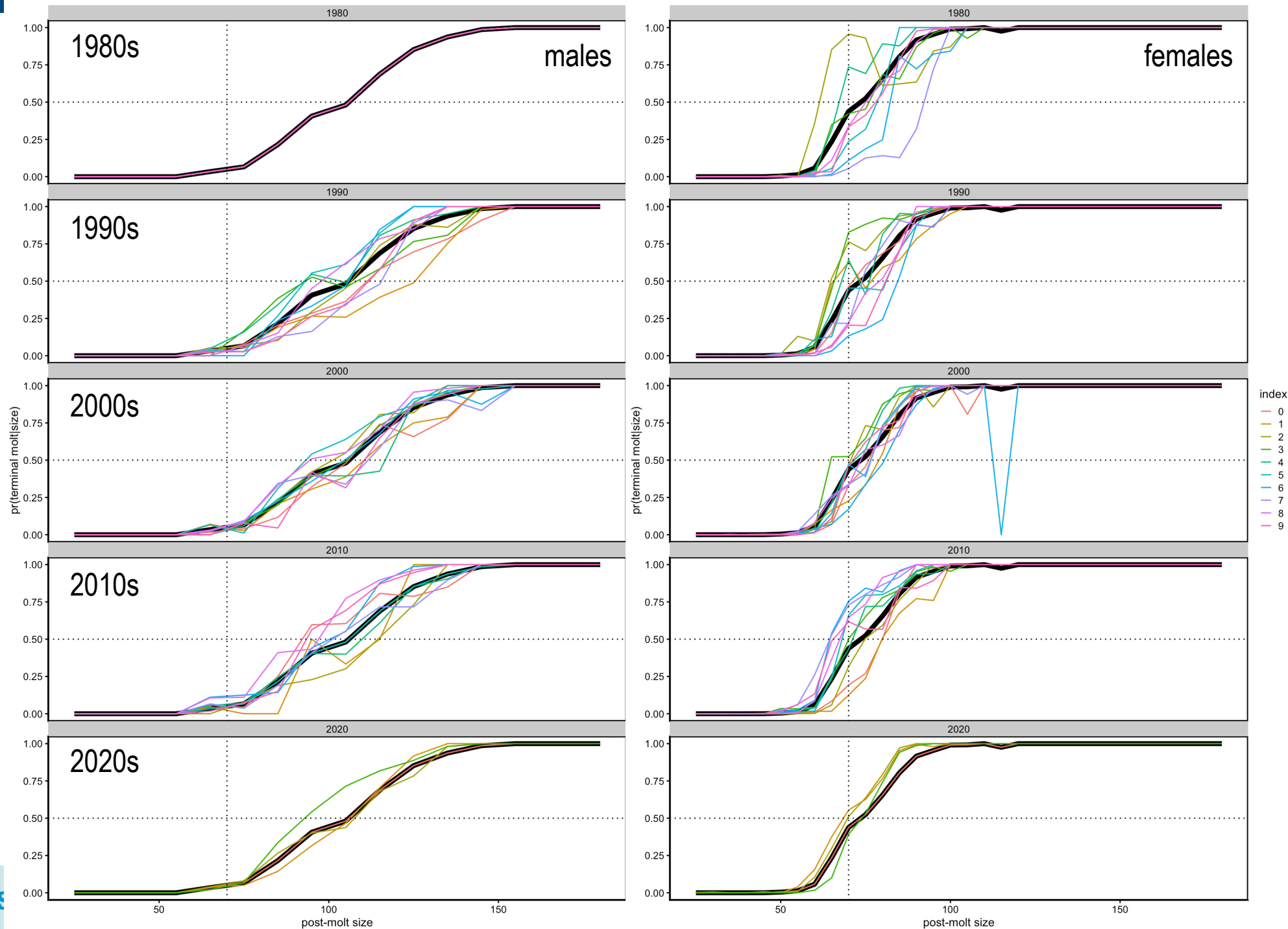




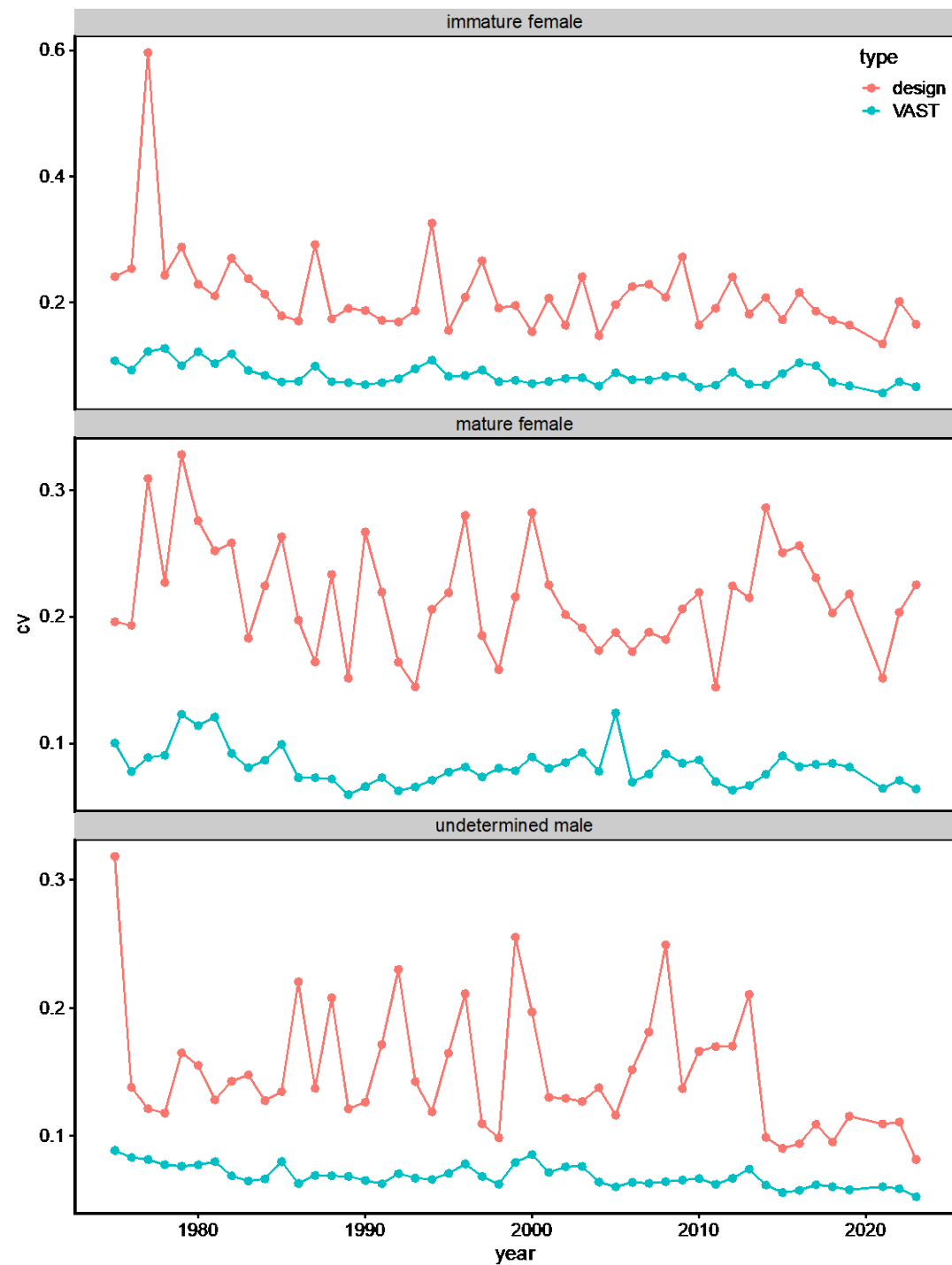
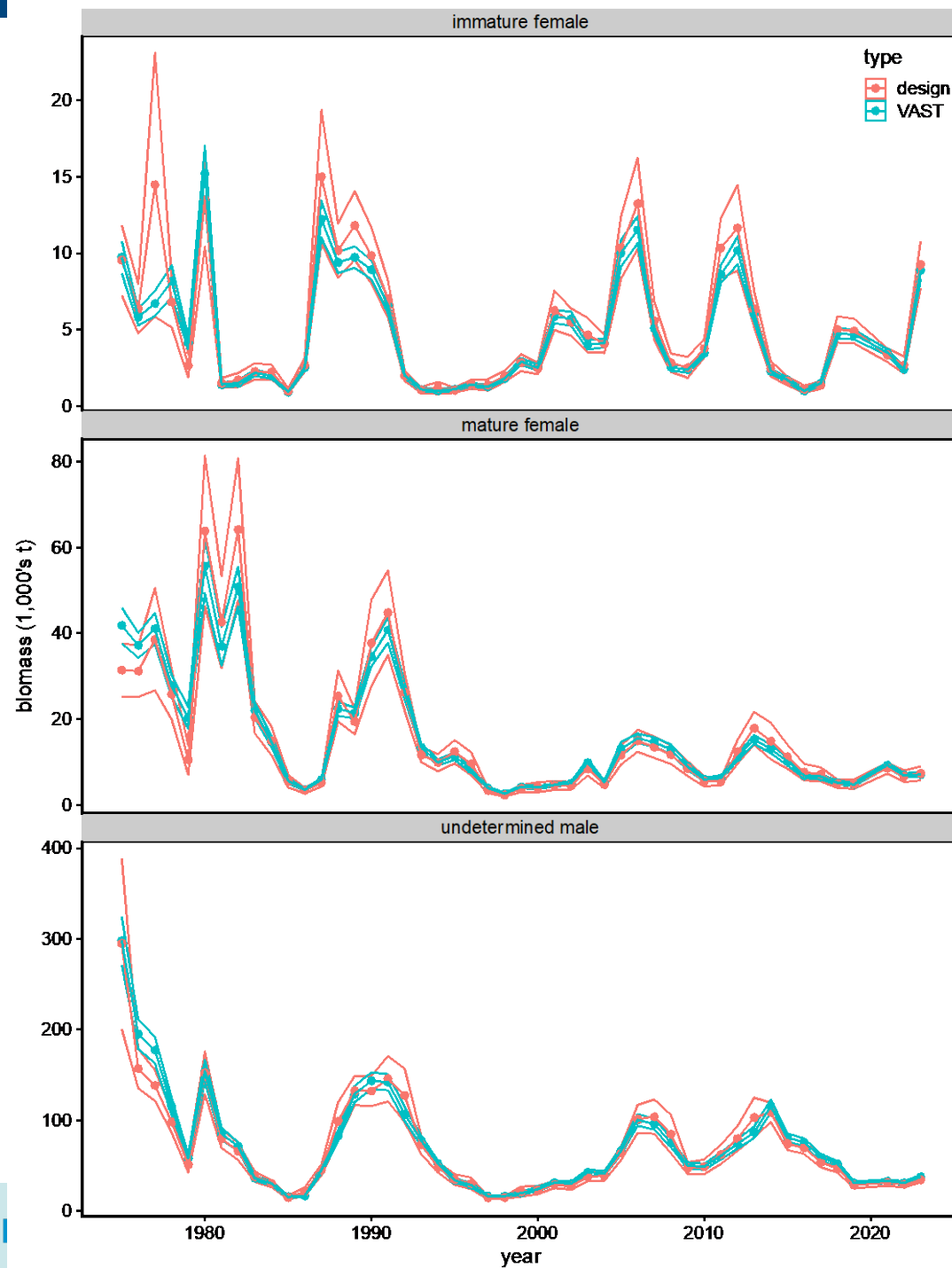
# Empirical Probability of Terminal Molt

$$prTM(z) = \frac{N_M(z)}{N_M(z) + N_I(z)}$$

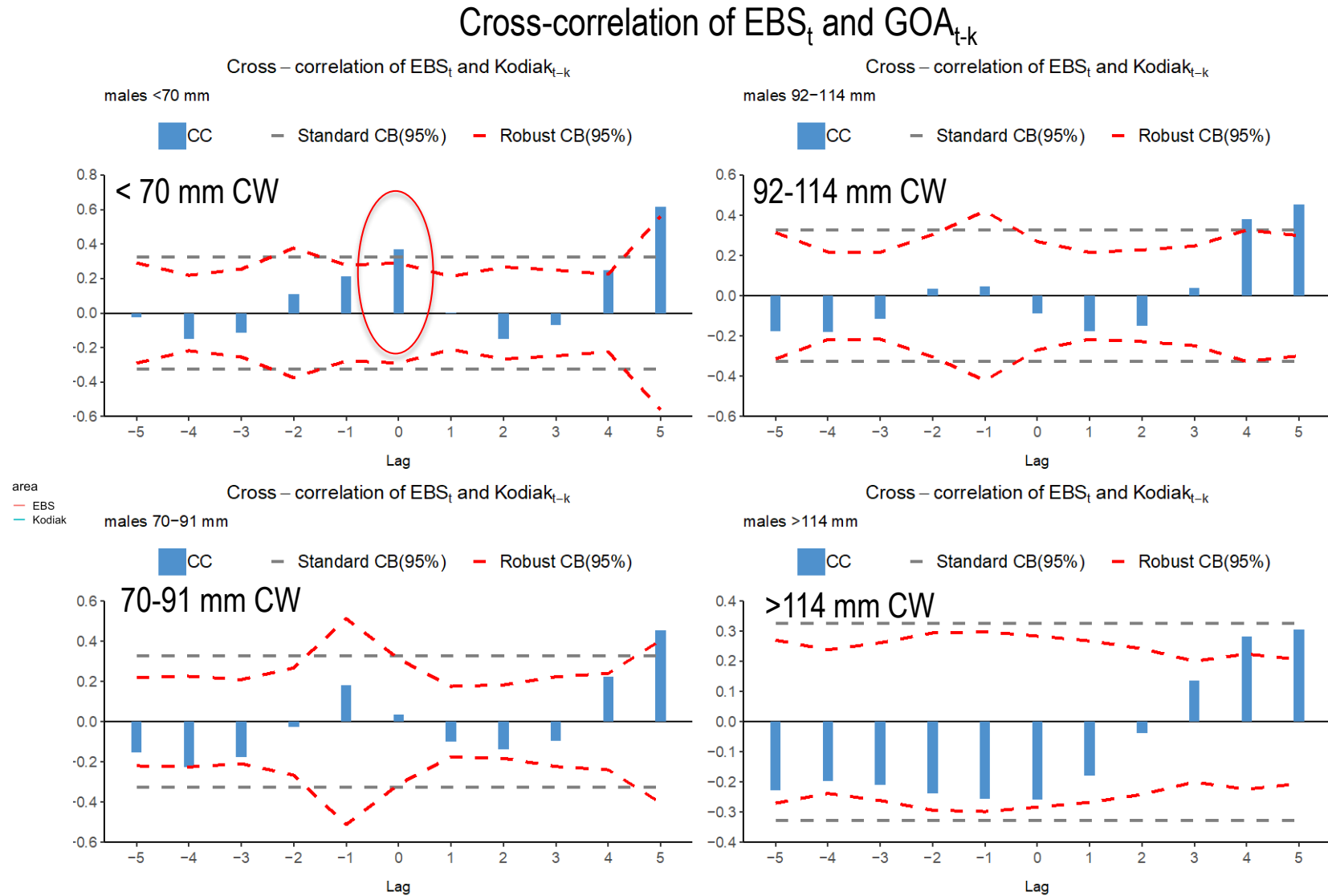
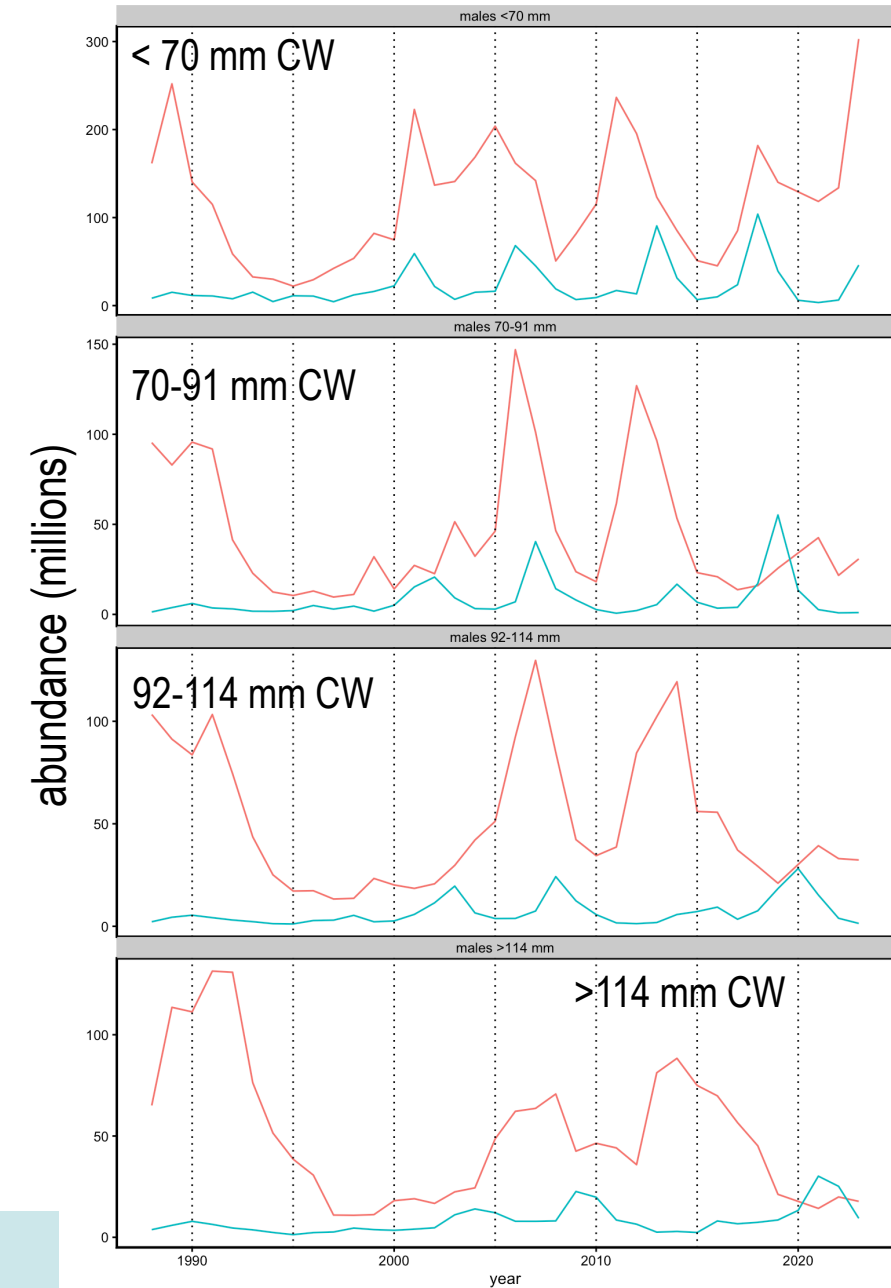
- 5-mm CW size bins
- male values linearly interpolated from J. Richar's CH: CW analysis



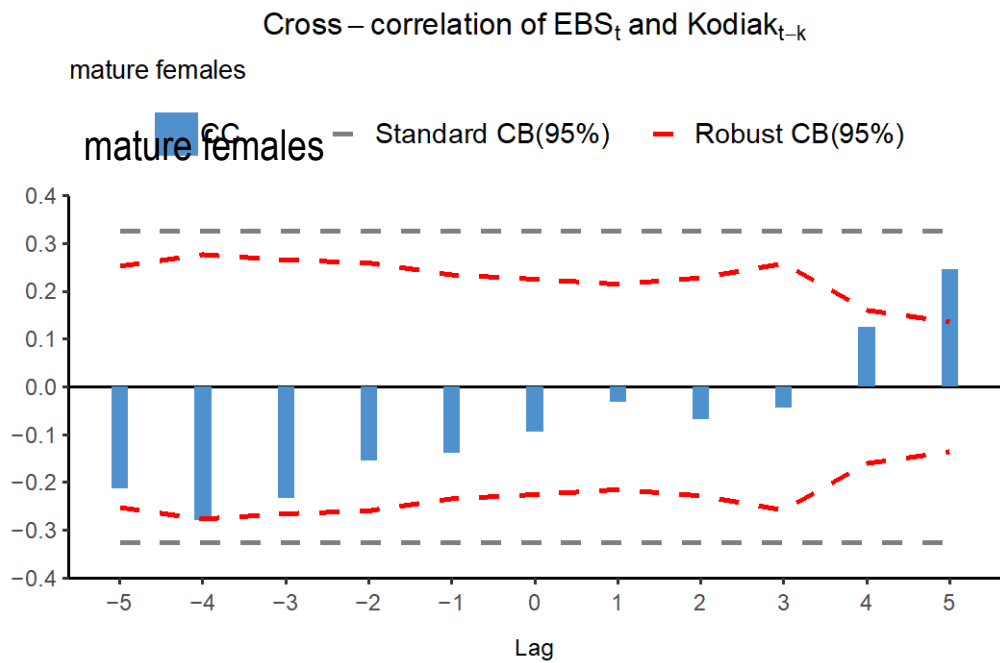
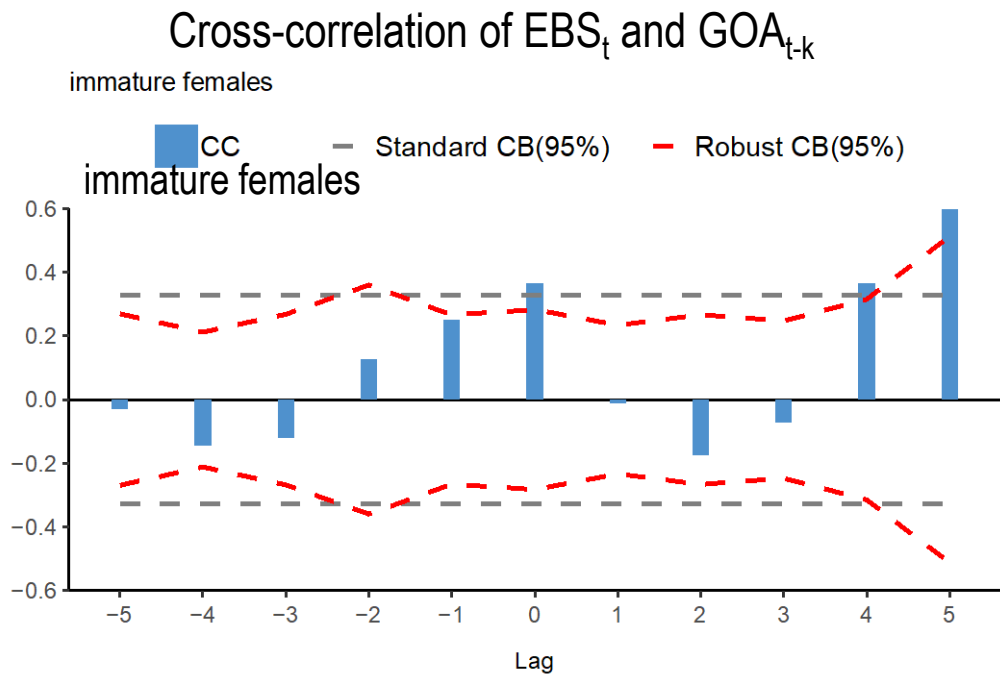
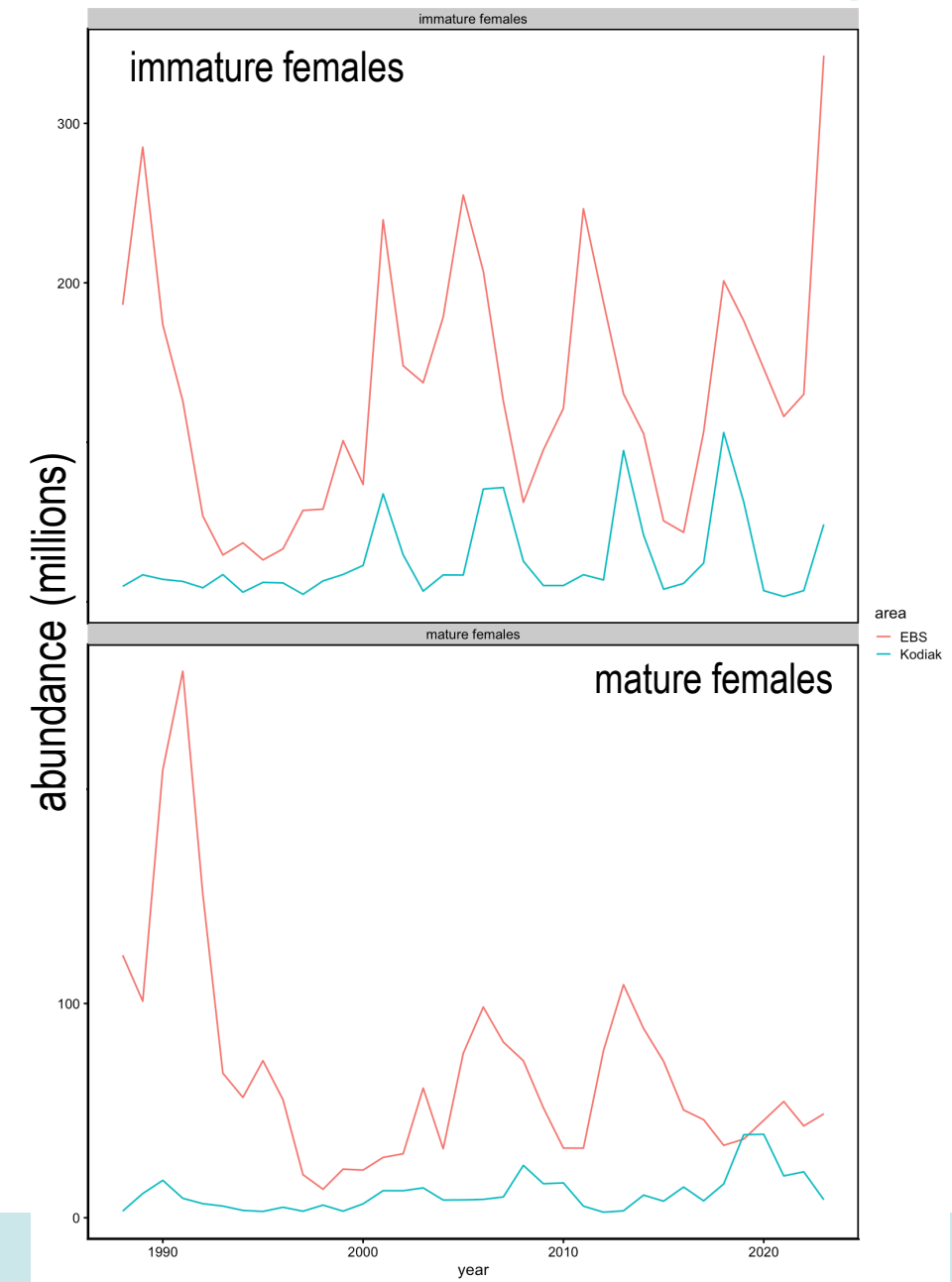
# VAST indices



# GOA Tanner crab trends (males)



# GOA Tanner crab trends (females)

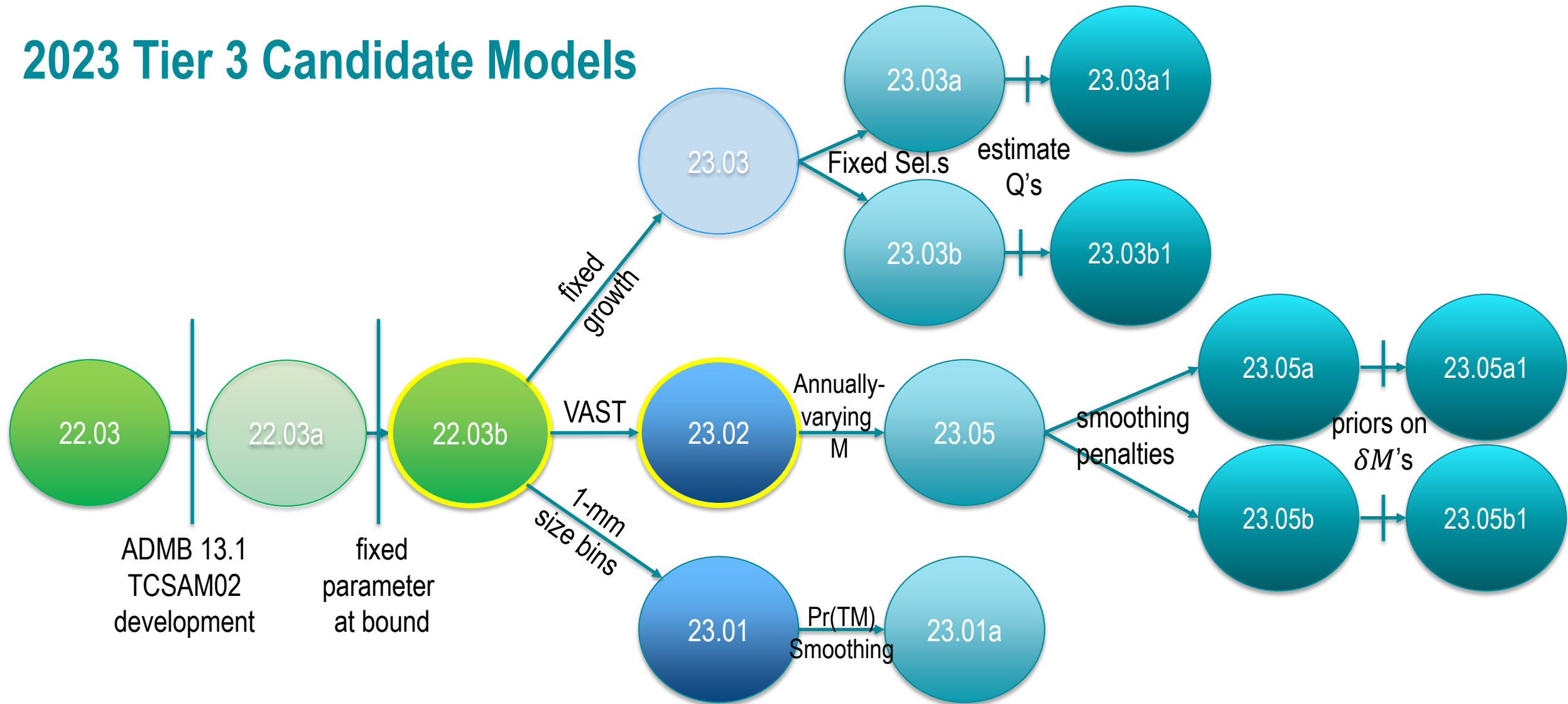


# Proposed Models

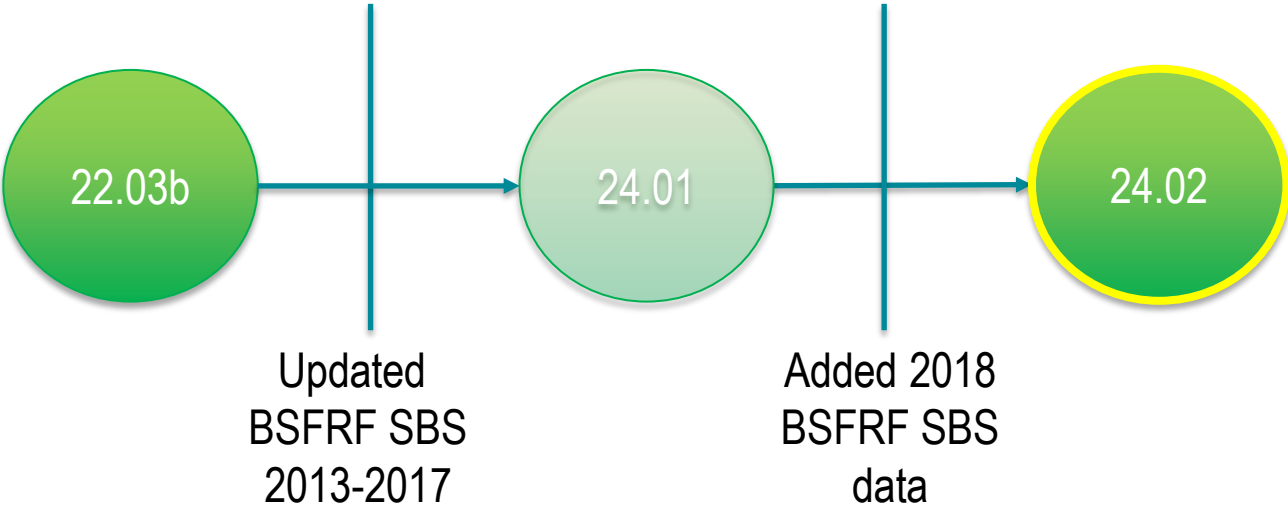
- TCSAM02 Models
  - model descriptions
  - model results
- GMACS Models
  - model descriptions
  - model results
- Comparison of TCSAM02 and GMACS Models



# 2023 Tier 3 Candidate Models



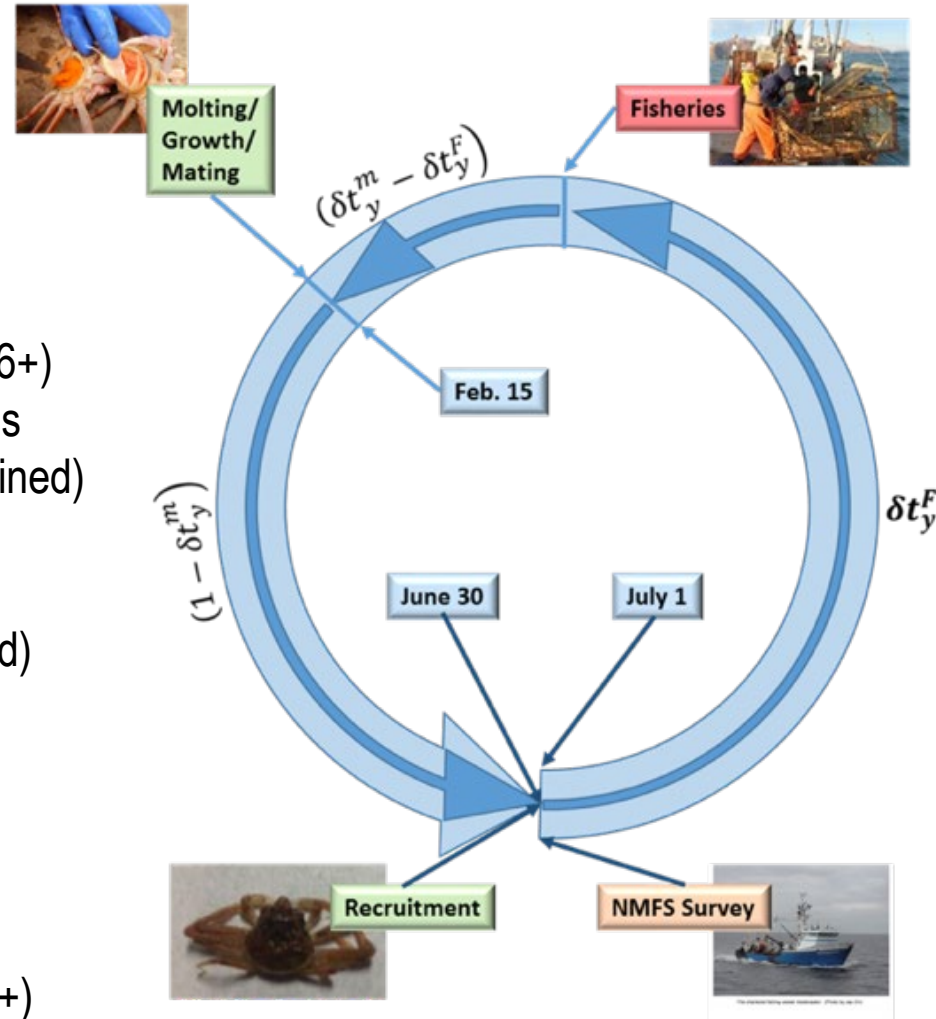
# 2024 TCSAM02 Candidate Tier 3 Models



# 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

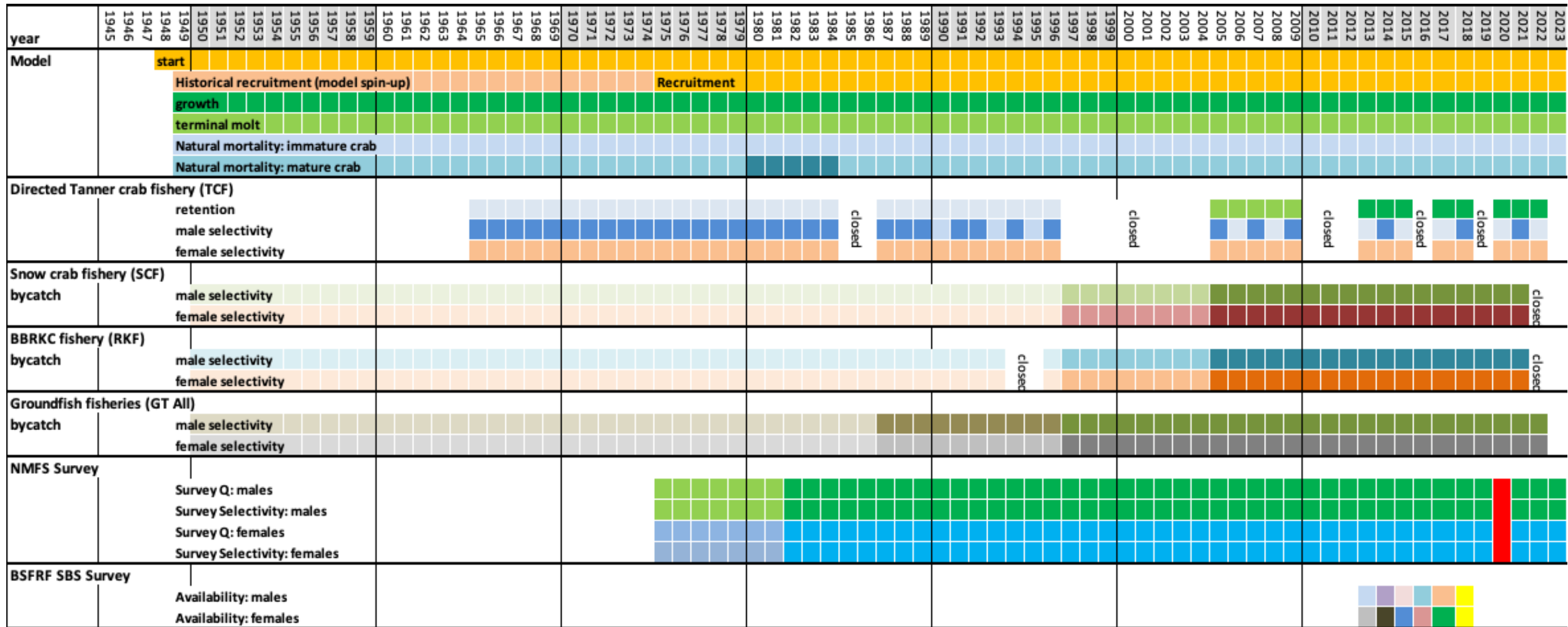
- weight-at-size
- handling mortality rates
- availability to BSFRF survey
- fully-selected sizes

## Determines

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



# Assessment model (22.03b) time frames and data



# Population dynamics

process	time blocks	22.03b description
Population rates and quantities		
Population built from annual recruitment		
Recruitment	1949-1974	In-scale mean + annual devs constrained as AR1 process
	1975+	In-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 mortality	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

Fishery/process	time blocks	22.03b description
<b>RKF</b>	<b>bycatch in BBRKC fishery</b>	
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
<b>GTF</b>	<b>bycatch in groundfish fisheries</b>	
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

Fishery/process	time blocks	22.03b description
<b>TCF</b>	<b>directed Tanner crab fishery</b>	
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-	ascending logistic
	1996; 2005-2009;	
	2013+	
% retained	pre-1988	fixed at 100%
	1991-1996	fixed at 100%
	2005-2009	fixed at 100%
	2013+	fixed at 100%
<b>SCF</b>	<b>bycatch in snow crab fishery</b>	
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
female selectivity	1997-2004	dome-shaped (double normal)
	2005+	dome-shaped (double normal)
	1949-1996	ascending logistic
	1997-2004	ascending logistic
	2005+	ascending logistic



# Surveys

Survey/process	time blocks	22.03b 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	2013-2017	fixed at 1 for all sizes
male availability	2013-2017	empirically-determined outside the model
female catchability	2013-2017	fixed at 1 for all sizes
female availability	2013-2017	empirically-determined outside the model

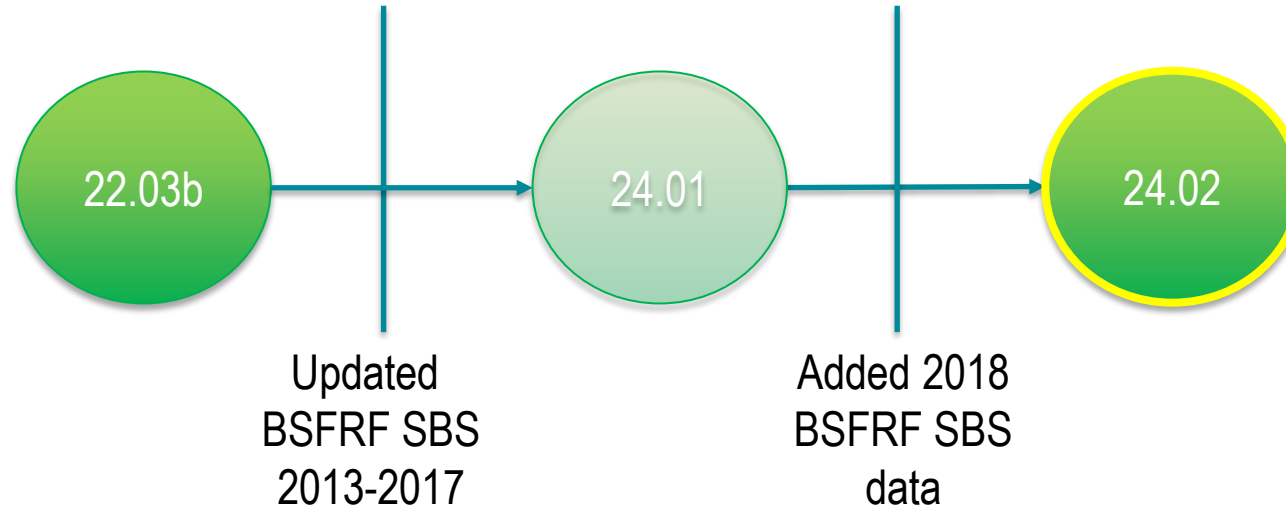


# Likelihoods

Model	Component	Type	included in optimization	Fits	Likelihood distribution
22.03b	TCF: retained catch	biomass	yes	males only	lognormal
		size comp.s	yes	males only	multinomial
	TCF: total catch	biomass	yes	total	lognormal
		size comp.s	yes	by sex (extended)	multinomial
	SCF: total catch	biomass	yes	total	lognormal
		size comp.s	yes	by sex (extended)	multinomial
	RKF: total catch	biomass	yes	total	lognormal
		size comp.s	yes	by sex (extended)	multinomial
	GF All: total catch	abundance	yes	total	lognormal
		biomass	yes	total	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	



# TCSAM02 Models



<b>model configuration</b>	<b>parent</b>	<b>number of estimated parameters</b>	<b>changes to parent model</b>
22.03b	--	354	--
24.01	22.03b	354	updated 2013-2017 BSFRF data & availability curves
24.02	24.01	354	2018 BSFRF data & availability curves

# TCSAM02 Models Results

## Summary

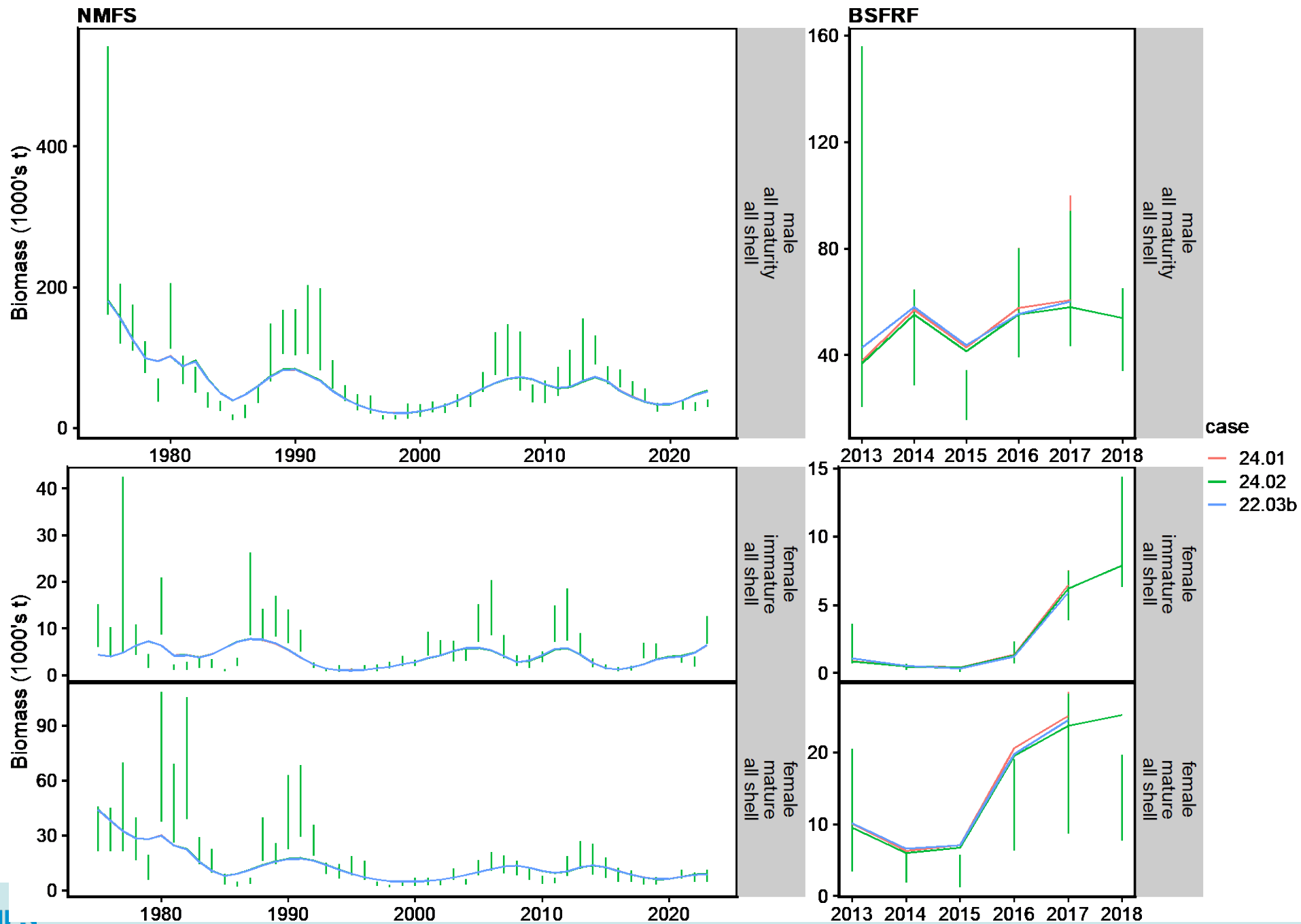
model configuration	number of parameters	no. of param.s at bounds	objective function value	max gradient	invertible for std. devs?
22.03b	354	0	3142.77	8.13E-05	yes
24.01	354	2	3021.33	3.96E-02	yes
24.02	354	2	3086.21	1.08E-02	yes

## Parameters-at-bounds

		name	label	22.03b	24.01	24.02
likelihood	Dirichlet-Multinomial	pLnDirMul[1]	ln(theta) parameter for BSFRF SBS M	-	1	1
		pLnDirMul[2]	ln(theta) parameter for BSFRF SBS F	-	1	1

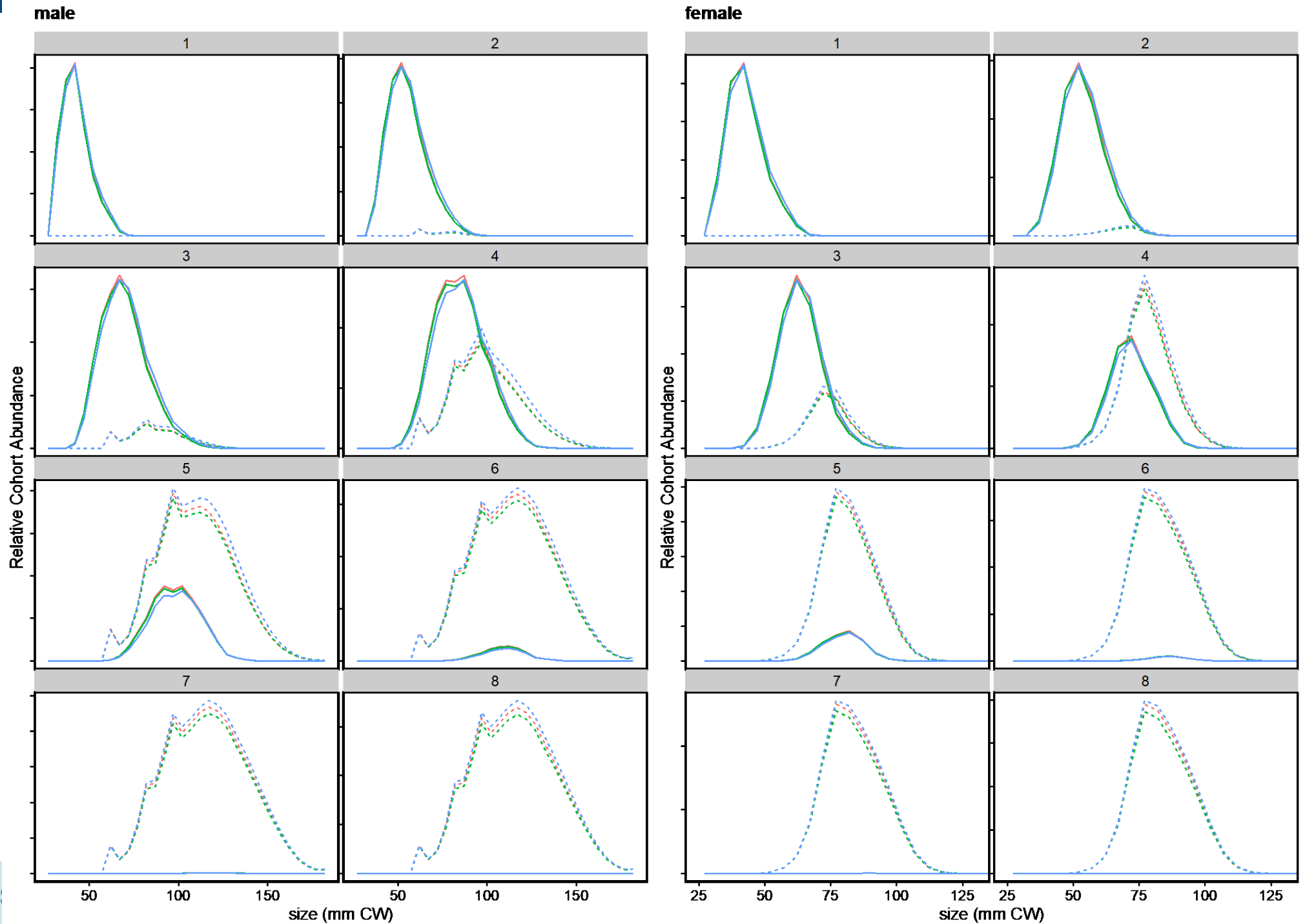


# TCSAM02 Models Results

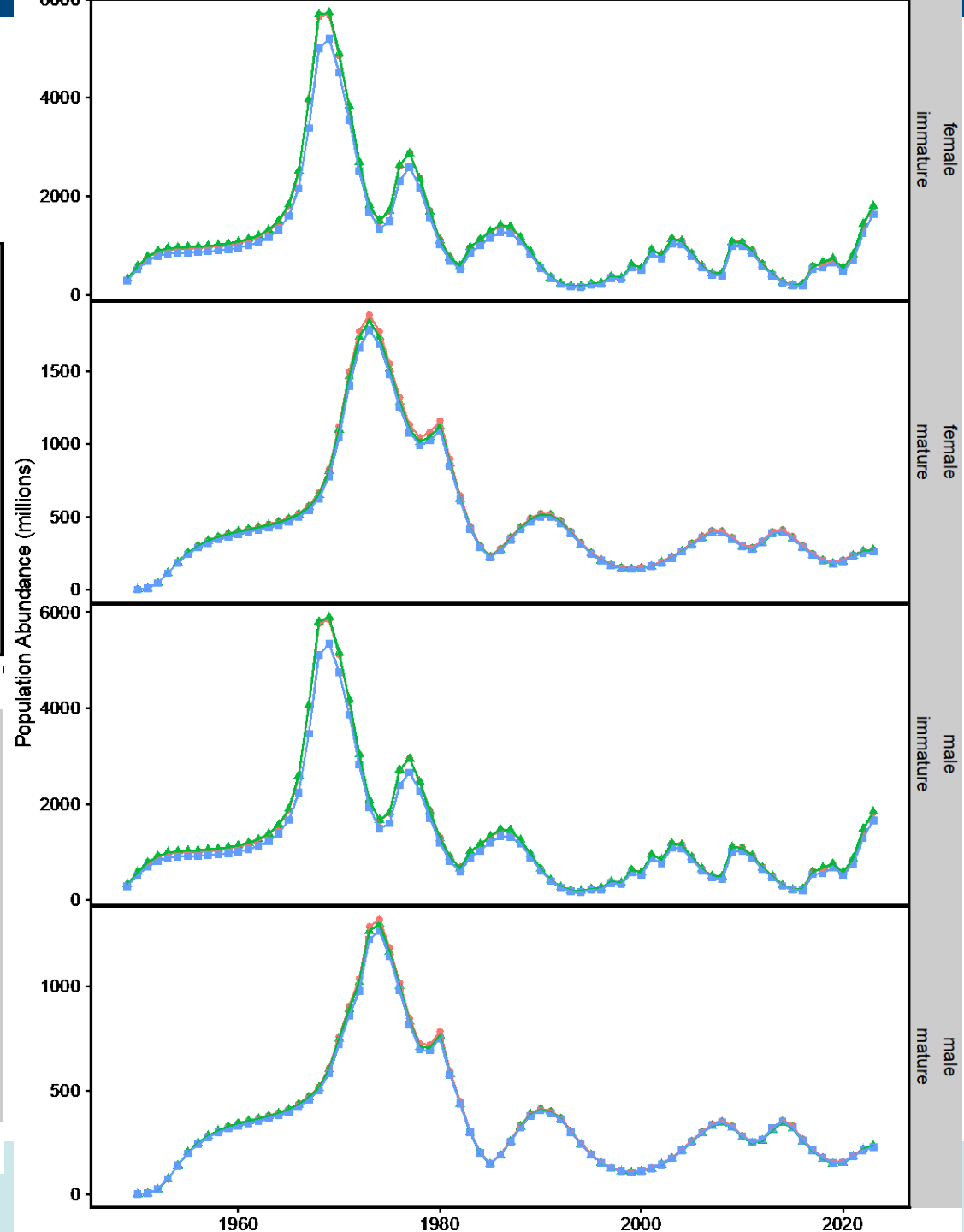
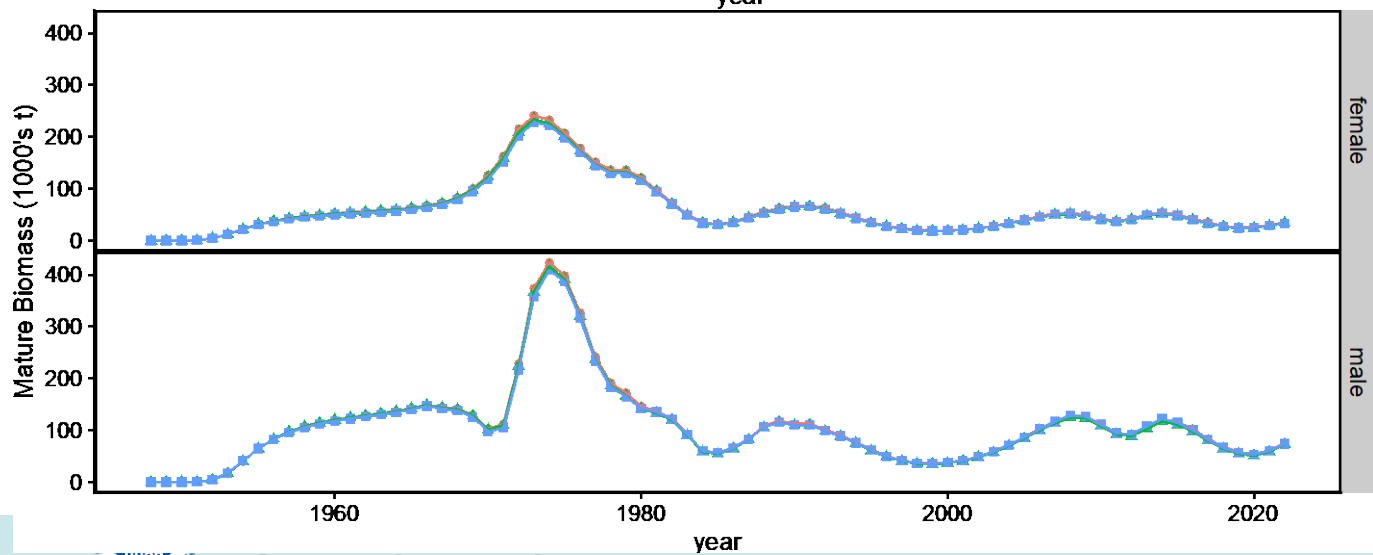
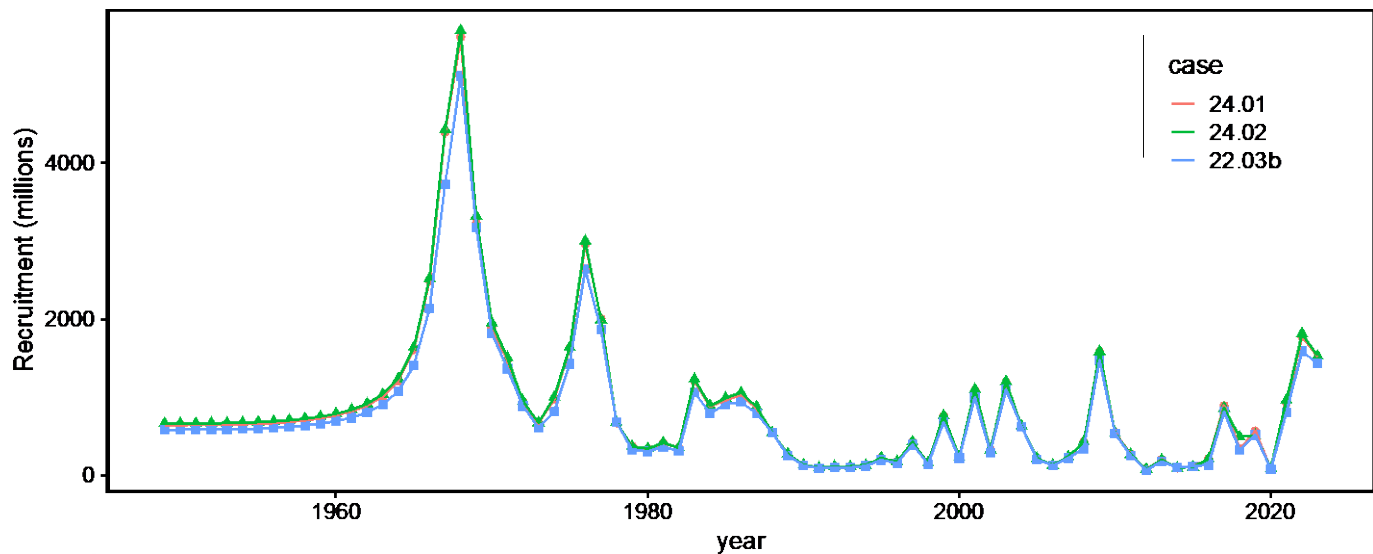




# TCSAM02 Models Results



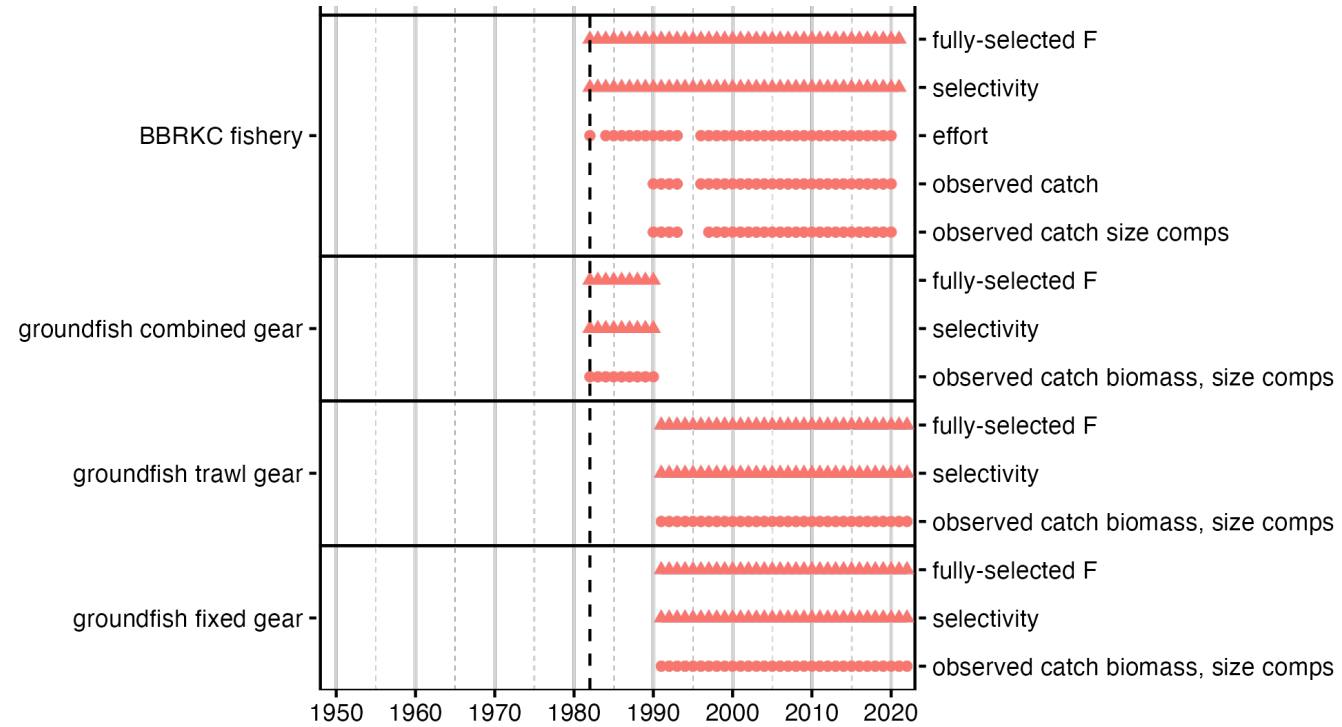
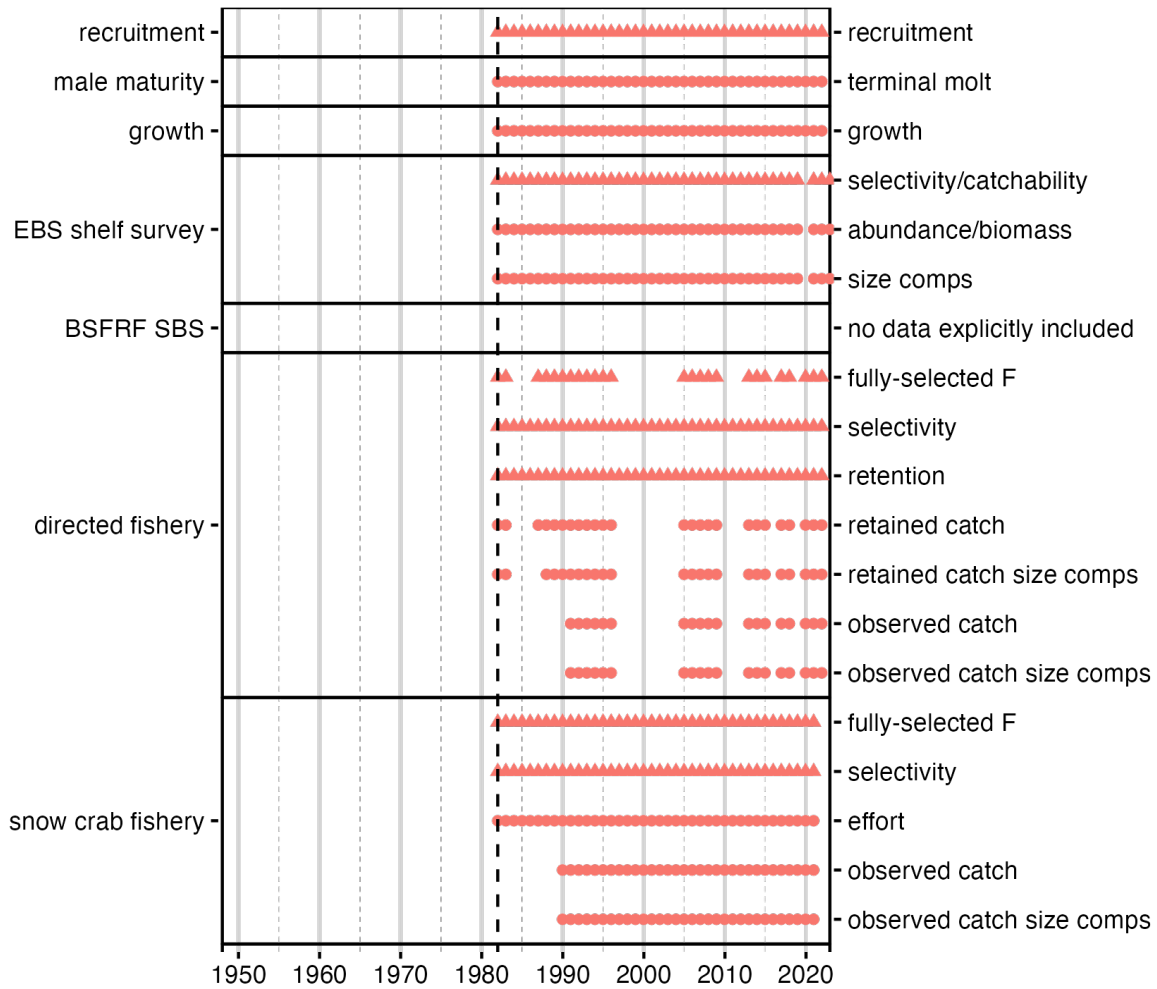
# TCSAM02 Models Results



# GMAC Models



# GMACS time frames and data



# Population dynamics

process	time blocks	G24.02 description
Population rates and quantities		
initial population stru	1982	estimated with smoothing penalties
Recruitment	1982+	In-scale mean + annual devs sex-specific, <b>determined outside model</b>
Growth	1982+	mean post-molt size: power function of pre-molt size post-molt size: gamma distribution conditioned on pre-molt size
Maturity	1982+	sex-specific probability of terminal molt depends on postmolt size <b>determined outside model</b>
Natural mortality	1982+	estimated sex/maturity state-specific offsets from base rate on mature males



# Crab Fisheries

Fishery/process	time blocks	G24.02 description
TCF	directed Tanner crab fishery	
capture rates	1982+	male ln-scale mean + annual devs
	1982+	ln-scale female offsets (mean+annual devs)
male selectivity	1982+	ascending logistic
female selectivity	1982+	ascending logistic
male retention	1982+	ascending logistic
% retained	1982+	fixed at 100%
SCF	bycatch in snow crab fishery	
capture rates	1982-1989	extrapolated from effort
	1990+	male ln-scale mean + annual devs
	1990+	ln-scale female offsets (mean+annual devs)
male selectivity	1982+	ascending logistic
female selectivity	1982+	ascending logistic
RKF	bycatch in BBRKC fishery	
capture rates	1982-1989	extrapolated from effort
	1990+	male ln-scale mean + annual devs
	1990+	ln-scale female offsets (mean+annual devs)
male selectivity	1982+	ascending logistic
female selectivity	1949-1996	ascending logistic



# Groundfish Fisheries

Fishery/process	time blocks	G24.02 description
<b>GFA</b>		
combined-gear bycatch in groundfish fisheries		
capture rates	1982-1990	male ln-scale mean + annual devs
	1982-1990	ln-scale female offsets (mean+annual devs)
male selectivity	1982-1990	ascending logistic
female selectivity	1982-1990	ascending logistic
<b>GFT</b>		
trawl-specific bycatch in groundfish fisheries		
capture rates	1991+	male ln-scale mean + annual devs
	1991+	ln-scale female offsets (mean+annual devs)
male selectivity	1991+	ascending logistic
female selectivity	1991+	ascending logistic
<b>GFF</b>		
fixed gear-specific bycatch in groundfish fisheries		
capture rates	1991+	male ln-scale mean + annual devs
	1991+	ln-scale female offsets (mean+annual devs)
male selectivity	1991+	ascending logistic
female selectivity	1991+	ascending logistic



# Surveys

Survey/process	time blocks	22.03b description
NMFS EBS trawl survey		
male survey q	1982+	In-scale w/ prior based on Somerton's underbag experiment
female survey q	1982+	In-scale w/ prior based on Somerton's underbag experiment
male selectivity	1982+	ascending logistic
female selectivity	1982+	ascending logistic



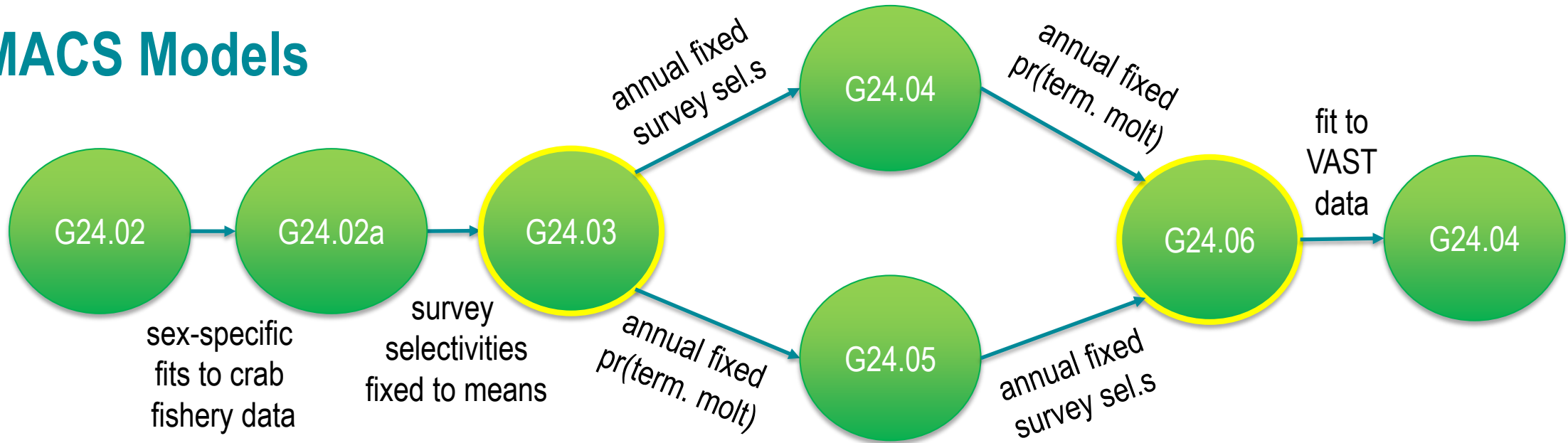


# Likelihoods

Model	Component	Type	included in optimization	Fits	Likelihood distribution
G24.02	TCF: retained catch	biomass	yes	males only	lognormal
		size comp.s	yes	males only	multinomial
	TCF: total catch	biomass	yes	combined sex	lognormal
		size comp.s	yes	by sex (extended)	multinomial
	SCF: total catch	biomass	yes	combined sex	lognormal
		size comp.s	yes	by sex (extended)	multinomial
	RKF: total catch	biomass	yes	combined sex	lognormal
		size comp.s	yes	by sex (extended)	multinomial
	GFA (combined gear): total catch	biomass	yes	combined sex	lognormal
		size comp.s	yes	by sex (extended)	multinomial
	GFT (trawl gear): total catch	biomass	yes	combined sex	lognormal
size comp.s		yes	by sex (extended)	multinomial	
GFF (fixed gear): total catch	biomass	yes	combined sex	lognormal	
	size comp.s	yes	by sex (extended)	multinomial	
NMFS "M" survey (males only, comb. maturity)	biomass	yes	design-based indices	lognormal	
	size comp.s	yes	design-based indices	multinomial	
NMFS "IF" survey (immature females)	biomass	yes	design-based indices	lognormal	
	size comp.s	yes	design-based indices	multinomial	
NMFS "MF" survey (mature females)	biomass	yes	design-based indices	lognormal	
	size comp.s	yes	design-based indices	multinomial	
growth data	EBS only	no	--	--	
male maturity ogive data	EBS only	no	--	--	



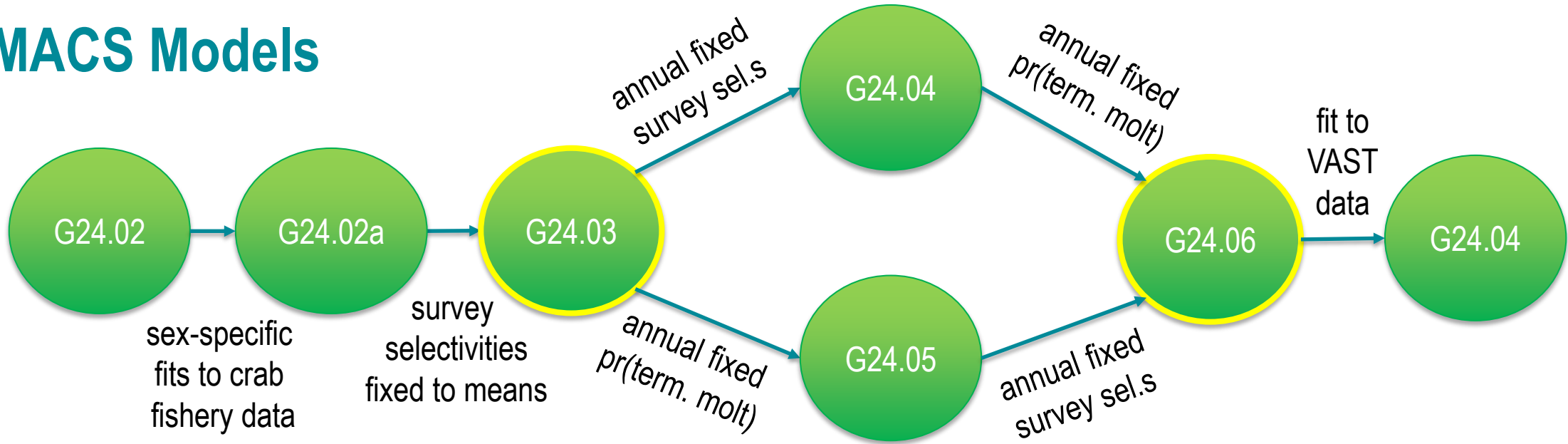
# GMACS Models



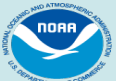
model configuration	parent(s)	number of estimated parameters	changes to parent model
G24.02	--	445	--
G24.02a	G24.02	445	fits to crab fishery catch data are sex-specific, not combined sex
G24.03	G24.02a	441	NMFS survey selectivities fixed to mean empirical selectivities
G24.04	G24.03	441	NMFS survey selectivities fixed to year-specific empirical selectivities
G24.05	G24.03	441	probability of terminal molt fixed to year-specific estimates
G24.06	G24.04, G24.05	441	probability of terminal molt fixed to year-specific estimates, NMFS survey selectivities fixed to year-specific empirical selectivities
G24.07	G24.06	441	fits to VAST survey biomass indices



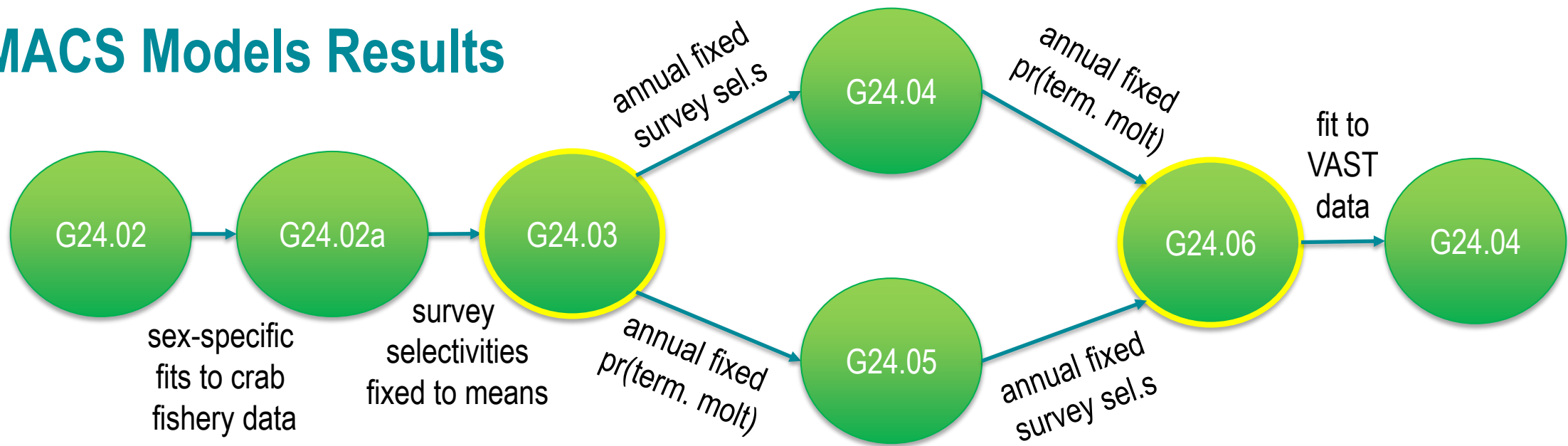
# GMACS Models



model configuration	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?
G24.02	445	400	55	2	13904.46	1.52E-03	yes
G24.02a	445	400	1	4	14158.37	1.24E-03	yes
G24.03	441	400	65	1	14501.77	8.42E-03	yes
G24.04	441	400	64	1	14539.93	1.56E-02	yes
G24.05	441	400	79	1	14364.97	6.34E-03	yes
G24.06	441	400	82	1	14419.92	3.42E-03	yes
G24.07	441	400	3	2	16139.12	9.48E-04	yes

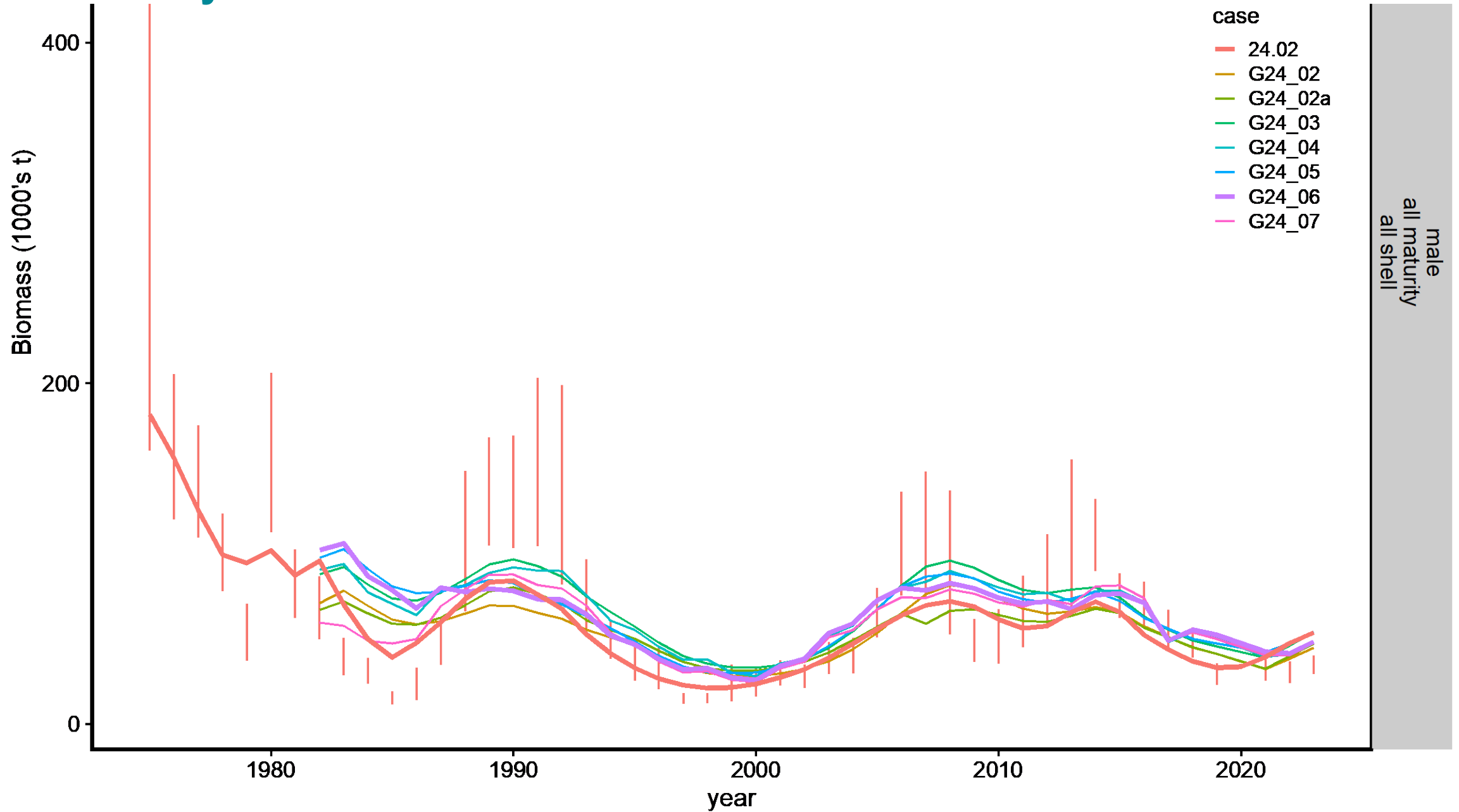


# GMACS Models Results

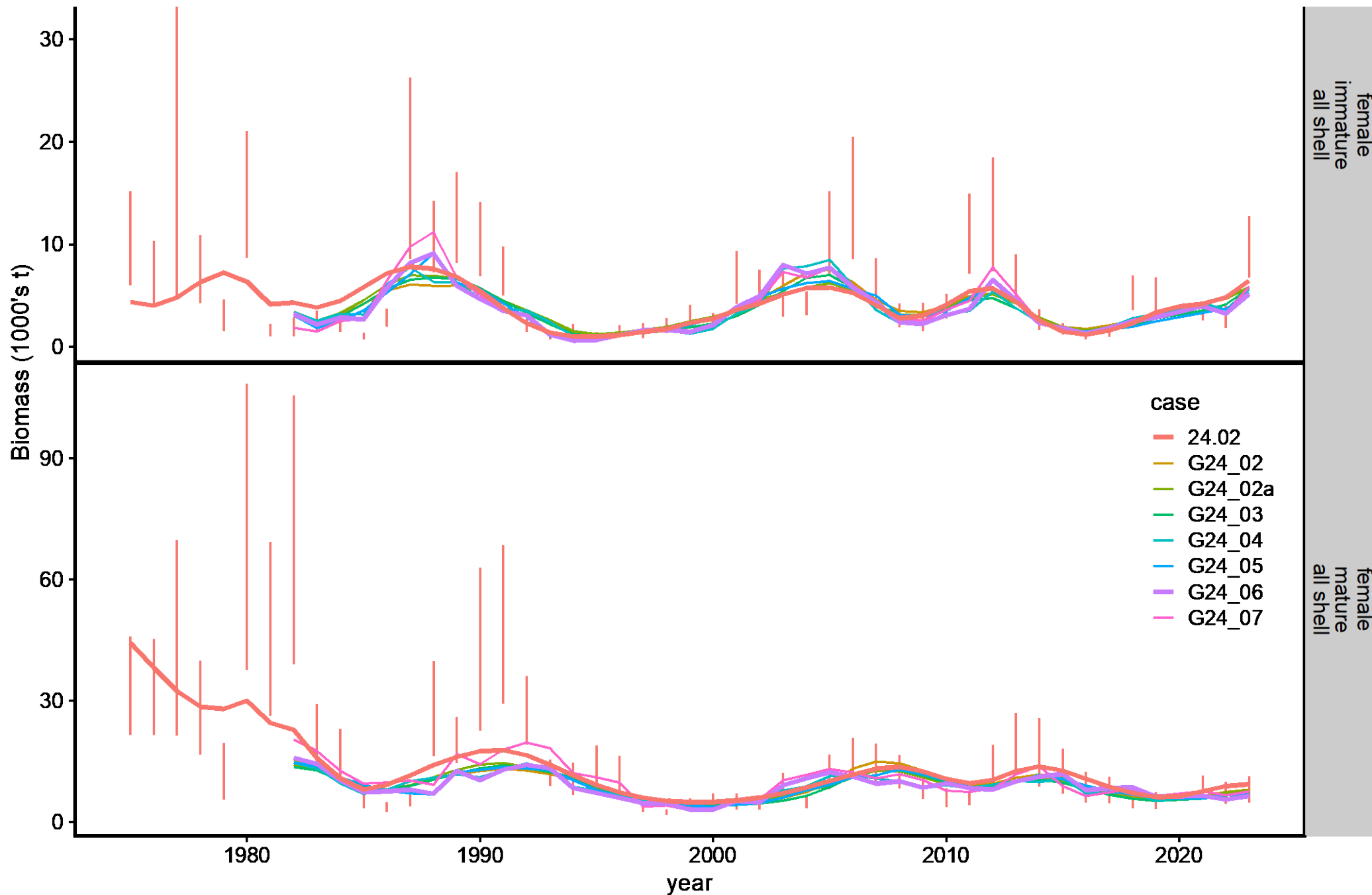


case	estimate	lb	ub	type	gradient	se	description
G24.02	5.011	1.609	5.011	1	0	0.000	Sel RKF male base Logistic mean
G24.02	3.912	0.000	3.912	1	0	0.000	Sel NMFSAM male base Logistic cv
G24.02a	-1.000	-1.000	1.000	-1	0	0.000	M base male immature
G24.02a	5.011	1.609	5.011	1	0	0.000	Sel TCF male base Logistic mean
G24.02a	5.011	1.609	5.011	1	0	0.000	Sel RKF male base Logistic mean
G24.02a	3.912	0.000	3.912	1	0	0.000	Sel NMFSAM male base Logistic cv
G24.03	5.011	1.609	5.011	1	0	0.000	Sel RKF male base Logistic mean
G24.04	5.011	1.609	5.011	1	0	0.000	Sel RKF male base Logistic mean
G24.05	5.011	1.609	5.011	1	0	0.000	Sel RKF male base Logistic mean
G24.06	5.011	1.609	5.011	1	0	0.000	Sel RKF male base Logistic mean
G24.07	5.011	1.609	5.011	1	0	0.000	Sel RKF male base Logistic mean
G24.07	0.015	0.000	3.912	-1	0	1.027	Sel RKF female base Logistic cv

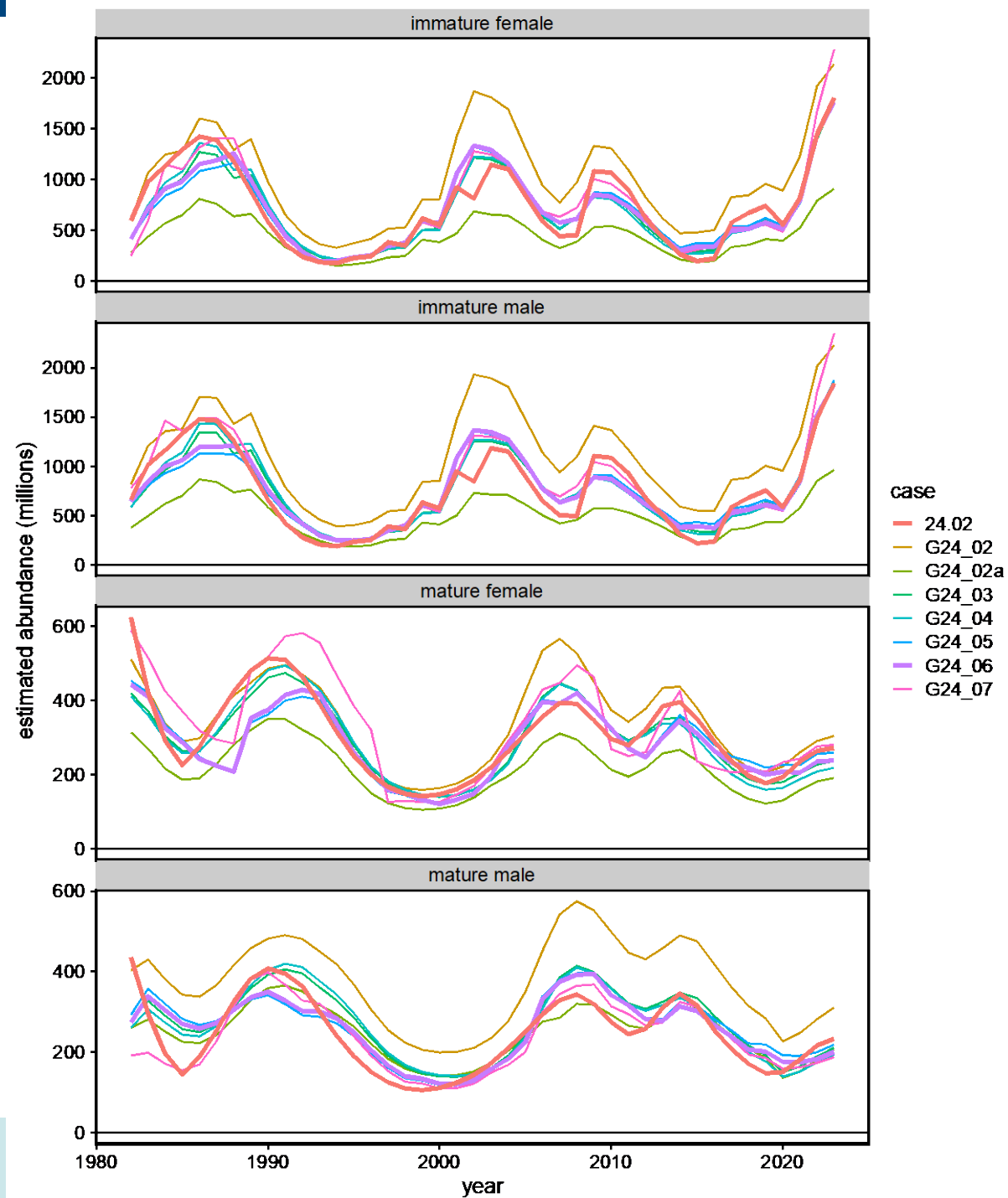
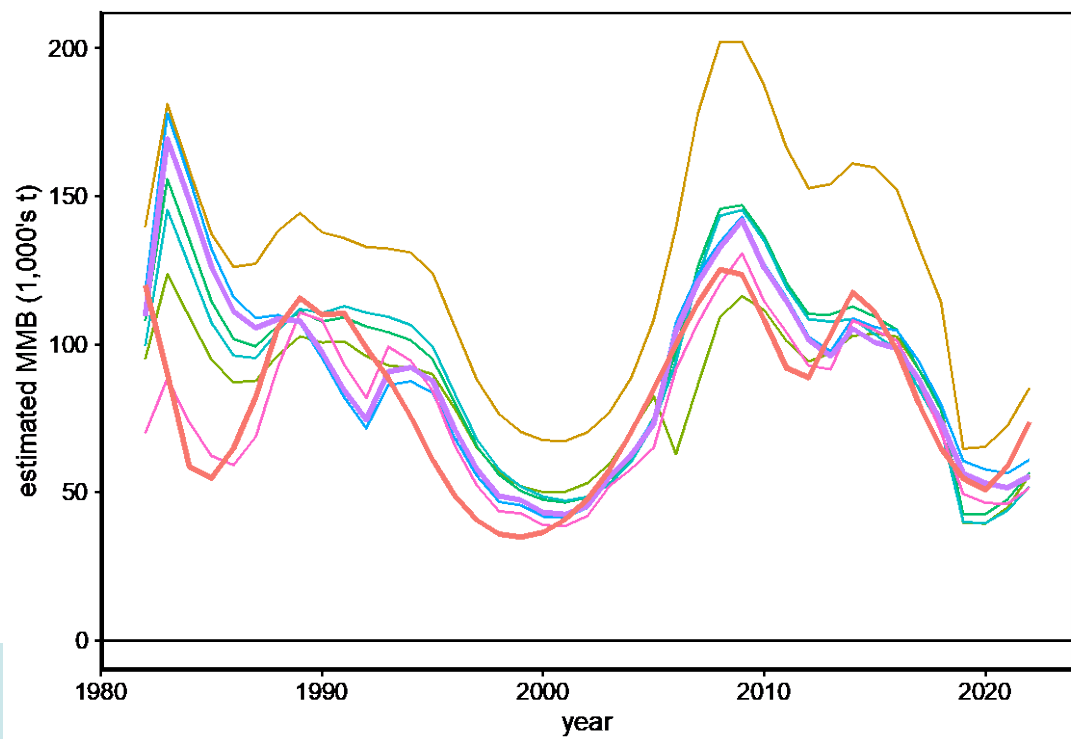
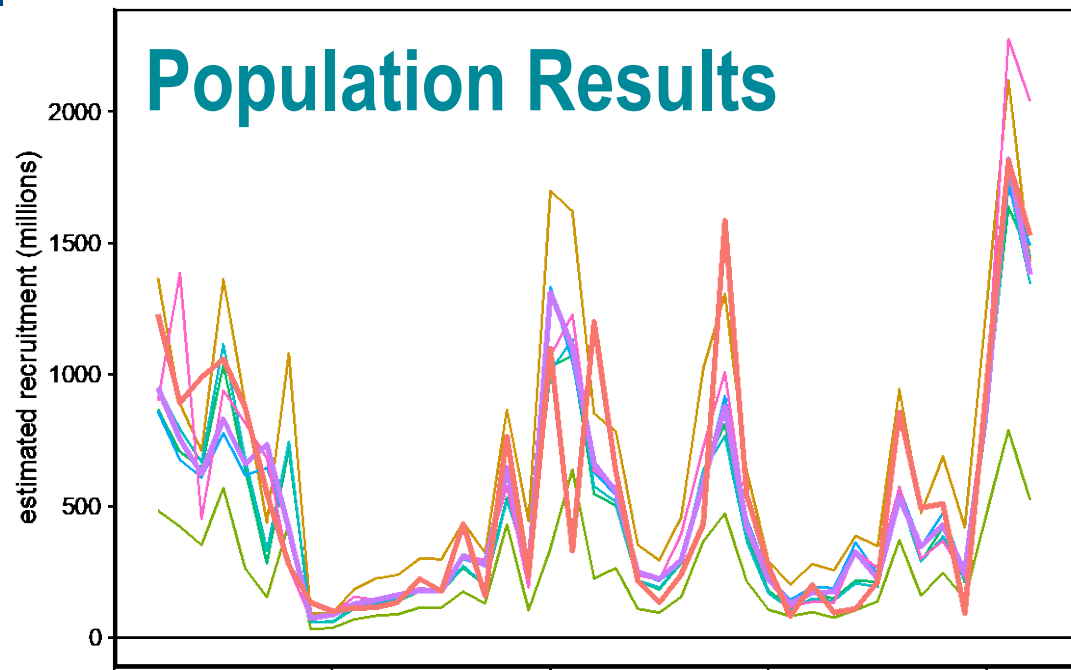
# Fits to Survey Biomass



# Fits to Survey Biomass

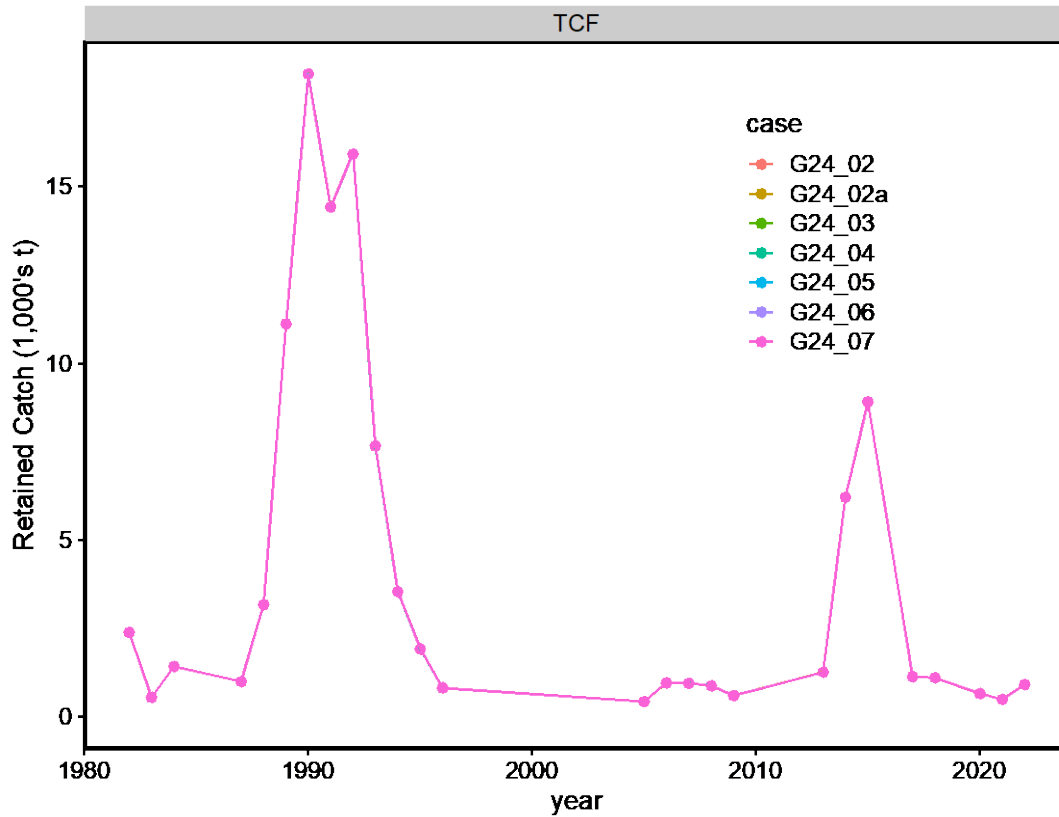


# Population Results



# GMACS Models: Fits to fishery catch data

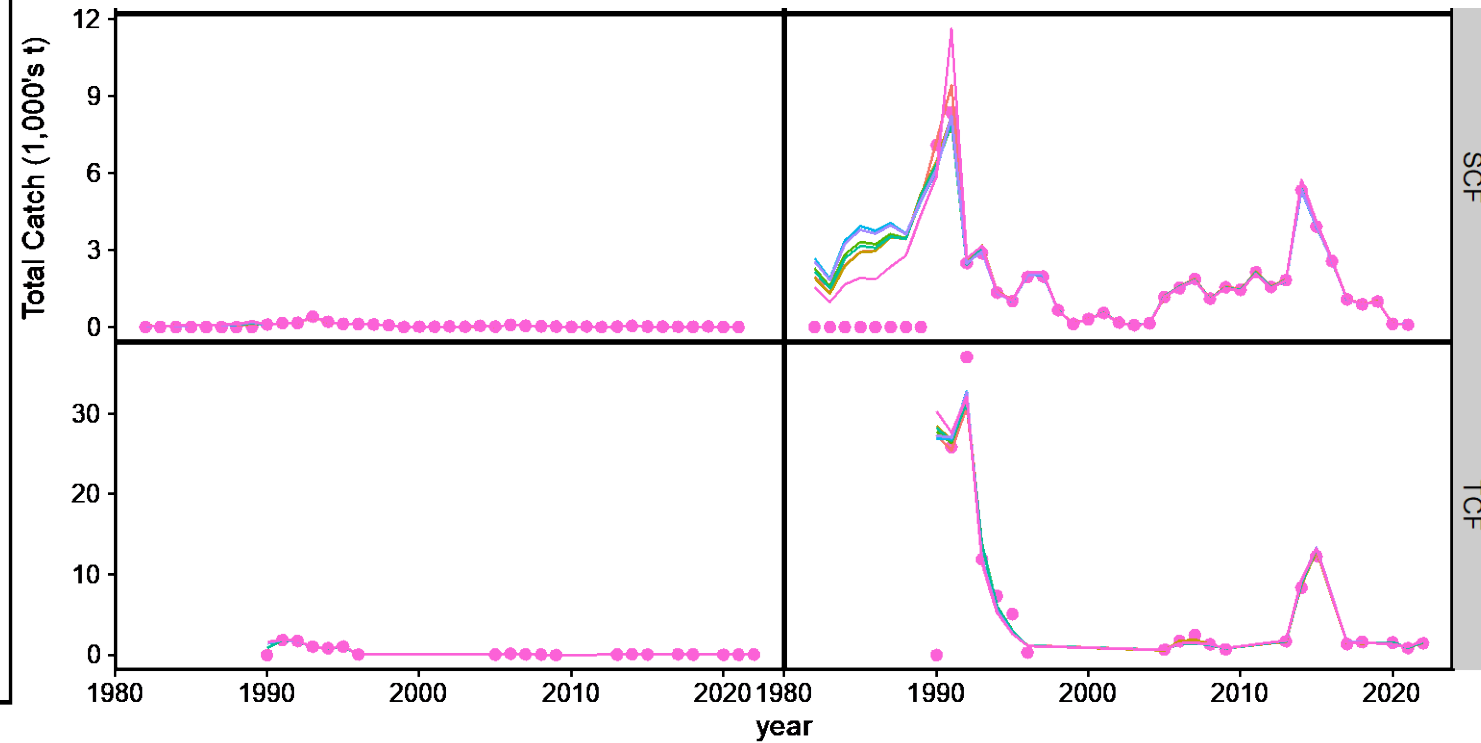
Retained catch



Total catch

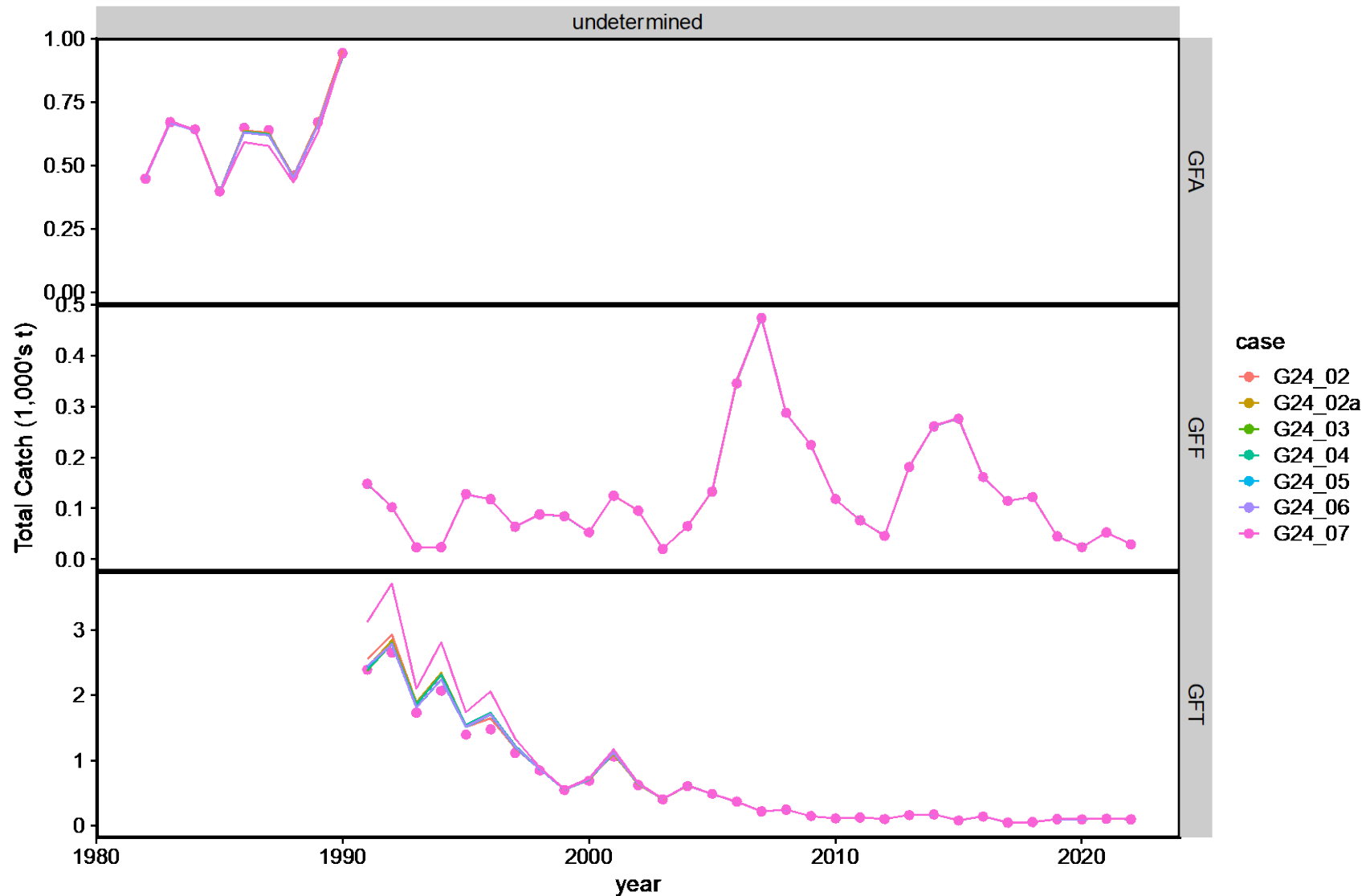
females

males

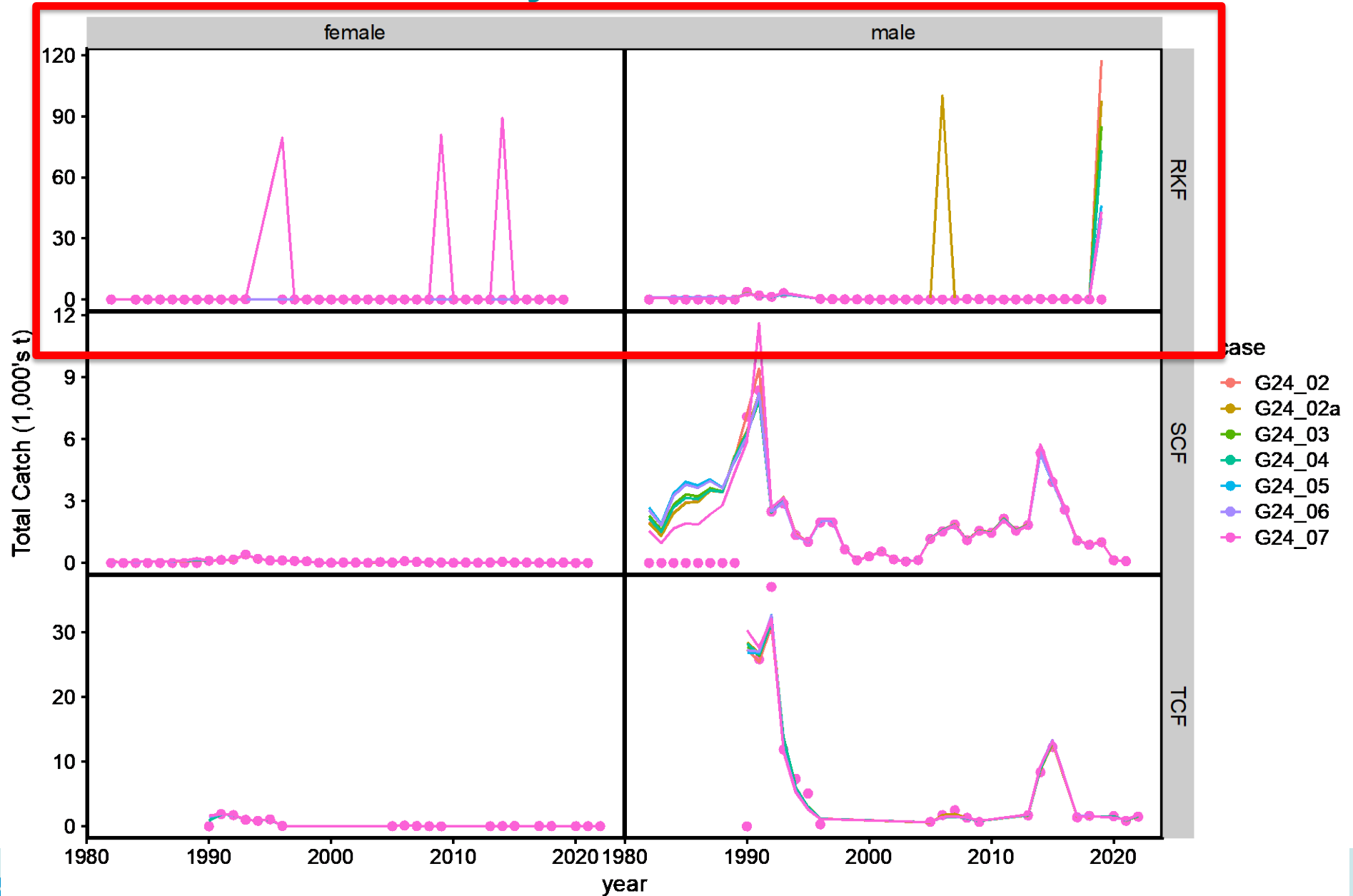




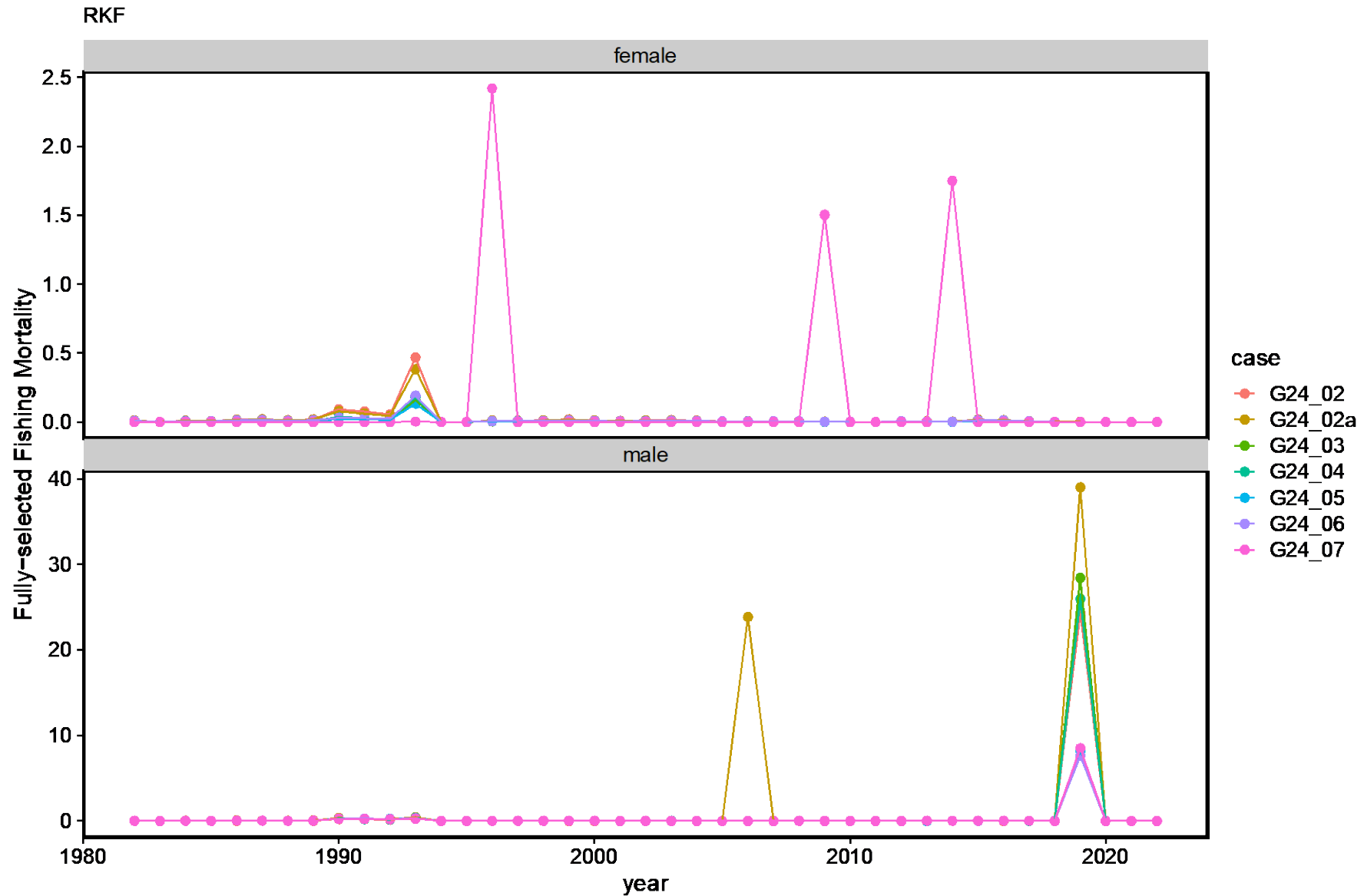
# GMACS Models: Fits to groundfish fisheries catch data



# GMACS Models: Fits to BBRKC bycatch data



# GMACS Models: Estimated BBRKC capture rates



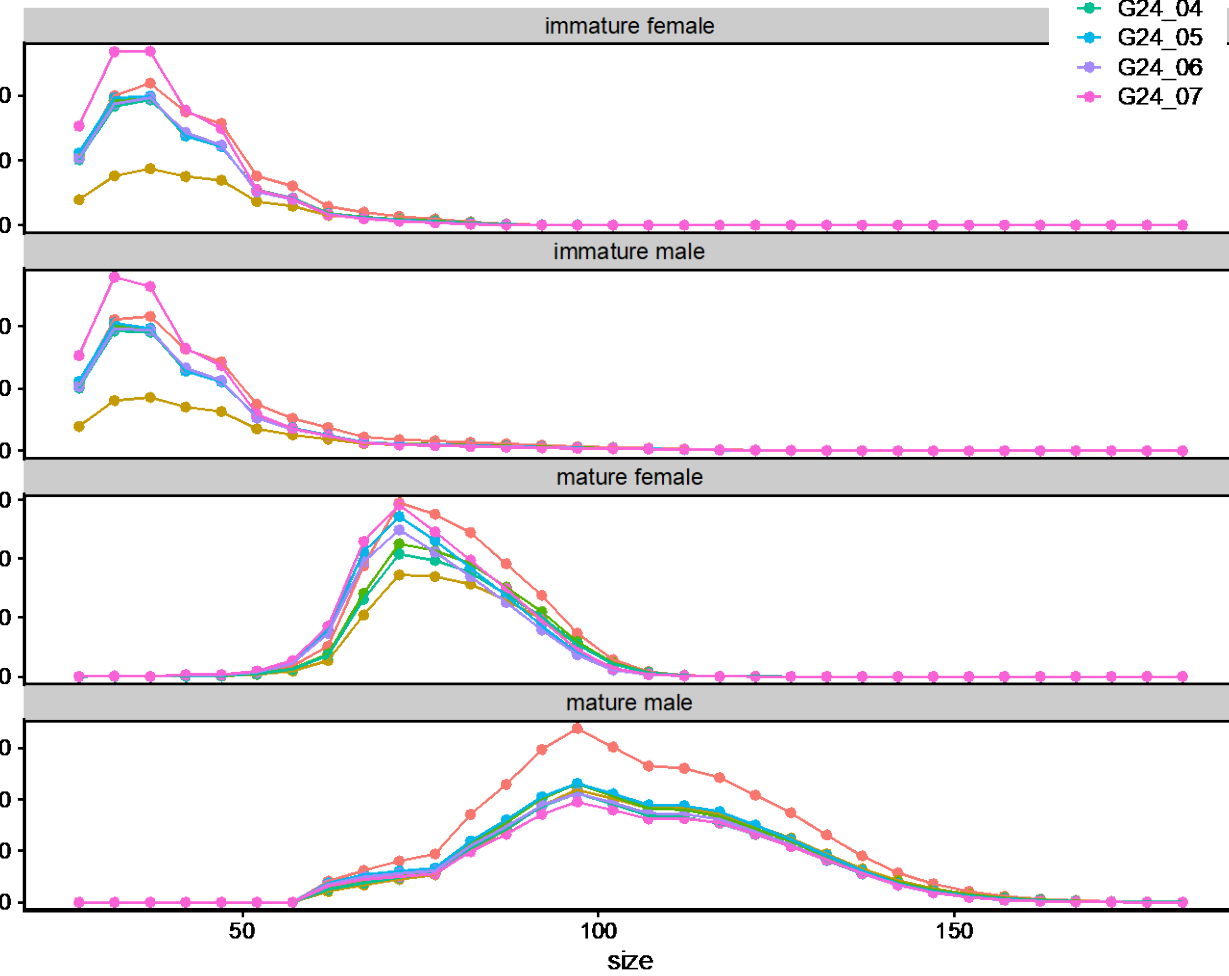
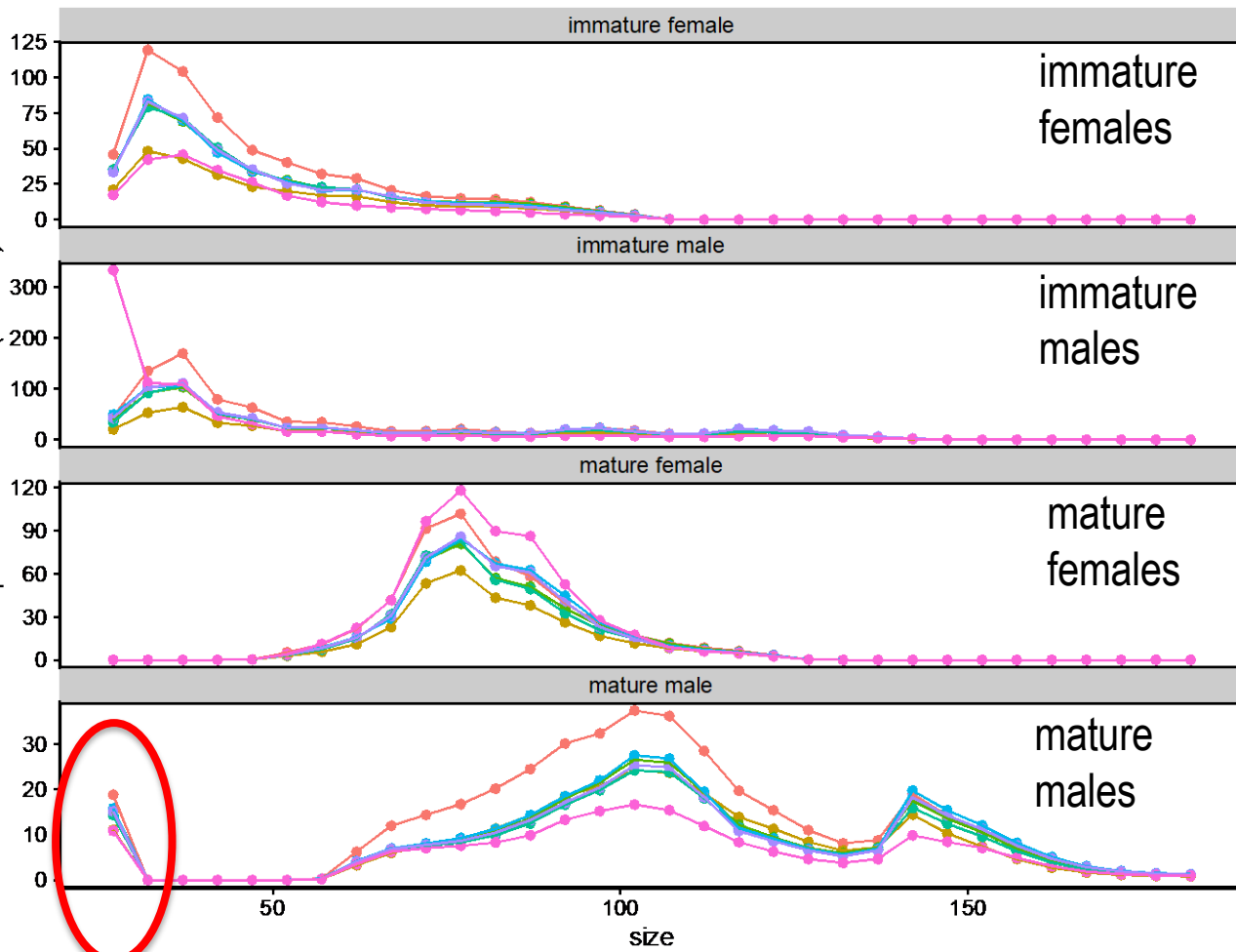
# GMACS Models: Population Structure

Initial

Final

case

- G24\_02
- G24\_02a
- G24\_03
- G24\_04
- G24\_05
- G24\_06
- G24\_07



y-axis units are millions of crab

# Proposed Tier 3 models for September

- 2023 assessment model (22.03b) is “base” model
  - update with 2023/24 fishery/survey data
- 24.02 recommended as alternative TCSAM02 model
  - develop model with no parameters at bounds
  - fix D-M sample size parameter or fit multinomial
- G24.03, G24.06 recommended as alternative GMACS models
  - modify GMACS to specify reference group for initial population size structure
  - resolve issue with spikes in fishing mortality
    - add small penalty term to annual devs
  - provide complete analysis
    - management quantities,
    - retrospective patterns, etc



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- Scott Goodman: 2018 BSFRF selectivity study data
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- Kally Spalinger (ADGF): Kodiak Large Mesh trawl survey results
- Nathaniel Nichols (ADGG): GOA Tanner crab harvest data