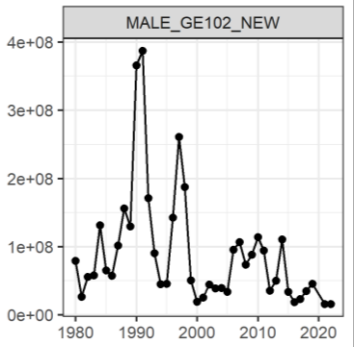
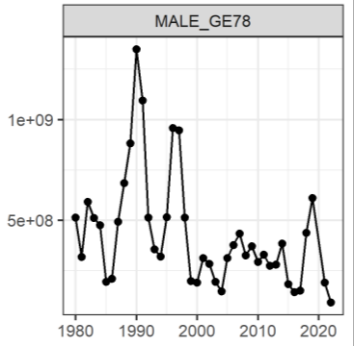
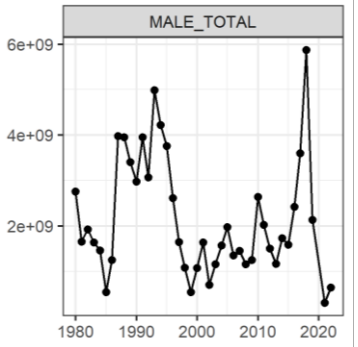
A draft assessment for eastern Bering Sea snow crab

Cody Szuwalski

September 13, 2022

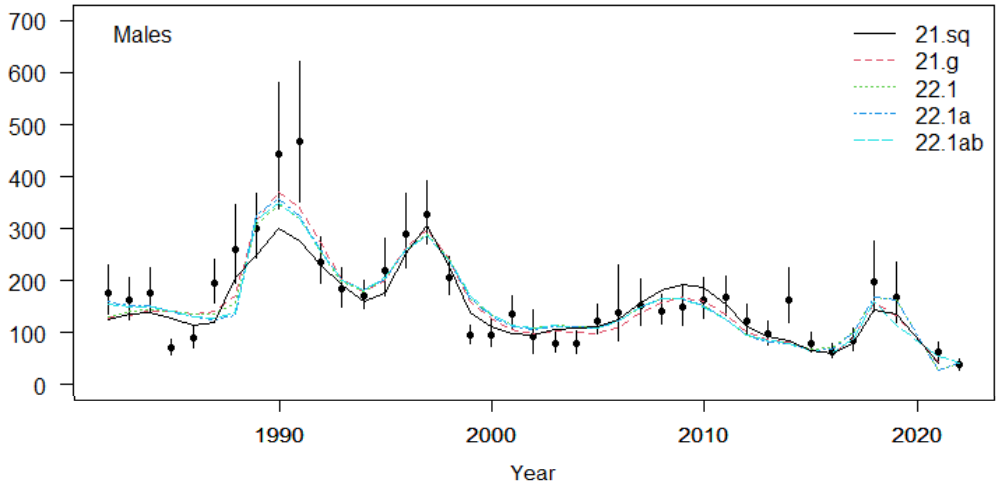


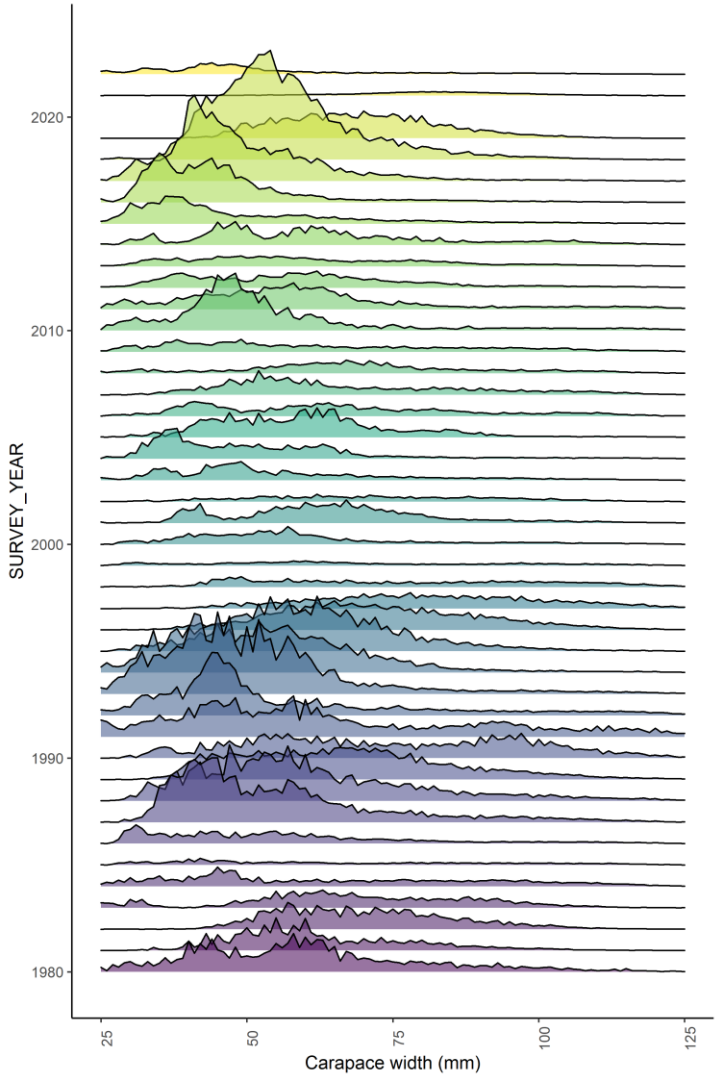




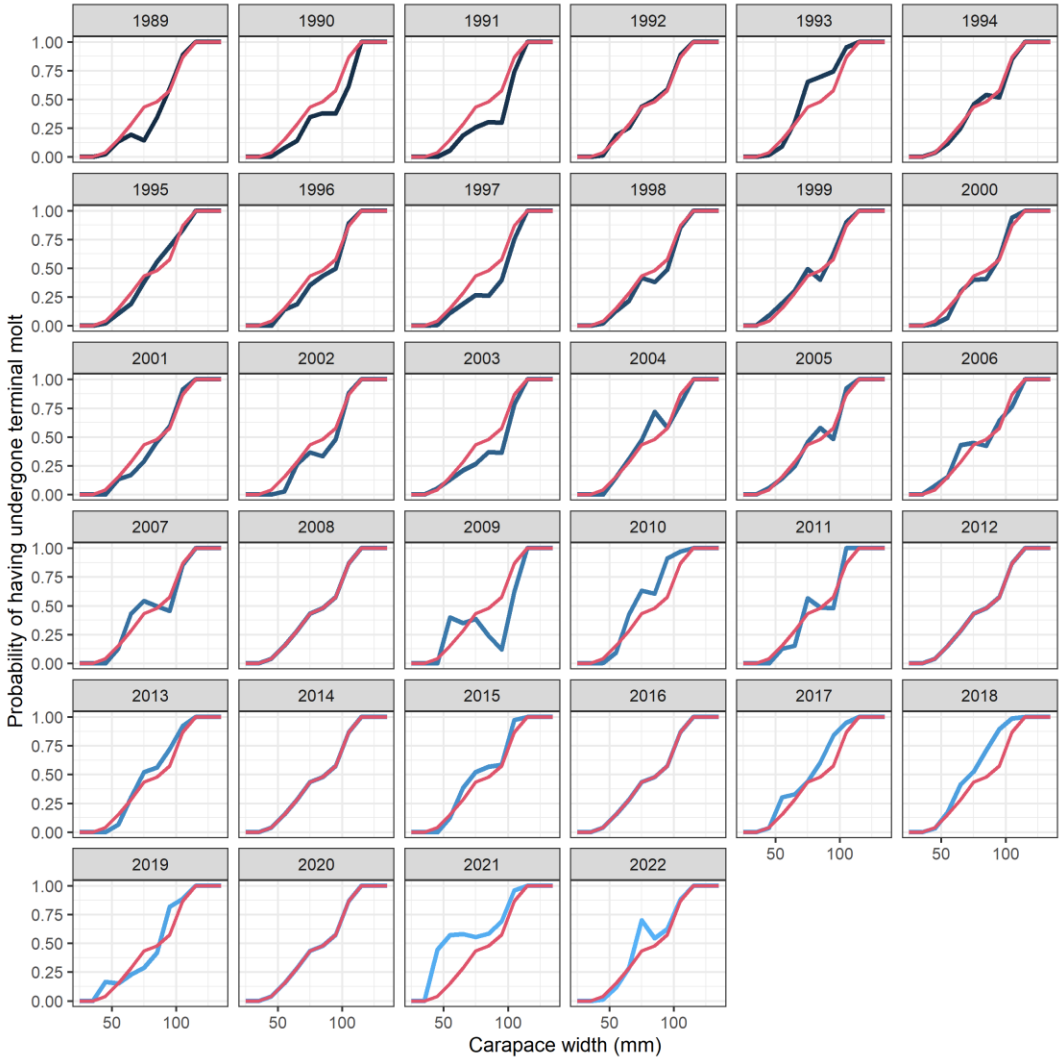
All measures of survey abundance are at or near **all-time lows**.

Survey MMB (morphometrically mature) was -40% compared to last year's all time low.





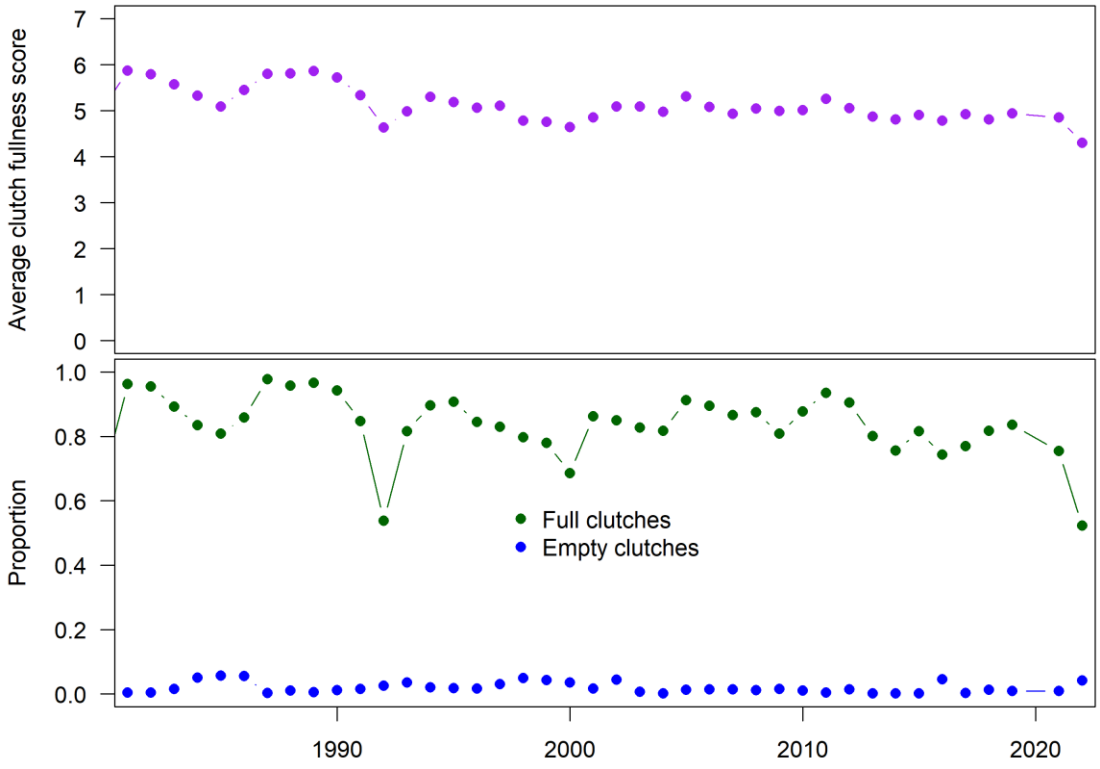
Small male recruitment signal in <50 mm carapace width range, but need more years to corroborate given false starts in the past.



More points for concern

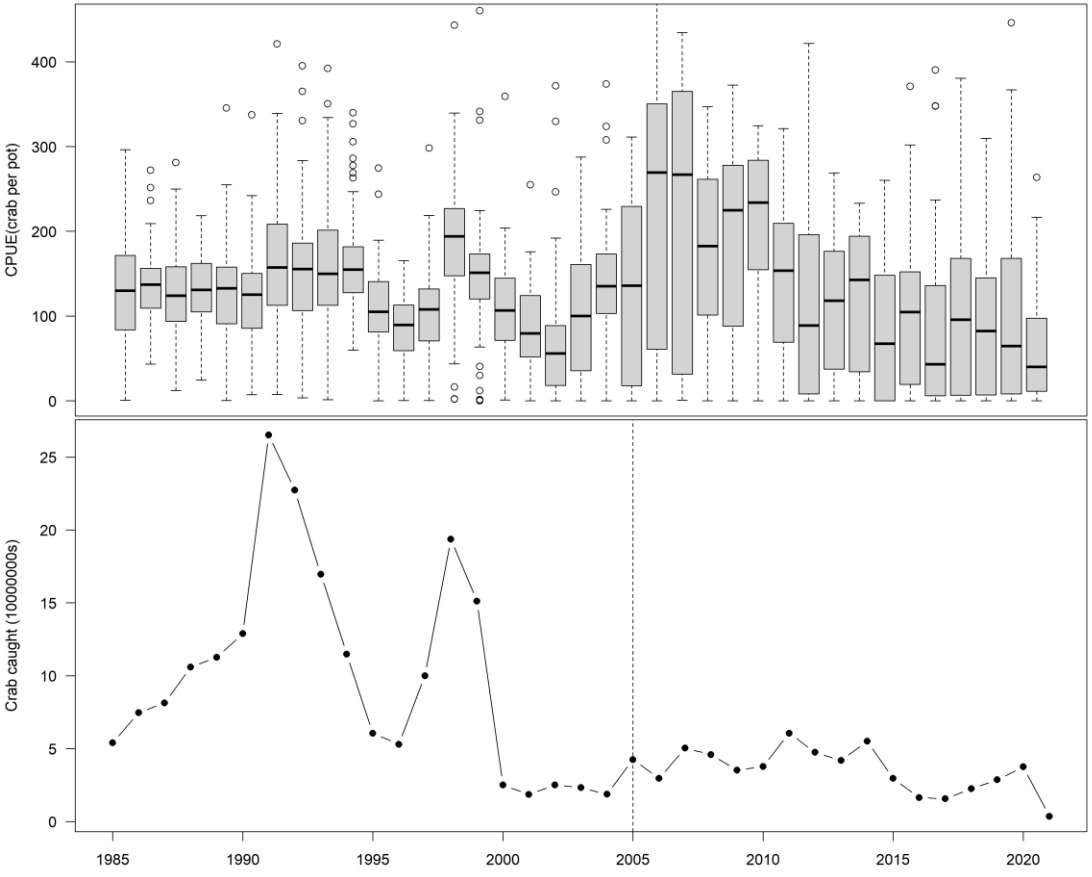
Increased probability of having undergone terminal molt at small sizes in 2021

More points for concern



Increased probability of having undergone terminal molt at small sizes in 2021

Average clutch fullness scores at all-time lows

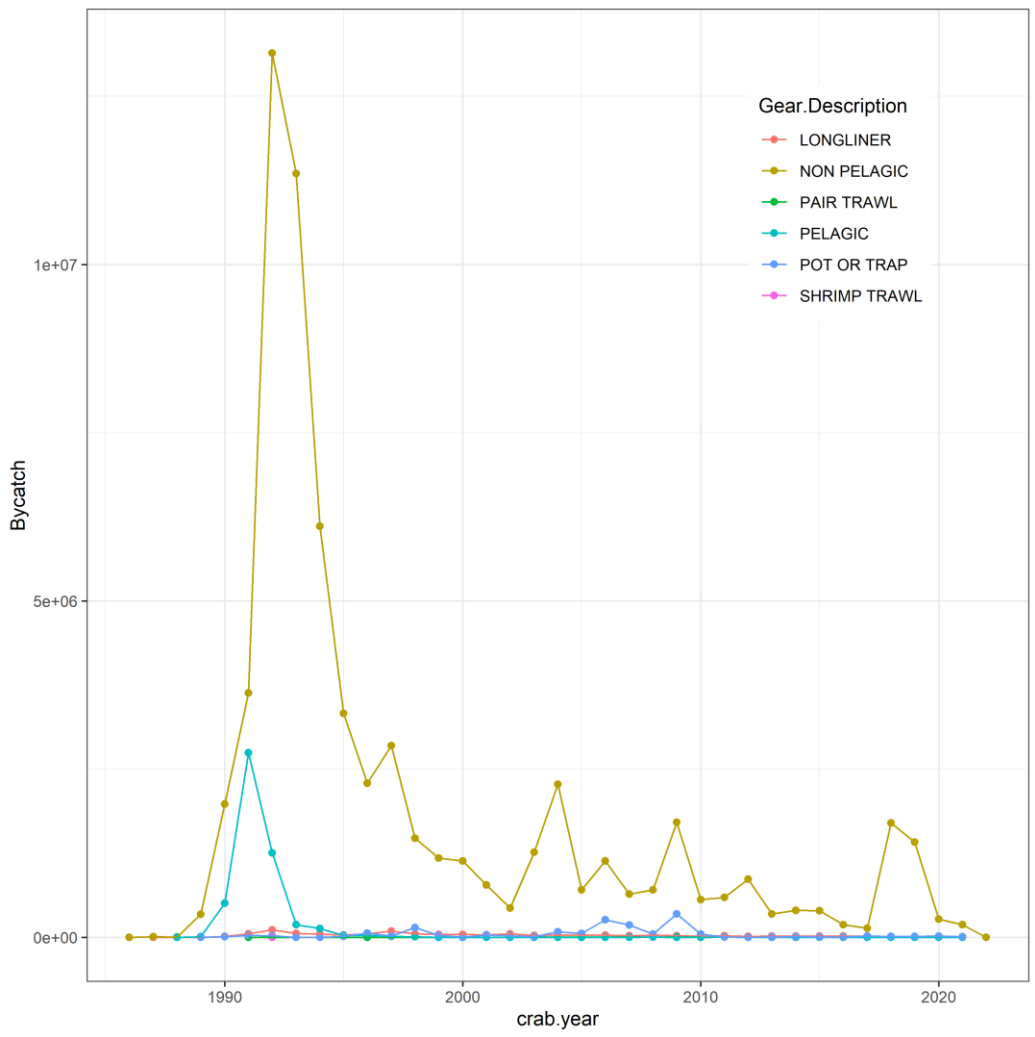


More points for concern

Increased probability of having undergone terminal molt at small sizes in 2021

Average clutch fullness scores at all-time lows

Fishery CPUE at all-time lows in 2021/2022 season



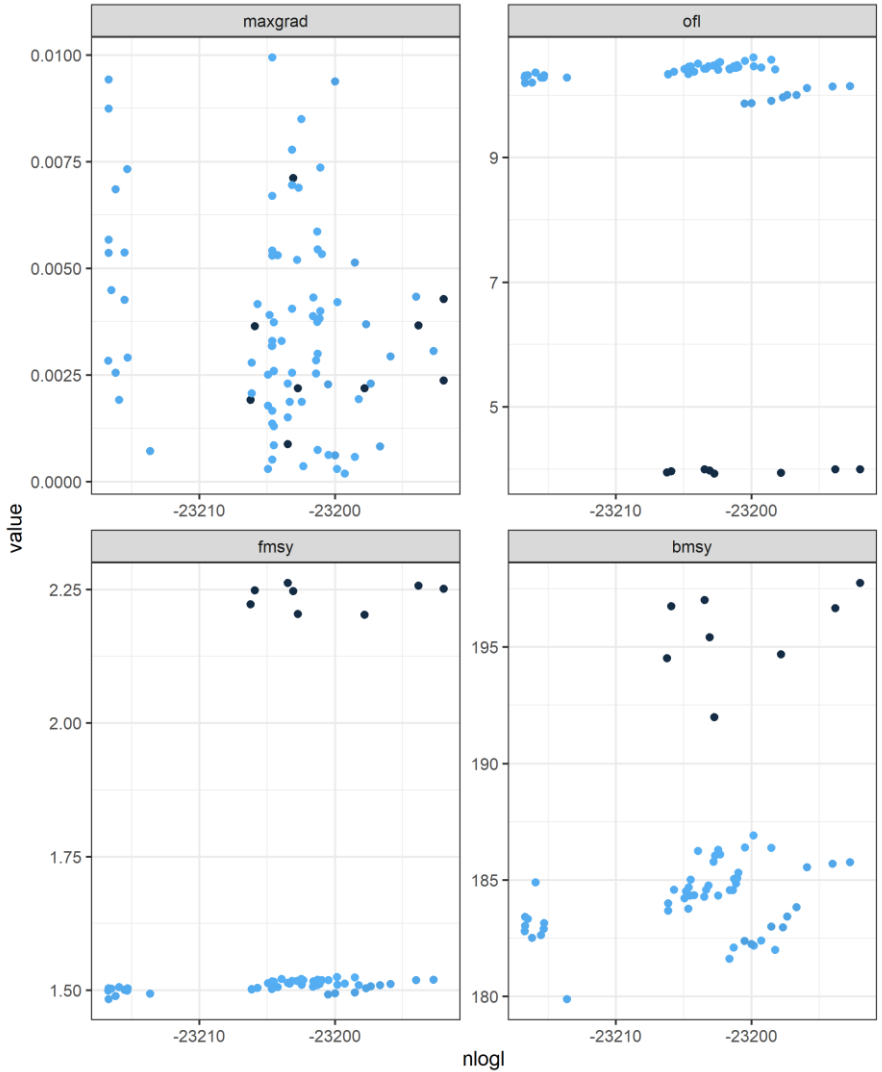
More points for concern

Increased probability of having undergone terminal molt at small sizes in 2021

Average clutch fullness scores at all-time lows

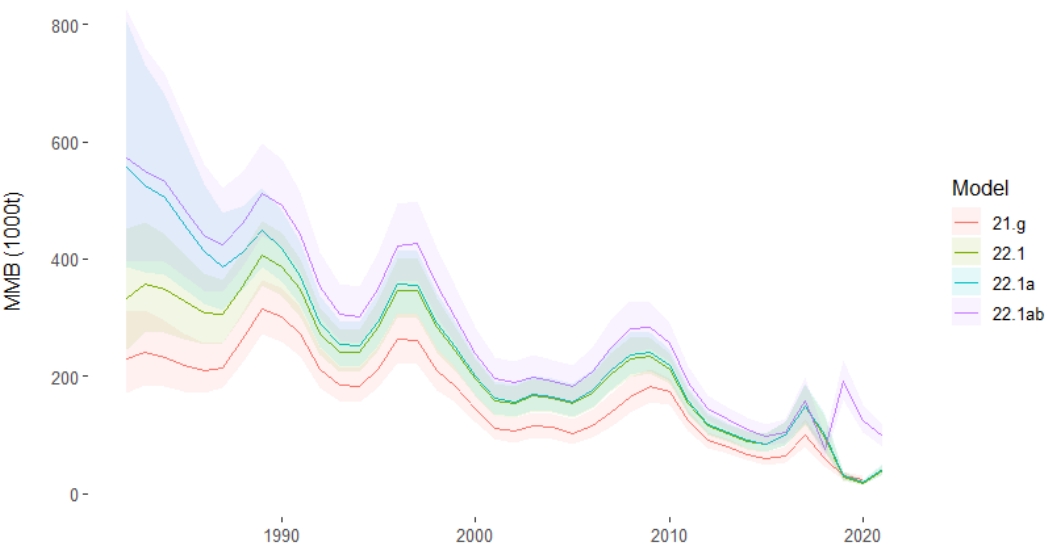
Fishery CPUE at all-time lows in 2021/2022 season

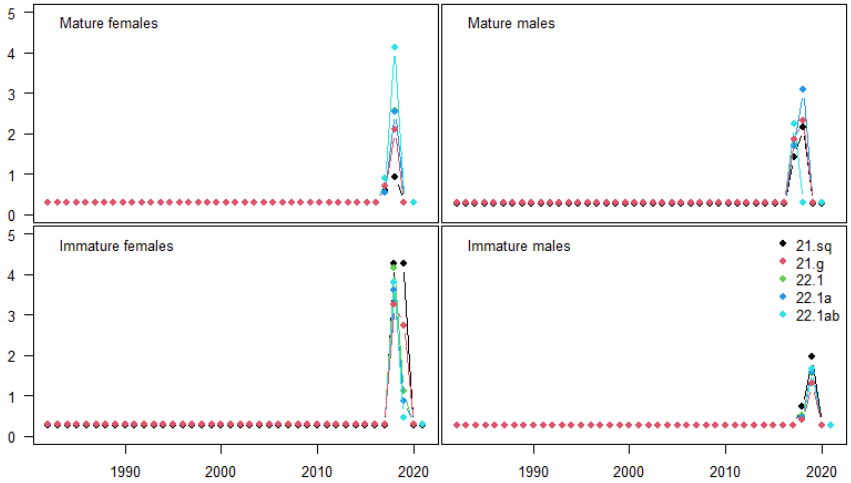
Bycatch near all-time lows



Modeling issues

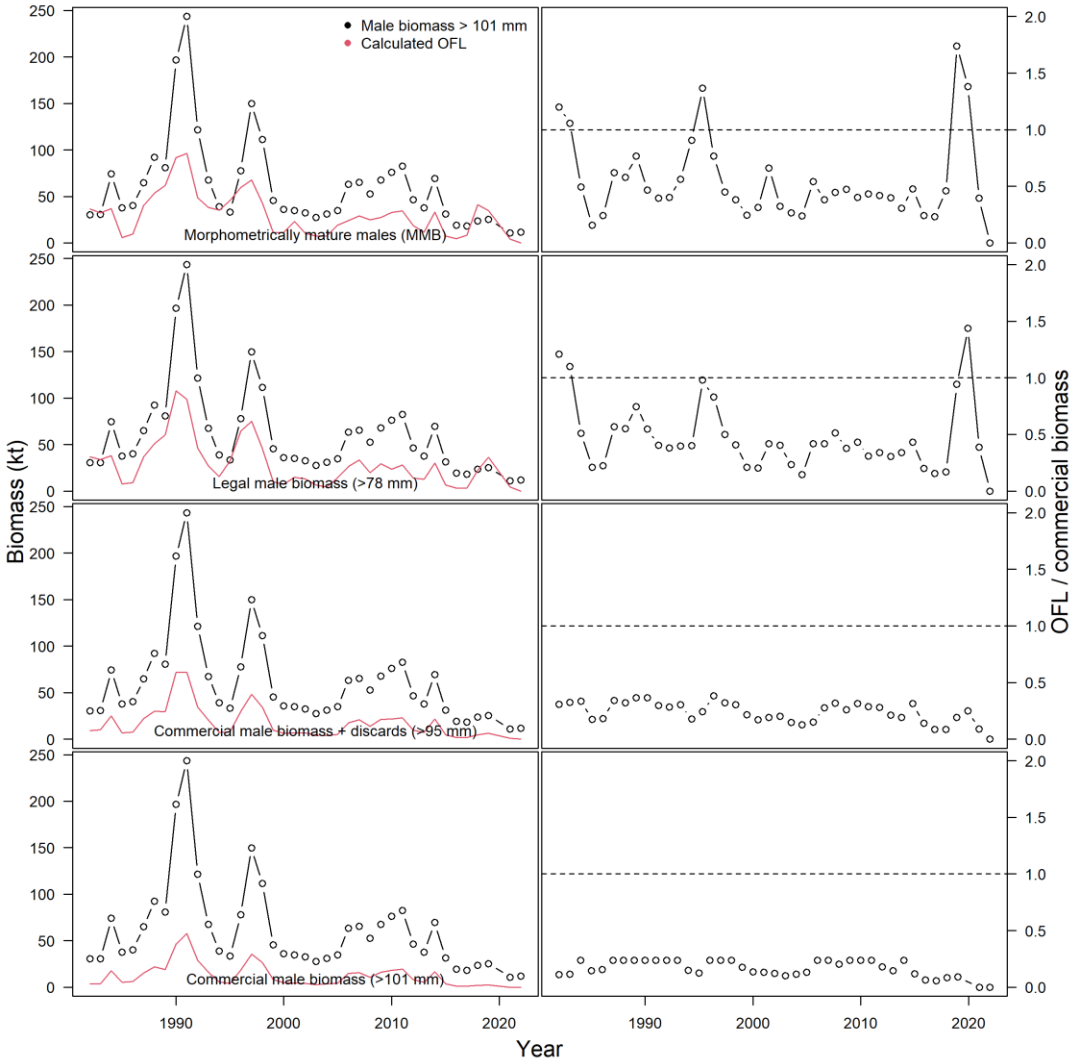
- Move to GMACS was useful, but…
- New data resulted in bimodal management quantities





Modeling issues

- Move to GMACS was useful, but…
- New data resulted in bimodal management quantities
- Bimodality results from two different interpretations about what happened in 2019-2020 and mortality events



Modeling issues

- Move to GMACS was useful, but…
- New data resulted in bimodal management quantities
- Bimodality results from two different interpretations about what happened in 2019-2020 and mortality events
- Tier 4 rules all close the fishery

Models presented

- Tier 3
  - 21.1: GMACS model accepted by SSC in June 2022 with prior on M to match status quo model
  - 22.1: 21.1 with updated data
  - 22.1a: 22.1 with initial numbers at size estimated as parameters rather than composition and a scaling factor
  - 22.1ab: 22.1a but from a different mode from the jittering analysis
- Tier 4
  - Morphometrically mature male biomass
  - Legal males (>78 mm carapace width)
  - Males >95 mm carapace width
  - Preferred males (>101 mm carapace width)

Other things I tried

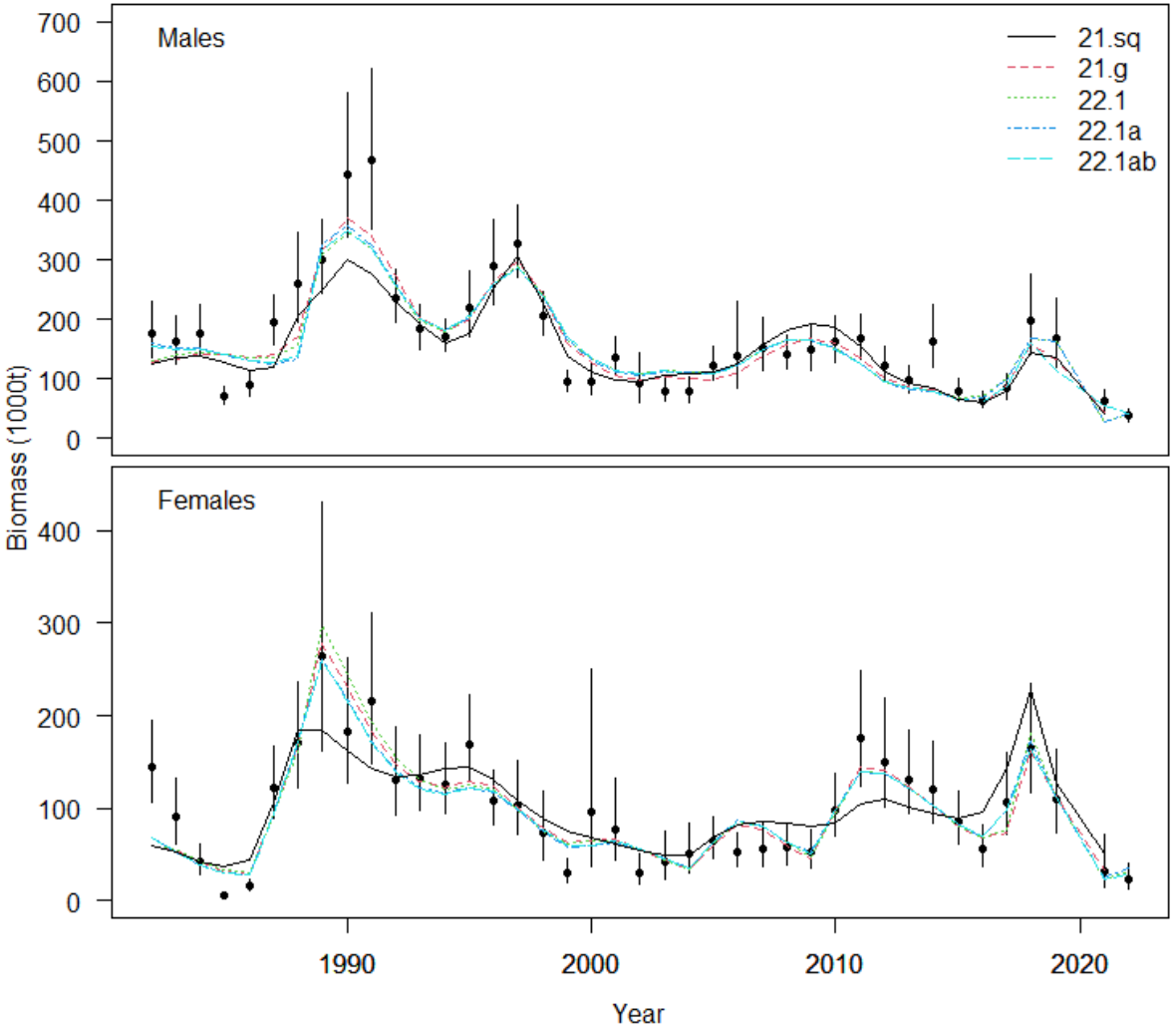
- Adding penalties on F devs
- Adding additional year of mortality events (i.e. adding 2020)
- Non-parametric survey selectivity
- Reweighting the size composition data
- Various combinations of the above
- Began a male only model

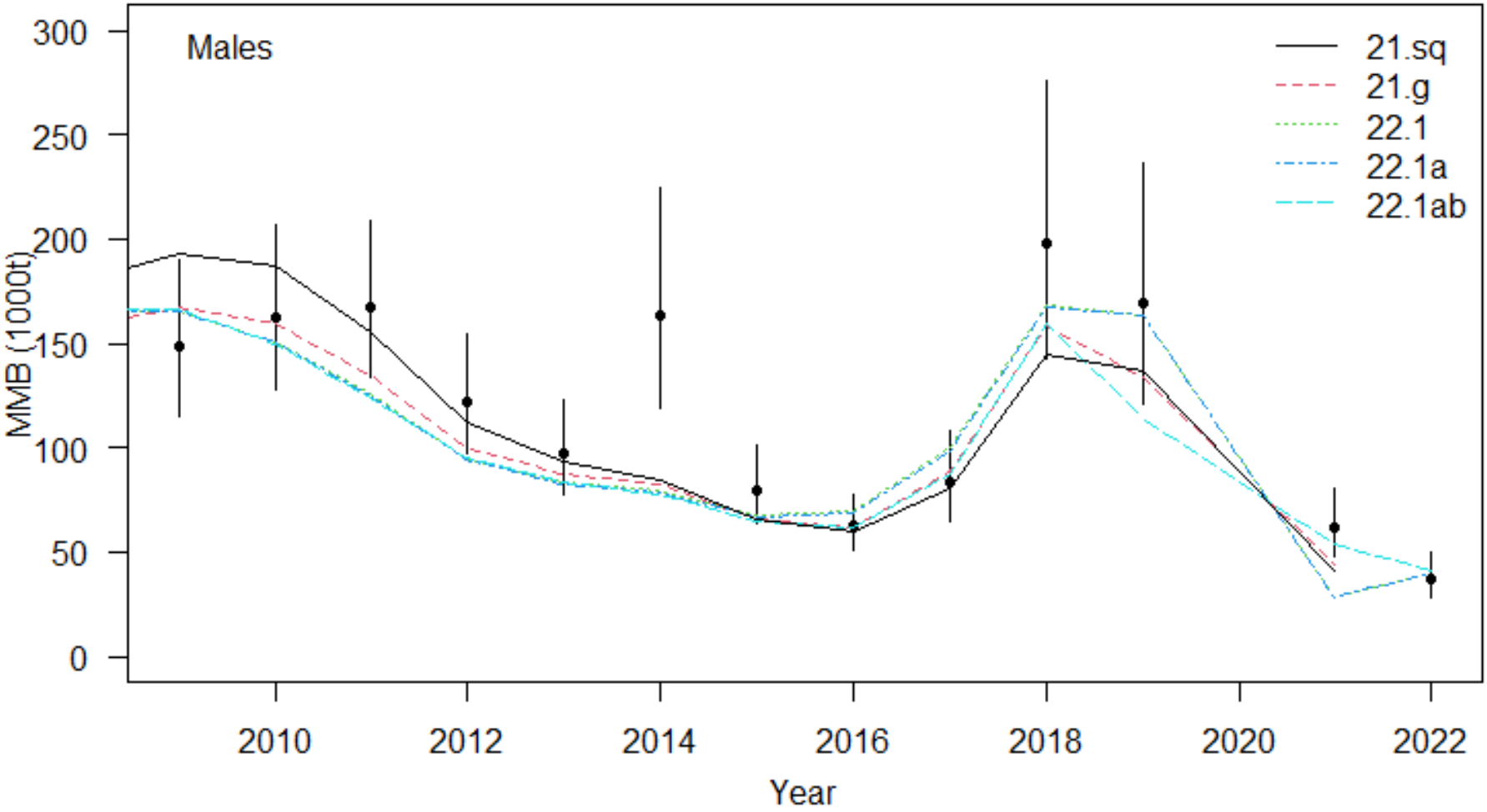
- Hoping to incorporate maturity data next year…but unclear if this will overcome issues with not having 2020 data

Decision points

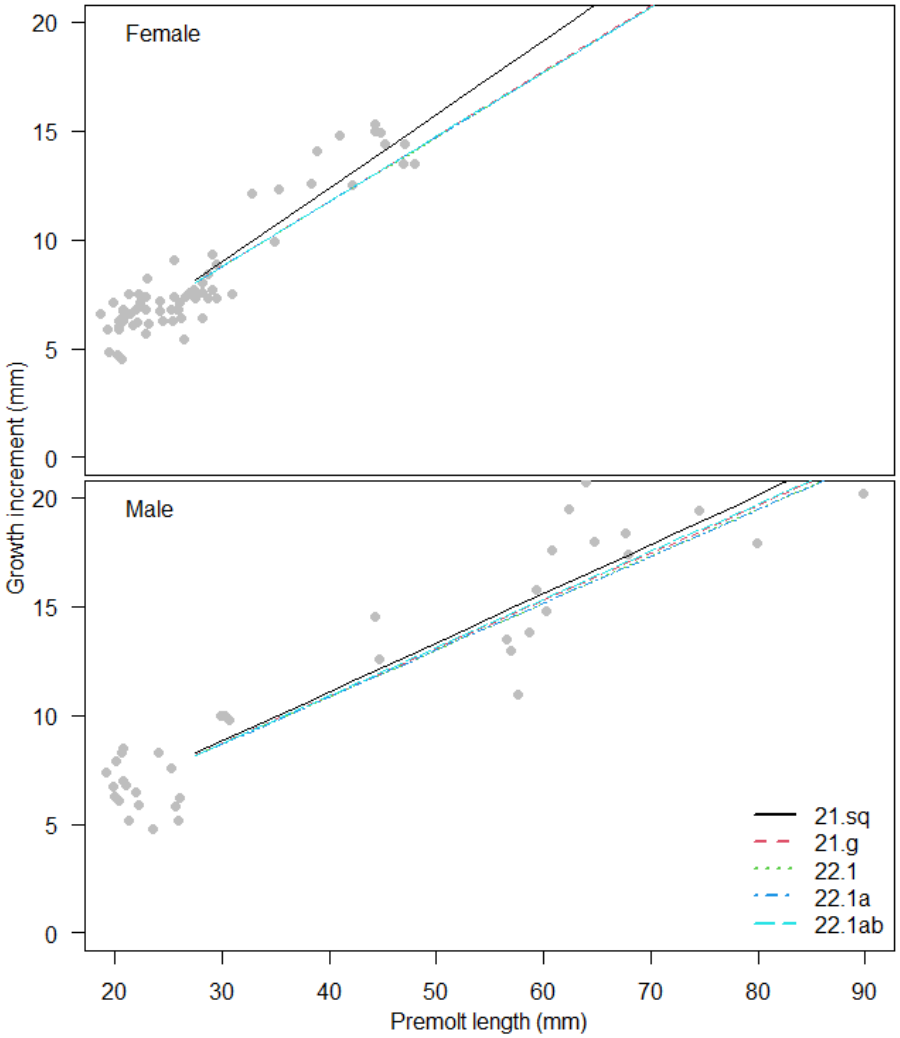
- How to consider a bimodal model?
  - Is it acceptable to use a mode that is a local minimum?
  - 4 criteria: **fits, plausibility, stability, convergence**
- If the bimodal model cannot be justified, is there justification for tier 4 models?
- Martin suggested potentially rolling over the OFL from last year.

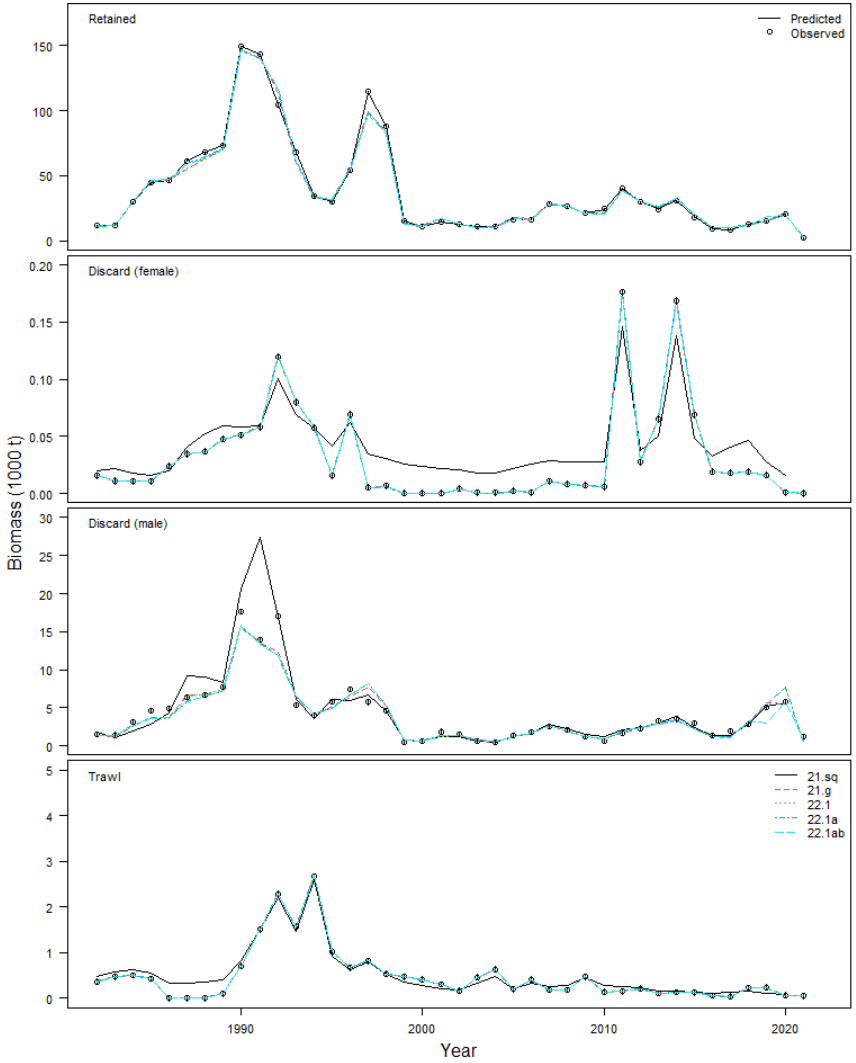
	Model 22.1a		Model 22.1ab	
Fits/Process	**Fits**	**Plausibility**	**Fits**	**Plausibility**
Survey MMB				
Growth				
Catch				
Size comps (catch)				
Size comps (survey M)				
Size comps (survey F)				
MMB				
Selectivity				
Maturity				
Fishing mortality				
Recruitment				
Natural mortality				


Males
Females
21.sq
21.g
22.1
22.1a
22.1ab
Biomass (1000t)
Year
0
100
200
300
400
500
600
700
1990
2000
2010
2020

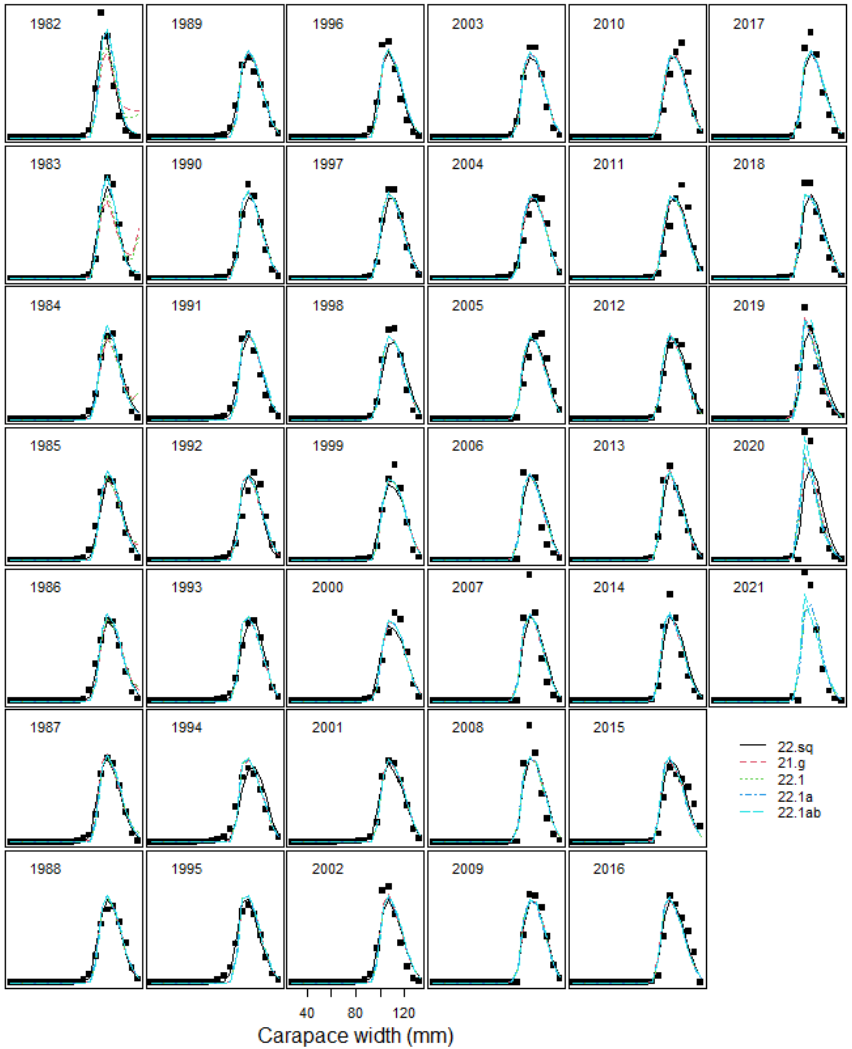

Males
21.sq
21.g
22.1
22.1a
22.1ab
MMB (1000t)
300
250
200
150
100
50
0
2010
2012
2014
2016
2018
2020
2022
Year

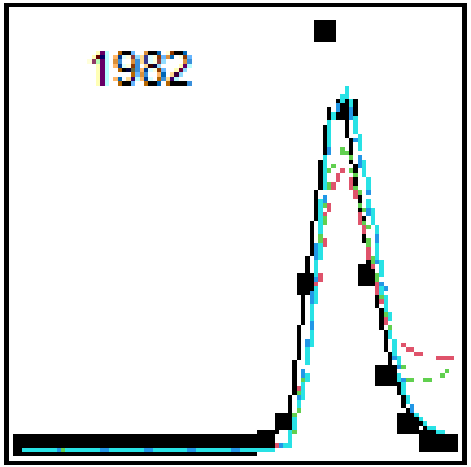
	Model 22.1a		Model 22.1ab	
Fits/Process	**Fits**	**Plausibility**	**Fits**	**Plausibility**
Survey MMB			Marginally better	
Growth				
Catch				
Size comps (catch)				
Size comps (survey M)				
Size comps (survey F)				
MMB				
Selectivity				
Maturity				
Fishing mortality				
Recruitment				
Natural mortality				

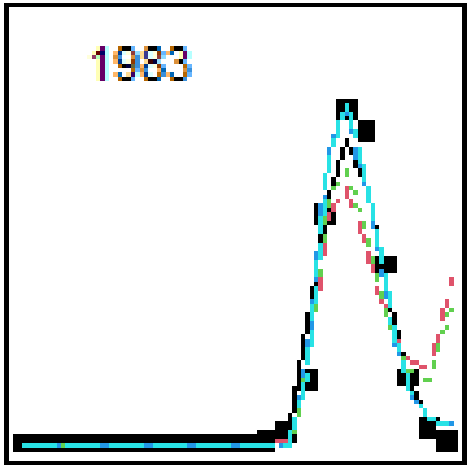

Female
Male
Growth increment (mm)
Premolt length (mm)
21.sq
21.g
22.1
22.1a
22.1ab


Retained
Predicted
Observed
Discard (female)
Discard (male)
Trawl
Biomass (1000 t)
Year
21.sq
21.g
22.1
22.1a
22.1ab

	Model 22.1a		Model 22.1ab	
Fits/Process	**Fits**	**Plausibility**	**Fits**	**Plausibility**
Survey MMB			Marginally better	
Growth			Marginally better	
Catch			Marginally better retained, better discard	
Size comps (catch)				
Size comps (survey M)				
Size comps (survey F)				
MMB				
Selectivity				
Maturity				
Fishing mortality				
Recruitment				
Natural mortality				

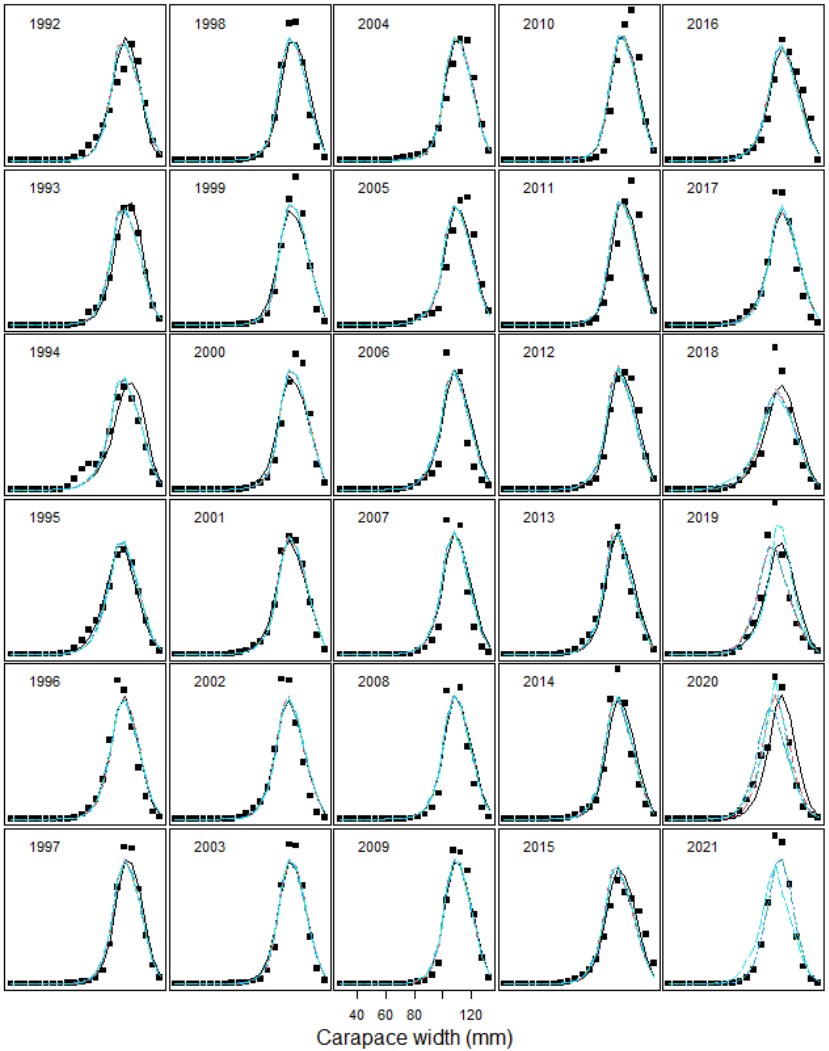






Model 22.1 produced ‘pigtails’ in early years.

Model 22.1a/b solved this issue.


1992
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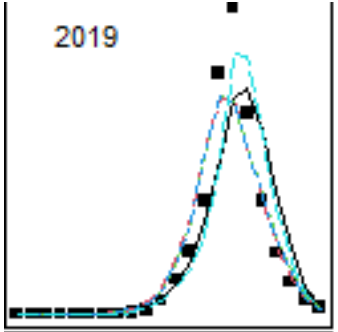
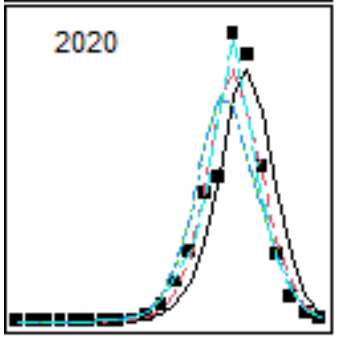
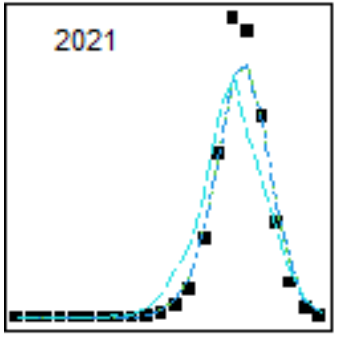
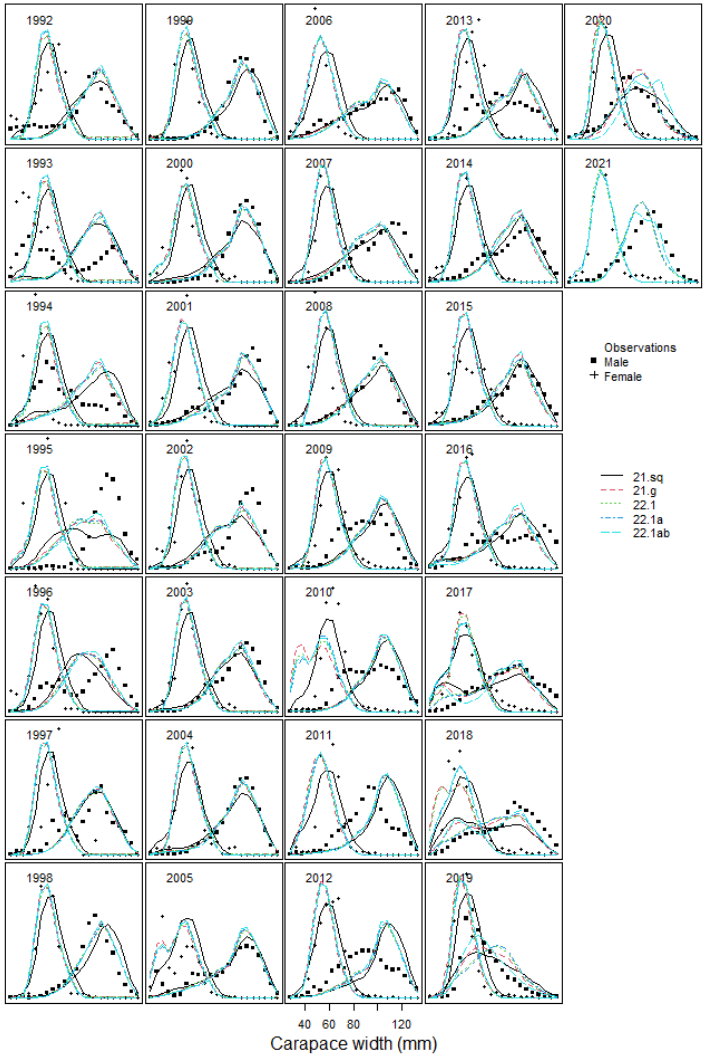
2002
2008
2014
2020
1997
2003
2009
2015
2021
40 60 80 120
Carapace width (mm)

21.sq
21.g
22.1
22.1a
22.1ab


2019


2020


2021


1992
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2011
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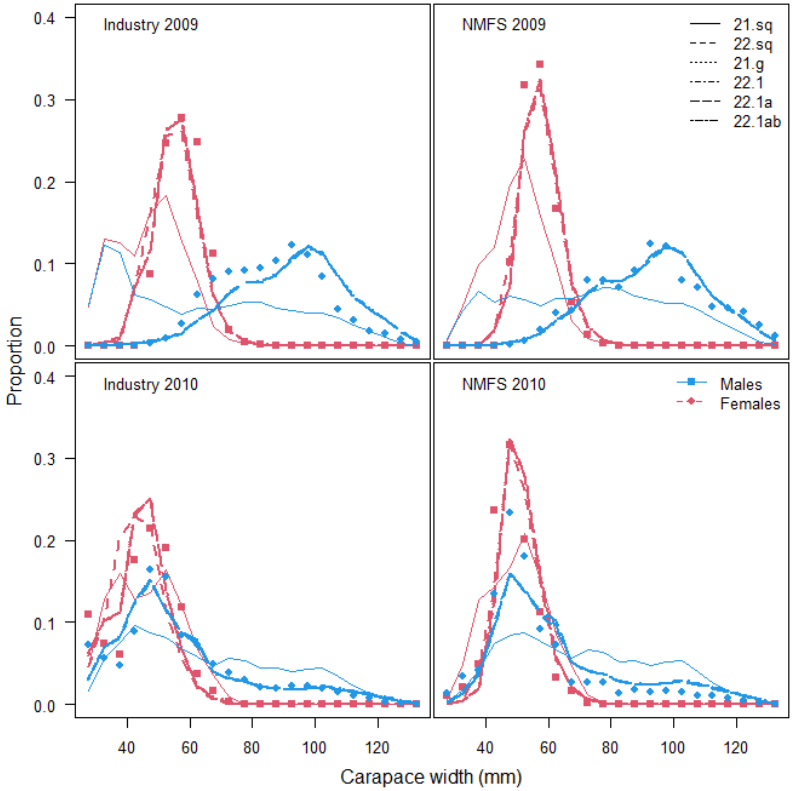
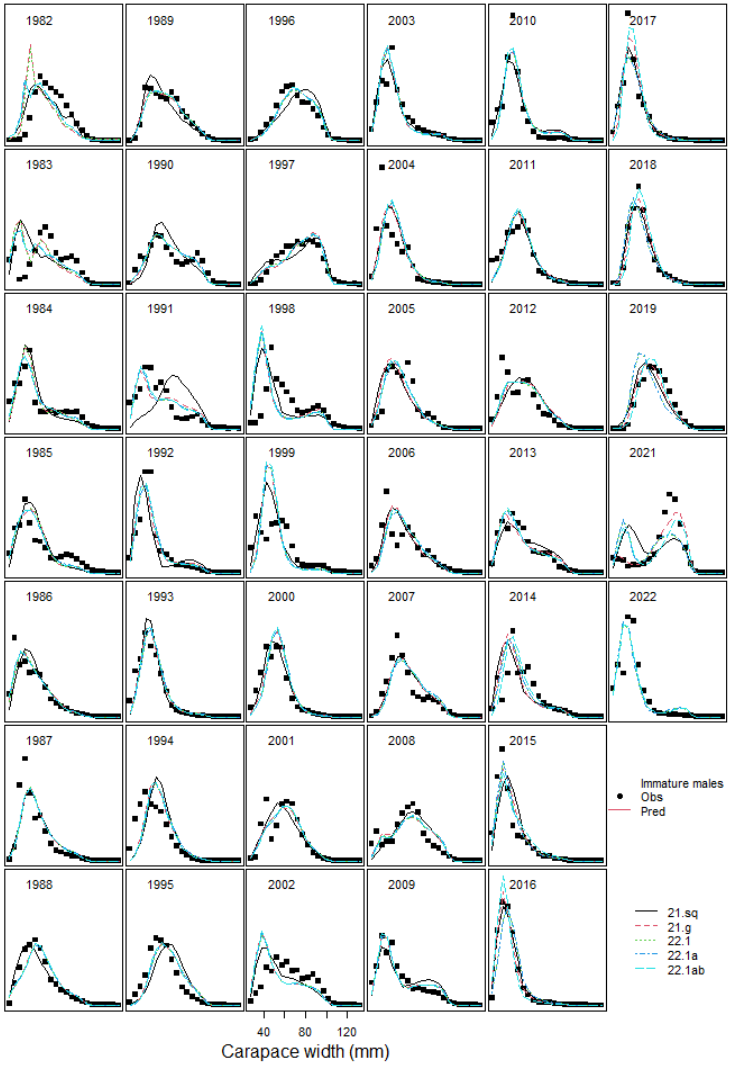
1998
2005
2012
2019
Observations
Male
Female
21.sq
21.g
22.1
22.1a
22.1ab
40 60 80 120
Carapace width (mm)


Industry 2009
NMFS 2009
21.sq
22.sq
21.g
22.1
22.1a
22.1ab
Industry 2010
NMFS 2010
Males
Females
Proportion
0.0
0.1
0.2
0.3
0.4
40 60 80 100 120
Carapace width (mm)

	Model 22.1a		Model 22.1ab	
Fits/Process	**Fits**	**Plausibility**	**Fits**	**Plausibility**
Survey MMB			Marginally better	
Growth			Marginally better	
Catch			Marginally better retained, better discard	
Size comps (catch)	Better to total			
Size comps (survey M)				
Size comps (survey F)				
MMB				
Selectivity				
Maturity				
Fishing mortality				
Recruitment				
Natural mortality				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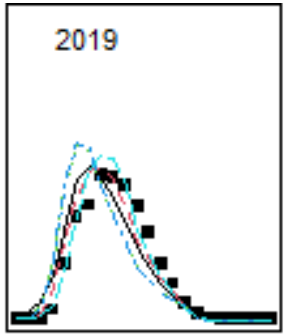
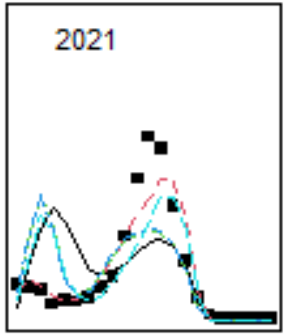
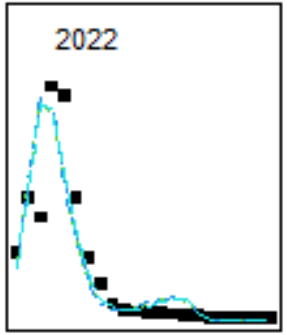
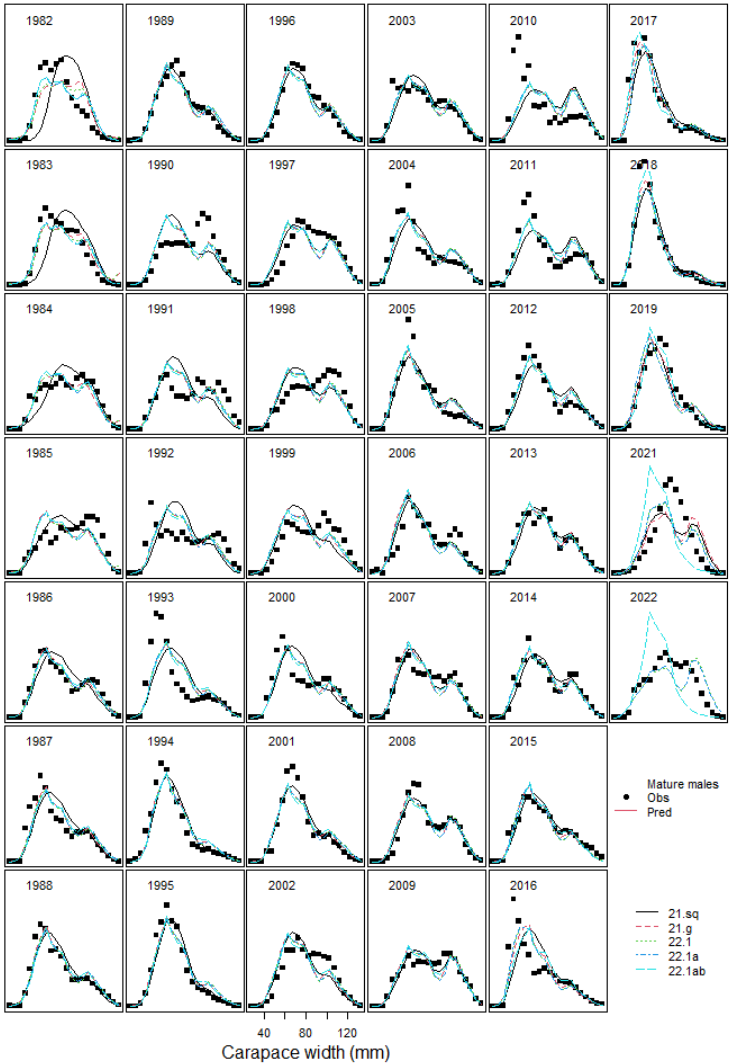
Immature males
Obs
Pred
21.sq
21.g
22.1
22.1a
22.1ab
40
80
120
Carapace width (mm)


2019


2021


2022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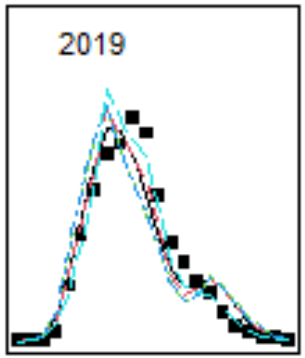
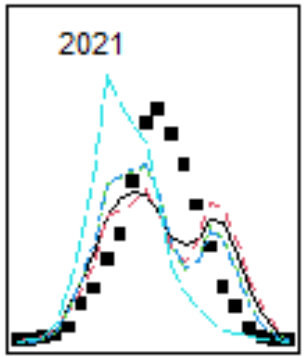
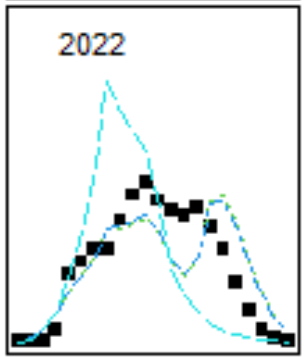
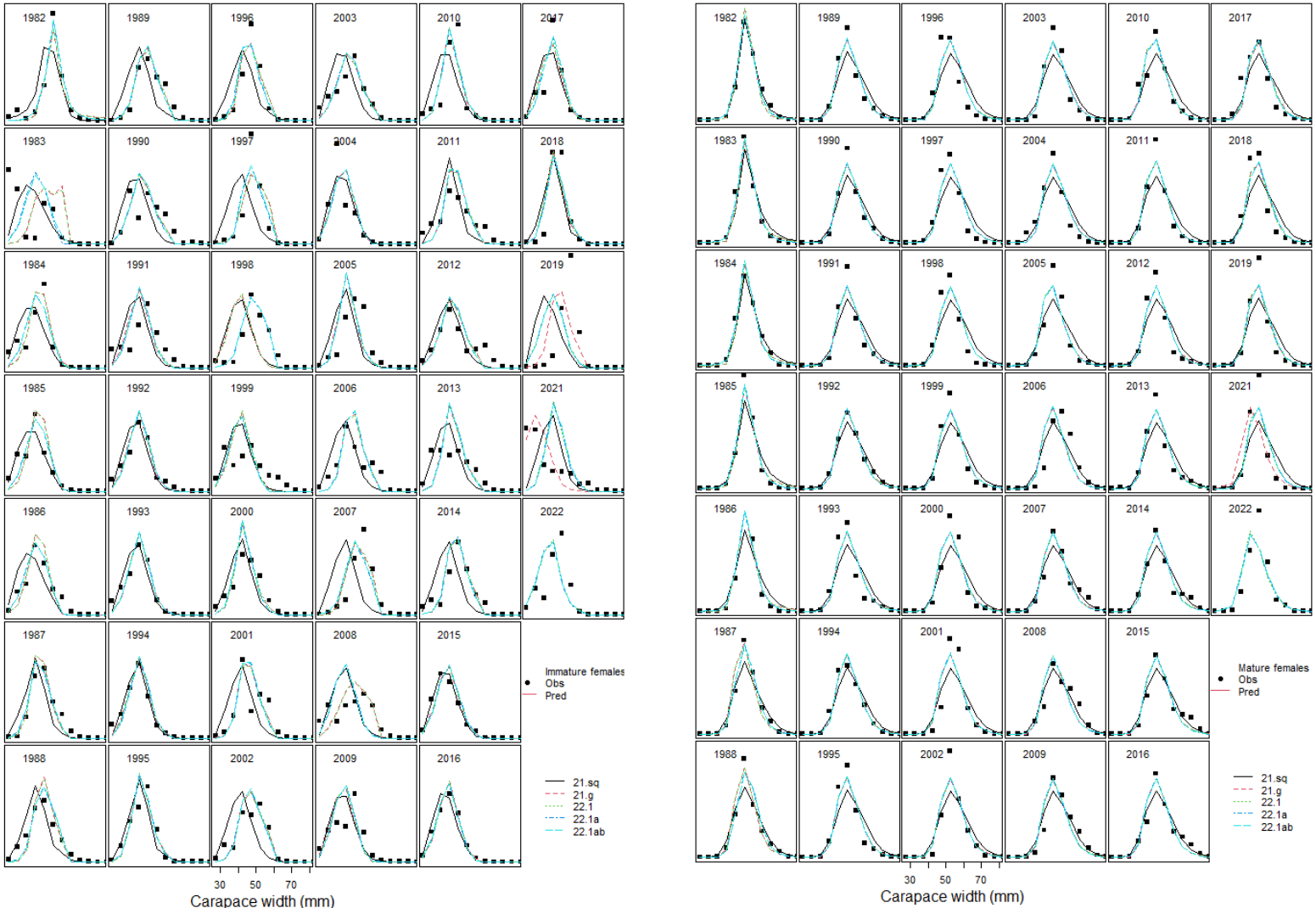
2015
1988
1995
2002
2009
2016
Mature males
Obs
Pred
21.sq
21.g
22.1
22.1a
22.1ab
40
80
120
Carapace width (mm)


2019


2021


2022

	Model 22.1a		Model 22.1ab	
Fits/Process	**Fits**	**Plausibility**	**Fits**	**Plausibility**
Survey MMB			Marginally better	
Growth			Marginally better	
Catch			Marginally better retained, better discard	
Size comps (catch)	Better to total			
Size comps (survey M)	Better to mature		Better to immature	
Size comps (survey F)				
MMB				
Selectivity				
Maturity				
Fishing mortality				
Recruitment				
Natural mortality				


1982
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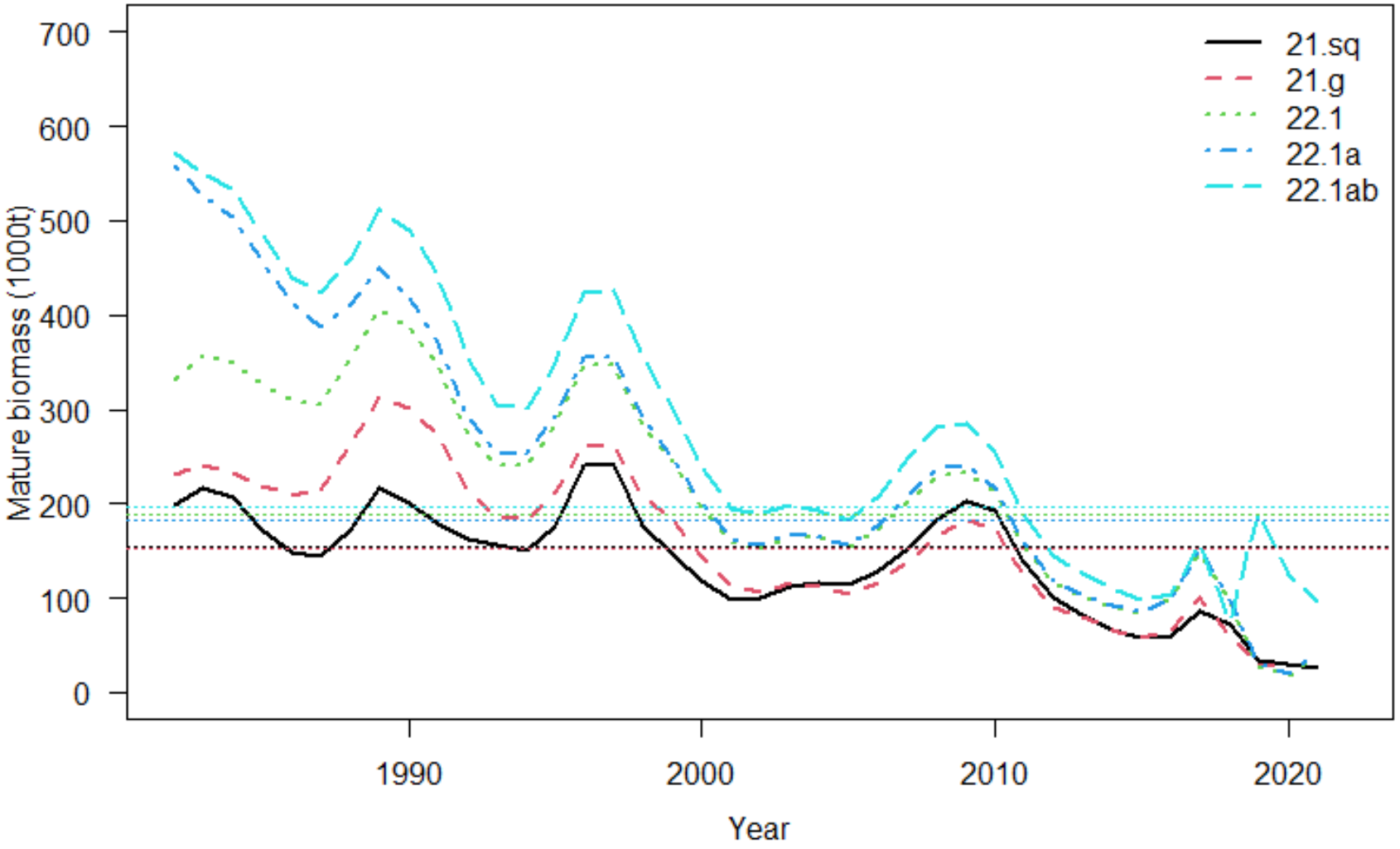
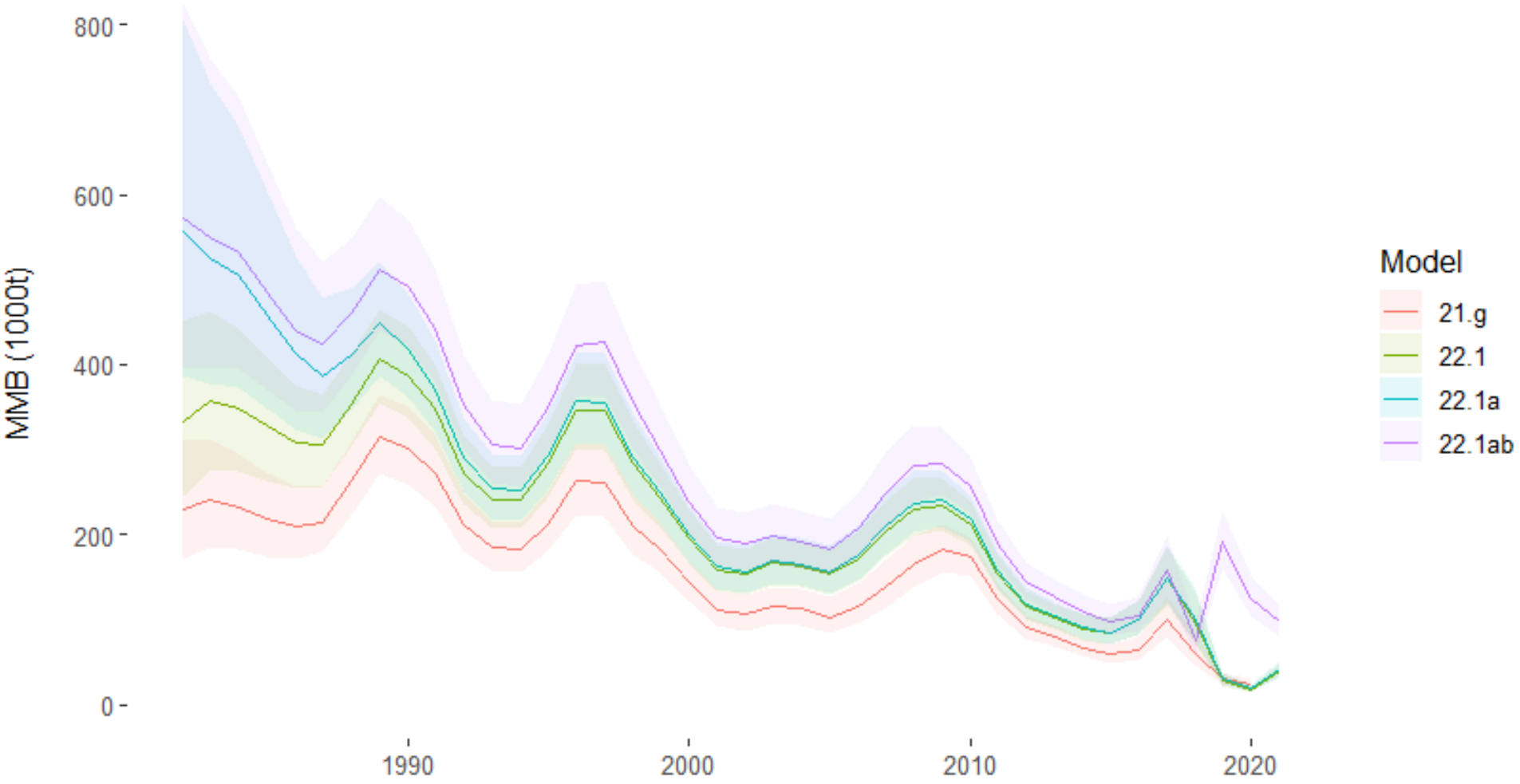
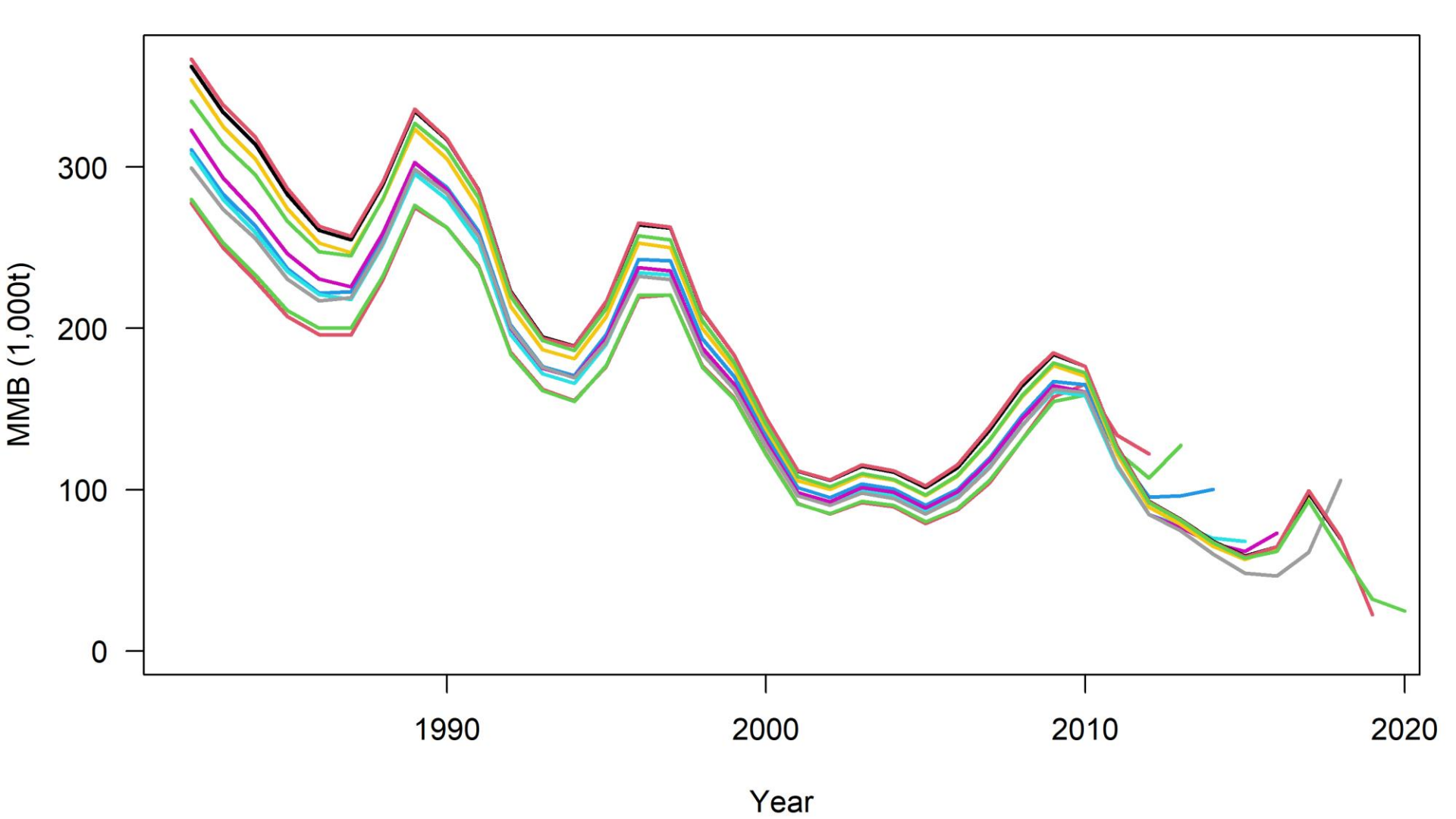
2021
1986
1993
2000
2007
2014
2022
1987
1994
2001
2008
2015
1988
1995
2002
2009
2016
Immature females
Obs
Pred
21.sq
21.g
22.1
22.1a
22.1ab
30
50
70
Carapace width (mm)
Mature females
Obs
Pred

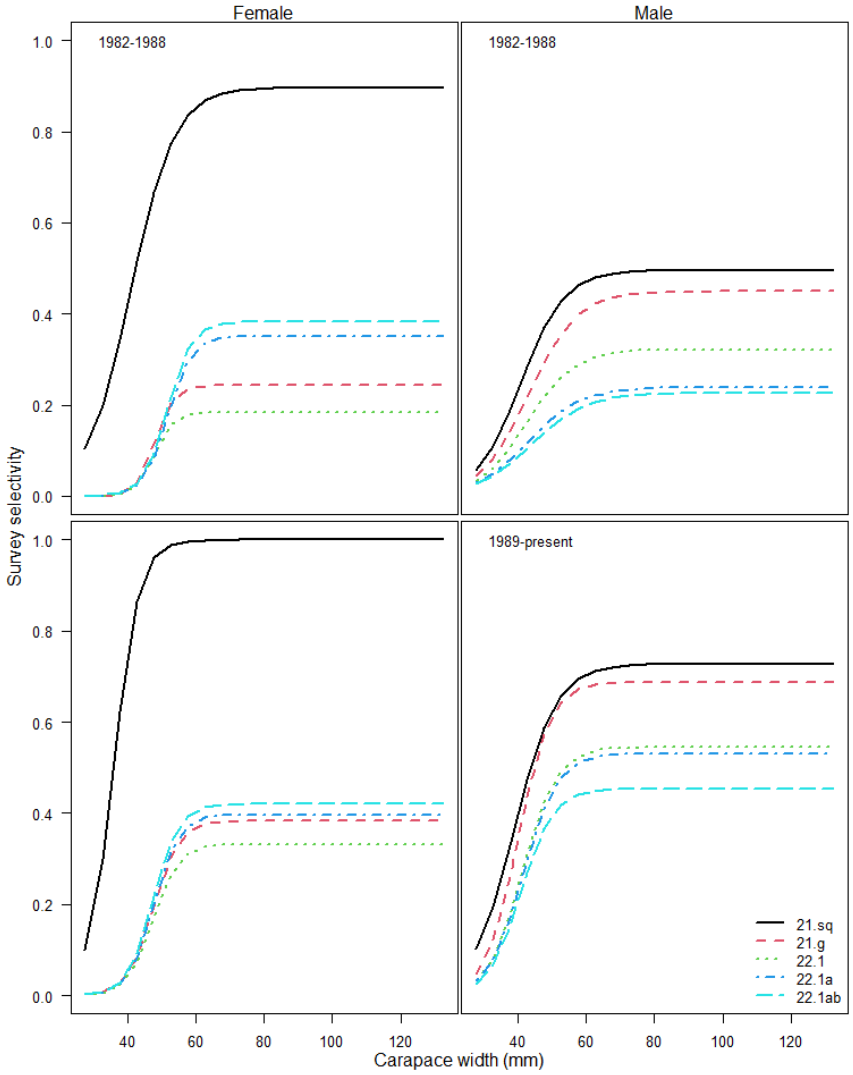
	Model 22.1a		Model 22.1ab	
Fits/Process	**Fits**	**Plausibility**	**Fits**	**Plausibility**
Survey MMB			Marginally better	
Growth			Marginally better	
Catch			Marginally better retained, better discard	
Size comps (catch)	Better to total			
Size comps (survey M)	Better to mature		Better to immature	
Size comps (survey F)	~		~	
MMB				
Selectivity				
Maturity				
Fishing mortality				
Recruitment				
Natural mortality				


21.sq
21.g
22.1
22.1a
22.1ab
Mature biomass (1000t)
0
100
200
300
400
500
600
700
1990
2000
2010
2020
Year

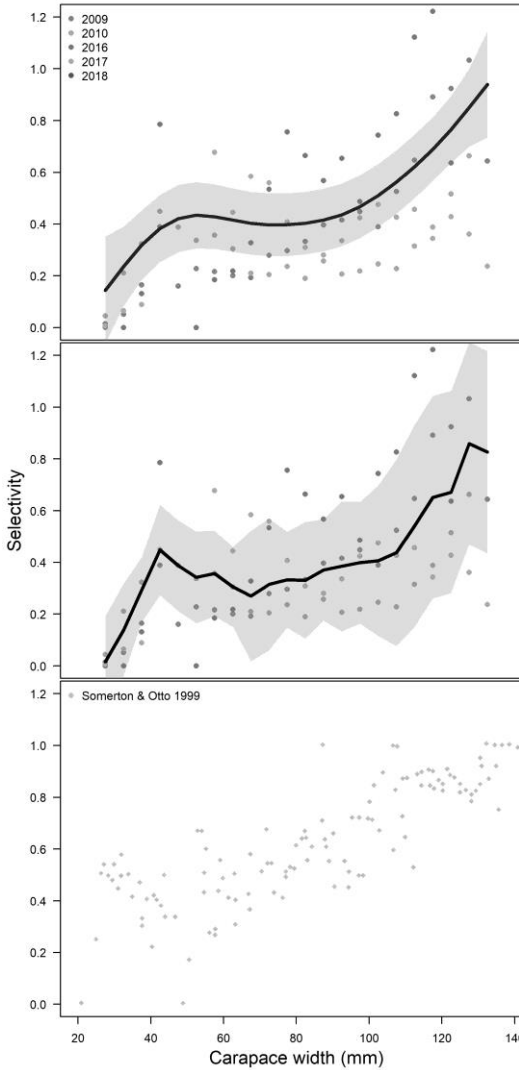

MMB (1000t)
800
600
400
200
0
1990
2000
2010
2020
Model
21.g
22.1
22.1a
22.1ab

	Model 22.1a		Model 22.1ab	
Fits/Process	**Fits**	**Plausibility**	**Fits**	**Plausibility**
Survey MMB			Marginally better	
Growth			Marginally better	
Catch			Marginally better retained, better discard	
Size comps (catch)	Better to total			
Size comps (survey M)	Better to mature		Better to immature	
Size comps (survey F)	~		~	
MMB		~		~
Selectivity				
Maturity				
Fishing mortality				
Recruitment				
Natural mortality				

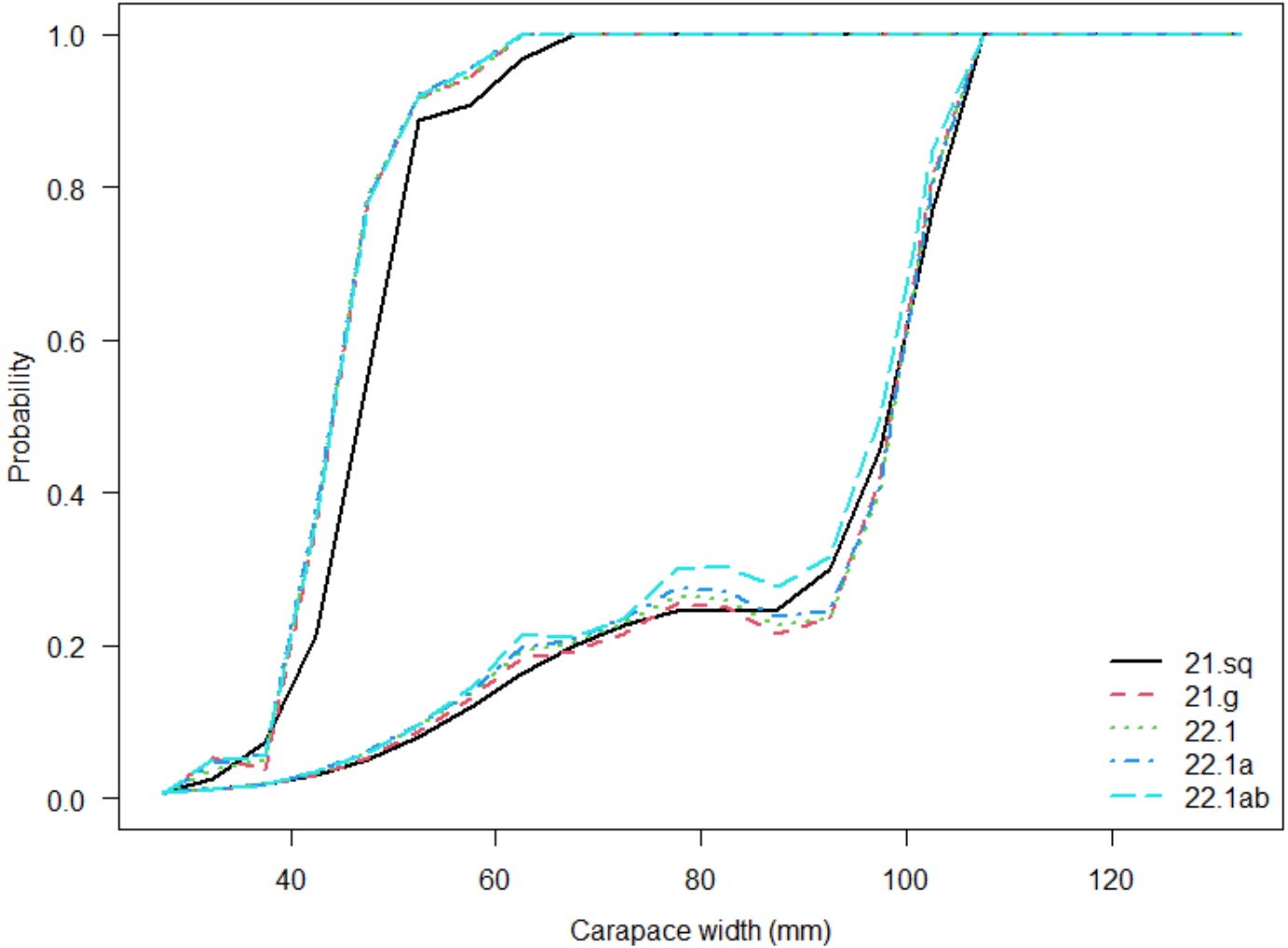

MMB (1,000t)
300
200
100
0
1990
2000
2010
2020
Year



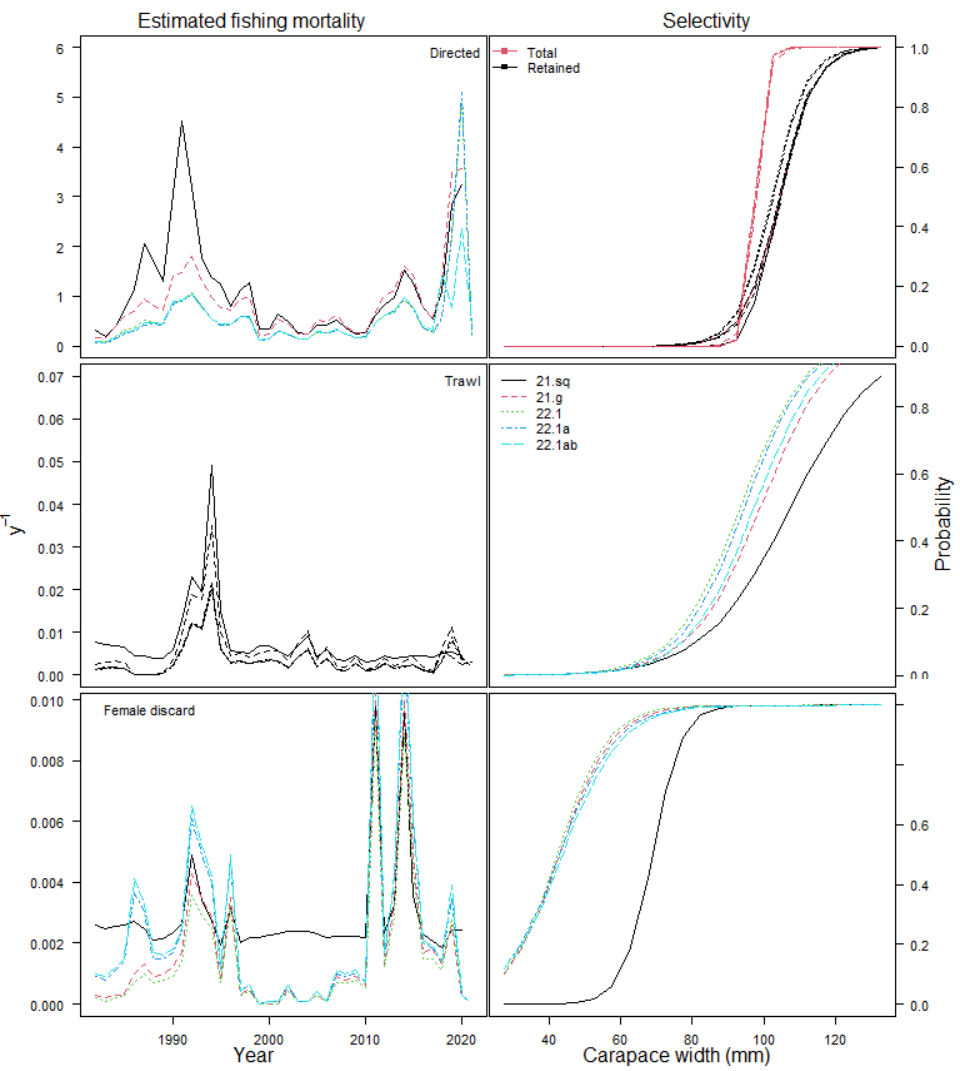
Model 22.1ab estimates of survey q lower than 22.1 or 22.1a, but closer to the implied q of the BSFRF data.

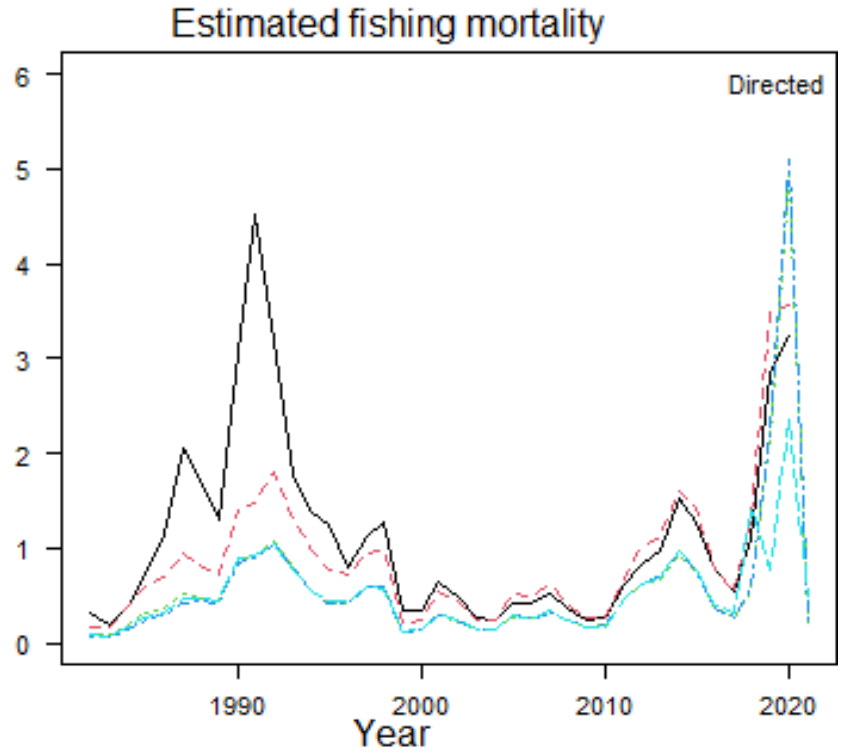


	Model 22.1a		Model 22.1ab	
Fits/Process	**Fits**	**Plausibility**	**Fits**	**Plausibility**
Survey MMB			Marginally better	
Growth			Marginally better	
Catch			Marginally better retained, better discard	
Size comps (catch)	Better to total			
Size comps (survey M)	Better to mature		Better to immature	
Size comps (survey F)	~		~	
MMB		~		~
Selectivity		Closer to status quo		Closer to BSFRF
Maturity				
Fishing mortality				
Recruitment				
Natural mortality				

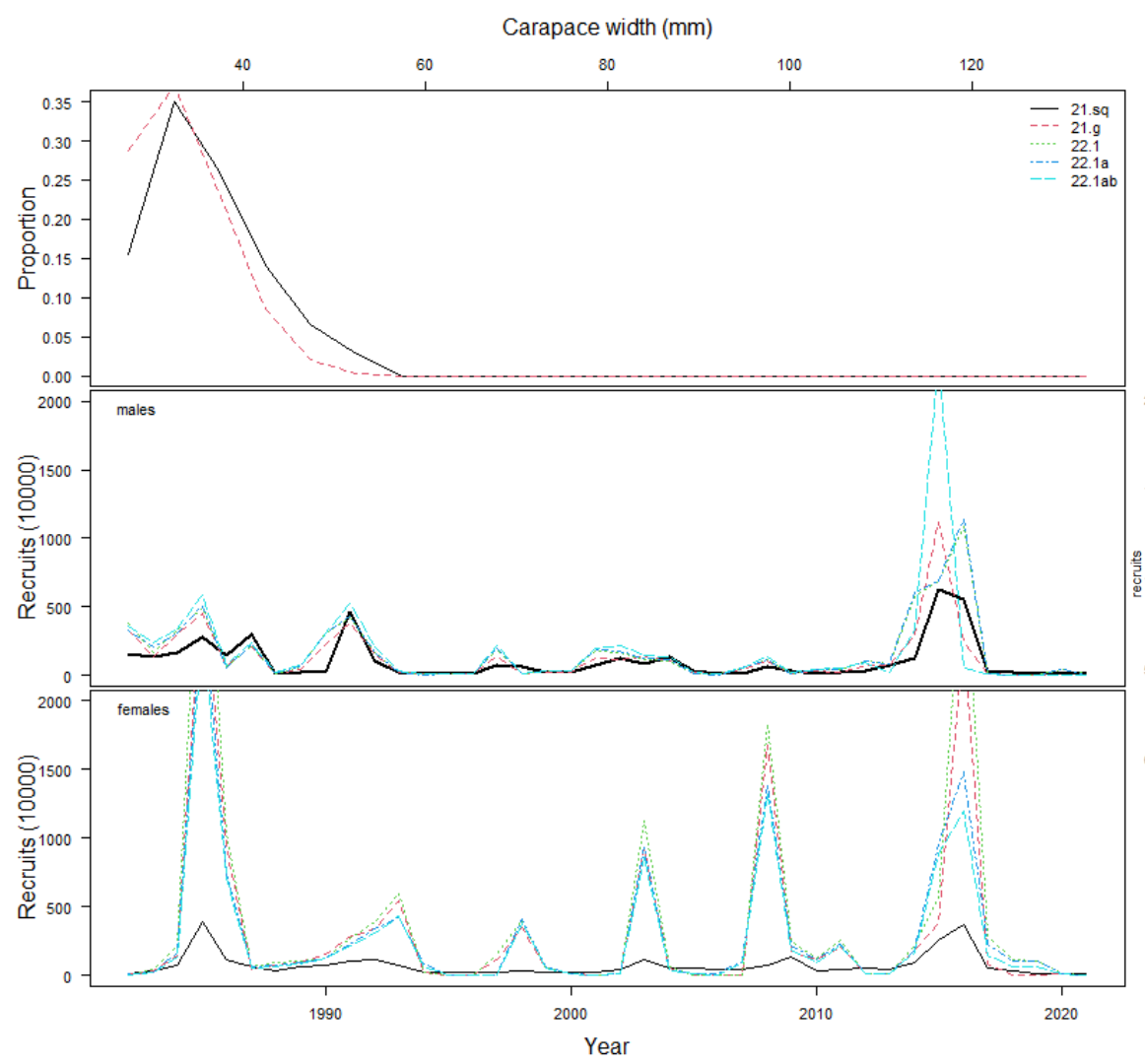

1.0
0.8
0.6
0.4
0.2
0.0
Probability
40
60
80
100
120
Carapace width (mm)
21.sq
21.g
22.1
22.1a
22.1ab

	Model 22.1a		Model 22.1ab	
Fits/Process	**Fits**	**Plausibility**	**Fits**	**Plausibility**
Survey MMB			Marginally better	
Growth			Marginally better	
Catch			Marginally better retained, better discard	
Size comps (catch)	Better to total			
Size comps (survey M)	Better to mature		Better to immature	
Size comps (survey F)	~		~	
MMB		~		~
Selectivity		Closer to status quo		Closer to BSFRF
Maturity		~		~
Fishing mortality				
Recruitment				
Natural mortality				

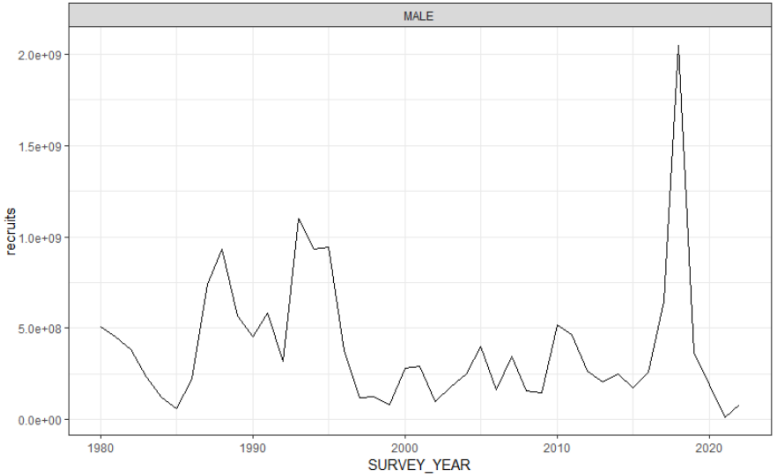

Estimated fishing mortality
Selectivity
Directed
Total
Retained
Trawl
21.sq
21.g
22.1
22.1a
22.1ab
Female discard
y−1
Probability
Year
Carapace width (mm)


Estimated fishing mortality
Directed
Year

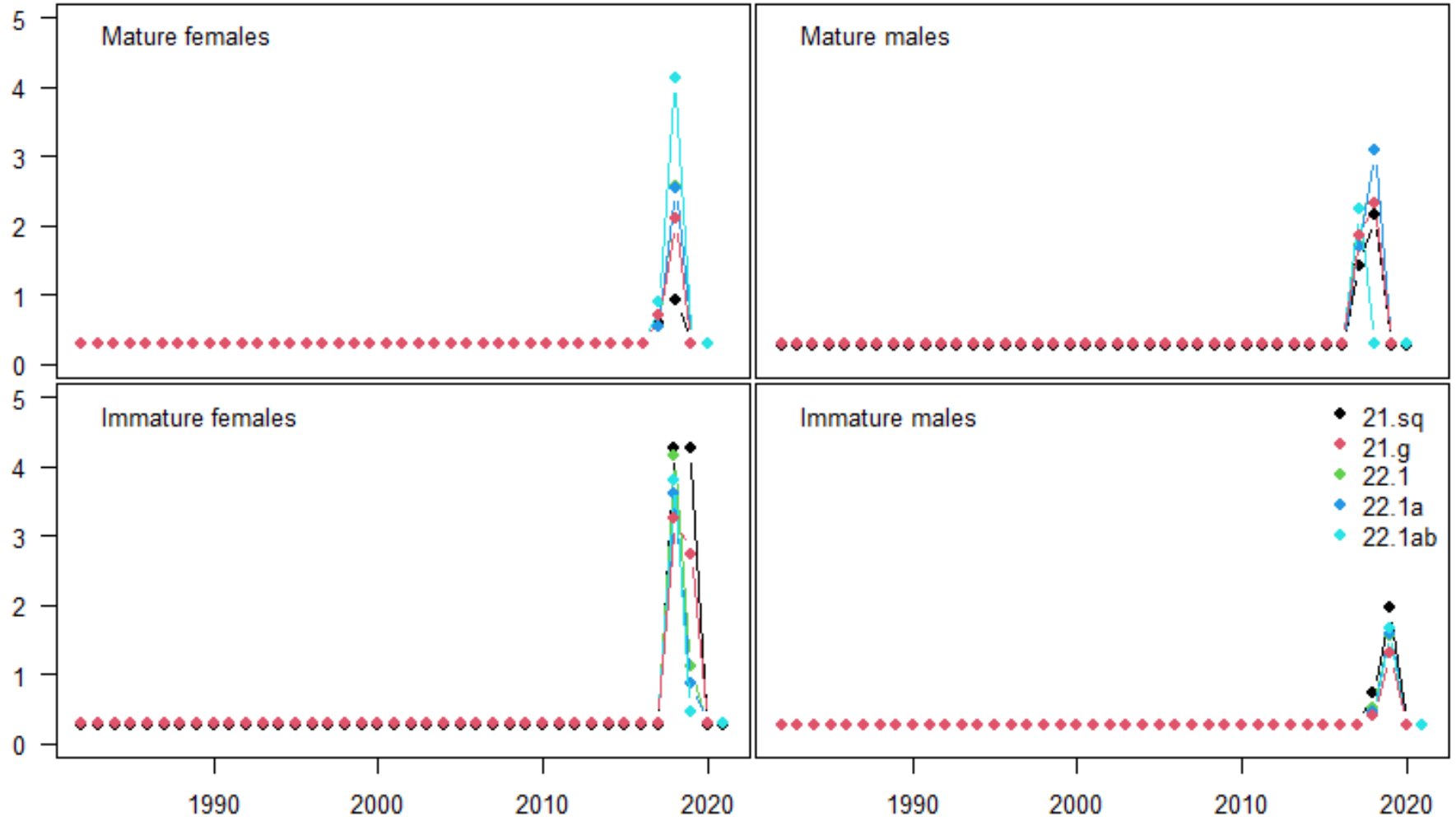
	Model 22.1a		Model 22.1ab	
Fits/Process	**Fits**	**Plausibility**	**Fits**	**Plausibility**
Survey MMB			Marginally better	
Growth			Marginally better	
Catch			Marginally better retained, better discard	
Size comps (catch)	Better to total			
Size comps (survey M)	Better to mature		Better to immature	
Size comps (survey F)	~		~	
MMB		~		~
Selectivity		Closer to status quo		Closer to BSFRF
Maturity		~		~
Fishing mortality		99.5% removals not plausible		
Recruitment				
Natural mortality				



Observed males
50 < carapace width < 60



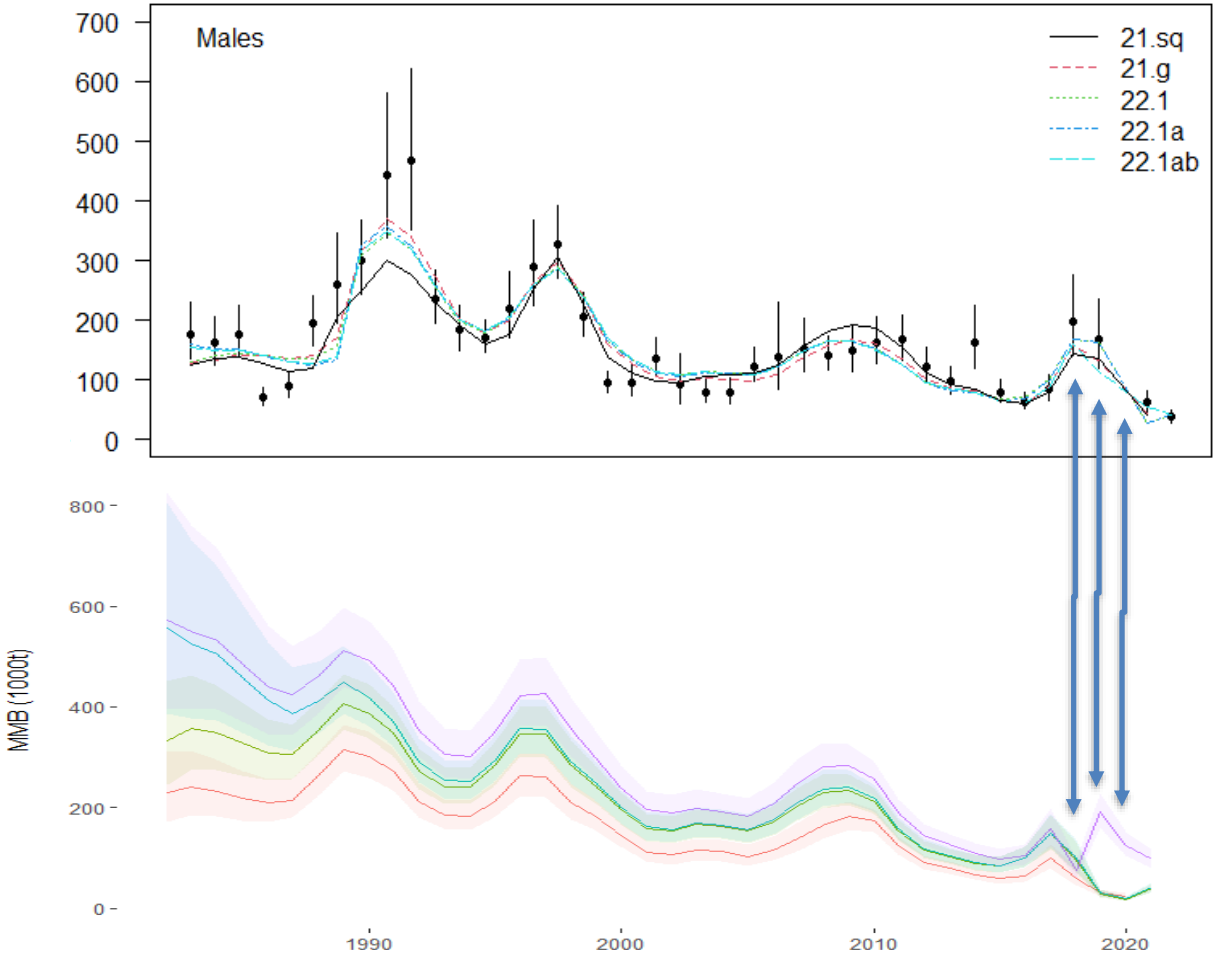
	Model 22.1a		Model 22.1ab	
Fits/Process	**Fits**	**Plausibility**	**Fits**	**Plausibility**
Survey MMB			Marginally better	
Growth			Marginally better	
Catch			Marginally better retained, better discard	
Size comps (catch)	Better to total			
Size comps (survey M)	Better to mature		Better to immature	
Size comps (survey F)	~		~	
MMB		~		~
Selectivity		Closer to status quo		Closer to BSFRF
Maturity		~		~
Fishing mortality		99.5% removals not plausible		
Recruitment				Very large 2015 recruit
Natural mortality				


Mature females
Mature males
Immature females
Immature males
21.sq
21.g
22.1
22.1a
22.1ab
0
1
2
3
4
5
1990
2000
2010
2020

	Model 22.1a		Model 22.1ab	
Fits/Process	**Fits**	**Plausibility**	**Fits**	**Plausibility**
Survey MMB			Marginally better	
Growth			Marginally better	
Catch			Marginally better retained, better discard	
Size comps (catch)	Better to total			
Size comps (survey M)	Better to mature		Better to immature	
Size comps (survey F)	~		~	
MMB		?		?
Selectivity		Closer to status quo		Closer to BSFRF
Maturity		~		~
Fishing mortality		99.5% removals not plausible		
Recruitment				Very large 2015 recruit
Natural mortality		?		?

Author-preferred model: 22.1ab

- Pros
  - No unrealistic fishing mortality in 2020
  - Decrease in survey q closer to BSFRF implied q (‘how could MMB go up if the survey went down?’)
- Cons
  - Not the best fit (but size composition overweighted)
  - Decrease in survey q a fairly large departure from the status quo
  - Larger recruitment event in 2015
- Trade-offs
  - Large fishing mortality vs. large recruitment
  - Fits to size composition data
- Overarching issues
  - No 2020 data
  - Probability of having undergone terminal molt
  - Two weeks is not enough time to do an assessment when problems arise



Two potential histories:

22.1a:

~3 recruitments

Two large mortalities on MMB

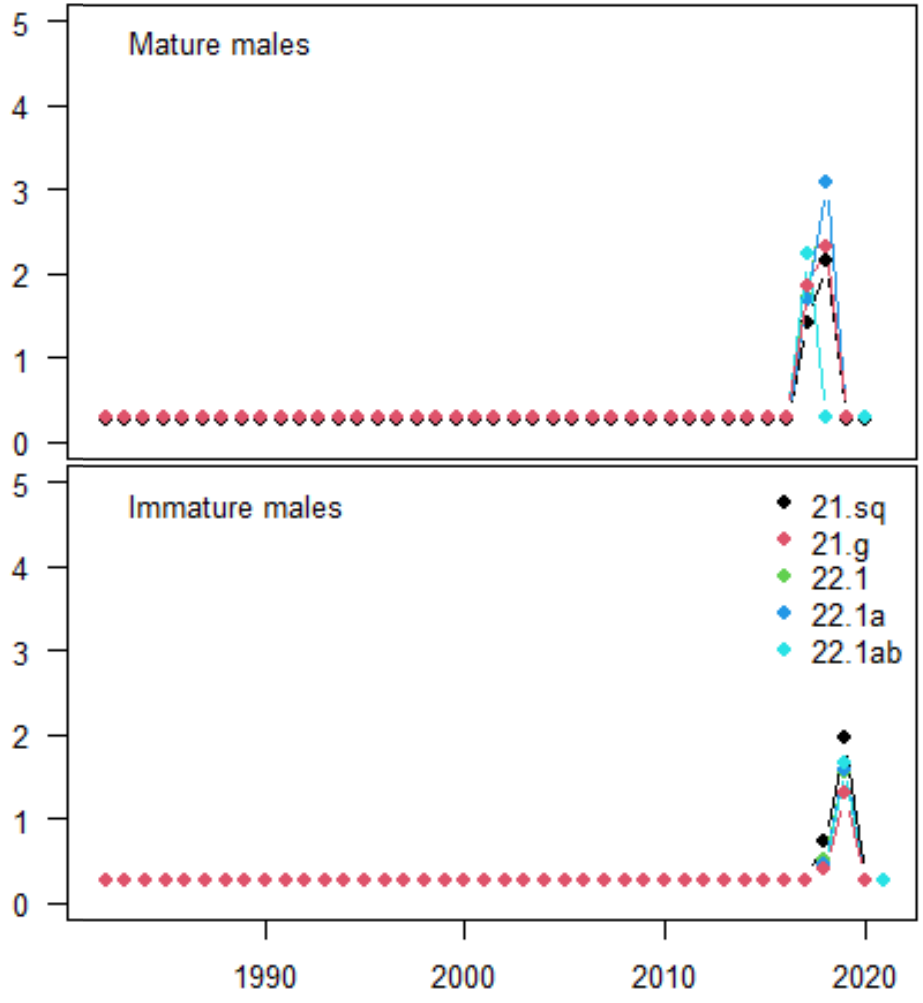
Implausibly high F

22.1ab:

One recruitment

One large mortality on MMB

Reasonable Fs



Two potential histories:

22.1a:

~3 recruitments

Two large mortalities on MMB

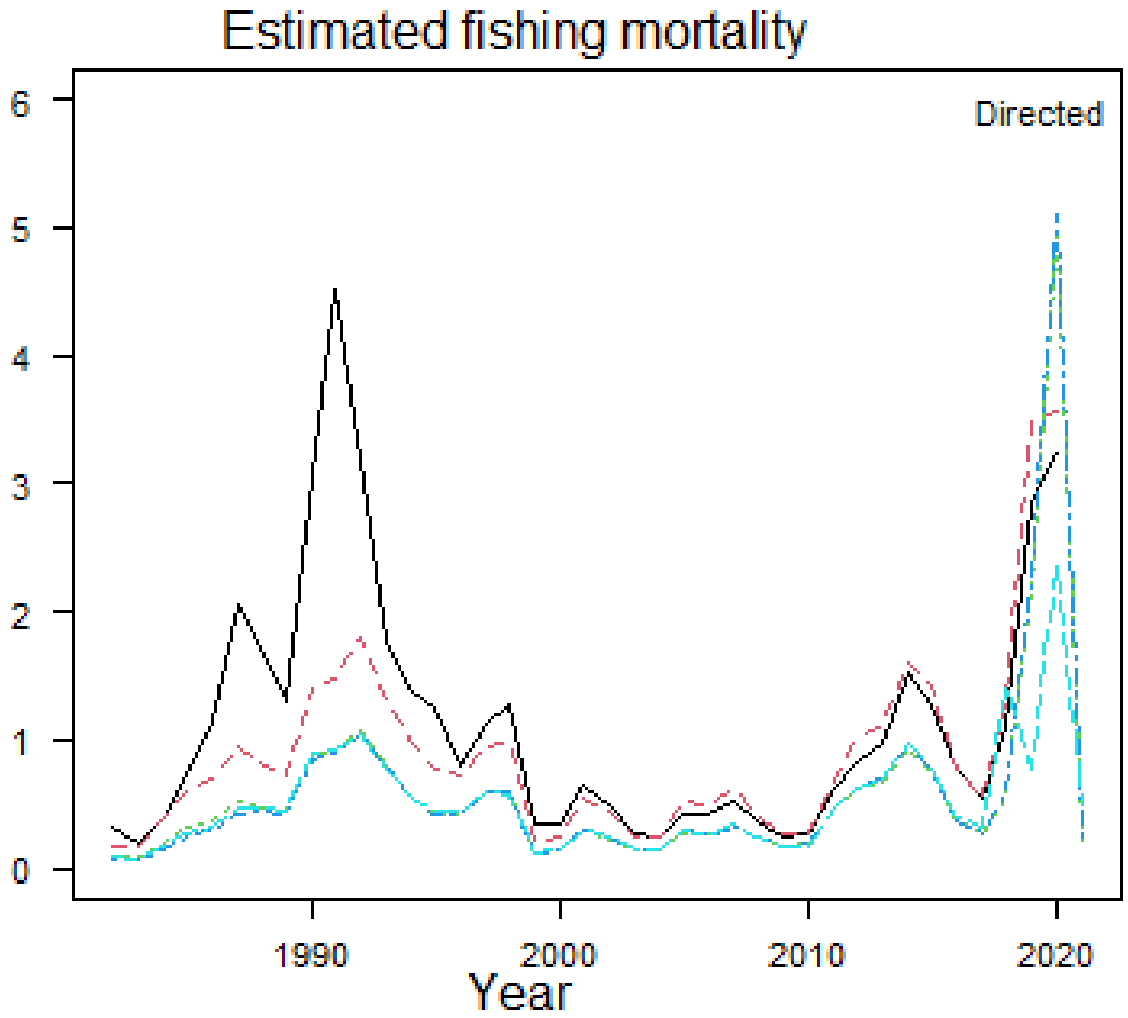
Implausibly high F

22.1ab:

One recruitment

One large mortality on MMB

Reasonable Fs



Two potential histories:

22.1a:

~3 recruitments

Two large mortalities on MMB

Implausibly high F

22.1ab:

One recruitment

One large mortality on MMB

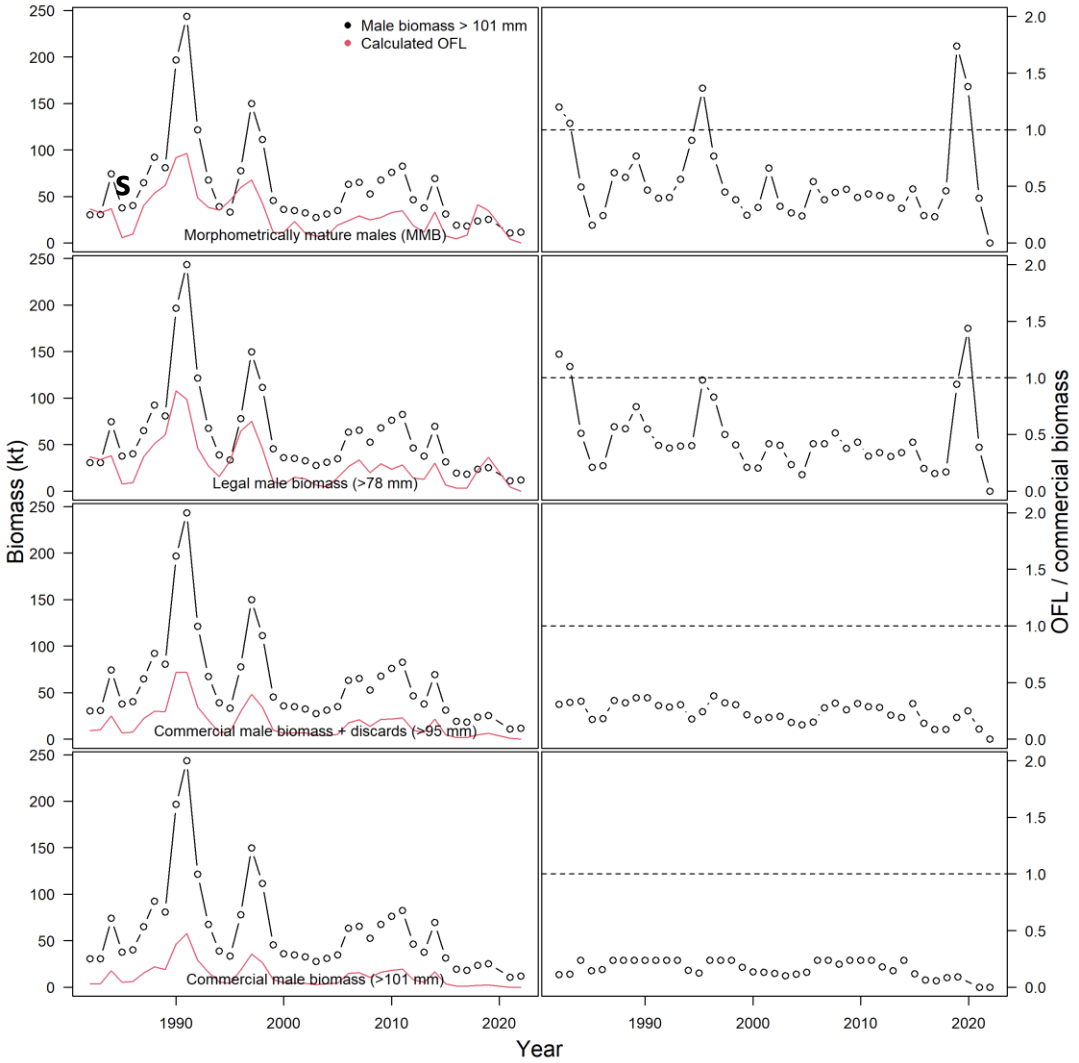
More reasonable Fs

Model	MMB	B35	F35	FOFL	OFL	M	avg_rec	Status
21.sq	26.74	153.42	1.43	0.37	7.50	0.27	106.14	0.17
21.g	23.71	153.33	1.59	0.36	7.89	0.28	131.71	0.15
22.1	39.85	189.12	1.37	0.28	9.06	0.28	161.82	0.21
22.1a	41.21	183.15	1.50	0.32	10.32	0.28	164.02	0.23
22.1ab	96.67	196.38	2.26	0.67	3.98	0.29	180.36	0.49

Among the updated models, 22.1a or 22.1ab are both an improvement over 22.1

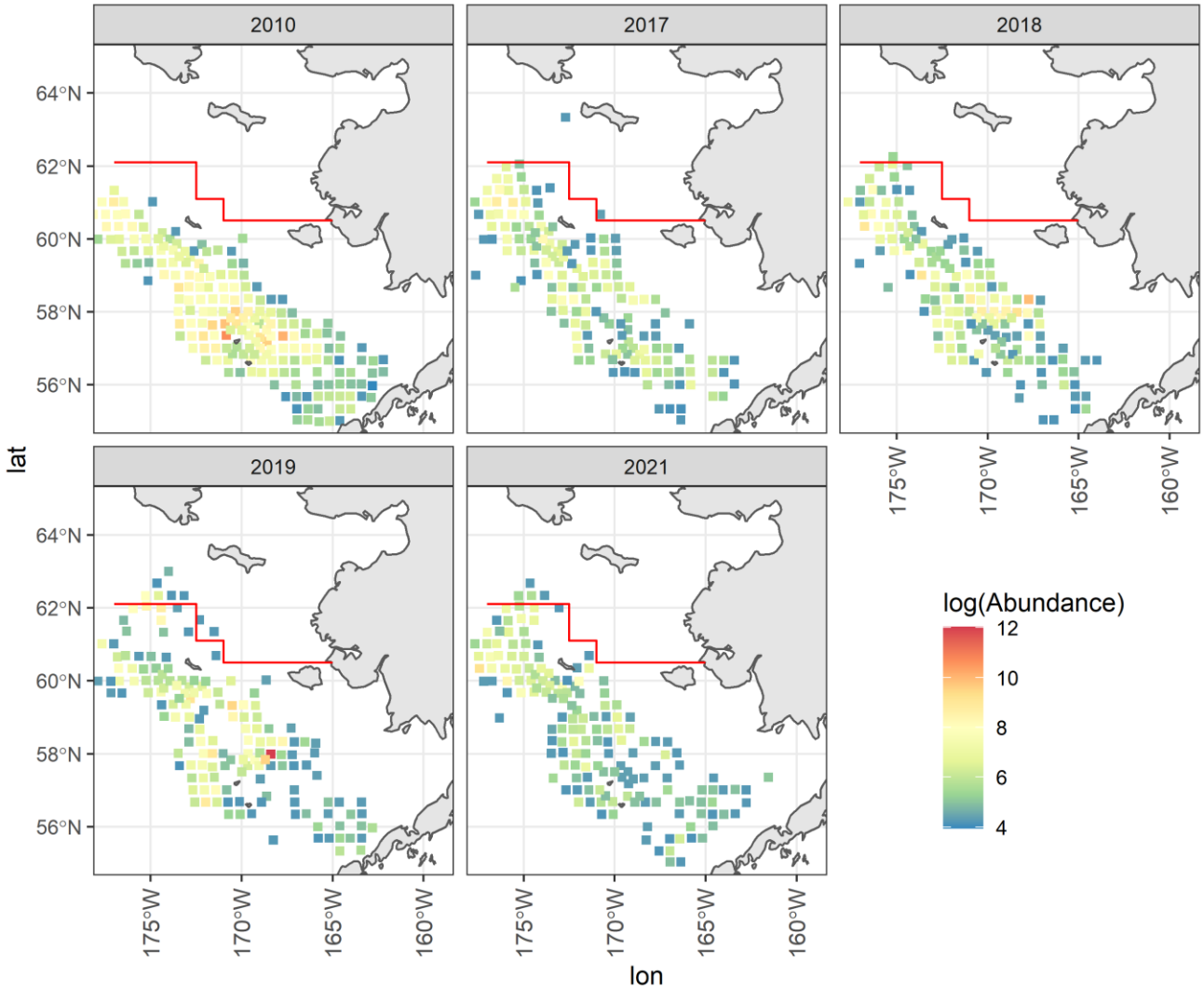
Given the difference in plausibility of fishing mortality,
22.1ab is my author-preferred model

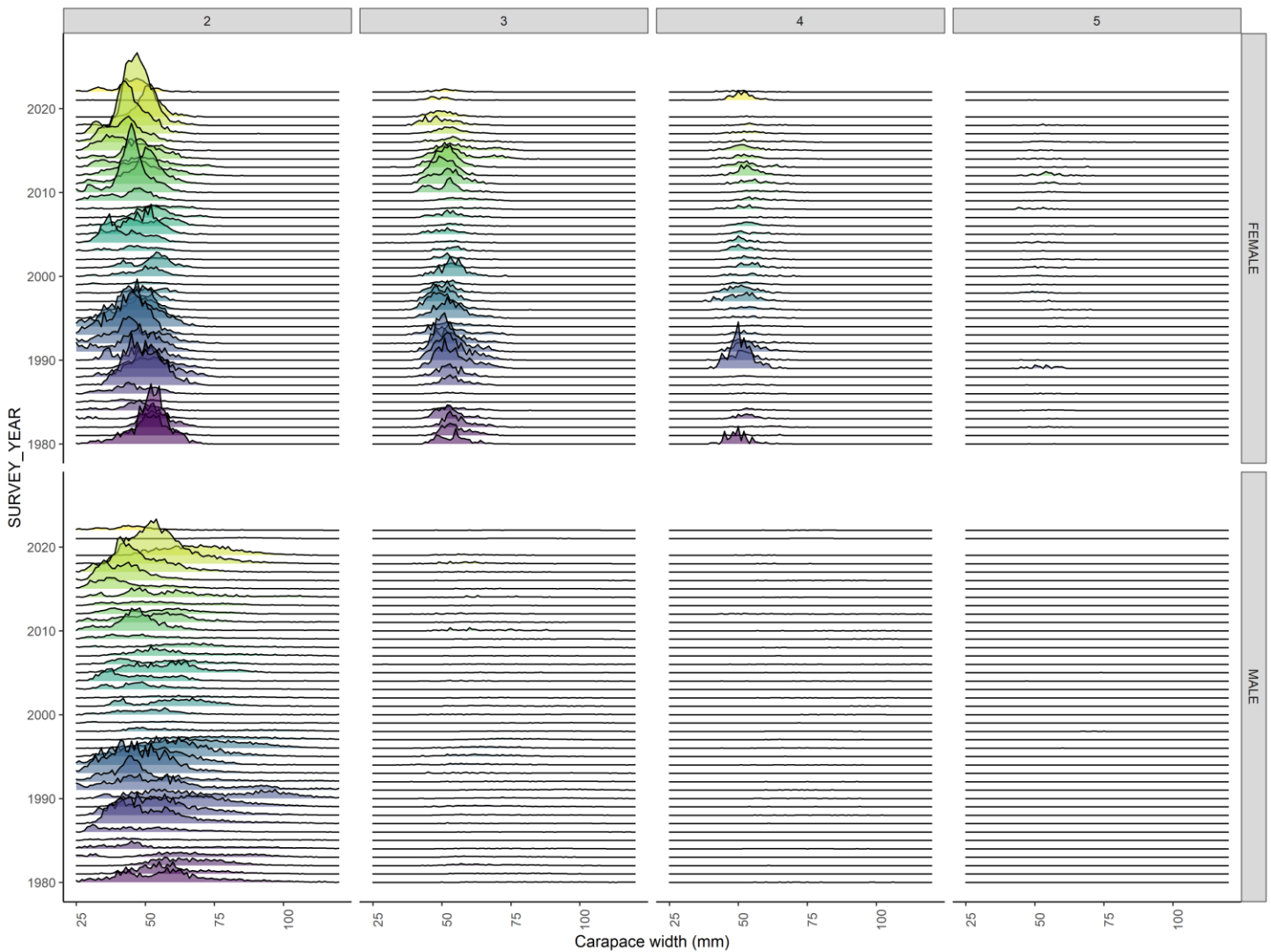
However, 22.1ab does possess undesirable characteristics

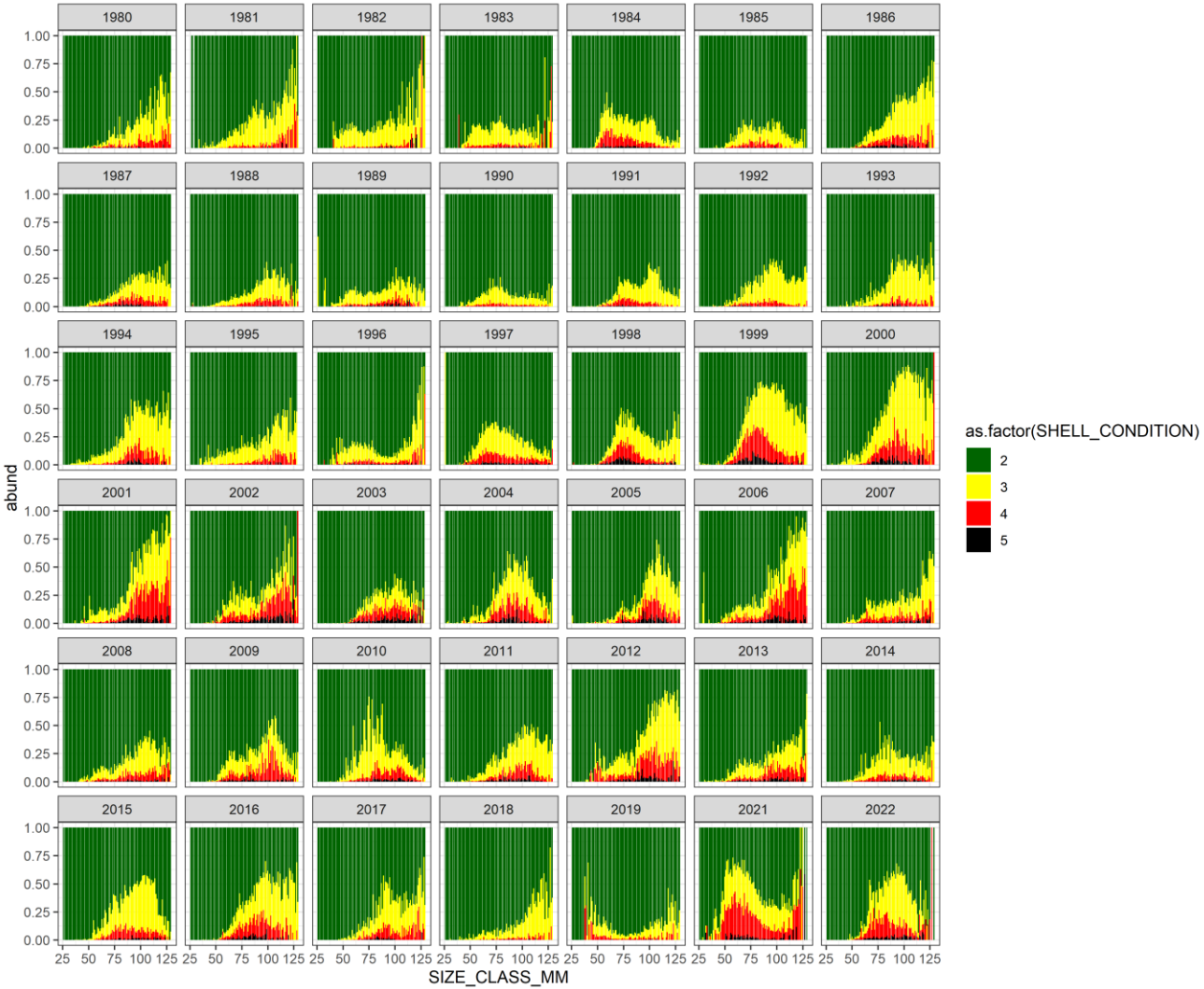


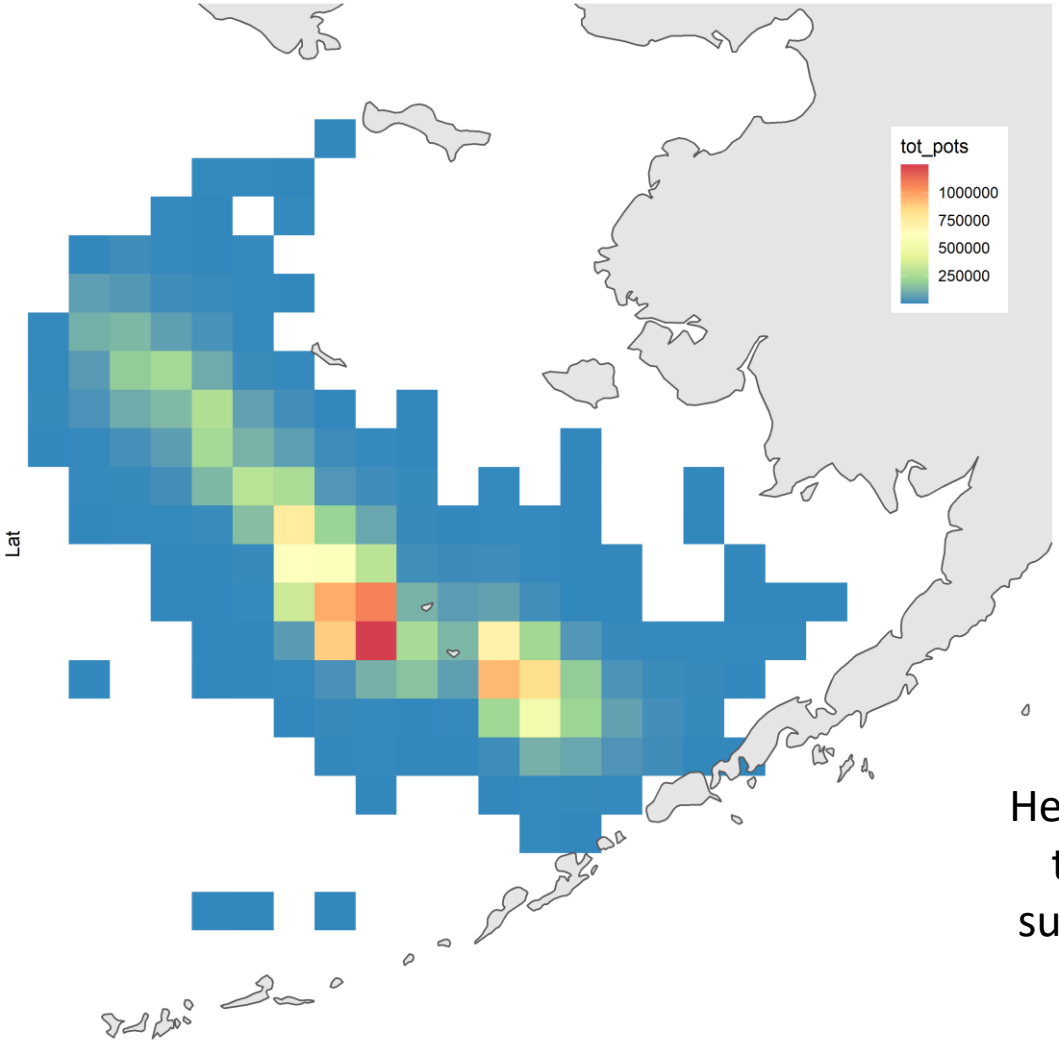
Tier 4

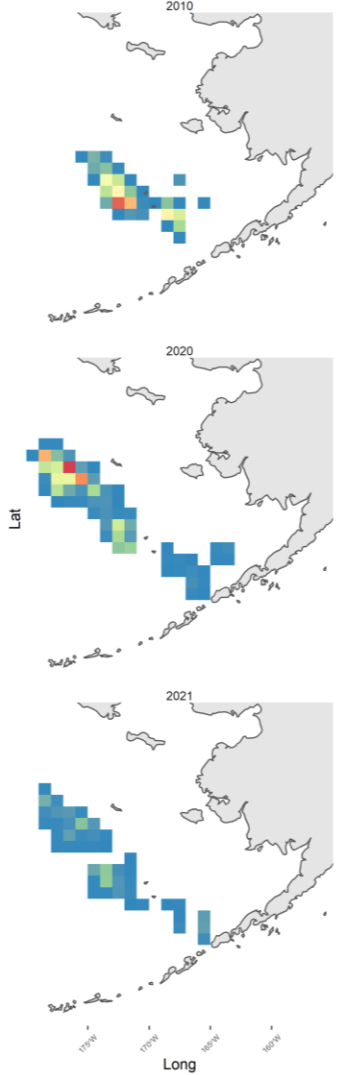
- 'Current biomass' should be a proxy for reproductive potential
- BMSY based on 1982-2021
- FMSY = 0.27 (M)
- All 4 proxies resulted in a closed fishery


2010
2017
2018
2019
2021
64°N
62°N
60°N
58°N
56°N
175°W
170°W
165°W
160°W
lat
lon
log(Abundance)
12
10
8
6
4


2
3
4
5
FEMALE
MALE
SURVEY_YEAR
2020
2010
2000
1990
1980
25
50
75
100
Carapace width (mm)


1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2021
2022
abund
1.00
0.75
0.50
0.25
0.00
25 50 75 100 125
SIZE_CLASS_MM
as.factor(SHELL_CONDITION)
2
3
4
5





Heatmap of effort in terms of potlifts summed over time.