Bristol Bay red king crab

Proposed models for 2023

May 2023

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Summary

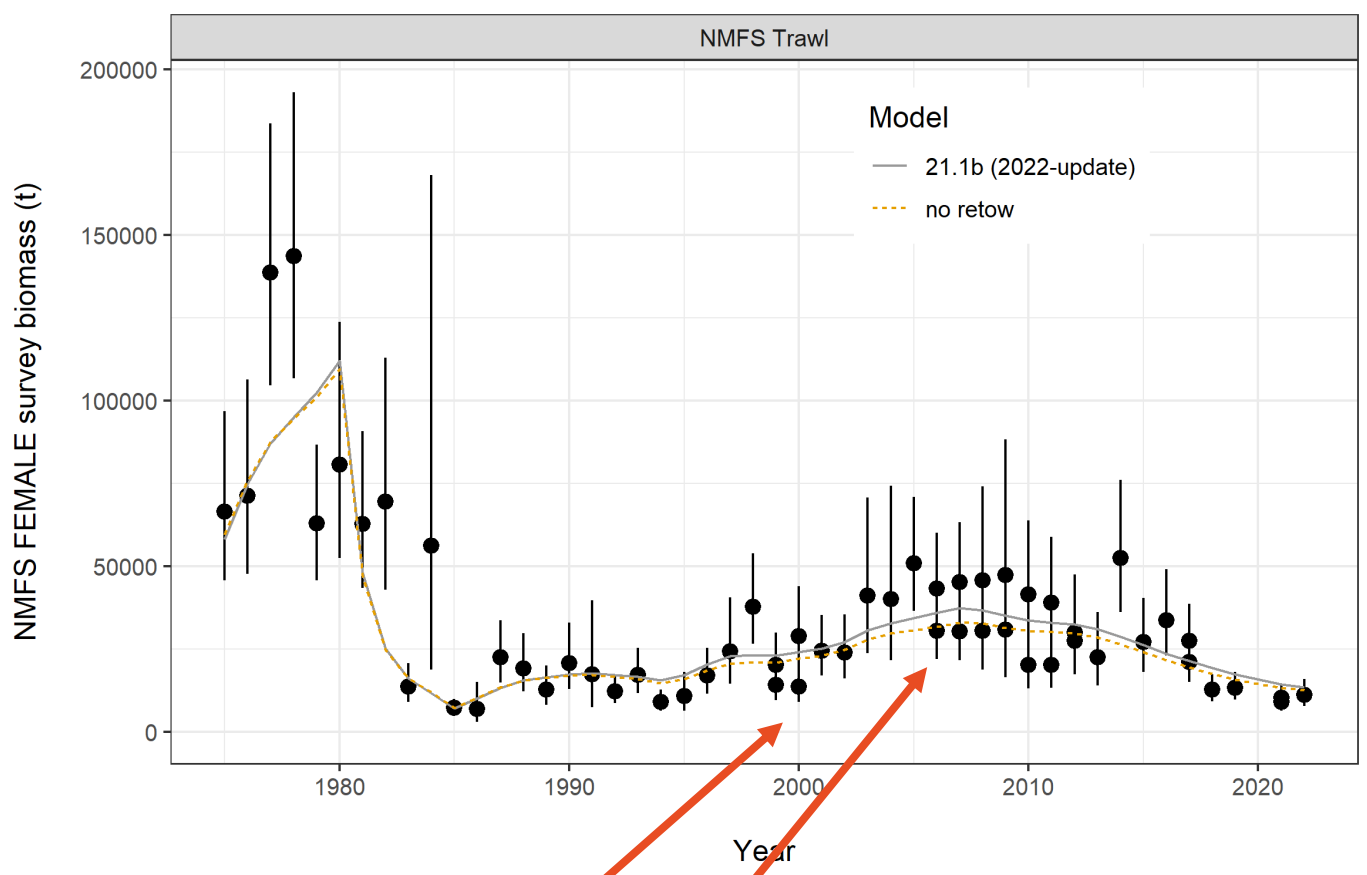
- Stable model in GMACS since 2018
- Directed fishery was closed in 2021/22 and 2022/23 season due to low mature female abundance.
- Low recruitment in recent years (last 8-12 years), projected decline in biomass without a large recruitment event
- Model explorations around a few themes:
  - GMACS updates
  - Start year for model (1975 vs 1985)
  - Natural mortality
  - Q for NMFS trawl survey
  - Sensitivity to female resample data (re-tow data)

CPT / SSC comments

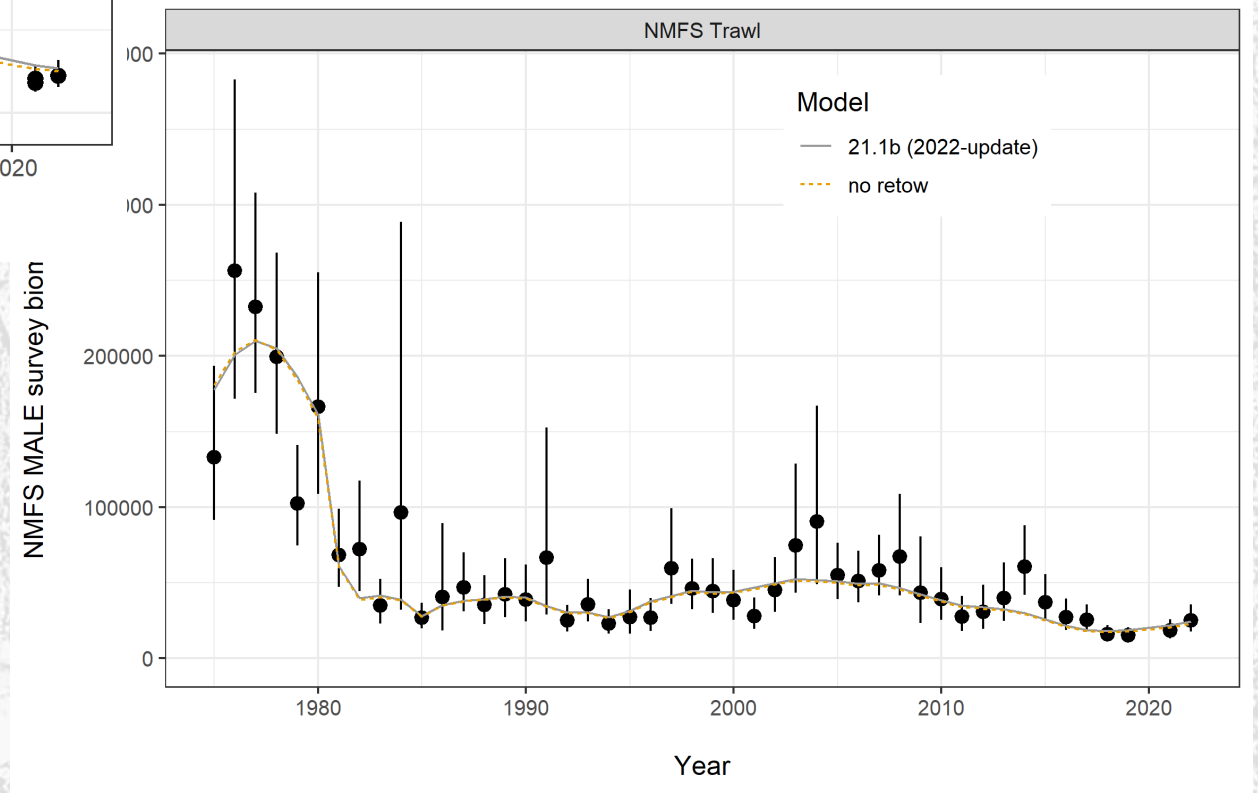
- Stock structure template for Bering Sea red king crab – draft May 2023
- Natural mortality – scale and whether it should be estimated or not
- Q for both surveys
  - Explore how to estimate them and potentially with linked in some fashion
- Retrospective patterns
  - High priority on source of these
  - Decreases some with estimated M – models in 23.0a, 23.0b, 23.0
- Re-tow / resampling for females and the utility of this data
  - Model 23.2
- Other comment themes not yet addressed: initial conditions, VAST, re-do M likelihood profile

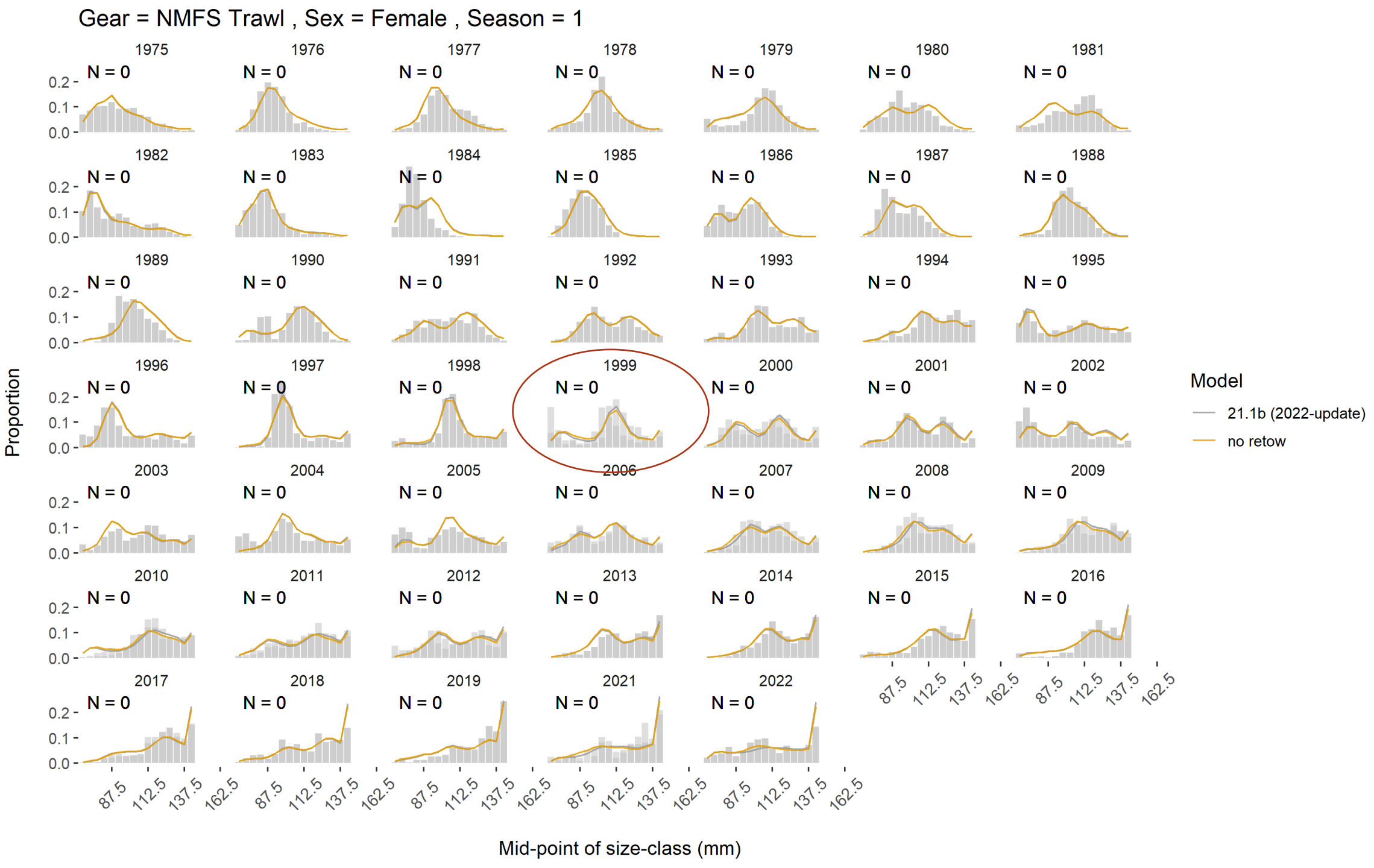
Female re-tow / resampling exploration

- Historic rationale:
  - Characterize the reproductive status of BBRKC mature females given temperature-driven delays in the molt/mate cycle
  - Accurately assess the relative abundance of BBRKC mature females given that females may be outside the surveyed area when the cycle is delayed
- Current rationale clarifications:
  - Improve accurate of size composition data post-molt for females
  - Abundance estimate of mature females (same as previous)
- Resampling occurred in 1999, 2000, 2006 to 2012, 2017, 2021
  - All except 2021 had at least 25% of mature females that did NOT complete the molt-mate cycle
- Model 23.2
  - Remove “re-tow” data from the base model by estimating the base model (21.1b) with only leg 1 survey data – both biomass and size compositions.

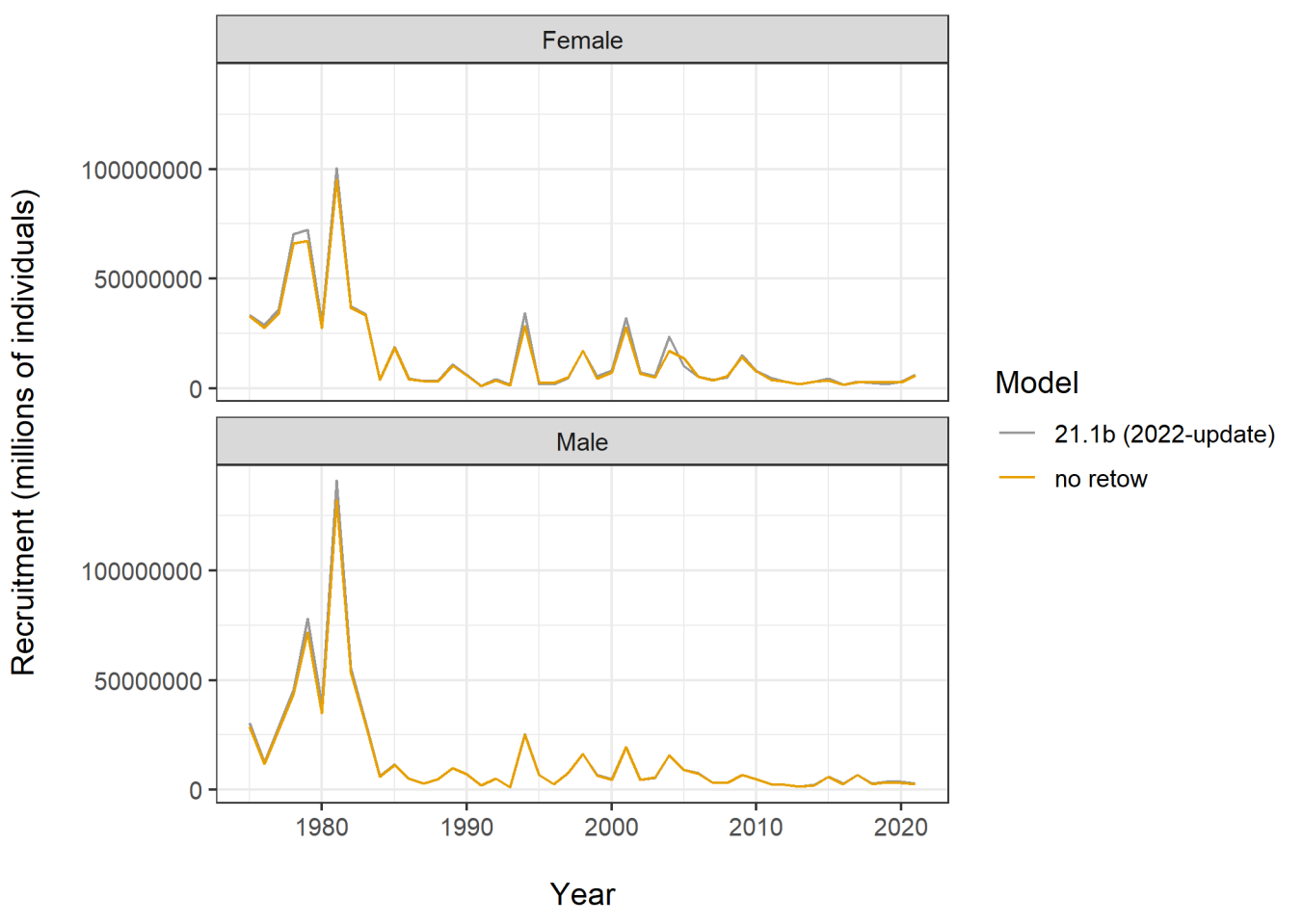


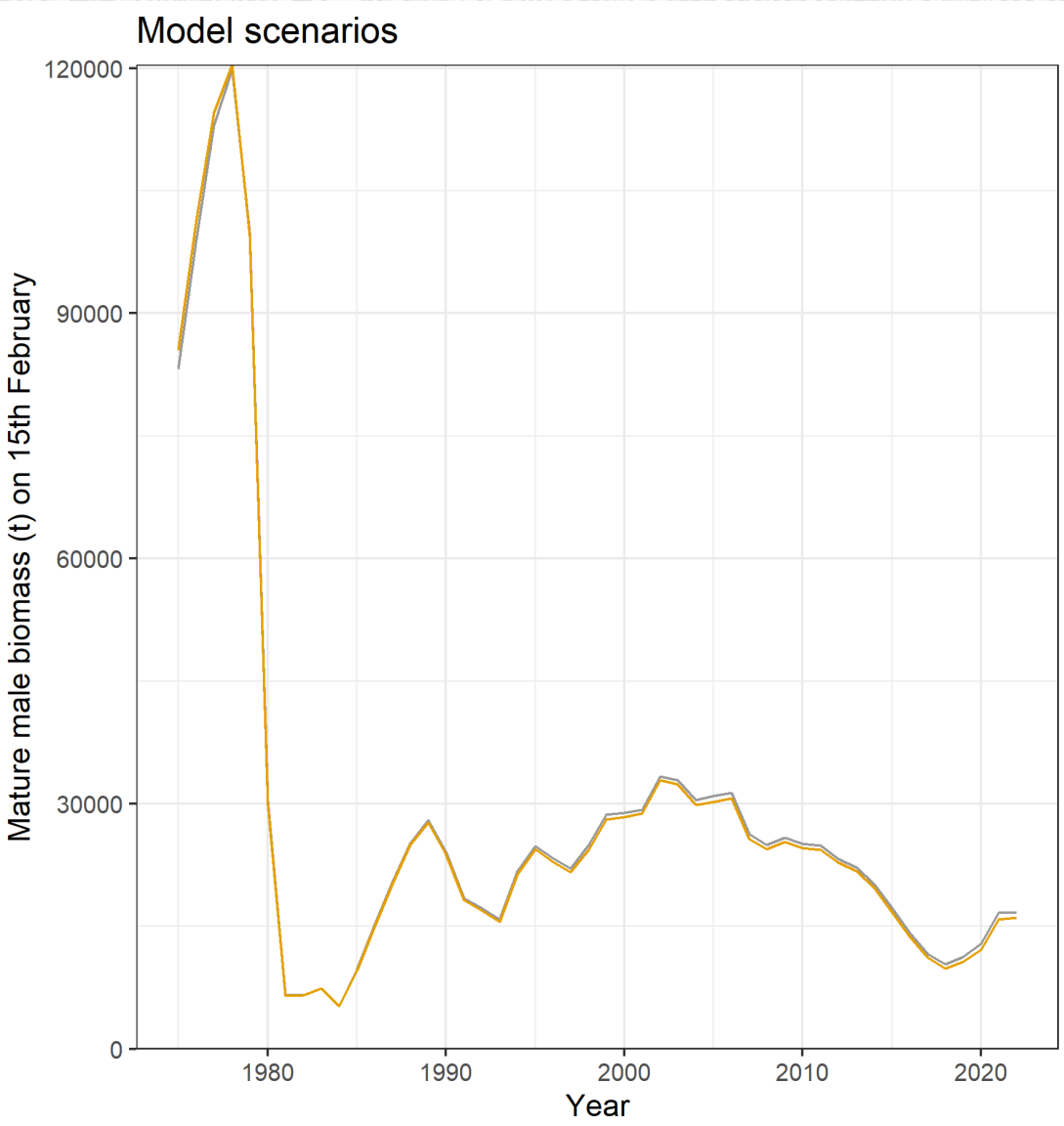
1999, 2000, 2006 to 2012, 2017, 2021

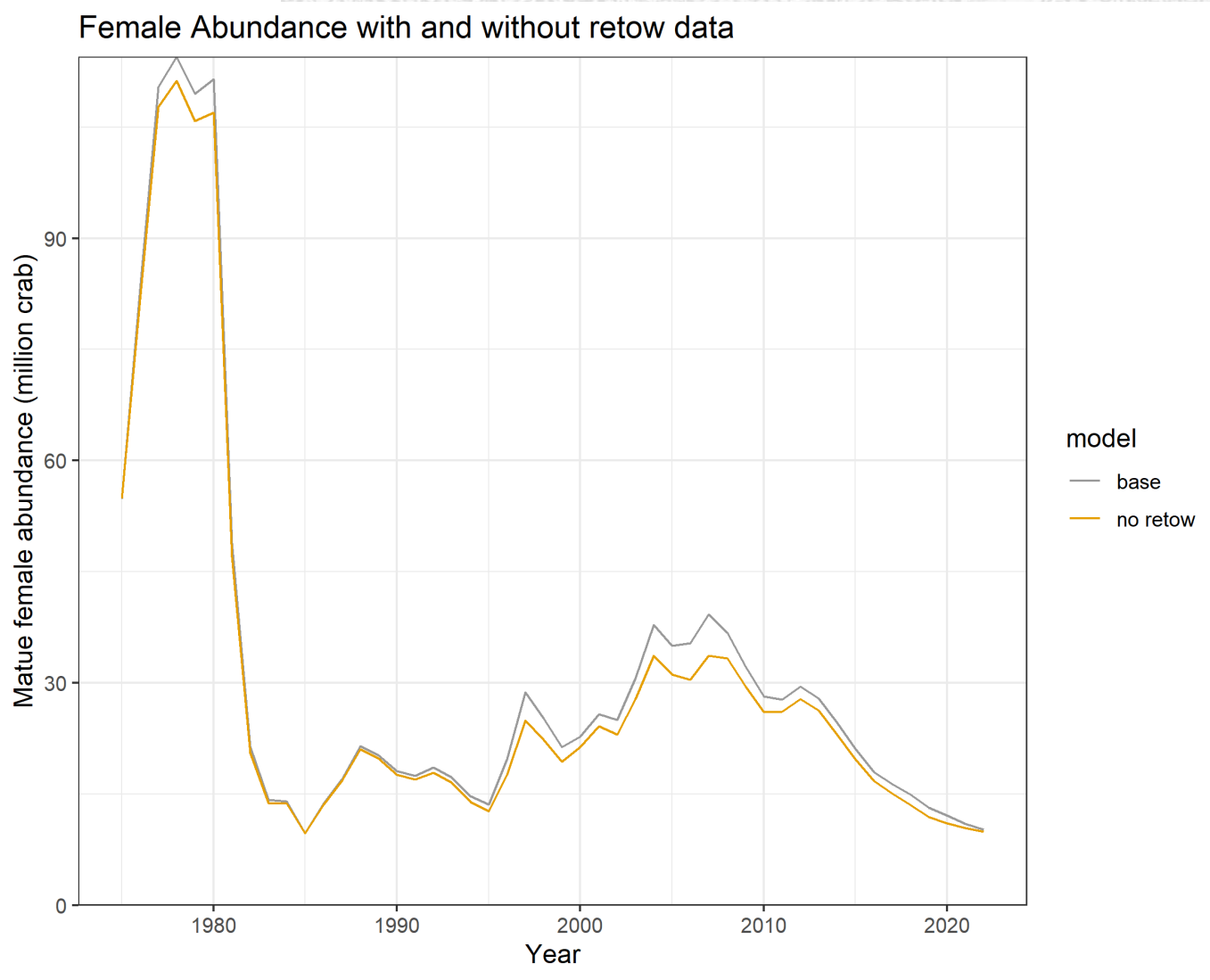



Gear = NMFS Trawl , Sex = Female , Season = 1
1975 1976 1977 1978 1979 1980 1981
1982 1983 1984 1985 1986 1987 1988
1989 1990 1991 1992 1993 1994 1995
1996 1997 1998 1999 2000 2001 2002
2003 2004 2005 2006 2007 2008 2009
2010 2011 2012 2013 2014 2015 2016
2017 2018 2019 2021 2022
N = 0
0.0 0.1 0.2
87.5 112.5 137.5 162.5
Proportion
Mid-point of size-class (mm)
Model
21.1b (2022-update)
no retow

Recruitment – model 23.2




Model scenarios
120000
90000
60000
30000
0
Mature male biomass (t) on 15th February
1980
1990
2000
2010
2020
Year


Female Abundance with and without retow data
90
60
30
0
Matue female abundance (million crab)
1980
1990
2000
2010
2020
Year
model
base
no retow

Model 23.2: Female re-tow

- Continuation of re-tow for females vital in years where large number of females are delayed in the molt-mate cycle
- Sampling females at the same point in their annual cycle is vital to the assumptions of the population dynamics and therefore the population model
- Did not address the current 10% threshold here or the influence on the State of Alaska harvest strategy

2023 Model explorations

21.1b: the base model from September 2022.

21.1b(update): model 21.1b + using the **recently updated version of GMACS** (version).

22.0: model 21.1b (update) + starting in 1985.

23.0: model 21.1b (update) + fixing M = 0.257 for males (Then et al. 2015).

23.0a: model 21.1b (update) + +estimating a constant *M* for males.

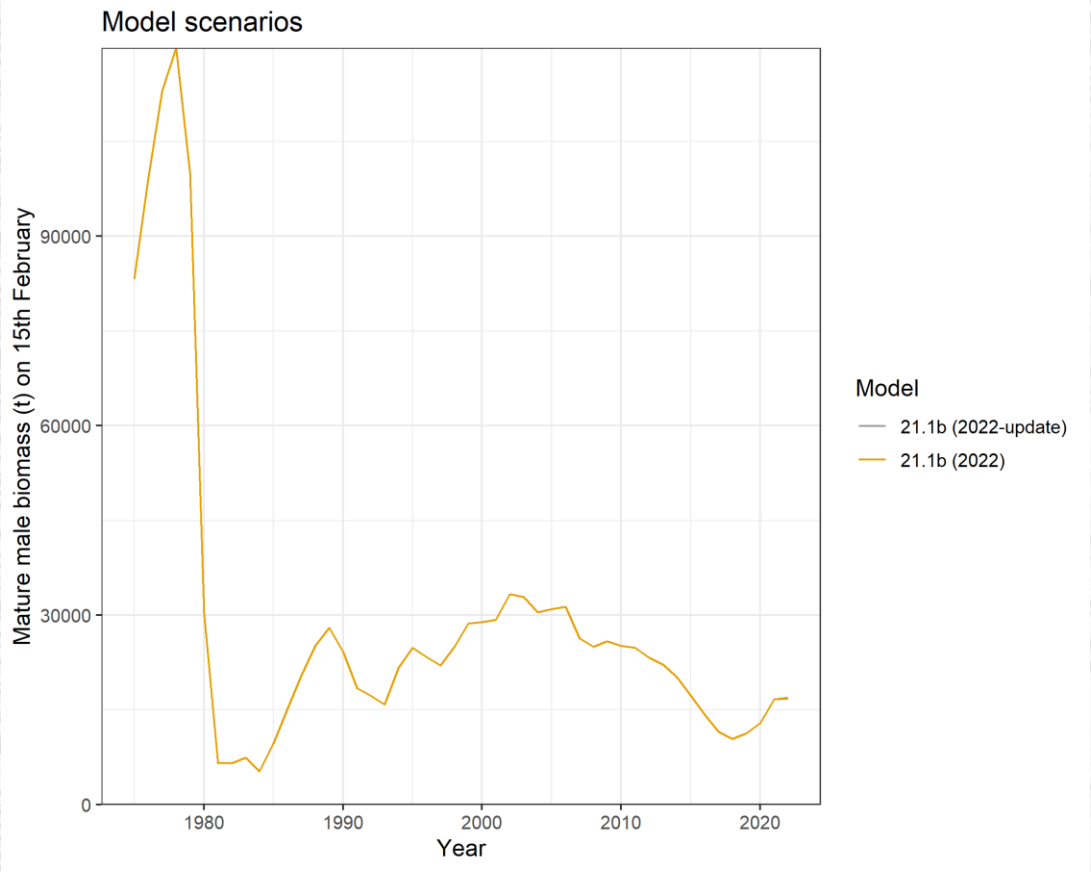
23.0b: model 21.1b (update) + fixing M = 0.31 for males from previous likelihood profile work (2020 & 2021)

23.1a: model 21.1b (update) + increased CV for *Q* prior for NMFS trawl.

23.3: model 23.1a + 23.0a (increased CV on *Q* estimating M)

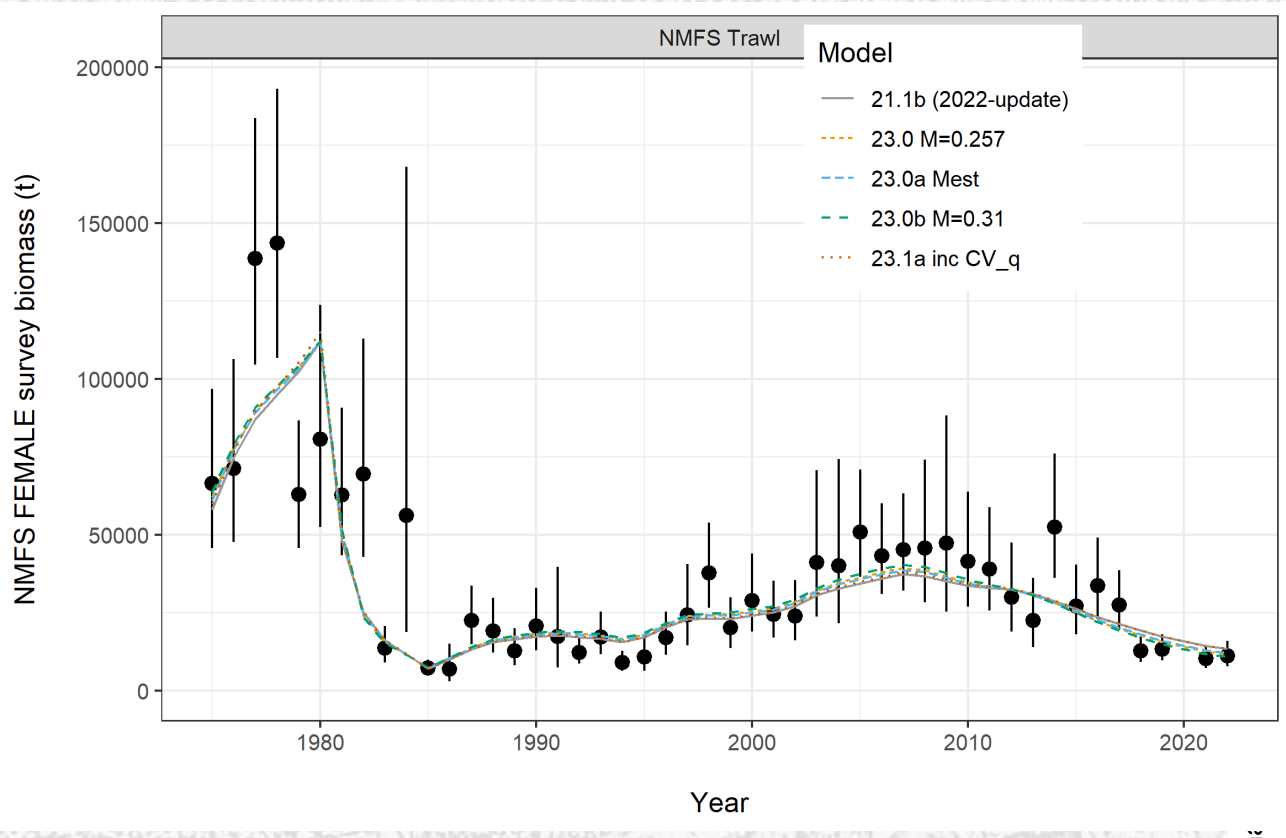
23.2: model 21.1b (update) – removing "retow" data for females in years they were resampled

GMACS updates

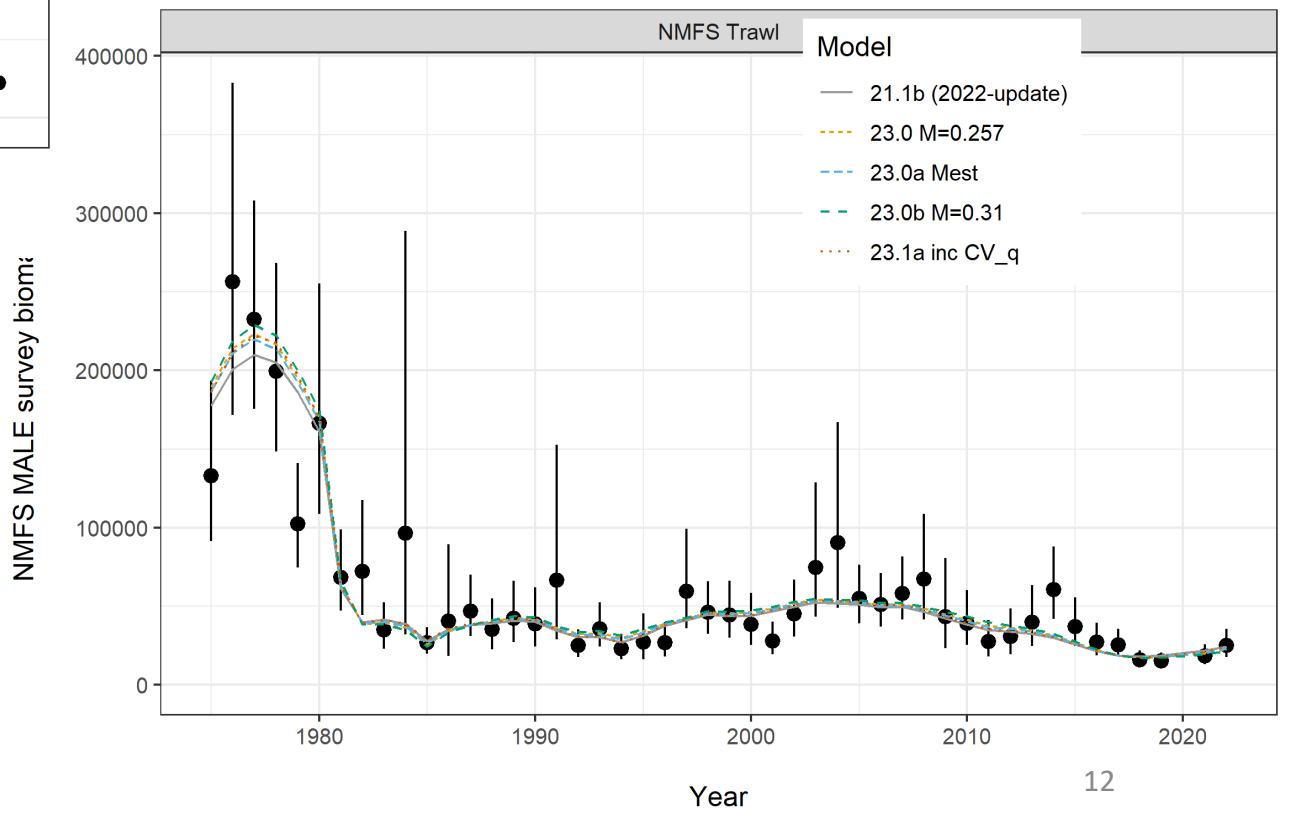


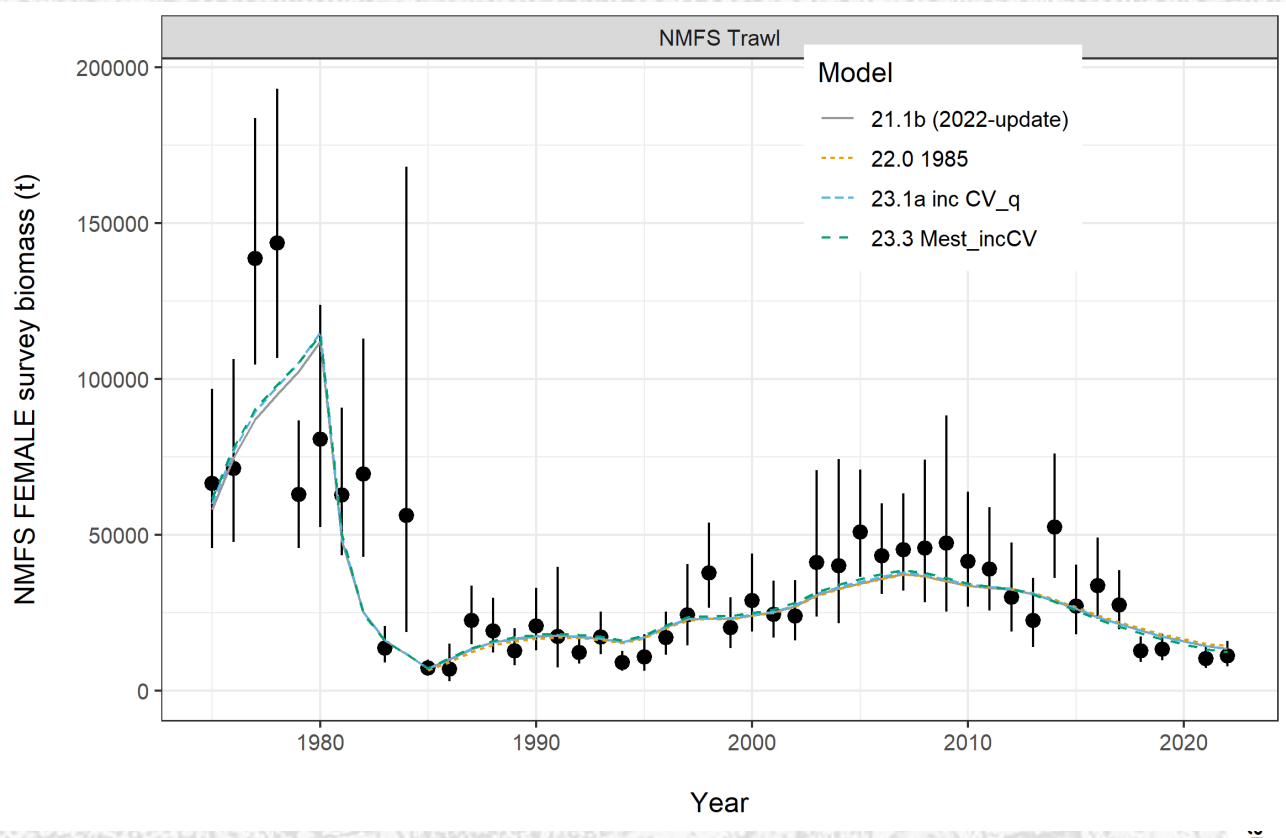
- Likelihoods identical (2 decimal places)
- Small differences in projected specifications – likely due to projection iterations

Model	Current MMB	$B_{35\%}$	MMB $/B_{MSY}$	$F_{35\%}$	F_{OFL}	OFL
21.1b (2022)	16.95	24.03	0.71	0.30	0.20	3.04
21.1b(update)	16.76	22.25	0.75	0.30	0.22	3.21

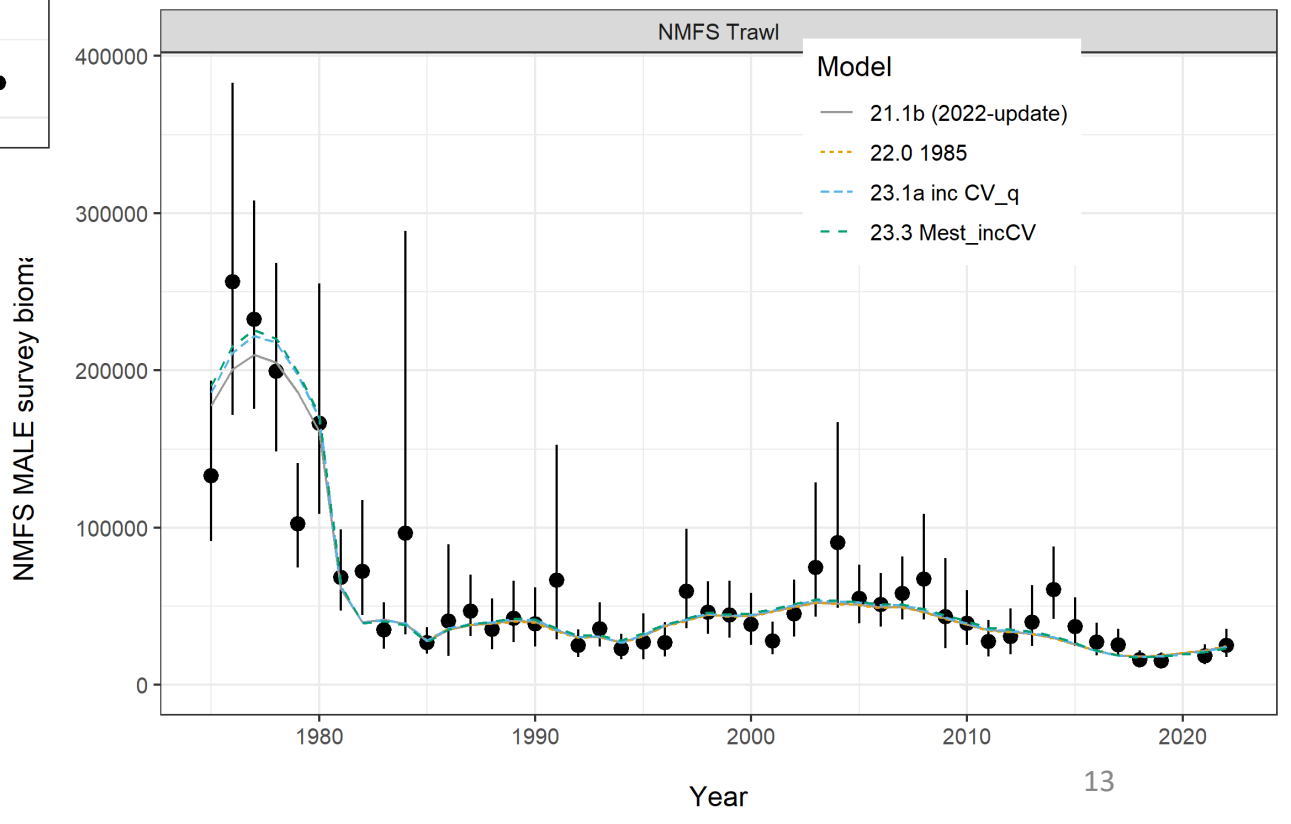


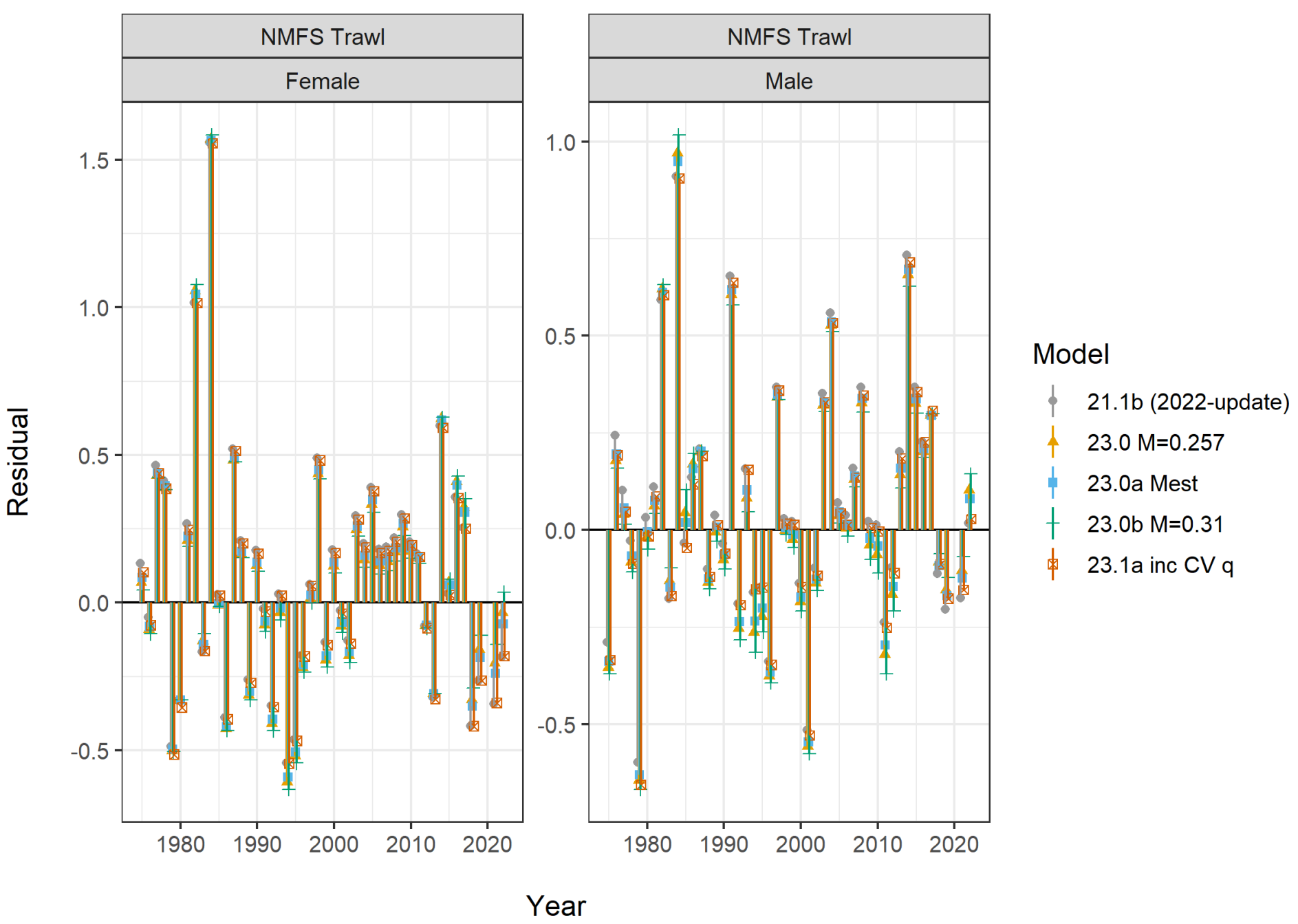
- Model fits to NMFS trawl survey data are similar.



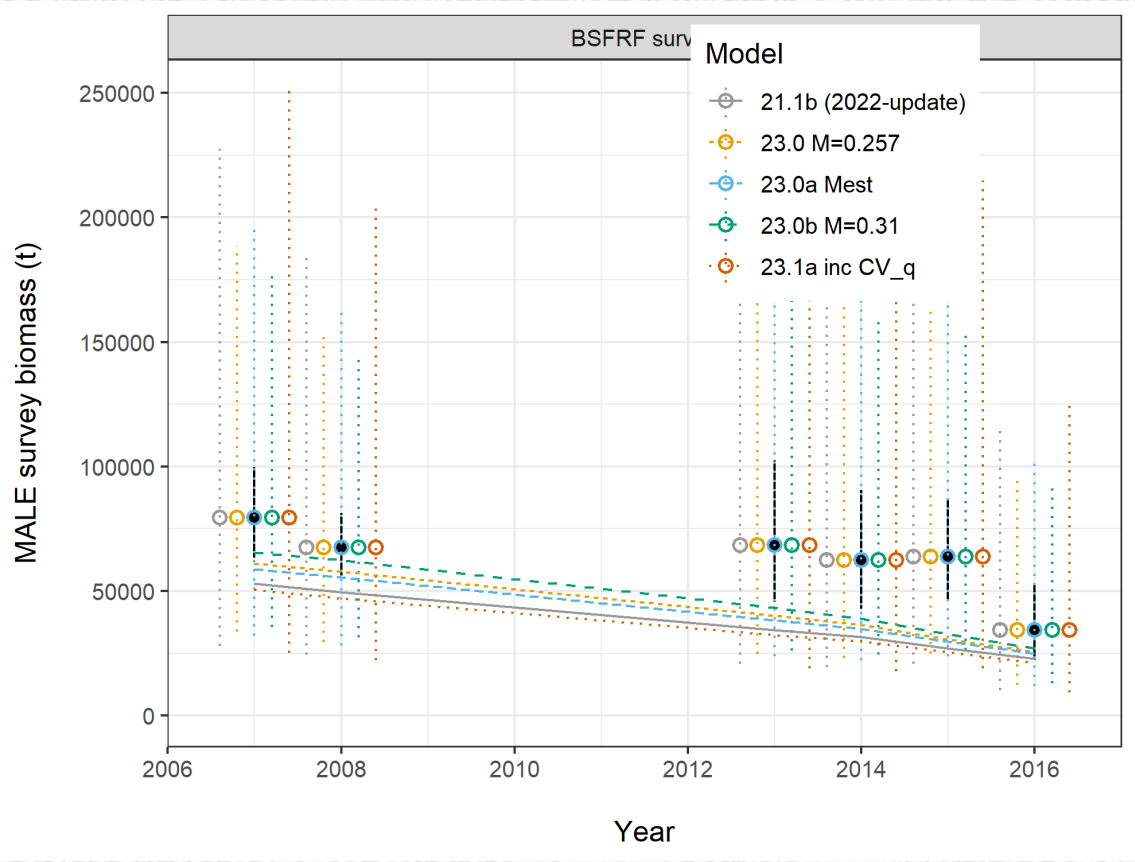


- Model fits to NMFS trawl survey data for models with change in CV on prior for Q.

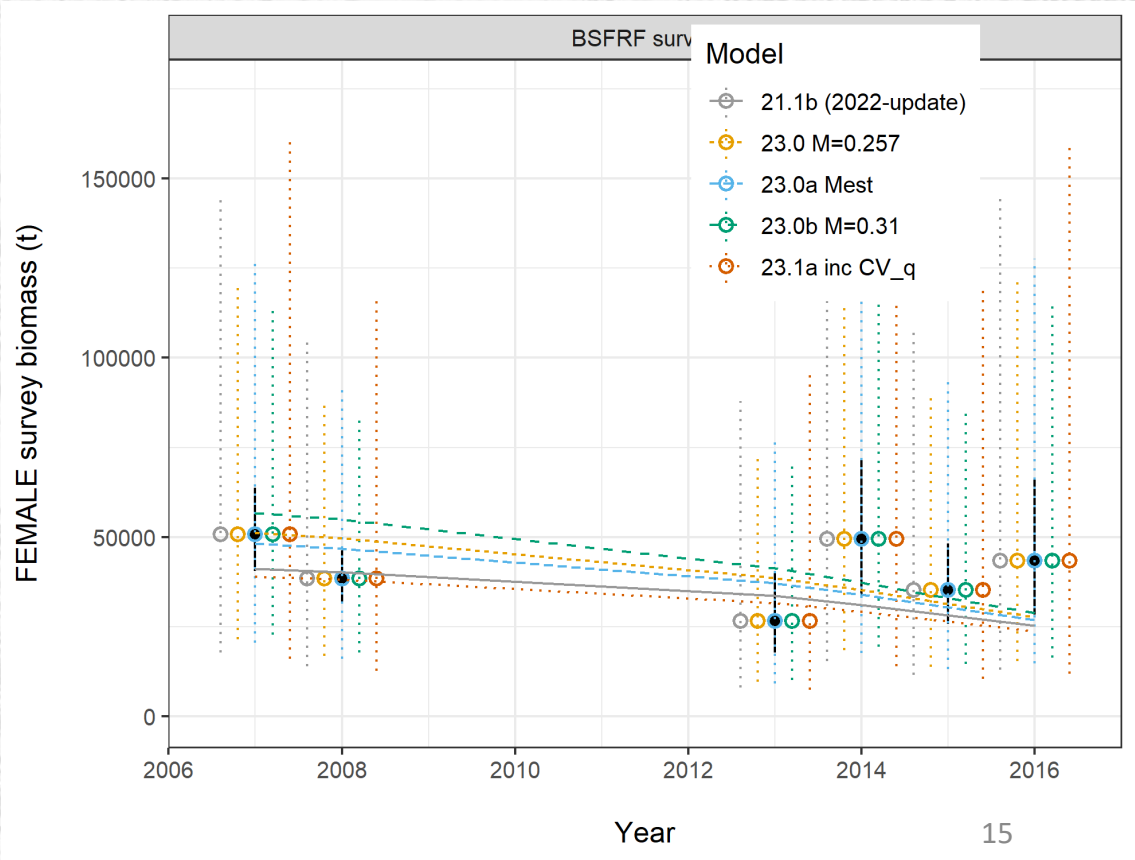




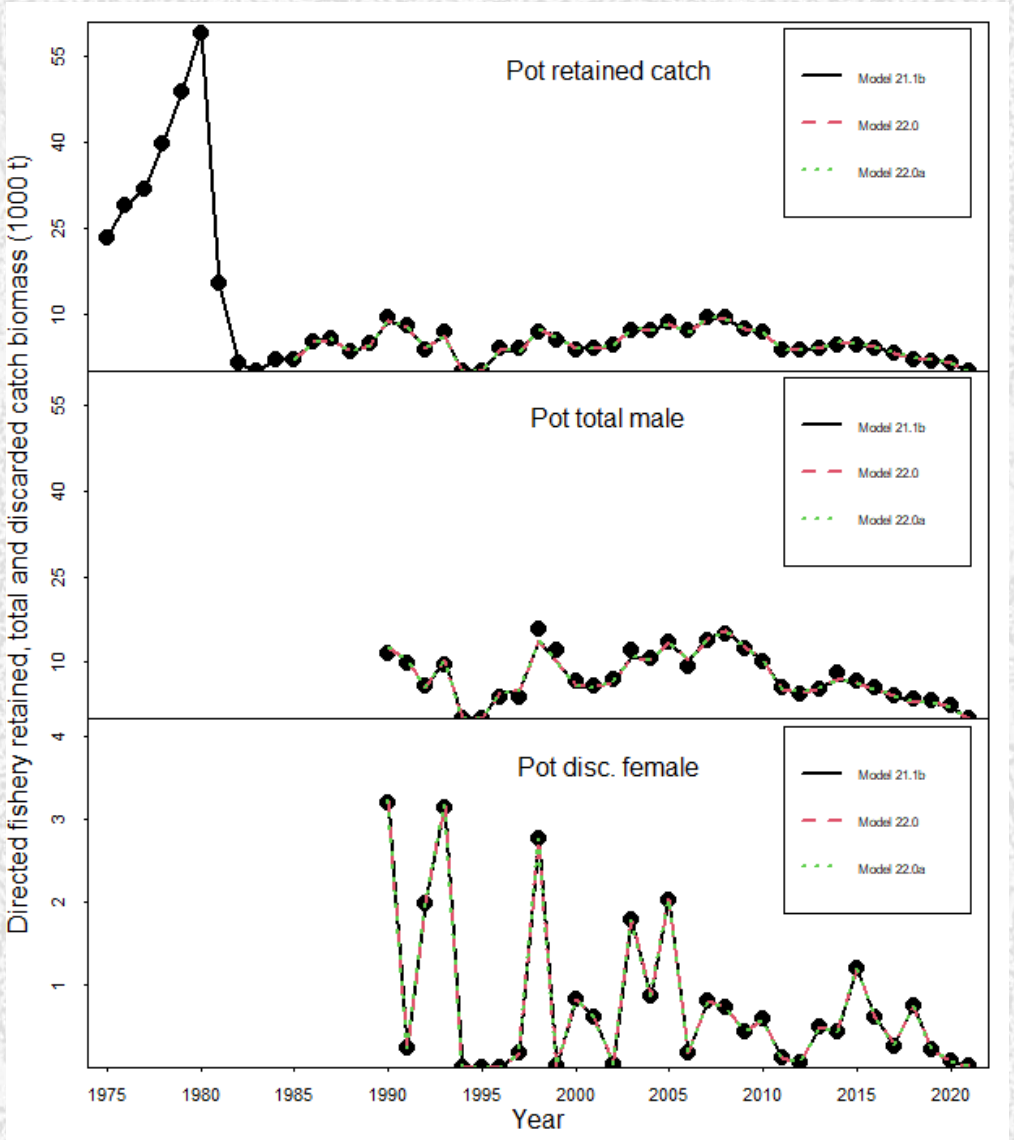
Residuals of total NMFS survey biomass

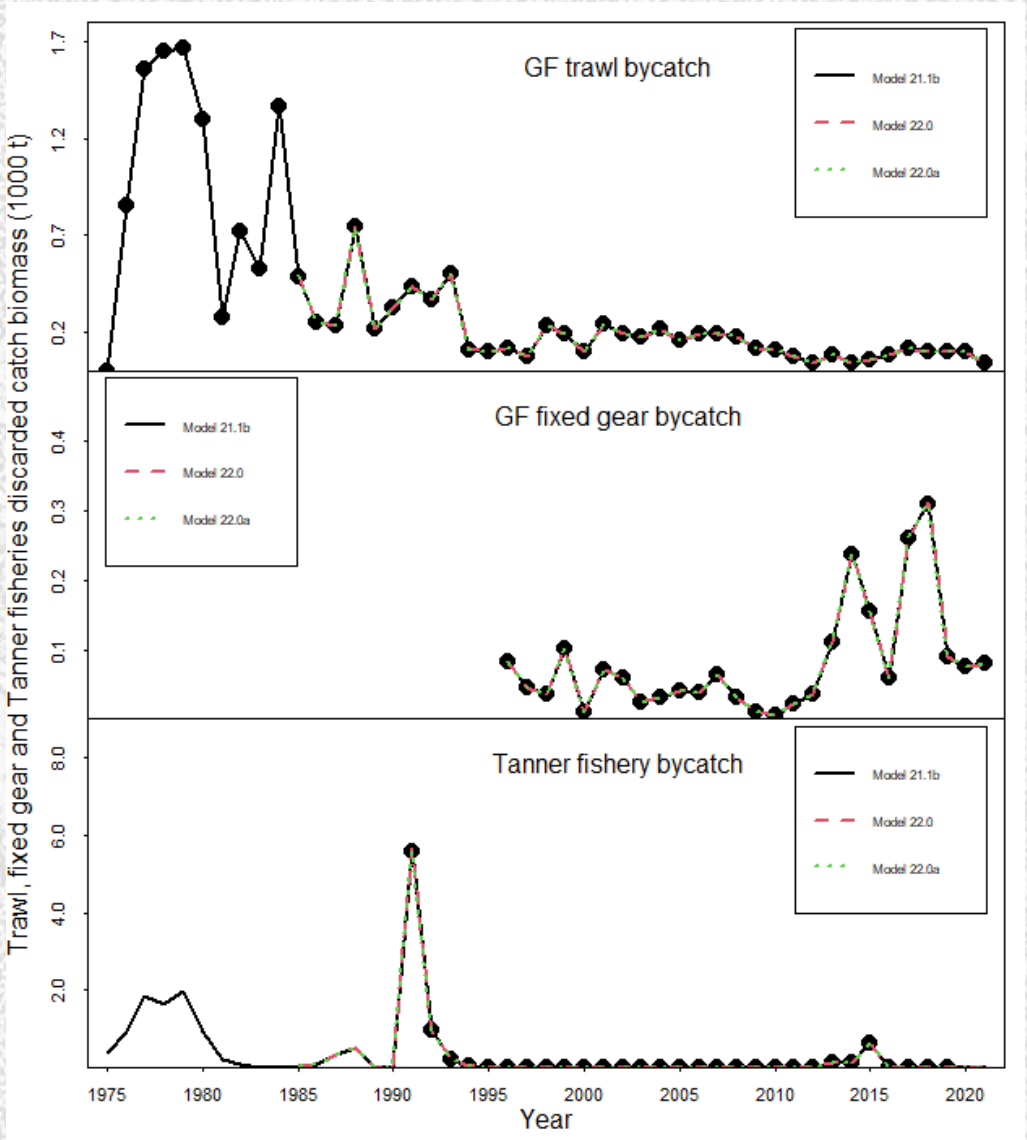


- Error bars show additional error
- BSFRF survey catchability is assumed to be 1.0
- Similar fits

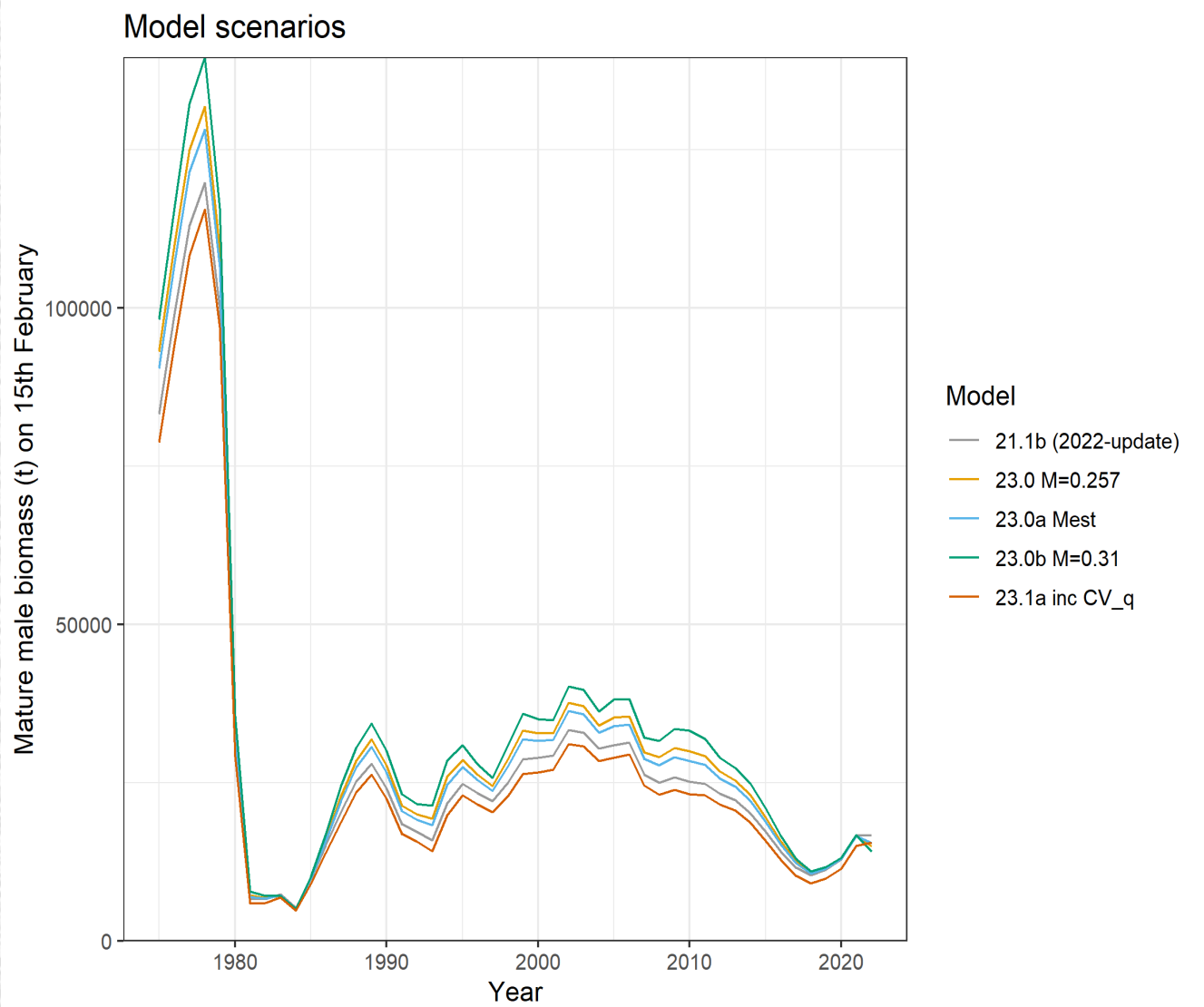


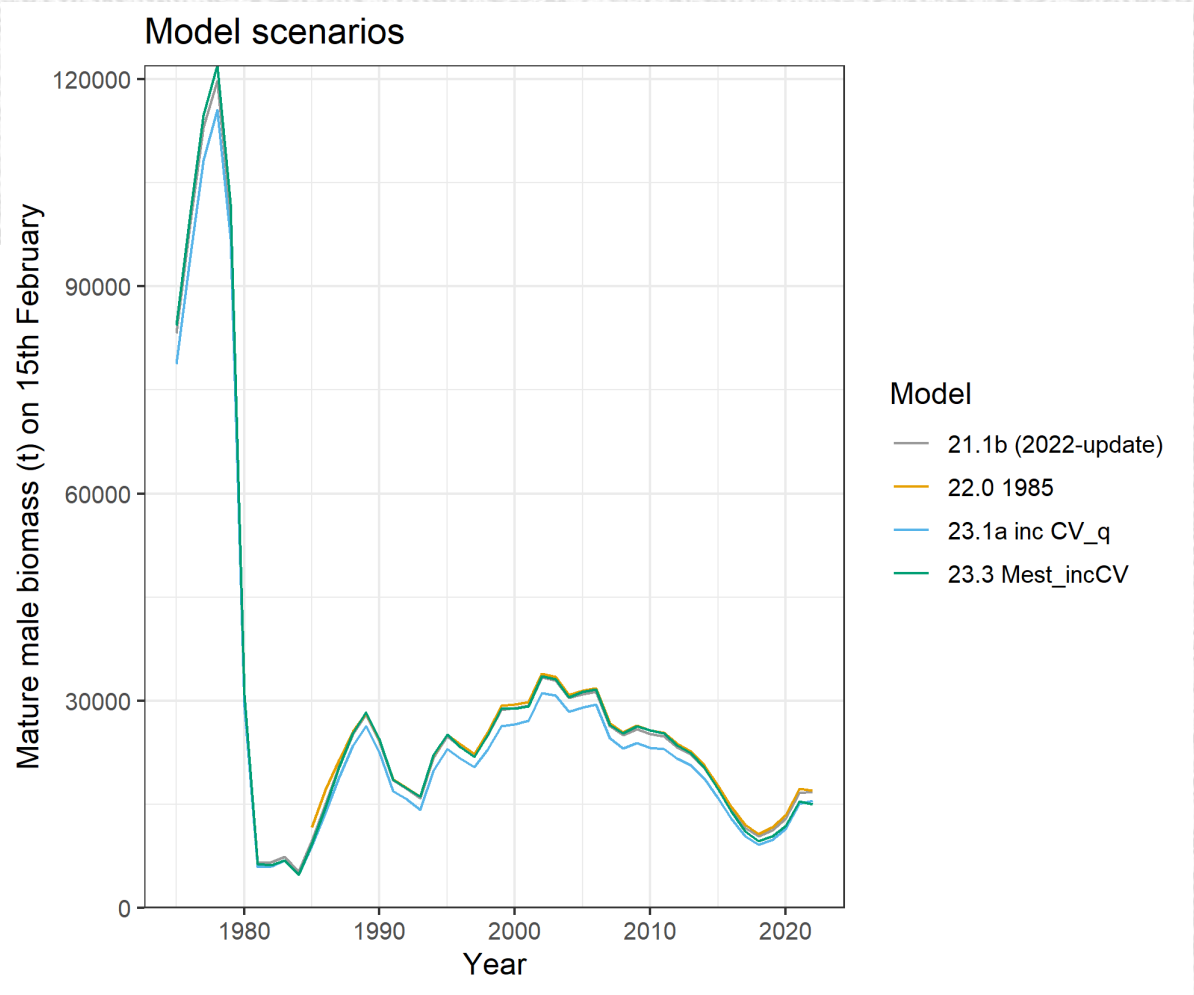
Mortality biomass (equal to catch biomass times handling mortality rate)



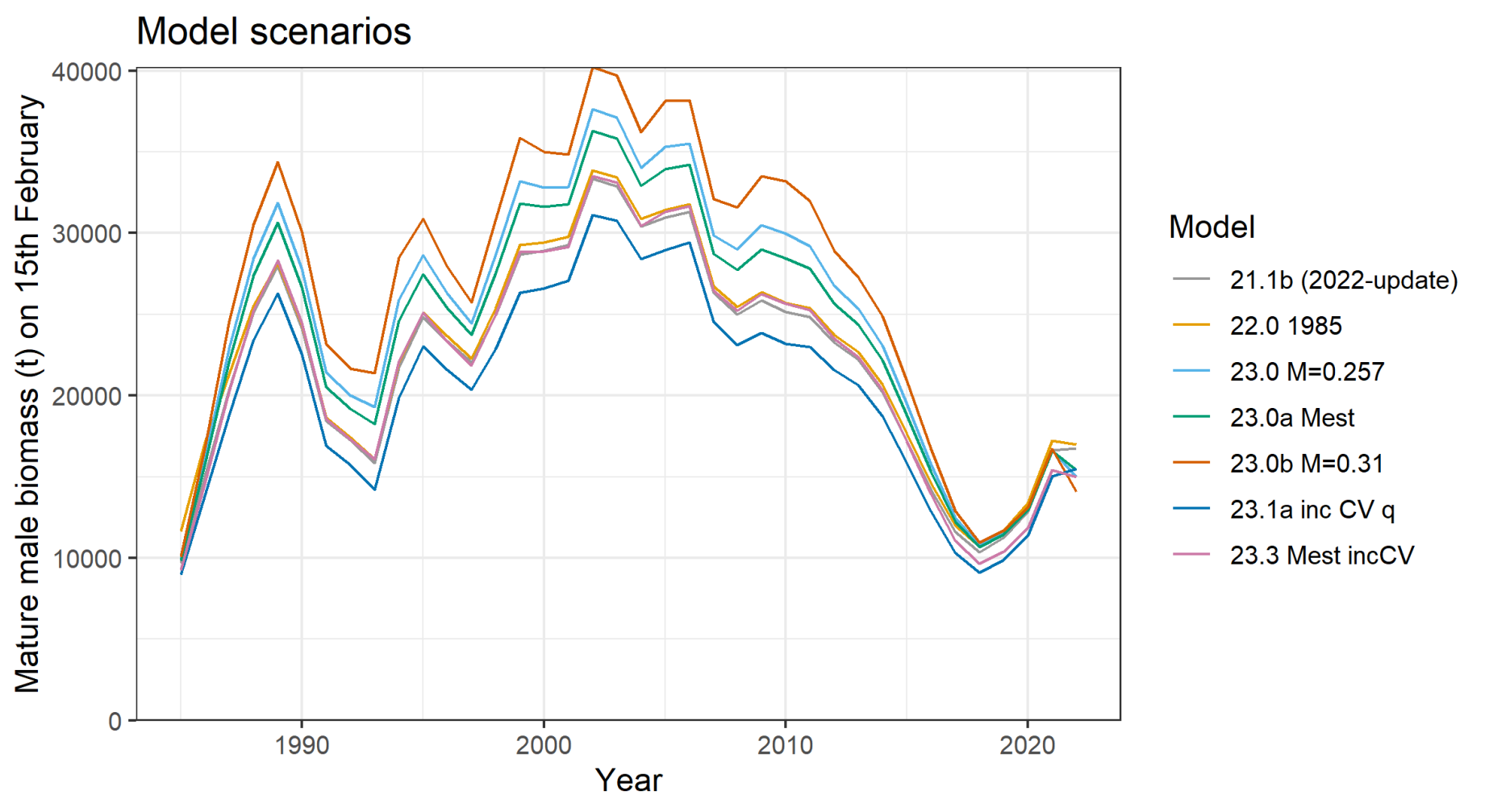


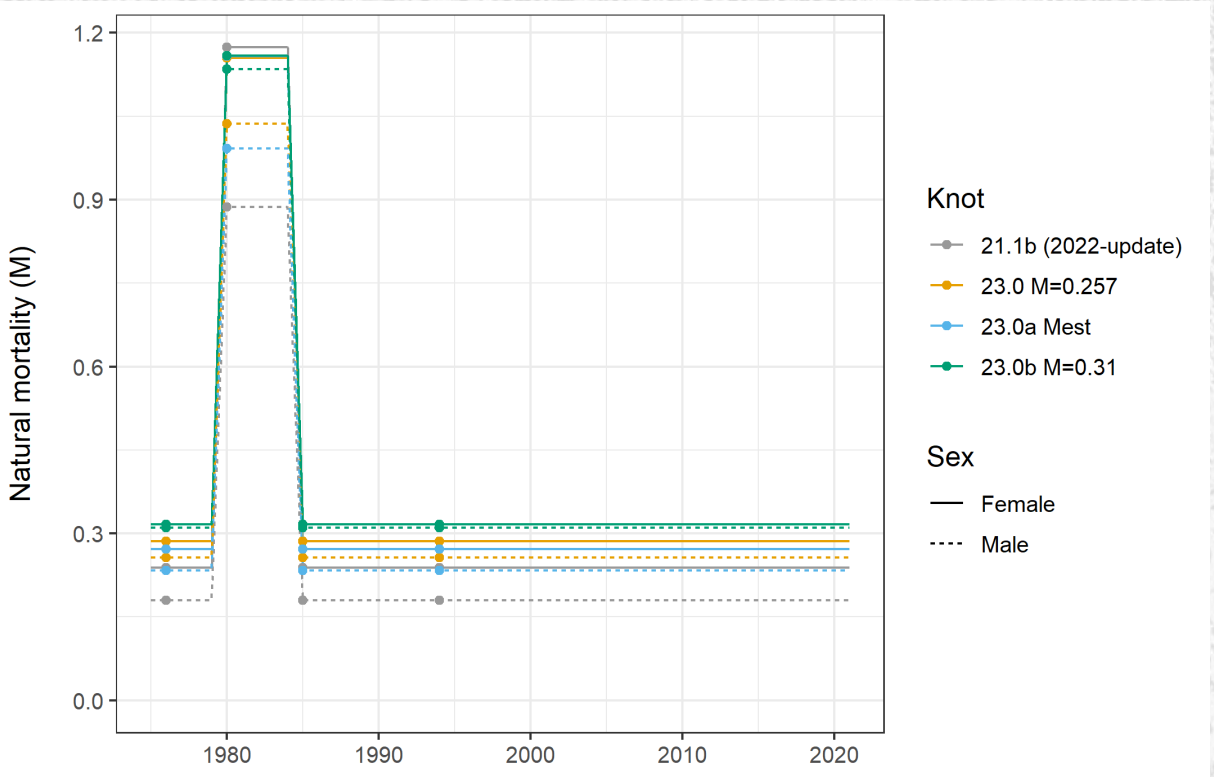
Mature male biomass





Mature male biomass – from 1985 +





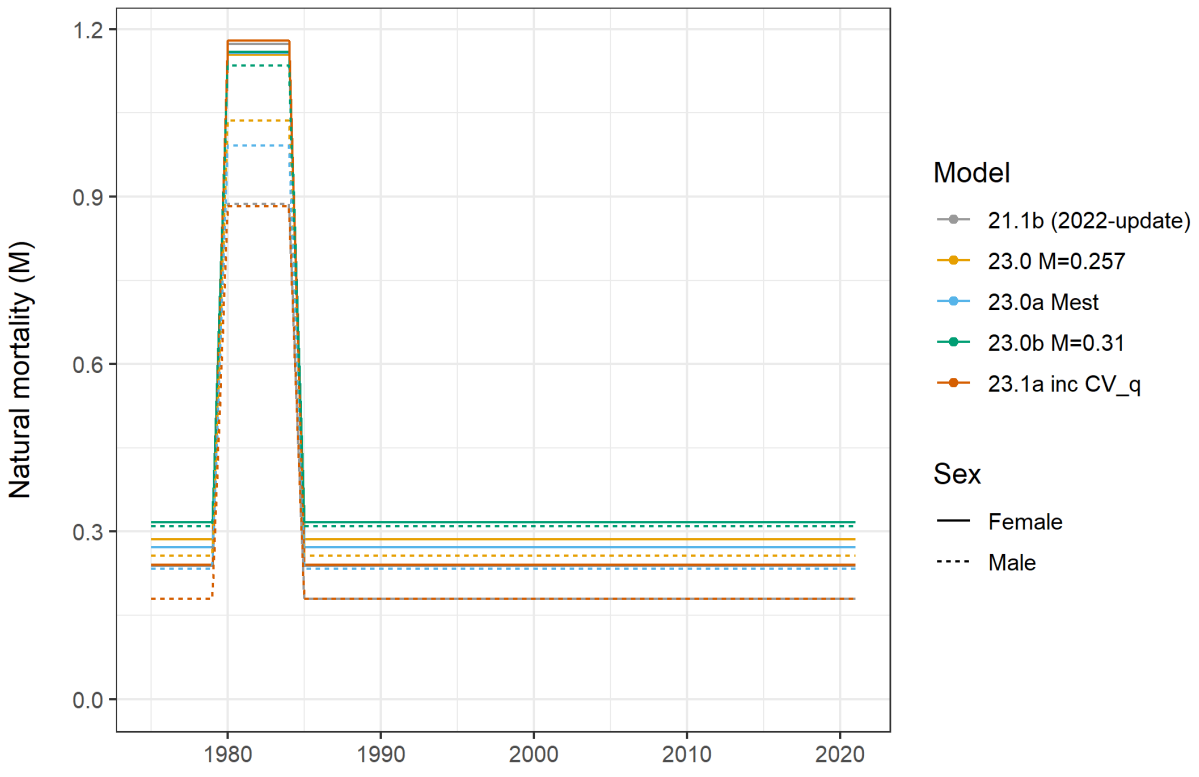
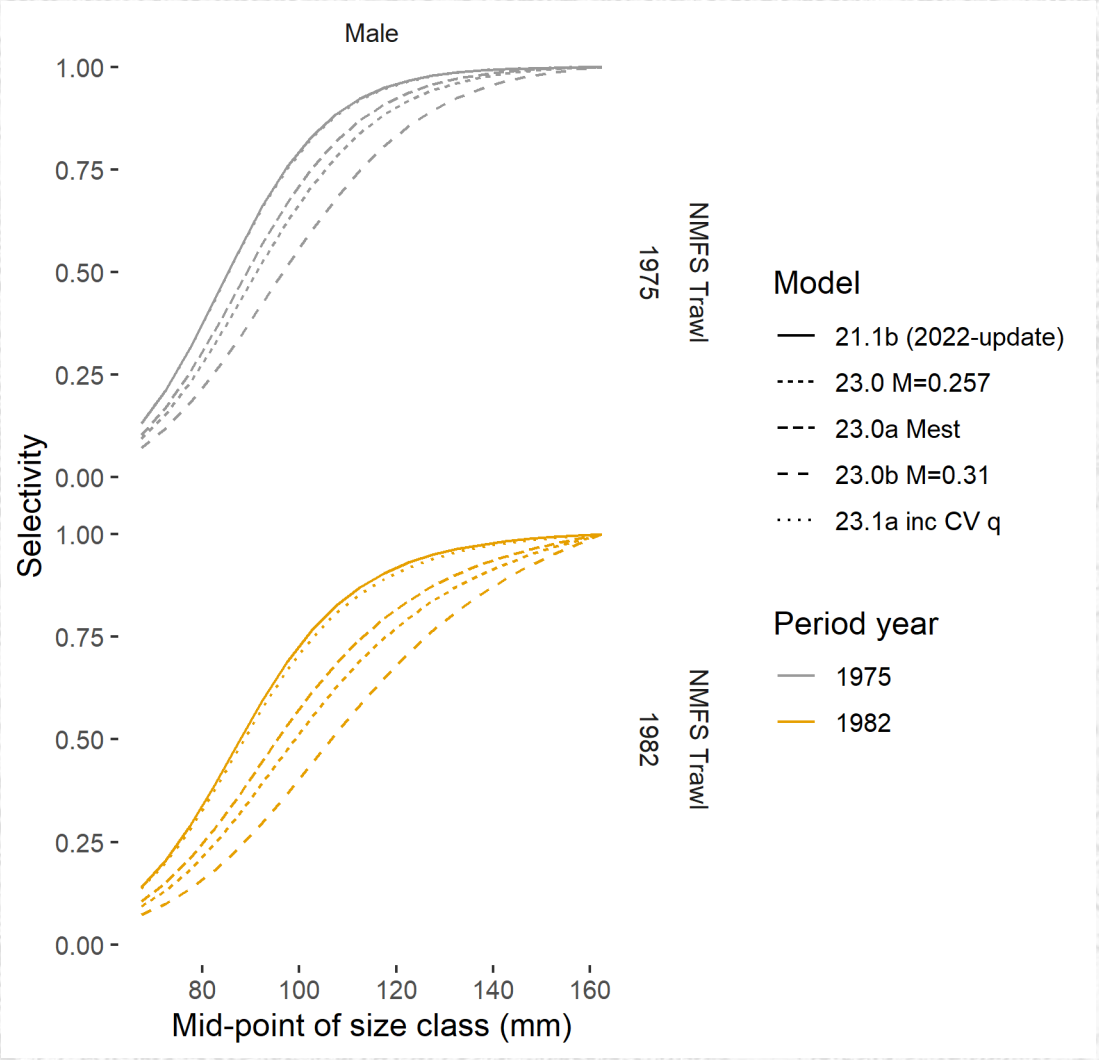
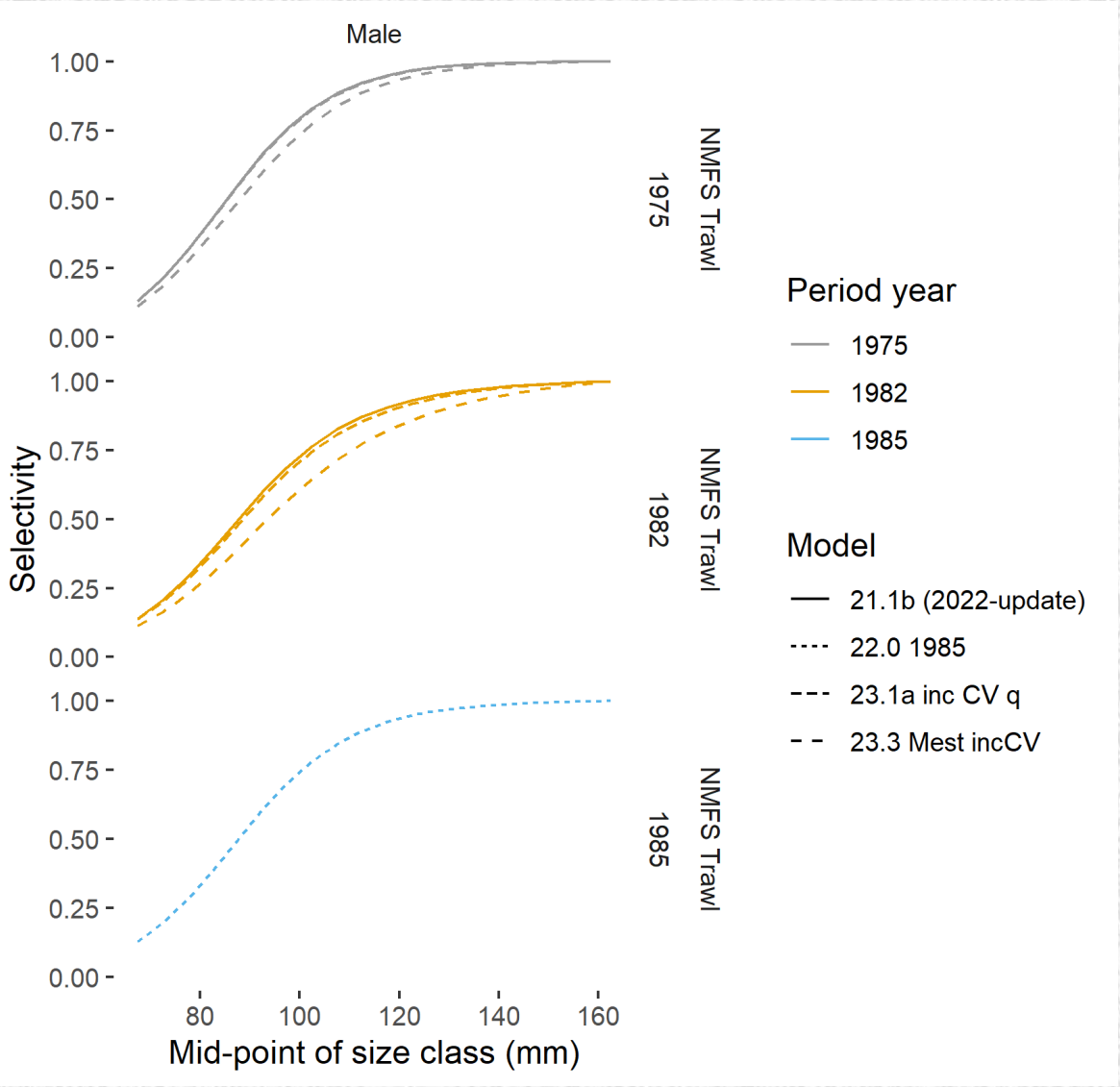


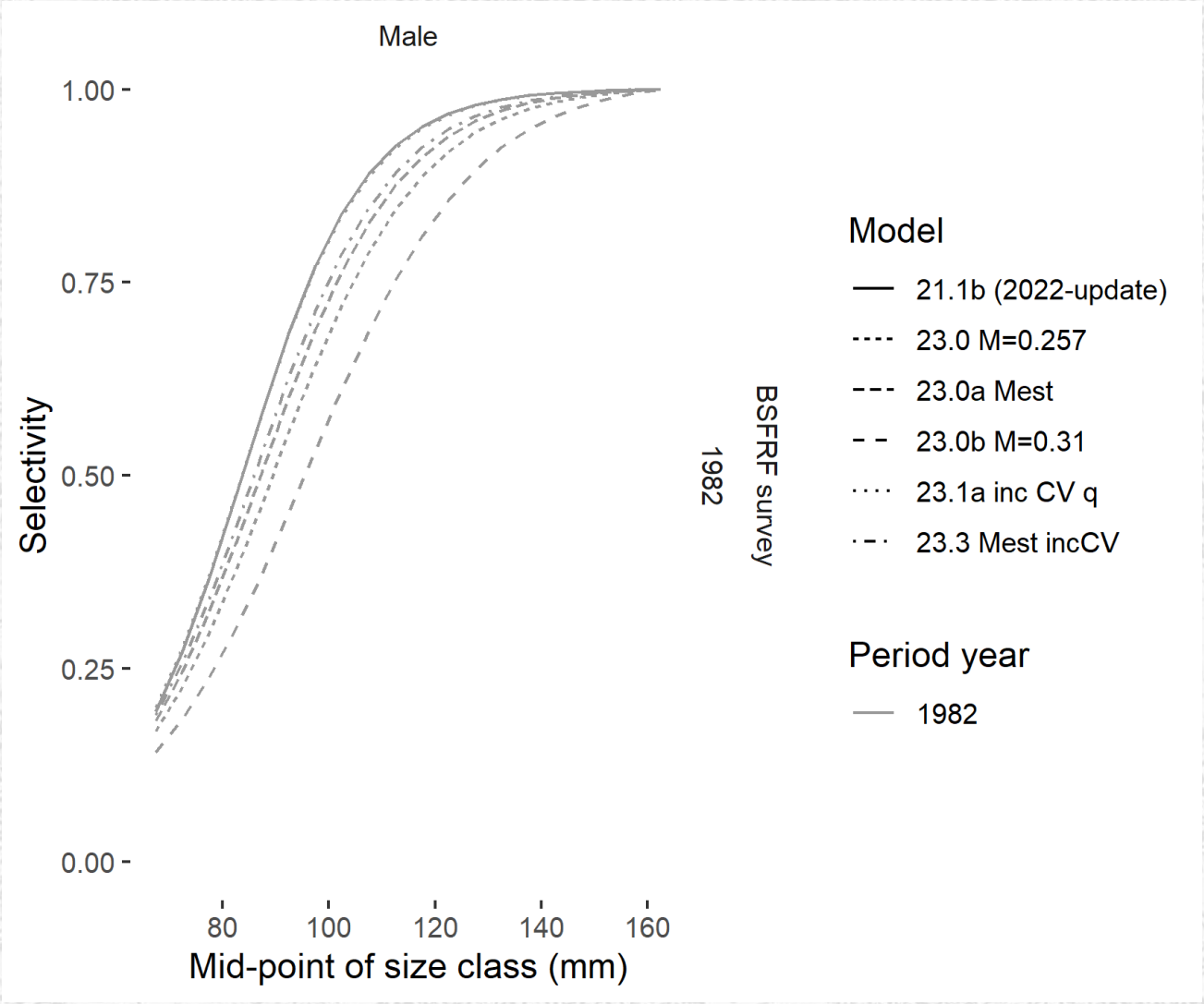
Table 3: Natural mortality estimates for model scenarios during different year blocks.

Model	Sex	baseM	1980-84	1985-22
21.1b (2022-update)	Female	0.24	1.17	
21.1b (2022-update)	Male	0.18	0.89	
22.0 1985	Female			0.23
22.0 1985	Male			0.18
23.0 M=0.257	Female	0.29	1.15	
23.0 M=0.257	Male	0.26	1.04	
23.0a Mest	Female	0.27	1.16	
23.0a Mest	Male	0.23	0.99	
23.0b M=0.31	Female	0.32	1.16	
23.0b M=0.31	Male	0.31	1.13	
23.1a inc CV q	Female	0.24	1.18	
23.1a inc CV q	Male	0.18	0.88	
23.3 Mest incCV	Female	0.26	1.17	
23.3 Mest incCV	Male	0.22	0.96	



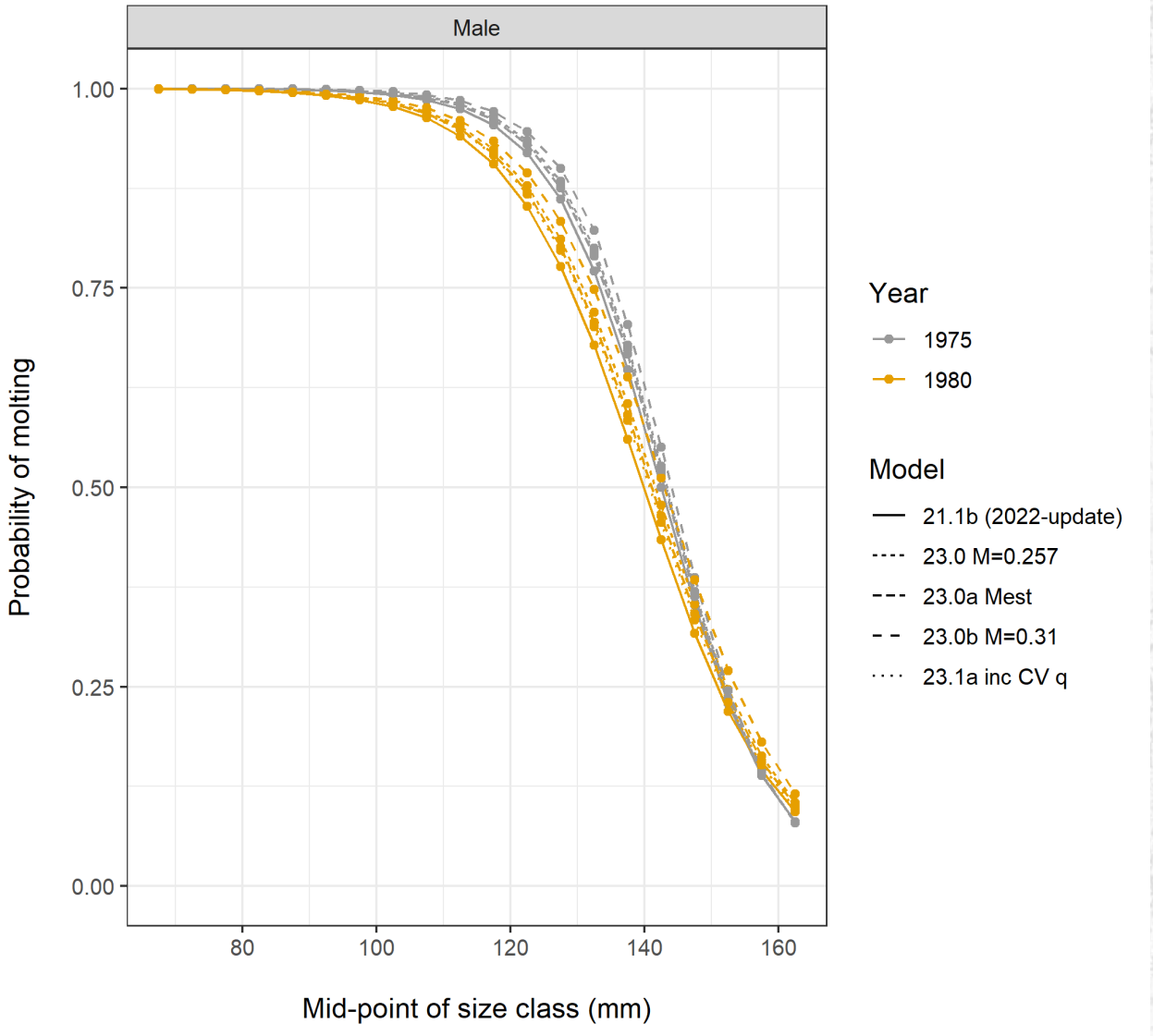


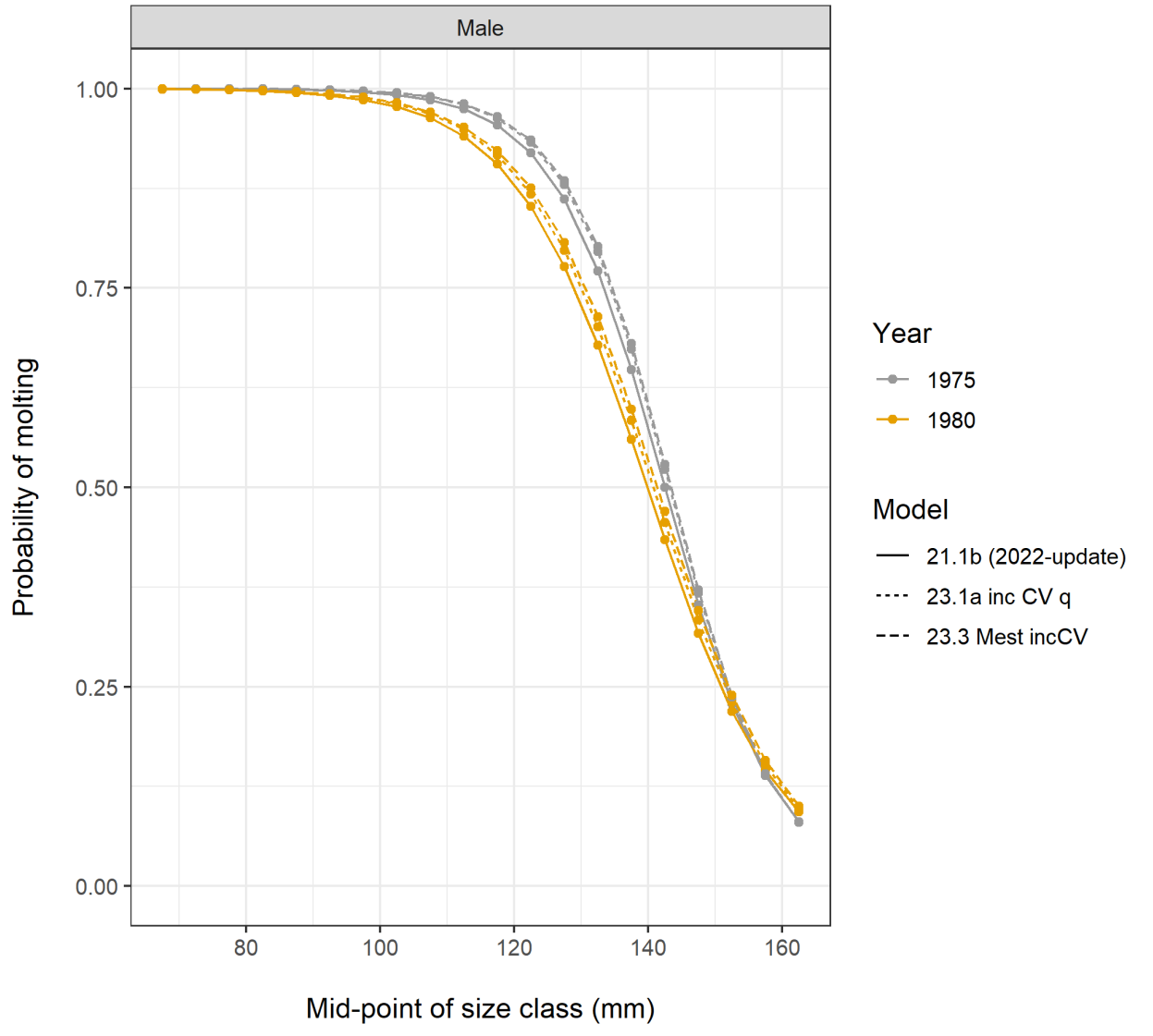
NMFS trawl survey selectivity:
- largest differences in high M



BSFRF survey selectivity - Changes with increased M on males

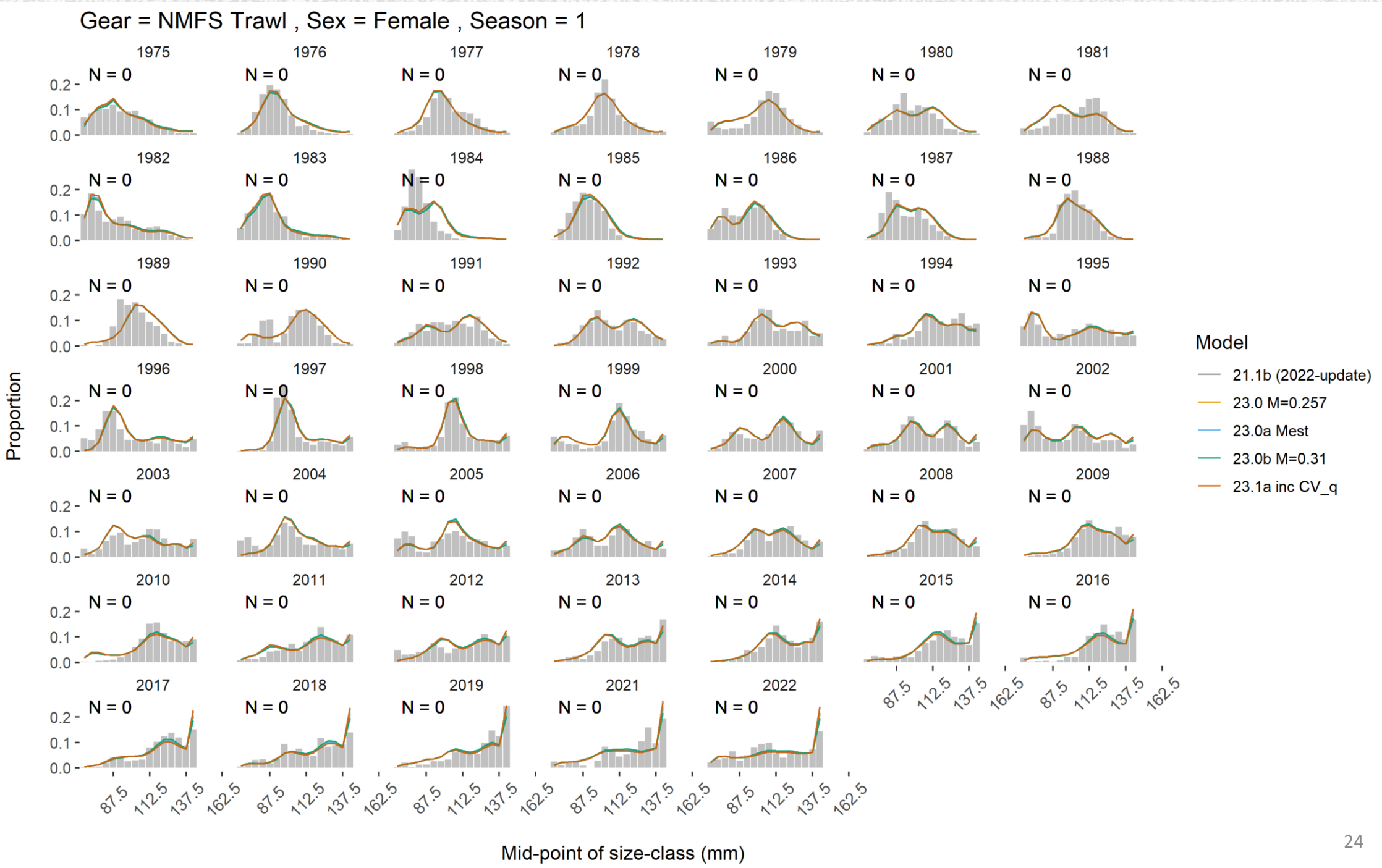
Molting probabilities

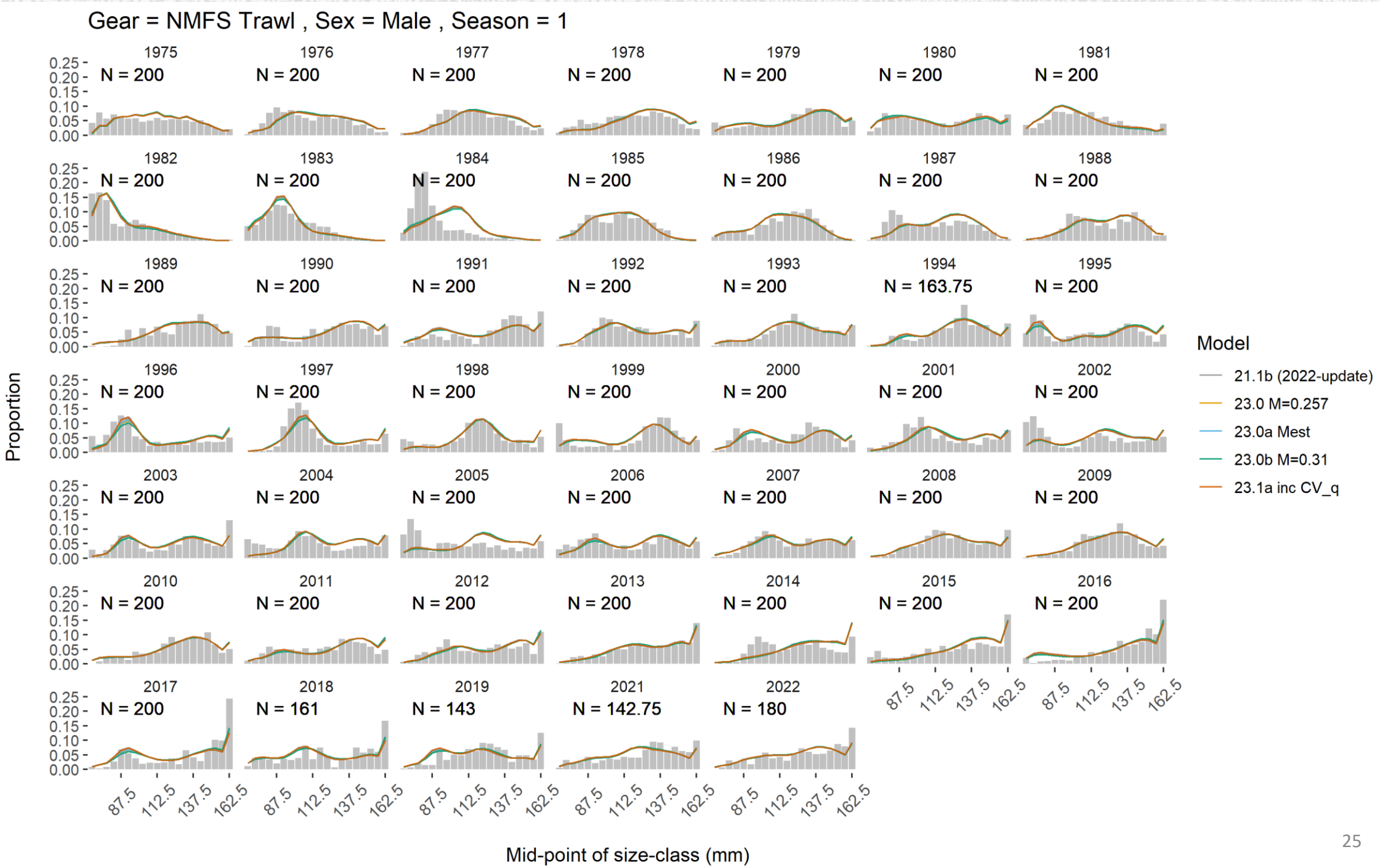


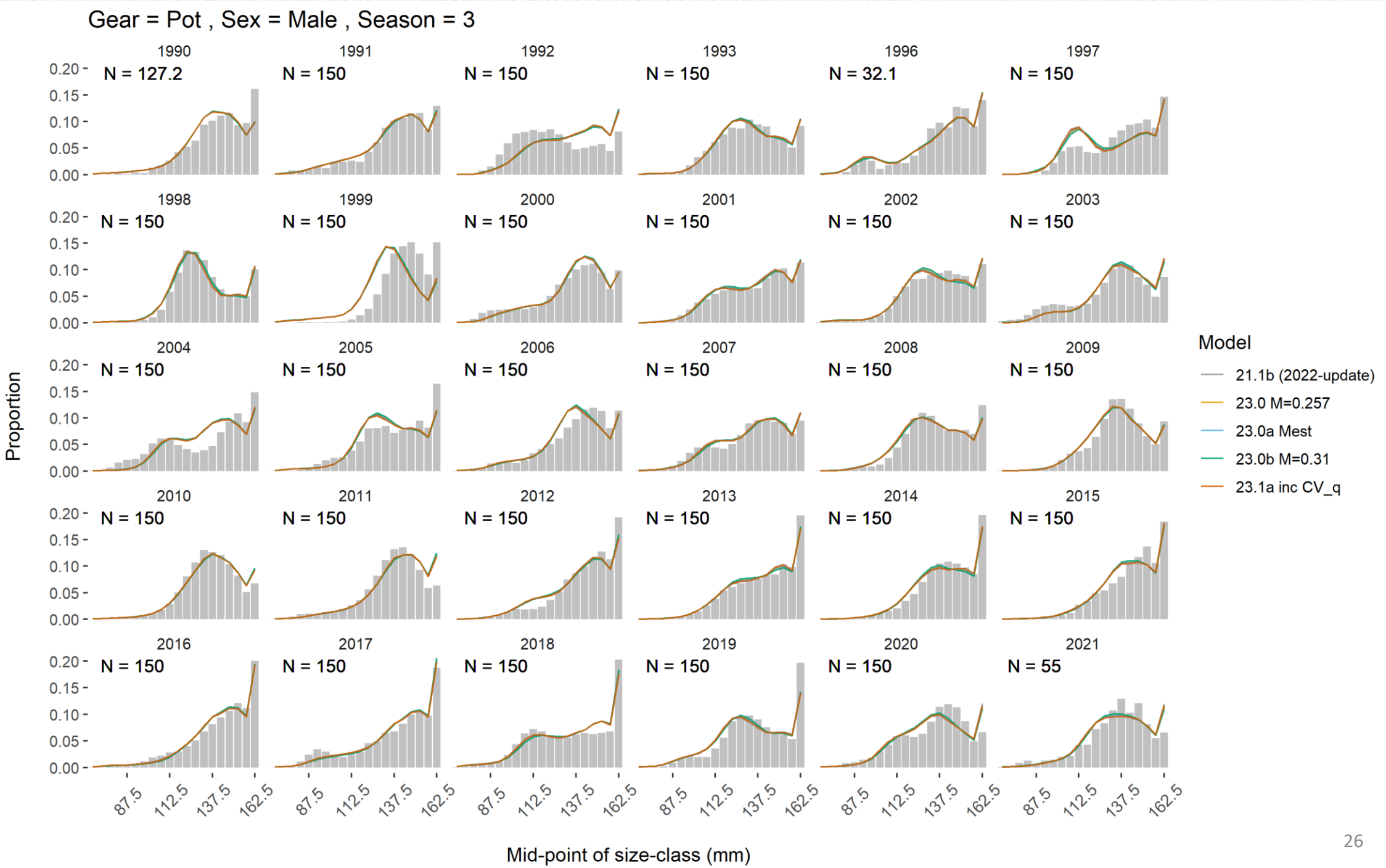


Size composition fit

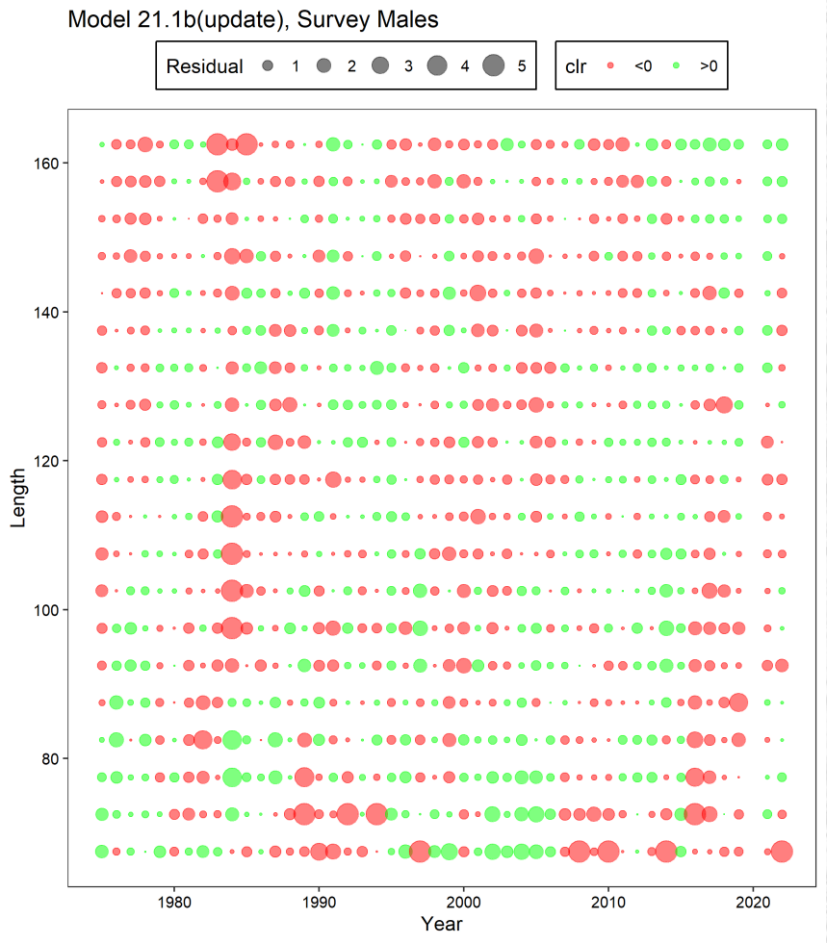
- Similar for all models
- Models with higher M values fit NMFS size comps slightly better at higher sizes

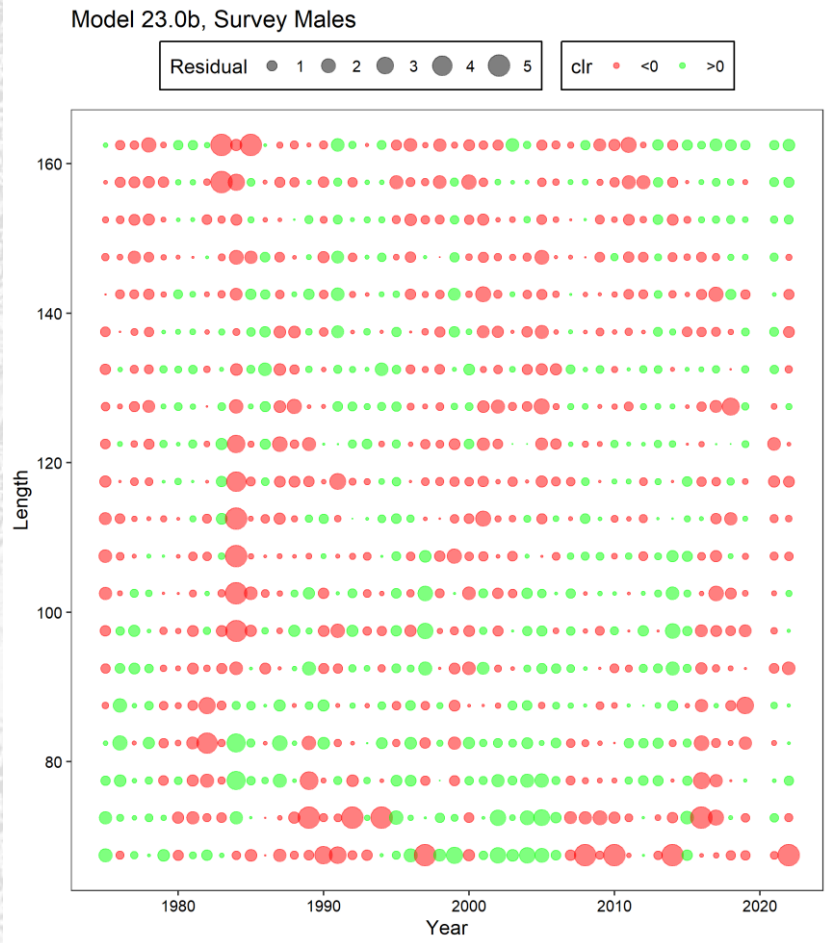

Gear = NMFS Trawl , Sex = Female , Season = 1
1975 1976 1977 1978 1979 1980 1981
1982 1983 1984 1985 1986 1987 1988
1989 1990 1991 1992 1993 1994 1995
1996 1997 1998 1999 2000 2001 2002
2003 2004 2005 2006 2007 2008 2009
2010 2011 2012 2013 2014 2015 2016
2017 2018 2019 2021 2022
N = 0
0.0 0.1 0.2
87.5 112.5 137.5 162.5
Proportion
Mid-point of size-class (mm)
Model
21.1b (2022-update)
23.0 M=0.257
23.0a Mest
23.0b M=0.31
23.1a inc CV_q

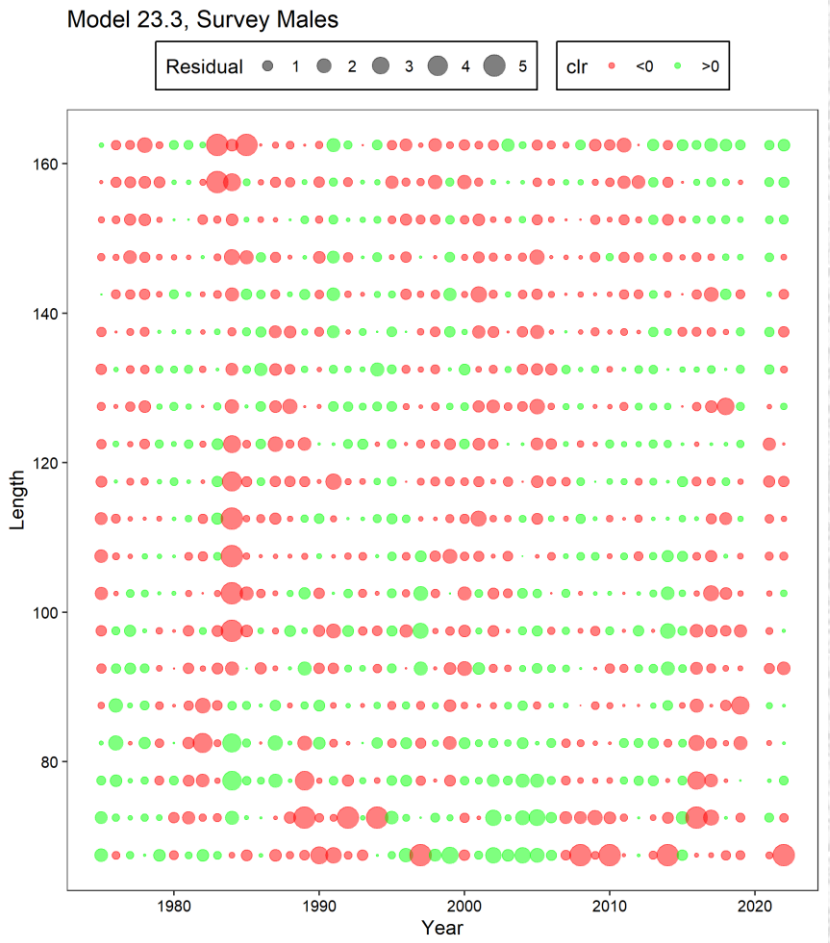

Gear = NMFS Trawl , Sex = Male , Season = 1
1975 N = 200
1976 N = 200
1977 N = 200
1978 N = 200
1979 N = 200
1980 N = 200
1981 N = 200
1982 N = 200
1983 N = 200
1984 N = 200
1985 N = 200
1986 N = 200
1987 N = 200
1988 N = 200
1989 N = 200
1990 N = 200
1991 N = 200
1992 N = 200
1993 N = 200
1994 N = 163.75
1995 N = 200
1996 N = 200
1997 N = 200
1998 N = 200
1999 N = 200
2000 N = 200
2001 N = 200
2002 N = 200
2003 N = 200
2004 N = 200
2005 N = 200
2006 N = 200
2007 N = 200
2008 N = 200
2009 N = 200
2010 N = 200
2011 N = 200
2012 N = 200
2013 N = 200
2014 N = 200
2015 N = 200
2016 N = 200
2017 N = 200
2018 N = 161
2019 N = 143
2021 N = 142.75
2022 N = 180
0.25
0.20
0.15
0.10
0.05
0.00
87.5
112.5
137.5
162.5
Proportion
Mid-point of size-class (mm)
Model
21.1b (2022-update)
23.0 M=0.257
23.0a Mest
23.0b M=0.31
23.1a inc CV_q


Gear = Pot , Sex = Male , Season = 3
1990 N = 127.2
1991 N = 150
1992 N = 150
1993 N = 150
1996 N = 32.1
1997 N = 150
1998 N = 150
1999 N = 150
2000 N = 150
2001 N = 150
2002 N = 150
2003 N = 150
2004 N = 150
2005 N = 150
2006 N = 150
2007 N = 150
2008 N = 150
2009 N = 150
2010 N = 150
2011 N = 150
2012 N = 150
2013 N = 150
2014 N = 150
2015 N = 150
2016 N = 150
2017 N = 150
2018 N = 150
2019 N = 150
2020 N = 150
2021 N = 55
Proportion
0.00
0.05
0.10
0.15
0.20
87.5
112.5
137.5
162.5
Mid-point of size-class (mm)
Model
21.1b (2022-update)
23.0 M=0.257
23.0a Mest
23.0b M=0.31
23.1a inc CV_q

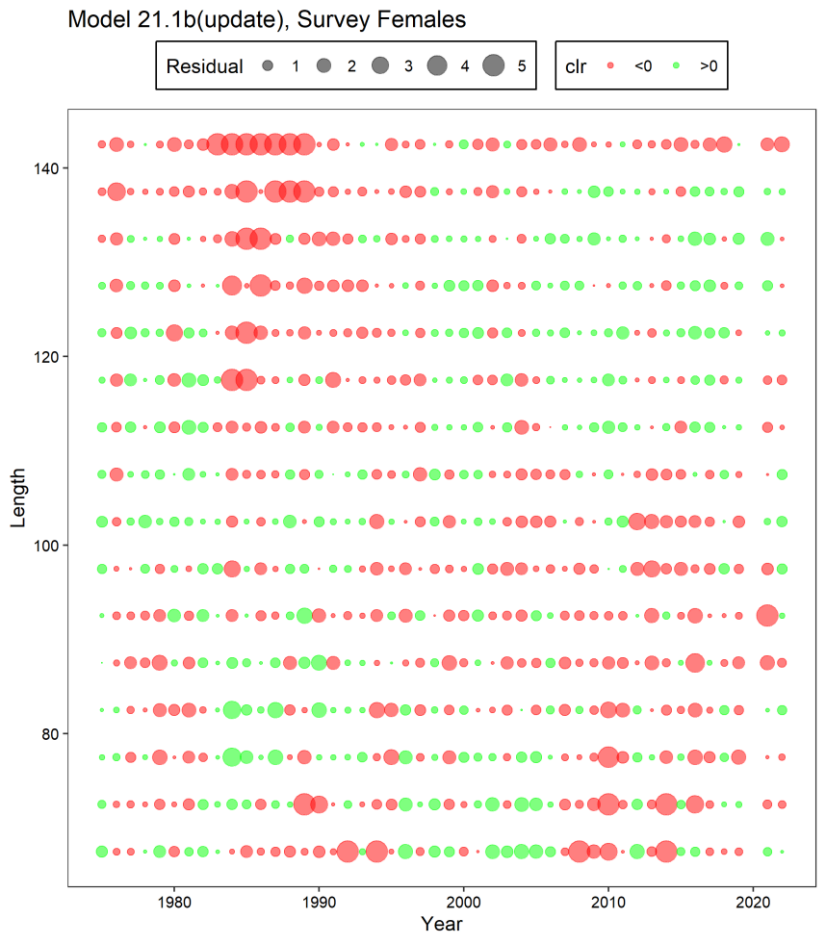
Comparison of residuals for NMFS survey males

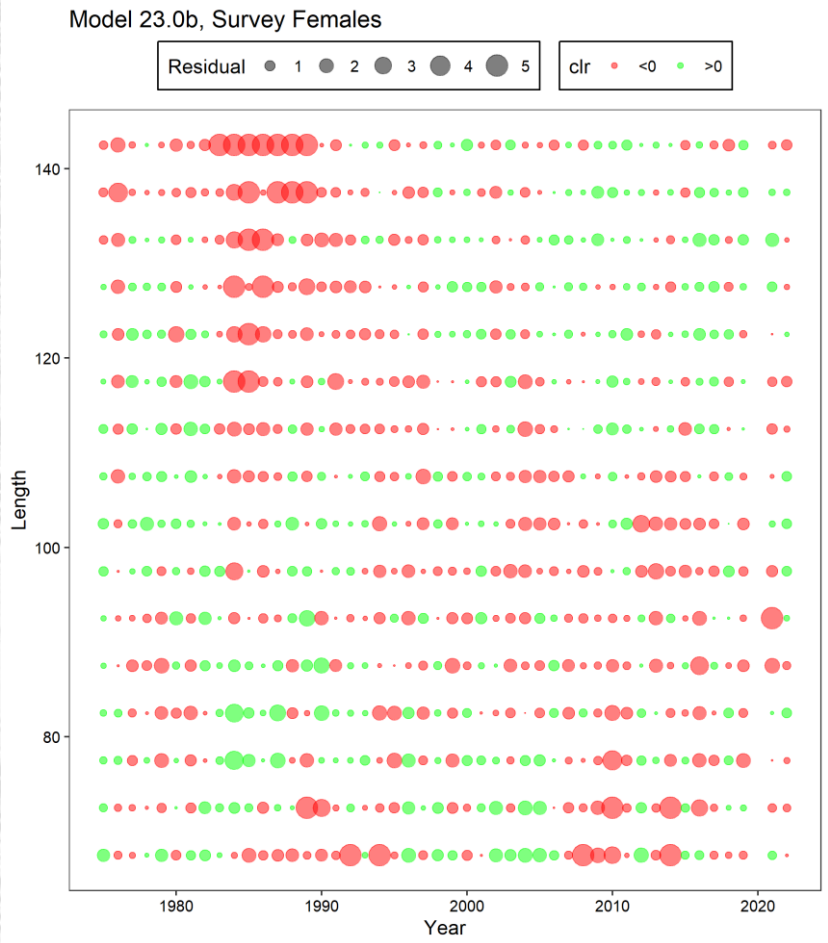


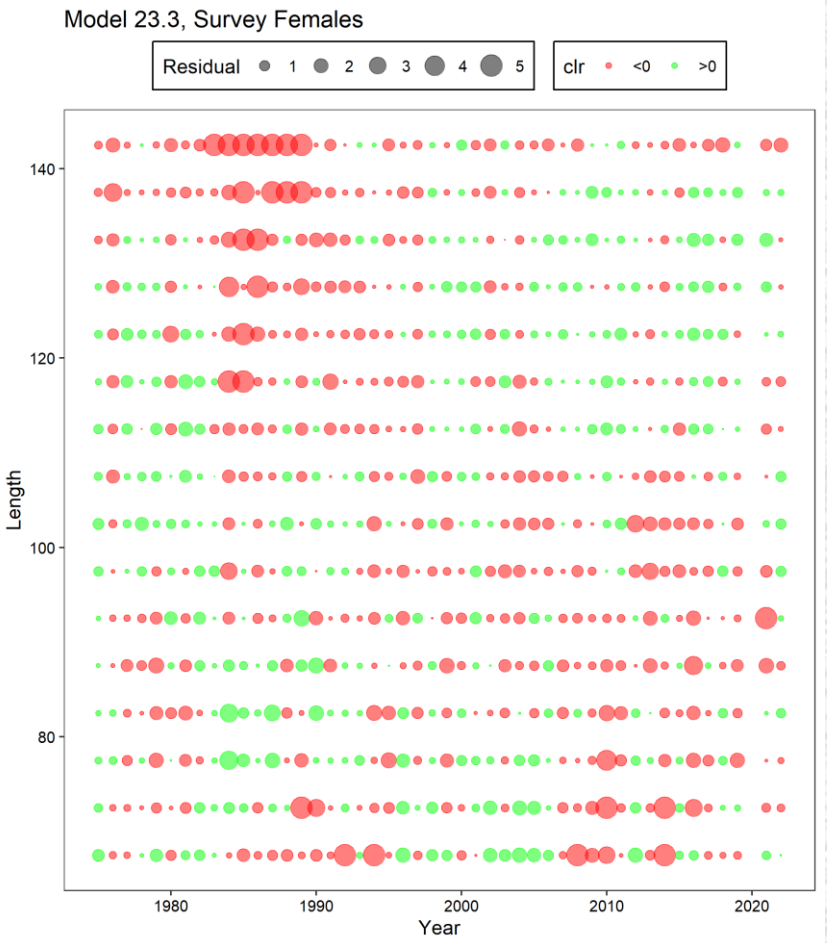




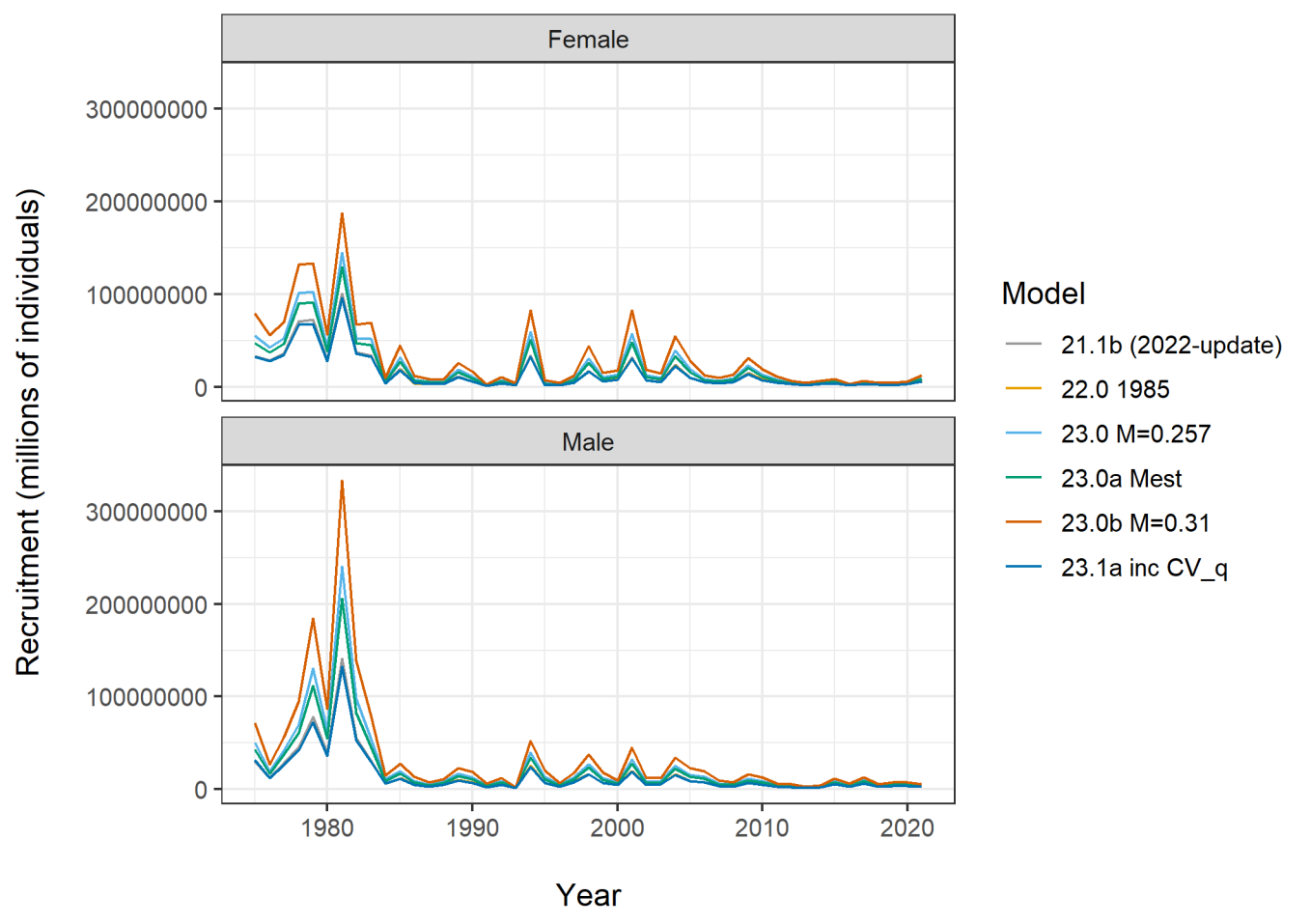
Comparison of residuals for NMFS survey females

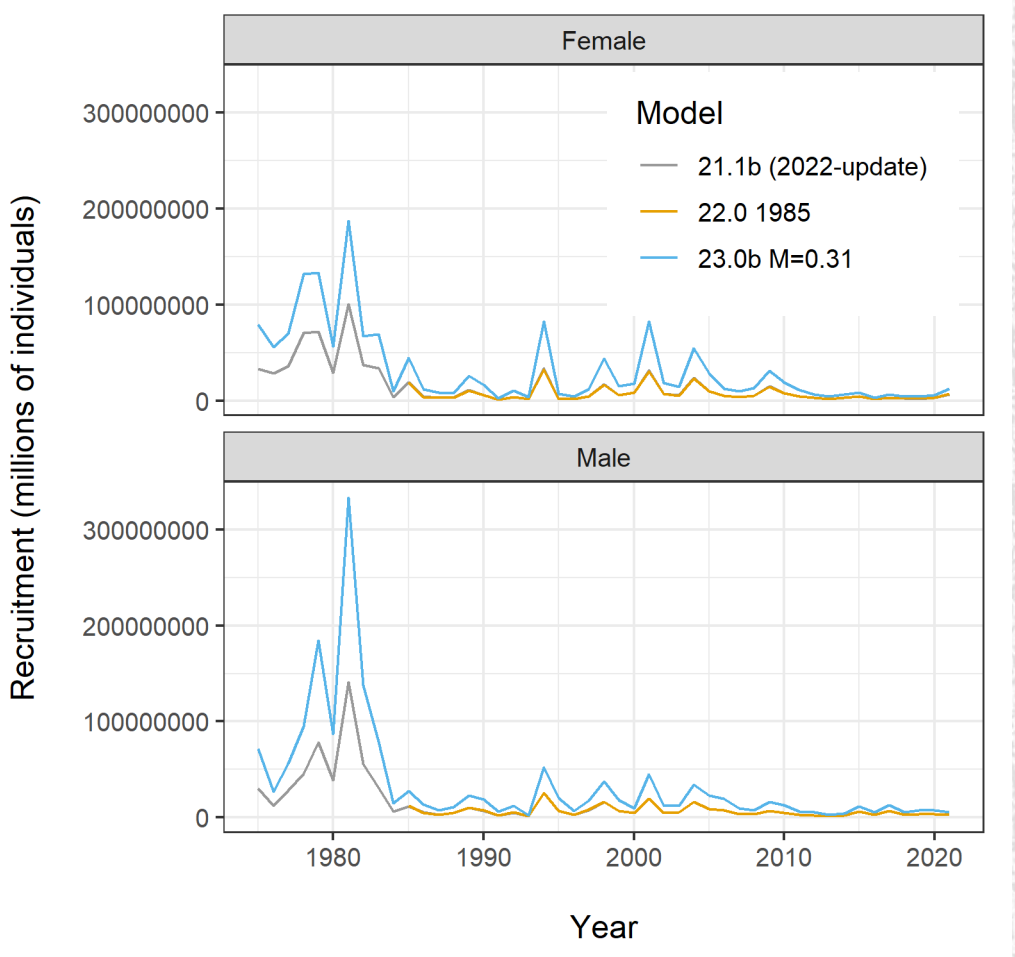






Recruitment





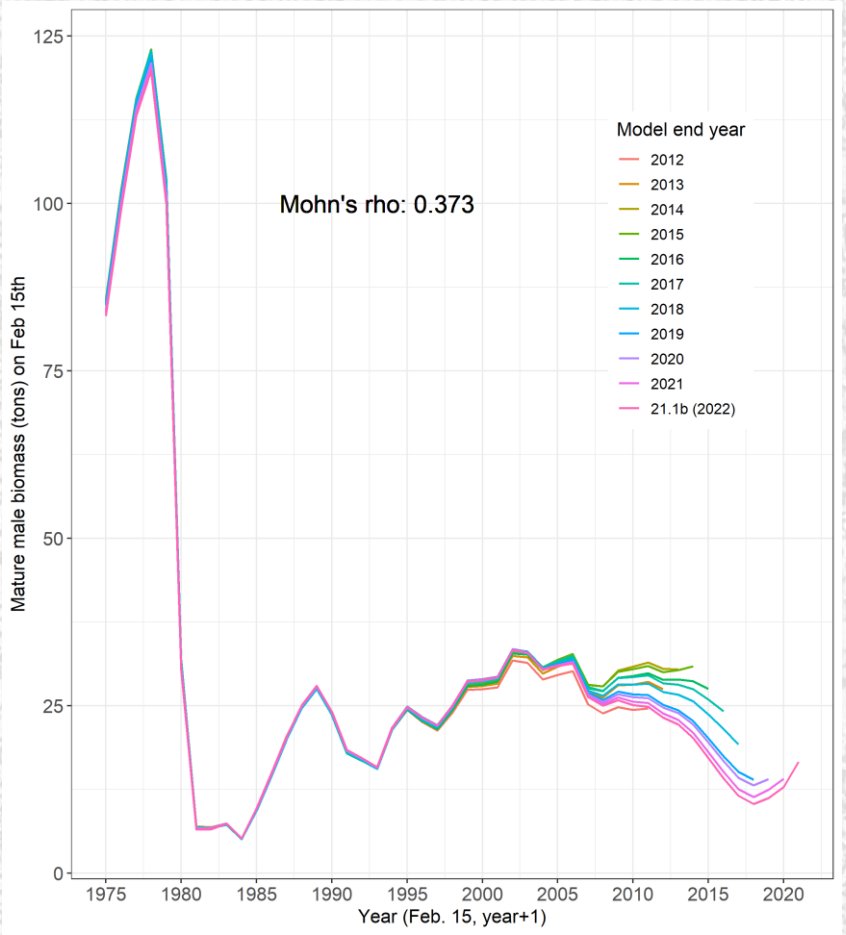
Highlighted cells show prior density values and total negative likelihood values without prior densities

Table 4: Comparisons of negative log-likelihood values and some parameters for all model scenarios.

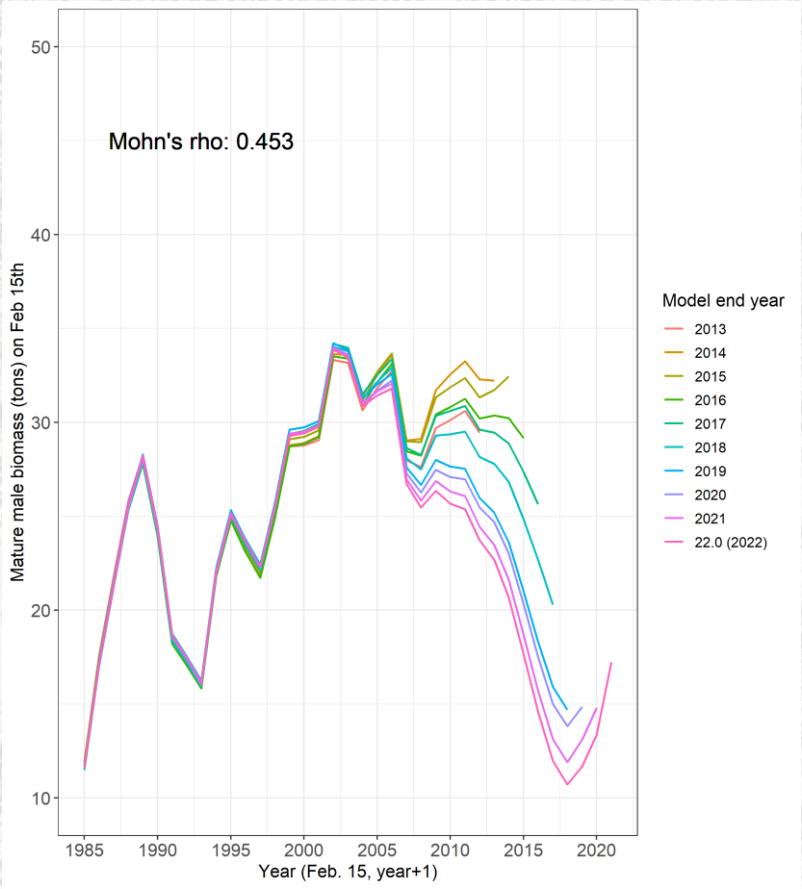
Component	Ref22	Ref23s	m23.0	m23.0a	m23.0b	m23.1a	m23.3
Pot-ret-catch	-60.88	-60.88	-62.32	-61.86	-63.32	-61.59	-61.97
Pot-totM-catch	26.55	26.55	25.44	25.87	24.37	25.25	25.29
Pot-F-discC	-55.70	-55.70	-55.72	-55.71	-55.72	-55.69	-55.71
Trawl-discC	-63.75	-63.75	-63.75	-63.75	-63.75	-63.74	-63.75
Tanner-M-discC	-43.54	-43.54	-43.54	-43.54	-43.54	-43.54	-43.54
Tanner-F-discC	-43.48	-43.48	-43.52	-43.51	-43.52	-43.48	-43.50
Fixed-discC	-36.04	-36.04	-36.04	-36.04	-36.04	-36.04	-36.04
Traw-suv-bio	-35.47	-35.47	-37.38	-37.66	-35.69	-36.47	-37.70
BSFRF-sur-bio	-2.94	-2.94	-5.51	-4.83	-6.47	-1.74	-3.28
Pot-ret-comp	-3932.20	-3932.20	-3941.02	-3938.84	-3945.00	-3933.46	-3937.79
Pot-totM-comp	-2369.46	-2369.46	-2370.57	-2370.25	-2371.05	-2370.45	-2370.66
Pot-discF-comp	-1449.36	-1449.36	-1449.76	-1449.83	-1449.45	-1449.48	-1449.91
Trawl-disc-comp	-5836.10	-5836.10	-5846.22	-5843.90	-5849.24	-5833.97	-5840.29
Tanner-disc-comp	-1274.28	-1274.28	-1277.41	-1276.99	-1277.43	-1274.82	-1276.69
Fixed-disc-comp	-3393.50	-3393.50	-3389.38	-3390.67	-3386.48	-3393.24	-3391.35
Trawl-sur-comp	-6984.67	-6984.67	-6994.36	-6993.08	-6993.27	-6989.36	-6994.41
BSFRF-sur-comp	-843.53	-843.53	-845.00	-845.16	-843.83	-844.36	-845.40
Recruit-dev	70.56	70.56	71.88	71.47	72.93	70.39	71.06
Recruit-ini	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recruit-sex-R	76.98	76.98	76.98	76.98	77.02	76.95	76.96
$Log_f dev_0$	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M-deviation	43.83	43.83	39.05	40.27	36.96	43.73	41.22
Sex-specific-R	0.01	0.01	0.02	0.01	0.04	0.01	0.00
Ini-size-struct		30.88	35.30	33.72	39.36	31.28	33.07
PriorDensity	267.30	267.30	227.65	252.04	220.97	271.19	259.03
Tot-likelihood	-25908.79	-25908.79	-25985.17	-25955.27	-25992.17	-25912.63	-25945.36
Tot-likeli-no-PD	-25641.49	-25641.49	-25757.52	-25703.23	-25771.20	-25641.45	-25686.33
Tot-parameter	372.00	372.00	372.00	373.00	372.00	372.00	373.00
MMB35	24026.11	22250.75	19136.75	19786.44	18209.52	21655.02	19919.11
MMB-terminal	16952.82	16761.49	14970.68	15431.45	14092.35	15489.83	14971.20
F35	0.30	0.30	0.46	0.40	0.58	0.30	0.37
$F_o fl$	0.20	0.22	0.35	0.31	0.44	0.20	0.27
OFL	3035.63	3213.98	4517.20	4132.66	5284.13	2783.29	3492.78
ABC	2428.50	2571.19	3613.76	3306.13	4227.30	2226.63	2794.22
NMFS Q	0.97	0.97	0.93	0.94	0.91	1.05	1.01

Retrospective patterns

Model 21.1b



Model 22.0



Model 23.0a

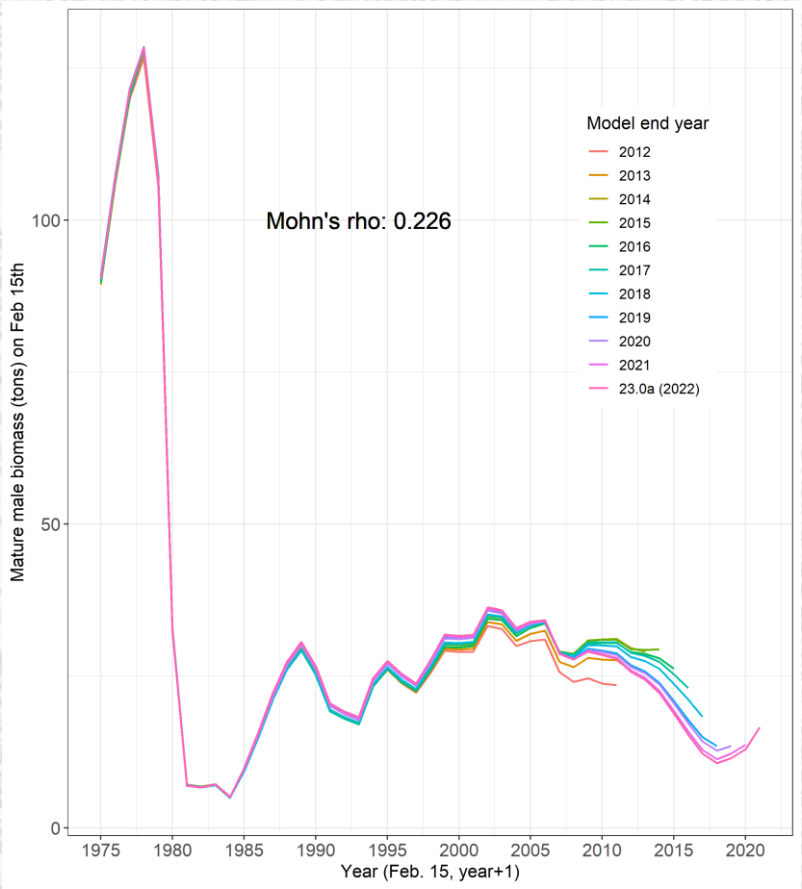


Table 1: Changes in management quantities for each scenario explored. Reported quantities are derived from maximum likelihood estimates. MMB, B35, OFL are reported in 1,000 t. Average recruitment is males and females combined in millions of animals.

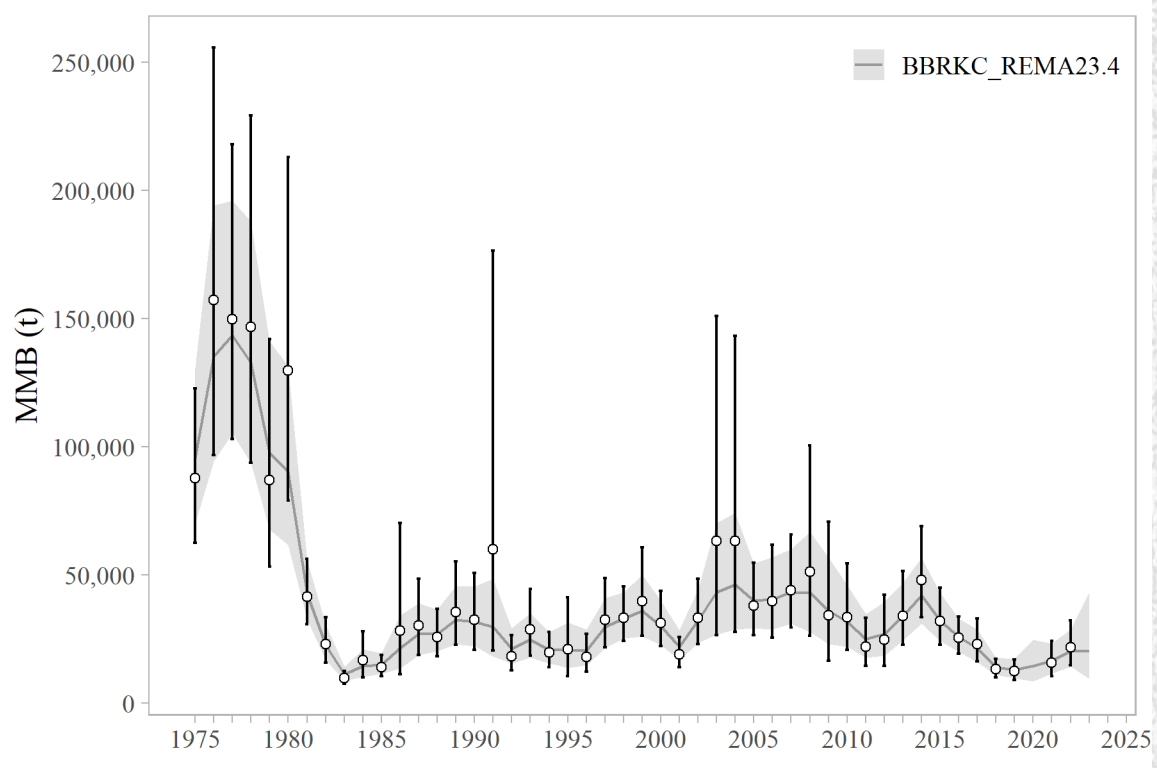
Model	Current MMB	B35	MMB/B_{MSY}	F35	F_{OFL}	OFL	avg rec	maleM
21.1b (2022-update)	16.76	22.25	0.75	0.30	0.22	3.21	15.26	0.18
21.1b (2022)	16.95	24.03	0.71	0.30	0.20	3.04		0.18
22.0 1985	16.97	20.48	0.83	0.30	0.24	3.64	13.99	0.18
23.0 M=0.257	14.97	19.14	0.78	0.46	0.35	4.52	25.77	0.26
23.0a Mest	15.43	19.79	0.78	0.40	0.31	4.13	21.97	0.23
23.0b M=0.31	14.09	18.21	0.77	0.58	0.44	5.28	36.23	0.31
23.1a inc CV q	15.49	21.66	0.72	0.30	0.20	2.78	14.68	0.18
23.3 Mest incCV	14.97	19.92	0.75	0.37	0.27	3.49	18.93	0.22

Summary and Recommendations

- Model 21.1b represents updated base – updates to GMACS and bycatch data
- Reducing the date time series produces similar results without complicated of M time block (late 70s/ early 80s)
  - Higher retrospective pattern not well understood
- Estimating M results in higher M and higher $F_{35\%}$, confounding issues
- Estimating M results in higher M for males but also reduced retrospective pattern (Mohn's rho reduced from 0.373 to 0.226)
- Recommendations:
  - Base model 21.1b
  - Model 23.0a – estimating M, reduces retrospective pattern, likely more accurate higher M
  - Model 22.0 – appealing but concern over retrospective pattern

Tier 4 simple modeling workgroup option

- Based on the simpler modeling working group discussions
- Mature male biomass (legal size + one growth increment below = mature for BBRKC)
- Average B – calculated using MMB from 1984 to 2021 (matches current Tier 3 assessment $B_{35\%}$ calcs)
- Assume 20% buffer – likely this would be different if we went with a Tier 4 option.



avgBb (t)	Current B	MMB/B_{ms} y	M	F_{OFL}	OFL	ABC
28443.11	20328.15	0.71	0.18	0.12	2499.12	1999.30

Future work

- Q explorations – modeling workshop topic? More input on potential modeling options
- Initial conditions – explorations on these and suggestions for what to look at
- Sensitivity of model to growth / molting / size increment assumptions
  - Hasn’t been revisited in awhile and would be good to explore
- Focus on retrospective pattern