BBRKC proposed models 2022

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ADF&G Juneau

May 2022

- Change in authorship
- CPT/SSC comments
- Model scenarios
  - Explore starting date for time series (status quo vs 1985)
  - Explore M assumptions
  - Impacts of BSFRF data
- Recommendation for Sept

CPT/SSC comments (May 2021)

“The CPT was concerned that the ‘information’ content of the data with respect to natural mortality could be related to strong assumptions elsewhere in the model, and recommended further exploration of natural mortality after September and suggested attending the June 2021 CAPAM workshop on natural mortality, which may provide some insights into best practices. A large increase in estimated natural mortality would likely increase fishing mortality reference points, with management implications.”

Response: We continue to examine *M* in May 2022. Estimated *M* values in the length-based crab models tend to have higher values than the other approaches, and confounding among estimated *M*, survey selectivity/catchability, and recruitment in a length-based model makes it difficult to accurately estimate *M* in the model. Among the eleven models in May 2022, seven are somewhat related to *M* change from the previous base model 21.1.

CPT/SSC comments

"The CPT was interested in more exploration of the retrospective patterns, which seem to have increased since the last assessment despite no new data being added. Reported Mohn's rhos were starting to reach concerning magnitudes in the proposed models?"

Response: The catch and bycatch updates make the retrospective patterns slightly worse than before. Higher than expected BSFRF survey biomass during 2007-2008 and 2013-2016 and NMFS survey biomass in 2014 likely caused these biases. Also, much lower than expected NMFS survey biomass during 2018-2019 and 2021 results in lower biomass estimates in 2020 and 2021. The biases for total abundance are much smaller than mature male biomass. High natural mortality during 2018-19 reduces these upward biases for model 21.2.

In May 2022, we continue to examine the retrospective patterns further. It appears that adding a time block of *M* during 2015-2018 and dropping BSFRF survey data greatly reduces retrospective bias from Mohn's rho of 0.347 for model 21.1b to 0.135 for model 22.1a.

CPT/SSC comments (Sept 2021)

"Consider a model with constant M, but estimated separately for males and females (i.e., similar to Model 21.0, but with sex-specific M's) for May 2022."

Response: Models 22.0, 22.0a, 22.0b, 22.0c and 22.0d with starting year of 1985 in May 2022 are constant *M* and estimated separately for males and females.

"Consider a model in which the data starts in 1985 (as suggested by the CIE reviewers)."

Response: Models 22.0, 22.0a, 22.0b, 22.0c, 22.0d, and 22.0e in May 2022 start in 1985. These models are used to examine *M*, BSFRF survey data, and retrospective bias.

Table 7. **Natural mortality estimates** for nine model scenarios during different year blocks. Rows denoted with “base” indicate the estimate defaulted to the base value in the first column or third column.

Model	Sex	1975-1979, 1985-2014, 2019-2021	1980-1984	1985-2014 2019-2021	2015-2018
21.1b	Males	0.180	0.890		base
	Females	0.238	1.179		base
22.0	Males			0.180	base
	Females			0.232	base
22.0a	Males			0.226	base
	Females			0.261	base
22.0b	Males			0.225	base
	Females			0.261	base
22.0c	Males			0.223	base
	Females			0.260	base
22.0d	Males			0.180	base
	Females			0.231	base
22.0e	Males			0.180	0.333
	Females			0.220	0.406
22.1	Males	0.180	0.883		base
	Females	0.239	1.172		base
22.1a	Males	0.180	0.909		0.304
	Females	0.231	1.164		0.389

CPT/SSC comments (Sept 2021)

"The SSC recommends that authors should carefully consider assessment implications of the stock boundaries given the evidence of crabs outside of the managed area. The SSC suggests that the authors should still be able to use data from outside stock boundaries, even if not used in the input survey abundance estimates. For example, the abundance seen outside stock boundaries could be treated as covariate informing catchability within the model. This analysis seems particularly important for females that are increasingly outside of the current stock boundaries and are at low abundance, triggering the State closure. The SSC recommends that the authors formulate separate survey abundance time series inside and outside of the defined area that could prove useful in the assessment model (e.g., informing catchability). If this is not an option in the stock assessment, then it highlights the need for ESRs or ESPs to track movement of these crabs both through survey results and developing indices from local knowledge."

Response: The current version of GMACS seems not to be able to use the Northern RKC survey index to inform BBRKC survey catchability. We tried to add a model to include both BBRKC and Northern RKC data, but the groundfish fisheries bycatch is not currently available in the Northern area. We plot more proportional data of the Northern RKC in Figures 35a and 35b. Overall, the proportions of different size groups of the Northern RKC during a recent dozen years are higher than in the past and do not trend higher except for mature females in 2021. The high survey mature female abundance in the Northern area in 2021 was primarily from three tows and one of them is more than 50% of total mature females. The survey abundance of the Northern RKC will continue to be plotted in the SAFE report in the future. After migration patterns between BBRKC and the Northern RKC are fully understood, we will model them in the stock assessment.

CPT/SSC comments (Sept 2021)

"It would be useful to investigate if there is a mechanism for higher natural mortality or fishing mortality for females only during that early time period while following the CPT recommendation of looking at model 21.0 with constant but separate Ms by sex. Since Model 21.0 estimates a very high level of fishing mortality, but does seem to account for the decline in large females, there may be a fishery selectivity issue in that period. If the modelers choose not to continue to use historic data prior to 1985, this suggestion may not be useful."

Response: Figuring out the exact causes of high mortality in the early 1980s is always difficult and we summarize the potential causes in Appendix A, section C-vi, "Potential Reasons for High Mortality during the Early 1980s". The directed fishery does not catch many large females and small crab, so it is difficult to remove these crab from the fishery. We prefer to start the model in 1985, which has two advantages: avoiding the early 1980s period so that a constant *M* over time can be used, and the same NMFS survey gear throughout the whole model time period.

Model explorations

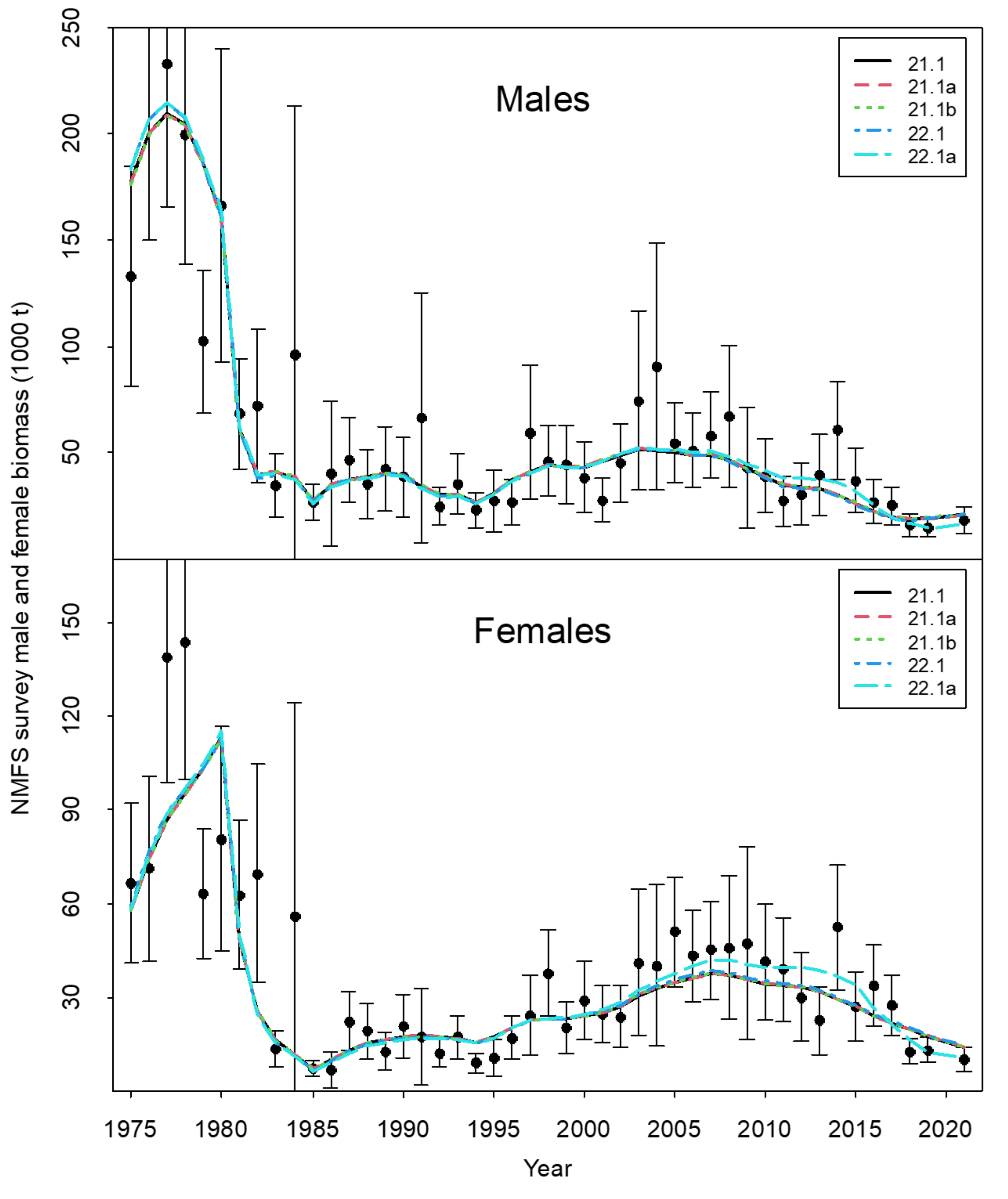
21.1: the base model from September 2021.

- **21.1a**: model 21.1 + using the **recently updated version of GMACS** (version 2.01.E).
- **21.1b**: model 21.1a + **updated groundfish fisheries bycatch** data.
  - **22.0**: model 21.1b + starting in 1985.
    - **22.0a**: model 22.0 (start in 1985) + estimating a constant *M* for males.
    - **22.0b**: model 22.0a + estimating a catchability Q for the BSFRF survey.
    - **22.0c**: model 22.0a + no BSFRF survey data.
    - **22.0d**: model 22.0c (start in 1985, no BSFRF) + fixing *M* = 0.18 for males.
    - **22.0e**: model 22.0d + estimating a constant *M* for males during 2015-2018.
  - **22.1**: model 21.1b + no BSFRF survey data.
  - **22.1a**: model 22.1 + estimating a constant *M* for males during 2015-2018.

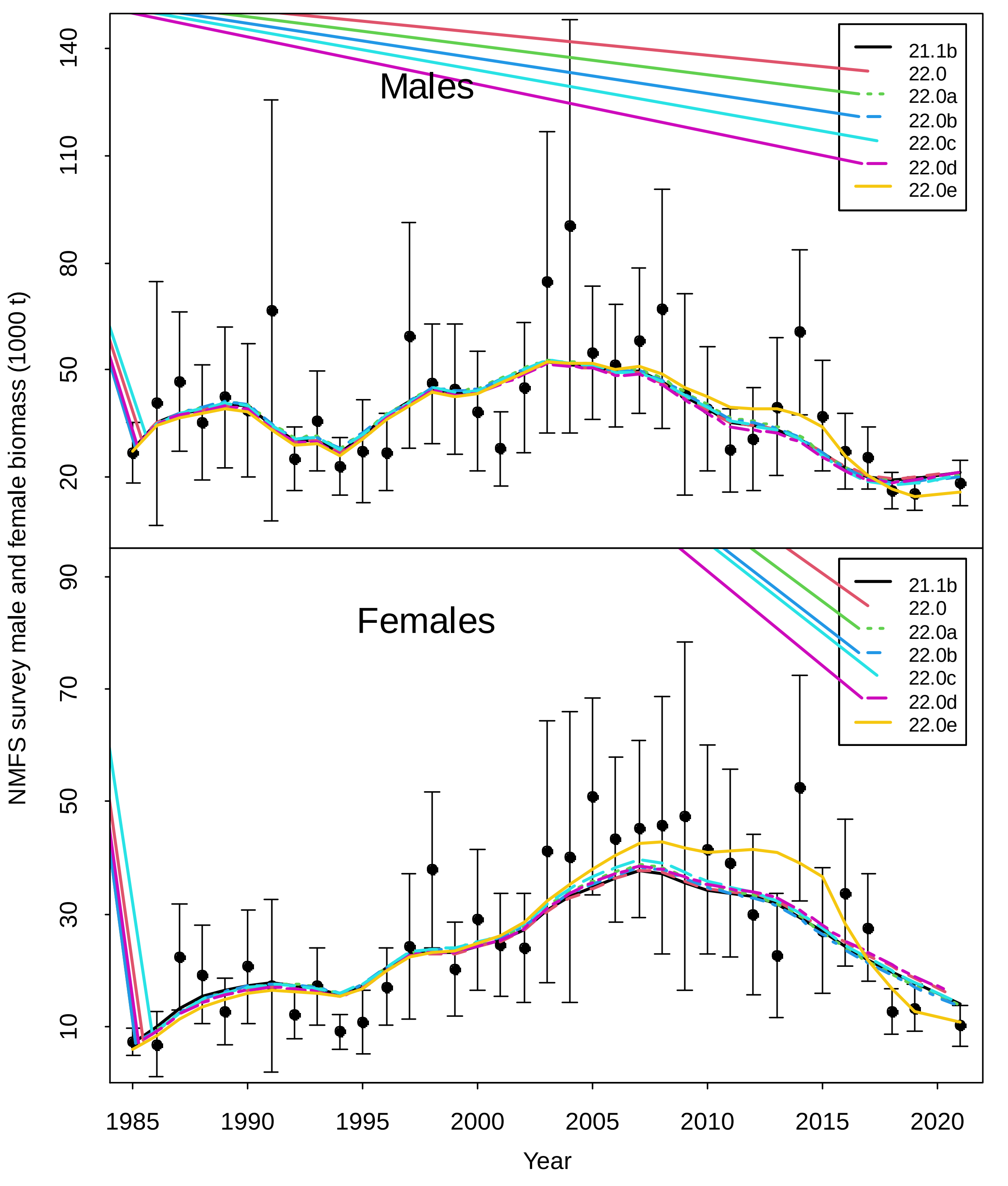
Comparison of Models

Model	New?	Male M	Starting date	M time block (2015-2018)	BSFRF data	BSFRF Q
21.1		80-84:M1, others: 0.18		N	Y	1.0
21.1a	GMACS version	80-84:M1, others: 0.18		N	Y	1.0
21.1b	21.1a + GF bycatch	80-84:M1, others: 0.18		N	Y	1.0
22.0		M = 0.18	1985	N	Y	1.0
22.0a		M = M1	1985	N	Y	1.0
22.0b		M = M1	1985	N	Y	Estimated
22.0c		M = M1	1985	N	N	--
22.0d		M = 0.18	1985	N	N	--
22.0e		M = 0.18, 15-18: M1	1985	Y	N	--
22.1		80-84:M1, others: 0.18		N	N	--
22.1a		80-84:M1, 15-18: M2, others: 0.18		Y	N	--

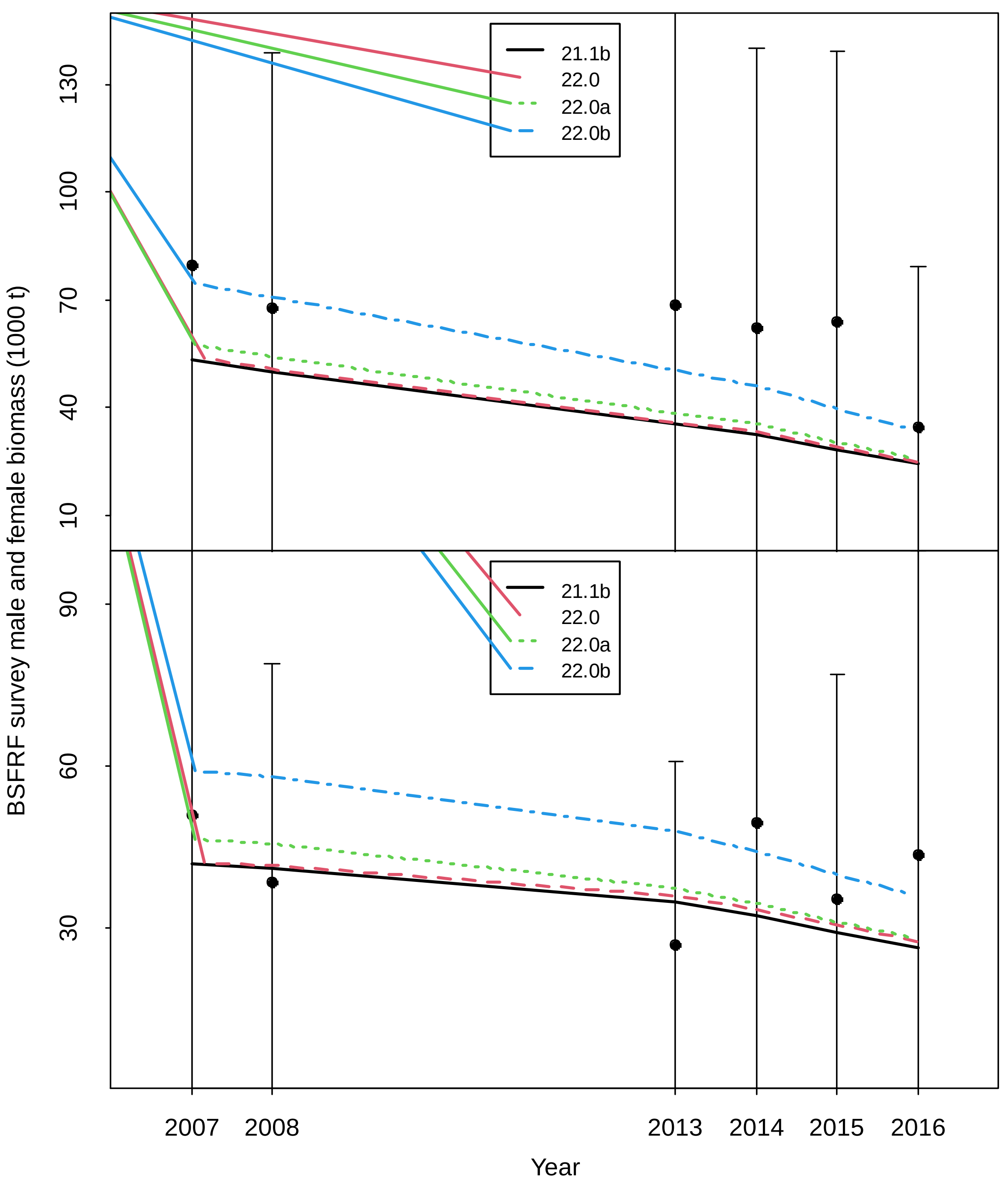
- Why 2015 to 2018 increase M time block?
  - Increased proportion of older crab in the population
  - Move “old shell” crab
  - Reduces retrospective pattern (slides to come)
- Why BSFRF data removed
  - Q potentially higher than 1 due to herding
  - Removal decreases retrospective patterns
  - Not an influential data set in current model



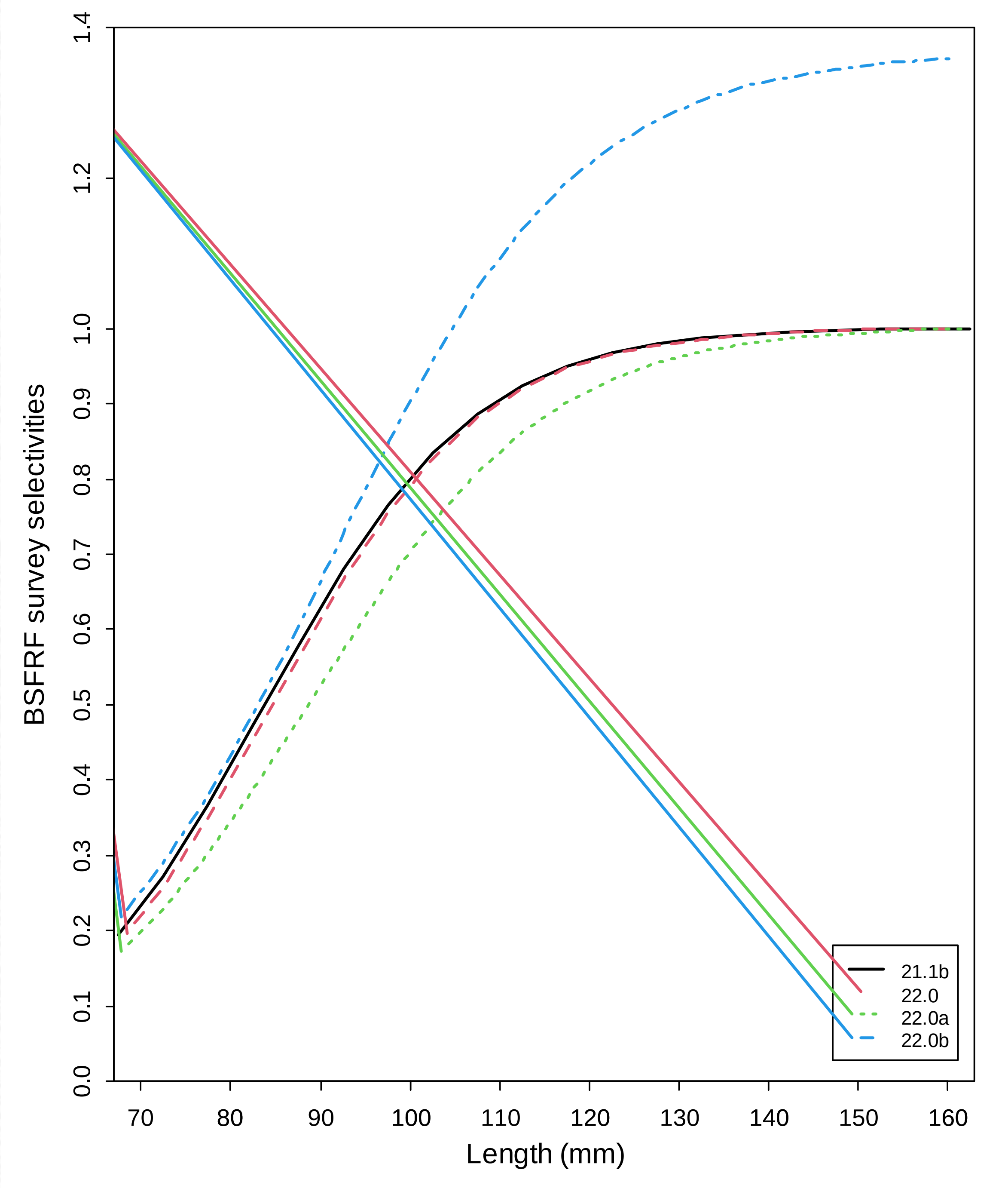
- Error bars are ± 2SD of model 21.1b
- Models start in 1975
- Models 22.1/22.1a (no BSFRF data)
- Model 22.1a has extra time block for M (2015-18)



- Error bars are ± 2SD of model 22.0 (base at 1985 start)
- Models start in 1985
- Model 22.0e has extra time block for M (2015-18)

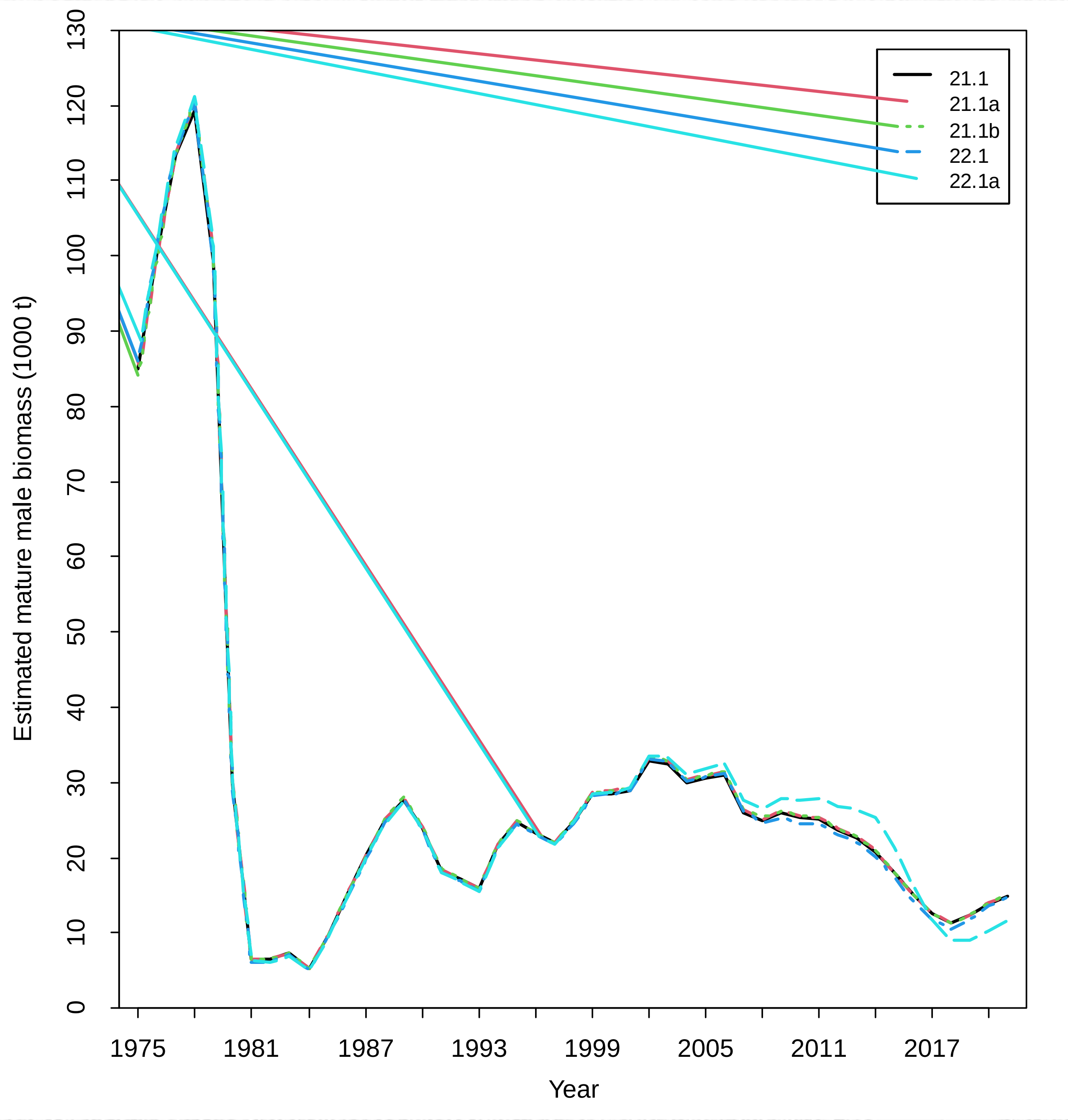


- Error bars are plus and minus 2 standard deviations of model 21.1b.
- BSFRF survey catchability is assumed to be 1.0 for all models except for model 22.0b which estimates the catchability.
- 22.0b –
    - Q =1.36

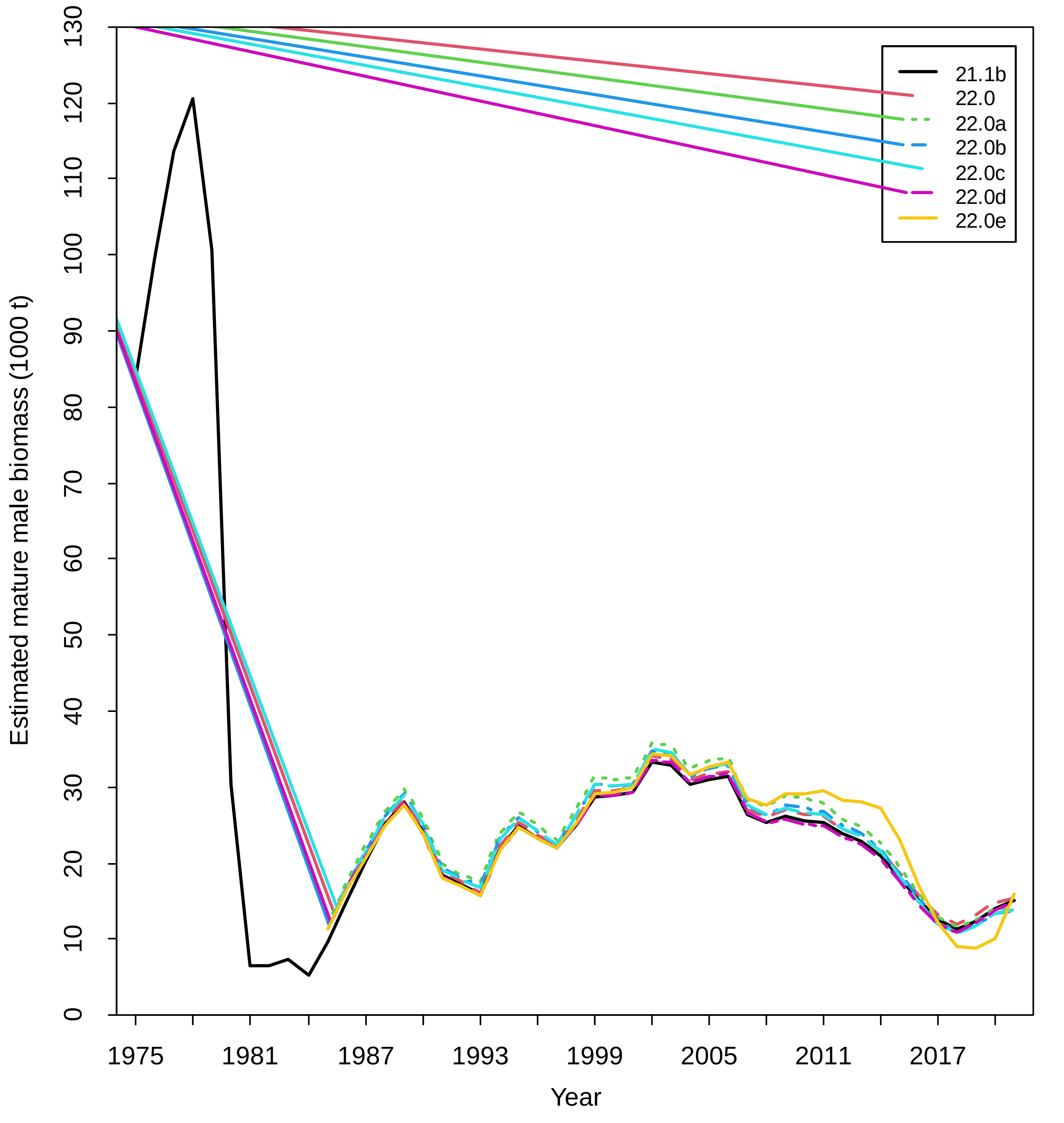


- Comparisons of estimated BSFRF survey selectivities with models 21.1b, 22.0, 22.0a, and 22.0b.

- The BSFRF survey catchability is assumed to be 1.0 for all models except for model 22.0b where it is estimated

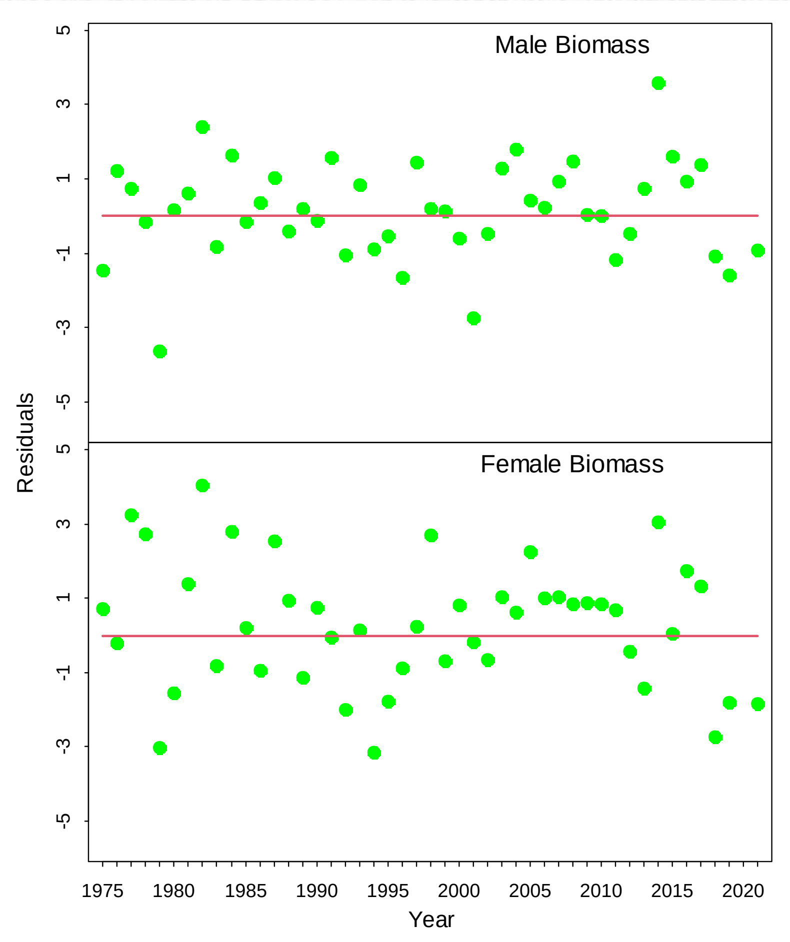


- Estimated absolute mature male biomasses during 1975-2021 for models 21.1, 21.1a, 21.1b, 22.1, and 22.1a. Mature male biomass is estimated on Feb. 15, year+1.

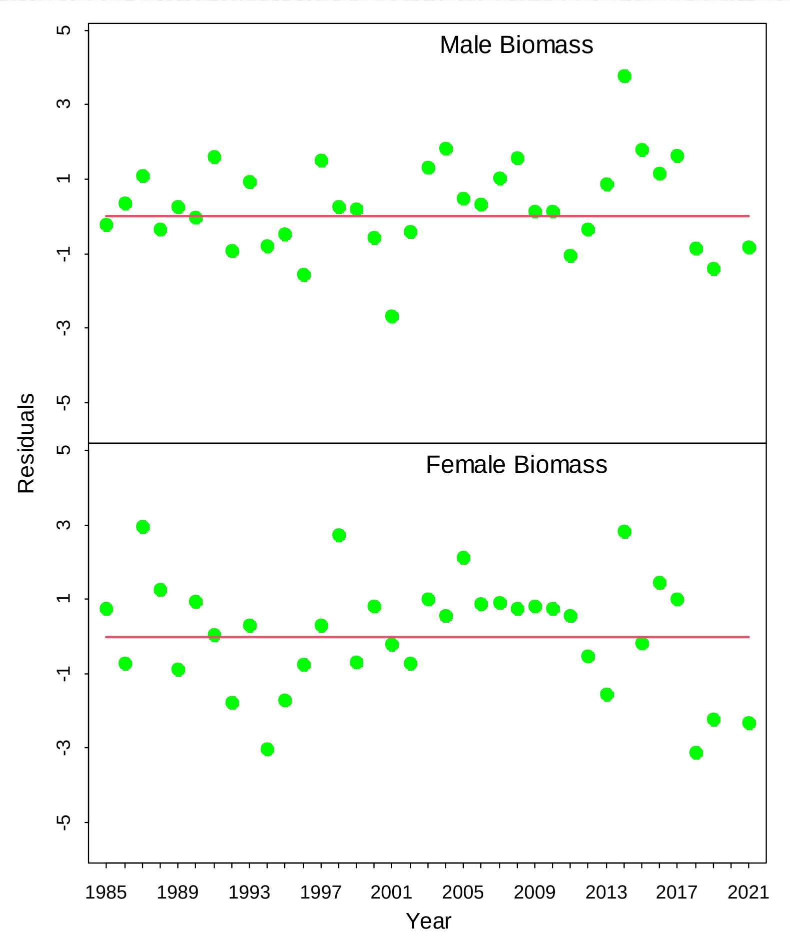


- Estimated absolute mature male biomasses during 1975-2021 for models:
    - 21.1b
- 1985-2021 for models:
    - 22.0, 22.0a, 22.0b, 22.0c, 22.0d, and 22.0e.
- 22.0e (extra M time block, no BSFRF data)

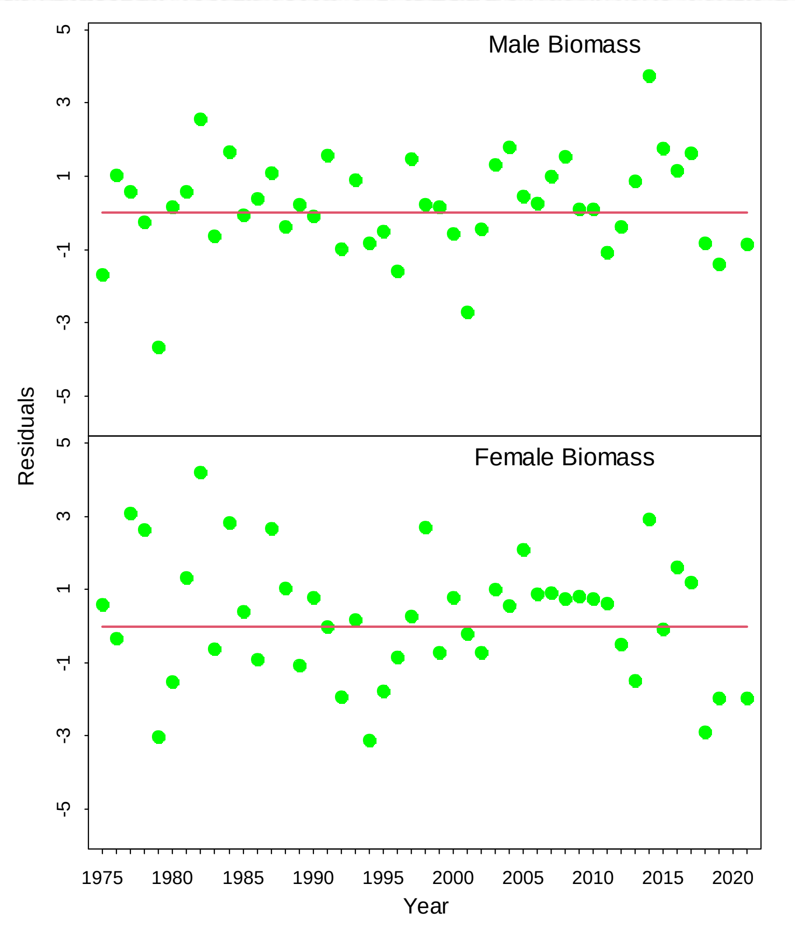
21.1b



22.0d (1985, no BSFRF)



22.1 (no BSFRF)



Comparison of estimated M and directed pot fishing mortality over time

(models: 21.1b, 22.0, 22.0e, 22.1a)

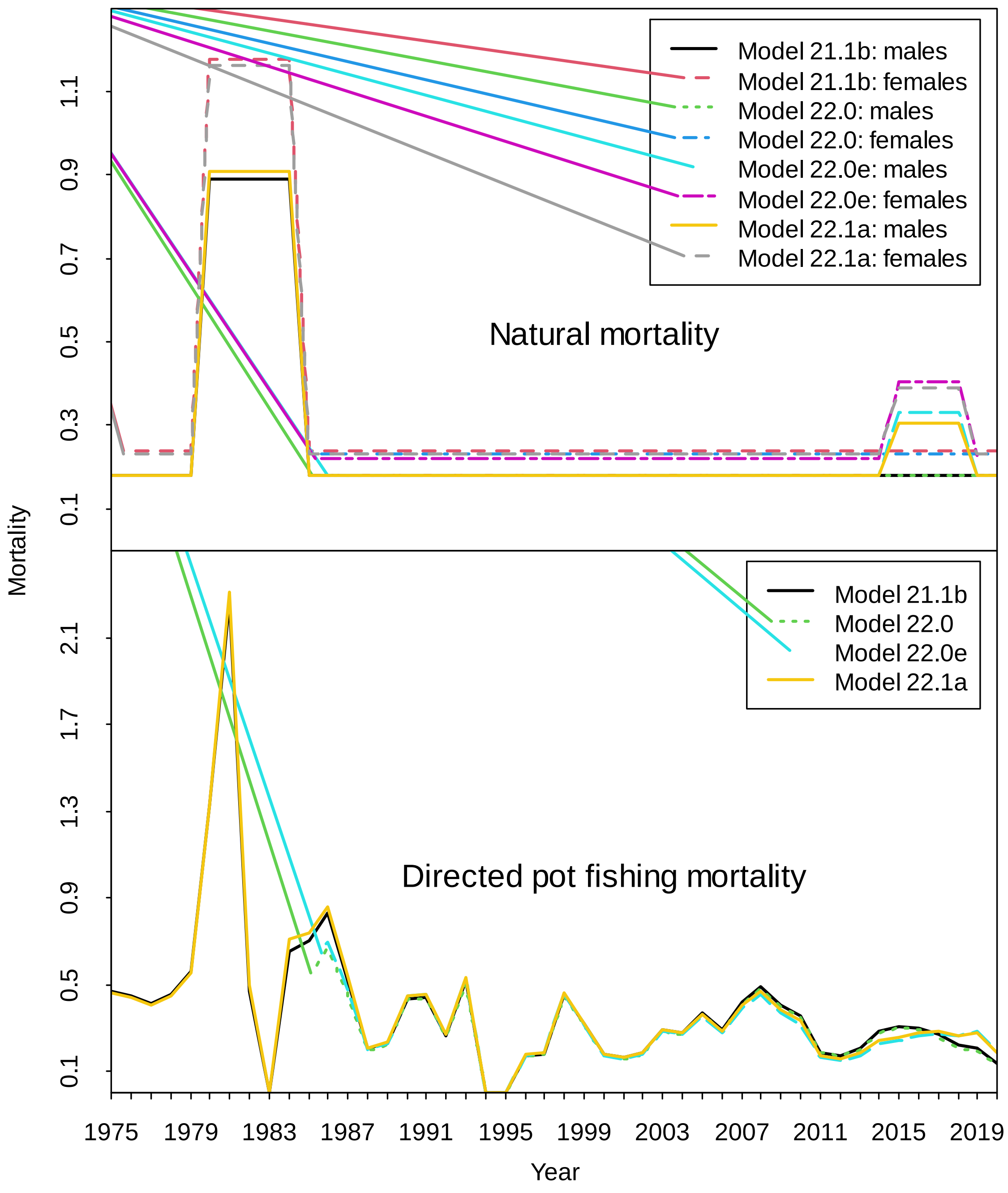


Table 7. **Natural mortality estimates** for nine model scenarios during different year blocks. Rows denoted with “base” indicate the estimate defaulted to the base value in the first column or third column.

Model	Sex	1975-1979, 1985-2014, 2019-2021	1980-1984	1985-2014 2019-2021	2015-2018
21.1b	Males	0.180	0.890		base
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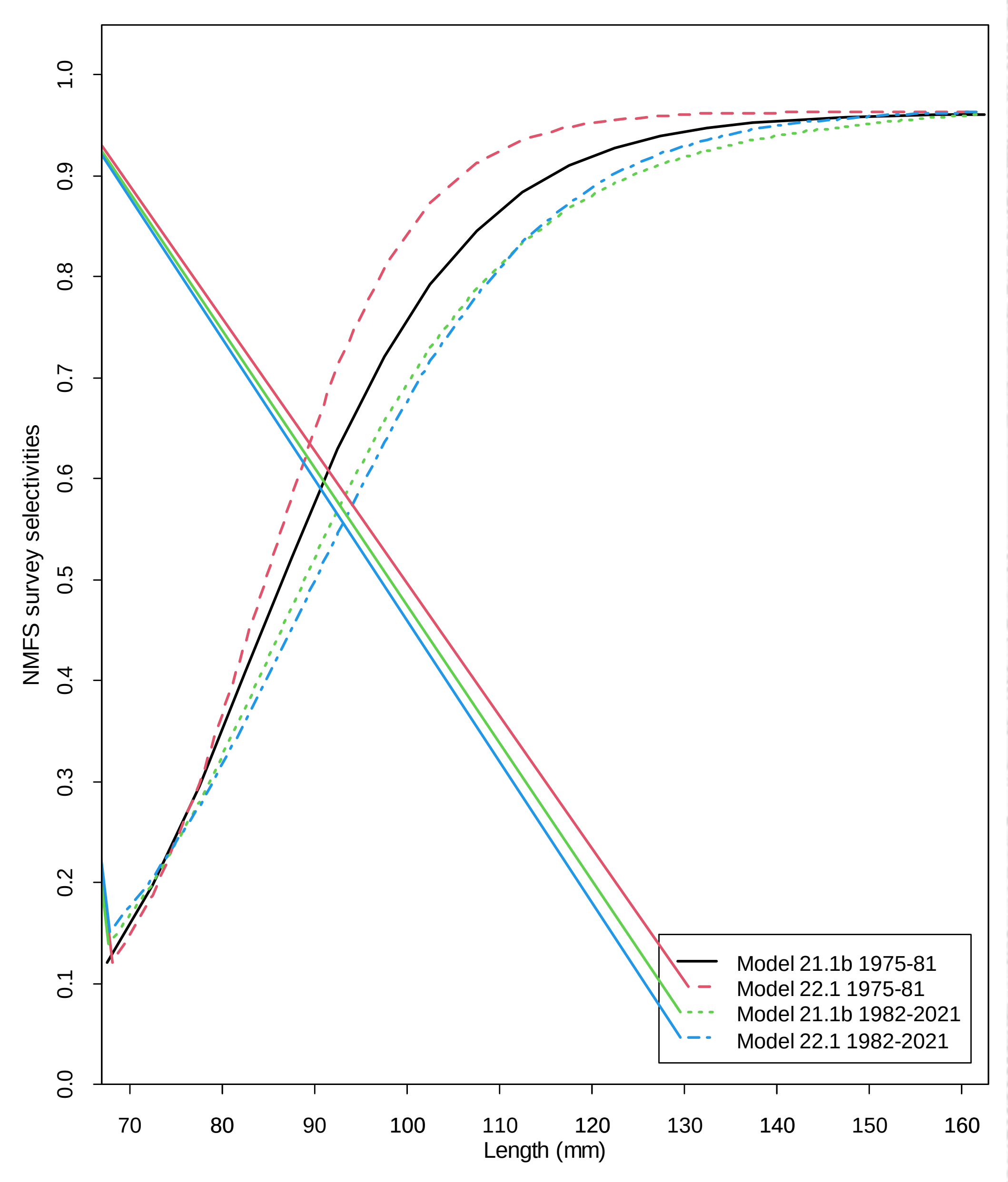
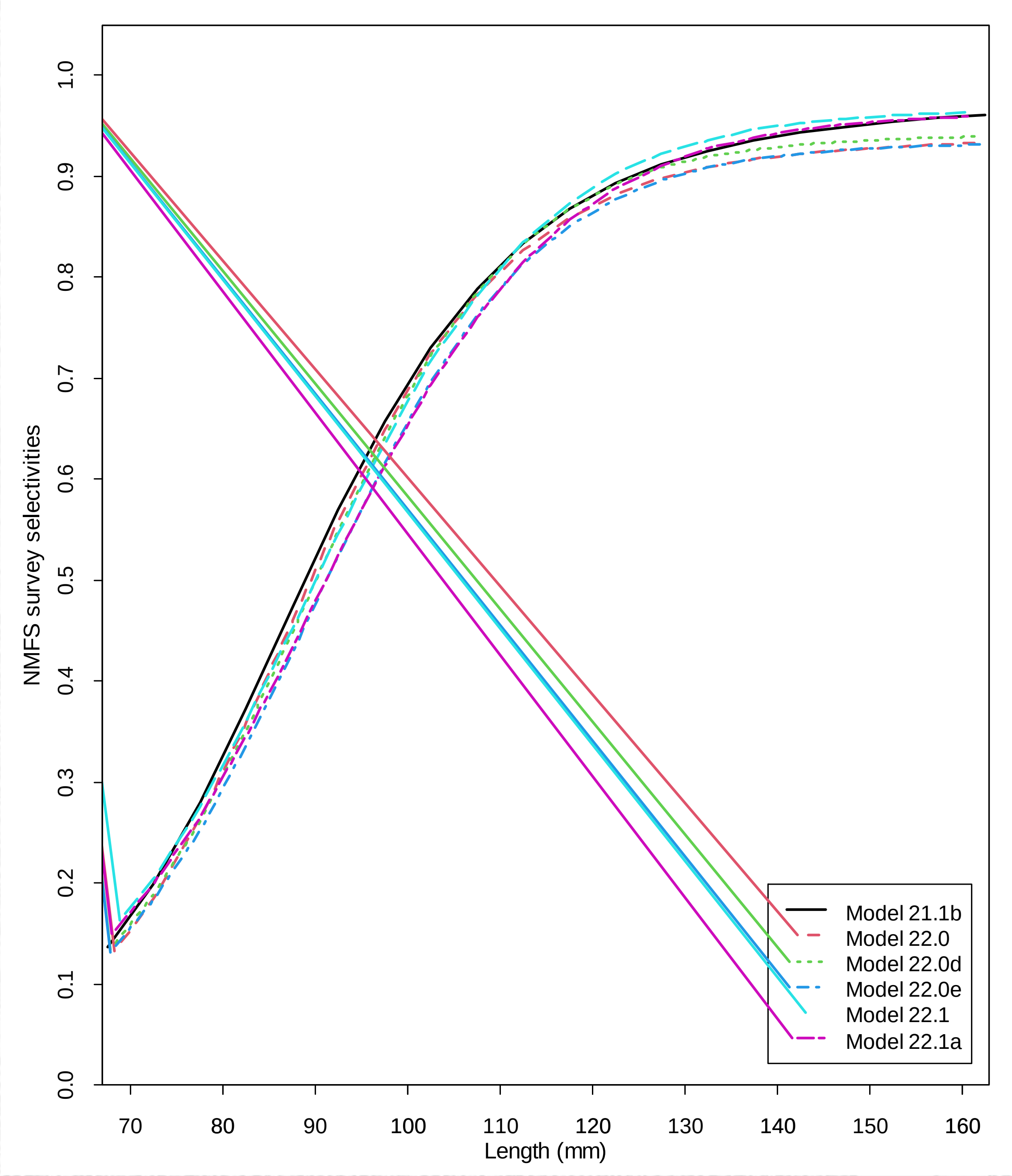
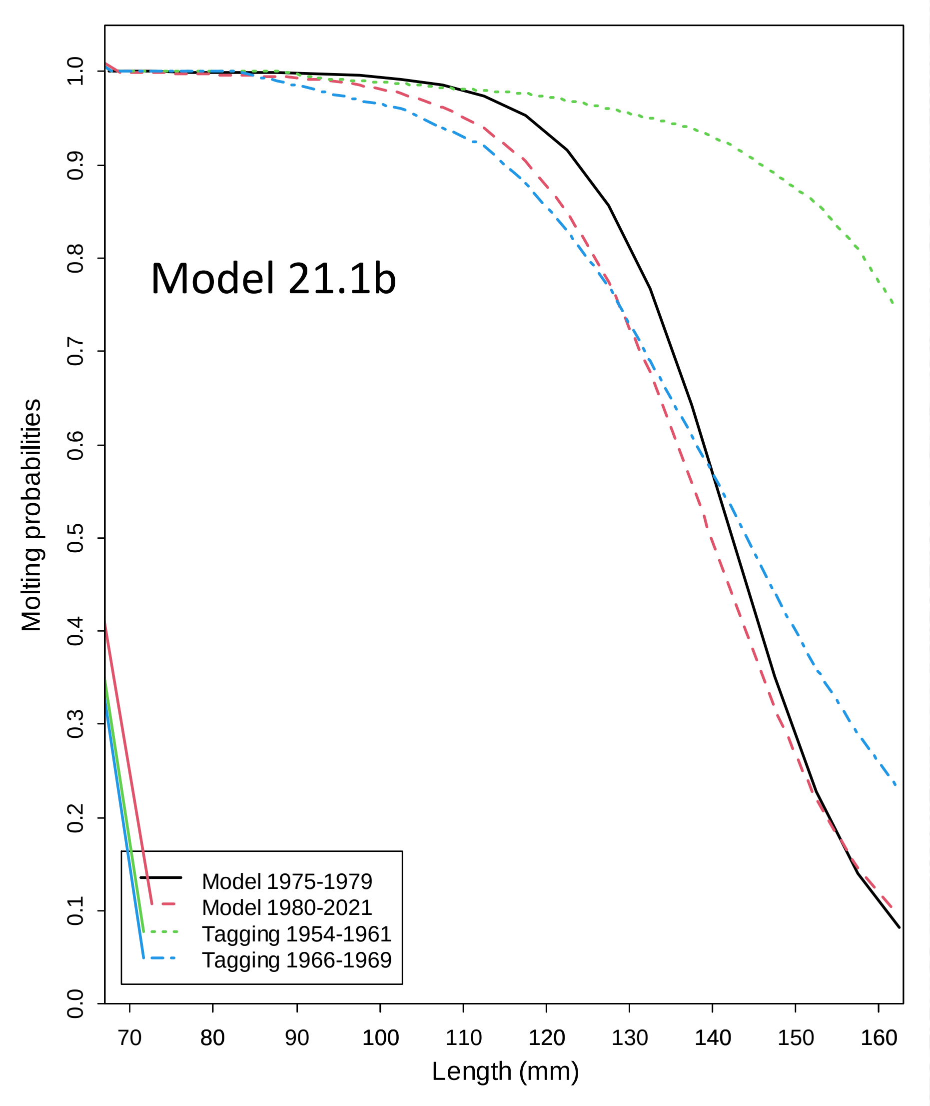


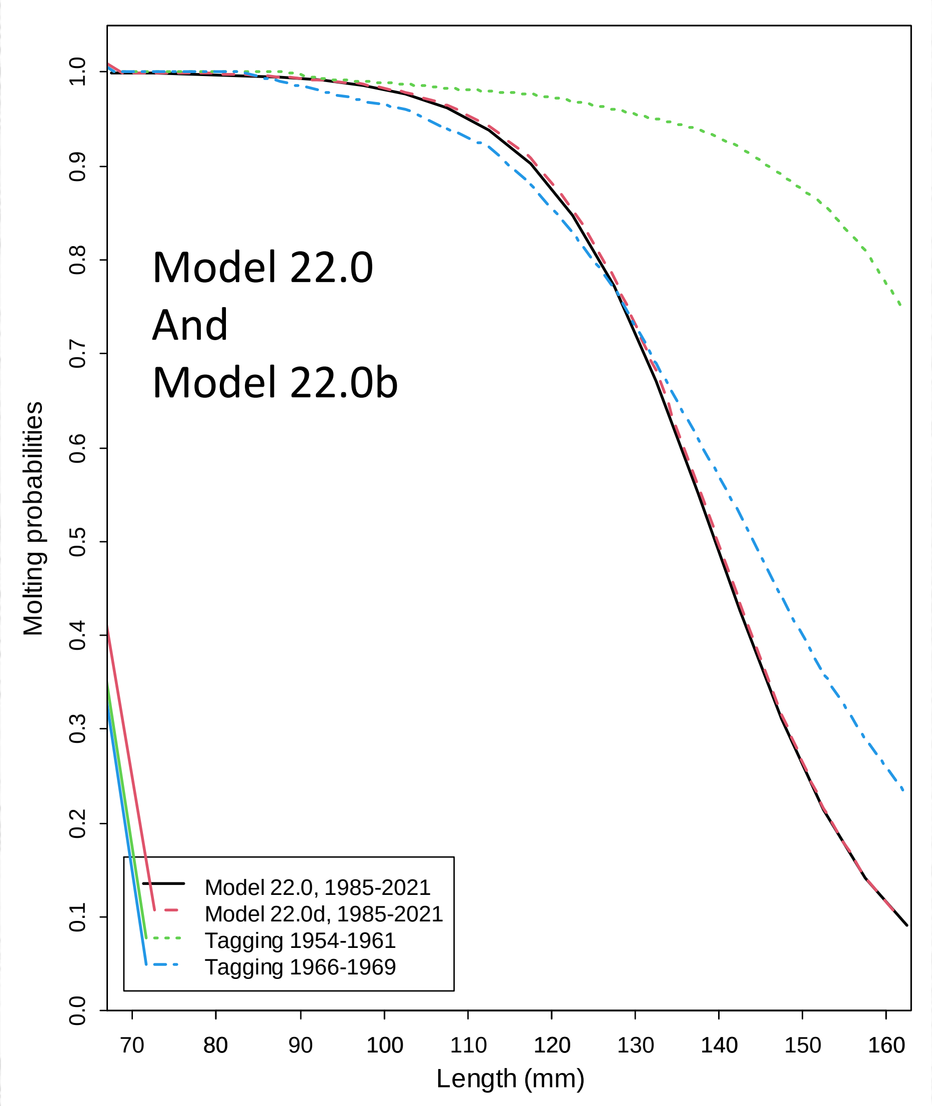
- Estimated NMFS trawl survey selectivities under models 21.1b and 22.1.
- Changes with dropping BSFRF data

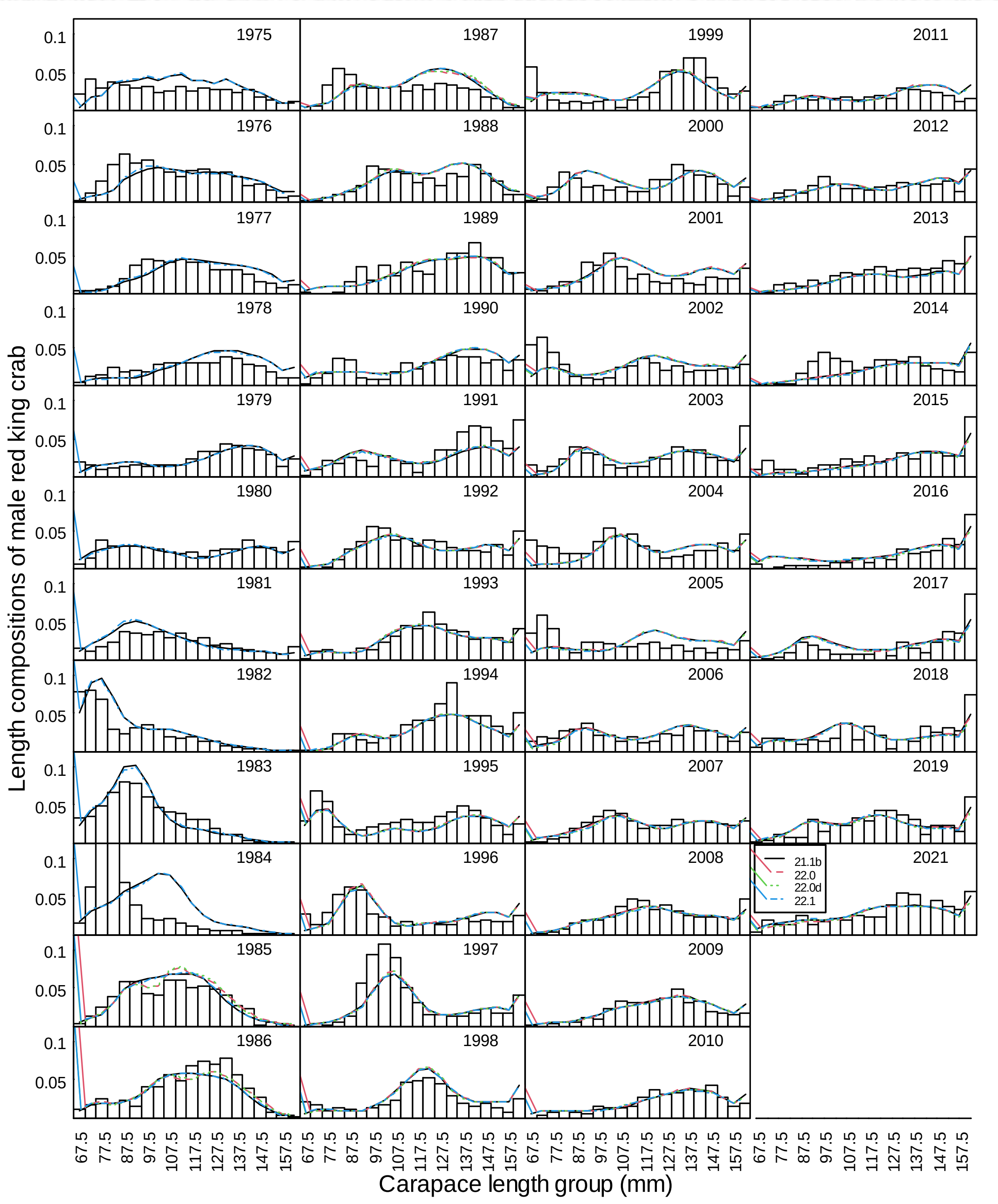


- Comparisons of estimated NMFS trawl survey selectivities with models 21.1b, 22.0, 22.0d, 22.0e, 22.1, and 22.1a during 1985-2021.

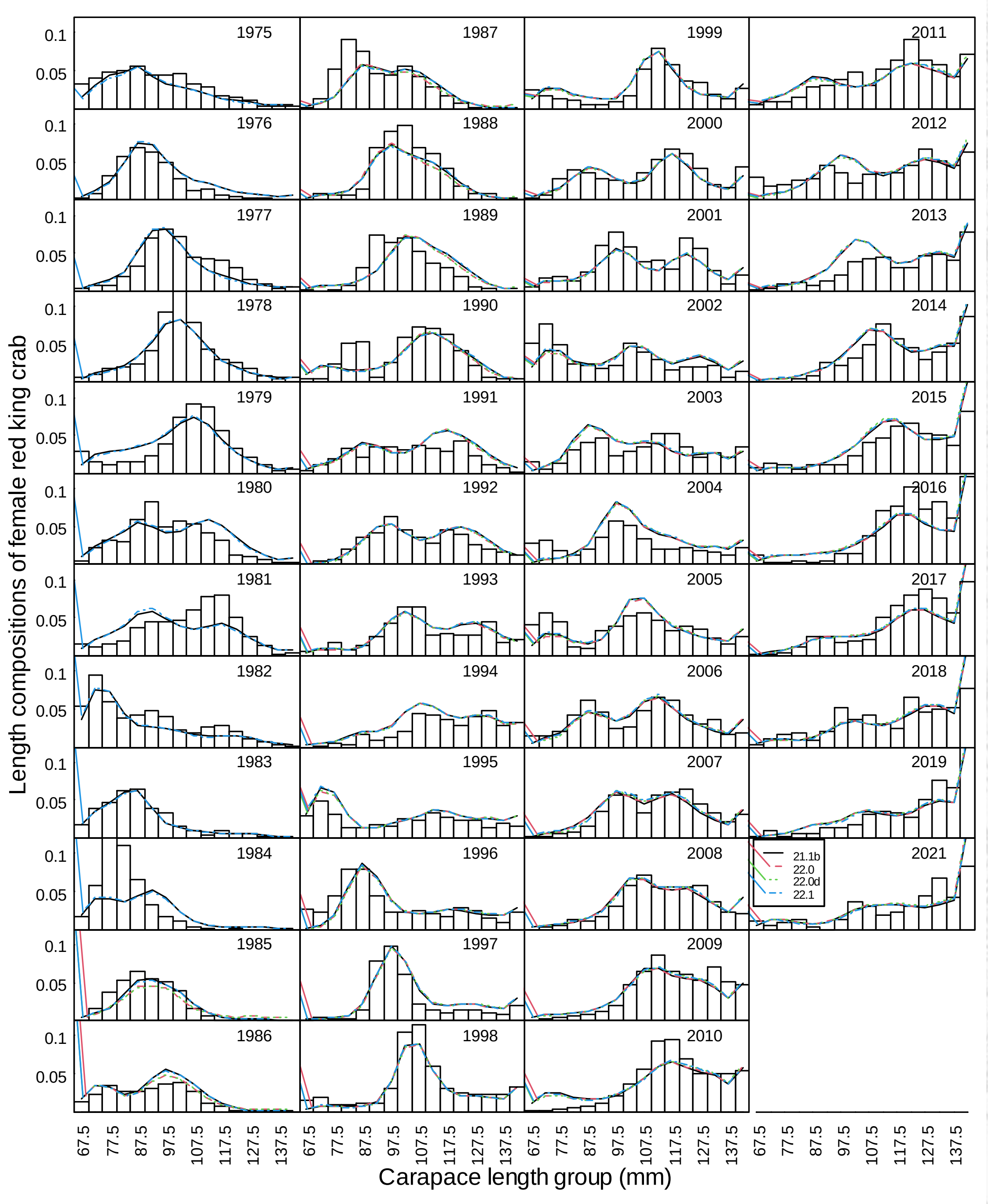
Molting probability



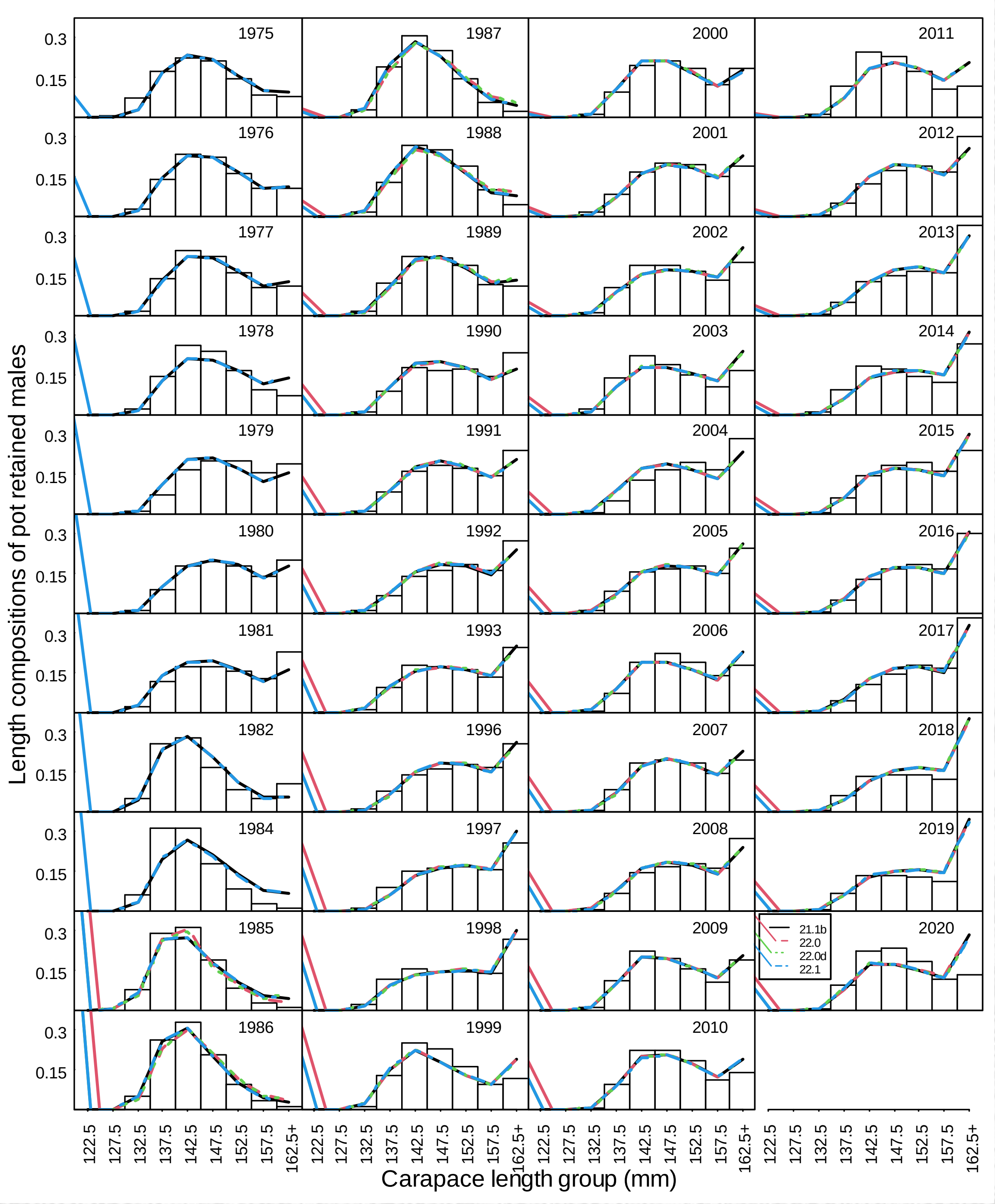




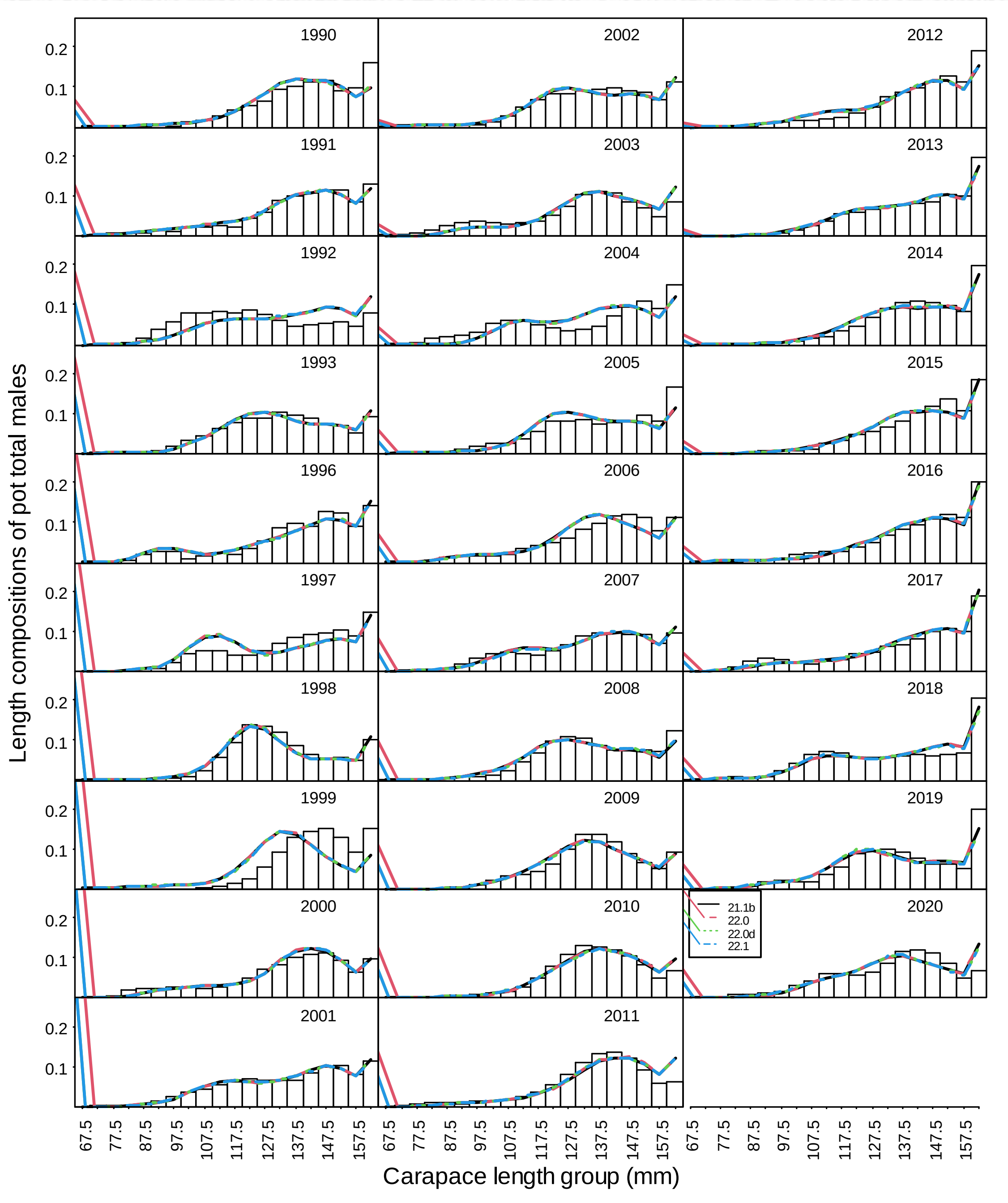
- Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay male red king crab by year under models 21.1b, 22.0, 22.0d, and 22.1



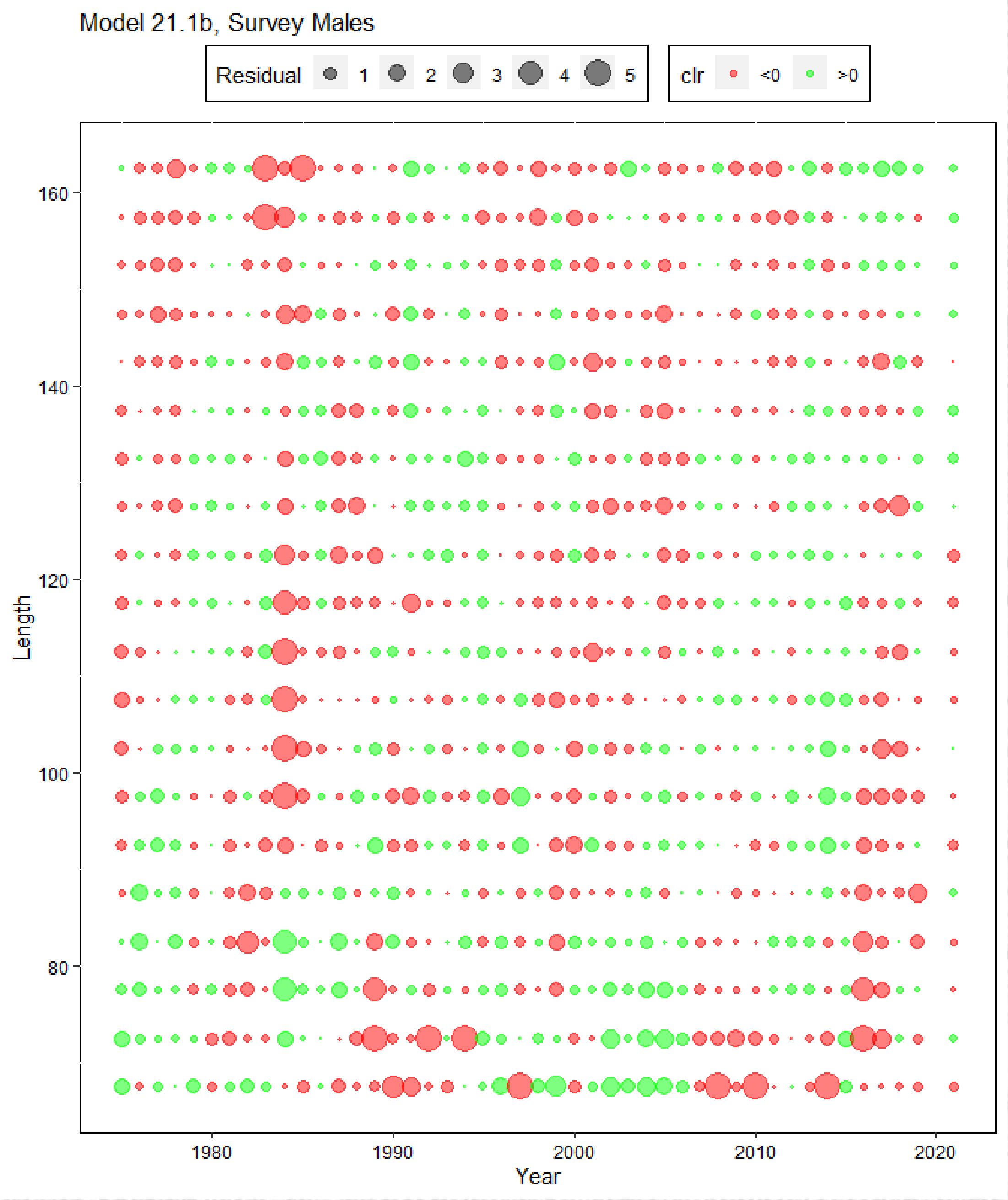
- Comparison of area-swept and model estimated NMFS **survey length frequencies** of Bristol Bay female red king crab by year under models 21.1b, 22.0, 22.0d, and 22.1.



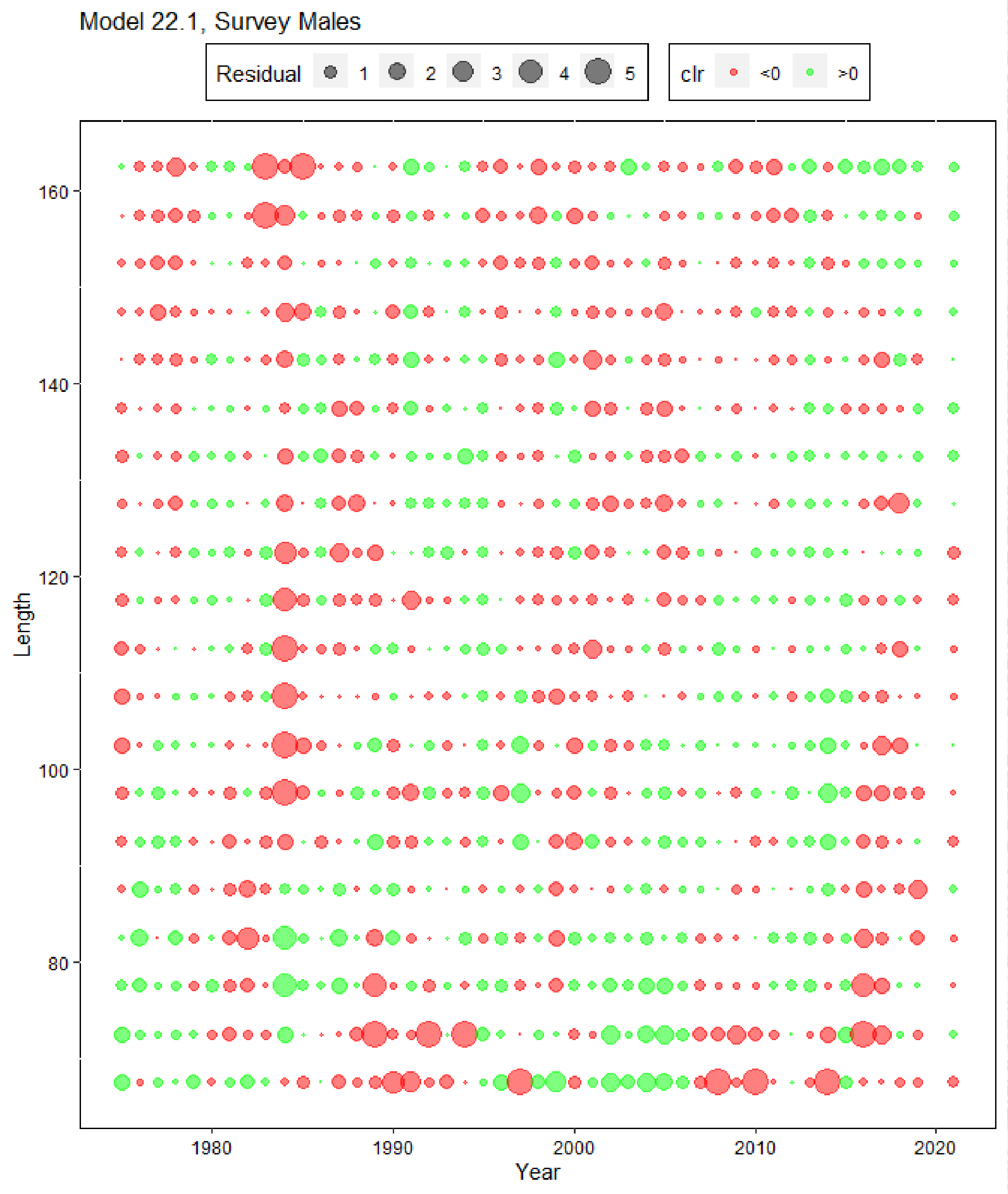
- Comparison of observed and model estimated **retained** length frequencies of Bristol Bay male red king crab by year in the directed pot fishery under models 21.1b, 22.0, 22.0d, and 22.1.



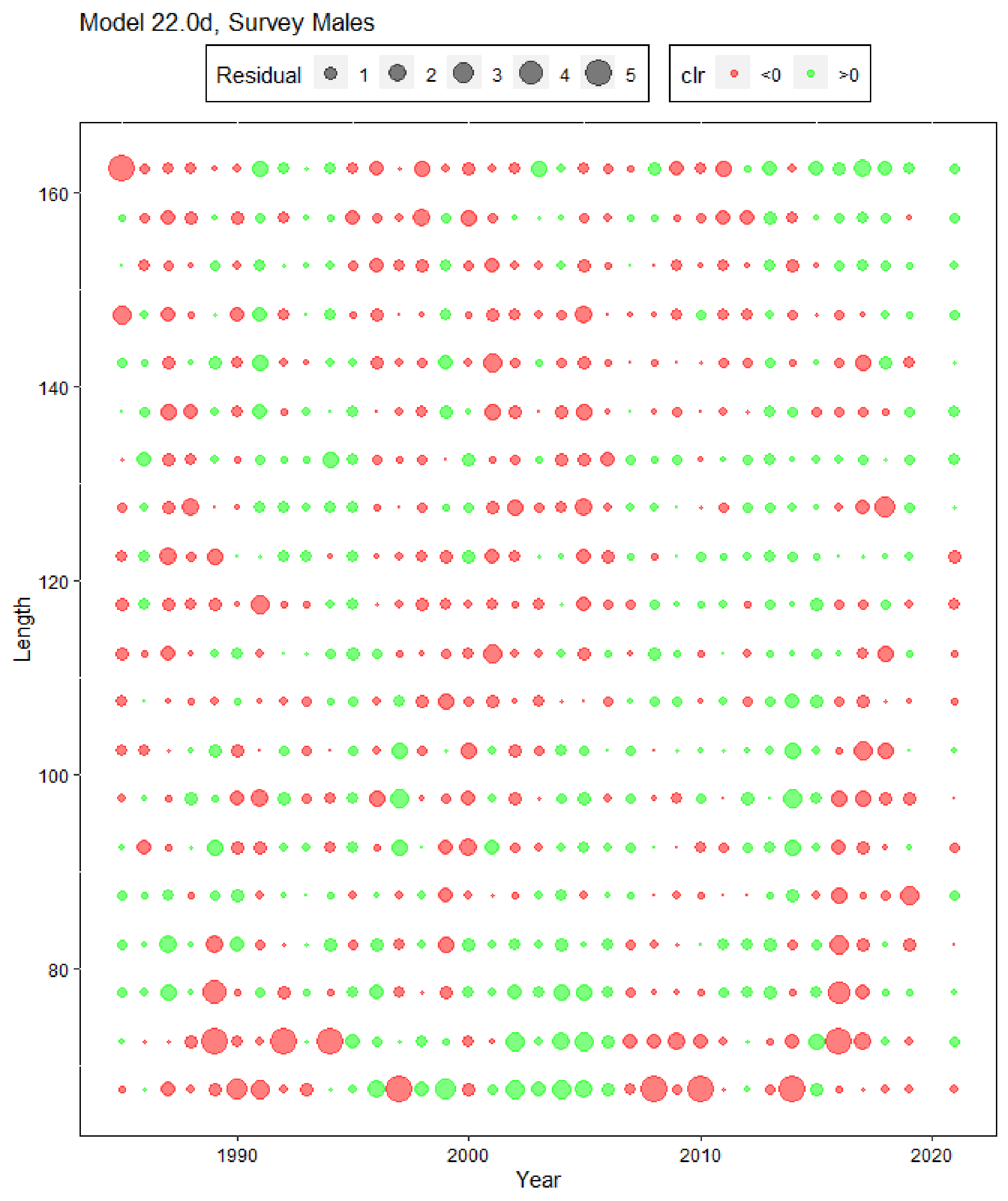
- Comparison of observer and model estimated **total observer** length frequencies of Bristol Bay male red king crab by year in the directed pot fishery under models 21.1b, 22.0, 22.0d, and 22.1.

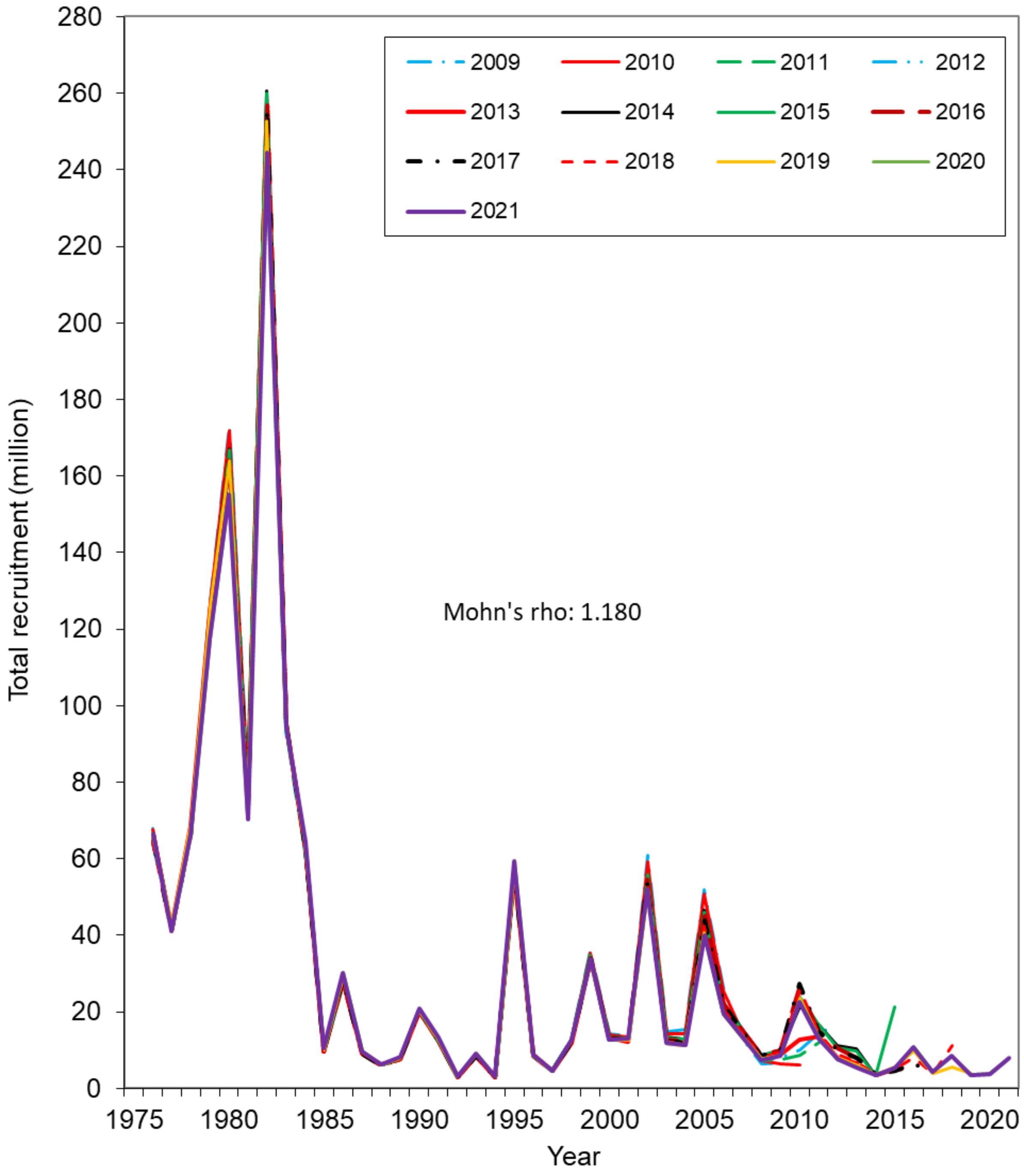


Model 21.1b, Survey Males
Residual 1 2 3 4 5
clr <0 >0
Length
160
140
120
100
80
Year
1980
1990
2000
2010
2020



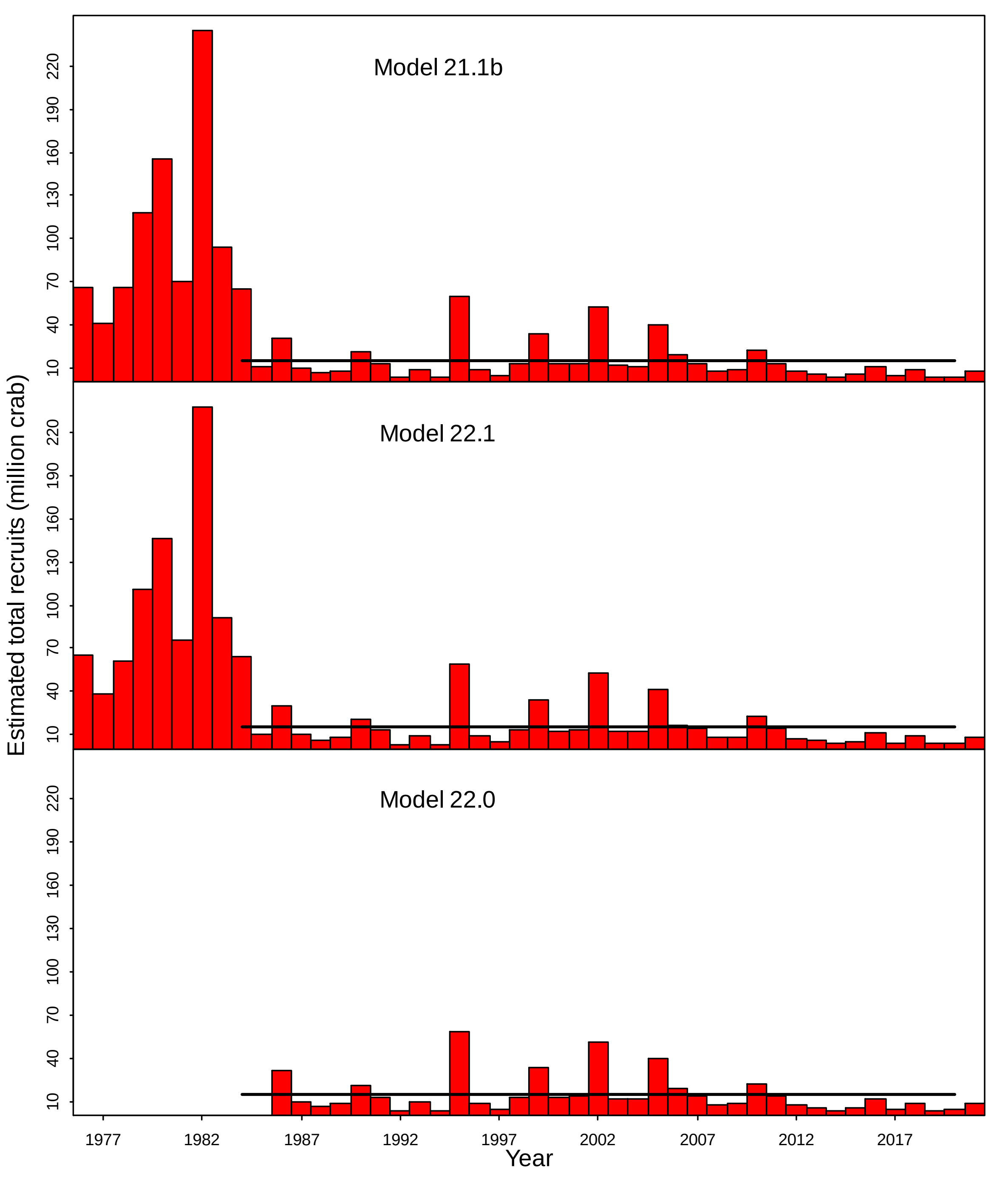
Model 22.1, Survey Males
Residual 1 2 3 4 5
clr <0 >0
Length
160
140
120
100
80
Year
1980
1990
2000
2010
2020


Model 22.0d, Survey Males
Residual
1
2
3
4
5
clr
<0
>0
Length
160
140
120
100
80
Year
1990
2000
2010
2020



Model 21.1b

- Hindcast estimates from 2021 model



RECRUITMENT

- Estimated recruitment time series during 1976-2021 with models 21.1b, 22.1, and 22.0. Mean male recruits during 1984-2020 was used to estimate $B_{35\%}$. Recruitment estimates in the terminal year (2021) are unreliable.

	Models			Differences		
	21.1b	22.1	22.1a	22.1-21.1b	22.1a-22.1	22.1a-21.1b
Pot-ret-catch	-59.84	-61.90	-62.09	-2.05	-0.20	-2.25
Pot-totM-catch	26.63	24.17	24.07	-2.46	-0.10	-2.56
Pot-F-discC	-53.95	-53.95	-53.93	0.00	0.02	0.02
Trawl-discC	-62.36	-62.36	-62.36	0.00	0.00	0.00
Tanner-M-discC	-43.54	-43.54	-43.54	0.00	0.00	0.00
Tanner-F-discC	-43.48	-43.48	-43.45	0.00	0.03	0.03
Fixed-discC	-34.65	-34.65	-34.65	0.00	0.00	0.00
Trawl-suv-bio	-34.32	-33.64	-48.21	0.68	-14.58	-13.90
BSFRF-sur-bio	-3.54					
Pot-ret-comp	-3873.93	-3875.36	-3877.21	-1.43	-1.85	-3.28
Pot-totM-comp	-2298.66	-2300.81	-2300.99	-2.15	-0.18	-2.33
Pot-discF-comp	-1394.66	-1394.31	-1393.92	0.35	0.39	0.74
Trawl-disc-comp	-5706.80	-5705.89	-5713.14	0.91	-7.25	-6.34
TC-disc-comp	-1274.23	-1274.42	-1274.93	-0.20	-0.51	-0.71
Fixed-disc-comp	-3287.71	-3292.38	-3291.66	-4.67	0.72	-3.95
Trawl-sur-comp	-6844.76	-6843.20	-6829.87	1.55	13.34	14.89
BSFRF-sur-comp	-843.68					
Recruit-dev	69.84	68.91	68.84	-0.93	-0.08	-1.01
Recruit-sex-R	75.40	75.47	75.54	0.07	0.07	0.14
Log_fdev=0	0.00	0.00	0.00	0.00	0.00	0.00
M-deviation	43.93	43.74	46.08	-0.18	2.34	2.16
Sex-specific-R	0.01	0.02	0.00	0.01	-0.02	-0.01
Ini-size-struct.	30.82	29.67	29.74	-1.15	0.07	-1.08
PriorDensity	266.97	256.27	246.28	-10.70	-9.99	-20.69
Tot-likelihood	-25346.5	-24521.6	-24539.4	824.88	-17.78	807.10
Tot-likeli-no-PD	-25613.5	-24777.9	-24785.7	835.58	-7.79	827.79
Tot-parameter	366	363	364	-3.00	1.00	-2.00
$MMB_{35\%}$	24324.64	22377.43	23565.61	-1947.22	1188.18	-759.03
MMB-terminal	15117.77	14690.78	11756.88	-426.99	-2933.90	-3360.88
$F_{35\%}$	0.298	0.298	0.297	0.00	0.00	0.00
F_{ofl}	0.173	0.184	0.132	0.01	-0.05	-0.04
OFL	2297.52	2356.41	1362.84	58.89	-993.57	-934.68
ABC	1838.02	1885.13	1090.27	47.11	-794.85	-747.74
NMFS Q	0.961	0.964	0.960	0.00	0.00	0.00
Mature females	10.294	10.470	7.998	0.18	-2.47	-2.30
Mohn's rho, 12yr	0.347	0.285	0.135	-0.06	-0.15	-0.21
Mohn's rho, 10yr	0.308	0.246	0.090	-0.06	-0.16	-0.22

Likelihood and parameter estimation:

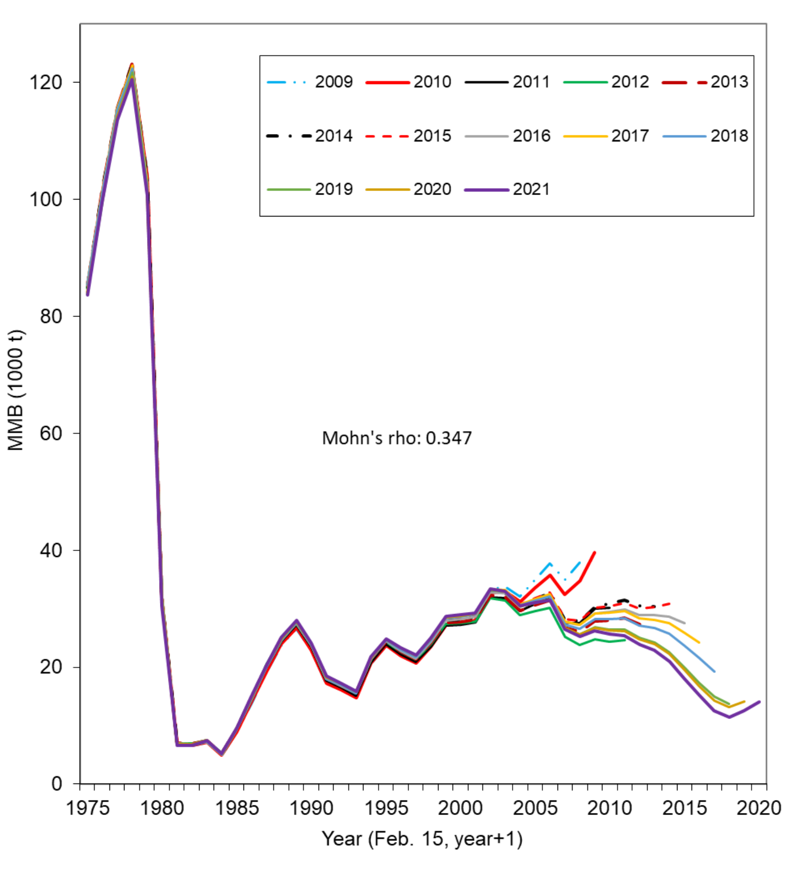
- 21.1b (closest to base model with GMACS and data updates)
- 22.1 – no BSFRF data
  - Reduction in Mohn's rho

Models	22.0	22.0a	22.0b	22.0c	22.0d	22.0e
Pot-ret-catch	-33.77	-35.02	-35.31	-36.83	-35.84	-36.51
Pot-totM-catch	26.95	25.21	24.79	23.17	24.32	23.76
Pot-F-discC	-53.96	-53.97	-53.97	-53.97	-53.96	-53.93
Trawl-discC	-49.89	-49.89	-49.89	-49.89	-49.89	-49.89
Tanner-M-discC	-26.12	-26.12	-26.12	-26.12	-26.12	-26.12
Tanner-F-discC	-26.08	-26.10	-26.09	-26.09	-26.07	-26.04
Fixed-discC	-34.65	-34.65	-34.65	-34.65	-34.65	-34.65
Trawl-suv-bio	-42.78	-45.92	-45.78	-45.60	-42.47	-58.52
BSFRF-sur-bio	-4.08	-5.06	-8.90			
Pot-ret-comp	-3077.50	-3076.20	-3076.53	-3076.72	-3074.10	-3074.42
Pot-totM-comp	-2299.43	-2300.56	-2301.01	-2302.70	-2301.75	-2301.75
Pot-discF-comp	-1394.68	-1395.23	-1395.21	-1394.83	-1394.31	-1394.13
Trawl-disc-comp	-4551.54	-4555.20	-4554.71	-4550.92	-4546.89	-4555.69
TC-disc-comp	-1273.30	-1276.01	-1276.21	-1276.15	-1273.33	-1273.81
Fixed-disc-comp	-3288.92	-3287.56	-3287.55	-3292.33	-3293.60	-3293.17
Trawl-sur-comp	-5364.11	-5373.73	-5373.89	-5371.44	-5361.80	-5350.07
BSFRF-sur-comp	-842.44	-844.72	-844.81			
Recruit-dev	40.97	41.44	41.52	40.88	40.61	40.32
Recruit-sex-R	58.98	58.98	58.97	59.03	59.03	59.08
M-deviation	0.00	0.00	0.00	0.00	0.00	2.43
Sex-specific-R	0.16	0.19	0.18	0.25	0.20	0.24
Ini-size-struct.	53.90	55.68	55.73	55.70	51.14	51.28
PriorDensity	233.10	221.11	223.61	209.61	221.55	209.45
Tot-likelihood	-21949.2	-21983.3	-21985.8	-21149.6	-21117.9	-21142.2
Tot-likeli-no-PD	-22182.3	-22204.4	-22209.5	-21359.2	-21339.5	-21351.6
Tot-parameter	302	303	304	300	299	300
$MMB_{35\%}$	22140.56	19757.11	19477.53	19801.19	22071.25	23629.49
MMB-terminal	15507.25	14231.05	13760.88	13910.34	14904.71	11491.02
$F_{35\%}$	0.299	0.390	0.386	0.384	0.299	0.298
F_{ofl}	0.200	0.269	0.260	0.257	0.191	0.128
OFL	2718.29	3278.66	3068.35	3038.05	2475.48	1293.32
ABC	2174.63	2622.93	2454.68	2430.44	1980.38	1034.65
NMFS Q	0.931	0.918	0.931	0.925	0.939	0.934
BSFRF Q	1.000	1.000	1.359			
Mature females	11.210	11.560	11.160	11.543	11.256	8.328
Mohn's rho, 12yr	0.376			0.235	0.329	0.135
Mohn's rho, 10yr	0.343			0.199	0.287	0.086

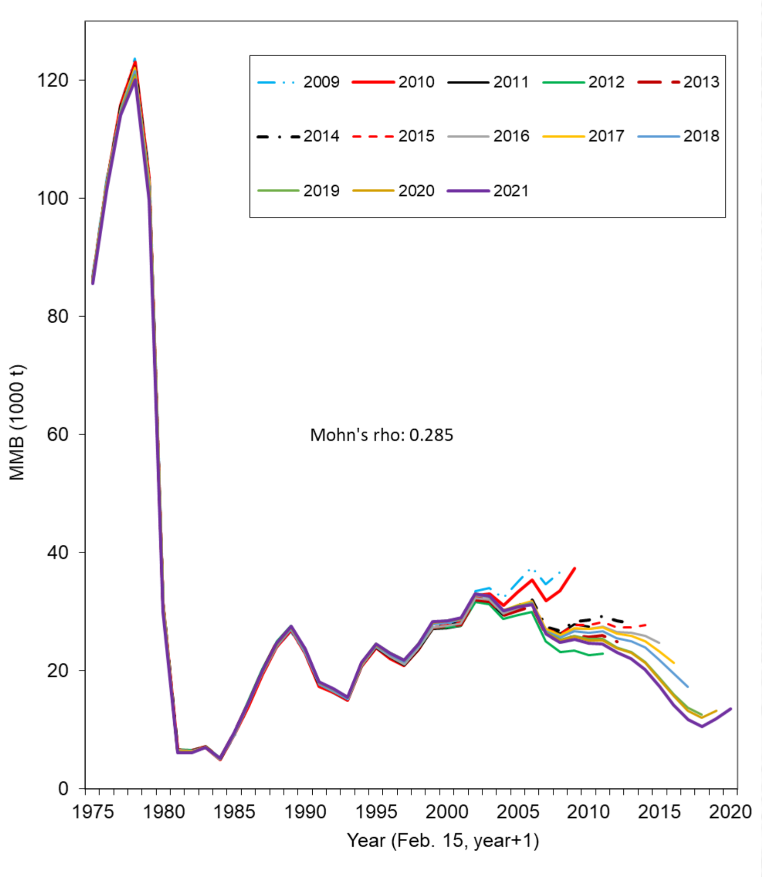
- Models that start at 1985
- 22.0 (closest to base)
- 22.0d (no BSFRF data)

Retrospective patterns for MMB for recommended models

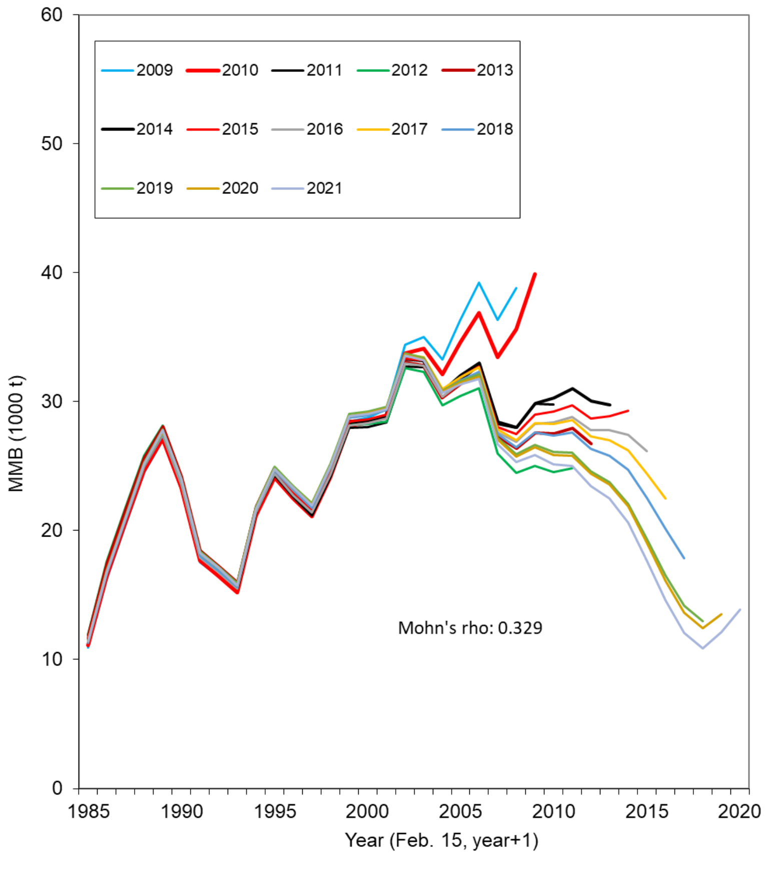
Model 21.1b

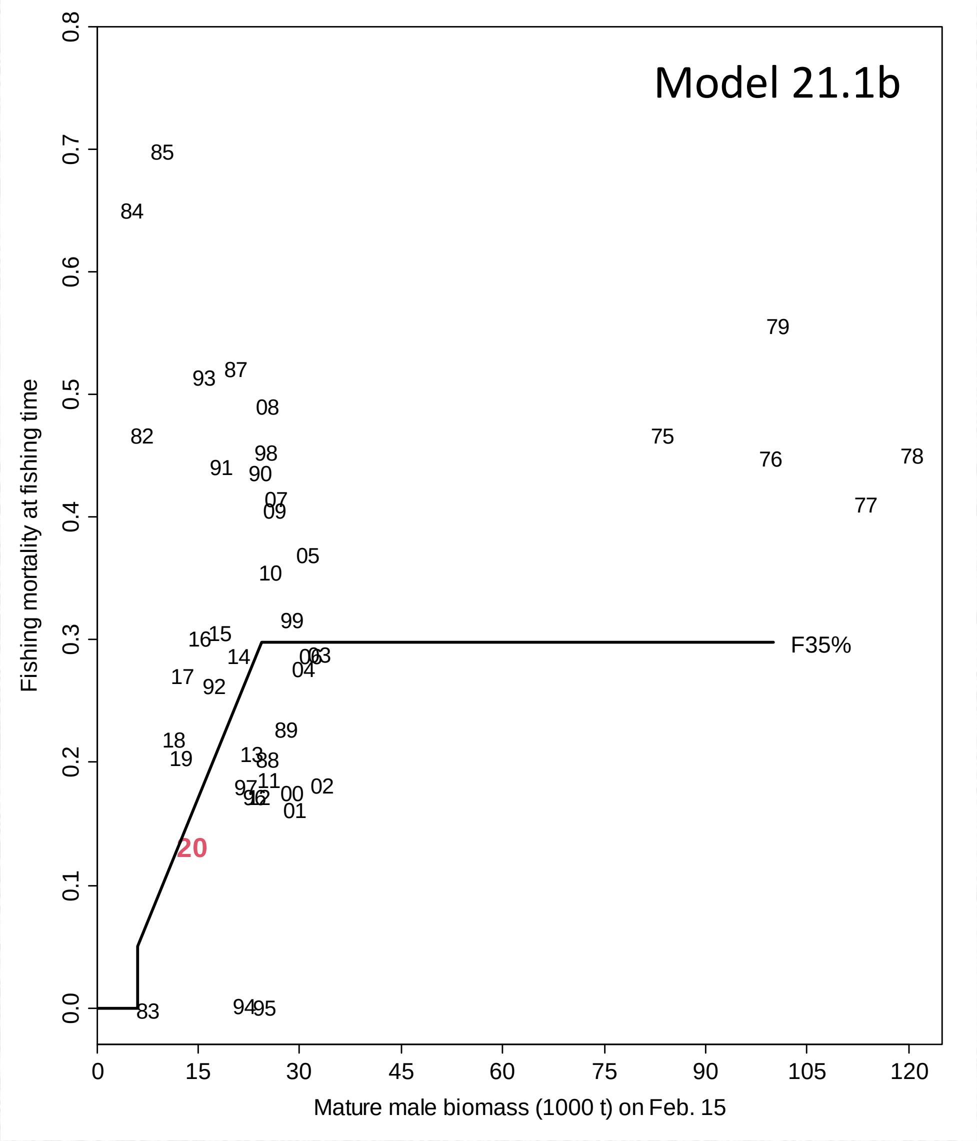


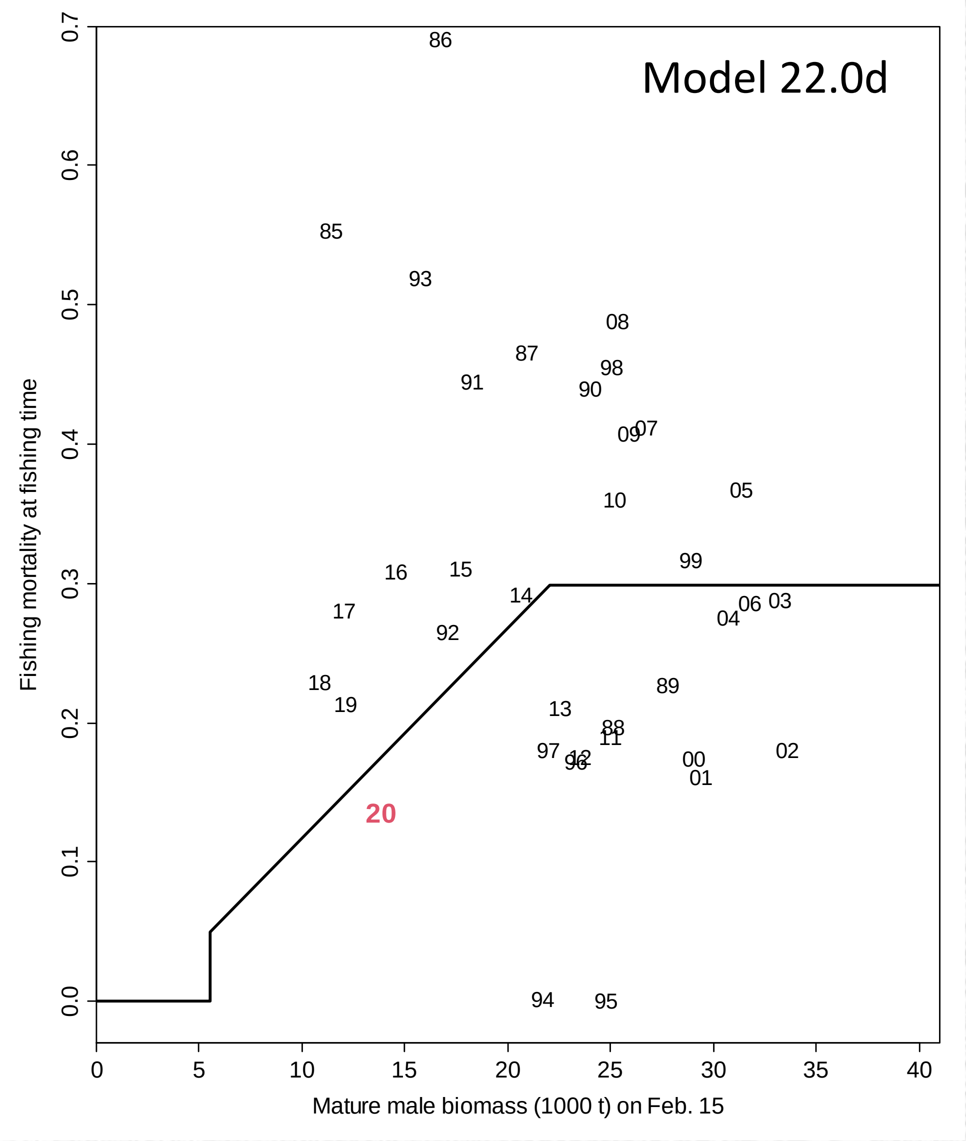
Model 22.1



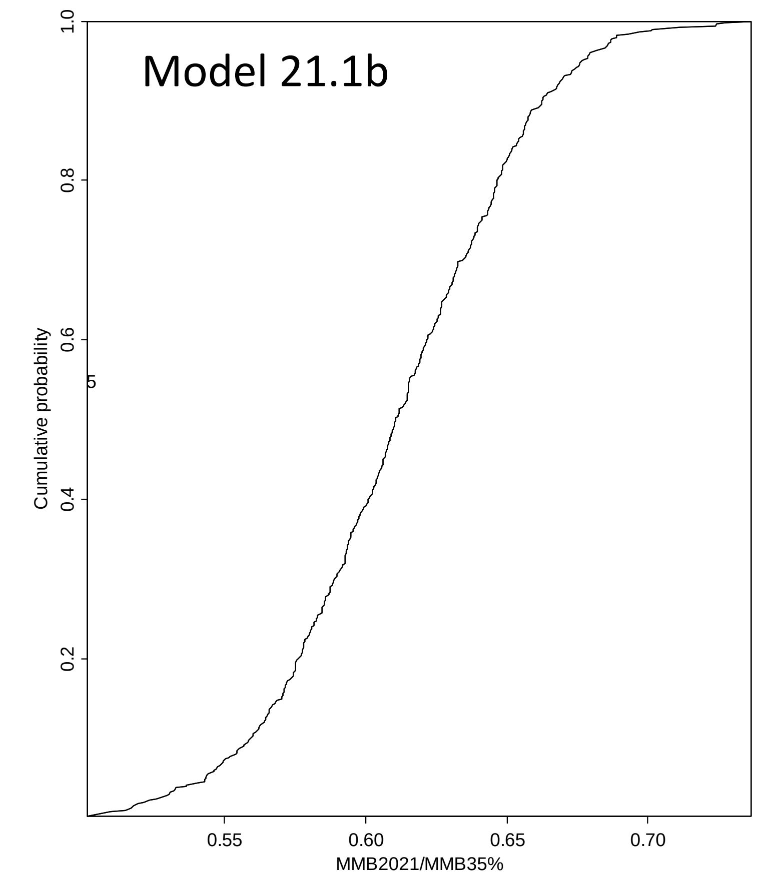
Model 22.0d

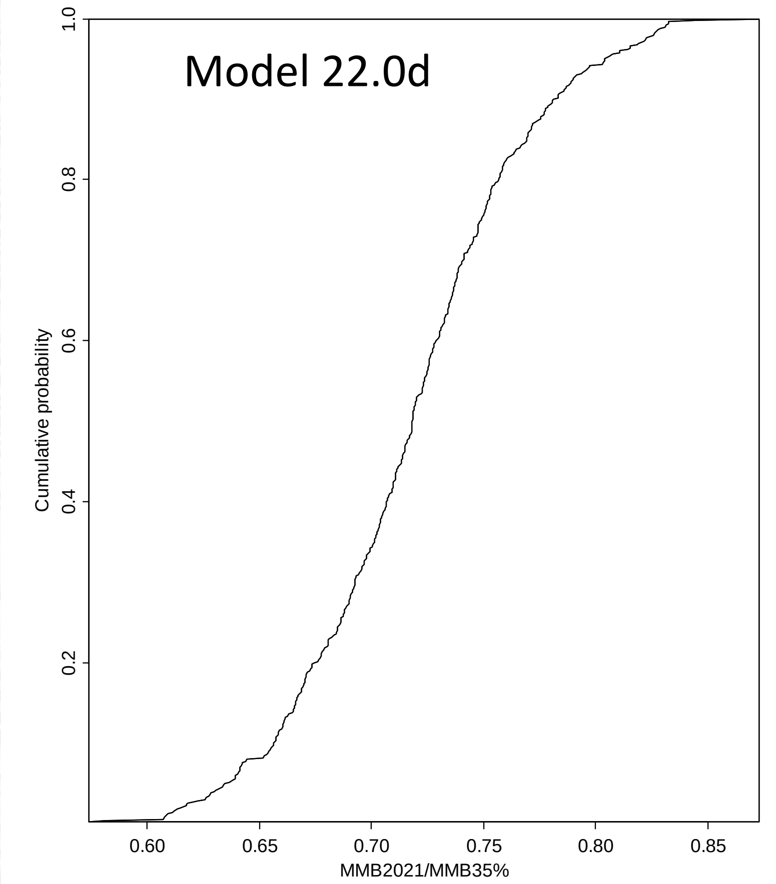


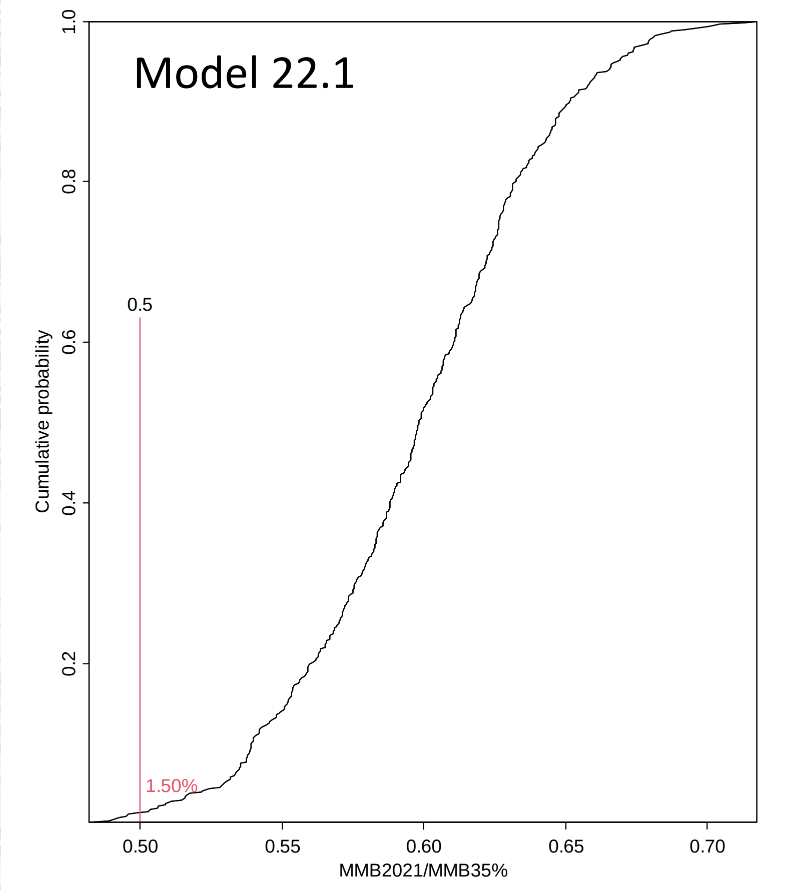

Model 21.1b
Fishing mortality at fishing time
Mature male biomass (1000 t) on Feb. 15
F35%
20


Model 22.0d
Fishing mortality at fishing time
Mature male biomass (1000 t) on Feb. 15
20

Approaching overfishing projections:
Cumulative probabilities of estimated ratios of MMB on Feb. 15, 2022, to corresponding estimated $B_{35\%}$ values with the MCMC approach.







Summary

- 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
- Estimating M results in higher M and higher F35%, confounding issues
- Estimating Q for BSFRF data >1.0, not much difference
- Dropping BSFRF data allows for better fits to other data and reduces some retrospective (Mohn's rho decreased)
- Extra time block – fits recent NMFS survey data better, reduces retrospective
- Two factors in model choice:
  - Assumption of BSFRF survey catchability
  - Estimation of M

Recommendations

- Model 22.0d
  - Fixed M of 0.18 for males
  - Less confounding between estimating M and survey catchability
  - Avoids dramatic abundance decline of early 1980s
  - No recruitment associated with extremely high M being used for estimating $B_{35\%}$
- Runner up: Model 22.1
  - Base model with BSFRF data removed
  - Still starts in 1975 and has spike in M 80-84 for males/females