Bristol Bay red king crab

Final SAFE

September 2023

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ADF&G

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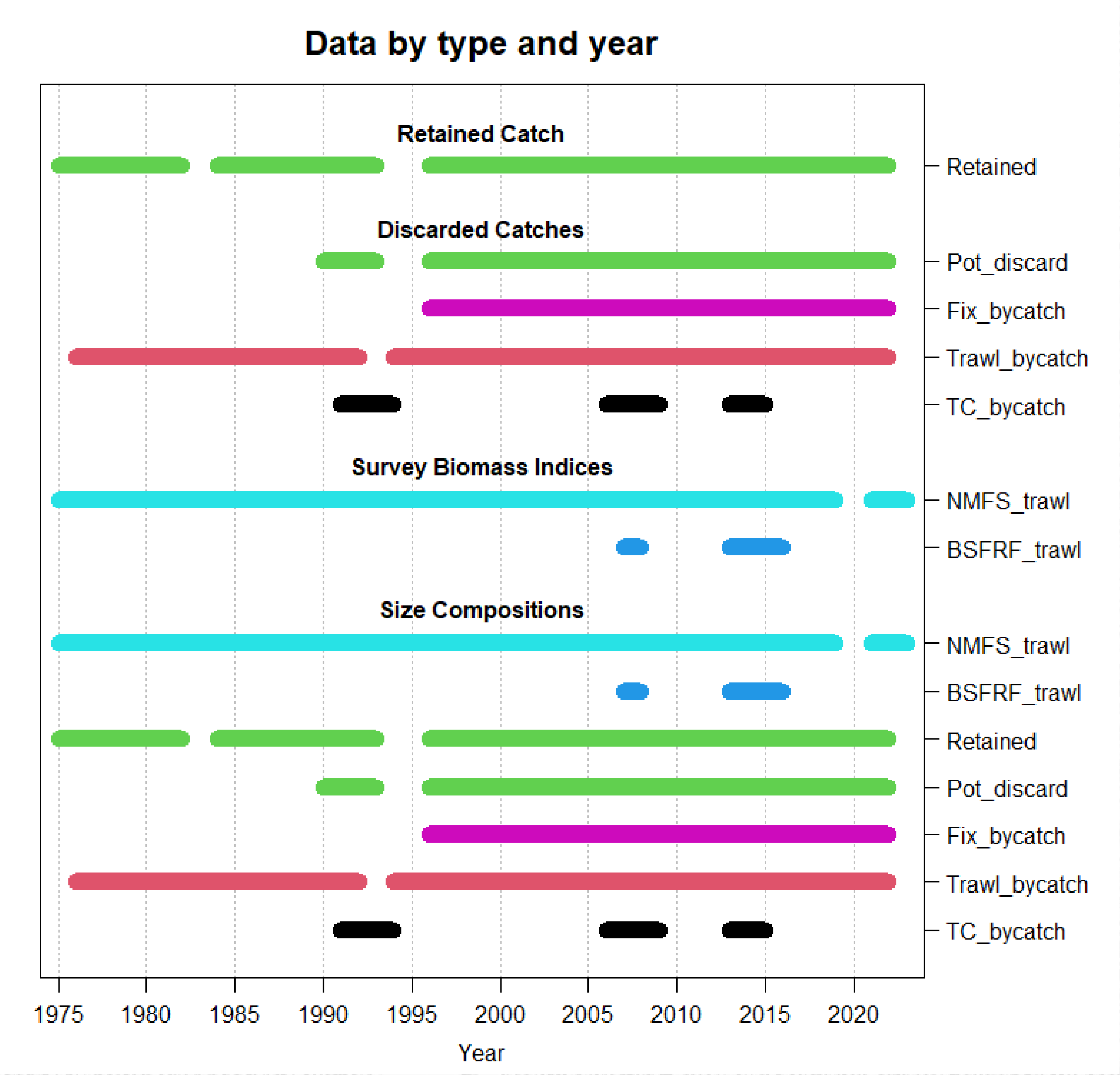
Summary

- Mature male biomass decreased from 2022, still low compared to long term average
- Directed fishery was closed in 2021/22 and 2022/23 seasons due to low mature female abundance.
- Estimated mature female biomass is higher recent years but still lower than it's been since the mid-90s
- 2023 area-swept and State of Alaska LBA model estimates of female abundance are above the State Harvest strategy thresholds (8.4 million) this year.
  - ADF&G will complete the process of determining an appropriate TAC, if applicable, after the CPT and Council process.
- Low recruitment in recent years (last 8-12 years), projected decline in biomass without a large recruitment event

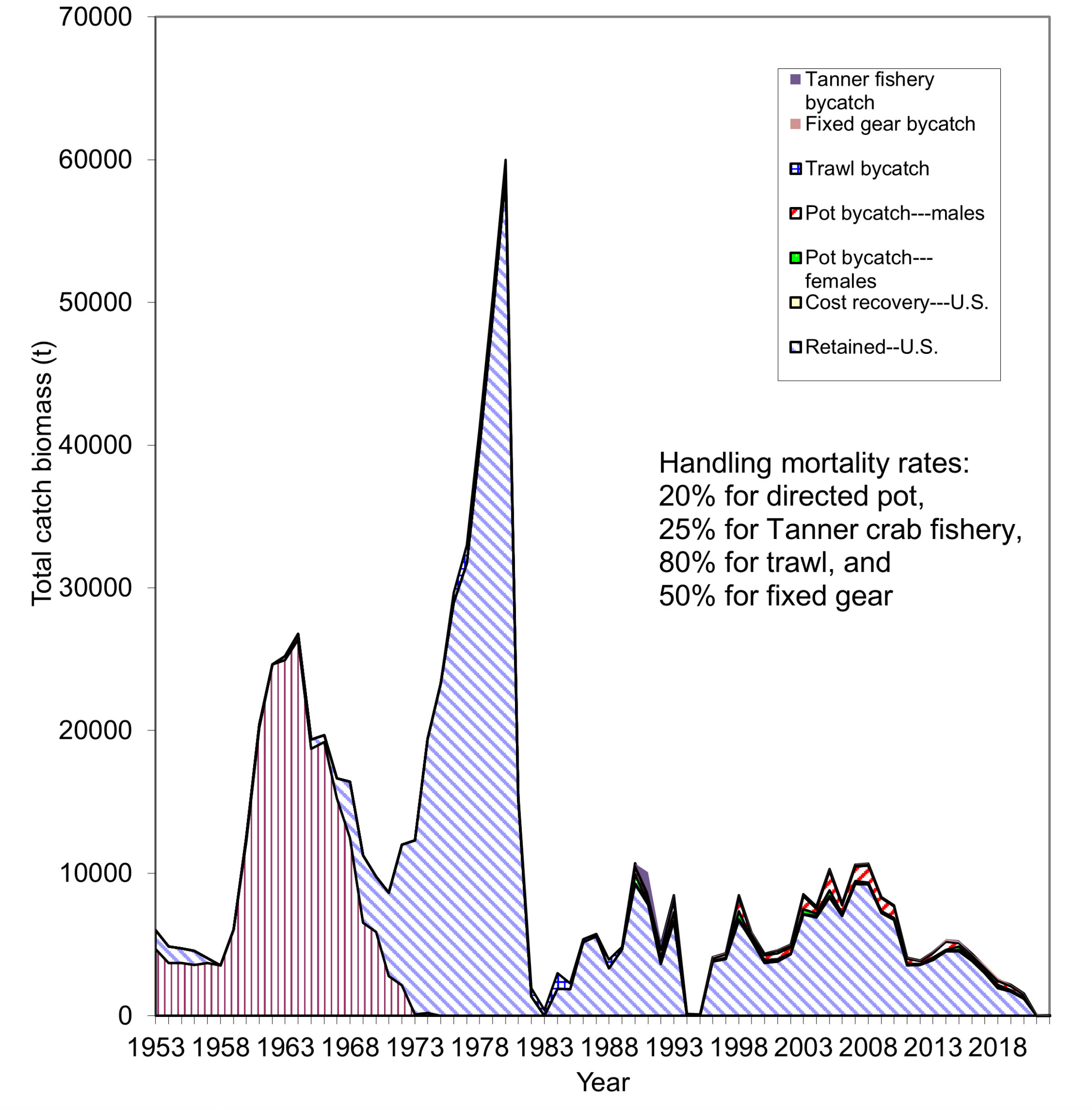
CPT / SSC comments

- Comments on document formatting were addressed this cycle
- Bering Sea red king crab stock structure template finalized
- Many addressed in May 2023, work will be continued for 2024 proposed model work
  - Growth
  - Q
  - BSFRF data used as a prior on Q
- Focus here on models recommended for specification in May 2023

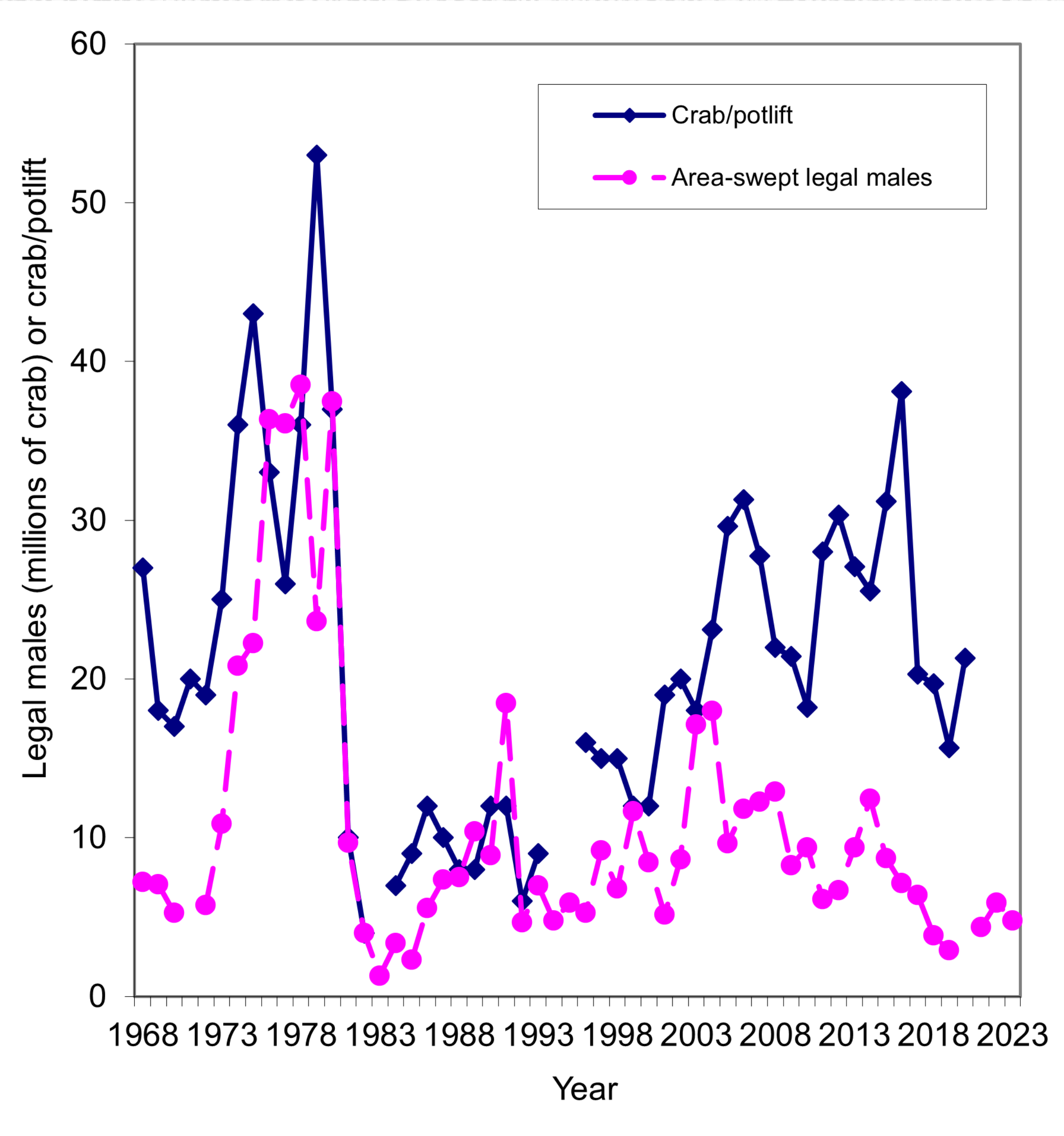
Data extent and new data for 2023



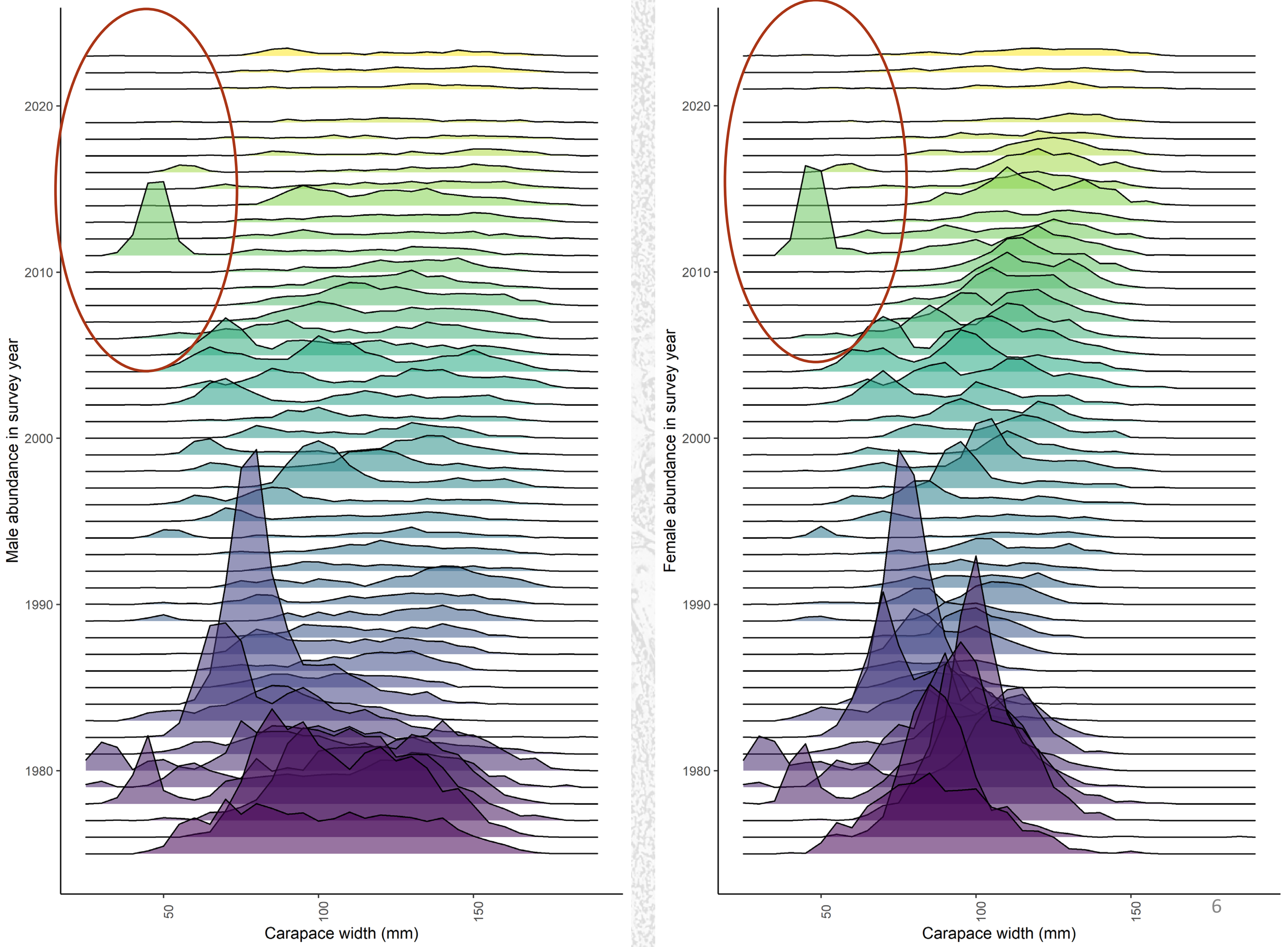
Retained and bycatch mortality (t)



Survey legal male abundance and CPUE for directed BBRKC fishery



Length composition from NMFS survey



Model explorations

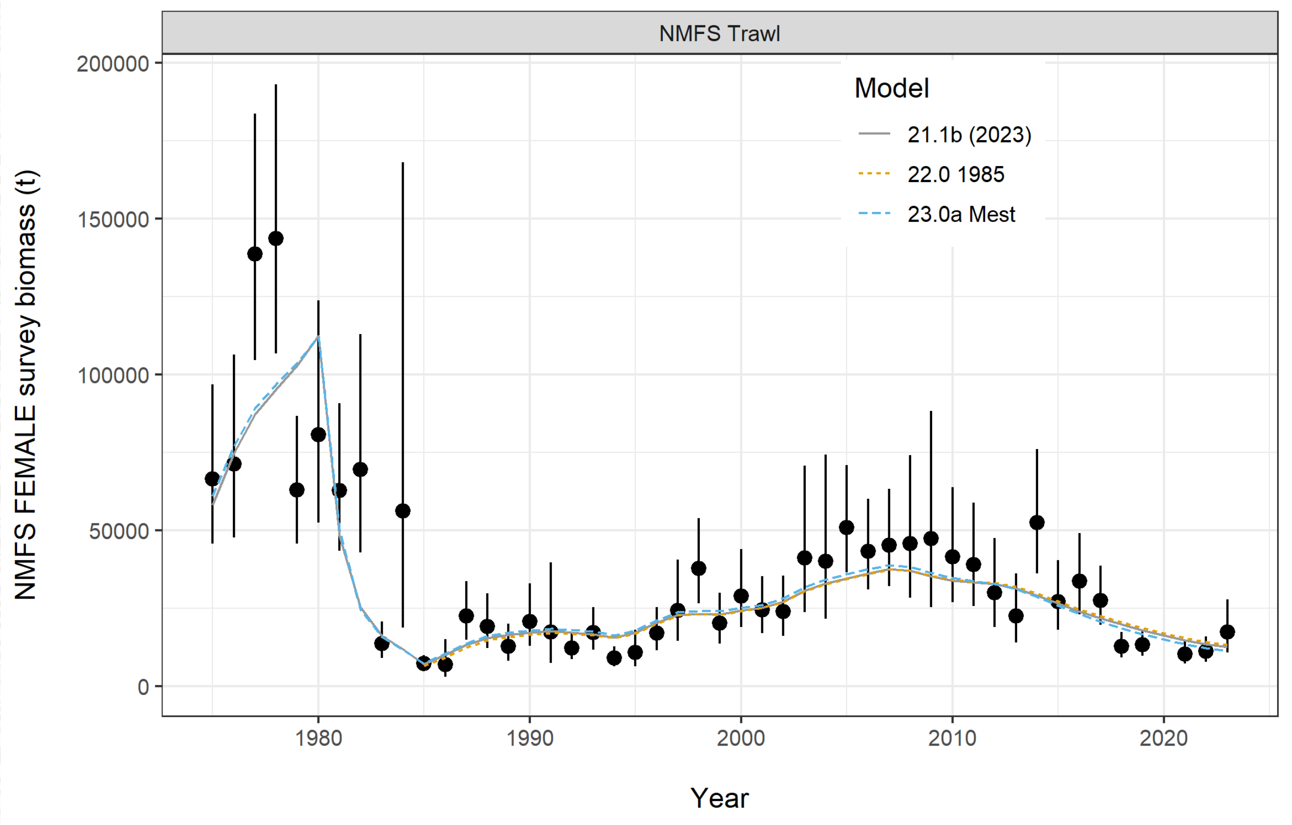
21.1b: 2022 model has base M for males fixed at 0.18, starts in 1975, mortality event in 80s, stable in GMACS since 2018

+ **GMACS updated version** (version 2.01.M.01, 2023-03-13)

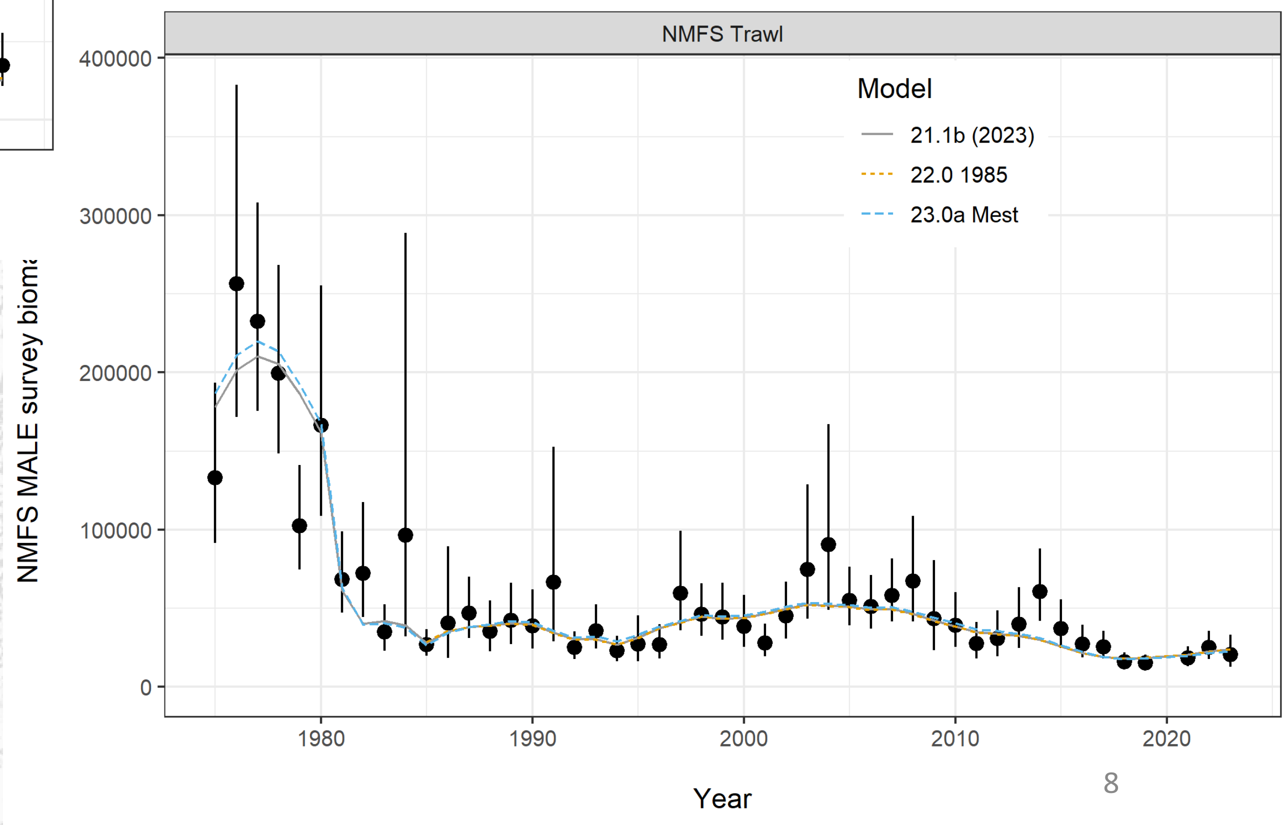
+ **New 2022/23 data** (fishery, bycatch, survey, etc.).

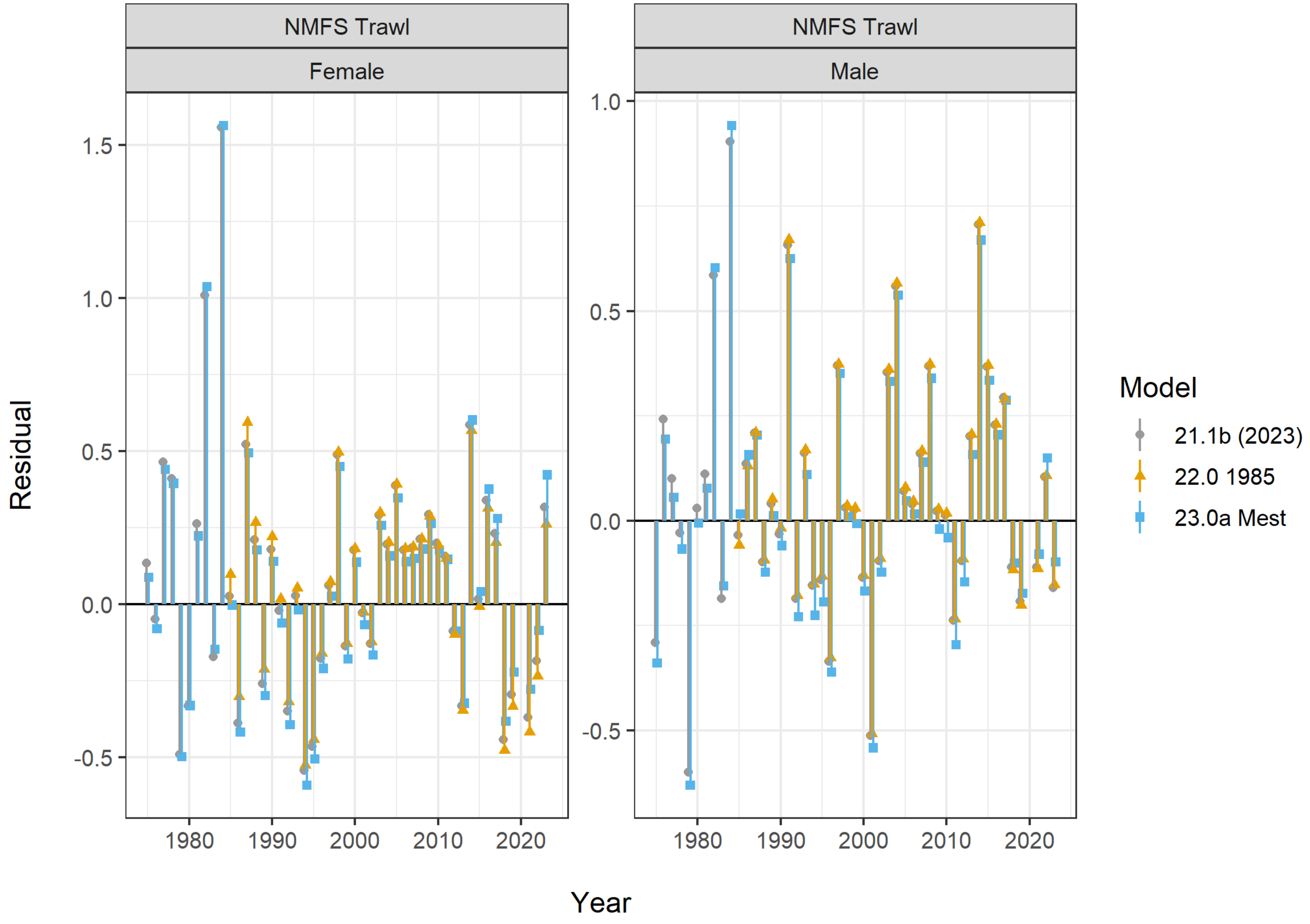
23.0a: model 21.1b + base M for males *estimated* in the model

22.0: model 21.1b + starting in 1985.

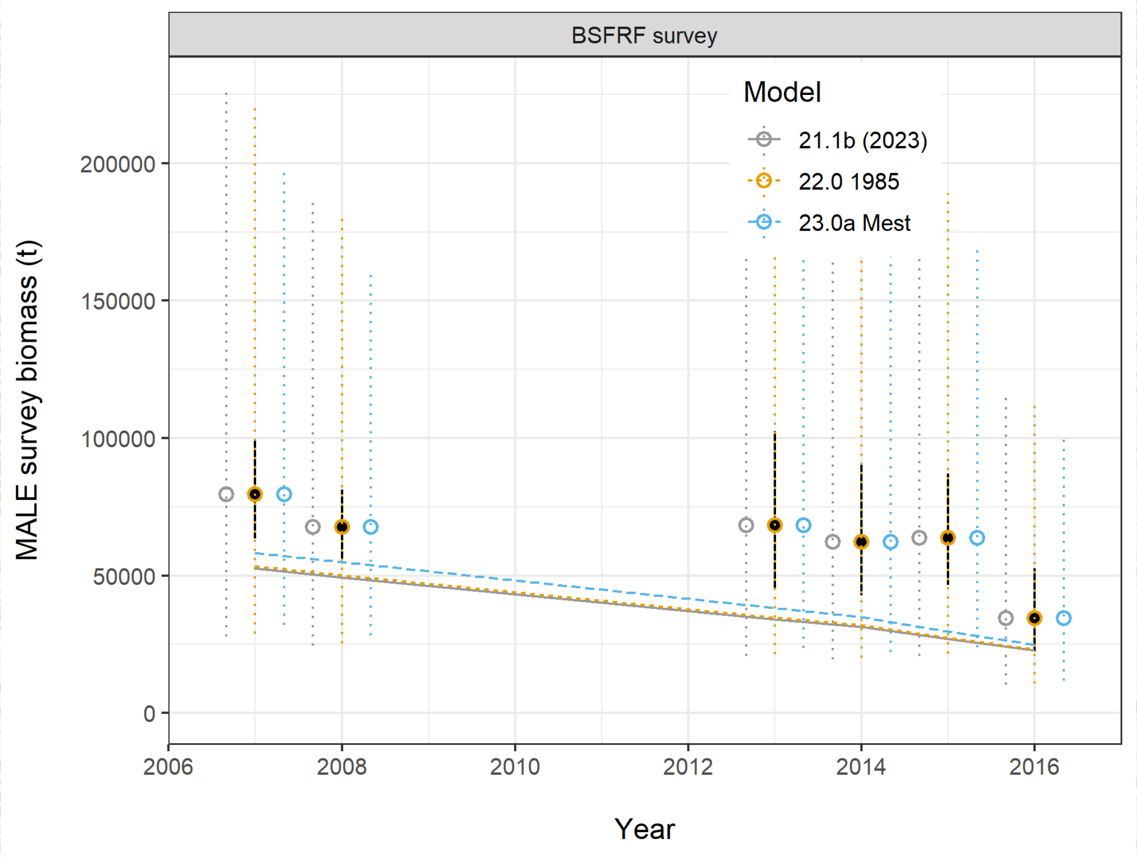


- Model fits to survey data are similar in all 3 models.

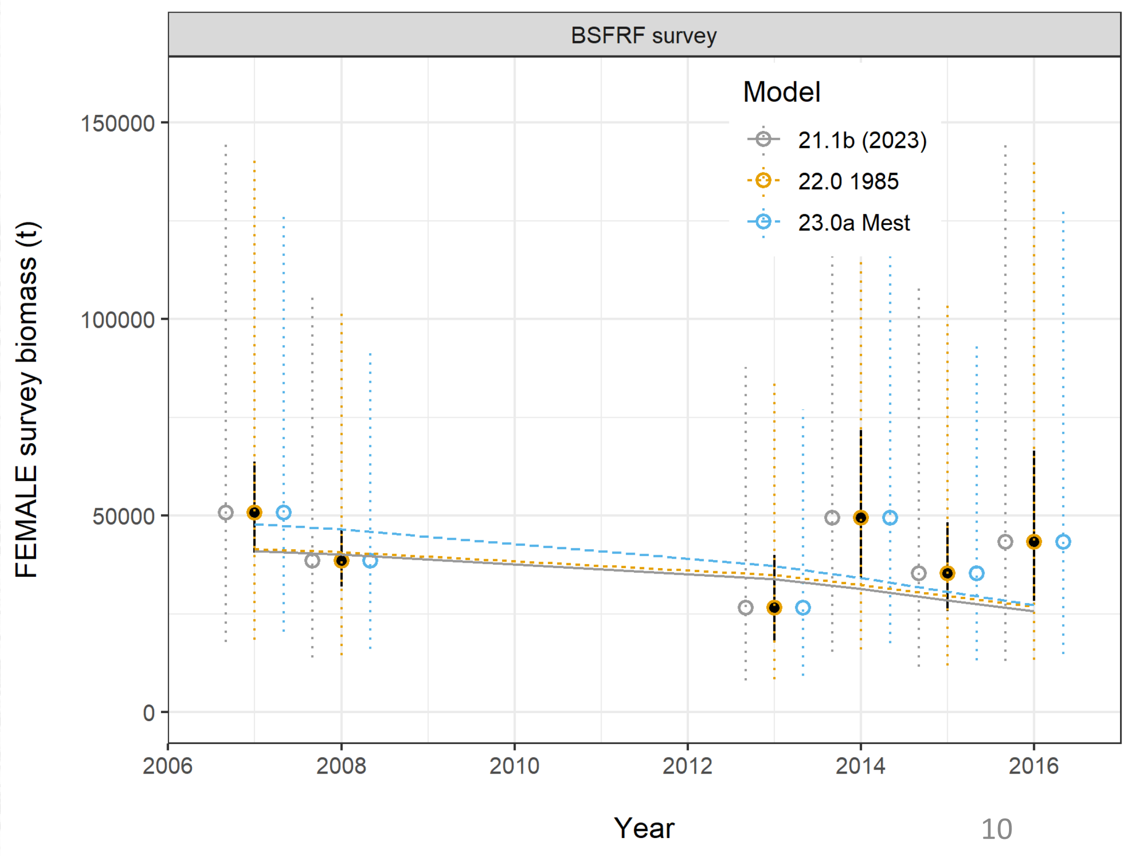




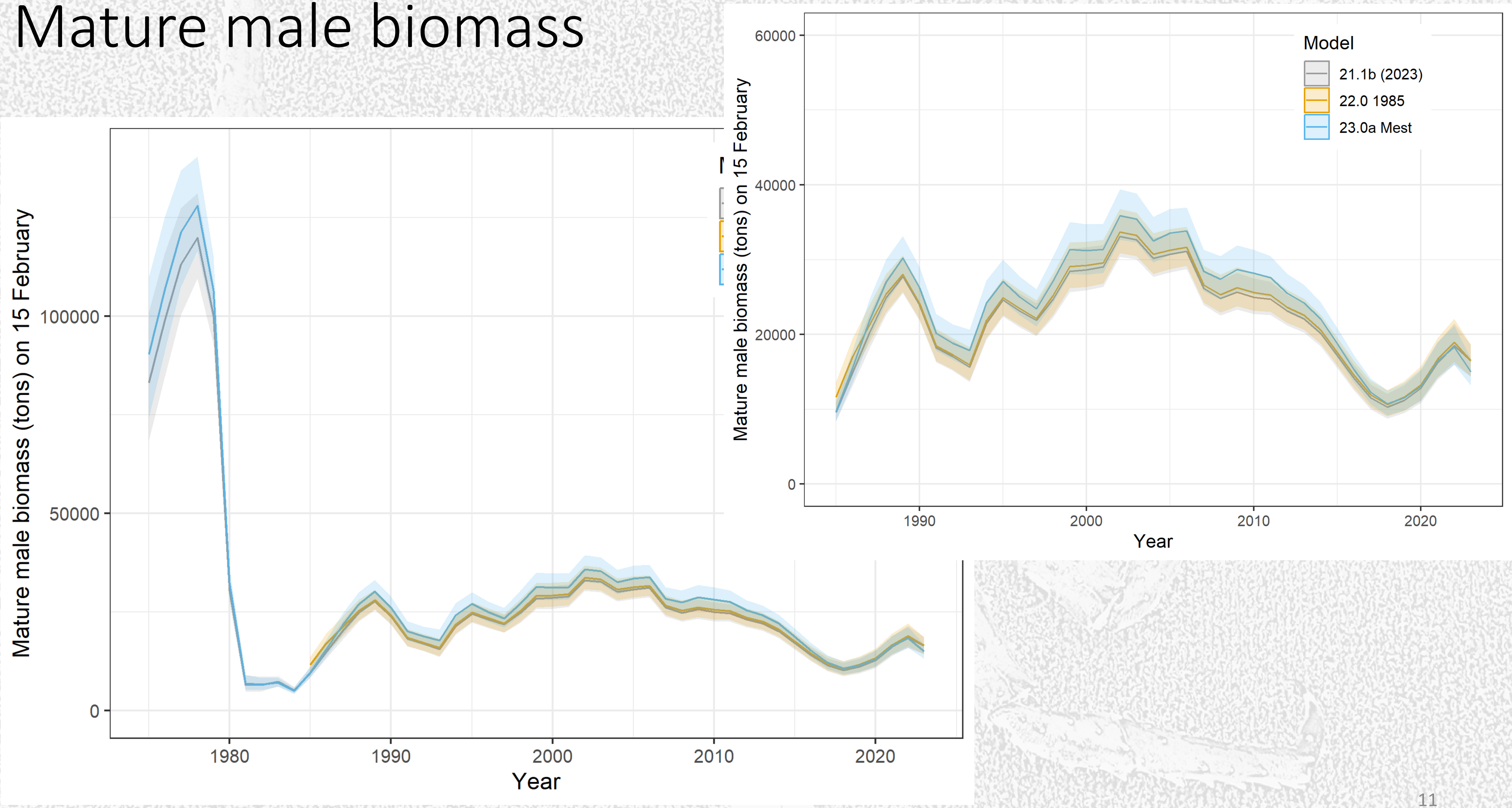
Residuals of total NMFS survey biomass



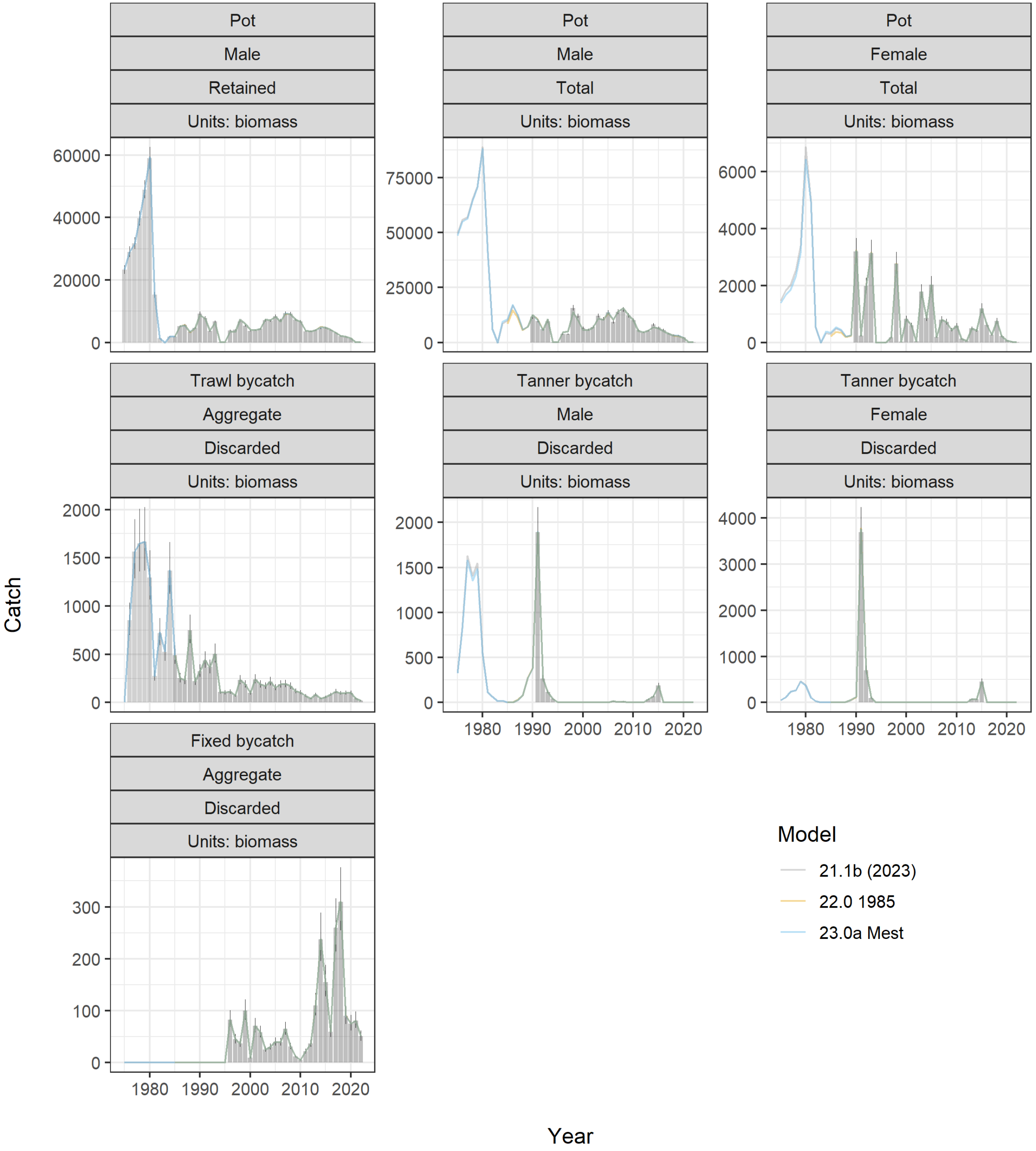
- Error bars show additional error
- BSFRF survey catchability is assumed to be 1.0
- Similar fits



Mature male biomass



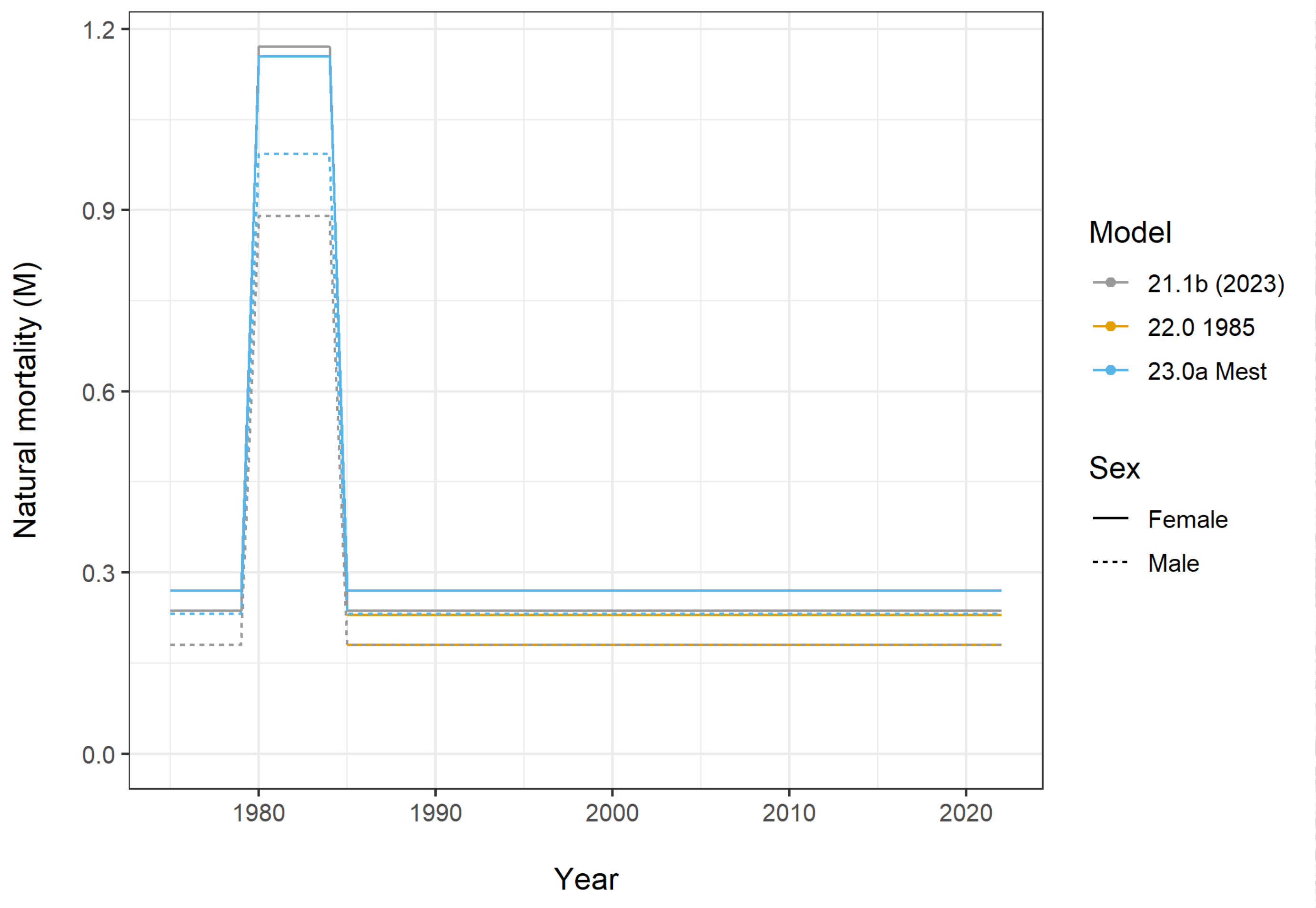
Mortality biomass (equal to catch biomass times handling mortality rate)

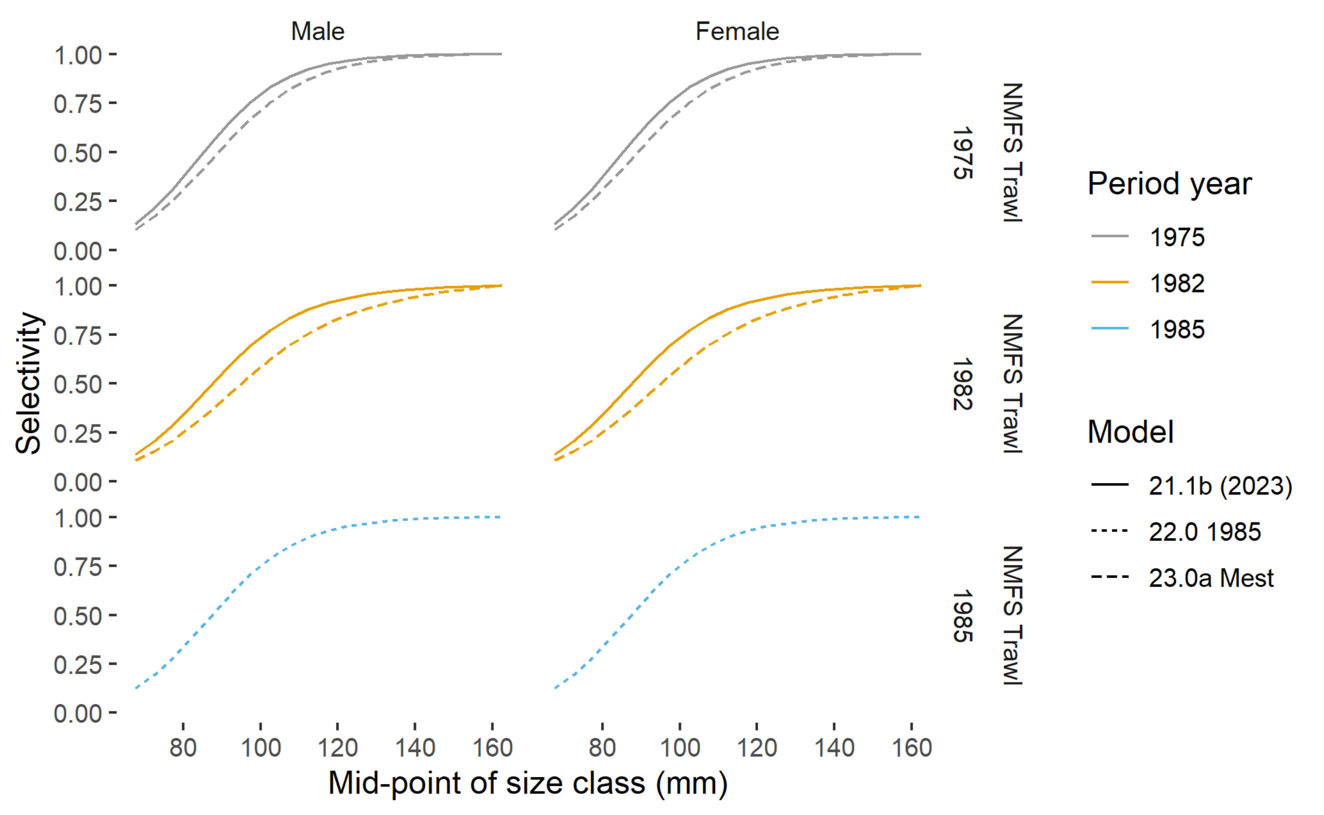


Natural Mortality

Table 14. Natural mortality estimates for three model scenarios during different year blocks.

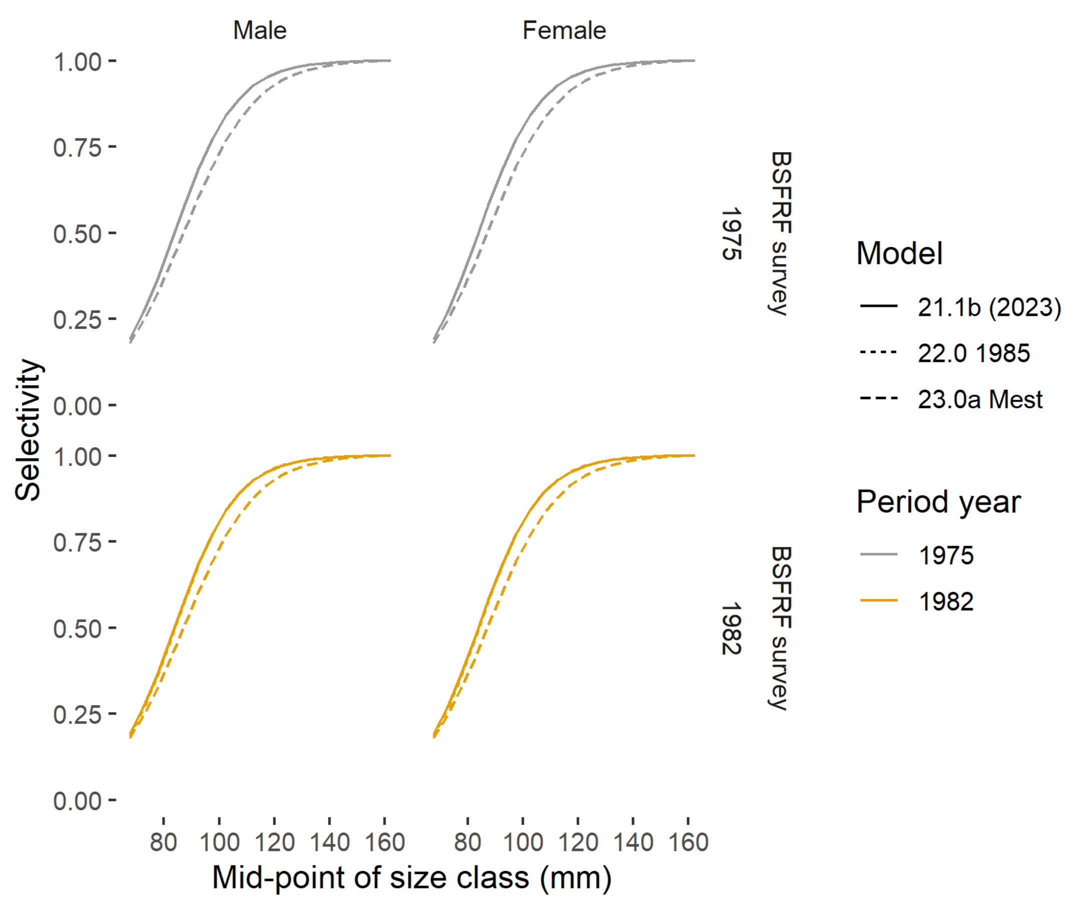
Model	Sex	1975-1979, 1985-2022	1980-1984	1985-2022
21.1b	Females	0.24	1.17	
	Males	0.18	0.89	
22.0	Females			0.23
	Males			0.18
23.0a	Females	0.27	1.15	
	Males	0.23	0.99	



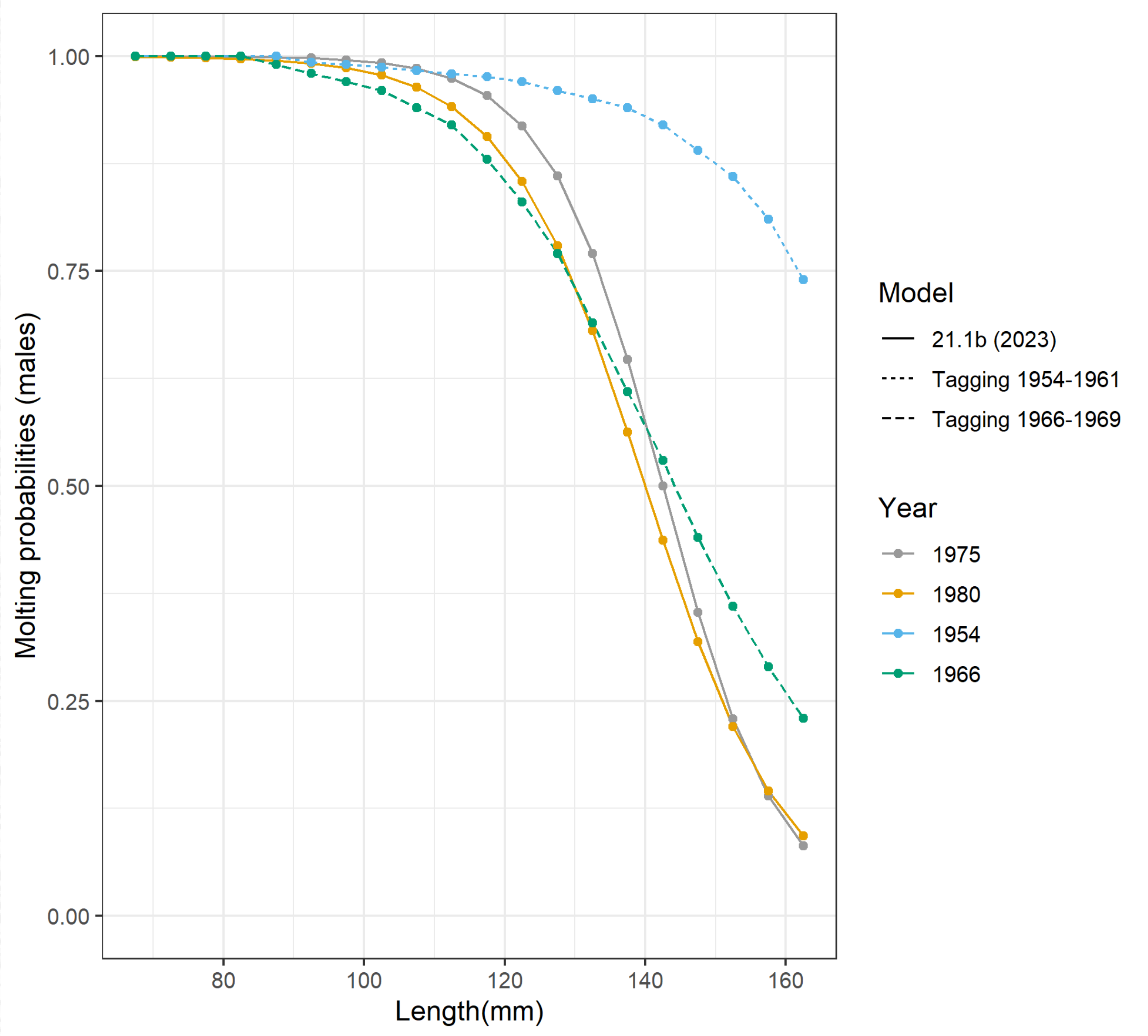


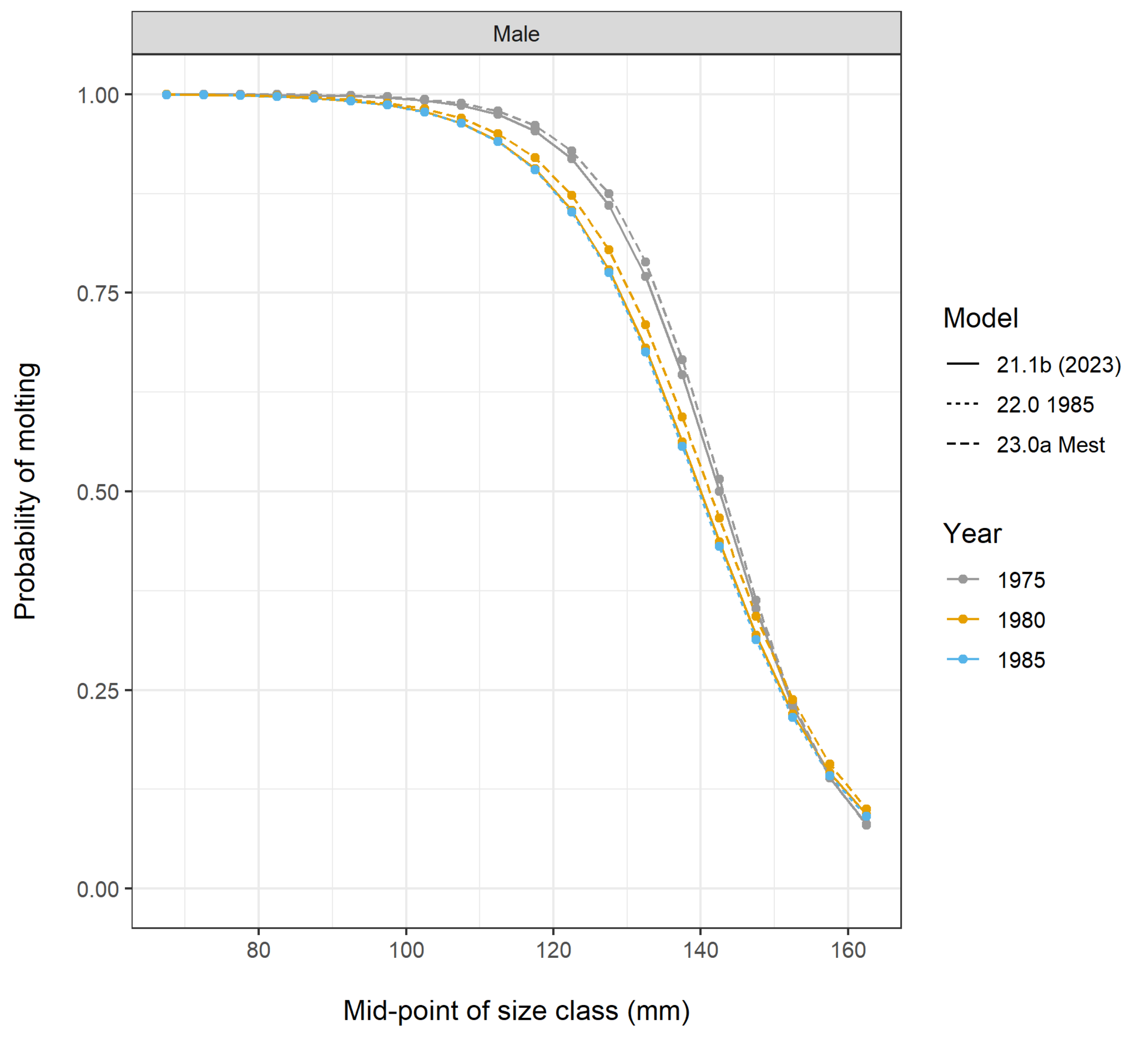
Survey selectivity:

- 23.0a (estimated base M)
  - largest difference
  - interplay between M and Q



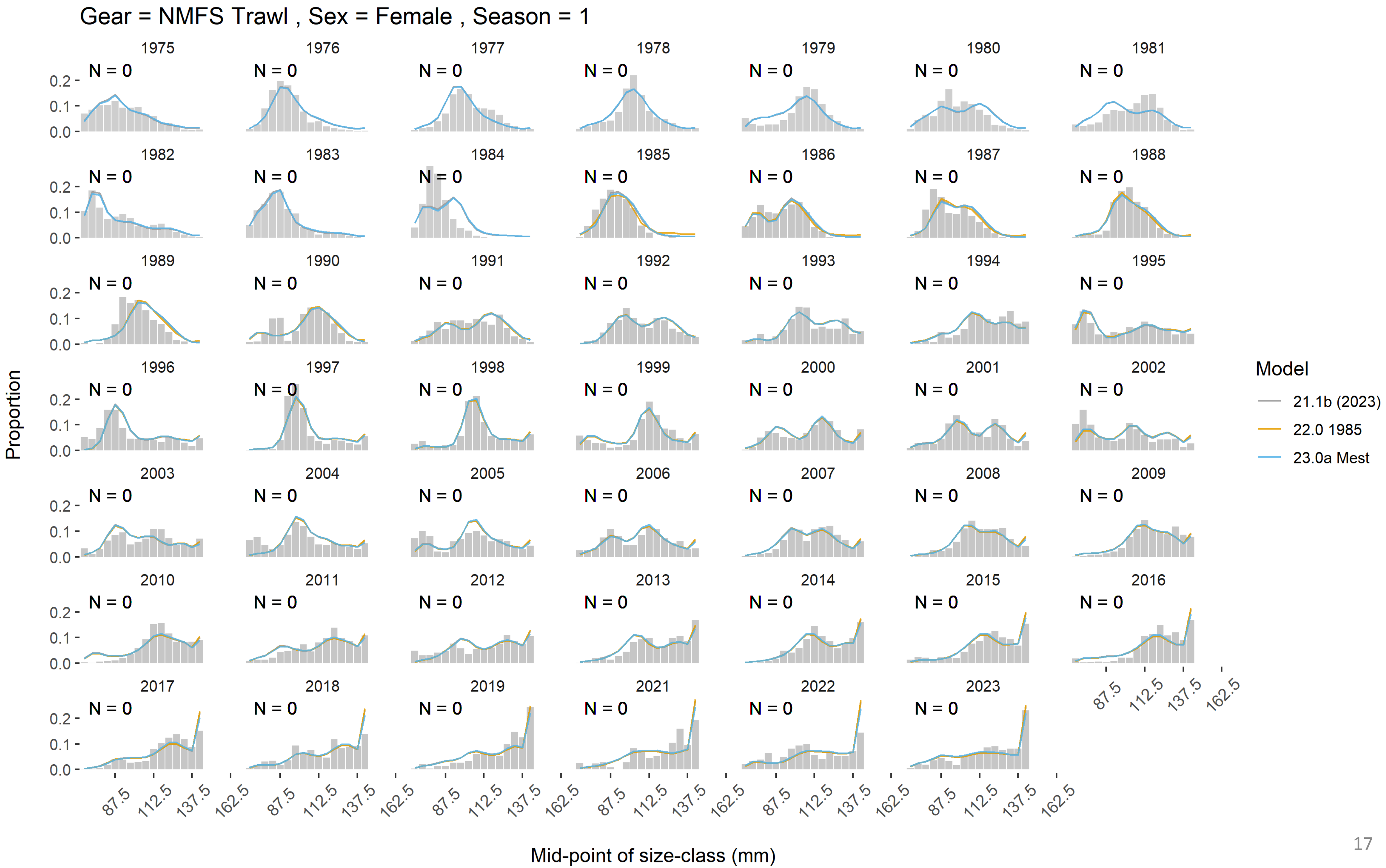
Molting probabilities



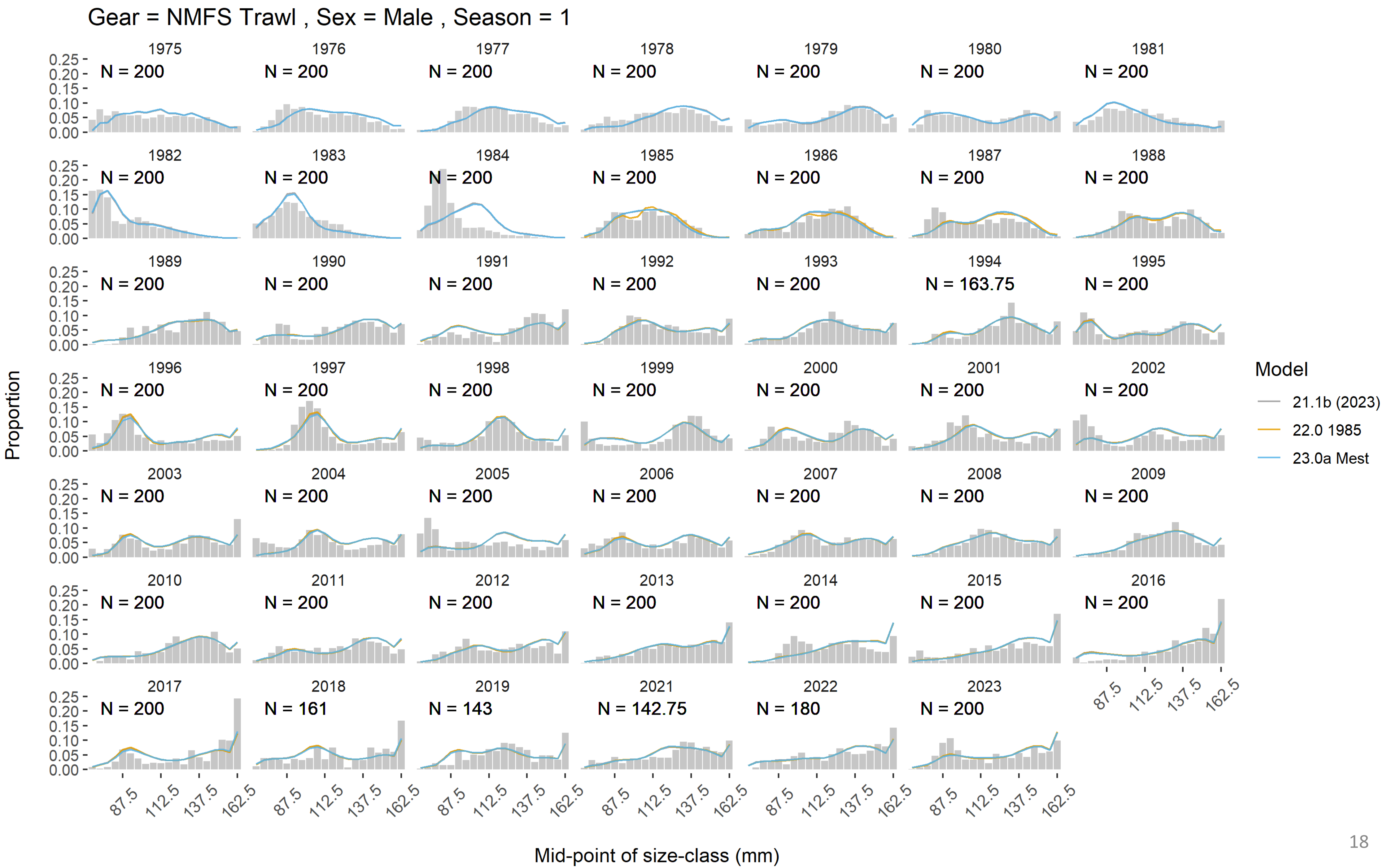


Size composition fit

- Similar for all models in bycatch and directed fisheries
  - See document for all size composition fits
- Survey data suggests some build up of plus group since 2014 in size comps, expected with low recruitment

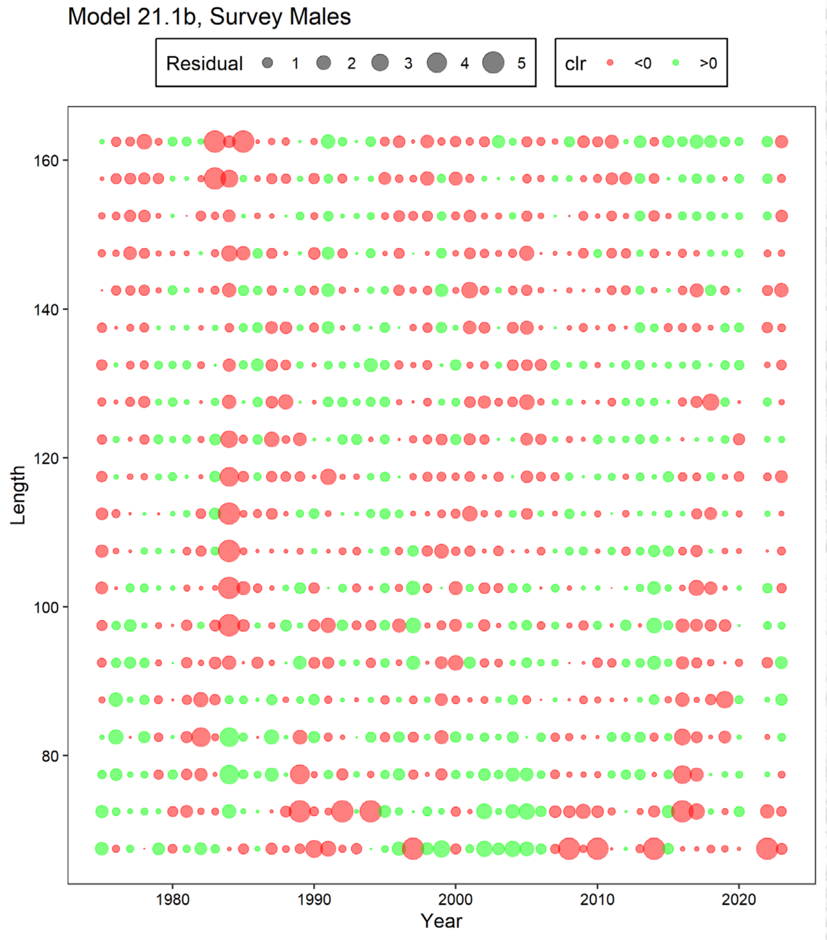


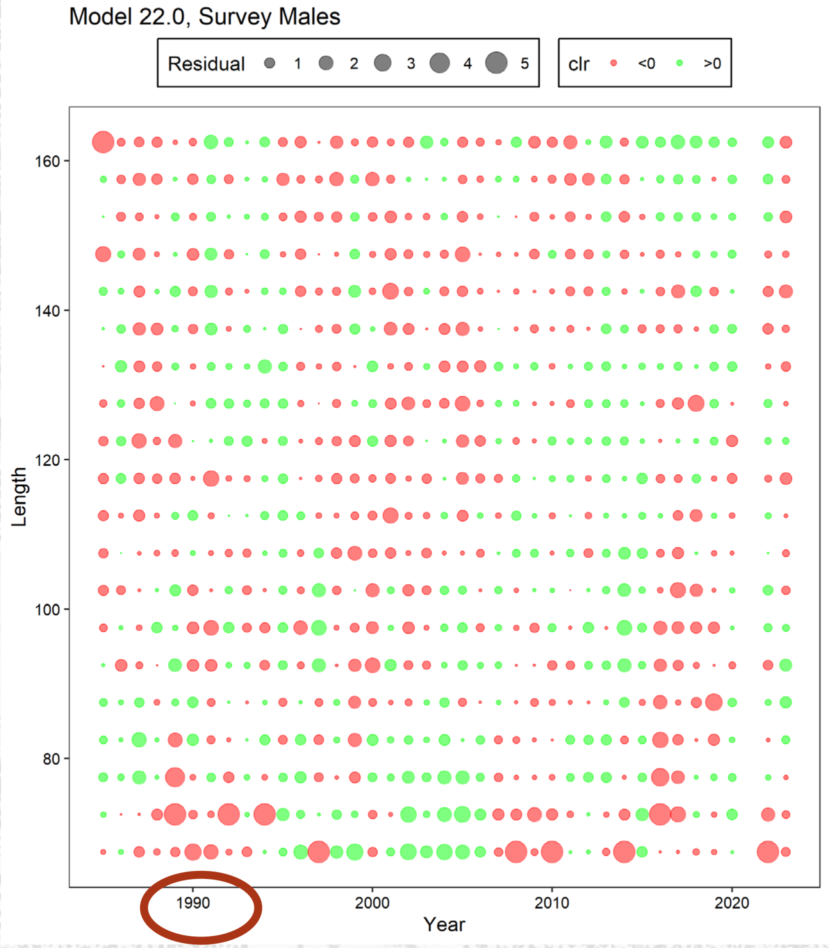
Gear = NMFS Trawl , Sex = Female , Season = 1
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2021
2022
2023
N = 0
Proportion
0.0
0.1
0.2
87.5
112.5
137.5
162.5
Mid-point of size-class (mm)
Model
21.1b (2023)
22.0 1985
23.0a Mest

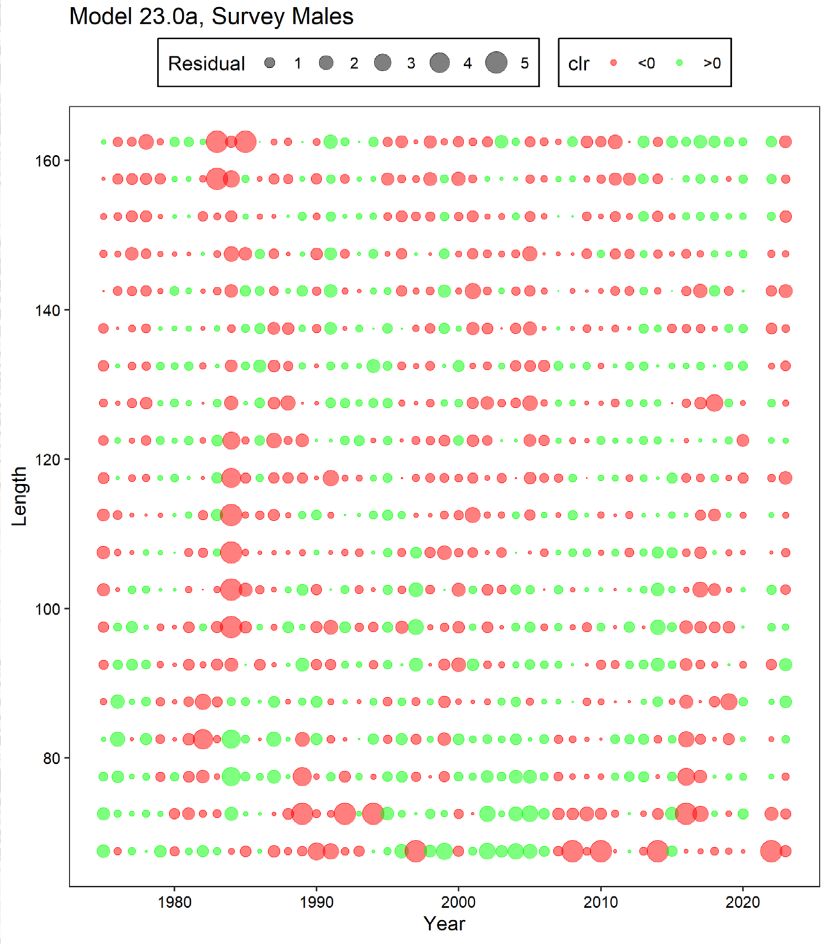


Gear = NMFS Trawl , Sex = Male , Season = 1
1975 N = 200
1976 N = 200
1977 N = 200
1978 N = 200
1979 N = 200
1980 N = 200
1981 N = 200
1982 N = 200
1983 N = 200
1984 N = 200
1985 N = 200
1986 N = 200
1987 N = 200
1988 N = 200
1989 N = 200
1990 N = 200
1991 N = 200
1992 N = 200
1993 N = 200
1994 N = 163.75
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
2023 N = 200
Proportion
0.00 0.05 0.10 0.15 0.20 0.25
87.5 112.5 137.5 162.5
Mid-point of size-class (mm)
Model
21.1b (2023)
22.0 1985
23.0a Mest

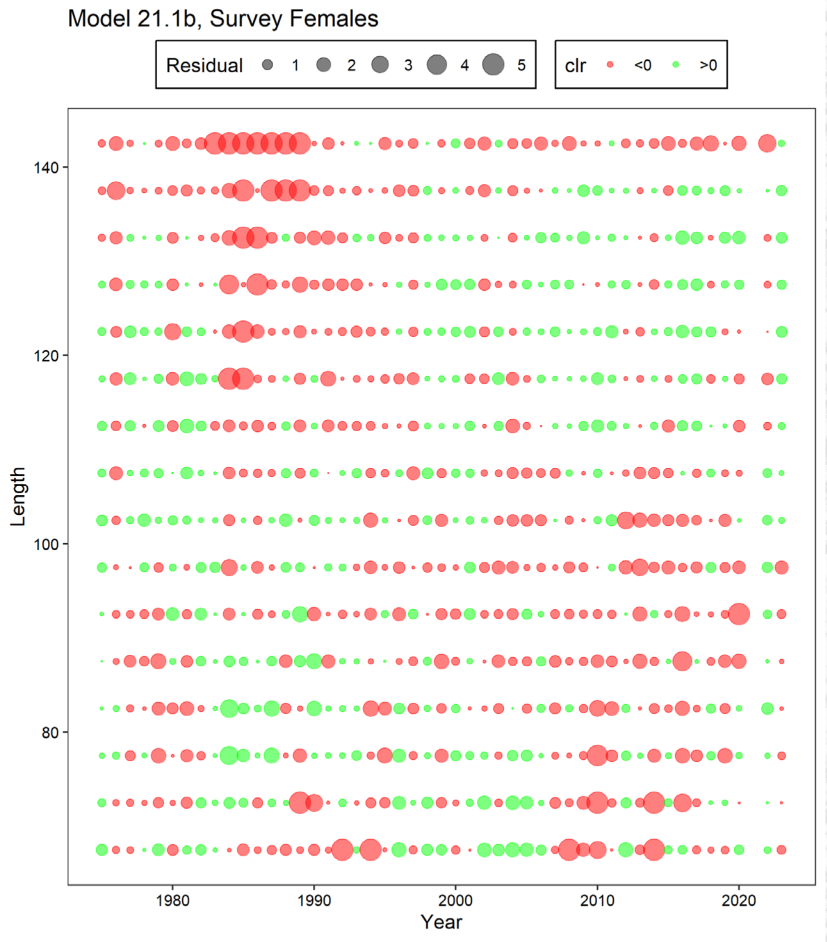
Comparison of residuals for NMFS survey males

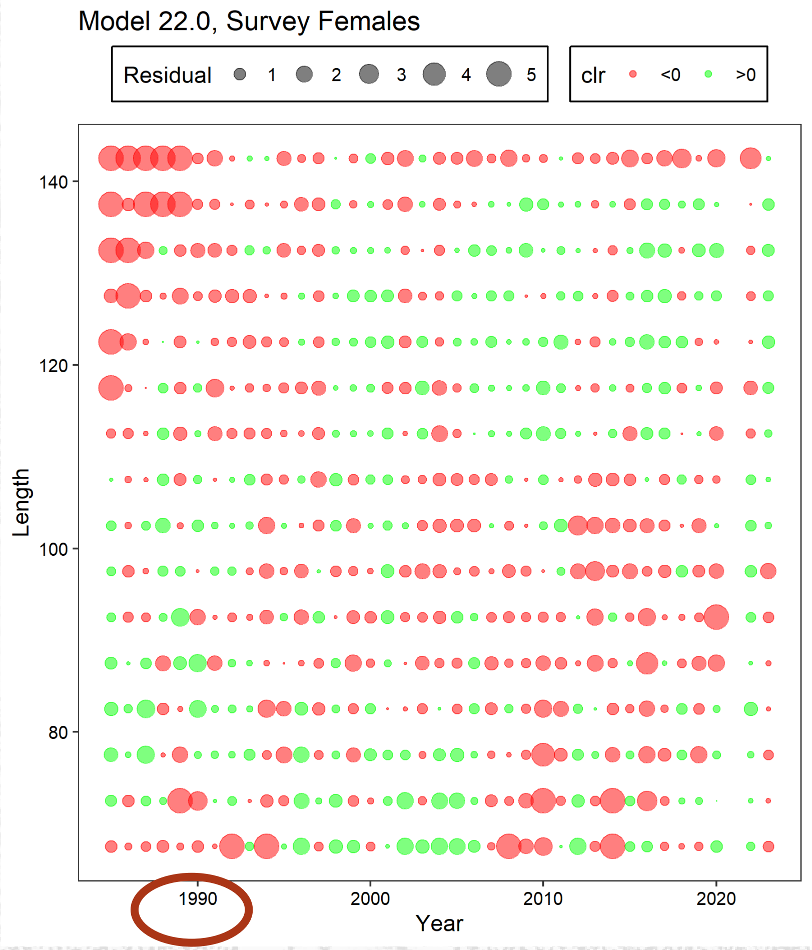


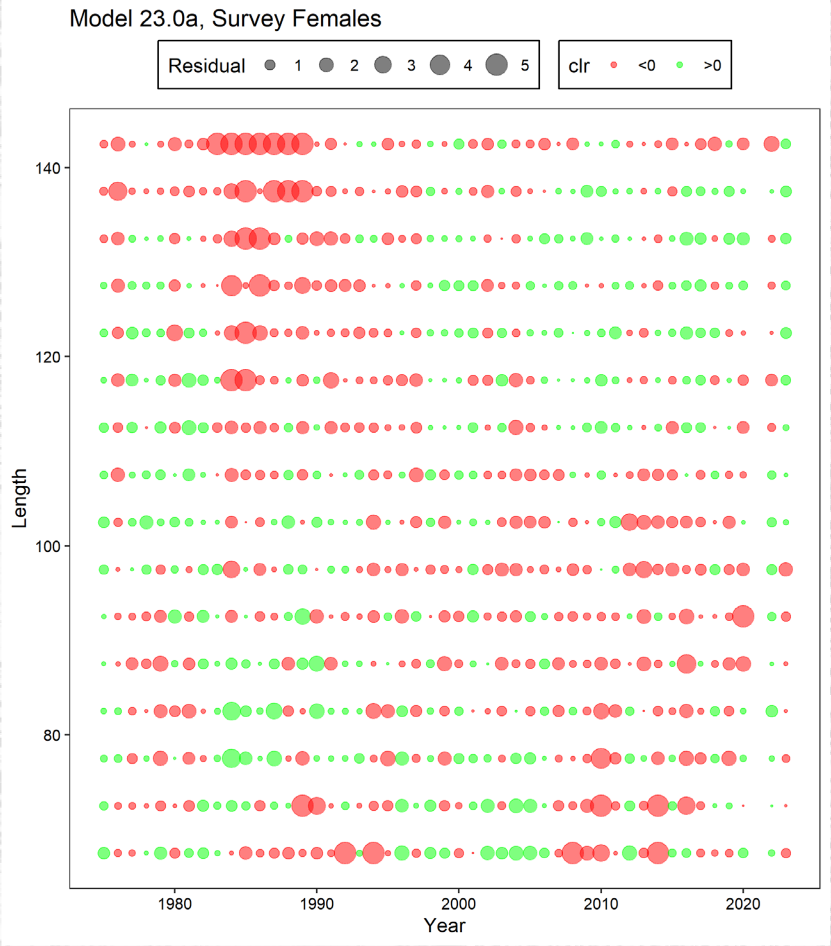




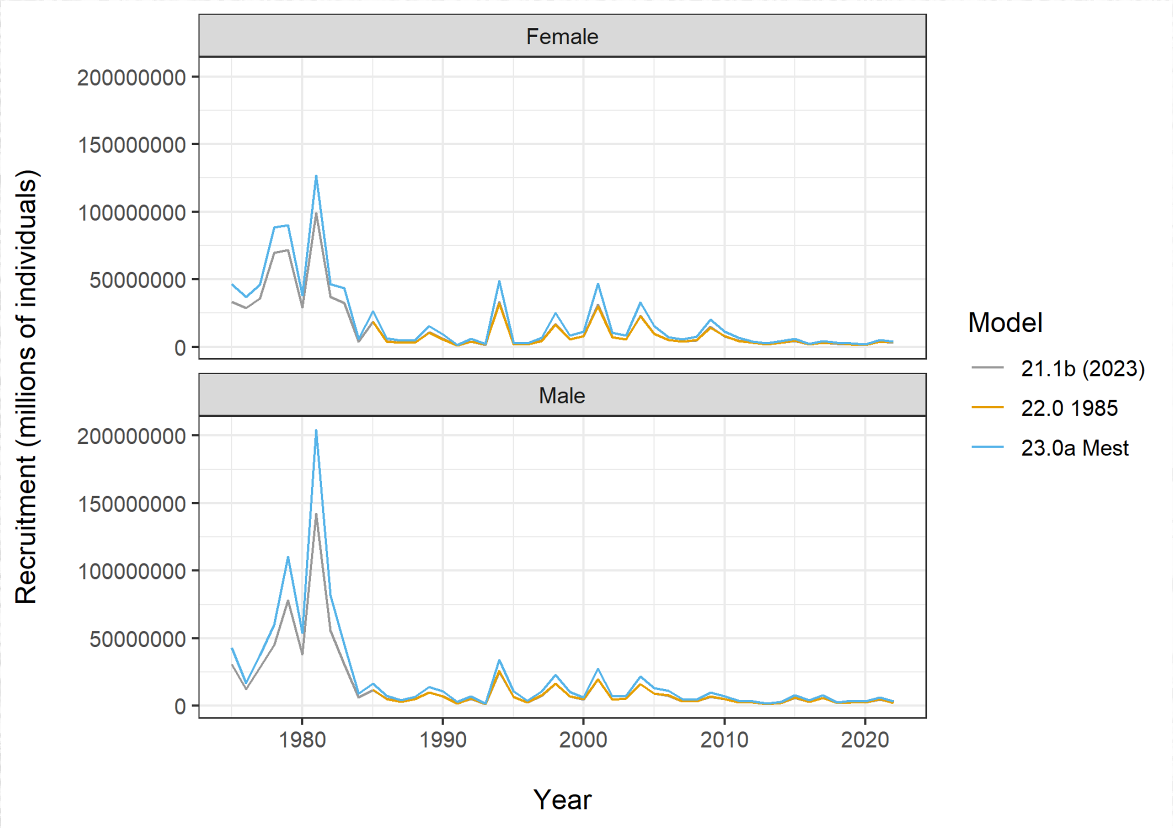
Comparison of residuals for NMFS survey females

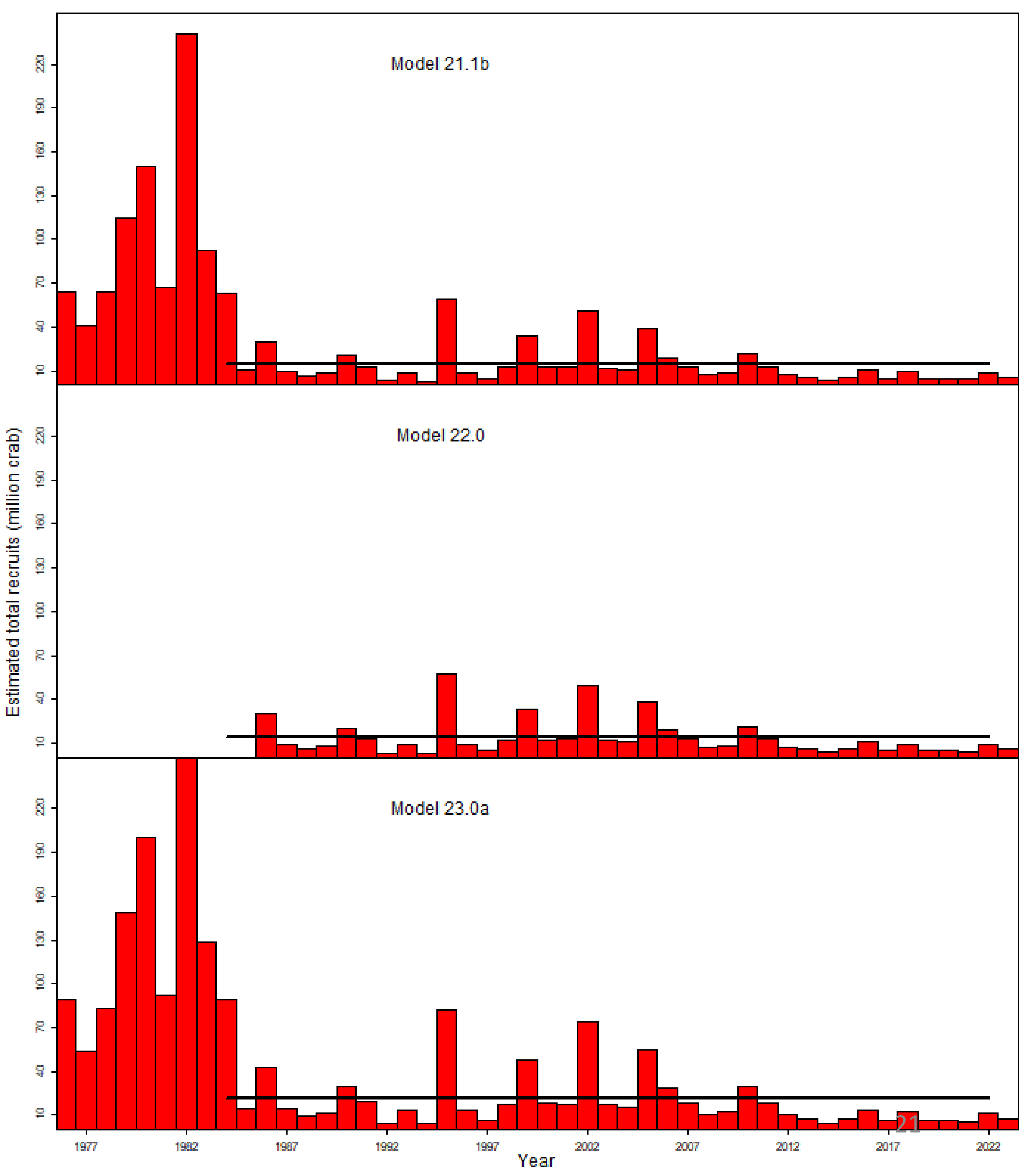




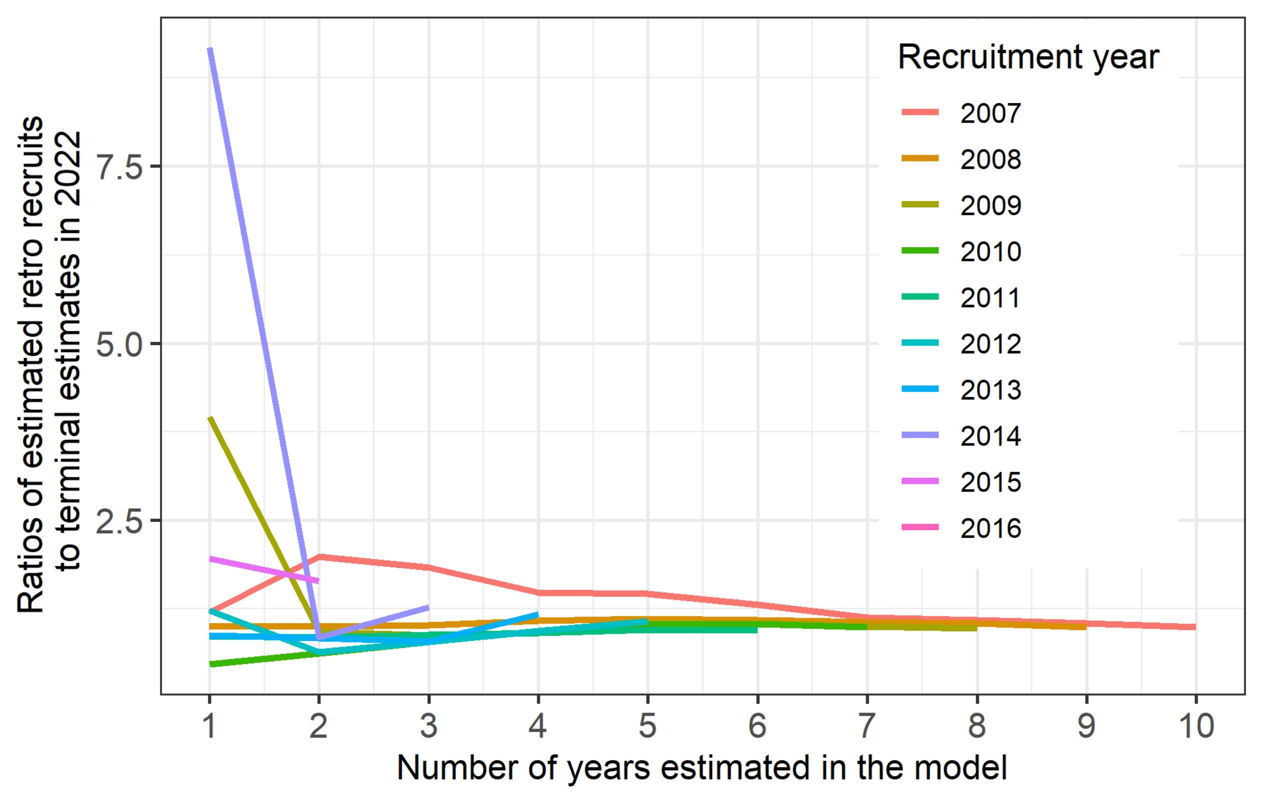


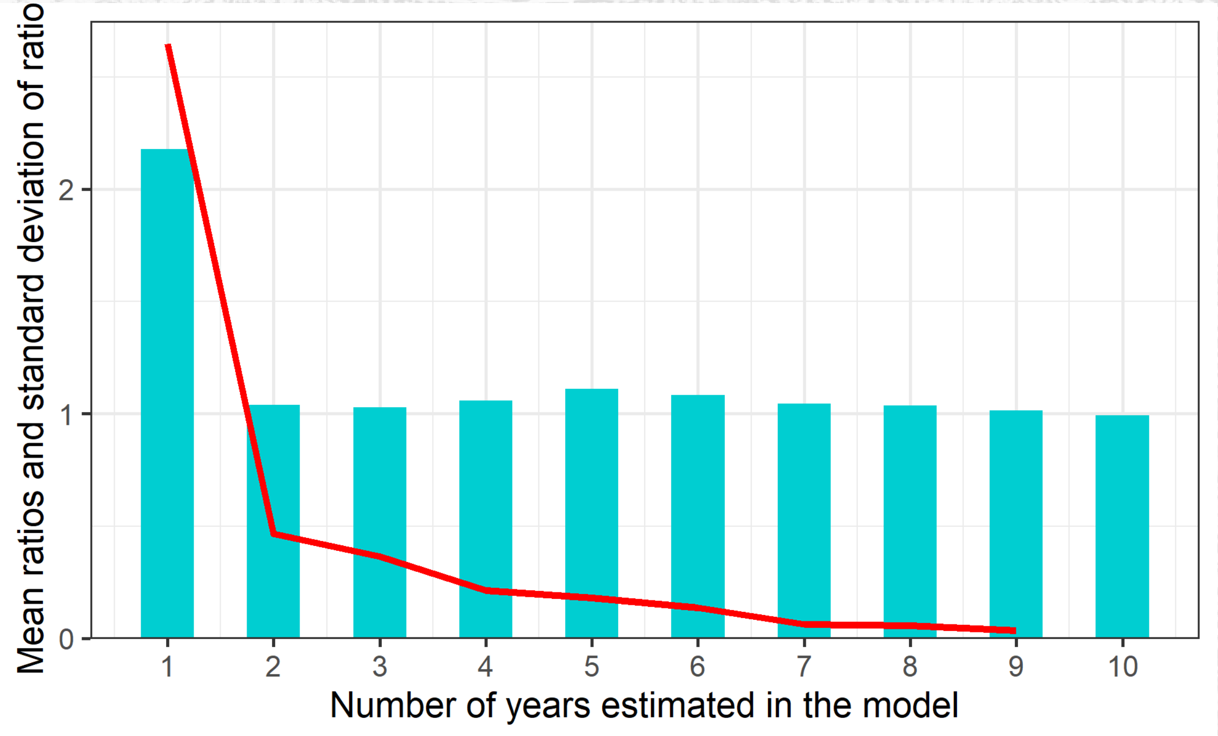
Recruitment





Recruitment to exclude from reference point calculations





Prior density values and total negative likelihood values without prior densities

(model 22.0 cannot be compared here)

Table 17: Comparisons of negative log-likelihood values and some parameters for all model scenarios.

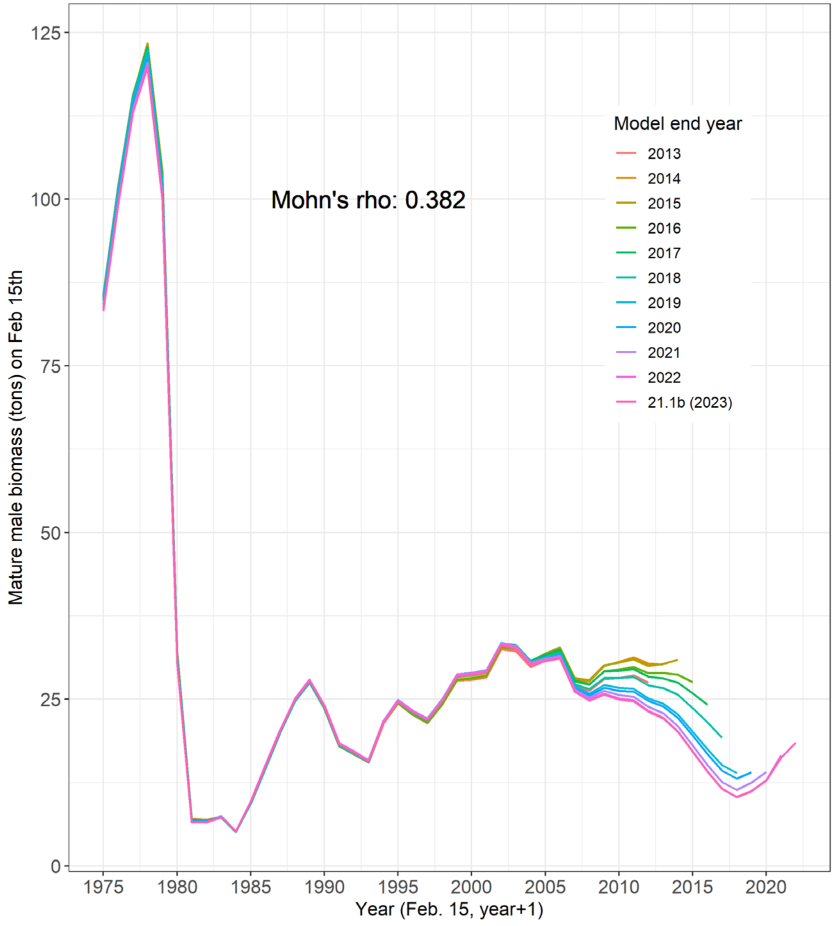
Component	base m21.1b	m23.0a	m22.0
Pot-ret-catch	-60.77	-61.84	-34.83
Pot-totM-catch	28.49	27.75	28.42
Pot-F-discC	-57.44	-57.45	-57.44
Trawl-discC	-65.13	-65.14	-52.67
Tanner-M-discC	-43.54	-43.54	-26.12
Tanner-F-discC	-43.48	-43.51	-26.07
Fixed-discC	-37.42	-37.42	-37.42
Traw-suv-bio	-37.28	-38.98	-46.15
BSFRF-sur-bio	-2.94	-4.82	-3.37
Pot-ret-comp	-3991.77	-3998.15	-3191.10
Pot-totM-comp	-2443.63	-2444.35	-2444.63
Pot-discF-comp	-1493.90	-1494.87	-1493.41
Trawl-disc-comp	-5937.57	-5945.91	-4782.21
Tanner-disc-comp	-1274.30	-1276.69	-1273.35
Fixed-disc-comp	-3486.24	-3483.07	-3487.49
Trawl-sur-comp	-7130.66	-7137.97	-5651.22
BSFRF-sur-comp	-843.09	-844.78	-841.91
Recruit-dev	72.95	73.83	43.06
Recruit-ini	0.00	0.00	0.00
Recruit-sex-R	78.49	78.50	62.18
$Log_f dev_0$	0.00	0.00	0.00
M-deviation	43.92	40.42	0.00
Sex-specific-R	0.00	0.01	0.13
Ini-size-struct	30.82	33.58	50.80
PriorDensity	265.30	250.58	231.58
Tot-likelihood	-26429.18	-26473.80	-23033.23
Tot-likeli-no-PD	-26163.88	-26223.23	-22801.65
Tot-parameter	378.00	379.00	314.00
MMB_{35}	21718.77	19361.24	19967.36
MMB-terminal	16480.20	14975.92	16481.06
F_{35}	0.30	0.40	0.30
F_{ofl}	0.22	0.30	0.24
OFL	3522.29	4424.14	3916.66
ABC	2817.83	3539.32	3133.32
NMFS Q	0.97	0.94	0.94

Retrospective analysis and projections

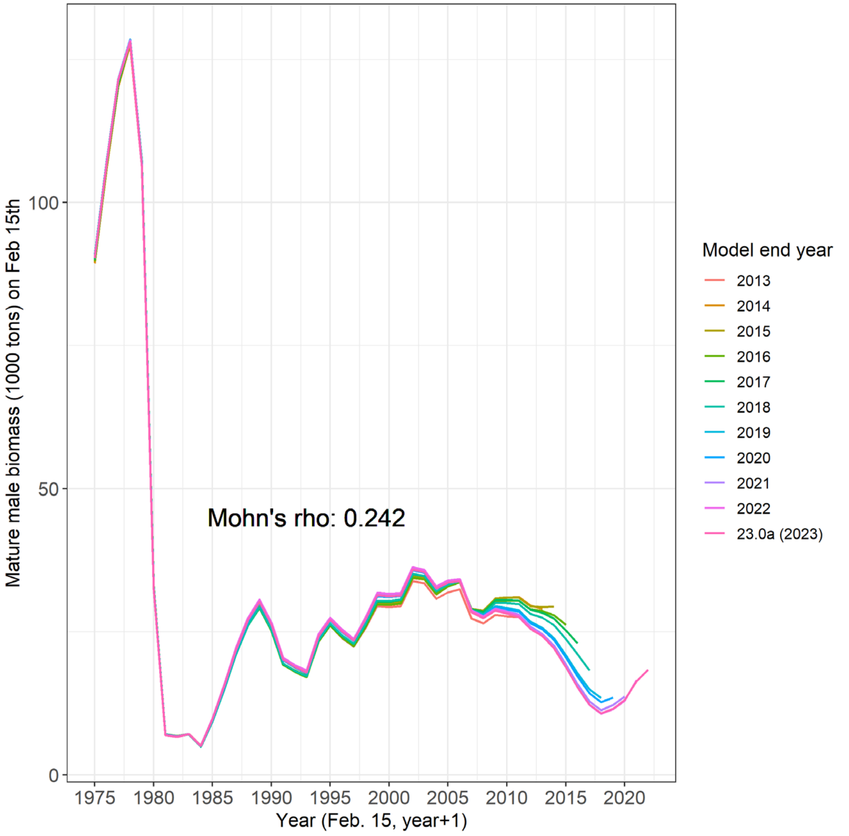
- Retrospective analysis – done for all model runs
- Jitter – run on all models, >95% of jitter runs converged to MLE and those that didn't were worse model fits
- MCMC runs to look at model variability
  - Performed on all models - model 21.1b (base/reference model) highlighted here
  - Other models were similar, nothing unexpected in results
- Projections
  - To inform population trajectory and the probability of "approaching an overfished condition"
  - Used low recruitment since 2013

Retrospective patterns

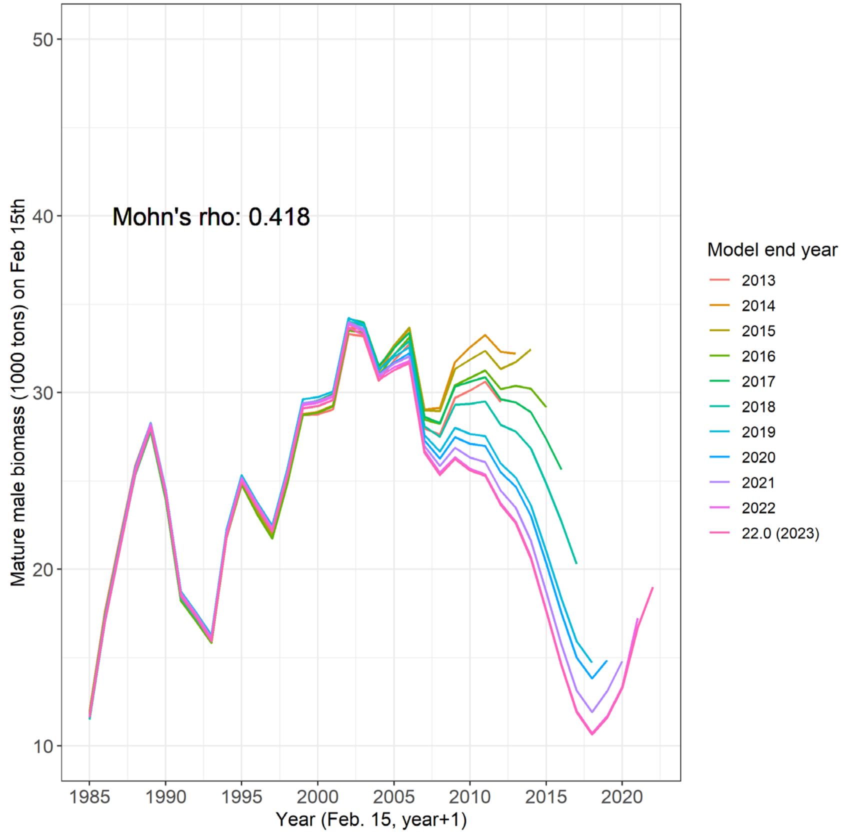
Model 21.1b



Model 23.0a

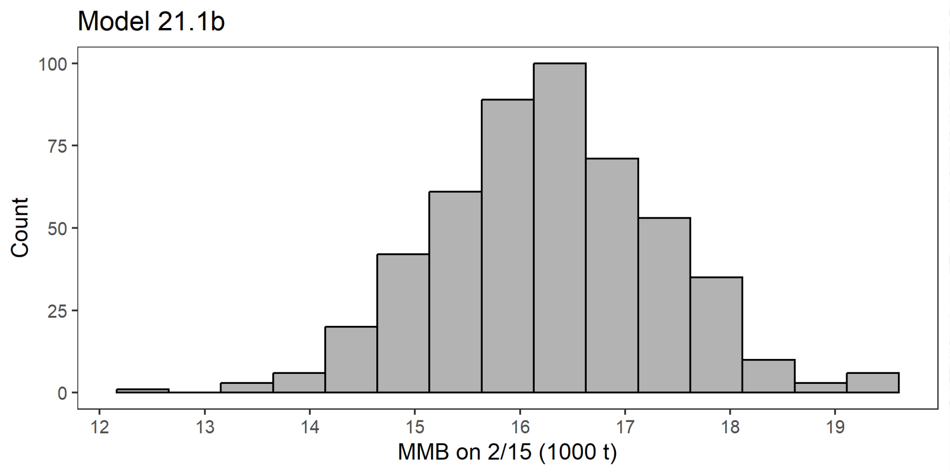


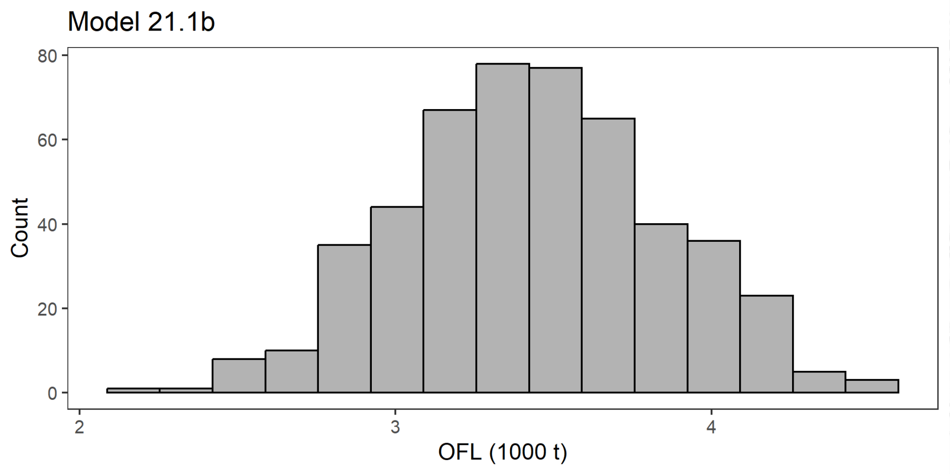
Model 22.0

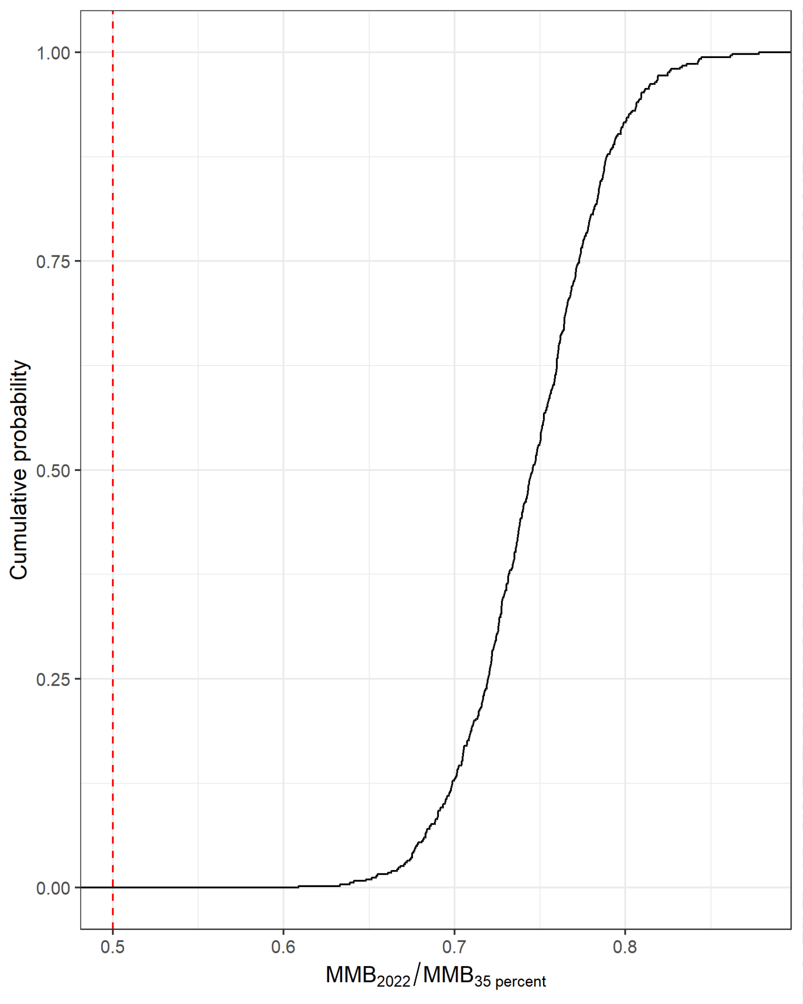


MCMC output (Model 21.1b)

Cumulative probabilities of estimated ratios of MMB in 2023 (Feb. 15th , 2024) to corresponding estimated $B_{35\%}$ values under model 21.1b with the MCMC approach.

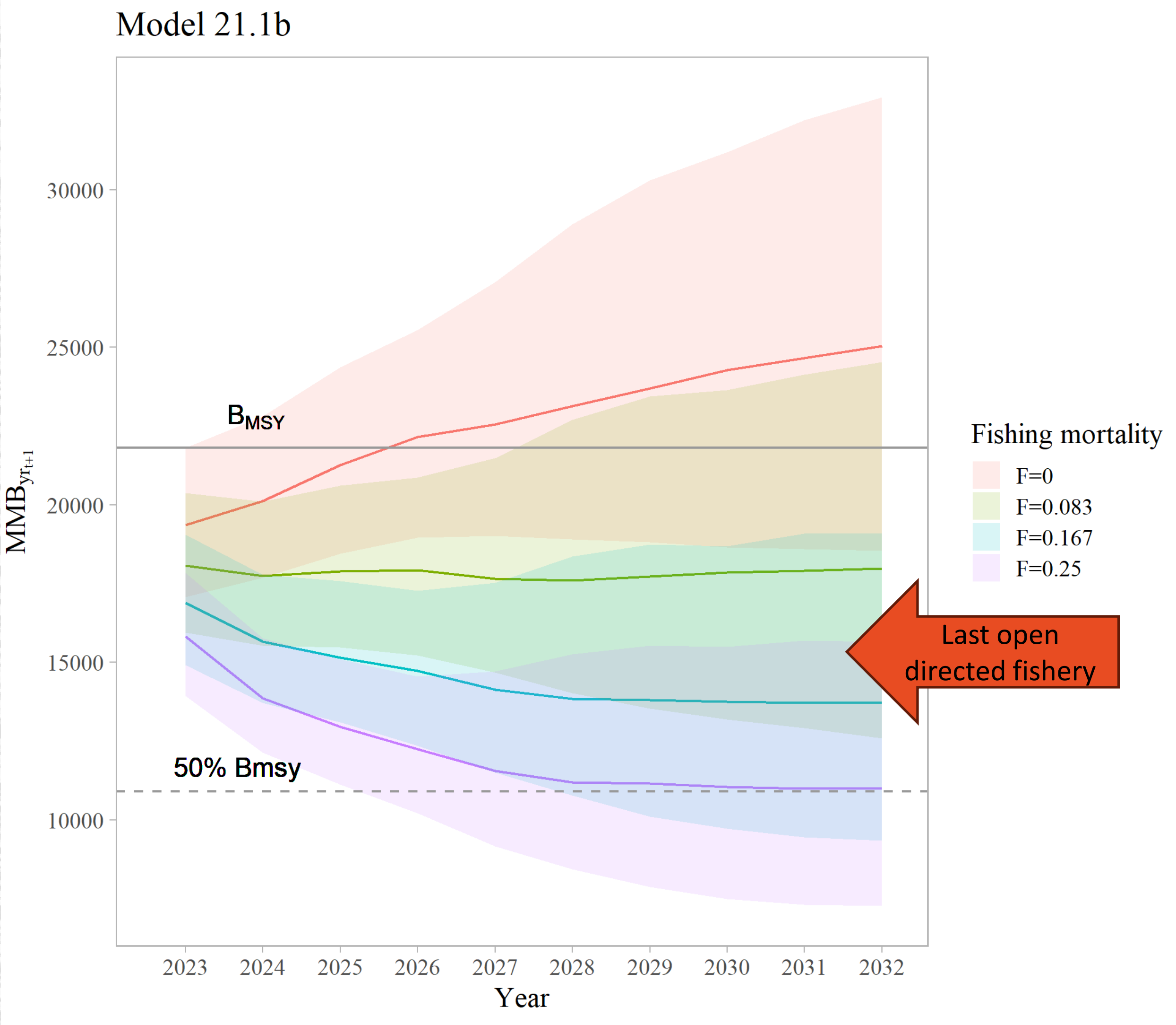


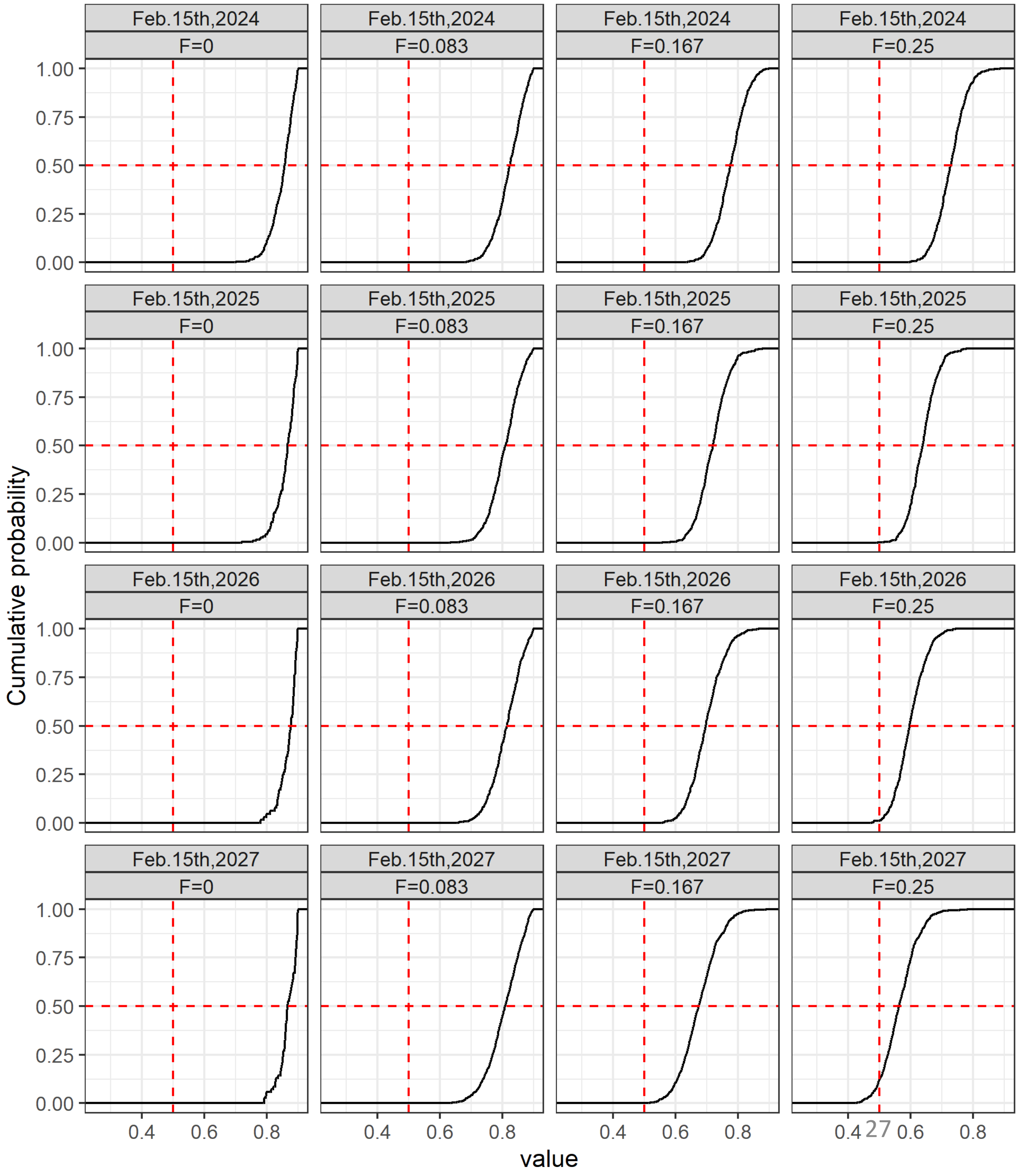




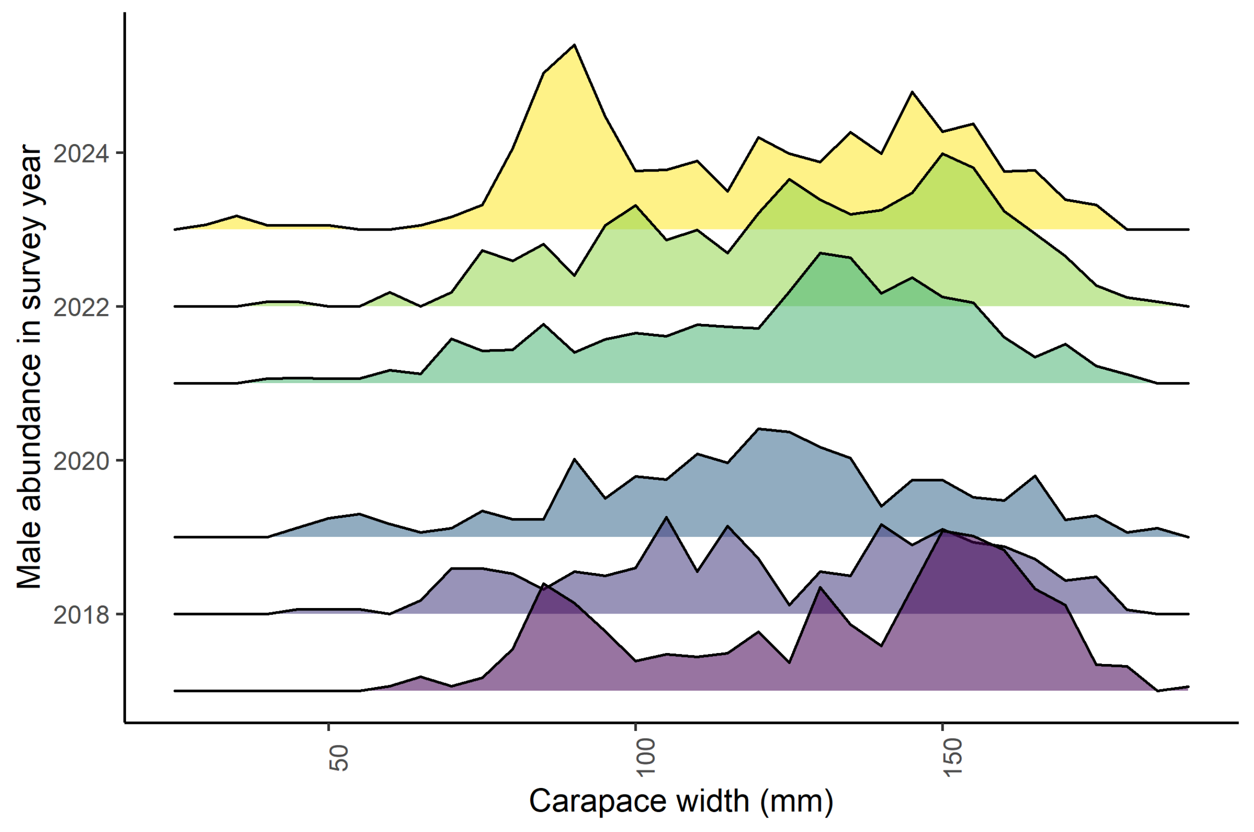
Projections for future status (21.1b MCMC output)

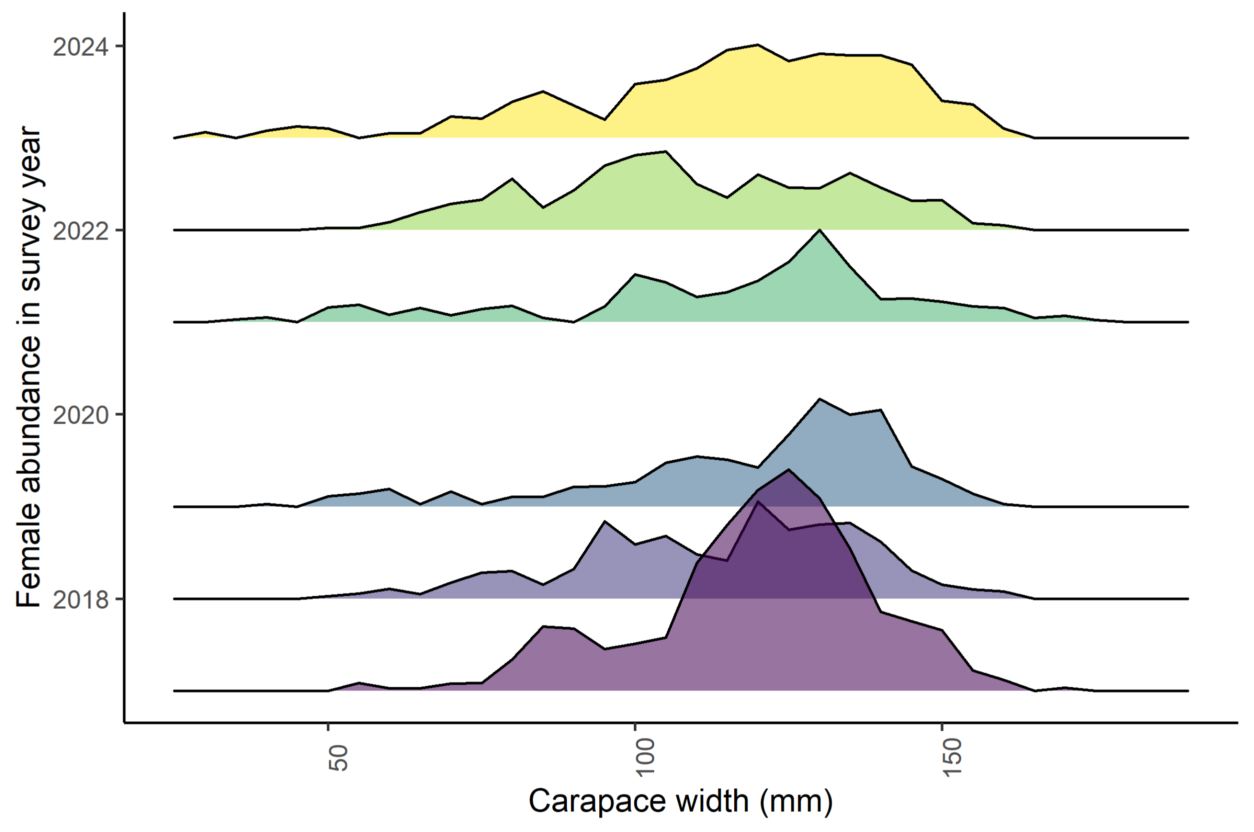
[2023 = projected MMB Feb 15th , 2024]





Last 6 years of size compositions NMFS survey data





Summary & Recommendations

- Models have similar output, some differences in model 23.0a due to estimated base M value for males
- Trend in mature male biomass similar
- Stock is not overfished in 2023 and not likely “approaching an overfished condition” in the next two years
- Recommend reference (base) model 21.1b OR model 23.0a for status determination
  - Is estimation of M for males appropriate?
    - Model 23.0a has a strong prior.
    - Other king crab stocks use 0.18 (Amendment 24 FMP)
    - Life history methods M ~0.23
    - Southeast RKC M~0.30
    - PIRKC M = 0.21
    - Increased OFL

Table 1: Status and catch specifications (1000 t) for the base model (21.1b).

Year	MSST	Biomass (MMB_{mating})	TAC	Retained catch	Total male catch	OFL	ABC
2019/20	12.72	14.24	1.72	1.78	2.22	3.40	2.72
2020/21	12.12	13.96	1.20	1.26	1.57	2.14	1.61
2021/22	12.01	16.64	0	0.02	0.10	2.23	1.78
2022/23	10.86	18.52	0	0.02	0.07	3.04	2.43
2023/24		16.48				3.52	2.82

Table 3: Basis for the OFL (1000 t) from the base model (model 21.1b).

Year	Tier	B_{MSY}	Biomass (MMB_{mating})	B/B_{MSY}	F_{OFL}	Basis for B_{MSY}	Natural mortality
2019/20	3b	21.2	16.0	0.75	0.22	1984-2018	0.18
2020/21	3b	25.4	14.9	0.59	0.16	1984-2019	0.18
2021/22	3b	24.2	14.9	0.62	0.17	1984-2020	0.18
2022/23	3b	24.03	17.0	0.71	0.20	1984-2021	0.18
2023/24	3b	21.72	16.48	0.76	0.22	1984-2022	0.18

All model specifications

Table 15: Management quantities for all models. Report quantities are derived from maximum likelihood estimates. Average recruitment (Avg Rec) is males and females combined in millions of animals.

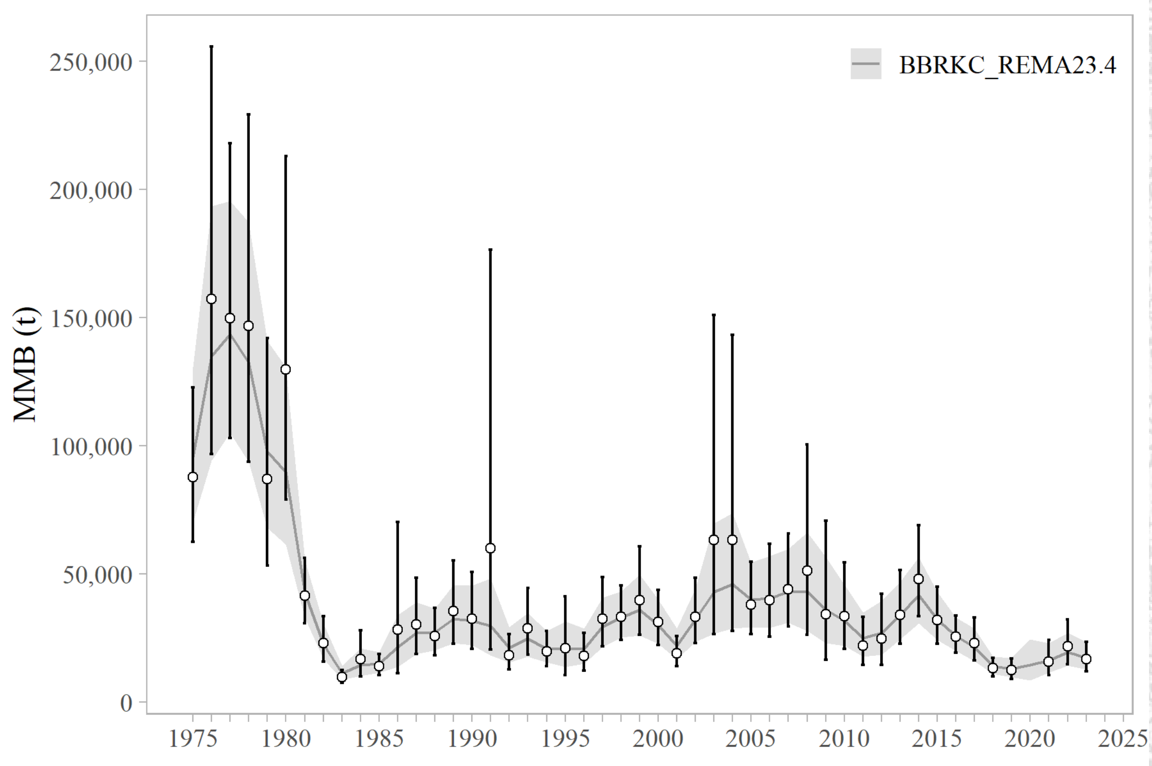
Model	Current MMB	B35	MMB/B_{MSY}	F35	F_{OFL}	OFL	Avg Rec	Male M
21.1b (2023)	16.48	21.72	0.76	0.30	0.22	3.52	14.85	0.18
22.0 1985	16.48	19.97	0.83	0.30	0.24	3.92	13.62	0.18
23.0a Mest	14.98	19.36	0.77	0.40	0.30	4.42	21.18	0.23

Buffer considerations

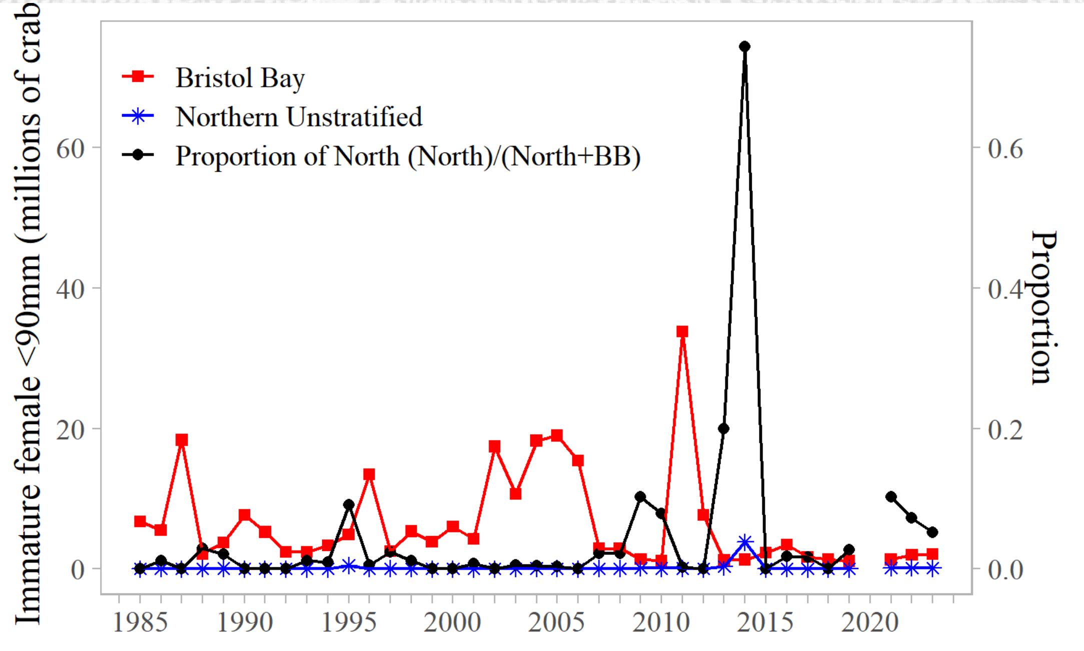
- Current at 20% - recommend 20% for upcoming year
- Cold pool distributional shifts
- Declining trend or low levels of mature male biomass and mature female biomass
- Lack of recruitment events
- Retrospective pattern

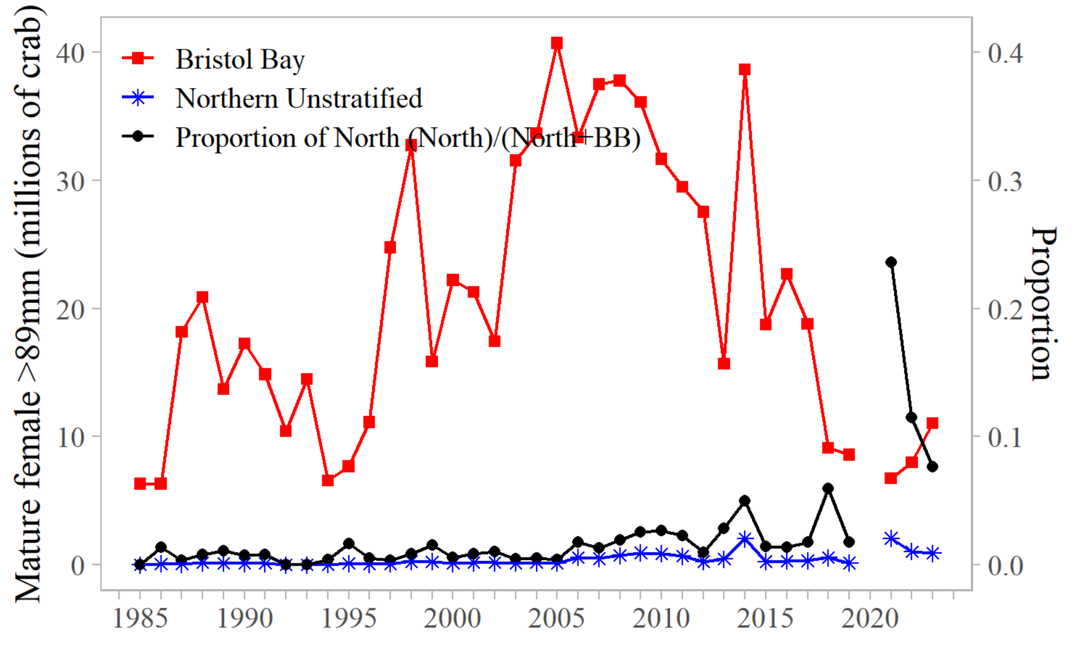
Tier 4 simple modeling workgroup option

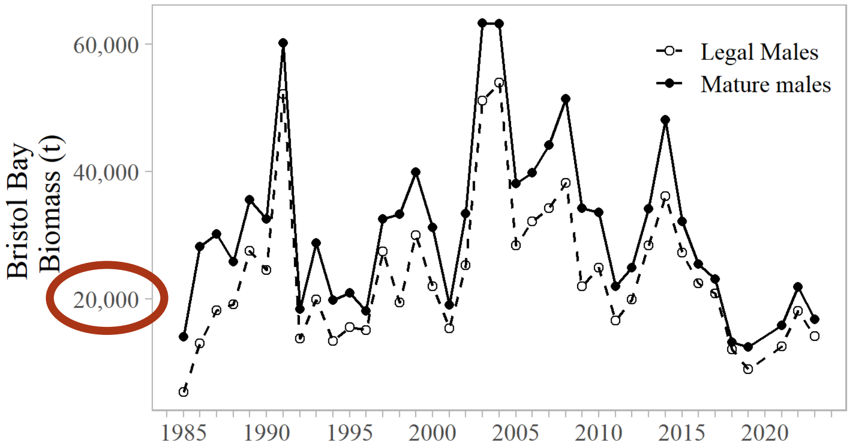
- Based on the simpler modeling working group discussions
- Mature male biomass (legal size + one growth increment below = mature for BBRKC)
- Average B – calculated using MMB from 1984 to 2022 (matches current Tier 3 assessment $B_{35\%}$ calcs)
- Assume 20% buffer – likely this would be different if we went with a Tier 4 option.

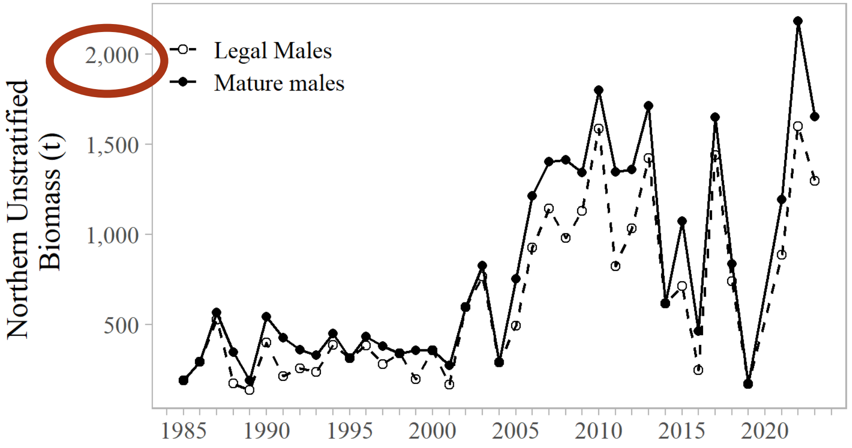


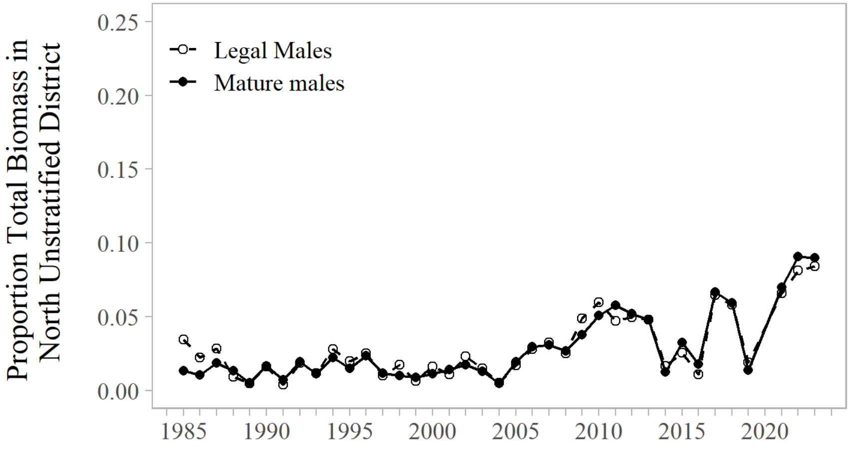
avgBb (t)	Current B	MMB/B_{msy}	M	F_{OFL}	OFL	ABC
28191.68	17377.32	0.61	0.18	0.10	1785.67	1428.54


Immature female <90mm (millions of crab
Proportion
Bristol Bay
Northern Unstratified
Proportion of North (North)/(North+BB)
0
20
40
60
0.0
0.2
0.4
0.6
1985
1990
1995
2000
2005
2010
2015
2020


Mature female >89mm (millions of crab)
Proportion
Bristol Bay
Northern Unstratified
Proportion of North (North)/(North+BB)
0
10
20
30
40
0.0
0.1
0.2
0.3
0.4
1985
1990
1995
2000
2005
2010
2015
2020


Bristol Bay
Biomass (t)
Legal Males
Mature males
20,000
40,000
60,000
1985
1990
1995
2000
2005
2010
2015
2020


Northern Unstratified
Biomass (t)
Legal Males
Mature males
500
1,000
1,500
2,000
1985
1990
1995
2000
2005
2010
2015
2020


Proportion Total Biomass in
North Unstratified District
Legal Males
Mature males
0.00
0.05
0.10
0.15
0.20
0.25
1985
1990
1995
2000
2005
2010
2015
2020