Assessment of the Northern Rock Sole stock in the Bering Sea and Aleutian Islands

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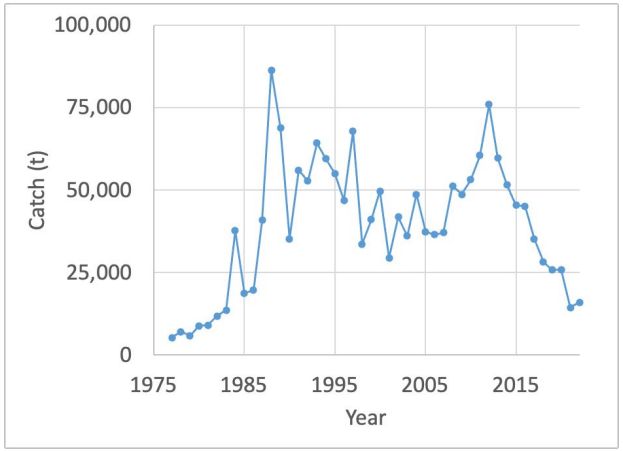
Life History and environmental relationships

- Winter spawners
- Cooper and Rogers (2020) showed a relationship between small cold pool/warmer temperatures + strong onshore winds with high recruitment success due to availability of a northern nursery area
- Recruitment success appears strongly tied to temperature conditions (warmer temperatures = high success)
- Ciannelli et al. (2022) showed overlap of most extreme predicted future temperatures in the nearshore + life stage of high vulnerability (physiologically) of juveniles residing there to extremes for NRS and other small-bodied flatfish
- Effects of ocean acidification on juvenile flatfish, but minor in climate-enhanced projections (Punt et al.)
- Effect of temperature on maximum length, but this assessment uses yearly data on empirical weight-at-age (Punt et al.)

Catch (1977-2022)



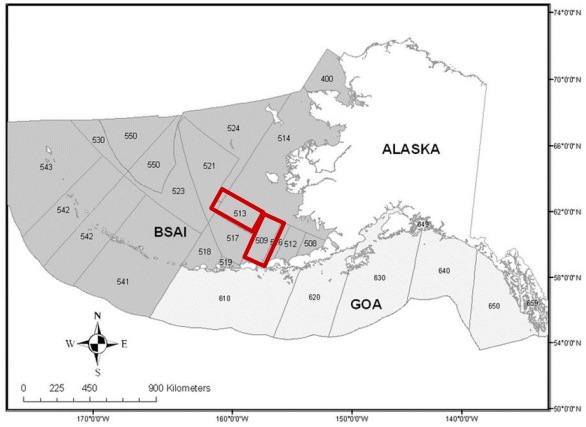
Year	Jan-Mar	Apr-June	July-Sep	Oct-Dec
2012	0.8	0.14	0.04	0.02
2013	0.68	0.17	0.12	0.03
2014	0.69	0.22	0.06	0.03
2015	0.64	0.23	0.11	0.02
2016	0.48	0.44	0.06	0.02
2017	0.42	0.46	0.1	0.02
2018	0.38	0.55	0.05	0.01
2019	0.34	0.57	0.07	0.03
2020	0.43	0.3	0.23	0.04
2021	0.37	0.51	0.07	0.05
2022*	0.5	0.35	0.13	0.02

Catch has been declining since 2012

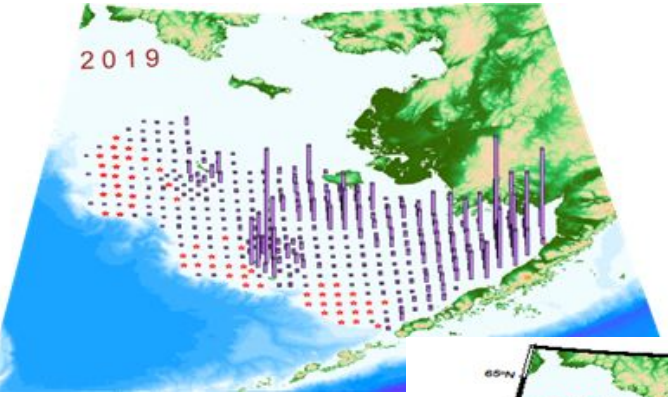
Predominant areas include: 509 and 513

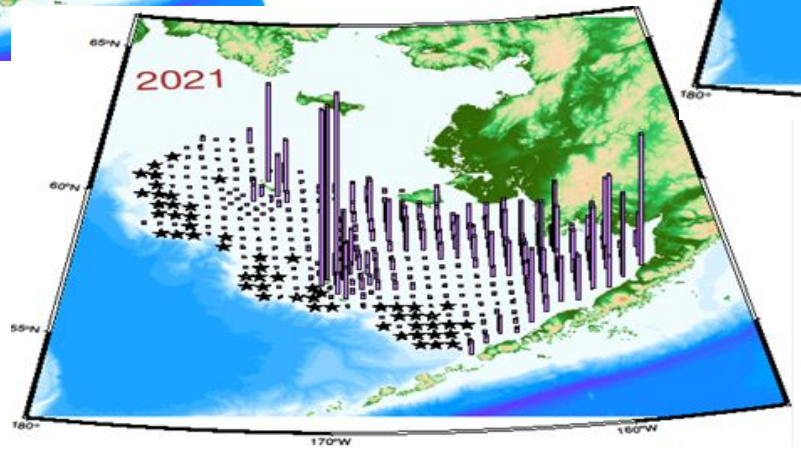
Mainly caught Jan-Mar or April-June, has varied over time

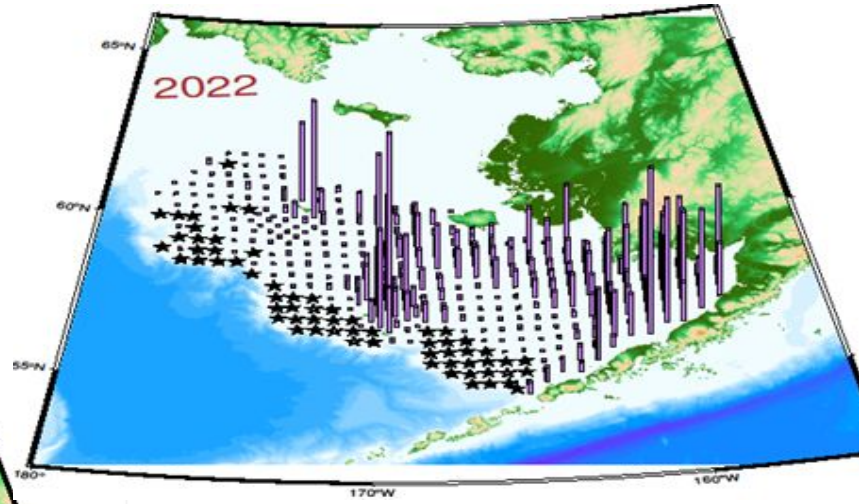
Year	509	511	512	513	514	516	517	518	519	521	522	523	524	540	541	542	543
2012	0.81	0	0	0.02	0.03	0.08	0.04	0	0	0.01	0	0	0	0	0	0	0
2013	0.64	0	0	0.06	0.02	0.16	0.09	0	0	0.02	0	0	0	0	0	0	0
2014	0.66	0	0	0.09	0.03	0.15	0.03	0	0	0.03	0	0	0	0	0	0	0
2015	0.59	0	0	0.07	0.22	0.09	0.01	0	0	0.02	0	0	0	0	0	0	0
2016	0.24	0	0	0.09	0.35	0.29	0.01	0	0	0	0	0	0	0	0	0	0
2017	0.33	0	0	0.21	0.24	0.19	0.02	0	0	0.01	0	0	0	0	0.01	0	0
2018	0.28	0	0	0.11	0.48	0.07	0.03	0	0	0.01	0	0	0.02	0	0.01	0	0
2019	0.19	0	0	0.12	0.55	0.08	0	0	0	0.02	0	0	0.01	0	0.01	0	0
2020	0.34	0	0	0.24	0.17	0.2	0.01	0	0	0.03	0	0	0	0	0	0	0
2021	0.4	0	0	0.2	0.29	0.08	0.01	0	0	0.01	0	0	0	0	0	0	0
2022	0.46	0	0.02	0.33	0.07	0.01	0.01	0	0	0.09	0	0	0	0	0	0	0



Survey CPUE



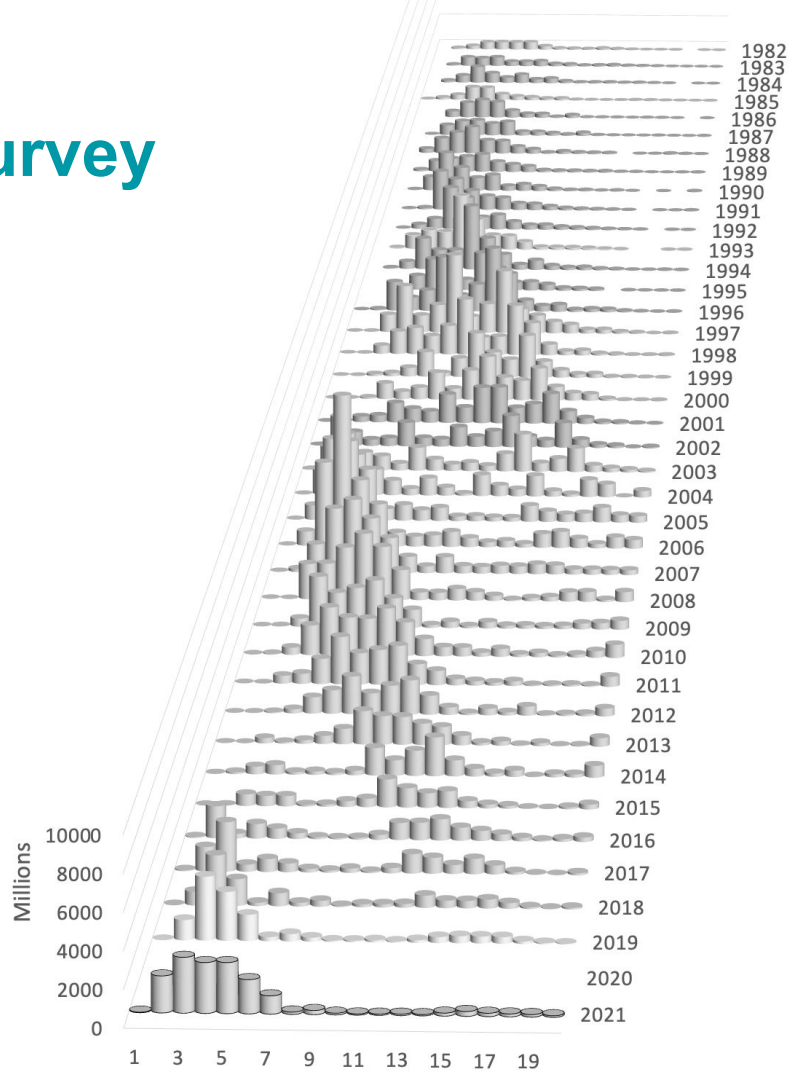




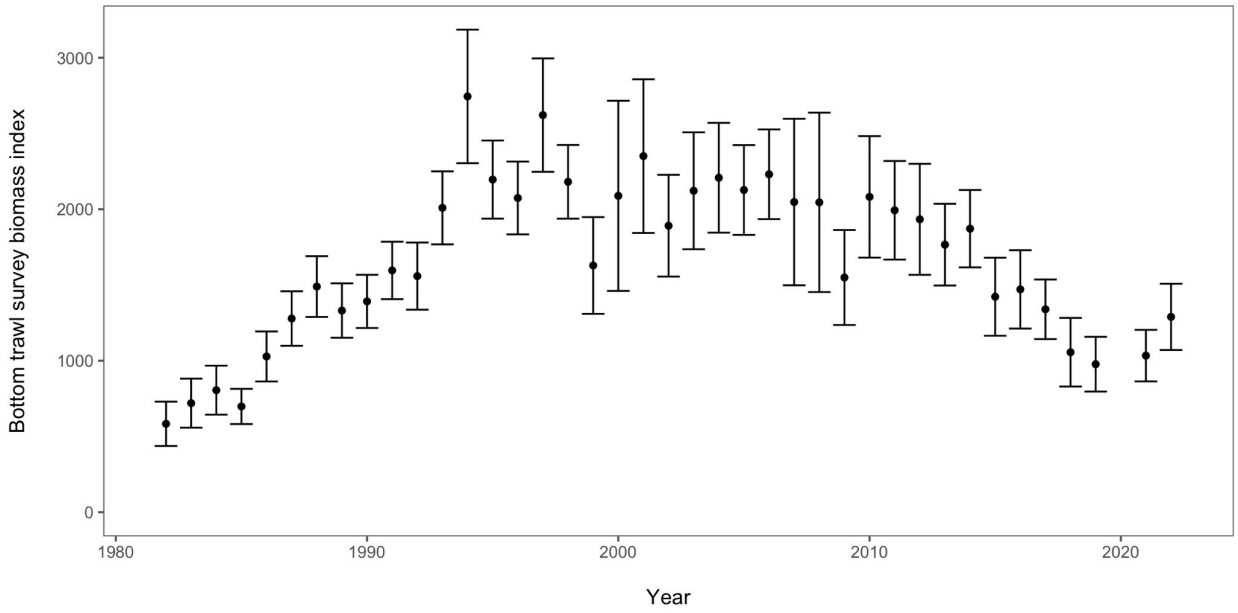
CPUE consistently high in Bristol Bay, north of Bristol Bay, and the Pribilof Islands

Combined sex, bottom trawl survey numbers-at-age

- Big cohorts from early 2000's dying out
- New recruitments coming through (2015-2020)



Survey biomass

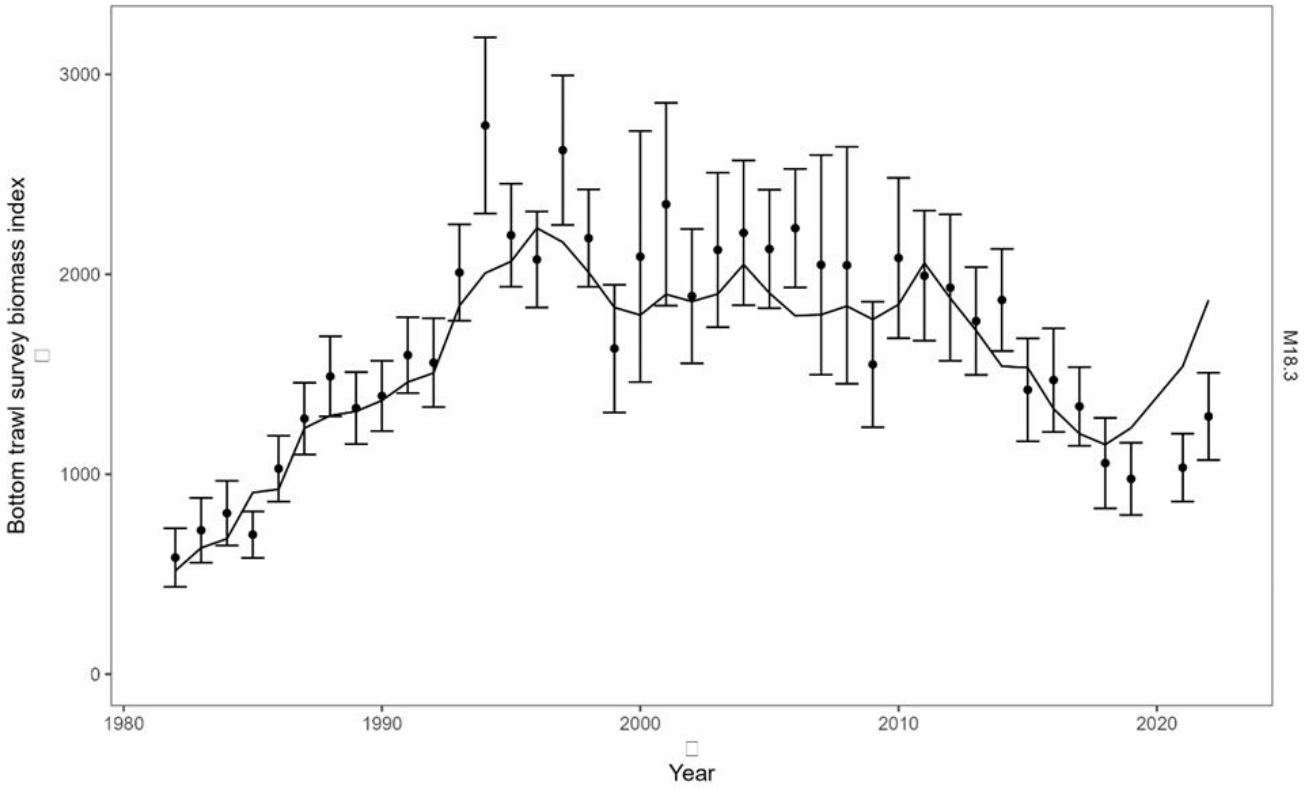


Declining biomass 2011 - 2019

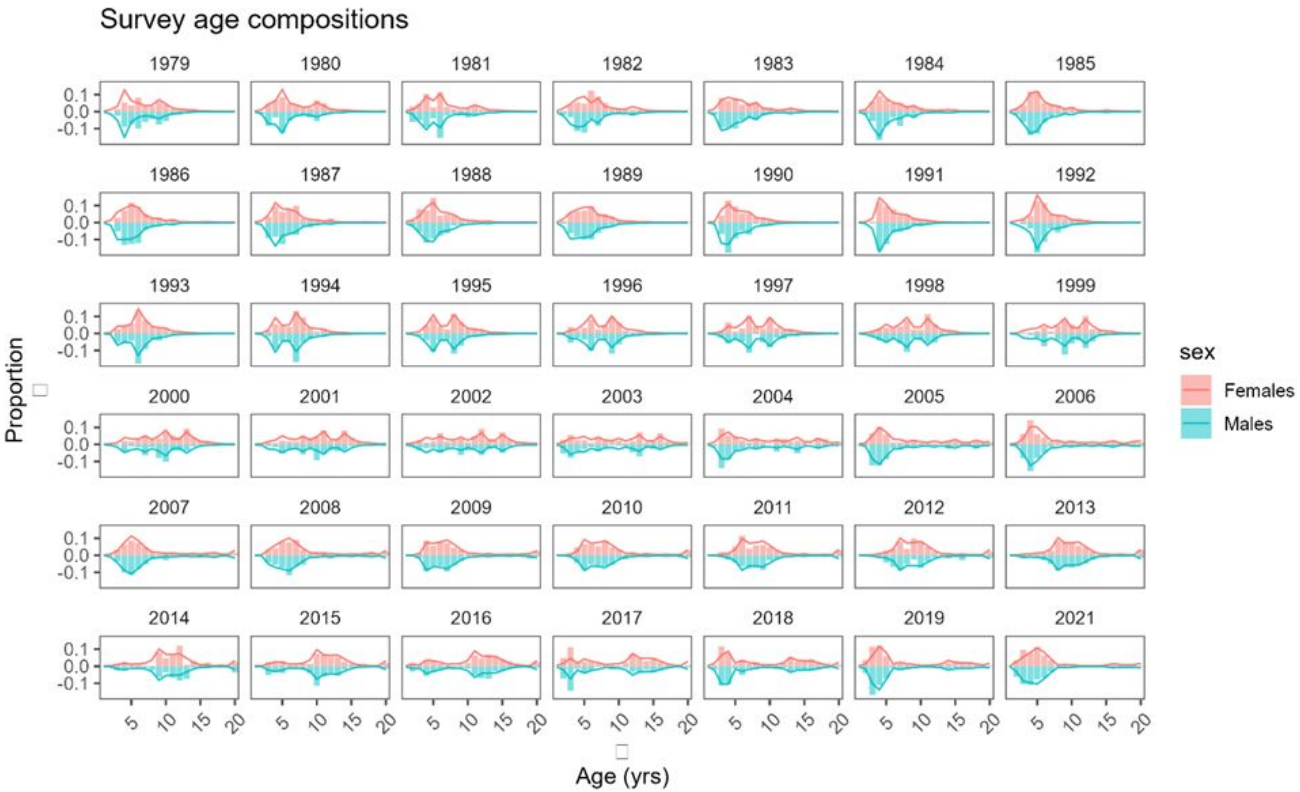
Seeing increases in recent years:

- 6% increase in 2021
- 25% increase in 2022

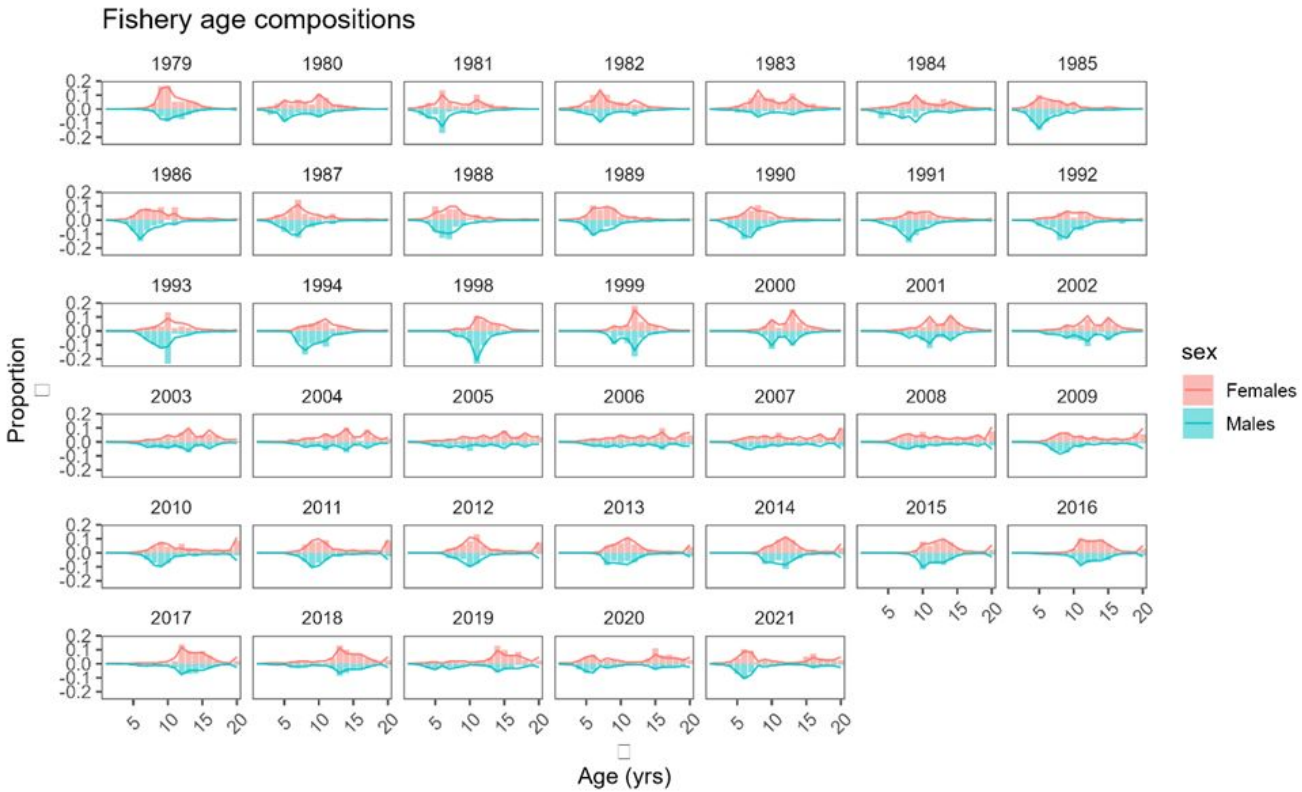
Base model fit to survey biomass



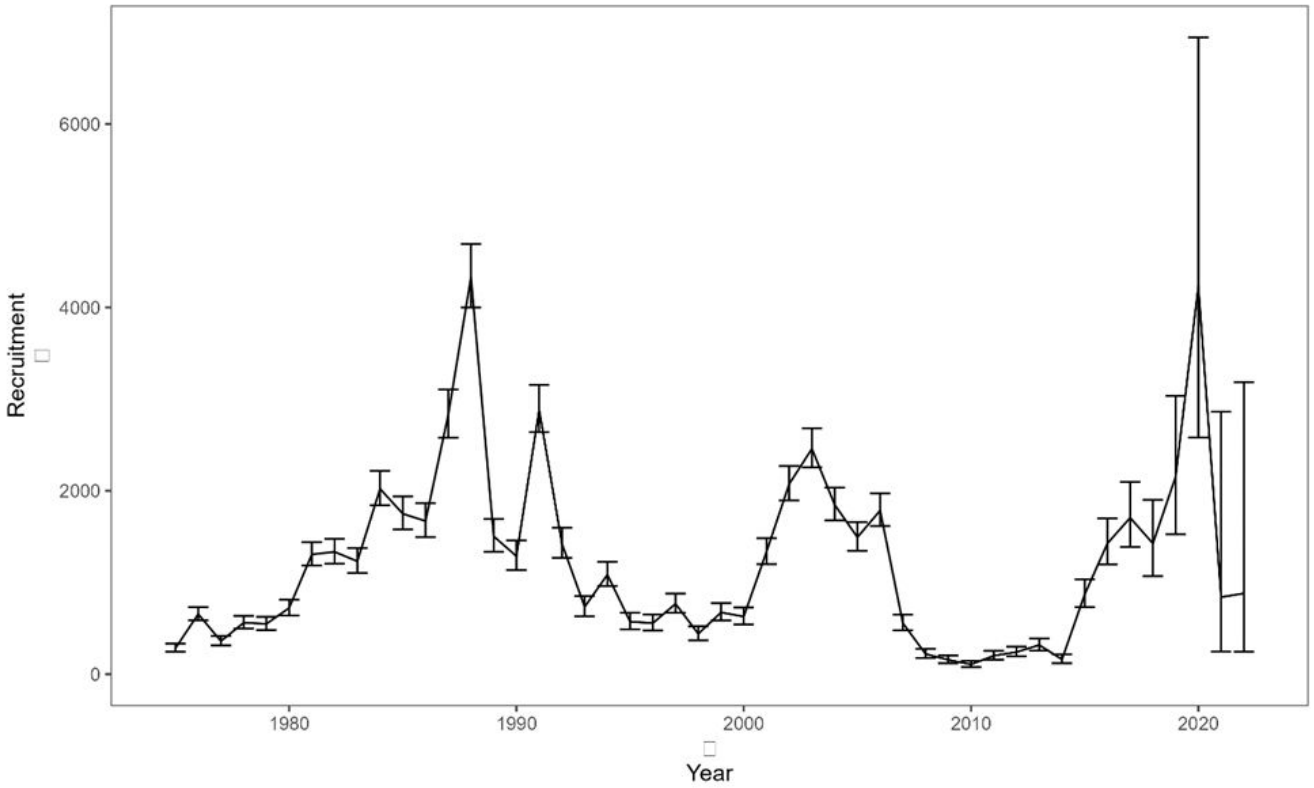
Base model fit to survey age compositions



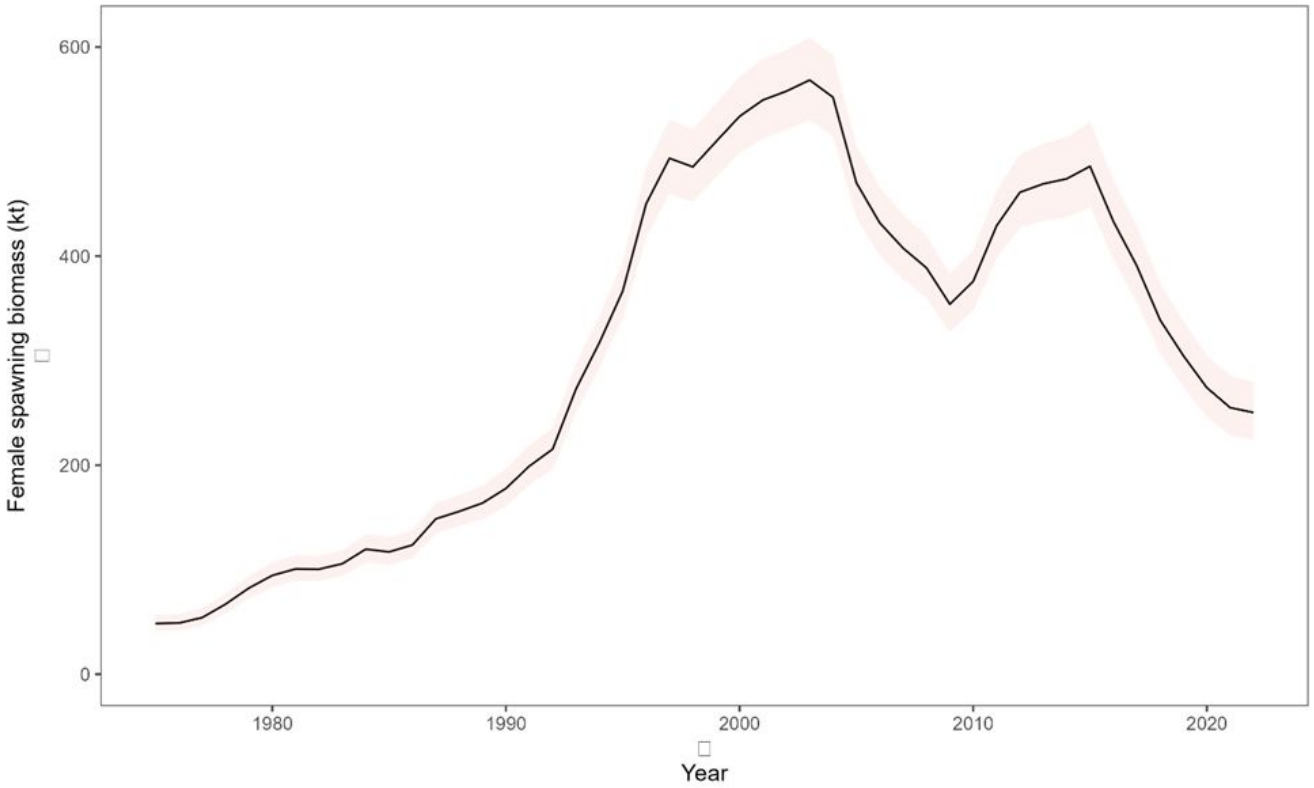
Base model fit to fishery age compositions



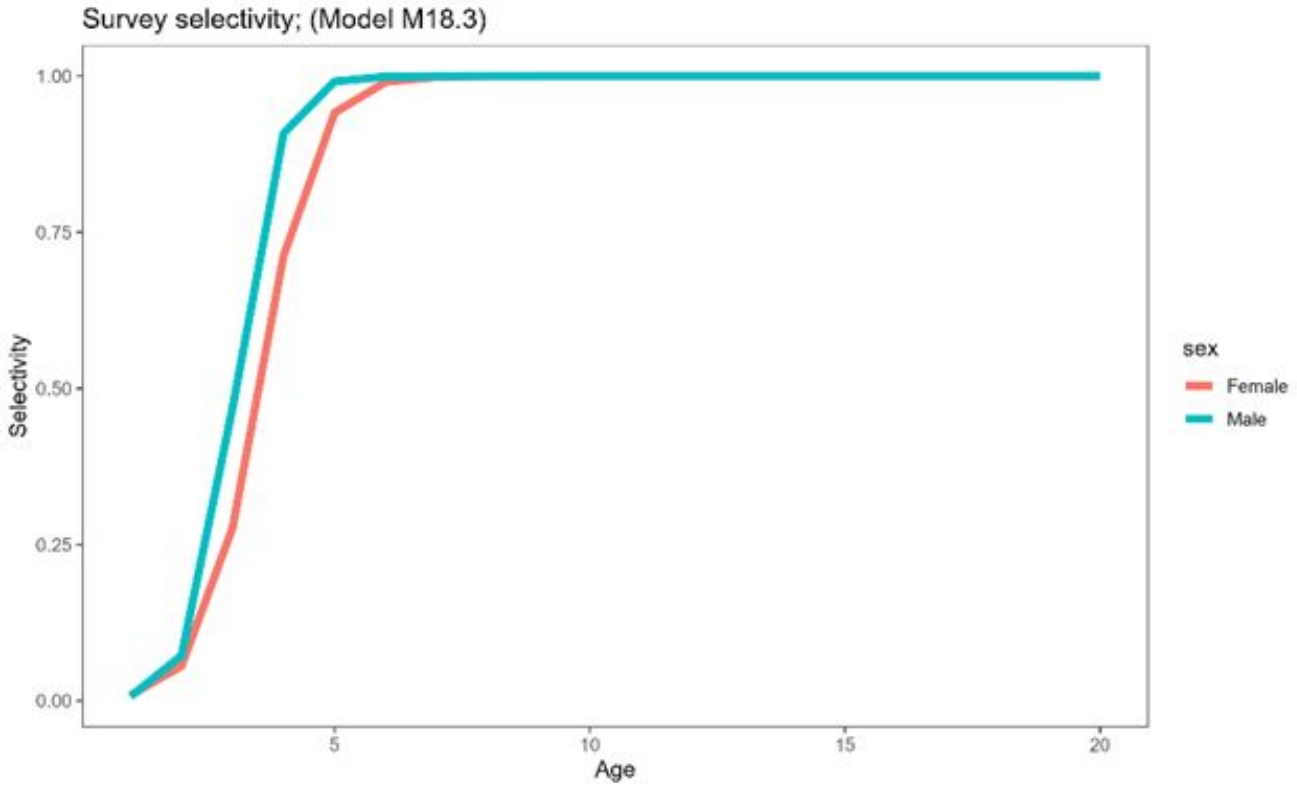
Base model recruitment



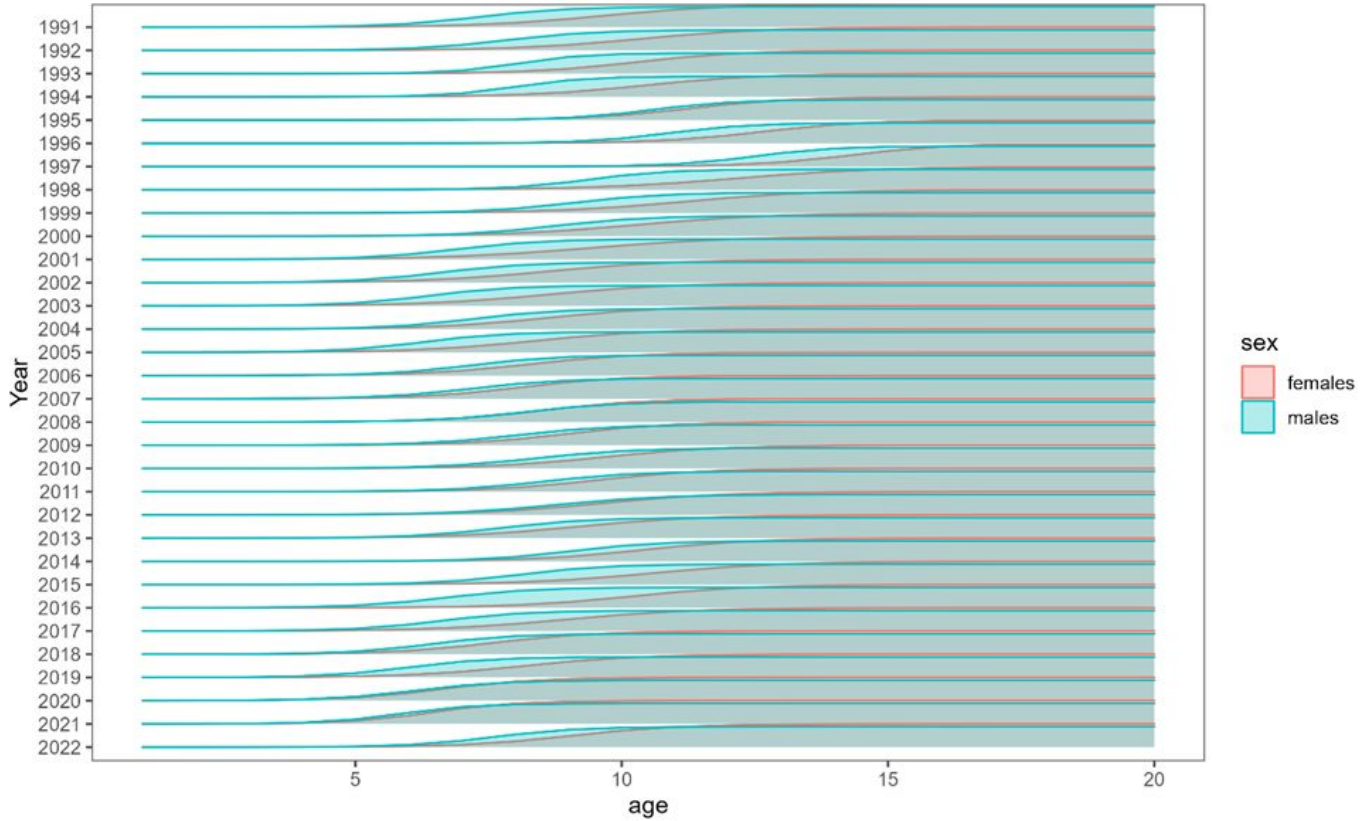
Base model spawning biomass



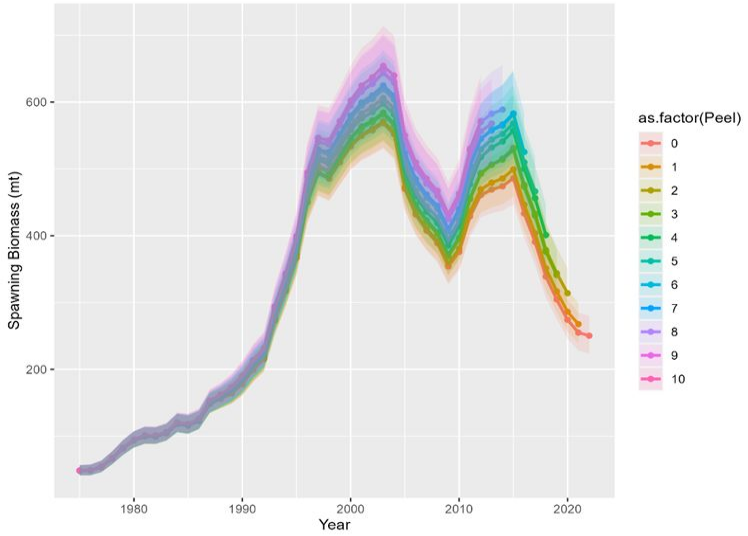
Base model survey and fishery selectivity

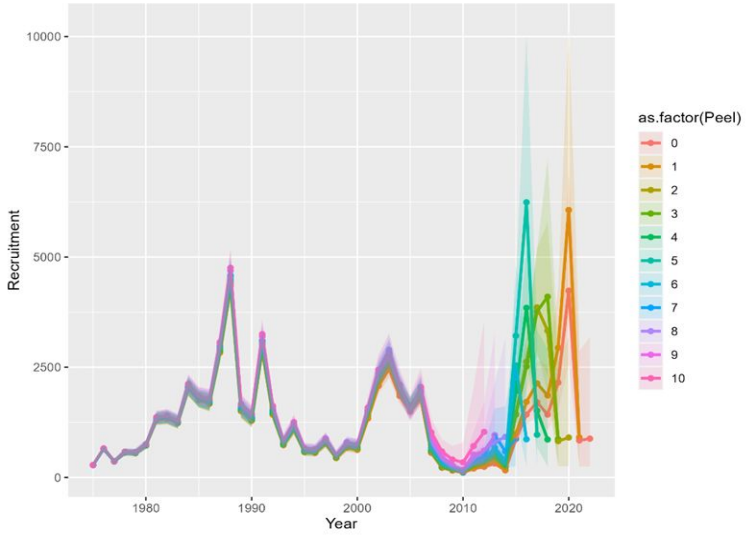


Base model survey and fishery selectivity



Retrospective Analysis





$\rho_{SSB} = 0.18$

Concerns about the base model

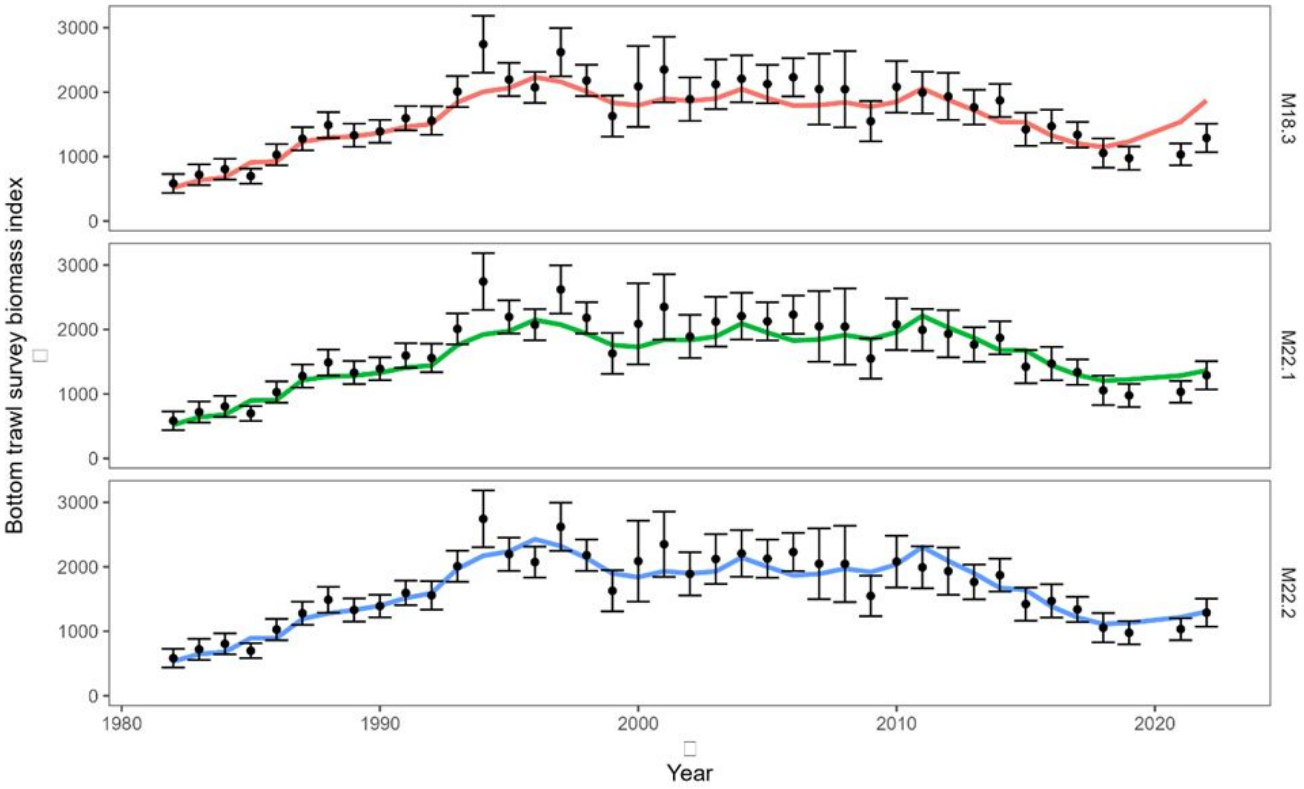
- No formal data weighting approach + conflict between survey biomass and age composition data
- Is 2020 estimate of recruitment (only observed once and only in survey data) driving biomass estimates?
- Why are uncertainty intervals so small?

Alternative models to better understand base model

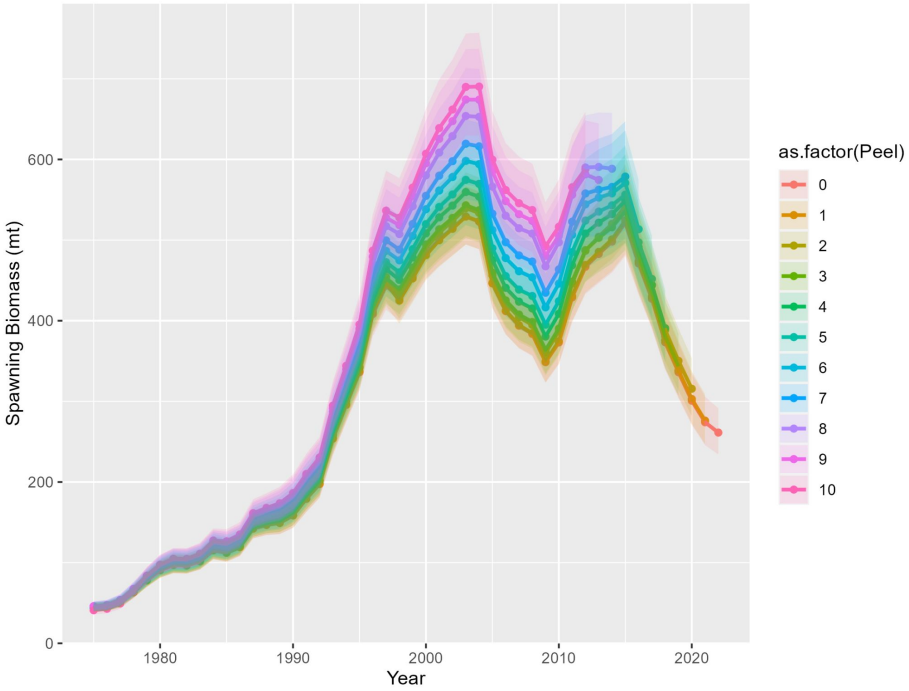
- M22.1: Francis (2011) methodology for data weighting
  - Philosophy that survey biomass should be weighted more heavily and scale of current population and reference points should be informed more by survey biomass and less by age compositions

- M22.2: As for M22.1, but additionally estimate female M such that both female and male M are estimated
  - This is an underutilized stock and data may be informative about natural mortality for this reason
  - Better representation of uncertainty in the model

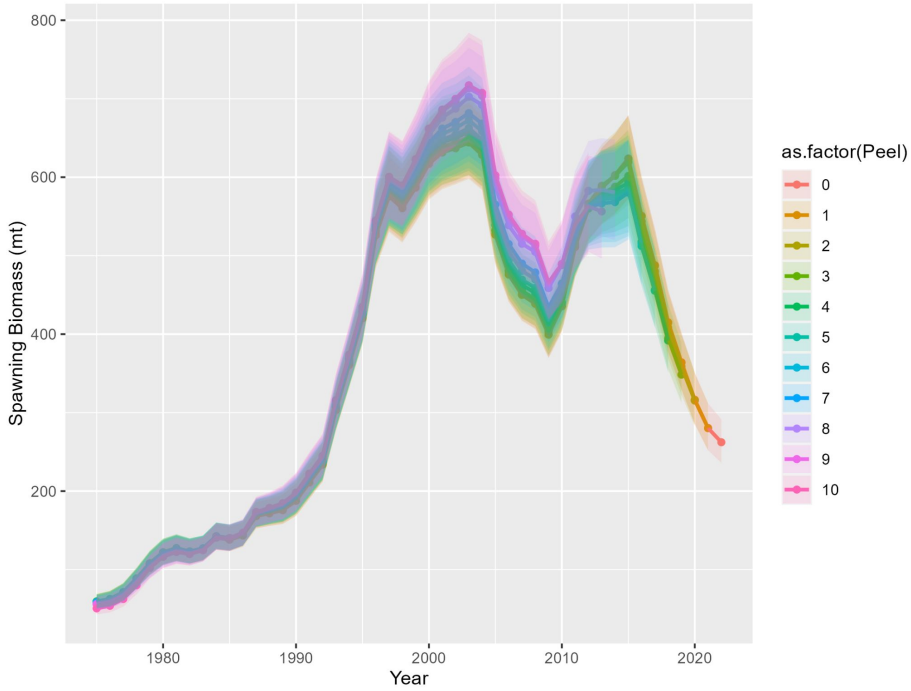
Alternative models: fits to survey biomass



Alternative models: retrospective patterns



Model 22.1: $\rho_{SSB} = 0.1$

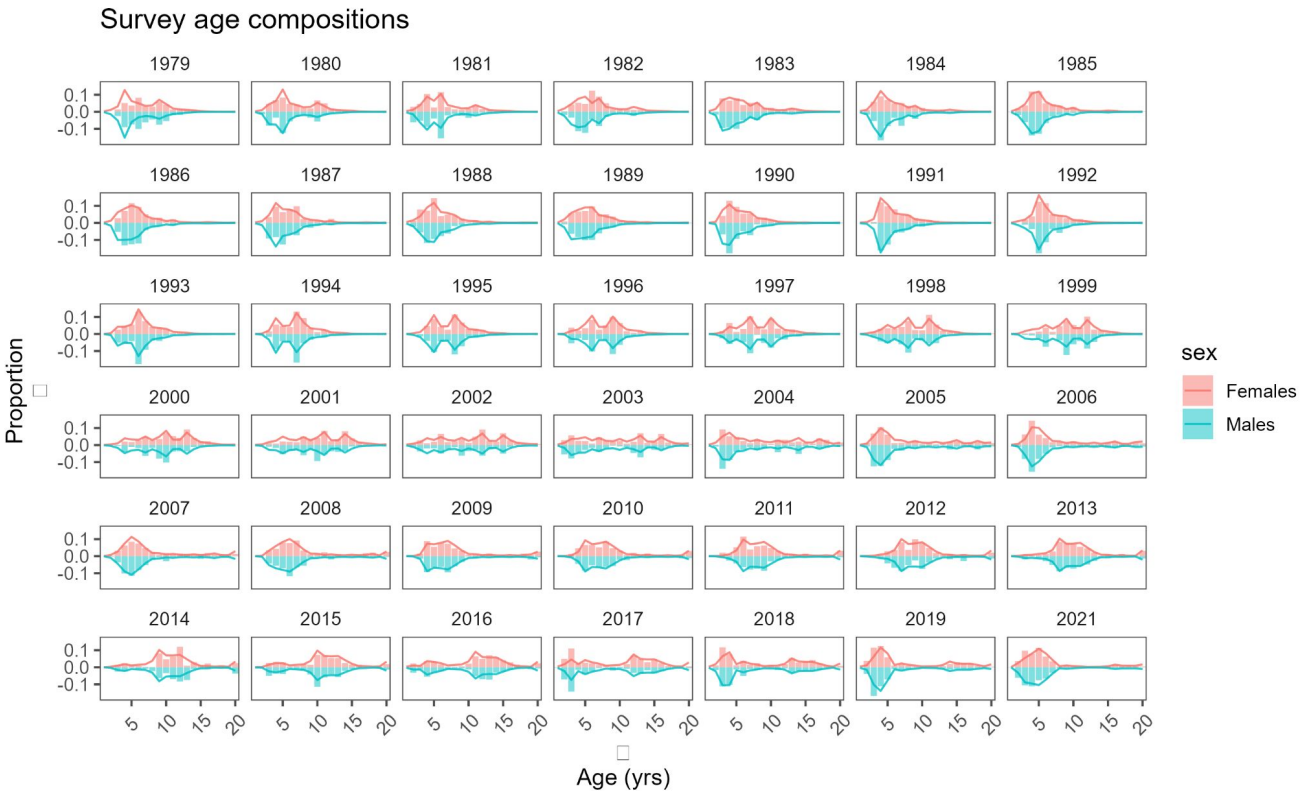


Model 22.2: $\rho_{SSB} = -0.04$

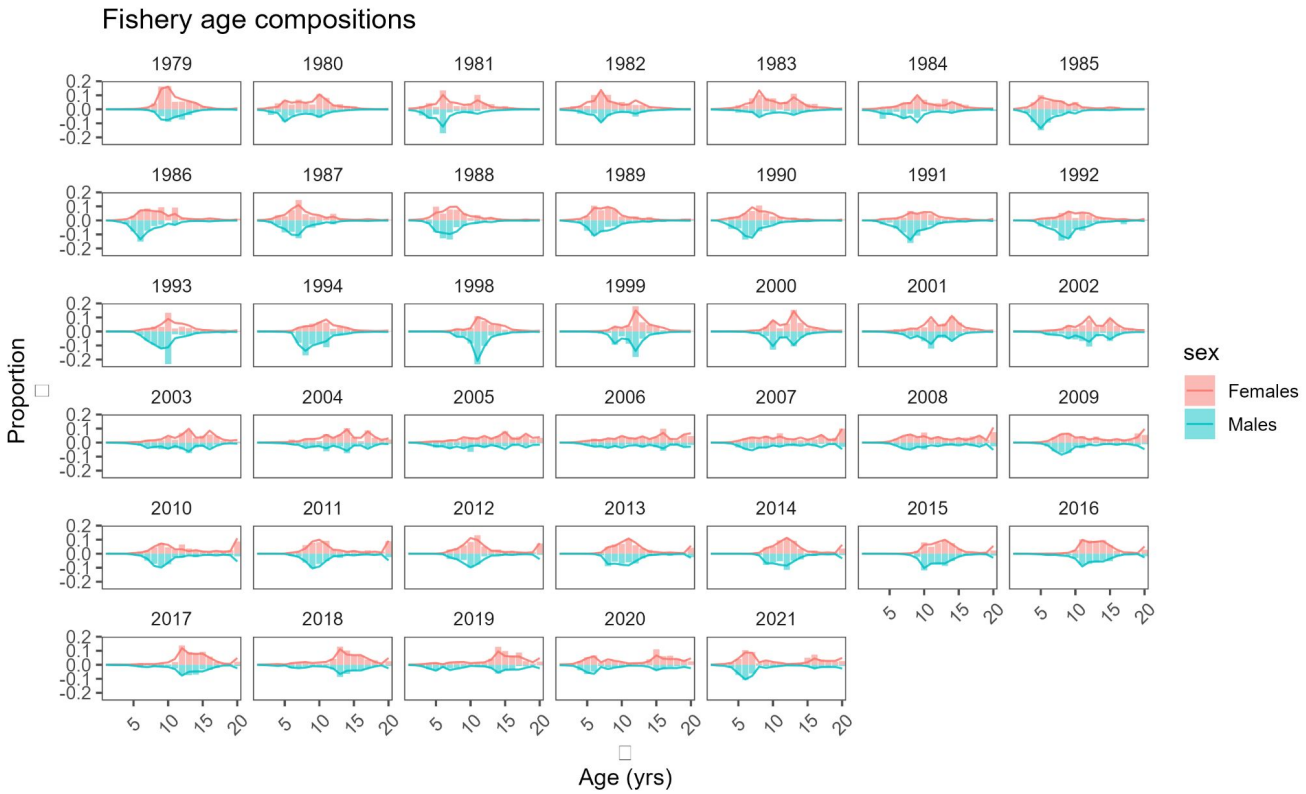
Alternative models: parameter estimates

Parameter	Model 18.3 (2022)		Model 22.1 (2022)		Model 22.2 (2022)	
	value	std.dev	value	std.dev	value	std.dev
log catchability	0.67	0.026	0.73	0.025	0.50	0.031
female natural mortality					0.19	0.004
male natural mortality	0.17	0.002	0.19	0.002	0.22	0.004
mean log recruitment	6.78	0.108	6.67	0.108	7.25	0.118
mean log initial age composition	3.38	0.125	3.26	0.120	3.60	0.127
log average fishing mortality	-2.26	0.087	-2.15	0.084	-2.30	0.086
average slope of fishery selectivity (f)	1.00	0.047	0.96	0.036	0.96	0.035
average age at 50% fishery selectivity (f)	9.05	0.477	9.18	0.476	9.44	0.490
average slope of fishery selectivity (m)	1.26	0.400	1.19	0.047	1.20	0.047
selectivity offset for males	-0.13	0.052	0.01	0.050	-0.14	0.055
slope of survey selectivity (f)	1.87	0.100	2.15	0.313	1.76	0.233
slope of survey selectivity (m)	0.26	0.070	0.20	0.188	0.28	0.173
age at 50% survey selectivity (f)	3.51	0.060	3.32	0.136	3.66	0.162
age at 50% survey selectivity (m)	-0.14	0.020	-0.13	0.049	-0.15	0.050
log alpha of Ricker stock-recruit curve	2.87	0.200	2.94	0.203	3.23	0.204
log beta of Ricker stock-recruit curve	-5.25	0.110	-5.18	0.108	-5.43	0.115
maximum sustainable yield	220.50	40.930	212.38	39.515	257.95	54.467
Fmsy	0.33	0.164	0.33	0.171	0.34	0.195
logFmsy	-1.11	0.501	-1.11	0.521	-1.07	0.572
Fmsyr	0.17	0.036	0.18	0.039	0.17	0.040
logFmsyr	-1.76	0.209	-1.72	0.219	-1.79	0.243
Bmsy	155.29	12.346	146.99	11.647	173.95	13.654
Bmsyr	1277.80	154.300	1191.00	150.430	1551.30	199.450

Alternative model M22.2: fits to survey age composition



Alternative model M22.2: fits to fishery age composition



Supporting analyses that could be done for M22.2

- Likelihood profiles over catchability and natural mortality and/or run MCMCs and calculate posterior distributions for these parameters
- Sensitivity to phase of estimation
- Sensitivity to starting values

Risk table

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ ecosystem considerations*	*Fishery Performance considerations*
Level 3: Major concern	Level 1: no increased concerns	Level 1: no increased concerns	Level 1: no increased concerns

- The new, large 2020 recruitment estimated by the model has only been observed once and is a mismatch with the survey biomass index
- The models with Francis data weighting have much improved fits to survey biomass data and much improved retrospective patterns
- It appears from the comparison of retrospective patterns across models that it is a feature of the base model to consistently overestimate recent recruitments and spawning biomass
- The SSC recommended evaluating the probability that ABC > true, but unknown OFL
- The models using Francis data weighting estimate OFL's that are lower than the ABC estimated by the base model
- Therefore ABC was reduced to the OFL for Model 22.1

Harvest recommendations

- Spawning biomass is down from previous assessment (declining trend as cohorts from early 2000's disappear)

- ABC reduced from maxABC due to assessment uncertainty in the Risk Table
- ABC = OFL from M22.1 (which just changed to Francis data weighting from base model)
- OFL M22.1 < OFL M22.2

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2022	2023	2023	2024
M (natural mortality rate)	0.15 (f),0.17 (m)	0.15 (f),0.17 (m)	0.15 (f),0.19 (m)	0.15 (f),0.19 (m)
Tier	1a	1a	1a	1a
Projected total (age 6+) biomass (t)	1,361,360	1,784,460	941,359	1,111,320
Projected Female spawning biomass (t)	287,600	320,399	260,887	291,774
B_0	476,820	476,820	447,795	447,795
B_{MSY}	158,972	158,972	155,293	155,293
F_{OFL}	0.157	0.157	0.176	0.176
$maxF_{ABC}$	0.152	0.152	0.169	0.169
F_{ABC}	0.152	0.152	0.169	0.169
OFL (t)	214,084	280,621	166,034	196,011
maxABC (t)	206,896	271,199	158,935	187,631
ABC (t)	206,896	271,199	121,719	119,969
Status	As determined *last* year for:		As determined *this* year for:	
	2020	2021	2021	2022
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

Alternative Model Harvest recommendations

Quantity (M22.1)	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2022	2023	2023	2024
M (natural mortality rate)	0.15 (f),0.17 (m)	0.15 (f),0.17 (m)	0.15 (f),0.19 (m)	0.15 (f),0.19 (m)
Tier	1a	1a	1a	1a
Projected total (age 6+) biomass (t)	1,361,360	1,784,460	666,361	656,779
Projected Female spawning biomass (t)	287,600	320,399	255,669	258,601
B_0	476,820	476,820	447,795	447,795
B_{MSY}	158,972	158,972	146,995	146,995
F_{OFL}	0.157	0.157	0.183	0.183
$maxF_{ABC}$	0.152	0.152	0.174	0.174
F_{ABC}	0.152	0.152	0.174	0.174
OFL (t)	214,084	280,621	121,719	119,969
maxABC (t)	206,896	271,199	116,002	114,334
ABC (t)	206,896	271,199	116,002	114,334
Status	As determined *last* year for:		As determined *this* year for:	
	2020	2021	2021	2022
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

Alternative Model Harvest recommendations

Quantity (M22.2)	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2022	2023	2023	2024
M (natural mortality rate)	0.15 (f),0.17 (m)	0.15 (f),0.17 (m)	0.15 (f),0.19 (m)	0.15 (f),0.19 (m)
Tier	1a	1a	1a	1a
Projected total (age 6+) biomass (t)	1,361,360	1,784,460	811,324	804,351
Projected Female spawning biomass (t)	287,600	320,399	256,816	266,079
B_0	476,820	476,820		
B_{MSY}	158,972	158,972	173,946	173,946
F_{OFL}	0.157	0.157	0.171	0.171
$maxF_{ABC}$	0.152	0.152	0.161	0.161
F_{ABC}	0.152	0.152	0.161	0.161
OFL (t)	214,084	280,621	138,942	137,748
maxABC (t)	206,896	271,199	130,985	129,859
ABC (t)	206,896	271,199	130,985	129,859
Status	As determined *last* year for:		As determined *this* year for:	
	2020	2021	2021	2022
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

Data Gaps and Research Priorities

- Evaluate reason for conflict between survey biomass and age composition
- Continue working group to identify environmental influences on NRS and their mechanisms
- Continue working on climate-enhanced projection model with BSAI NRS

Future model modifications:

- Update formal data weighting approach (M22.1 and M22.2, Appendix A)
- Estimate female and male M (M22.2, Appendix A) with further supporting analyses
- Include ageing error estimates