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Stock assessment for Rex Sole (*Glyptocephalus zachirus*) along the U.S. West Coast in 2023

Markus Min, Emily Sellinger, Terrance Wang, Sabrina Beyer, Alberto Rovellini, Matthieu Véron, Sophia N. Wassermann, Vladlena Gertseva, Kiva L. Oken, Owen Hamel, and Melissa A. Haltuch

August 2023 GFSC Meeting

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Acknowledgements

- John Wallace (NWFSC)
- Kelli Johnson (NWFSC)
- Chantel Wetzel (NWFSC)
- Julia Coates (CDFW)
- Ali Whitman (ODFW)
- Theresa Tsou (WDFW)
- Vanessa Tuttle (NWFSC)
- Andi Stephens (NWFSC)
- Marlene Bellman (PFMC)
- Ian Taylor (NWFSC)
- Jason Cope (NWFSC)
- Tyler Johnson (PSMFC/ NWFSC)
- Nikki Paige (PSMFC/ NWFSC)
- Patrick McDonald (NWFSC)

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Outline

- Summary of previous assessments
- Data overview
  - Fishery-dependent data
  - Fishery-independent data
  - Biological data
- Model description
- Model results
- Decision tables
- Model diagnostics
- Unresolved problems and major uncertainties

Summary of previous assessments

Summary of 2013 Stock Assessment (Cope et al. 2015)

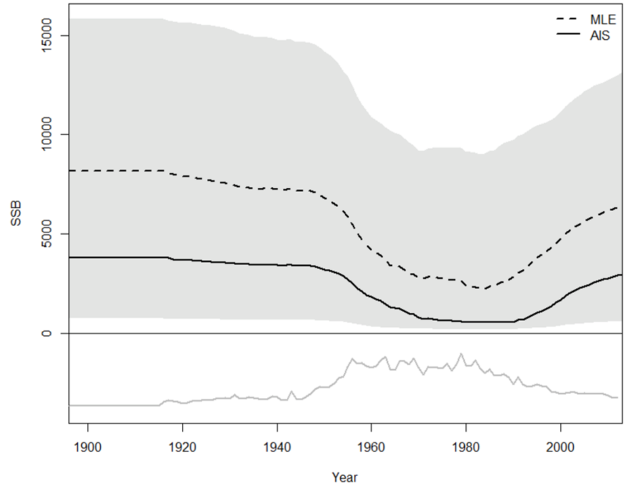


Figure 116. Time series of spawning biomass from the exSSS MLE (broken line) and AIS (solid line with gray uncertainty bars) for rex sole. Catch history is provided below the 0 line.

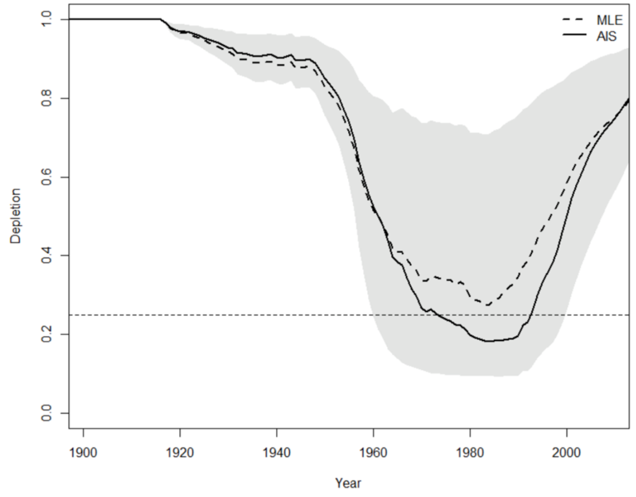
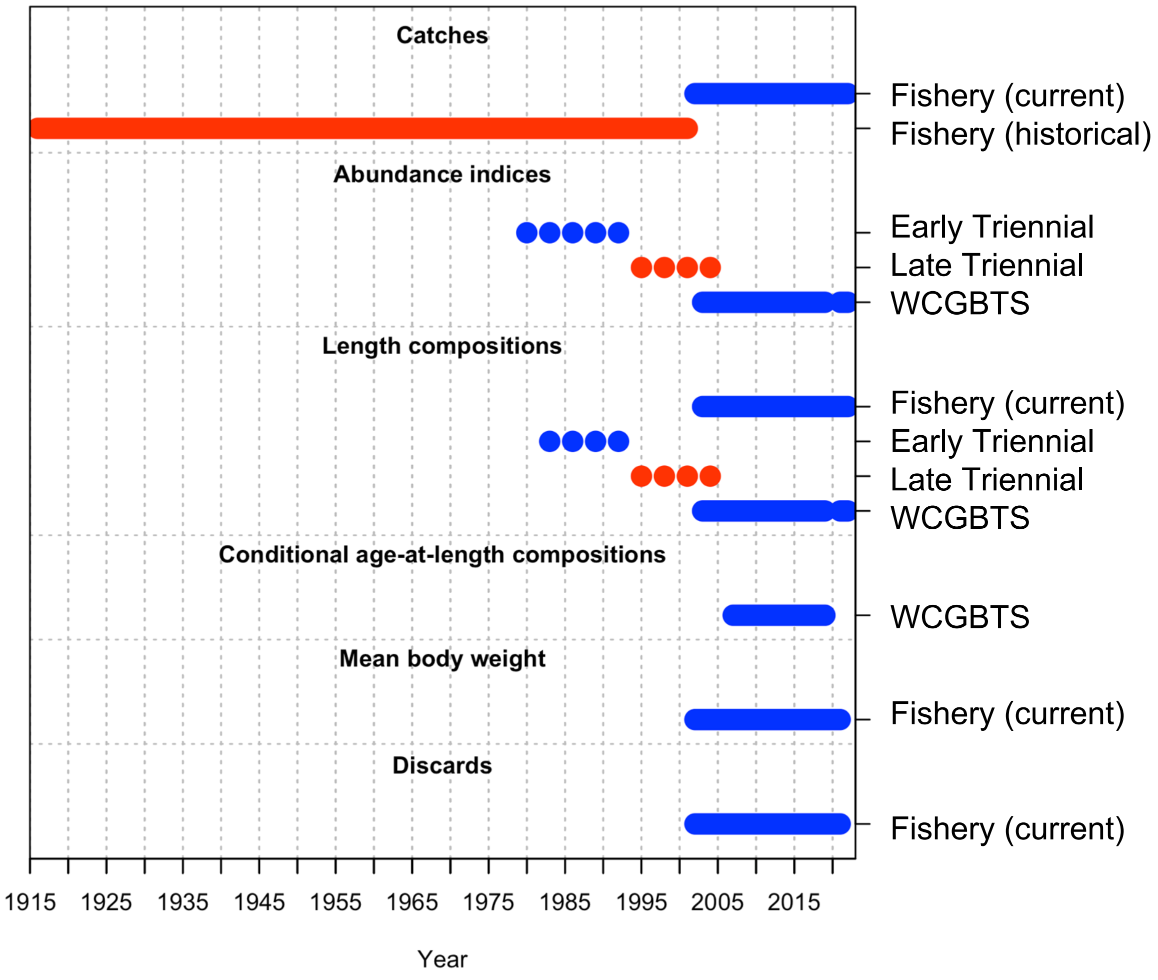


Figure 117. Time series of stock status (depletion) from the exSSS MLE (broken line) and AIS (solid line with gray uncertainty bars) for rex sole.

- No category 1 or 2 assessments prior to 2013
- 2013: Data-moderate stock assessment, with Extended Simple Stock Synthesis (exSSS) applied to **removal and index data** (no length or age data)
- Hessian NOT POSITIVE DEFINITE; uncertainty instead estimated using AIS (adaptive importance sampling)
- Surveys: Two triennial survey time series (1980 1994, 1995-2004) and one annual survey time series (2003-2012)
- Fishery: One coastwide fleet
- Stock assessed to be at 80% of virgin biomass

Data Overview

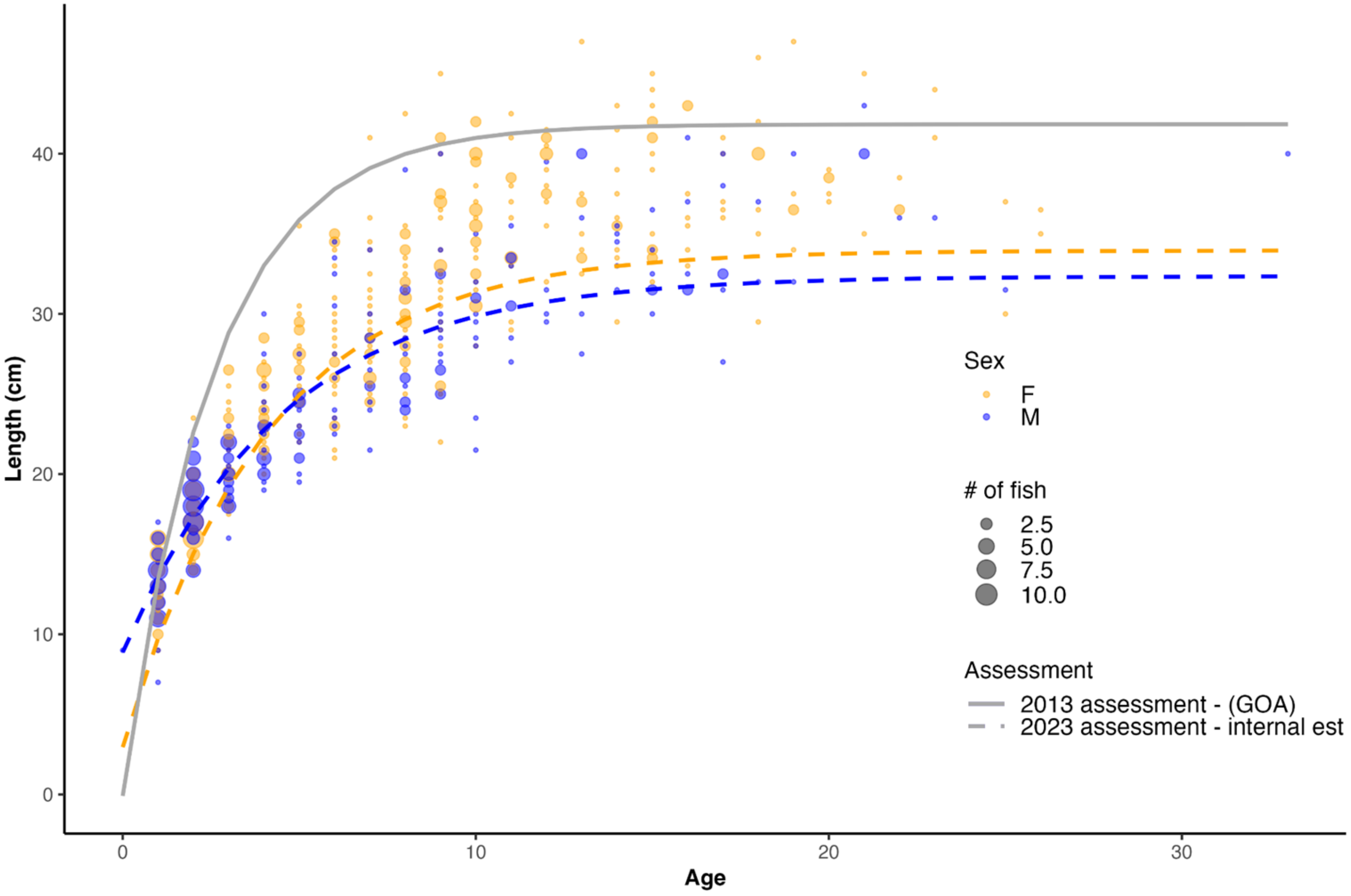
Data Overview



- Biological data
- Survey Indices
- Landings
- Discards
- Length compositions from fishery and surveys
- Conditional age-at-length from WCGBTS

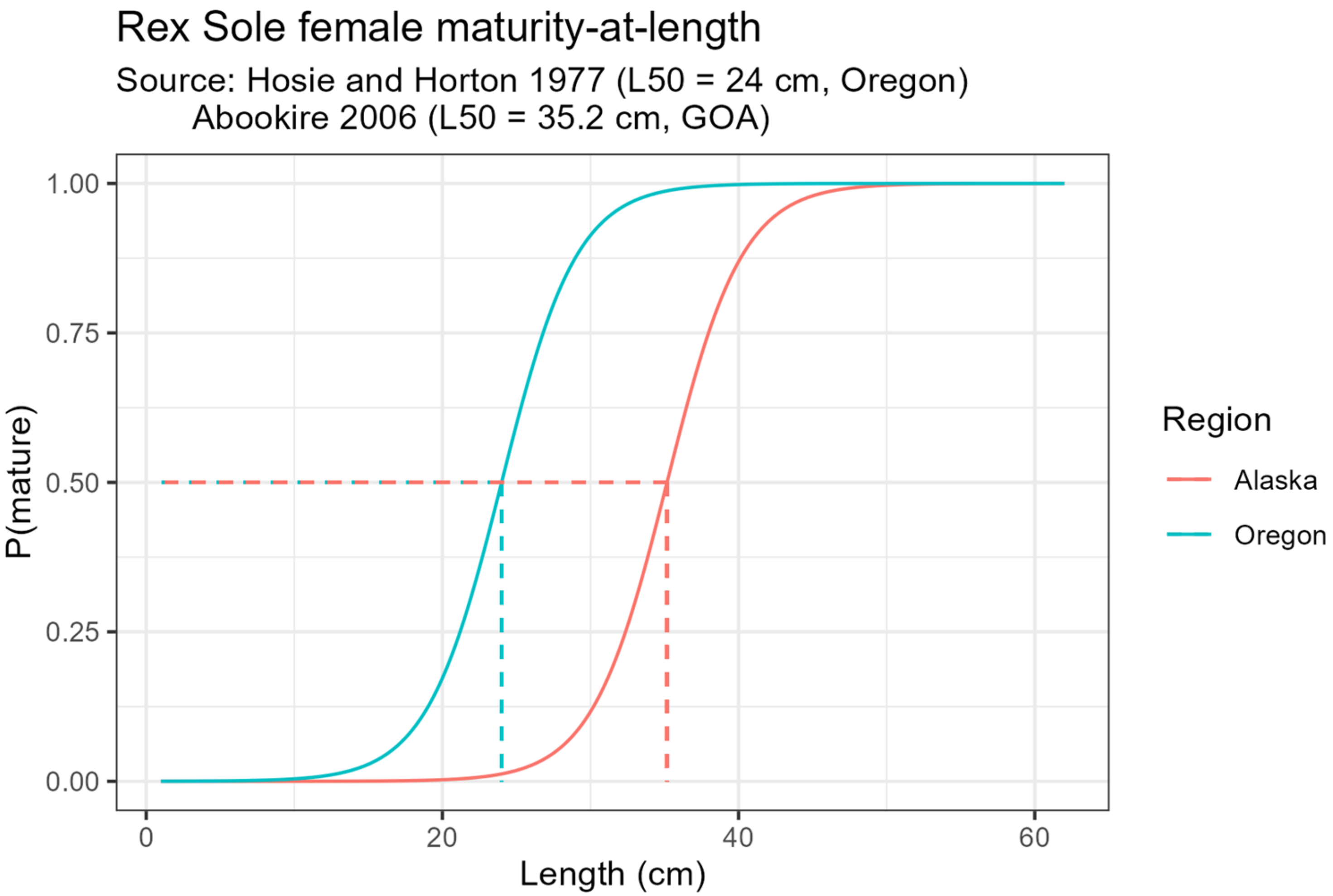
Data Overview - Growth updated

- Newly available length-at-age data from WCGBTS
- West Coast fish smaller than fish in Gulf of Alaska (GOA) (GOA parameters used in 2013)
- 2023: Growth internally estimated using CAAL data (externally estimated growth curves were not used due to likely bias originating from selective aging of smallest and largest fish)



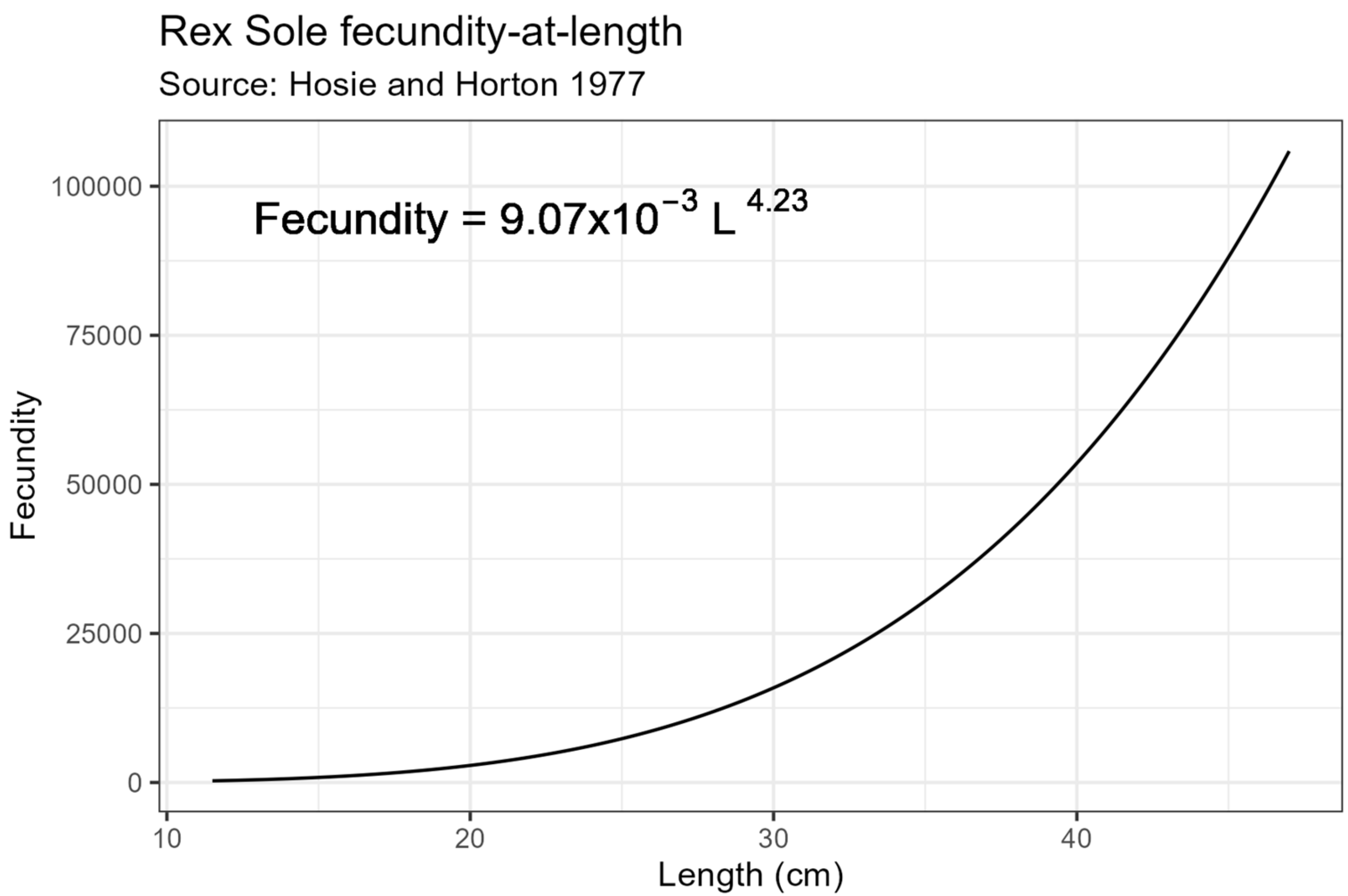
Data Overview - Maturity updated

- Fixed
- Females mature at smaller size on West Coast
  - Hosie and Horton (1977)
  - $L_{50\%}$ = 24 cm
  - 453 females
  - Oregon
  - 1969-1973
  - macroscopic maturity and no statistical fit to the data
- Assumed same slope as GOA fish (Abookire 2006)



Data Overview - Fecundity updated

- Fixed
- 2013 assessment: spawning biomass assumed equivalent to spawning output
- Added fecundity-at-length
  - hyper-allometric relationship meanir larger females produce more eggs p kg of body weight
  - Hosie and Horton (1977)
  - 13 females
- Similar to other flatfish
  - Petrale Sole (Lefebvre *et al.* 2019)
  - $b = 4.55$ (95% CI: 3.97-5.13, n = 70)



Data Overview - Natural Mortality

- 2013: internally estimated $M = 0.199$

- 2023: Fixed at the median of a prior based on longevity (Hamel 2015, Hamel and Cope 2022)

  - Equation for the prior: $M = 5.40/ Age_{max}$, where $Age_{max} = 29$ years

- 2023 assessment fixed $M = 0.186$ (median of the prior ; SD = 0.31 in logspace)

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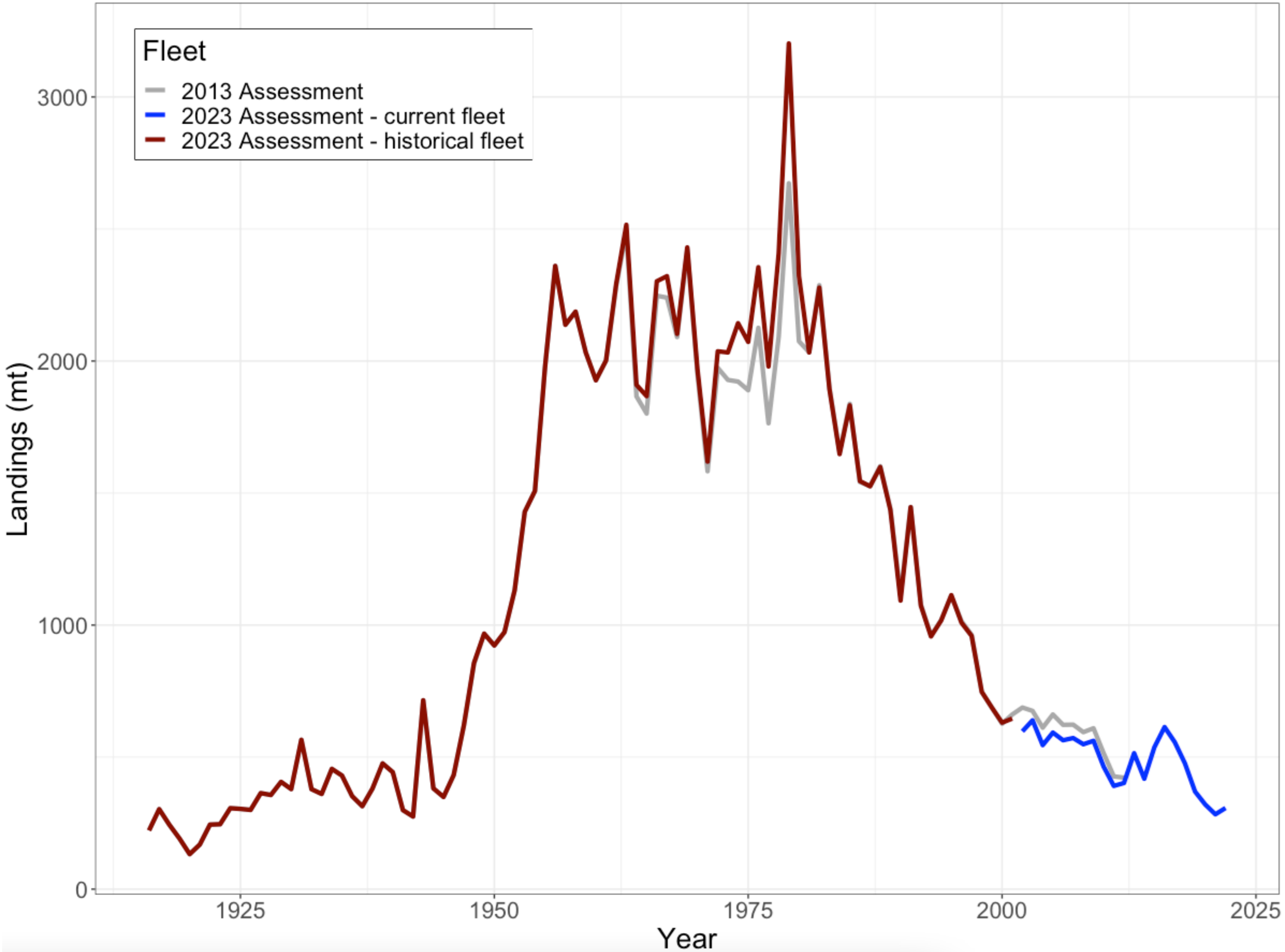
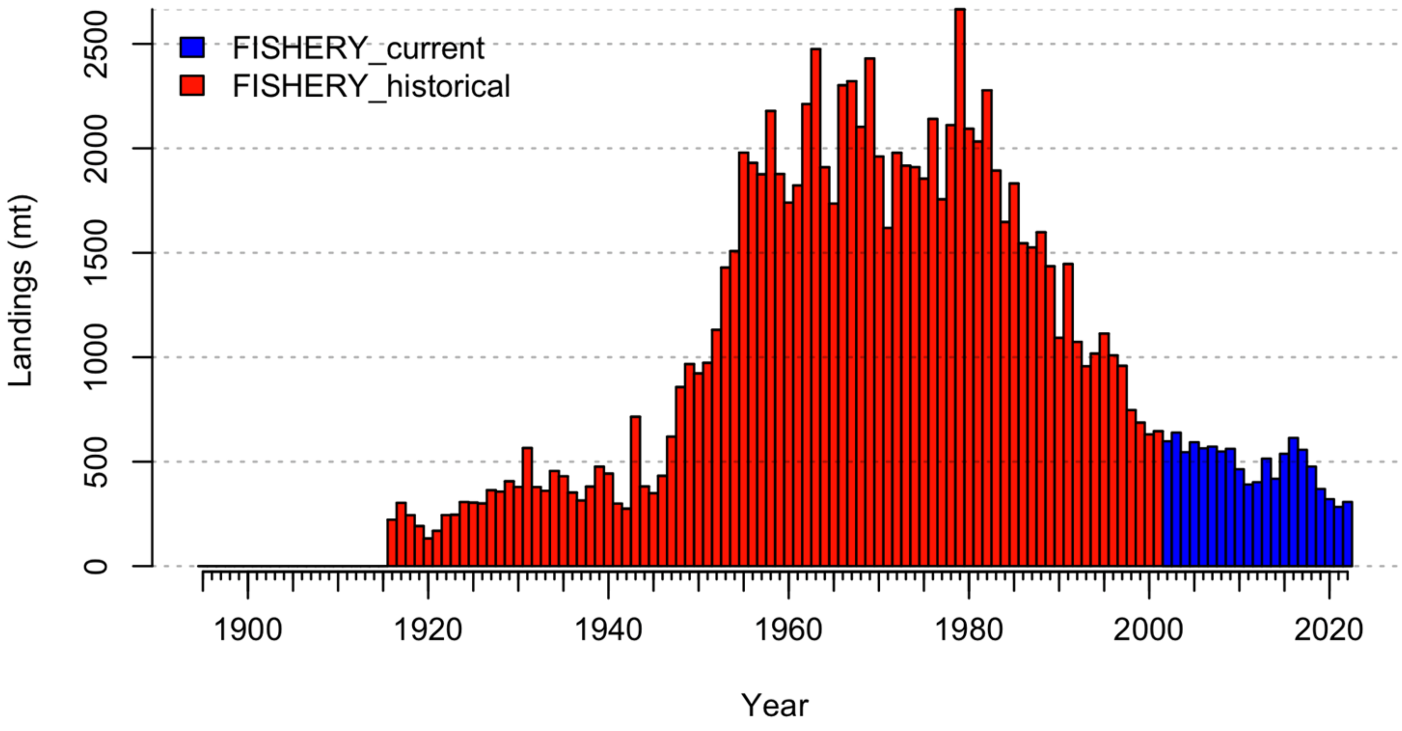
Landings Updated



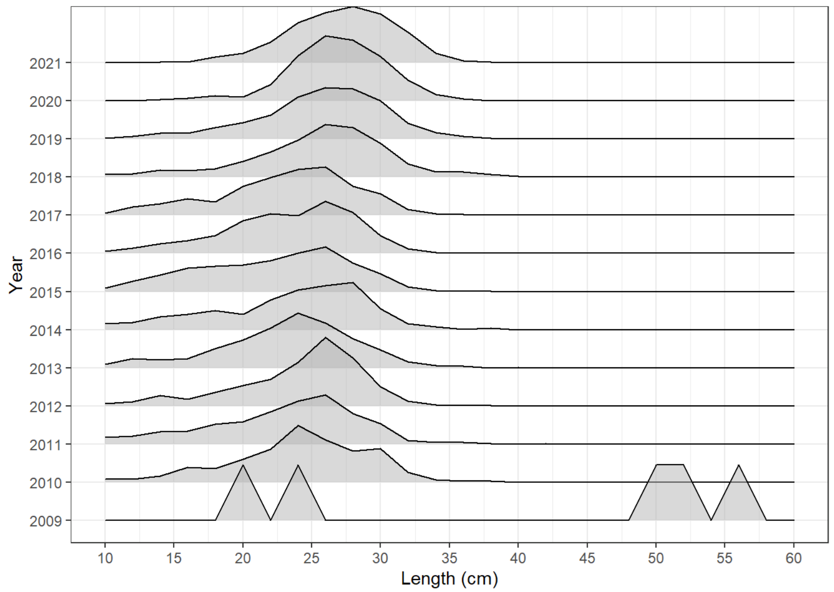
- Unchanged Data from 2013 Assessment
  - CA Comm Recon (1931-1968)
  - CALCOM (1969-1980)
  - CDFG Bulletin (1916-1930)
- Updated Data
  - OR Comm Recon (1929-1987)
  - PacFIN (1981-2022)
  - NORPAC Hake (1990-2022)
- New Data
  - WA Comm Recon (1948-1980)
- Removed Data
  - WA PMFC (1956-1976)

Fleet structure split

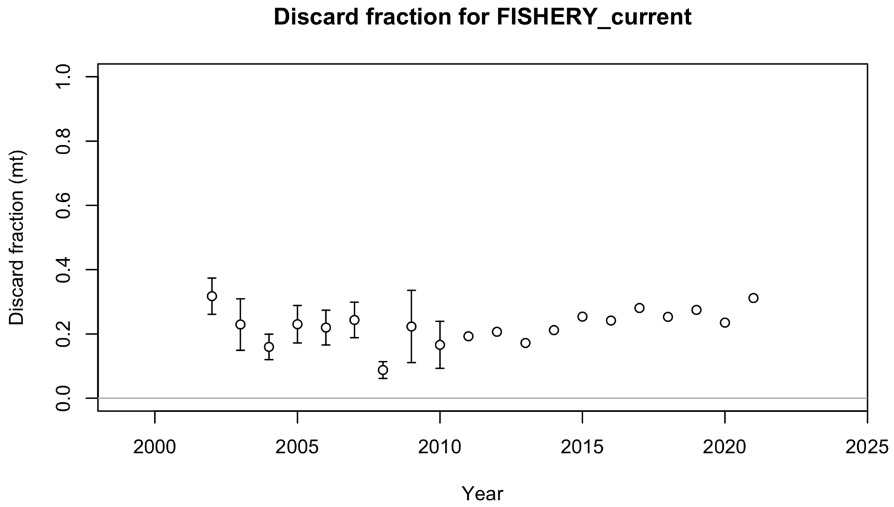


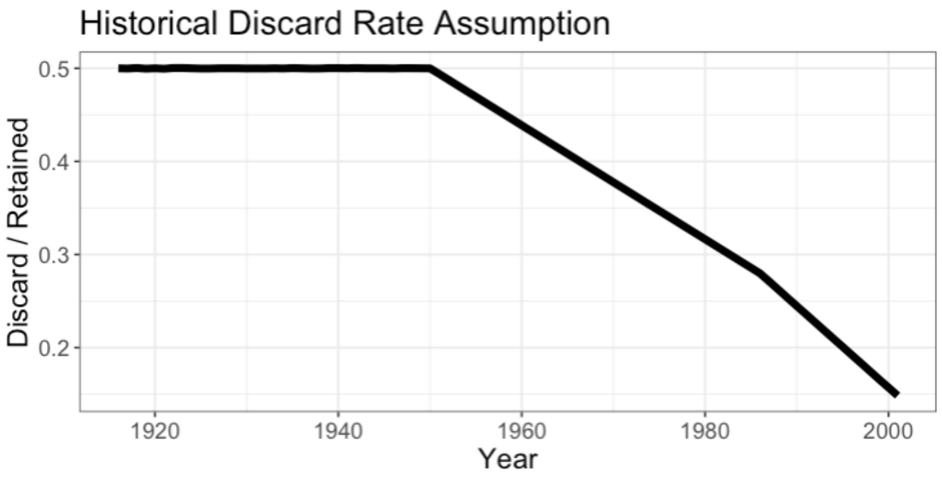
- Coastwide
- Recreational
  - Negligible (no update)
- Single Gear Fleet
  - >98% Trawl (no update)
- Fleet Structure
  - Historical and current
  - Motivated by discard data

New Discard Data



- 2013: Discards were added to landings within the only fishery fleet with time-varying discard rate assumption
- 2023: Motivation for separating discards in current fleet:
  a. 20-30% of caught Rex Sole gets discarded
  b. Discarded fish are smaller than retained fish
  c. Source of length composition data
  d. Lack of data in historical fleet
- Data sources:
  a. West Coast Groundfish Observer Program (WCGOP, 2002-2021): % ratios, length-frequency, average weight



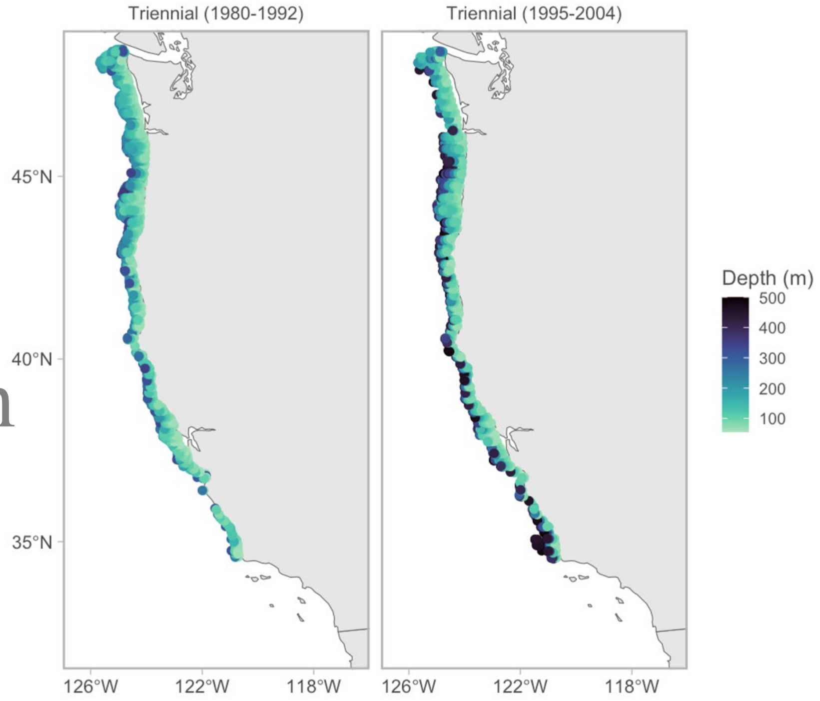


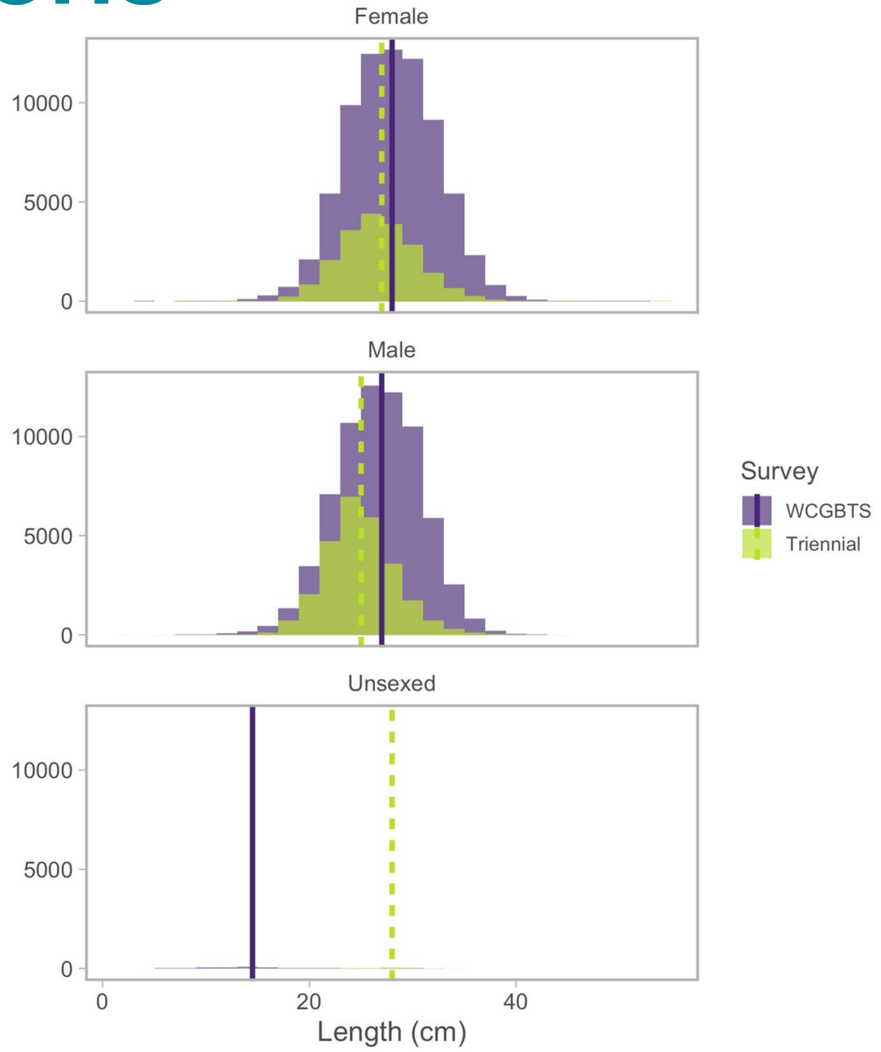
sdmTMB indices of abundance

- Spatio-temporal delta model - sdmTMB
- WCGBTS (2003-2022)
- Triennial (1980-2005)
    - Calculated as single time series across early and late periods
    - Split into 2 survey fleets to account for different selectivities

New survey length compositions

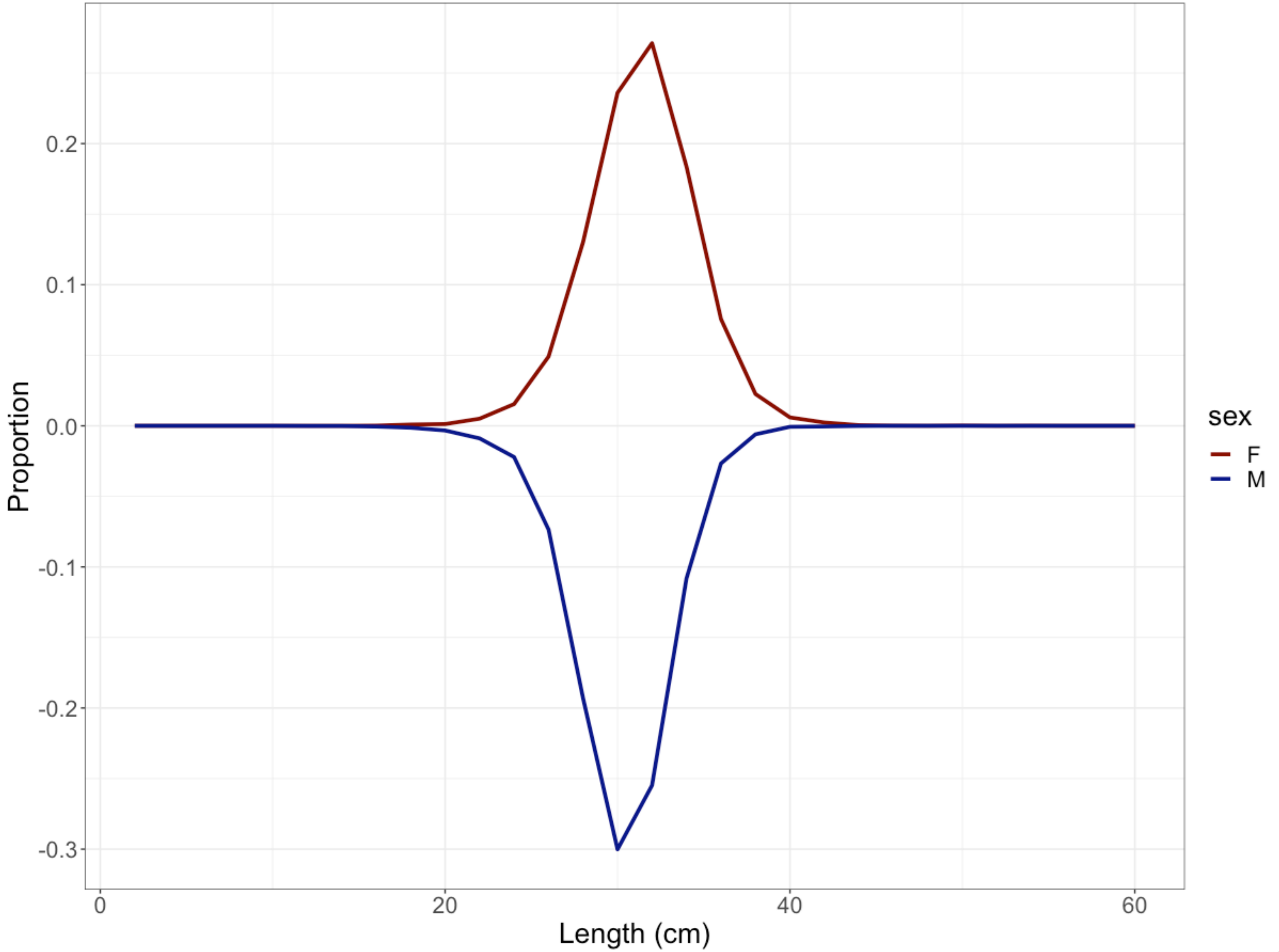
- WCGBTS & Triennial
- Length bins 2-60cm, 2cm increments
- Males & females; 0.3% unsexed
- Split Triennial between early & late periods to account for increase in depth for late





New fishery length c ompositions

- Data for 2002 - 2022
- 2 cm length bins from 2-60 cm
- Unsexed represent 3% of data



2023 Proposed Base Model

Model Changes from the Last Assessment

1. Updating biological parameters (fecundity, maturity, length-weight)
2. Internally estimating growth parameters
3. Including length composition data
4. Including CAAL data
5. Two-fleet structure (historical 1916-2001 vs. current 2002-2022)
6. Including mean body weight of discarded fish for current fishery
7. Estimating discard rates for current fishery
8. Sex-specific fishery selectivity (male selectivity as offset from female)
9. Dropping WCGBTS extra standard deviation
10. Fixing steepness of stock-recruit relationship
11. Estimating recruitment deviations
12. Fixing natural mortality (M)
13. Data weighting
14. Block design for current fishery retention

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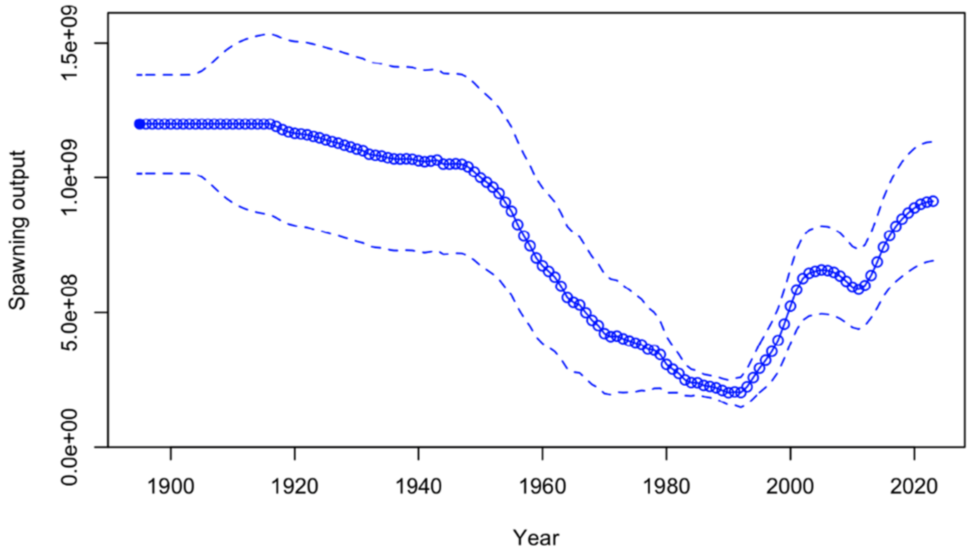
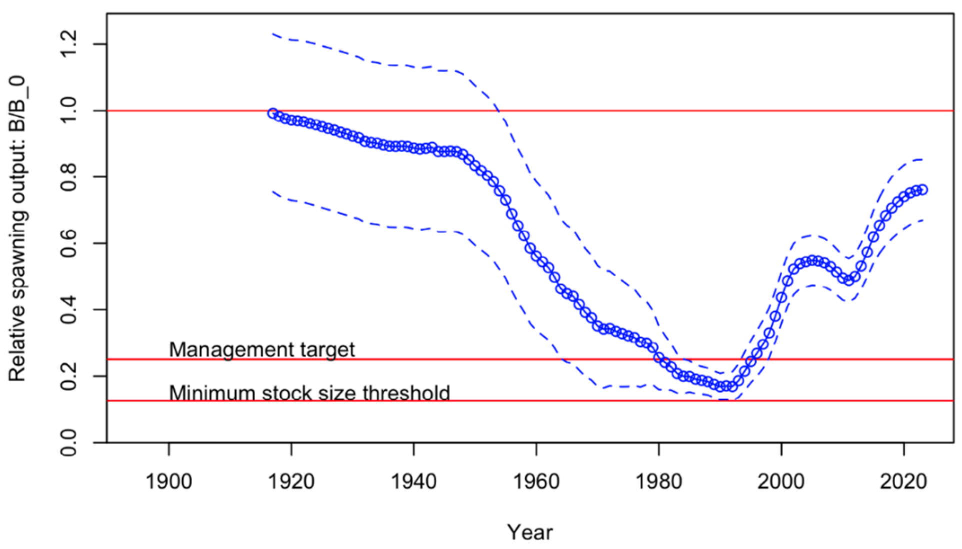
Model Results

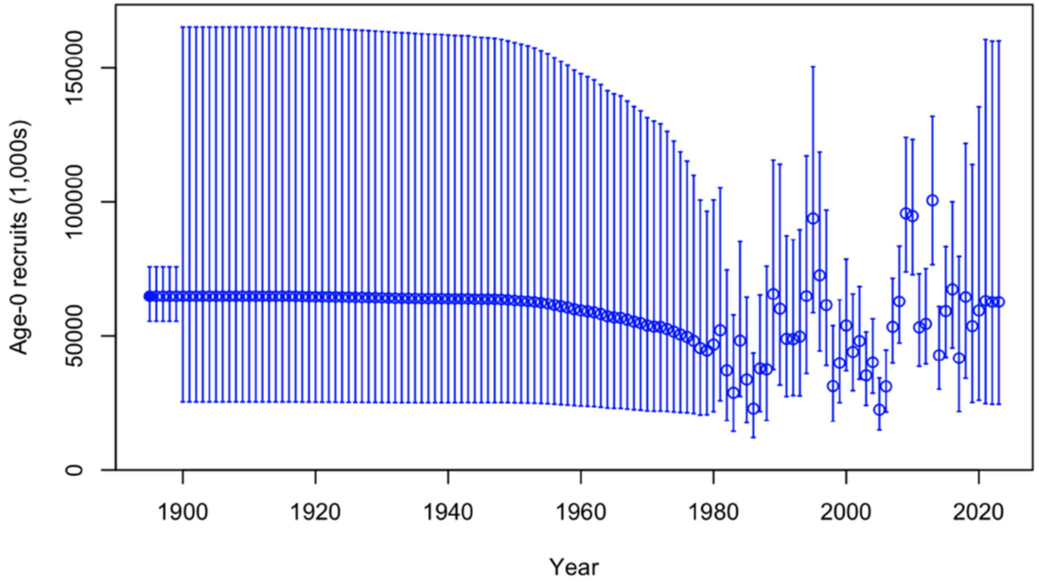
Population trajectory

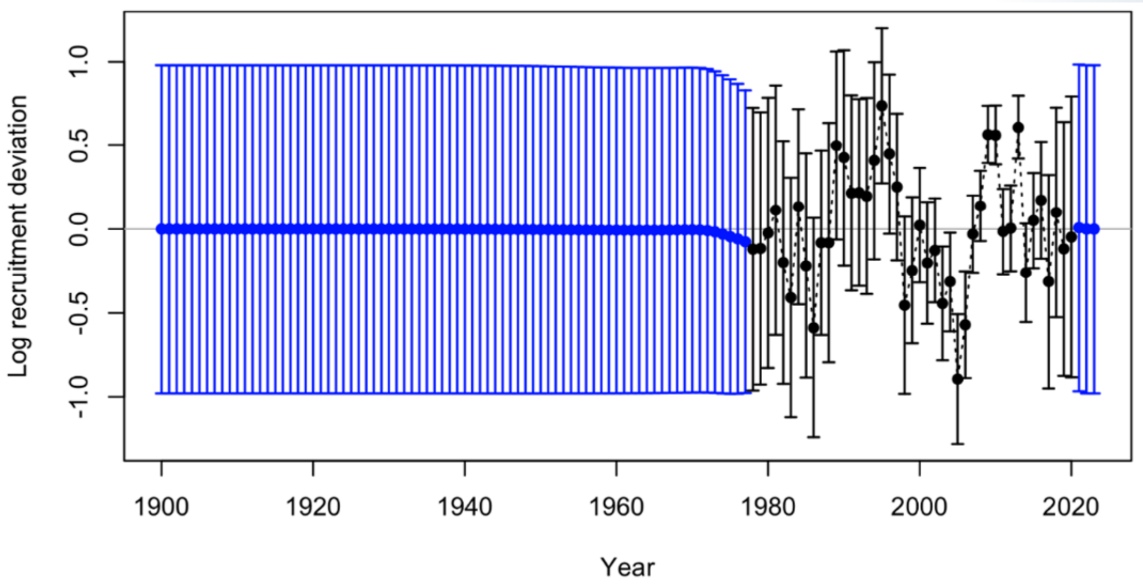




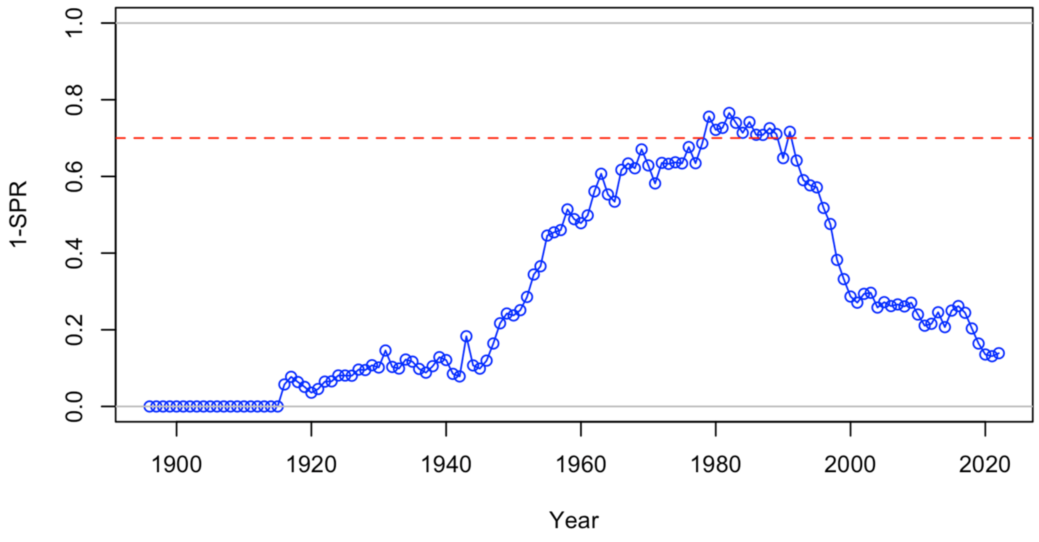
- 76% of unfished in 2023

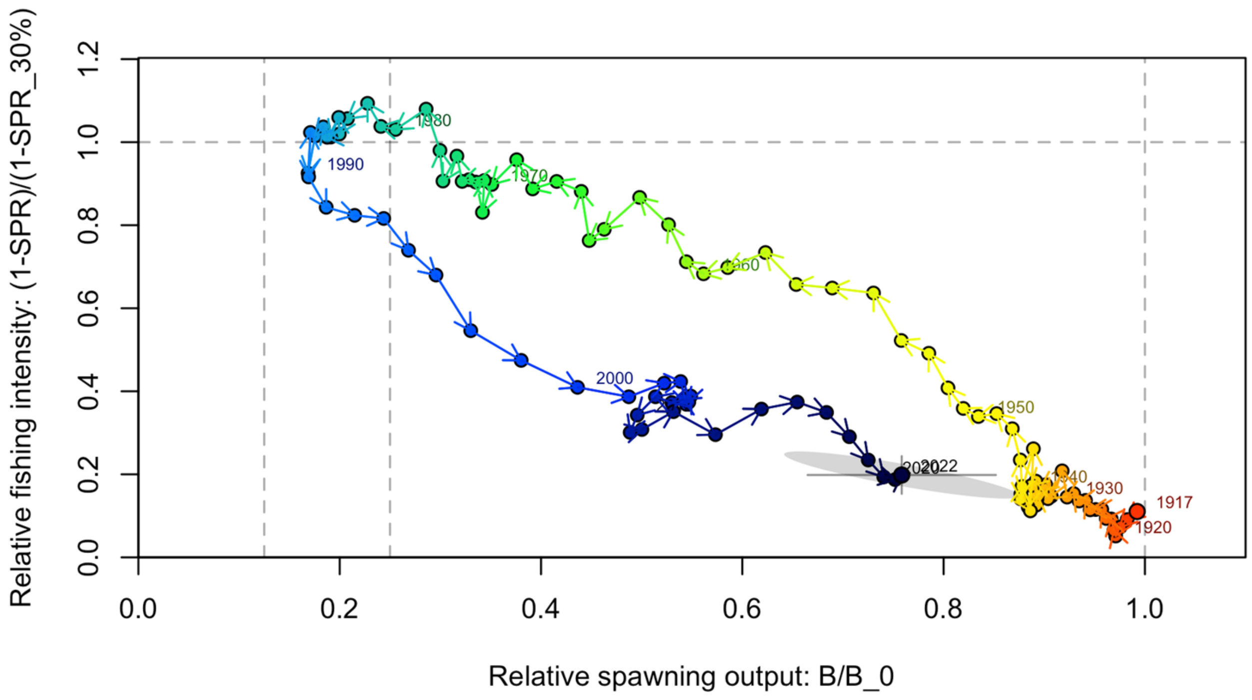
Recruitment Deviations





Total mortality and fishing intensity





Summary of reference points and management quantities

	Estimate	Lower Interval	Upper Interval
Unfished spawning output (millions)	1199	1011	1387
Unfished Age 0+ Biomass (mt)	30007	25380	34635
Unfished Recruitment (R0)	64798	54653	74944
Spawning Output (2023) (millions)	913	692	1133
Fraction Unfished (2023)	0.761	0.67	0.853
Reference Points Based SB25%	-	-	-
Proxy Spawning Output (millions) SB25%	300	253	347
SPR Resulting in SB25%	0.33	0.33	0.33
Exploitation Rate Resulting in SB25%	0.573	0.381	0.764
Yield with SPR Based On SB25% (mt)	1680	1419	1942
Reference Points Based on SPR Proxy for MSY	-	-	-
Proxy Spawning Output (millions) (SPR30)	259	218	300
SPR30	0.3	-	-
Exploitation Rate Corresponding to SPR30	0.651	0.432	0.869
Yield with SPR30 at SB SPR (mt)	1658	1400	1916
Reference Points Based on Estimated MSY Values	-	-	-
Spawning Output (millions) at MSY (SB MSY)	321	270	371
SPR MSY	0.346	0.34	0.352
Exploitation Rate Corresponding to SPR MSY	0.537	0.363	0.712
MSY (mt)	1683	1421	1945

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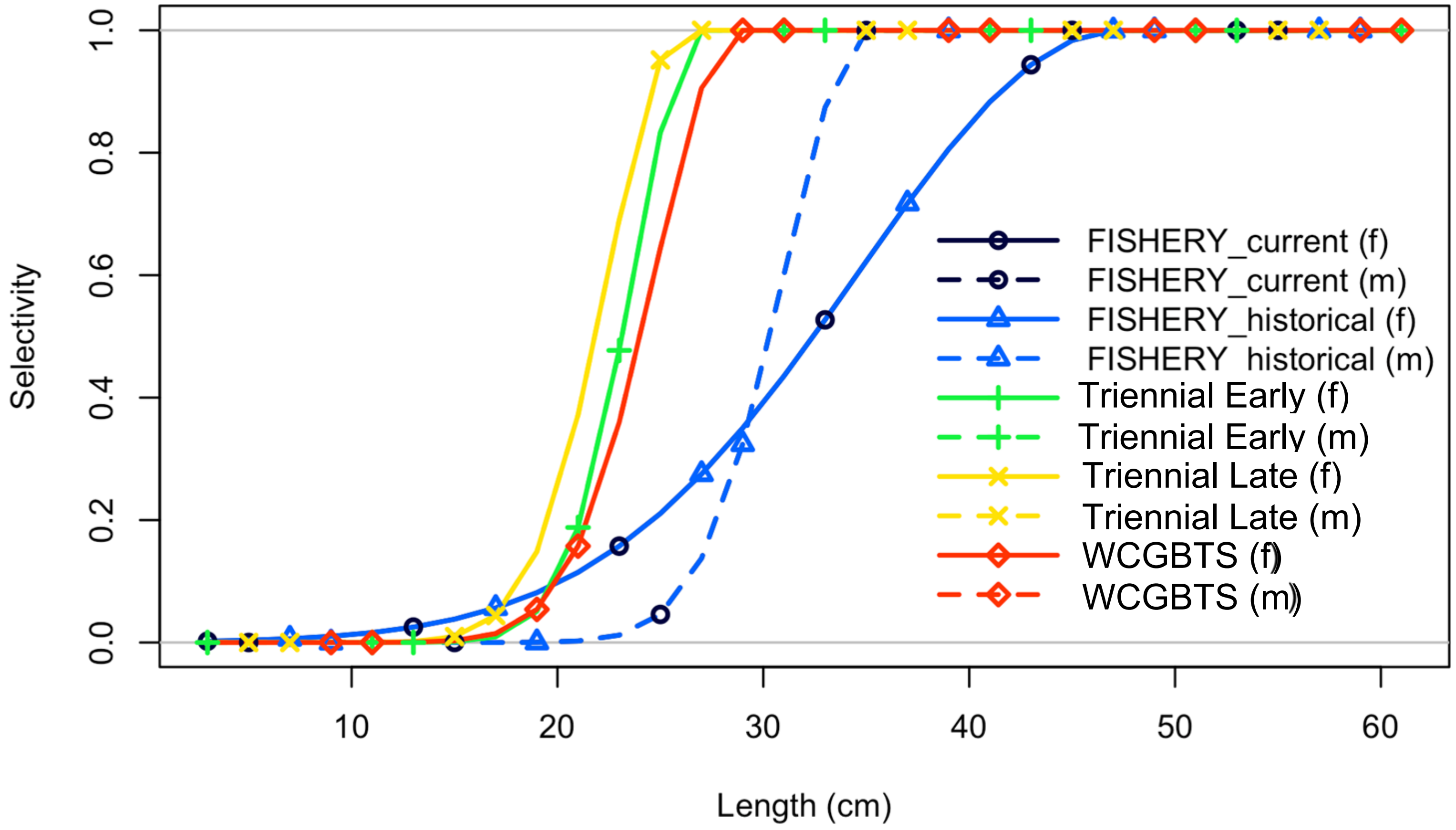
Decision Table

		M = 0.175		M = 0.186		M = 0.210	
Year	Catch	Spawning Output (millions)	Fraction unfished	Spawning Output (millions)	Fraction unfished	Spawning Output (millions)	Fraction unfished
ACL P* = 0.4							
2023	447	792	0.669	913	0.761	1054	0.886
2024	447	801	0.676	915	0.764	1046	0.879
2025	3967	811	0.685	920	0.767	1039	0.873
2026	3310	671	0.566	783	0.653	909	0.764
2027	2850	570	0.481	684	0.570	815	0.685
2028	2527	497	0.420	613	0.511	749	0.629
2029	2305	446	0.377	563	0.470	702	0.590
2030	2147	411	0.347	528	0.441	670	0.564
2031	2032	386	0.326	504	0.421	649	0.545
2032	1942	367	0.310	487	0.407	634	0.533
2033	1869	354	0.299	475	0.396	623	0.524
2034	1810	343	0.290	467	0.389	617	0.519
ACL P* = 0.45							
2023	447	792	0.669	913	0.761	1054	0.886
2024	447	801	0.676	915	0.764	1046	0.879
2025	4550	811	0.685	920	0.767	1039	0.873
2026	3719	646	0.545	759	0.633	888	0.747
2027	3153	529	0.446	645	0.538	781	0.657
2028	2769	447	0.377	565	0.471	707	0.594
2029	2510	390	0.329	510	0.425	655	0.551
2030	2334	351	0.296	471	0.393	620	0.522
2031	2212	323	0.273	445	0.371	597	0.502
2032	2119	302	0.255	425	0.355	580	0.488
2033	2044	285	0.241	411	0.343	568	0.478
2034	1983	271	0.229	400	0.333	560	0.471

- Female natural mortality used as axis of uncertainty
- Projections start in 2025

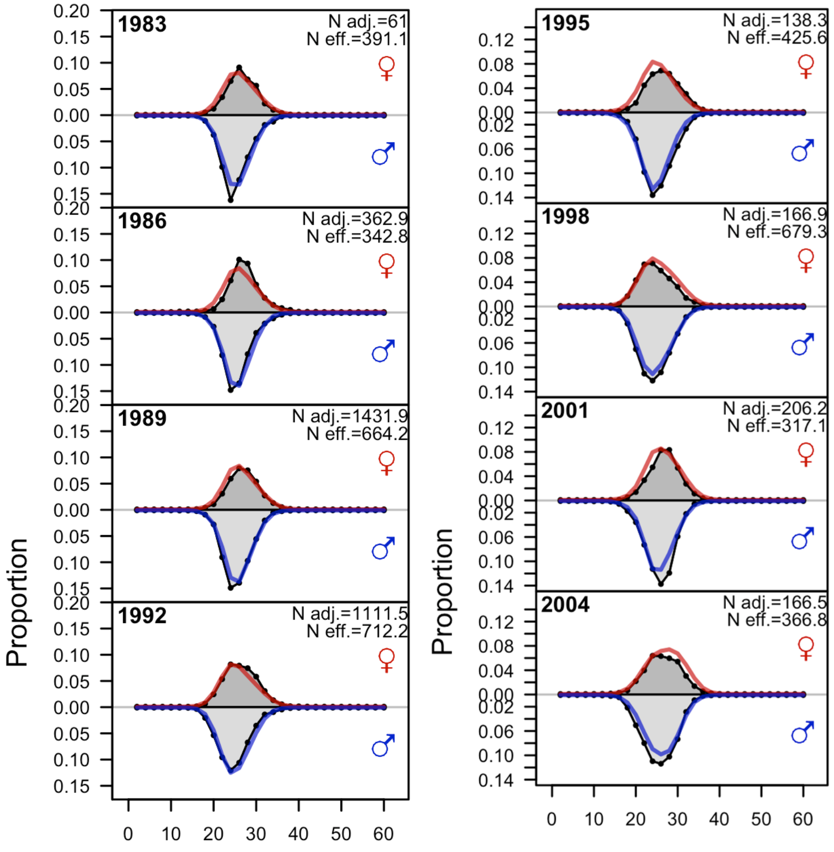
Model evaluation and diagnostics

Estimated selectivity curves

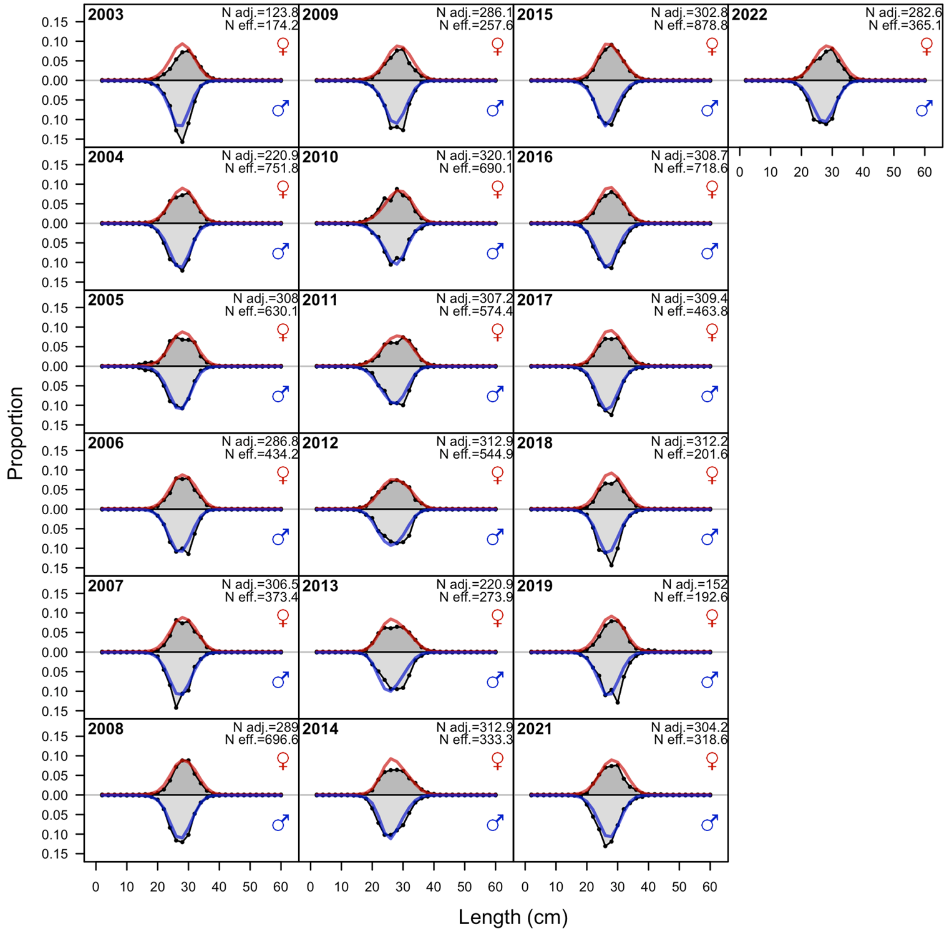


- Sex-specific selectivity improved fit
- All fleets fixed to have asymptotic selectivity
- Historical fishery selectivity fixed to mirror current fishery selectivity

Fit to survey length compositions

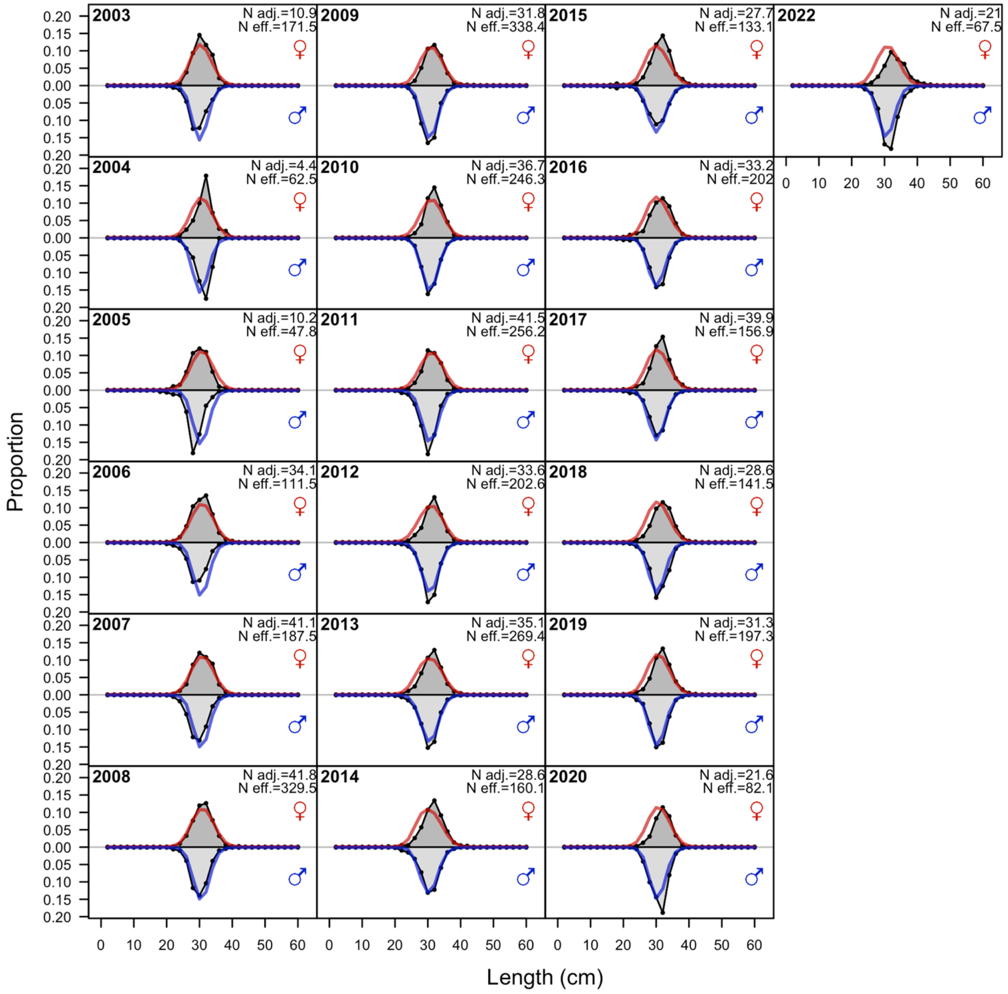


Triennial (early & late)

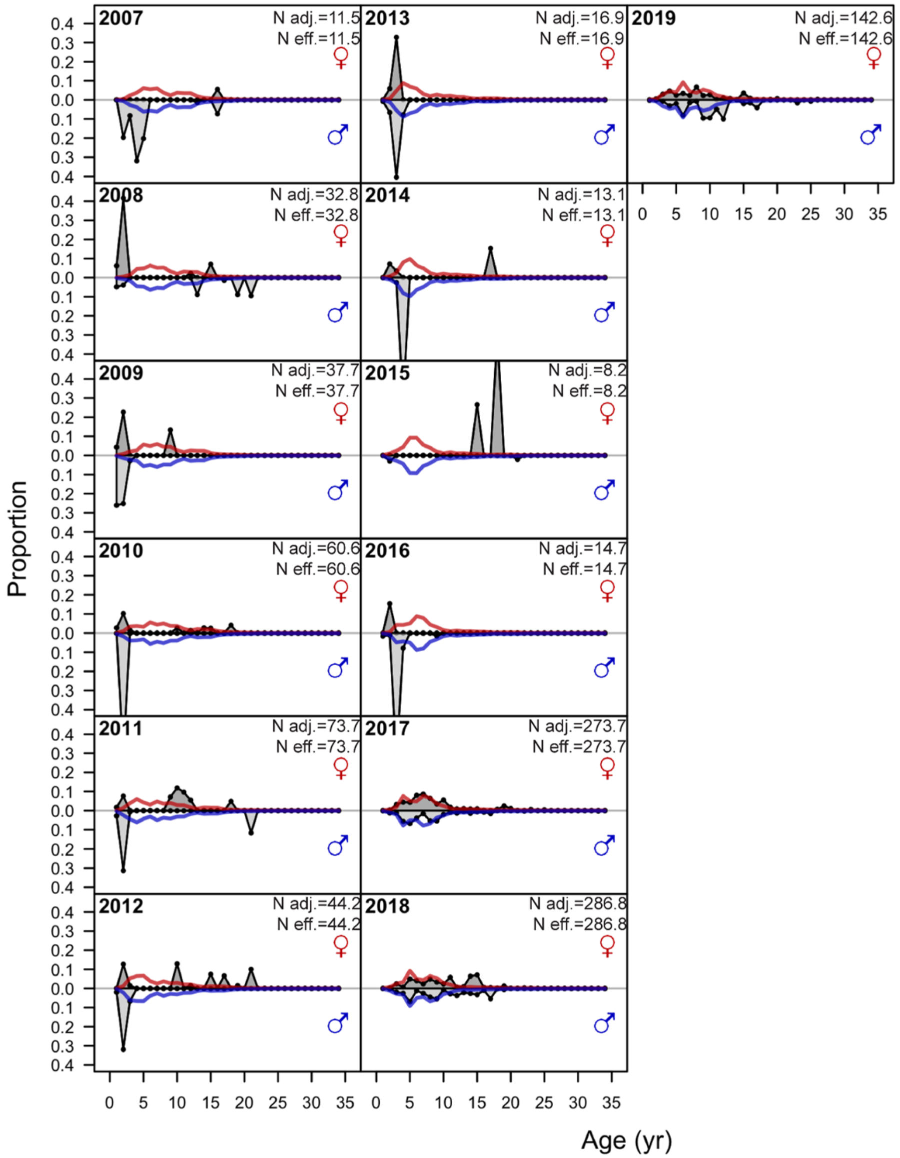


WCGBTS

Fit to length compositions - Fishery

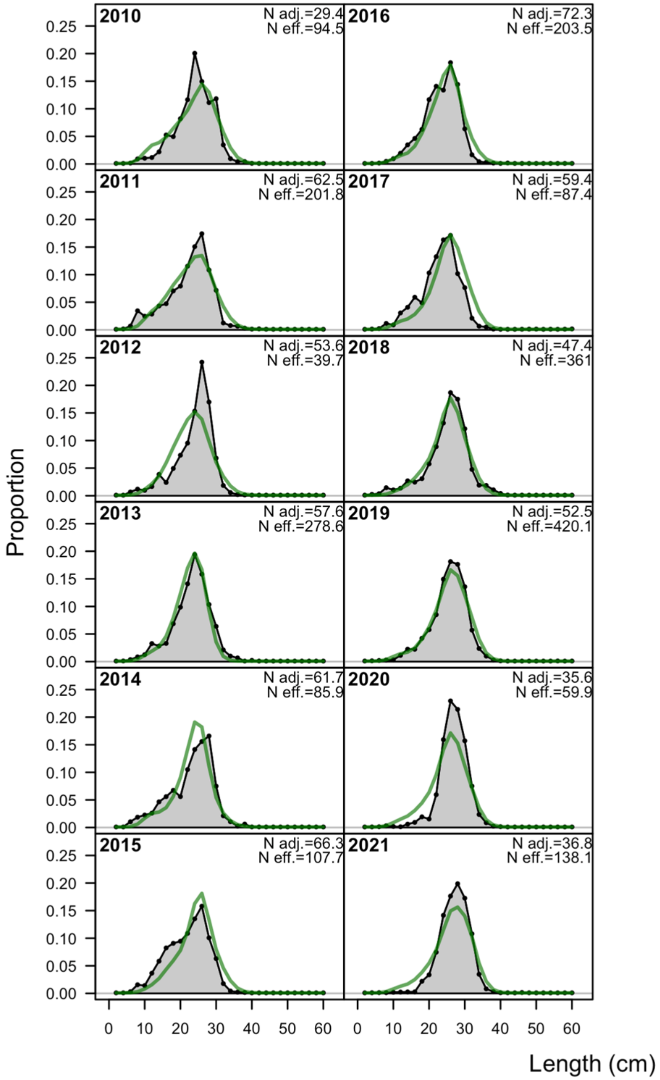


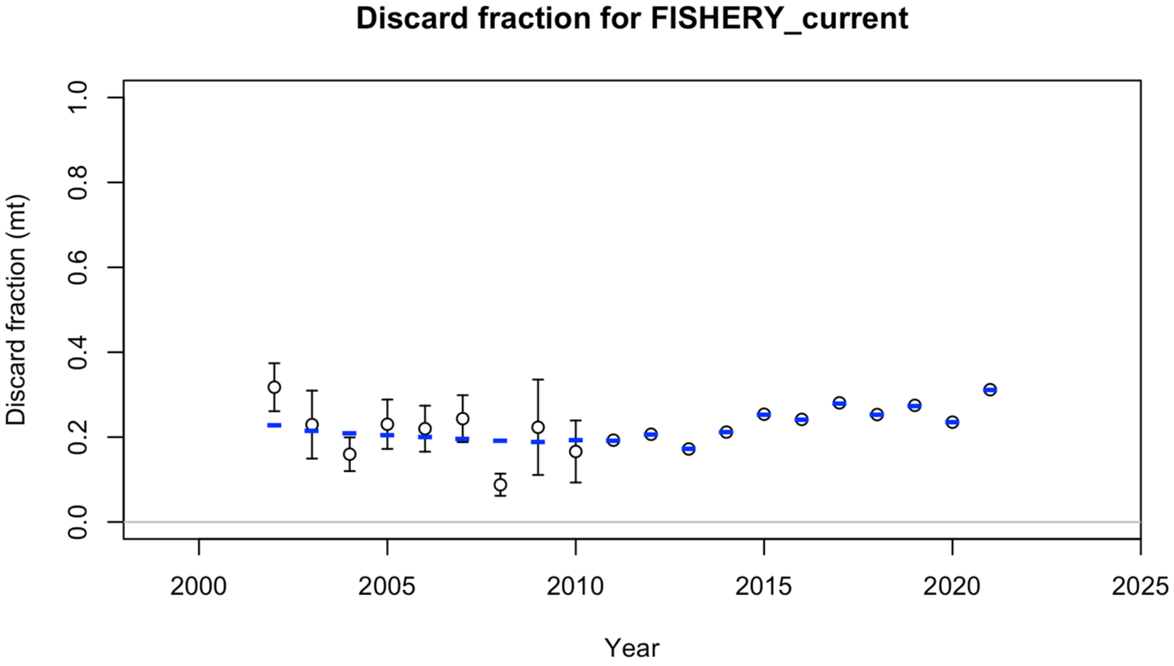
Fit to WCGBTS CAAL



- N = 620 ages across all years
- Poor fits in earlier years with low sample sizes
- 2017, 2018, 2019 have better fit (>85 samples)
- Francis weight = 1.6

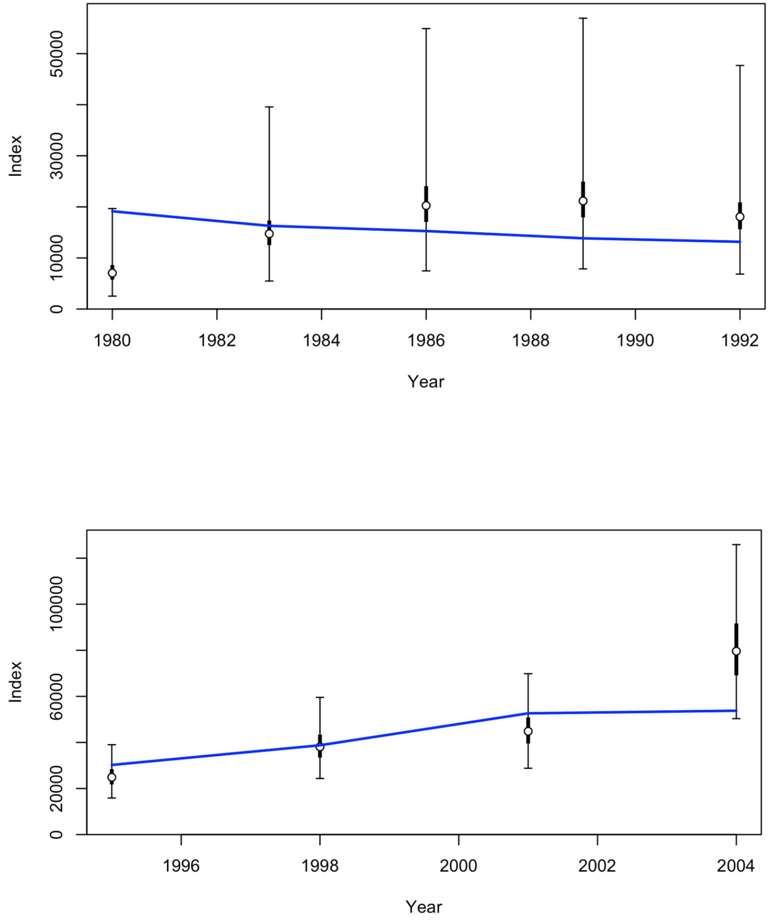
Fit to discard data



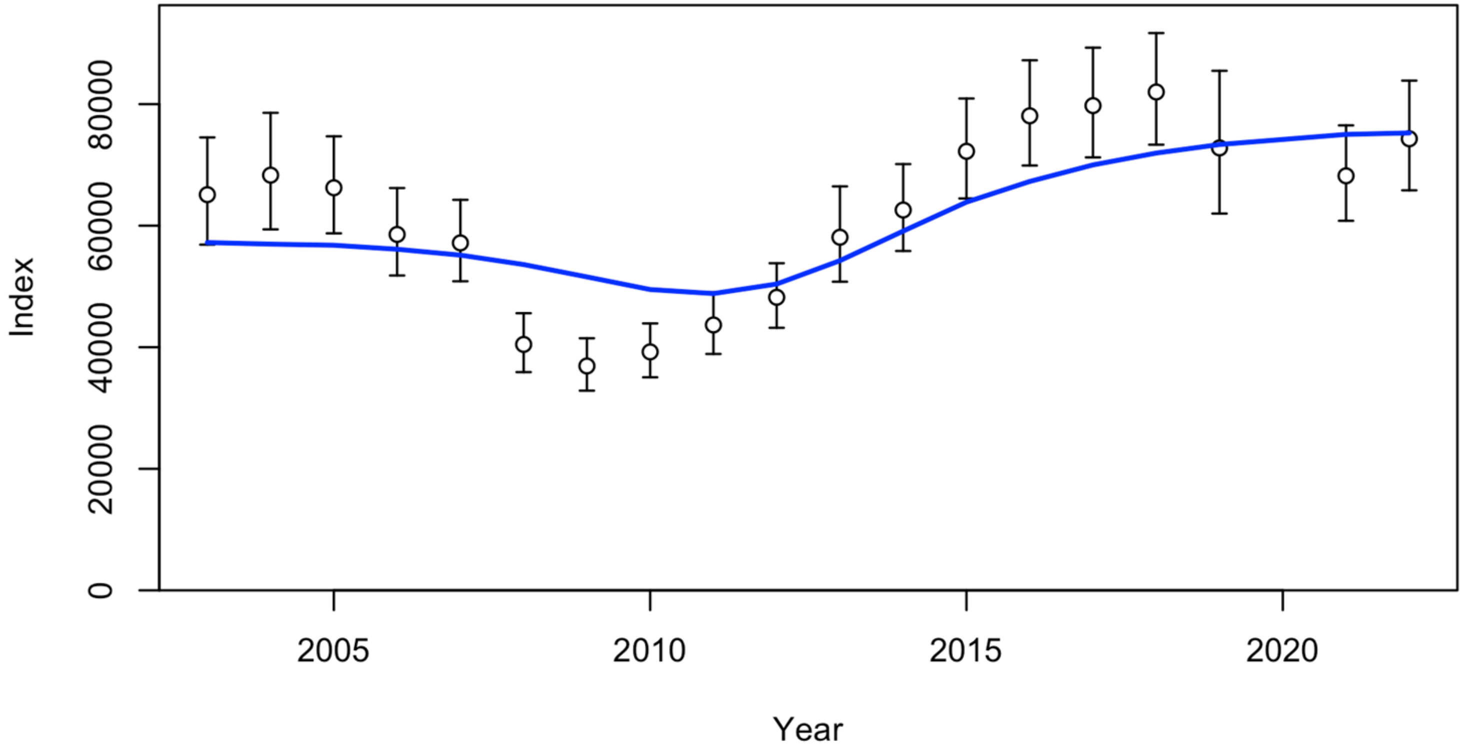


OK fit to indices of abundance

Triennial (early & late)



WCGBTS



Diagnostics: Retrospectives, likelihood profiles

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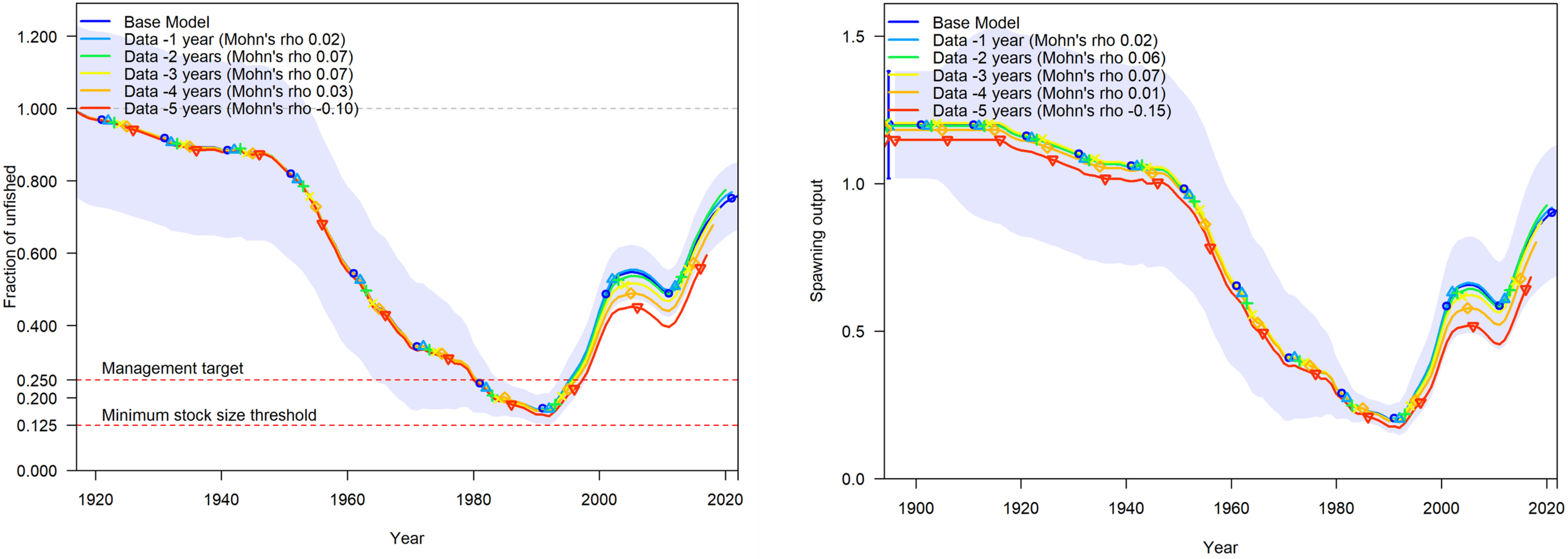
Patterns in retrospective analysis emerge when age data is removed



- Last year of age data = 2019

Likelihood Profiles: M, h, R0, Q

- Steepness (h) and natural mortality (M) fixed
  - MLE value of female M is considerably lower than prior median (which M is fixed at in the base model). MLE value of female M considered implausible based on longevity
  - likelihood surface for h is quite flat in the range of 0.6-0.9; fixed value at 0.7
- R0 and WCGBTS Q at MLE value
- Across range of values for h, R0, and Q, stock status is above management target; for M, stock status is above management target for all values except lowest values

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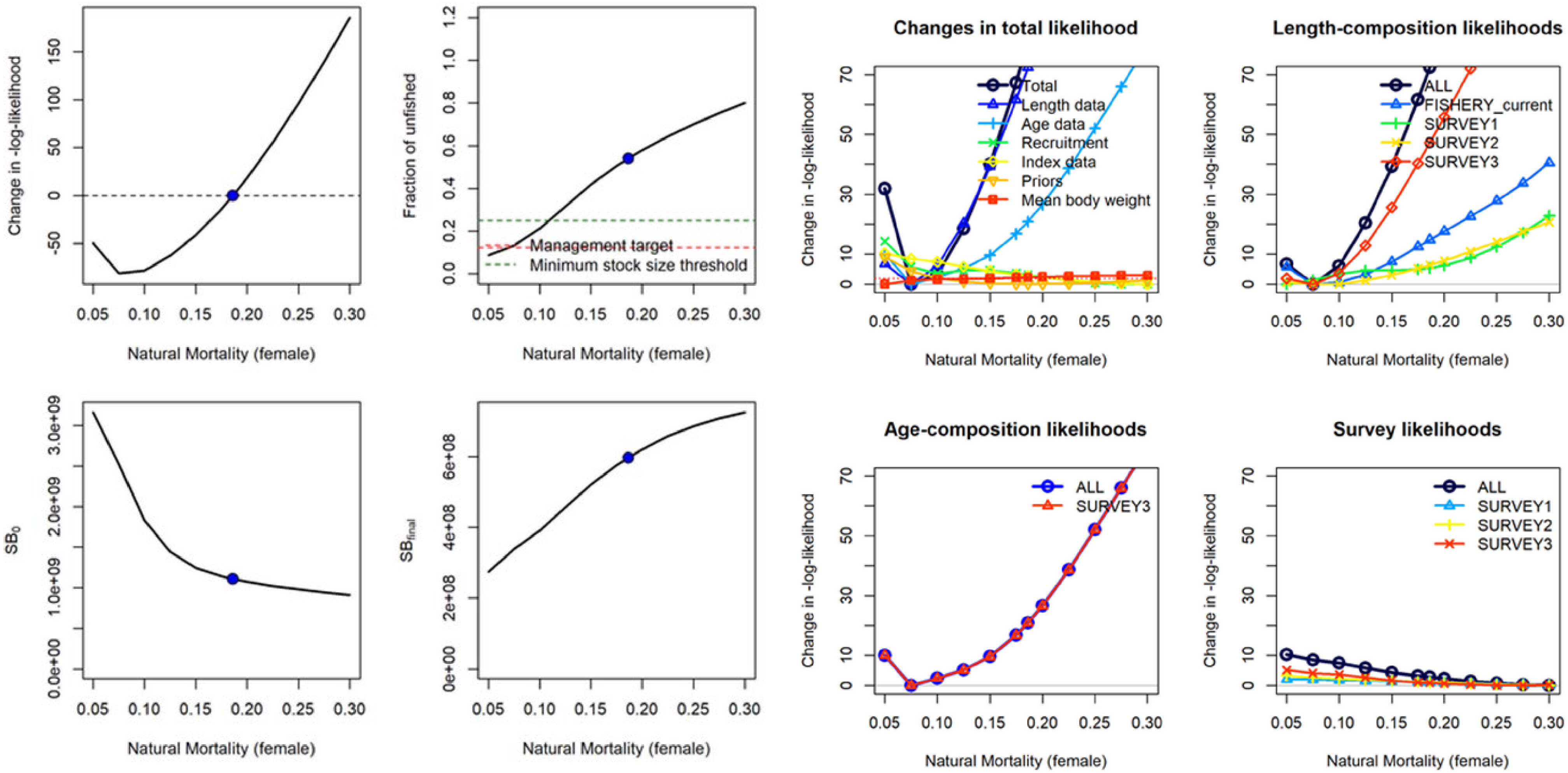
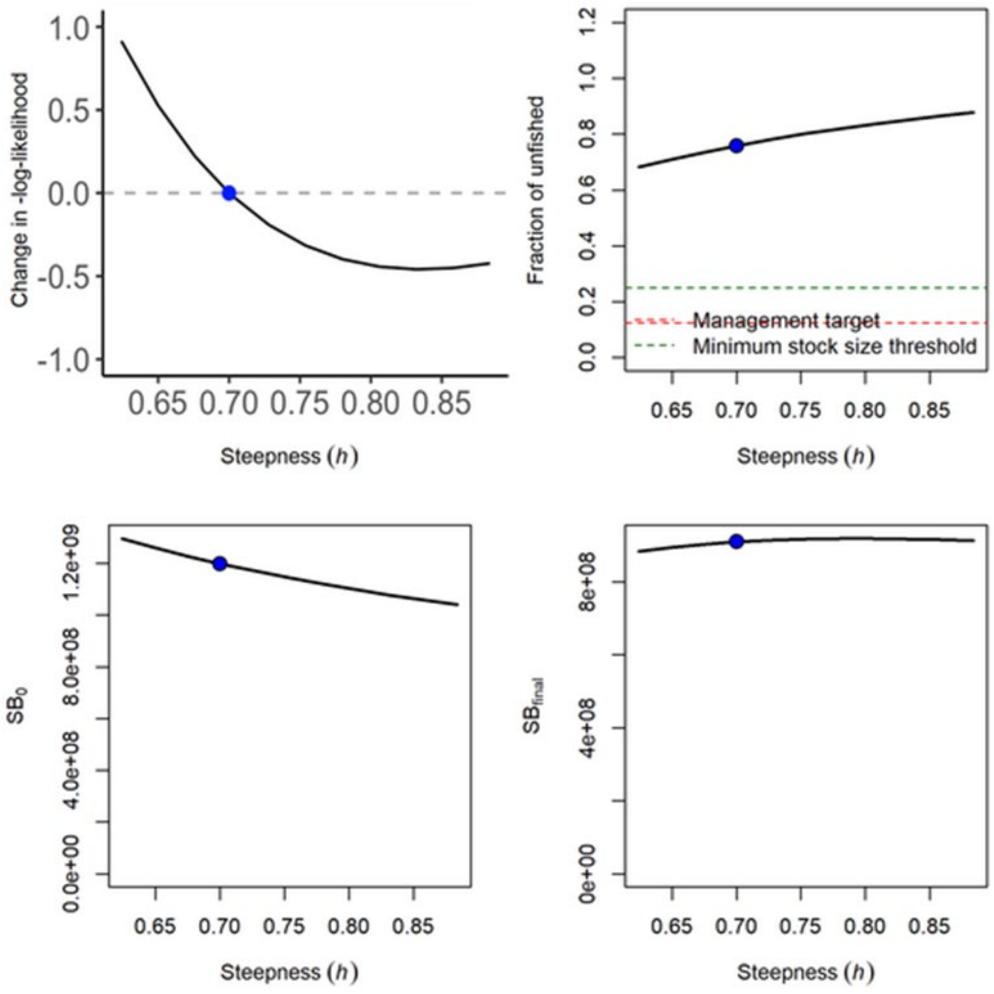
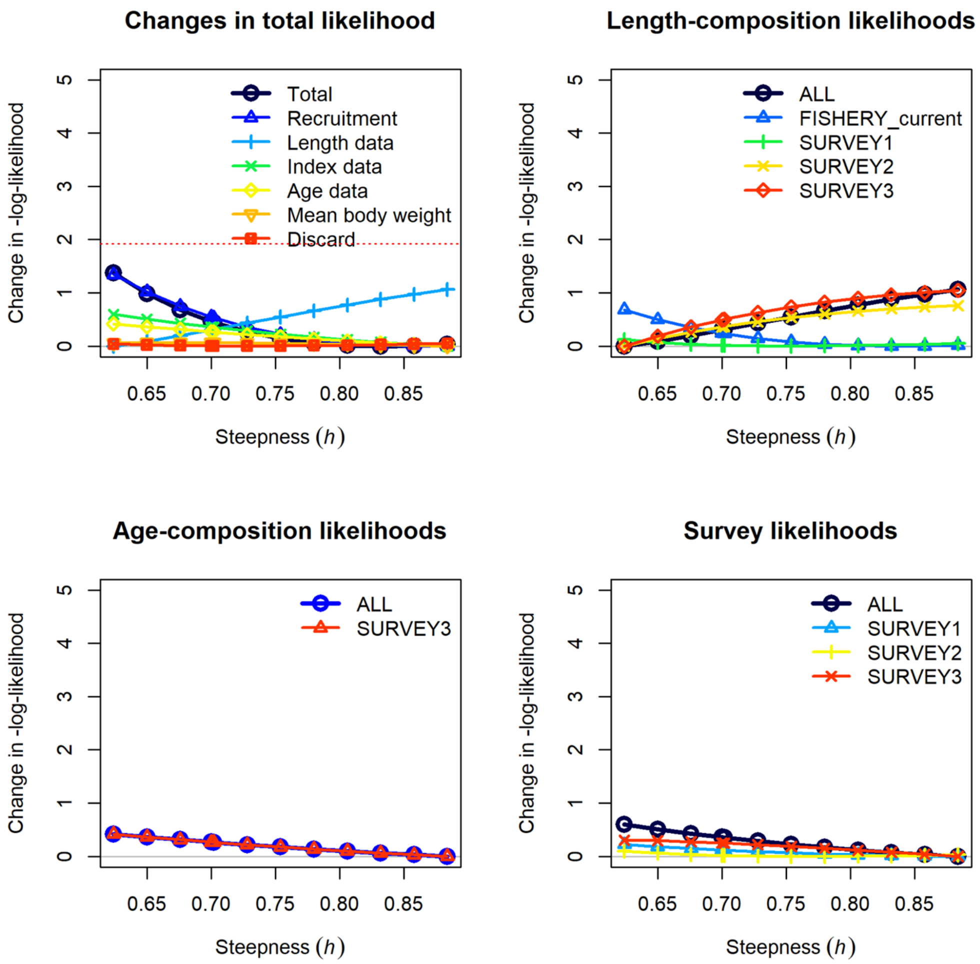
Likelihood Profile: M

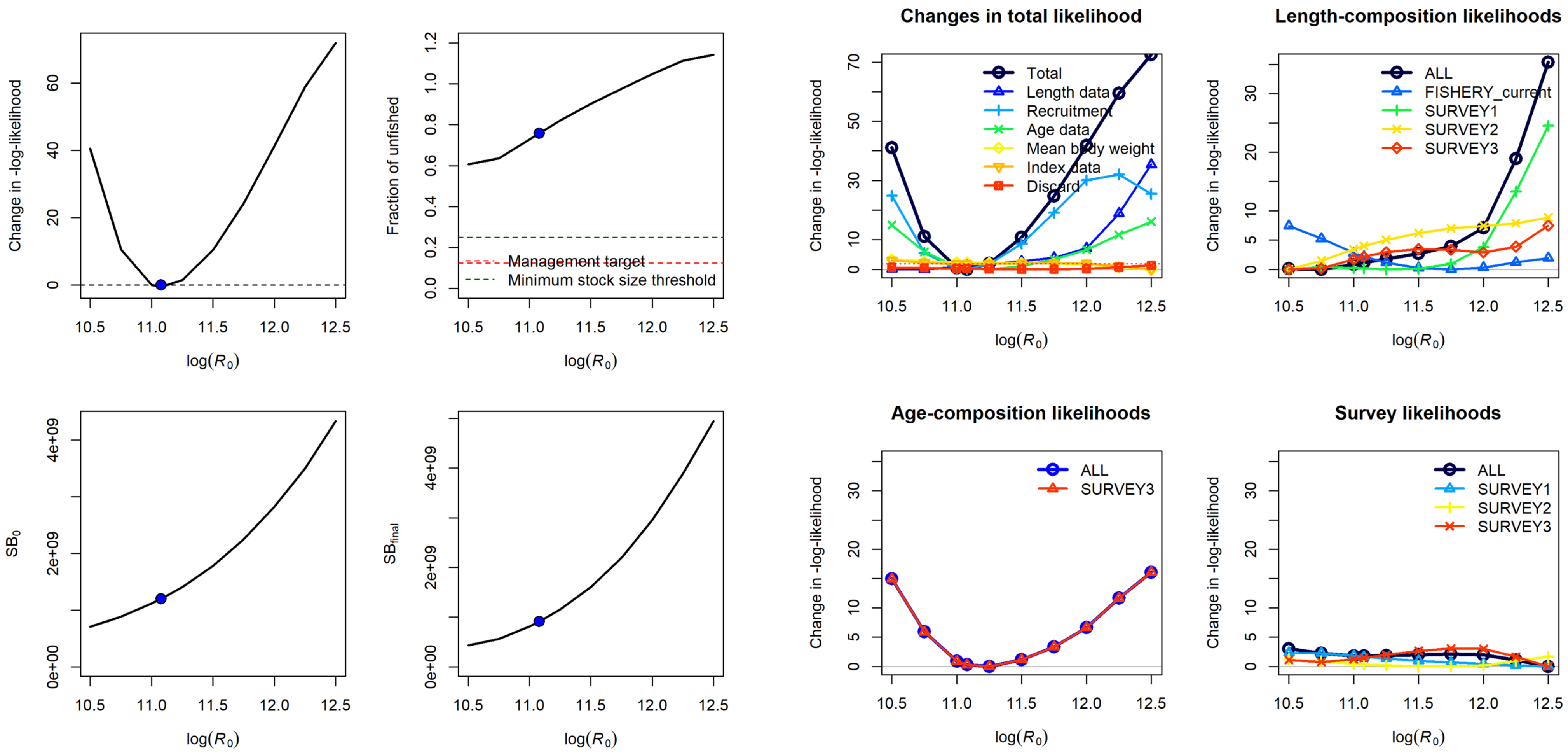


Likelihood Profile: steepness





Likelihood Profile: R0



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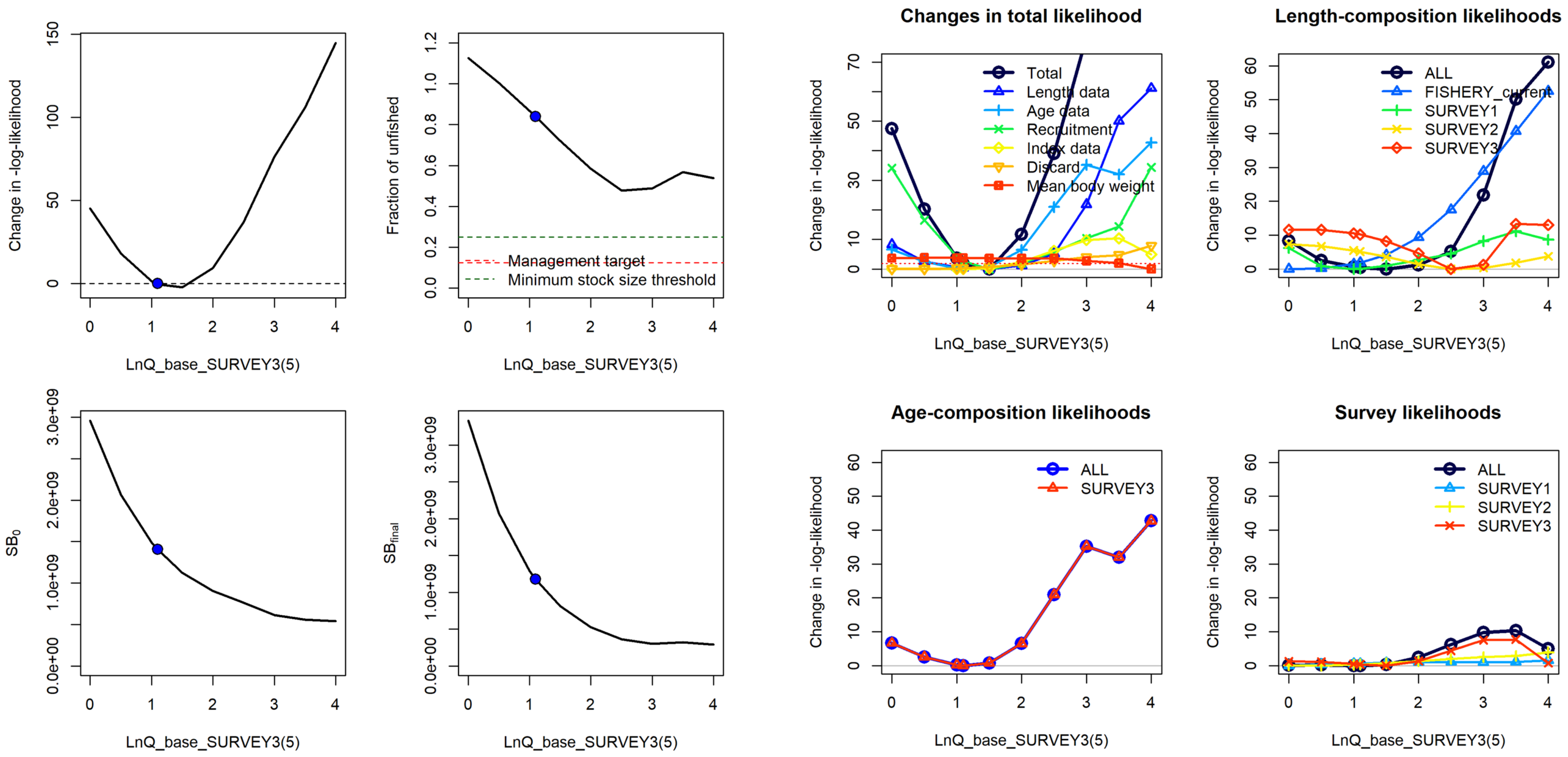
Likelihood Profile: WCGBTS Q



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Sensitivity Analyses

	Scenario	Outcome
Selectivity and catchability	1. Fixing Q at prior mean in AFSC Rex Sole assessment 2. Dome-shaped fishery selectivity	Stock status sensitive to different Q values, not sensitive to dome-shaped fishery selectivity
Biology from 2013 assessment	1. Weight-length relationship 2. Fecundity and maturity 3. Growth 4. Estimate M for males and females 5. Estimate M for males only	Model unstable with old growth assumptions. Old fecundity/maturity produced lower stock status. Estimating M led to small differences in status and scale. Not sensitive to other scenarios.
Data weighting	1. Tuning sample sizes with Dirichlet-Multinomial method 2. Tuning sample sizes with McAllister-Ianelli method 3. Adding extra SD to WCGBTS index	Not sensitive to Dirichlet-Multinomial weighting or extra SD for WCGBTS. McAllister-Ianelli weighting produced higher stock status, but model did not converge.
Stock-recruit relationship	1. Estimate steepness	Slightly higher stock status
Historical Discards	1. Increase (50%) in historical discard rate 2. Decrease (50%) in historical discard rate	Not sensitive

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Major uncertainties: Natural mortality (M), growth, and WCGBTS catchability (Q)

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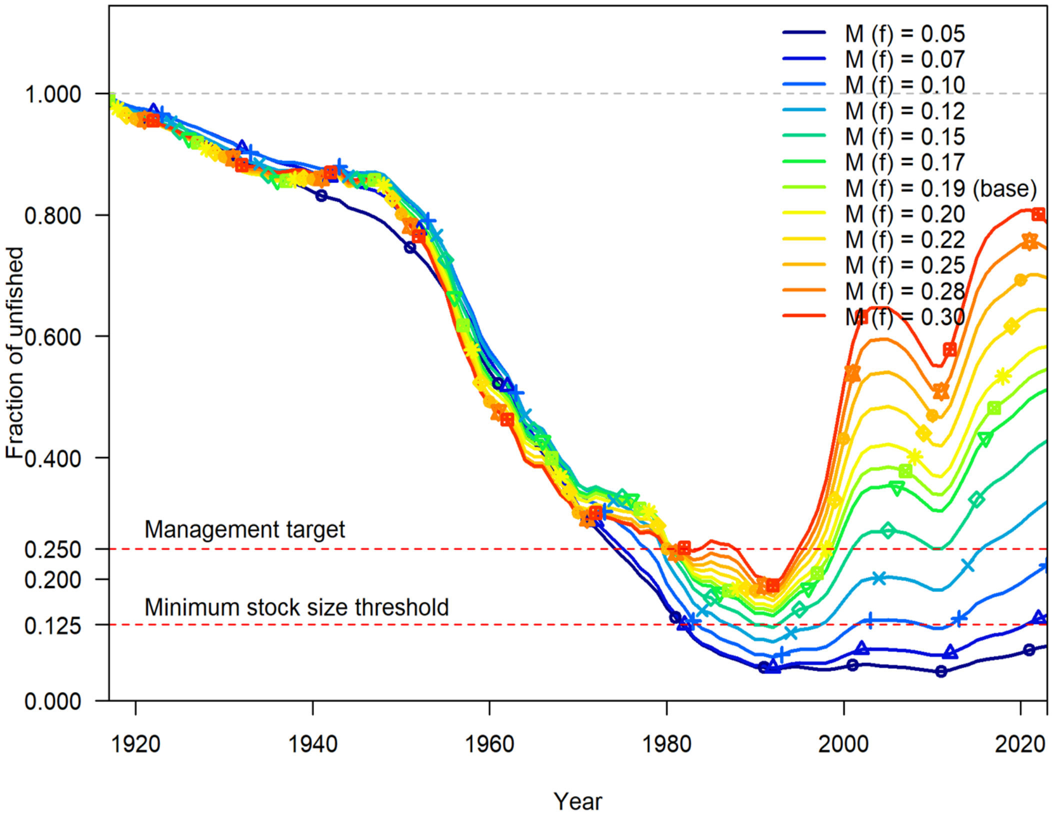
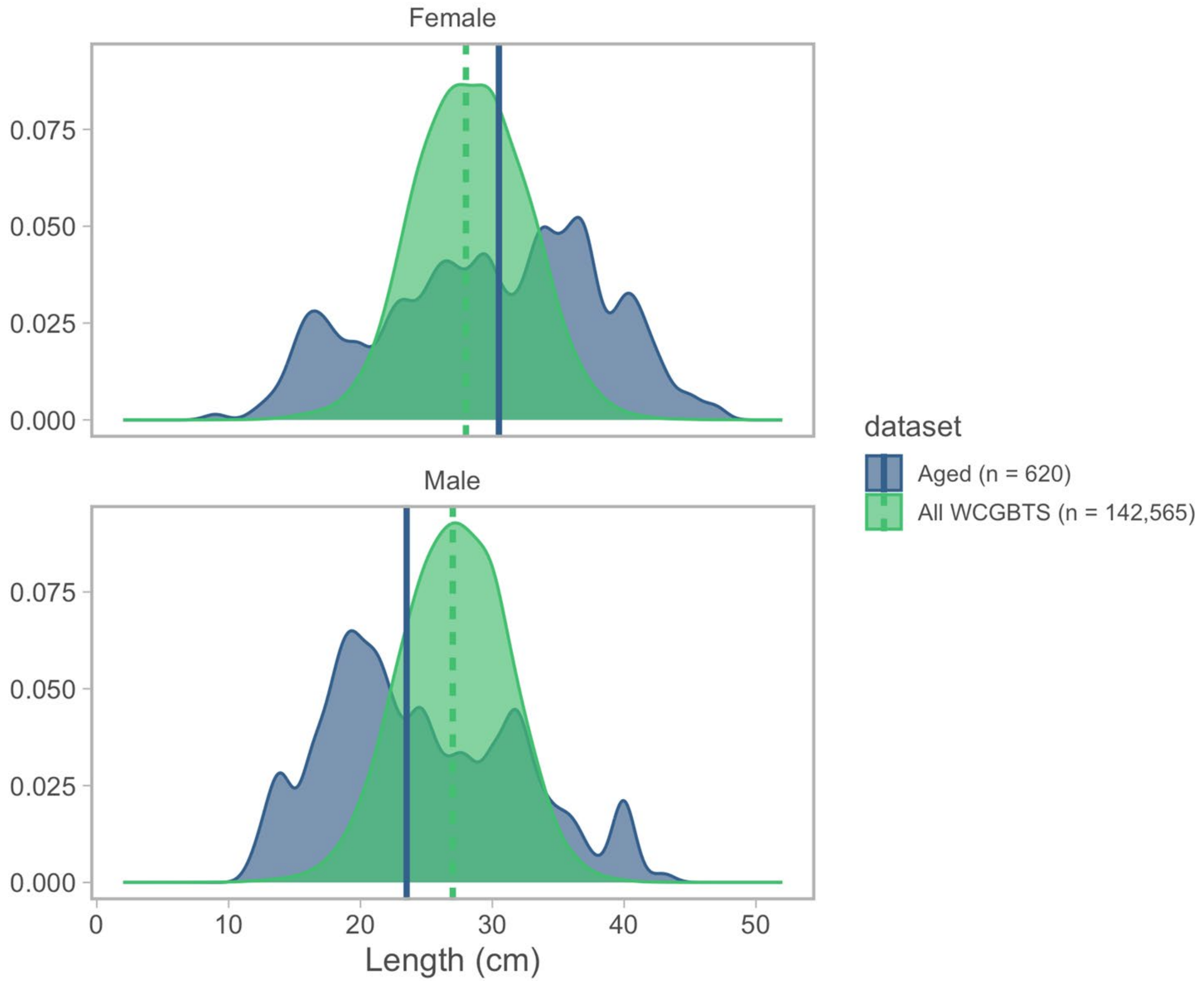
Natural mortality



- M poorly informed by available data
- Chosen as axis of uncertainty for decision table

Growth



- Externally estimated growth curves deemed to be unreliable due to bias introduced by length-stratified sampling
- Internally estimated growth curves, but based on a very limited amount of age data

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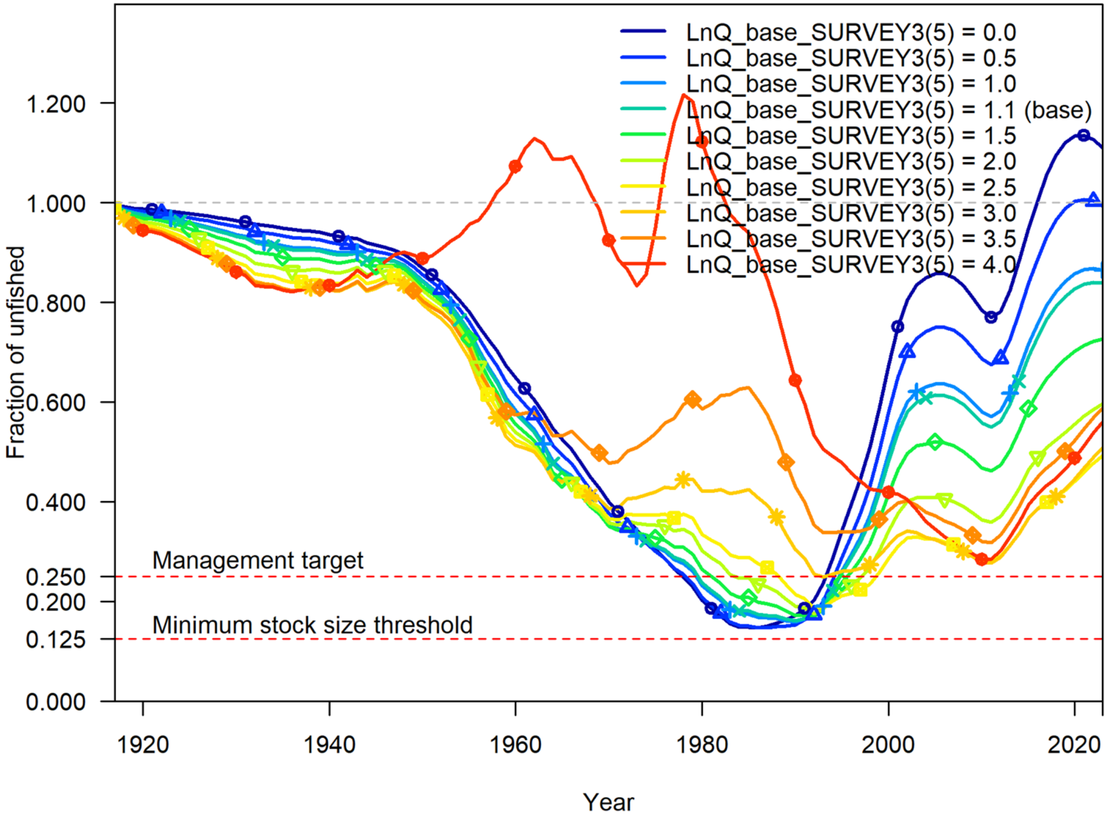
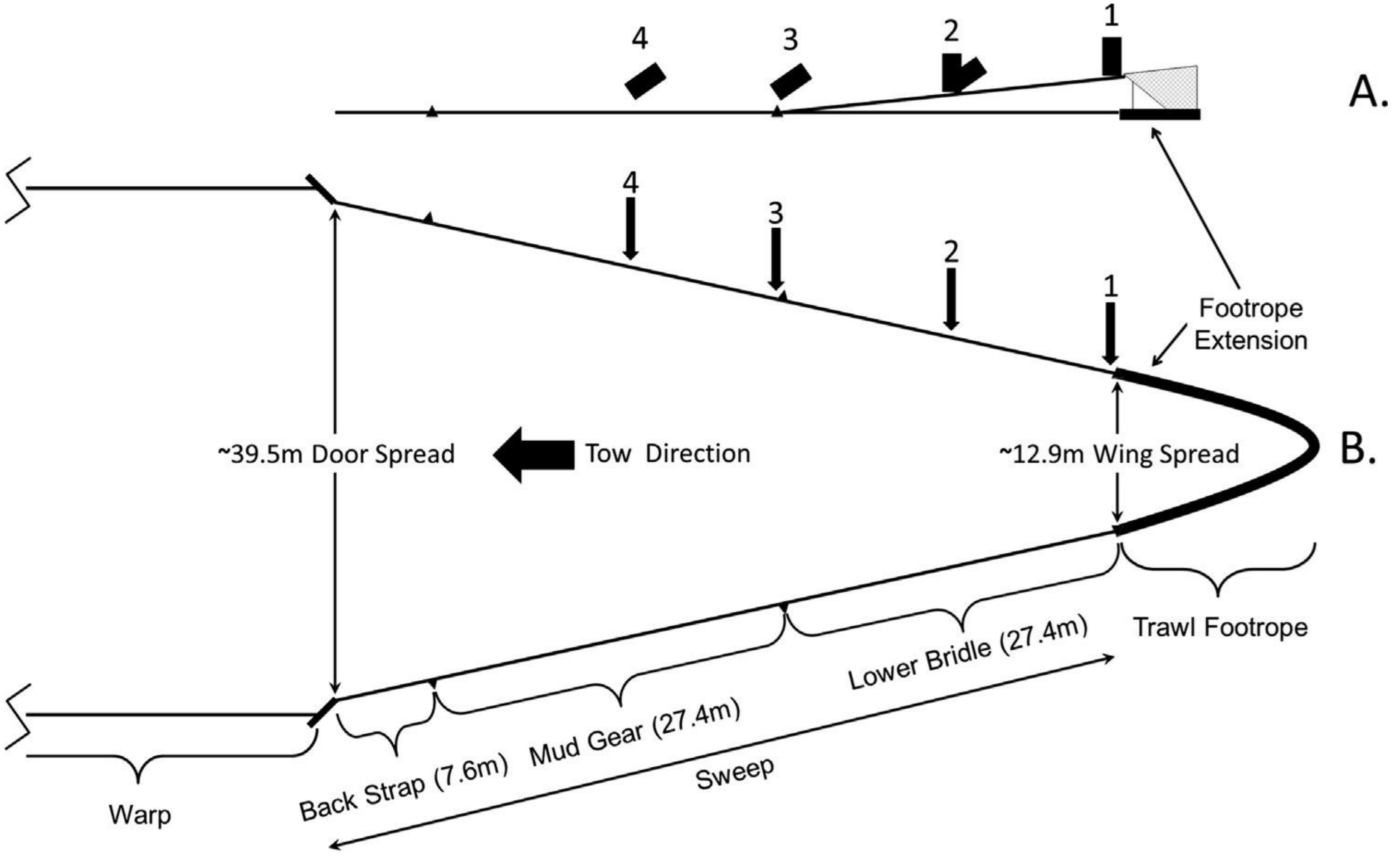
WCGBTS catchability



- Value in base model (analytically solved for): 3.97
- Q significantly affects stock status and scale; however, lower values of Q would result in higher stock status and scale

Note that this is profiling over lnQ

WCGBTS Q - herding response to gear



- Bryan et al. (2014): Q for flatfish expected to be between 1 and 3 for WCGBTS, given observed herding behavior and ratio of door spread (39.5 m) to wing spread (12.9 m)
- Value in base model: 3.97

Conclusions and Research Needs

Research and Data Needs

- More age data to inform growth and longevity along with estimates of aging error
- Understanding catchability for WCGBTS
- Updated biological information for West Coast Rex Sole (maturity, fecundity)

Conclusions

- 2023 model is structurally different from 2013 model, due to inclusion of multiple new data sources
- Despite considerable uncertainty, no conservation concern for the stock

Extra Slides

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Life history

- Distributed from Baja California to the Aleutian Islands
- Found commonly up to 500 m, range down to more than 1100 m
- Medium sized (up to 61 cm), moderately long-lived (up to 29 years)
- Muddy sandy bottom
- Diet of benthic infaunal and epifaunal invertebrates
- Consumed by other flatfish, rockfish, salmon, sharks, skates
- Peak spawning from March- April

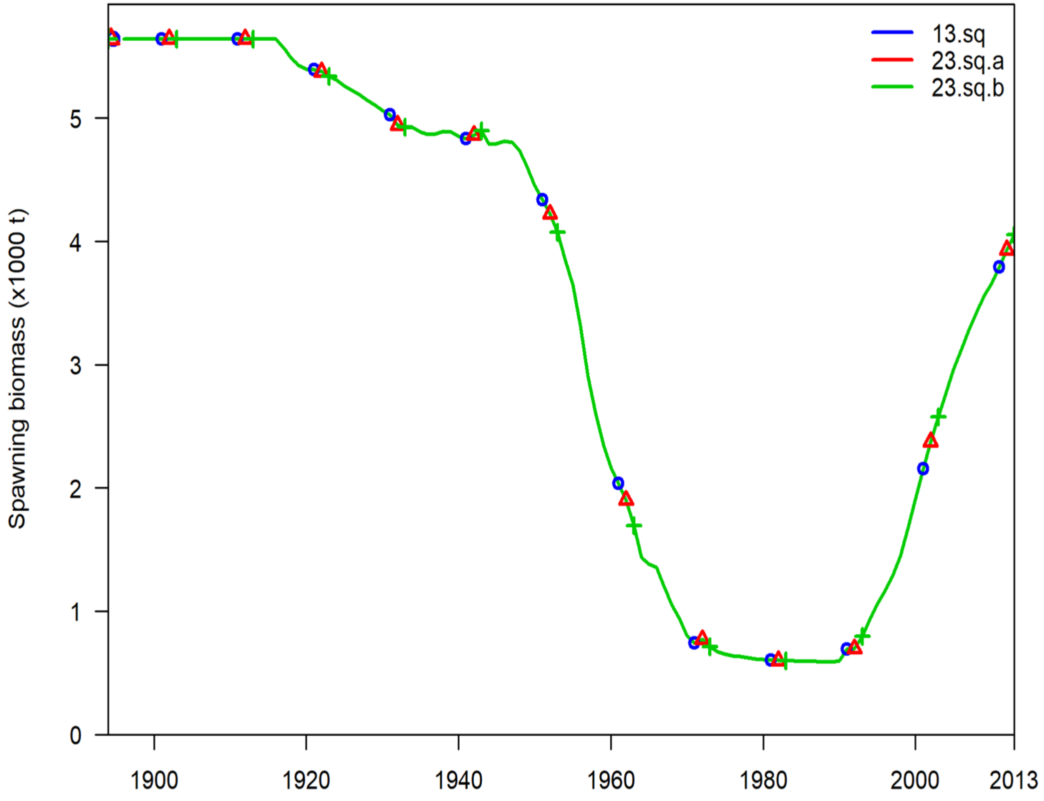
NOAA FISHERIES

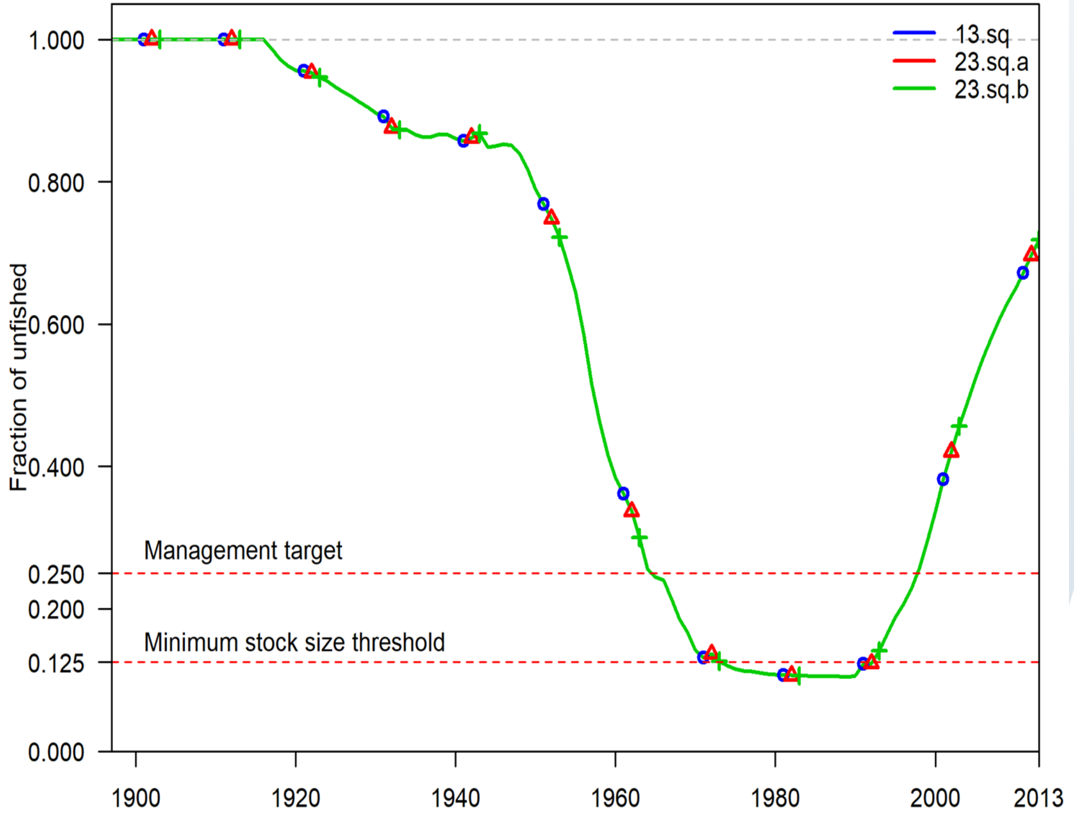
Stock

- Larger in Alaska than on the West Coast
- Commercial bottom trawl
- Important commercial flatfish in 1950s
- Recent decline in harvest

NOAA FISHERIES

Bridging v3.24 to v3.30.21

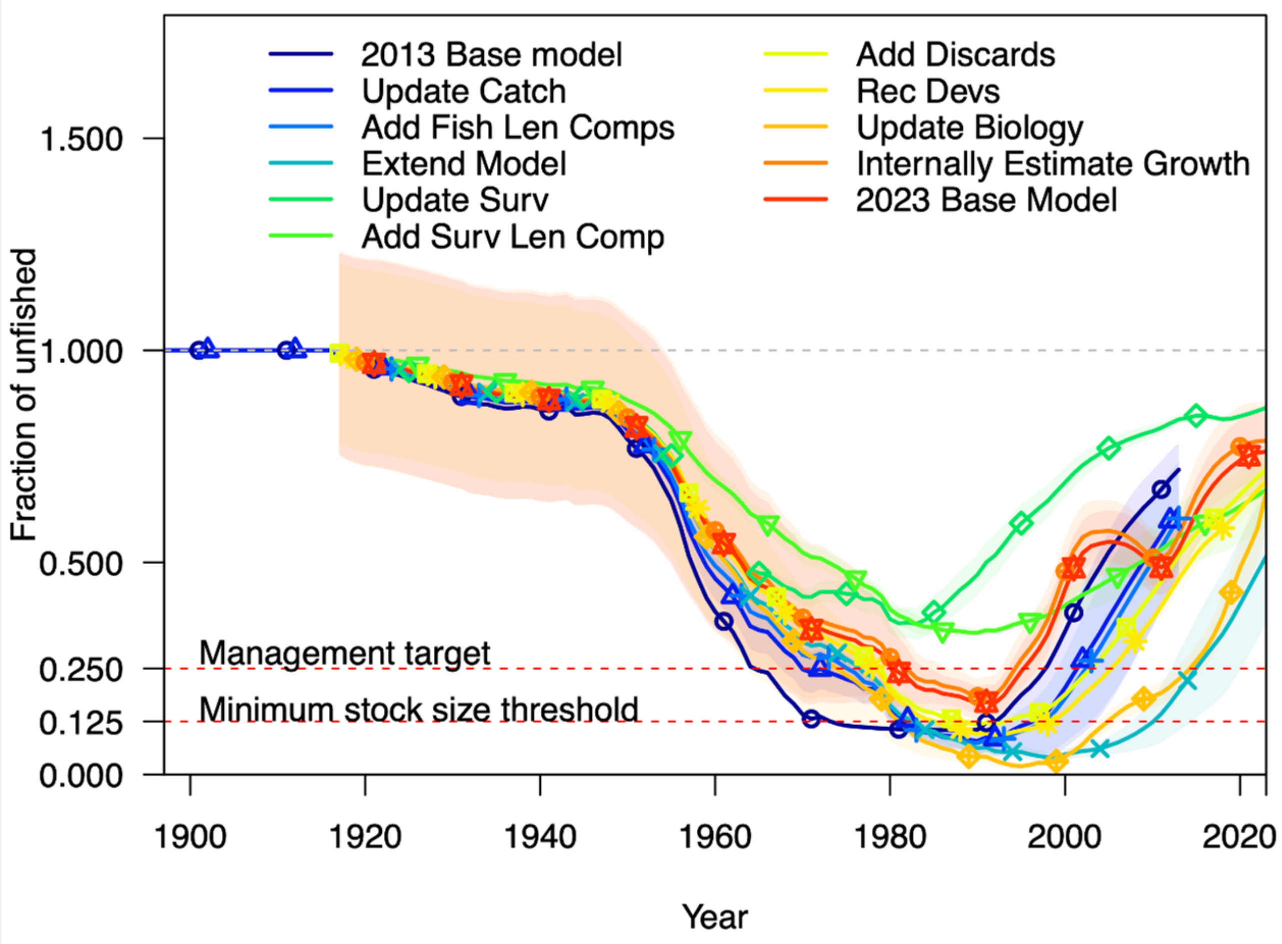


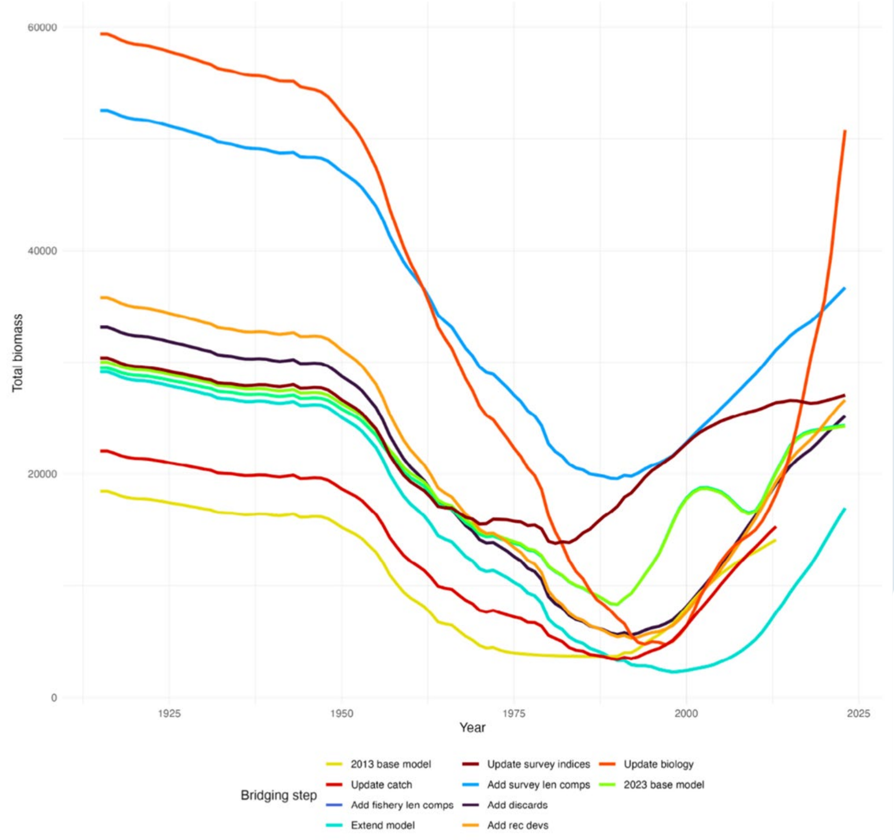


SS3 version	Model	Description
3.24	13.sq	2013 assessment
3.30.21	23.sq.a	13.sq - All param fixed
3.30.21	23.sq.b	13.sq - All param estimated

NOAA FISHERIES

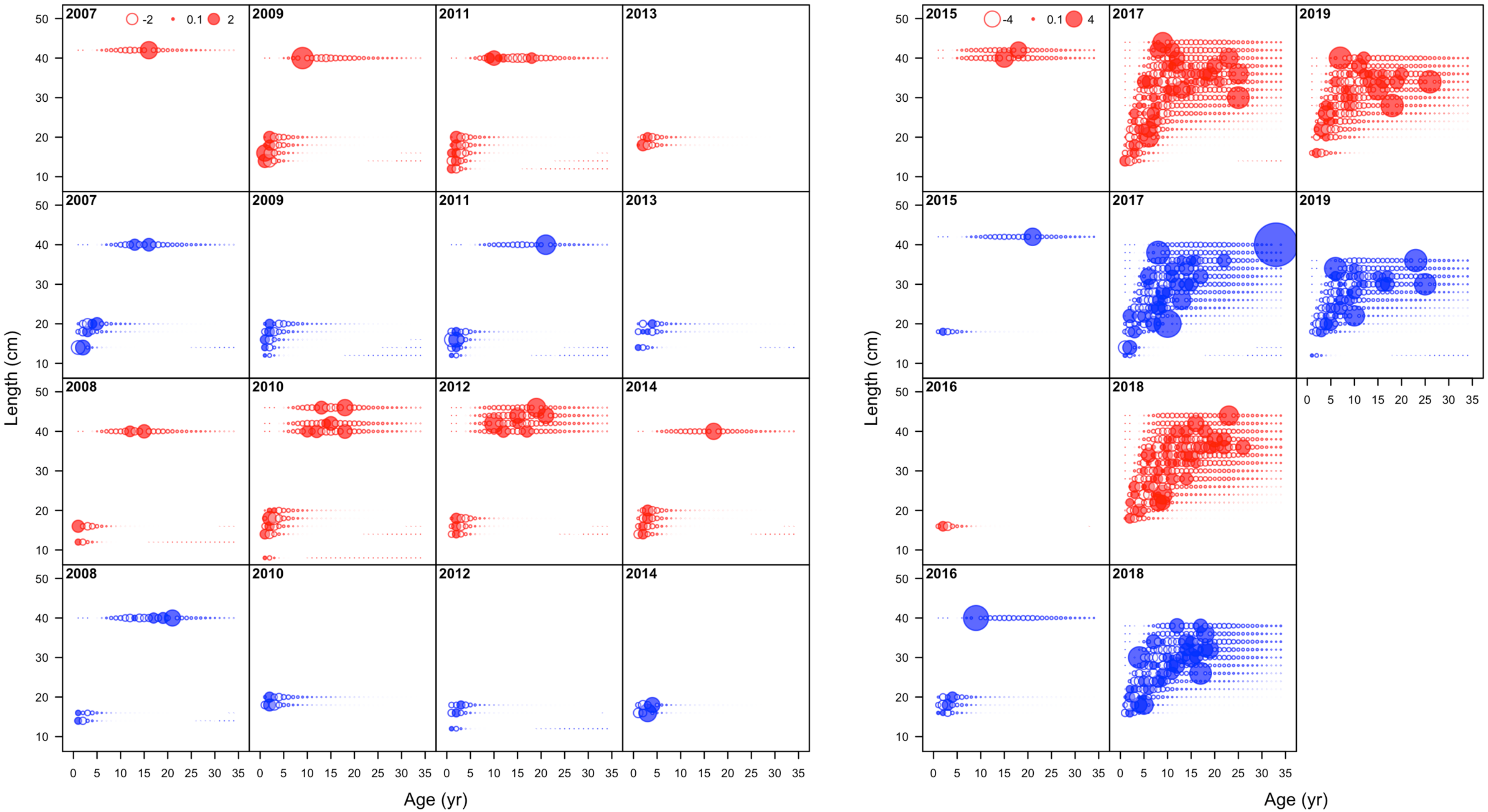
Bridging 2013 to 2023



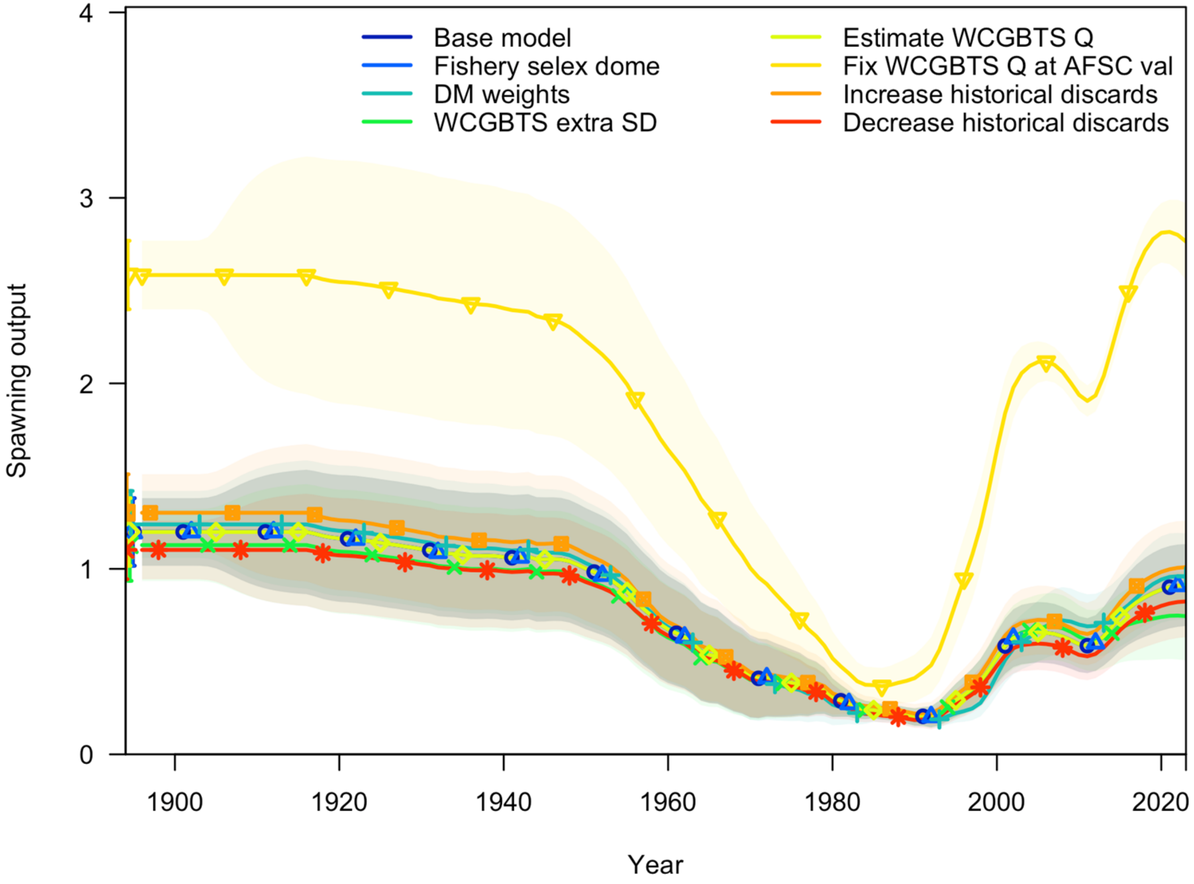


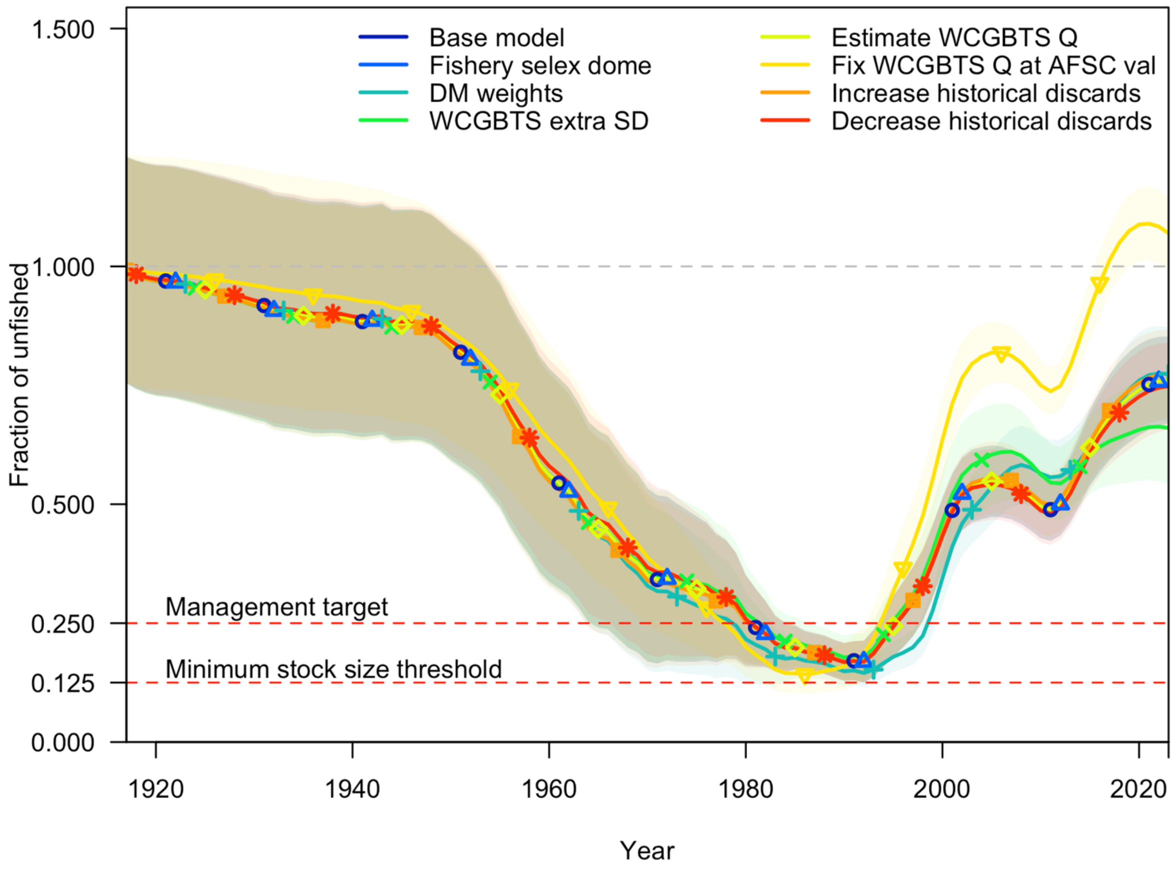
NOAA FISHERIES

Residuals - Fit to WCGBTS CAAL

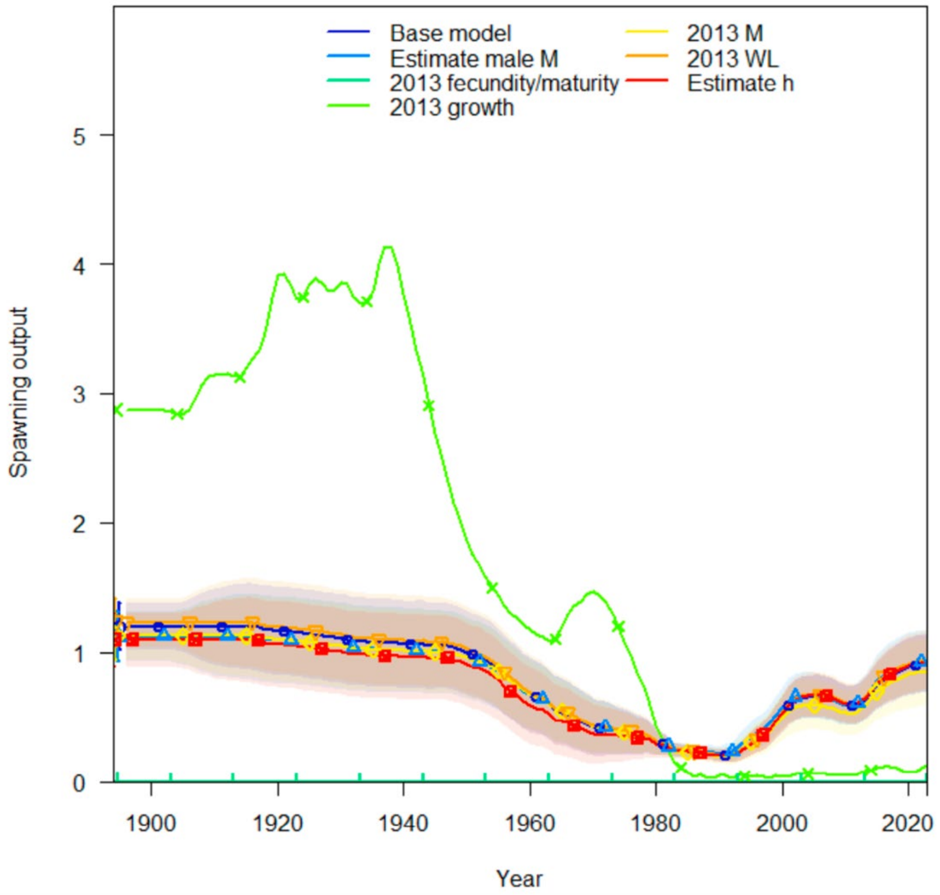


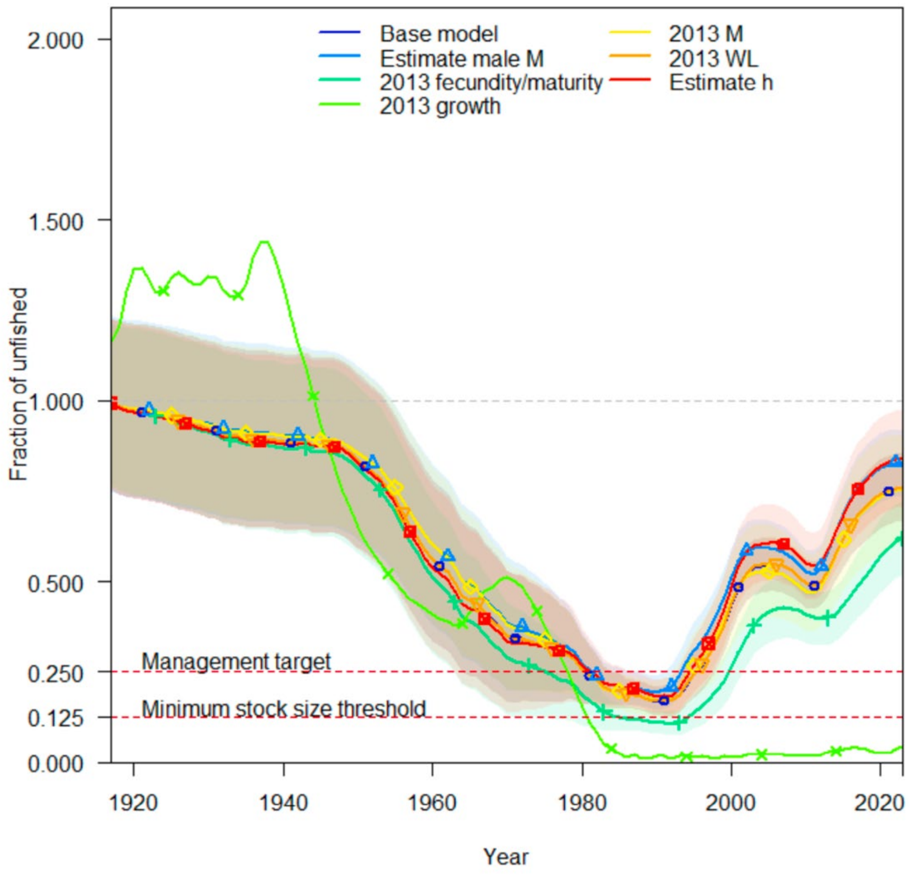
Sensitivity Analyses



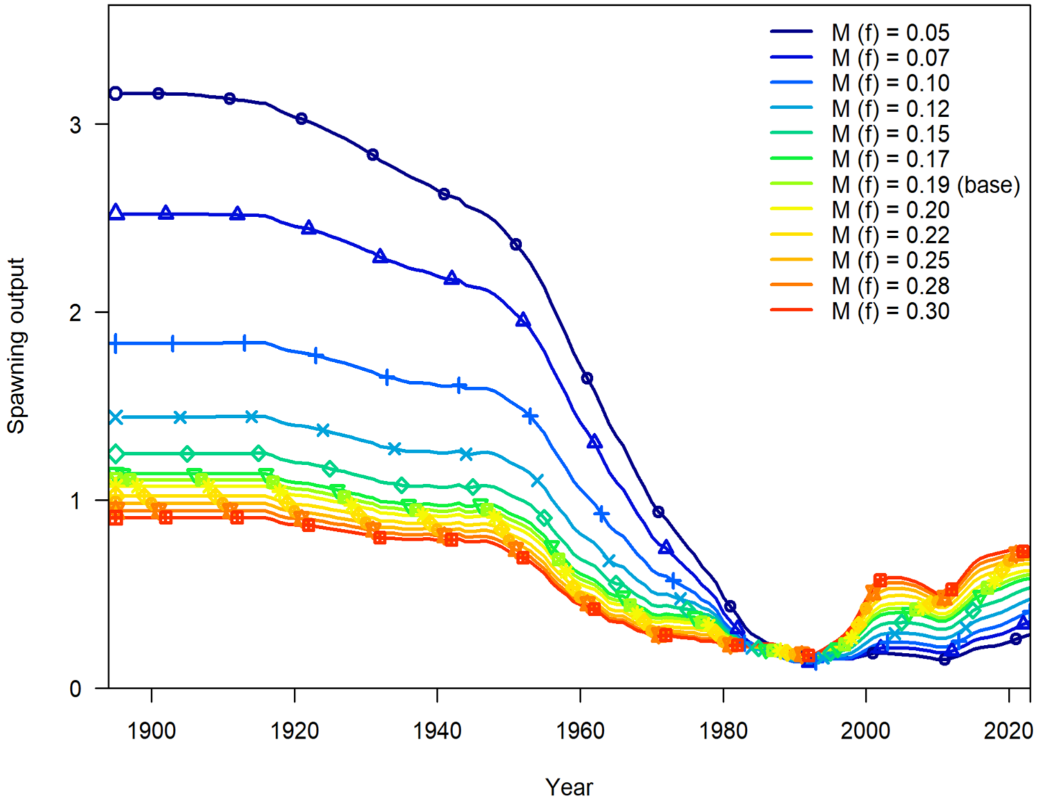


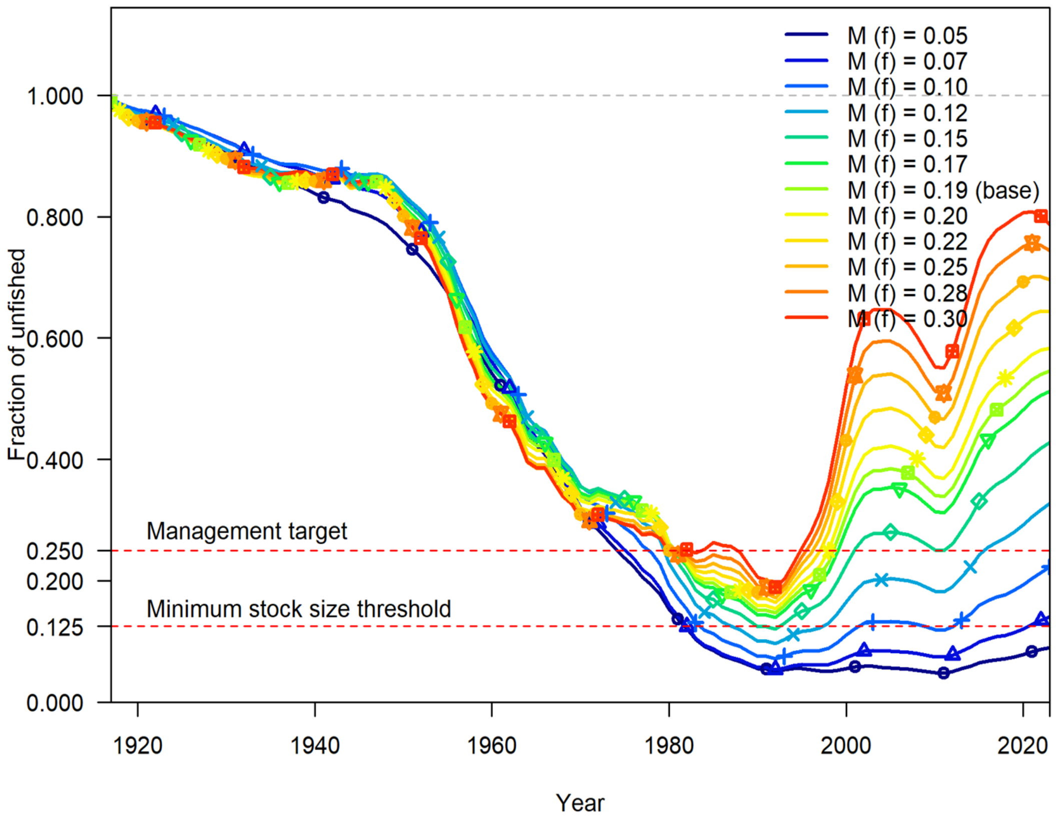
Sensitivity Analyses - Biology



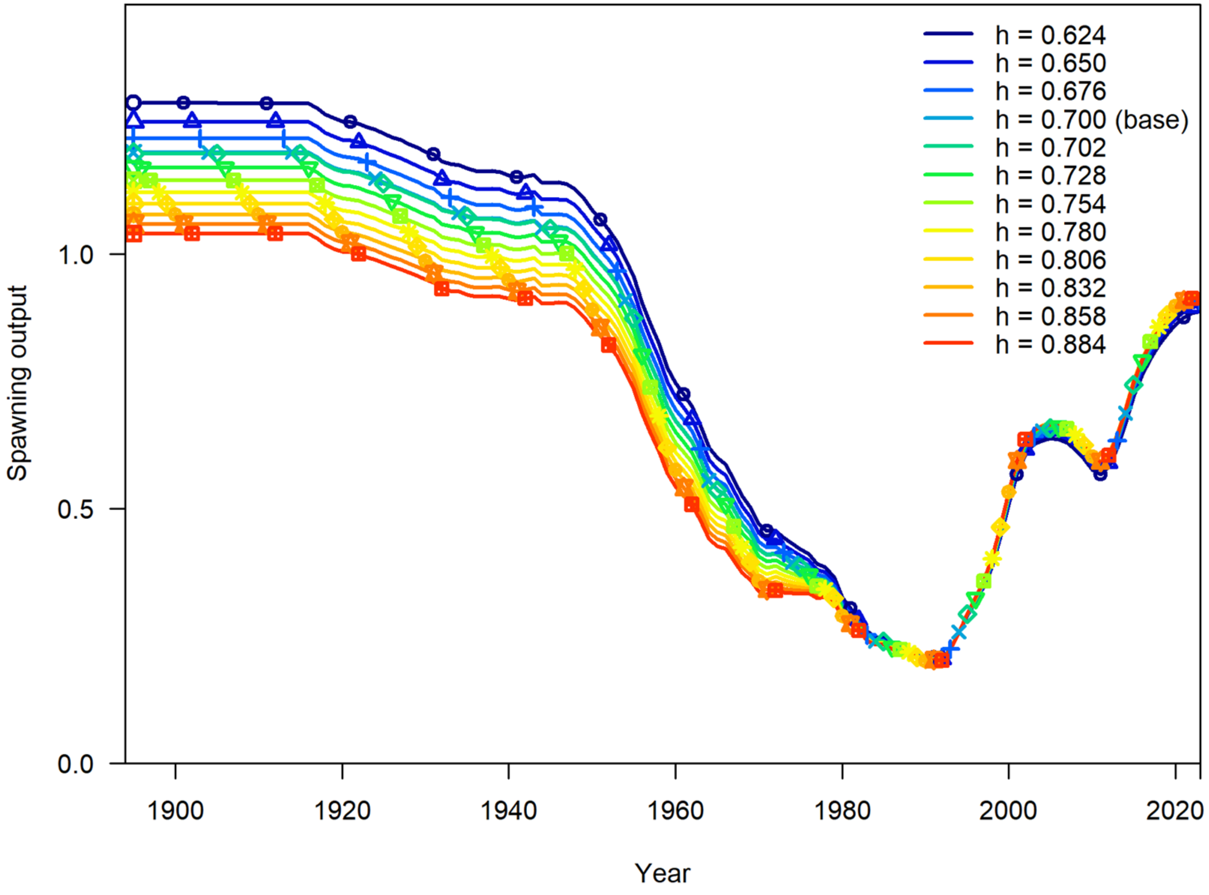


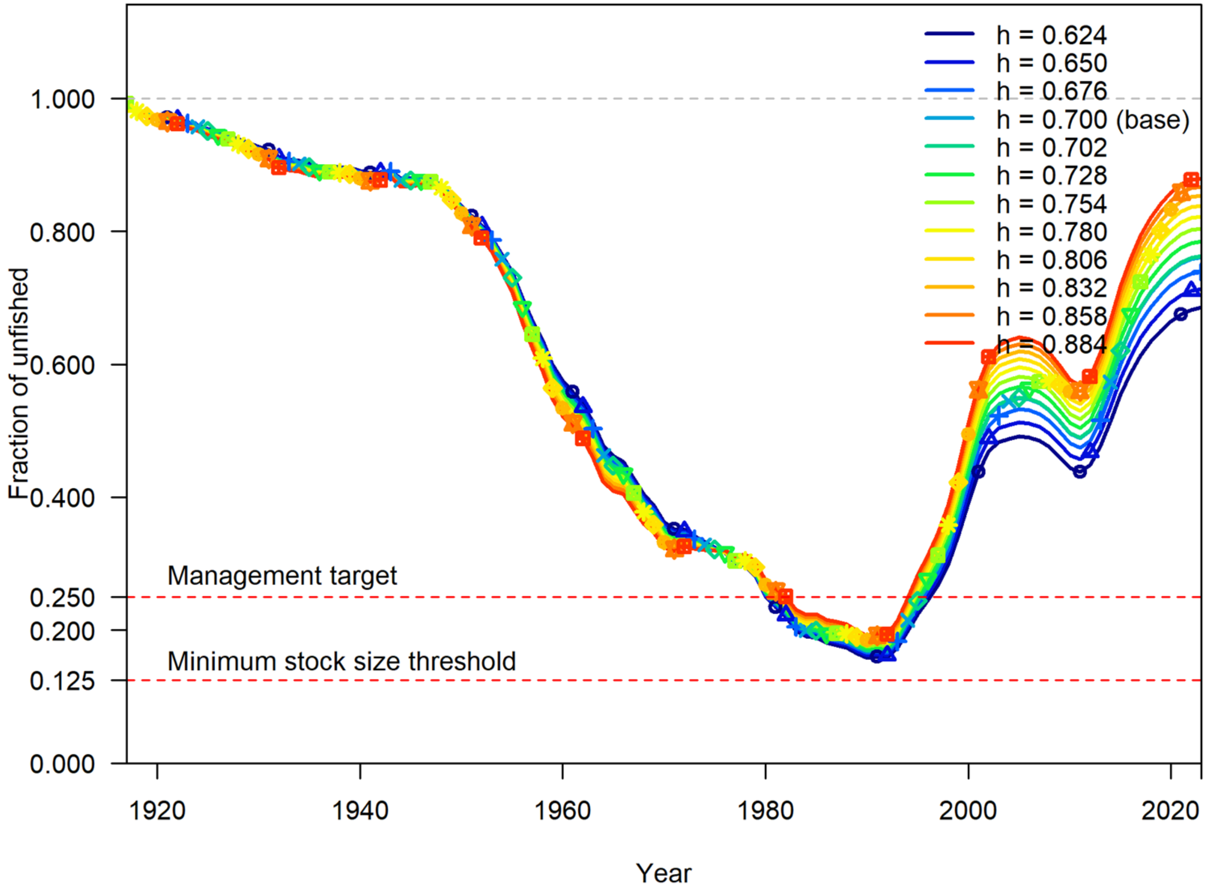
Likelihood Profile: Female M



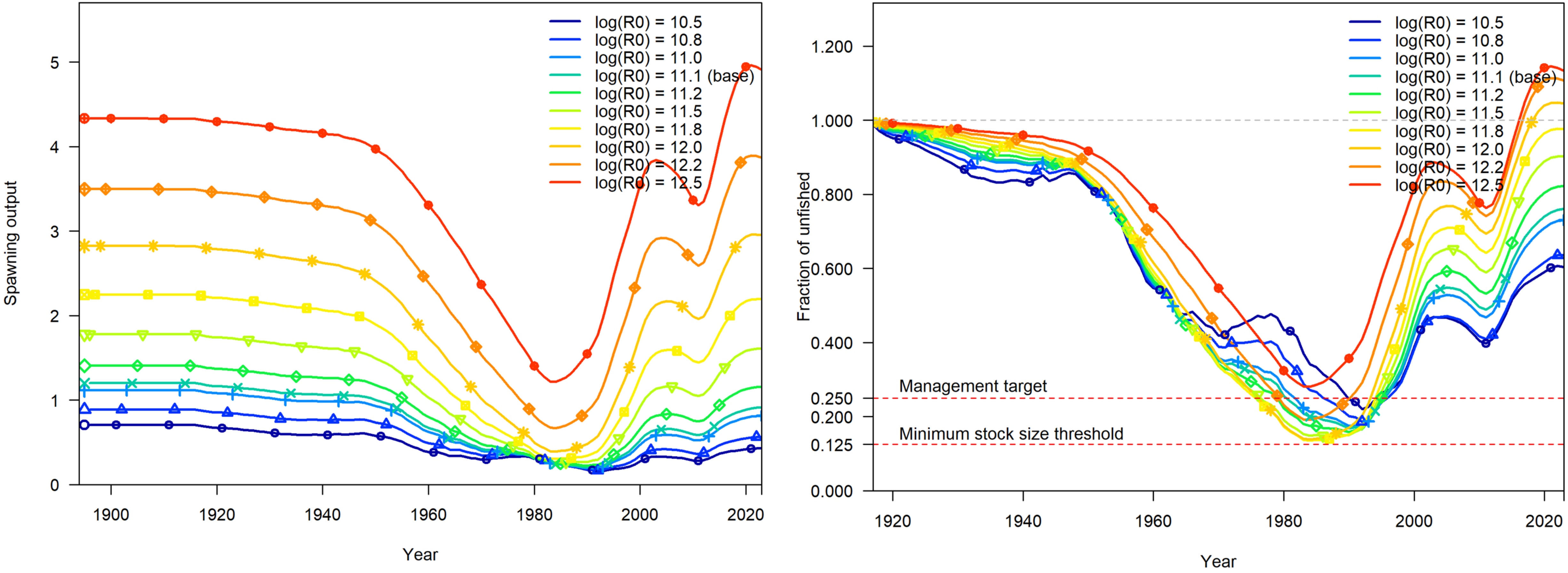


Likelihood Profile: steepness





Likelihood Profile: R0



Likelihood Profile: WCGBTS Q