Status of the Rougheye and Blackspotted Rockfishes stock off the U.S. West Coast in 2025



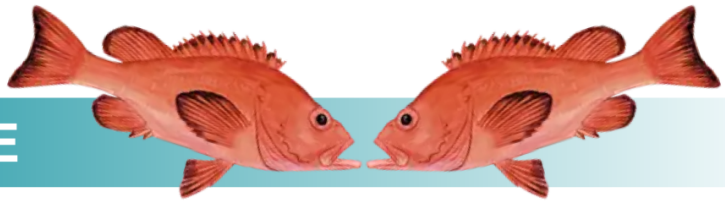
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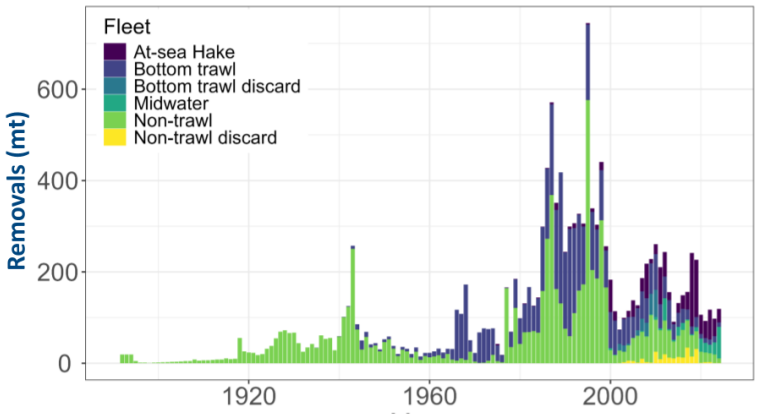
U.S. West Coast Rougheye and Blackspotted Rockfishes in 2025

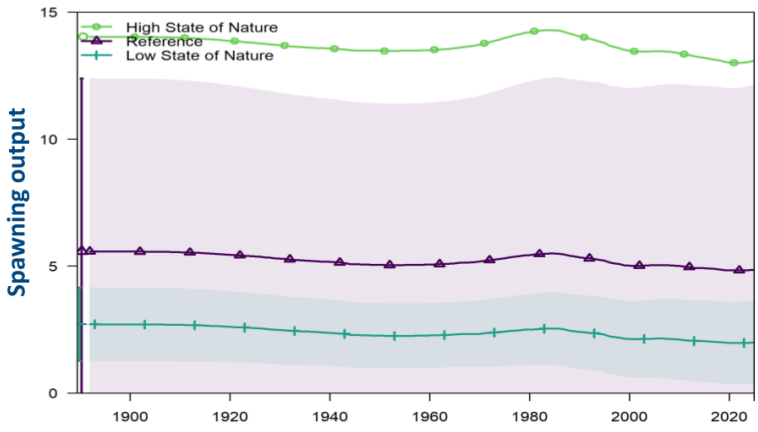
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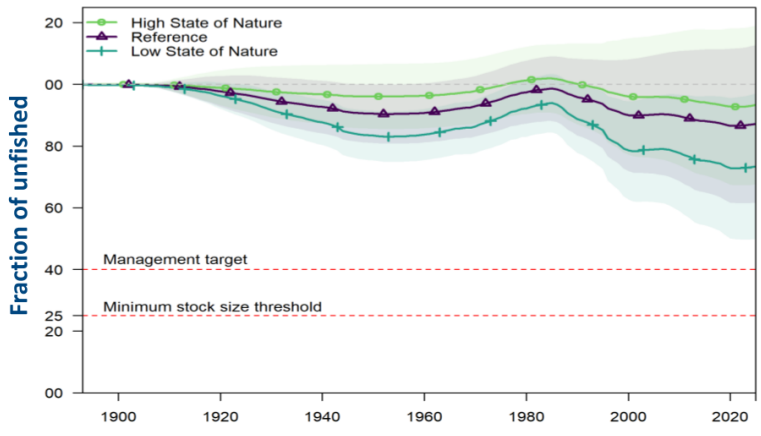
Northwest Fisheries Science Center

Data and Stock Assessment Model

This assessment reports the status of the Rougheye (*Sebastes aleutianus*) and Blackspotted (*Sebastes melanostictus*) Rockfishes off the coast of the United States (U.S.) using data through 2024.







Year

Data sources



Landings & Discards



Survey Indices



Age Composition



Length Composition

Key Takeaways

- At the start of 2025, the estimated status of the complex is 87% of unfished, which is above the management target.
- Absolute scale of the stock is highly uncertain
- Numerous simulations show no indication that stock is approaching the target of 40% unfished.
- More ages and reducing ageing error may help decrease uncertainty in stock scale.

Base Model Removals & Stock Projections

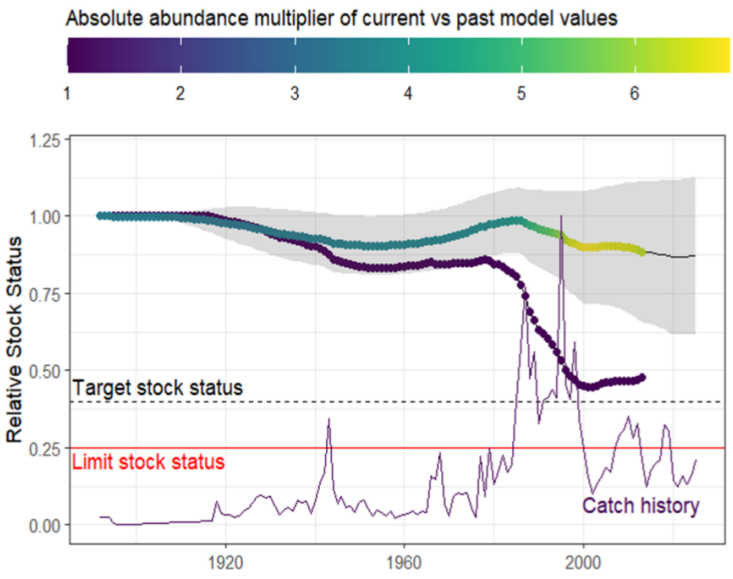
Year	Removals (mt)	Spawning Output (trillions of eggs)	Stock Status (target = 40%)
2025	155[a]	4.86	87%
2026	187[a]	4.87	88%
2027	881[b]	4.89	88%
2028	866[b]	4.82	86%
2029	850[b]	4.75	85%
2030	834[b]	4.68	84%
2031	818[b]	4.62	83%

[a] *Based on Groundfish Management Team Recommendations for Forecasting*
[b] *Annual Catch Limit (ACL) from the default harvest control rule with P* of 0.45, sigma = 1.0*

Major Changes from Recent Assessments

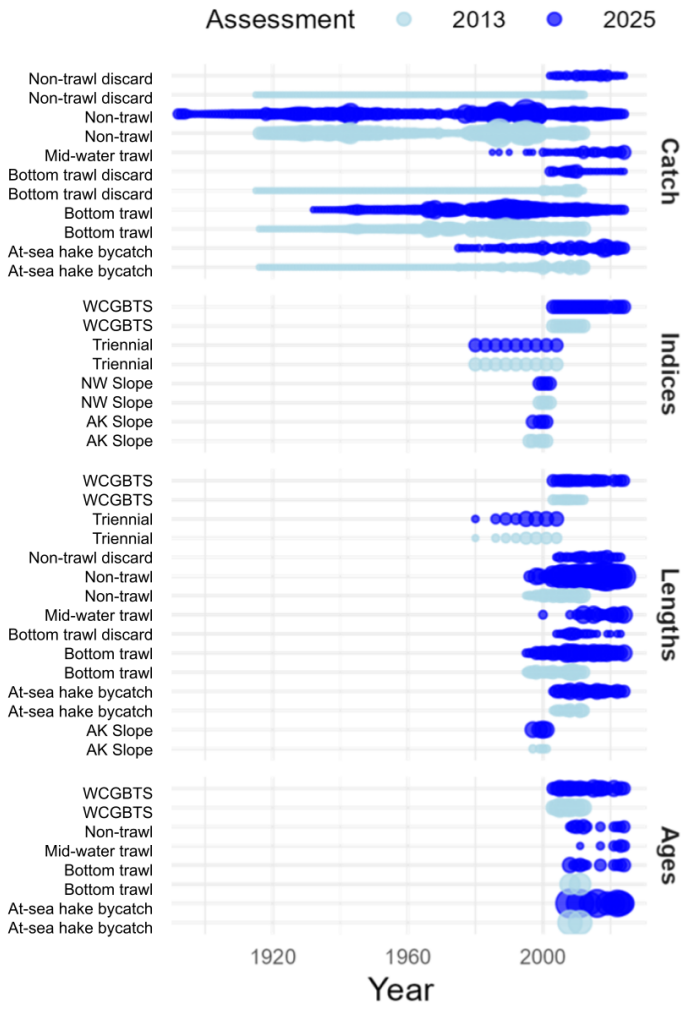
- The last assessment was conducted in 2013.
- Numerous data were added since the last assessment (plot on the right), with thousands of new ages informing increased stock status.
- Stock status and scale increased from the last assessment (plot below).
- Length data and expert knowledge from fishery participants supported dome-shaped selectivity for bottom trawl fleets, which increased the scale and stock status.

Comparison with 2013 Assessment



- Line with uncertainty and longer time series is the 2025 stock assessment.
- Shorter time series is the 2013 stock assessment show lower stock status.
- Catch time series was transformed to be on a [0,1] scale.

Data used in current and 2013 assessment



Major Sources of Model Sensitivity

- Natural mortality
- Shape of selectivity curves

Ways to reduce uncertainty

- Increase the amount and quality of age data
- Reduce ageing error

View all groundfish stock assessments

For any questions, please reach out to Jason Cope (jason.cope@noaa.gov) or Vladlena Gertseva (vladlena.gertseva@noaa.gov)

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Executive Summary

Stock

This assessment reports the status of the Rougheye (*Sebastes aleutianus*) and Blackspotted (*Sebastes melanostictus*) rockfishes that reside in the waters off California, Oregon, and Washington from the U.S.-Canadian border in the north to the U.S.-Mexico border in the south.

These two species are difficult to differentiate visually in the catch, thus they are commonly reported and treated as one management complex of Rougheye/Blackspotted rockfishes (RE/BS). Despite recent advances in genetic identification of Rougheye Rockfish and Blackspotted Rockfish, there is still little ability to reliably separate historical fishery data in order to differentiate these two species into two stocks. Therefore, this assessment maintains a species complex approach, though given Rougheye Rockfish tend to be encountered more often than Blackspotted Rockfish off the U.S. West Coast, this may be considered more of a Rougheye than Blackspotted Rockfish stock assessment. While we treat these species as one stock complex, we recognize and are mindful of the above species distinctions as we conduct our analyses.

Catches

RE/BS are not targeted by a specific fishery, but are desirable and marketable, thus are typically retained when caught.

The historical reconstruction of landings for RE/BS suggests that non-trawl (largely hook-and-line gear) fisheries have caught RE/BS since the end of the 19th century. The bottom trawl fishery developed in the 1930s and 1940s, and trawl landings for RE/BS first peaked in the 1960s and 1970s, when the foreign trawl fleet was targeting Pacific Ocean perch. The declaration of the Exclusive Economic Zone (established in 1977) resulted in the buildup of a domestic fleet and landings increased rapidly into the late 1980s and early 1990s (generally $>$ 300 mt with a peak of 745mt in 1995). Subsequently, landings declined in the late 1990s, with catches under 250 metric tons in the last two decades. The contribution of mid-water trawl catches gradually grew over the past 15 years, and now they represent the majority of the trawl removals.

Since RE/BS are marketable, discarding has been low historically. However, management restrictions (e.g., trip limits) resulted in increased discarding. Trawl rationalization was introduced in 2011, and since then very little discarding of RE/BS has occurred.

RE/BS also has long been bycaught in the fishery for the coastal population of Pacific Hake, which is almost exclusively conducted with mid-water trawl.

Time series of landings are shown Figure i, with recent landings detailed in Table i.

Table i: Recent landings by fleet, total landings summed across fleets, and the total dead catch including discards.

Year	Trawl	Trawl discard	Non-trawl	Non-trawl discard	Midwater trawl	At-sea-hake	Total Landings	Total Dead
2015	30.67	0.01	46.56	13.79	19.26	21.80	132.09	132.09
2016	30.79	0.11	60.27	12.61	15.53	29.63	148.95	148.95
2017	21.93	0.00	59.03	34.42	2.48	38.15	156.02	156.02
2018	16.49	0.00	46.67	14.55	2.58	161.24	241.52	241.52

2019	22.06	0.04	38.75	31.13	9.25	125.37	226.59	226.59
2020	9.86	0.03	24.35	1.03	28.92	41.88	106.07	106.07
2021	10.33	0.01	21.06	2.36	21.39	37.62	92.76	92.76
2022	11.54	0.02	19.06	2.72	18.63	65.46	117.43	117.43
2023	13.29	0.48	18.67	0.48	26.22	38.50	97.63	97.63
2024	9.97	0.12	9.90	0.48	69.15	29.32	118.94	118.94

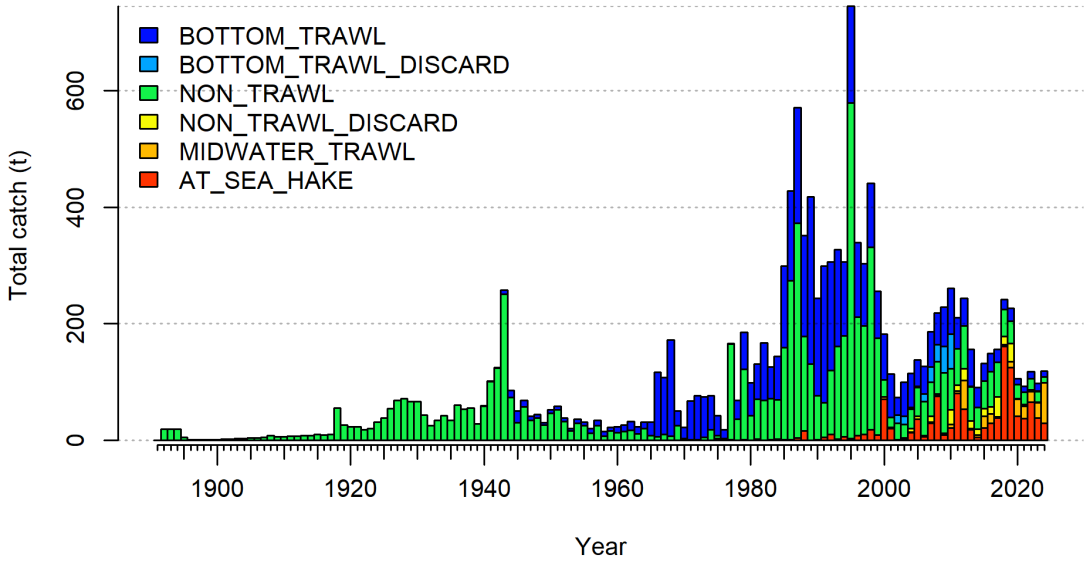


Figure i: Landings in metric tons (mt) by year for each fleet.

Data and Assessments

The only previous RE/BS benchmark stock assessment for the U.S. West Coast area was in 2013 (Hicks et al. 2013). It was conducted with the Stock Synthesis statistical catch-at-age modelling framework (Methot and Wetzel 2013).

This 2025 assessment also uses Stock Synthesis, version 3.30.23.2. The modeling period begins in 1892, and the stock prior to that is assumed to be in an unfished equilibrium condition.

RE/BS fishery-dependent data in this assessment are divided among six fleets, treating discard catches separately from the retained fisheries. Following the 2013 assessment, it maintains the at-sea hake fishery as its own fleet, and adds a mid-water fishery that has emerged in the last decade. This stock assessment adds 10+ years of additional length data, and several more years of age data (included as conditioned on length data). The same four surveys (the West Coast Groundfish Bottom Trawl Survey (WCGBTS), AFSC/NWFSC Triennial Shelf Survey, AFSC Slope Survey,

and NWFSC Slope Survey) as used in the last stock assessment are used here, with the WCGBTS data extended to 2024. The index standardization of all survey data uses the newer approach of applying spatiotemporal generalized linear mixed models.

This is a sex-specific model. Females and males have separate growth curves and sex-specific weight-at-length parameters. Growth is assumed to follow the von Bertalanffy growth model, and the assessment explicitly estimates all parameters describing somatic growth. The natural mortality for females is estimated in the assessment and natural mortality for males is fixed a the lowest value supported by the likelihood profile, and is consistent with values associated with a longevity of 150 years. Externally estimated life history parameters, including those defining the length-weight relationship, female fecundity and maturity schedule were revised for this assessment to incorporate new information. Recruitment dynamics are assumed to follow the Beverton-Holt stock-recruit function, and recruitment deviations are estimated. Stock-recruitment steepness is fixed at the value generated from a meta-analytical study on steepness in *Sebastes* species routinely used in West Coast groundfish assessments. The base model estimates parameters for length-based selectivity, and estimated selectivity curves are a mix of dome-shaped (for bottom trawl gears) and logistic (for mid-water trawl).

Stock Output and Dynamics

The model estimates that the stock complex currently is in a healthy state, well above management target (Figure ii, Figure iii). Approximate confidence intervals based on the asymptotic variance estimates show that the uncertainty in the estimated spawning output is high. Estimates of spawning output (in trillions of eggs) in the most recent decade are shown in Table ii.

The fraction unfished shows a slight decline between the 1940s and the 1960s, and also a gradual decline since the early-1980s, which correspond to the catch history.

Table ii: Estimated recent trend in spawning output and the fraction unfished and the 95 percent confidence intervals.

Year	Spawning output (trillions of eggs)	Lower Interval (mt)	Upper Interval (mt)	Fraction Unfished	Lower Interval	Upper Interval
2015	4.912	<0.001	12.096	0.881	0.650	1.113
2016	4.900	<0.001	12.085	0.879	0.645	1.113
2017	4.886	<0.001	12.071	0.877	0.640	1.113
2018	4.871	<0.001	12.056	0.874	0.635	1.114
2019	4.846	<0.001	12.031	0.870	0.625	1.114
2020	4.825	<0.001	12.013	0.866	0.617	1.115
2021	4.823	<0.001	12.016	0.865	0.615	1.116
2022	4.827	<0.001	12.029	0.866	0.615	1.117
2023	4.832	<0.001	12.050	0.867	0.614	1.120
2024	4.845	<0.001	12.083	0.869	0.615	1.123
2025	4.860	<0.001	12.124	0.872	0.617	1.127

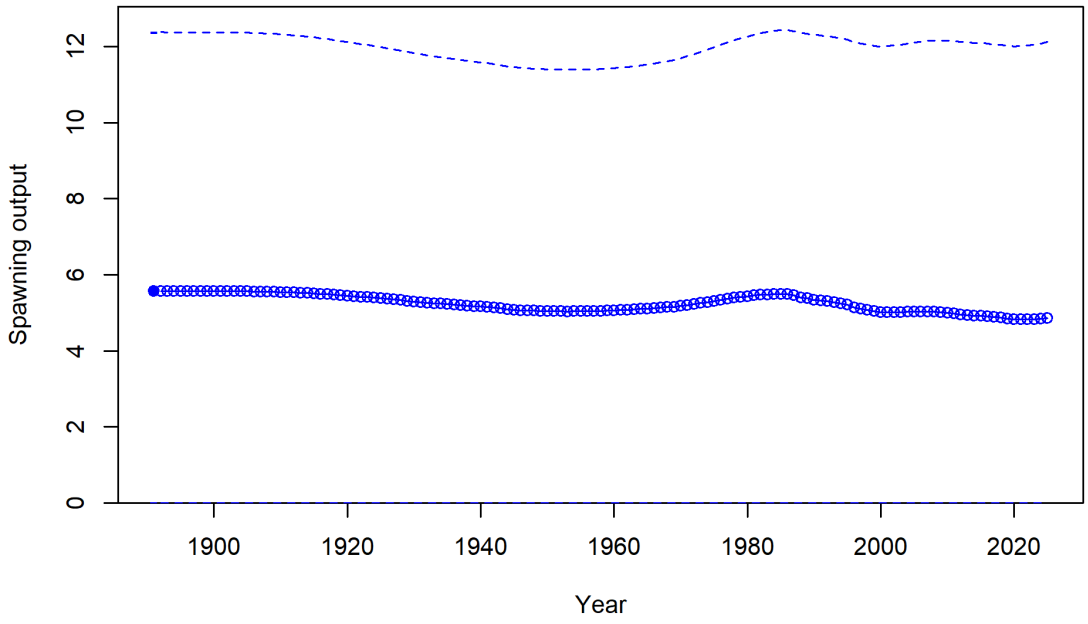


Figure ii: Estimated time series of spawning output (trillions of eggs) for the base model.

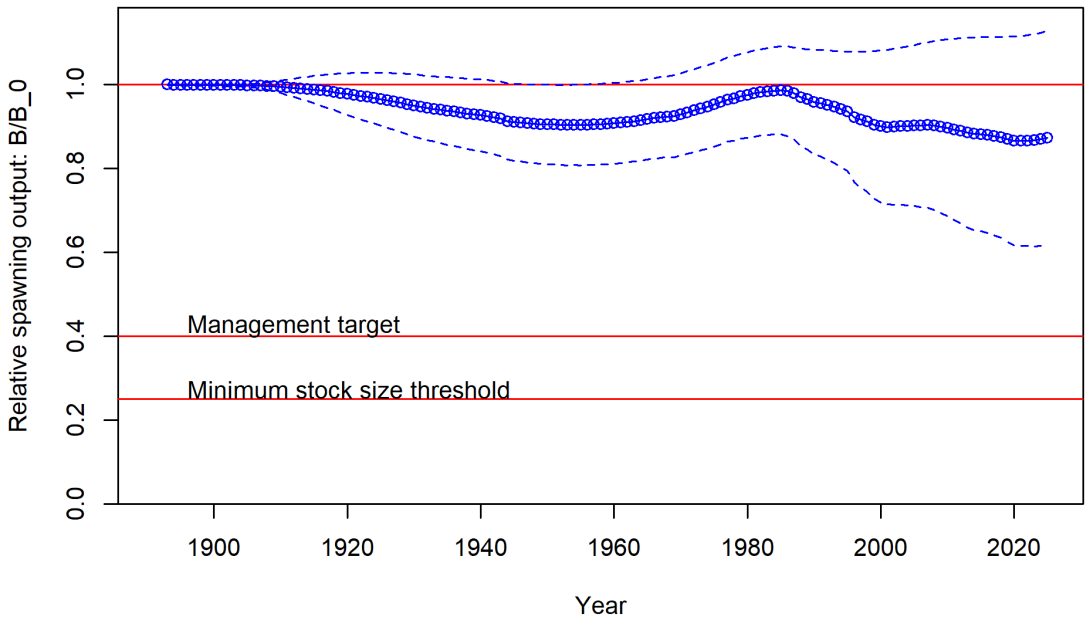


Figure iii: Estimated time series of fraction of unfished spawning output for the base model.

Recruitment

Recruitment dynamics (Table iii, Figure iv) are assumed to follow the Beverton-Holt stock-recruit function and the steepness parameter was fixed at the value of 0.72, which is the mean of the steepness prior probability distribution, derived from a meta-analysis of rockfish stocks. The level of virgin recruitment (lnR_0) is estimated to inform the magnitude of the initial stock size. Annual recruitment is treated as stochastic. "Main" recruitment deviations were estimated for modeled years between 1892 and 2023, with the forecast recruitment period starting in 2024 (Figure v).

Table iii: Estimated recent trend in recruitment (1,000s) and recruitment deviations and the 95 percent confidence intervals.

Year	Recruitment (1,000s)	Lower Interval (1,000s)	Upper Interval (1,000s)	Recruitment Deviations	Lower Interval	Upper Interval
2015	652	173	2,459	-0.445	-1.271	0.382
2016	861	228	3,253	-0.172	-1.012	0.668
2017	2,147	585	7,885	0.737	-0.010	1.484
2018	1,326	354	4,972	0.250	-0.565	1.066
2019	1,184	317	4,415	0.132	-0.678	0.943
2020	837	221	3,170	-0.220	-1.083	0.643
2021	913	236	3,529	-0.138	-1.050	0.773
2022	1,006	254	3,979	-0.046	-1.008	0.916
2023	1,056	266	4,195	-0.003	-0.982	0.975
2024	1,064	268	4,230	0.000	-0.980	0.980

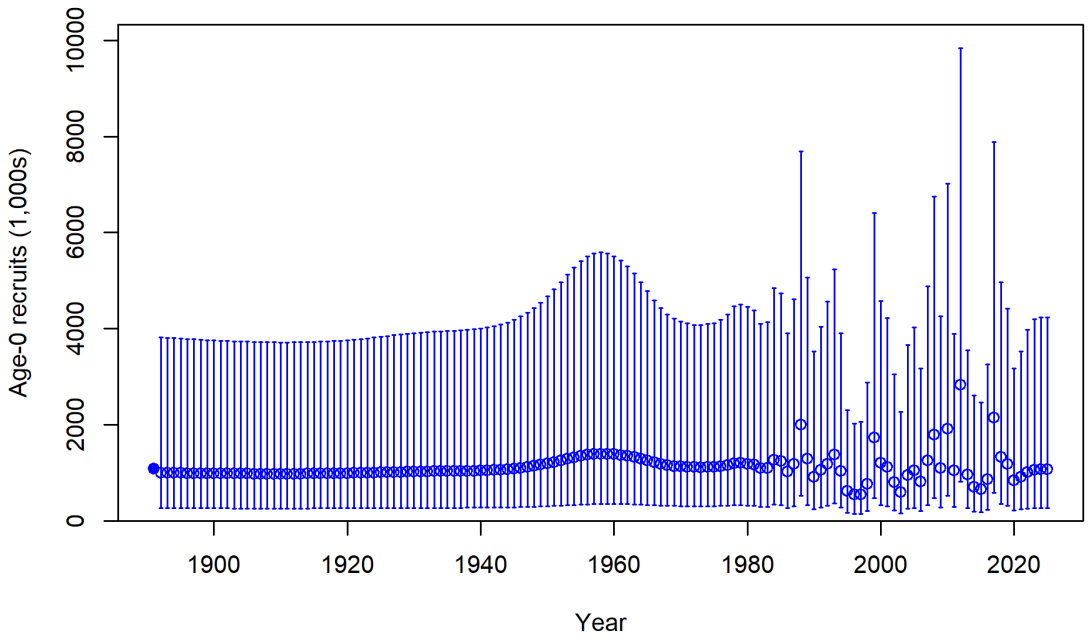


Figure iv: Estimated time series of age-0 recruits for the base model.

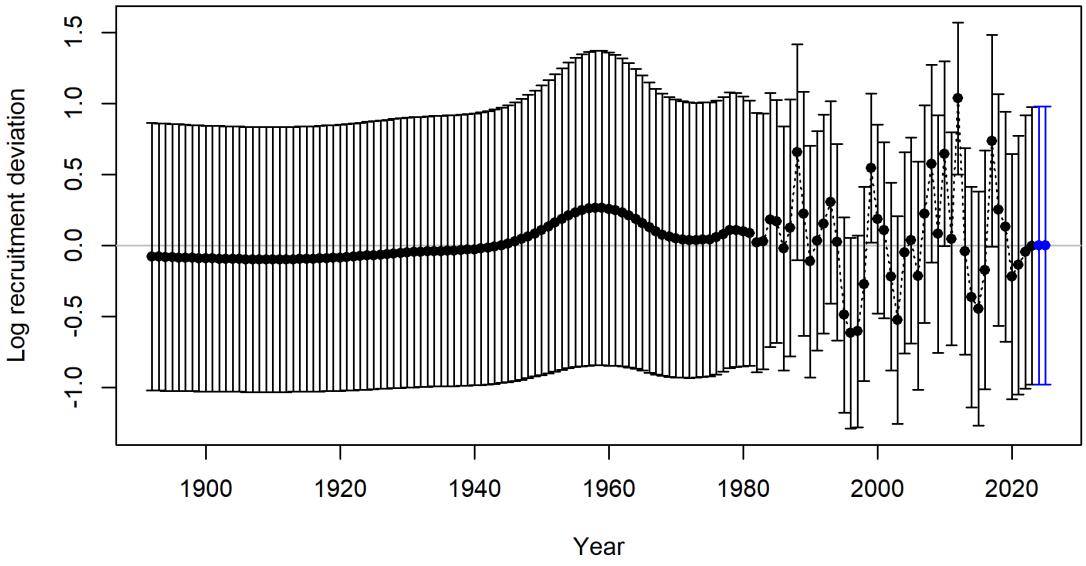


Figure v: Estimated time series of recruitment deviations for the base model.

Exploitation Status

Two measures of exploitation are fishing intensity and exploitation rate. Fishing intensity is defined here as 1 - SPR, where SPR (Spawning Potential Ratio) is the equilibrium spawning output at a given combination of F and selectivity relative to spawning output at unfished equilibrium. Using the units of 1-SPR means that more intense fishing is associated with a higher value. The value of 1-SPR in the absence of fishing is 0 and the maximum is 1.0 if all spawning fish are killed before spawning. The Pacific Fishery Management Council (PFMC) has chosen an SPR target of 0.5 for RE/BS, so harvest which leads to SPR below 0.5 (or fishing intensity (1-SPR) greater than 0.5) would be overfishing. Exploitation rate is defined as the catch relative to age 26+ biomass, which refers to the age at functional maturity. This metric is included to aid interpretation of stock status, but it is not used as a basis for management.

Exploitation rates were below the management target of a fishing intensity that leads to a SPR of 0.5 throughout most of the time series except for 1995, when the catch peaked at 744 metric tons (Table iv, Figure vi).

Table iv: Estimated recent trend in fishing intensity 1-SPR, where SPR is the spawning potential ratio, and the exploitation rate, along with the 95 percent confidence intervals for both quantities.

Year	1-SPR	Lower Interval (SPR)	Upper Interval (SPR)	Exploitation Rate	Lower Interval (Rate)	Upper Interval (Rate)
2015	0.115	<0.001	0.267	0.005	<0.001	0.011
2016	0.129	<0.001	0.297	0.005	<0.001	0.013
2017	0.134	<0.001	0.309	0.005	<0.001	0.013
2018	0.190	<0.001	0.425	0.008	<0.001	0.021
2019	0.182	<0.001	0.410	0.008	<0.001	0.019
2020	0.091	<0.001	0.215	0.004	<0.001	0.009
2021	0.080	<0.001	0.191	0.003	<0.001	0.008
2022	0.099	<0.001	0.234	0.004	<0.001	0.010
2023	0.084	<0.001	0.200	0.004	<0.001	0.009
2024	0.100	<0.001	0.234	0.004	<0.001	0.011

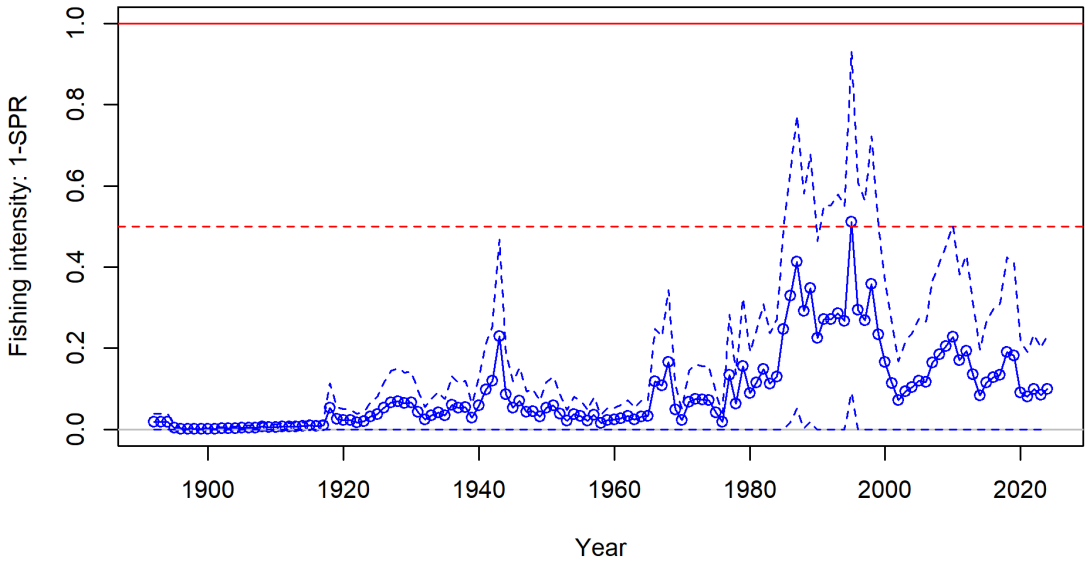


Figure vi: Estimated time series of the fishing intensity (1 - SPR), where SPR is the spawning potential ratio, with approximate 95% asymptotic intervals. The horizontal line at 0.5 corresponds to $SPR = 0.5$, the management reference point. The horizontal line at 1.0 corresponds to $SPR = 0$ (all spawning fish removed from the population).

Ecosysystem Considerations

Rockfishes are an important component of the California Current ecosystem along the U.S. West Coast, with its many dozens of species filling various niches in both soft and hard bottom habitats from the nearshore to the continental slope. RE/BS are one of the larger species of rockfishes and occupy shelf areas when they are young and move into deeper slope waters with age. As they age, they tend to become more solitary, but may form aggregations during the spawning season. Due to a paucity of life-history data for RE/BS, most ecosystem considerations are implied from the understanding of rockfishes in general.

Recruitment is one mechanism by which the ecosystem may directly impact the population dynamics of RE/BS. The specific pathways through which environmental conditions exert influence on RE/BS dynamics are unclear. However, changes in water temperature and currents, distribution of prey and predators, and the amount and timing of upwelling are all possible linkages. Changes in the environment may also result in changes in age-at-maturity, fecundity, growth, and survival which can affect how the status of the stock and its susceptibility to fishing are determined. Unfortunately, there are no data for RE/BS that provide insights into these effects.

Reference Points

Reference points (Table v) were calculated using the estimated fishery selectivity and removals in the most recent year of the model (2024). Reference points were based on the rockfish $F_{MSY\%}$ proxy ($SPR_{50\%}$), target relative biomass (40%), and estimated selectivity and catch for each fleet (Table v). The proxy MSY values of management quantities are by definition more conservative compared to the estimated MSY and MSY relative to 40% of unfished spawning output because of the assumed steepness value. Sustainable total yield, removals, using the proxy $SPR_{50\%}$ is 519.31 mt. The spawning output equivalent to 40% of the unfished spawning output ($SO_{40\%}$) calculated using the SPR target ($SPR_{50\%}$) was 2.48651 trillions of eggs.

The 2025 spawning output relative to unfished equilibrium spawning output, based on the 2024 fishing year, is 87%, above the management target of 40% of unfished spawning output (Figure iii). The fishing intensity, $1 - SPR$, was below to just slightly above harvest rate limit ($SPR_{50\%}$) from the mid-1980s through the 1990s. Removals since 2000 have been below the point estimate of potential long-term yields calculated using an $SPR_{50\%}$ reference point (Table 23 and Figure vi).

The relative biomass and the ratio of the estimated SPR to the management target ($SPR_{50\%}$) across all model years are shown in Figure vii. The stock status has not decreased below the target relative biomass, and fishing intensity (except for in 1995) has been below the target fishing intensity based on $SPR_{50\%}$.

Table v: Summary of reference points and management quantities, including estimates of the 95 percent confidence intervals. SO is spawning output (in trillions of eggs), SPR is the spawning potential ratio, and MSY is maximum sustainable yield.

Reference Point	Estimate	Lower Interval	Upper Interval
Unfished Spawning output	5.573	<1	12.328
Unfished Age 26+ Biomass (mt)	33,189	<1	73,425
Unfished Recruitment (R0)	1,077	<1	2,371

2025 Spawning output	4.860	<1	12.124
2025 Fraction Unfished	0.872	0.617	1.127
Reference Points Based SO40%	—	—	—
Proxy Spawning output SO40%	2.229	<1	4.931
SPR Resulting in SO40%	0.458	0.458	0.458
Exploitation Rate Resulting in SO40%	0.048	0.045	0.051
Yield with SPR Based On SO40% (mt)	545	<1	1,200
Reference Points Based on SPR Proxy for MSY	—	—	—
Proxy Spawning output (SPR50)	2.487	<1	5.500
SPR50	0.500	—	—
Exploitation Rate Corresponding to SPR50	0.040	0.038	0.042
Yield with SPR50 at SO SPR (mt)	519	<1	1,142
Reference Points Based on Estimated MSY Values	—	—	—
Spawning output at MSY (SO MSY)	1.477	<1	3.270
SPR MSY	0.337	0.334	0.339
Exploitation Rate Corresponding to SPR MSY	0.085	0.079	0.090
MSY (mt)	585	<1	1,285

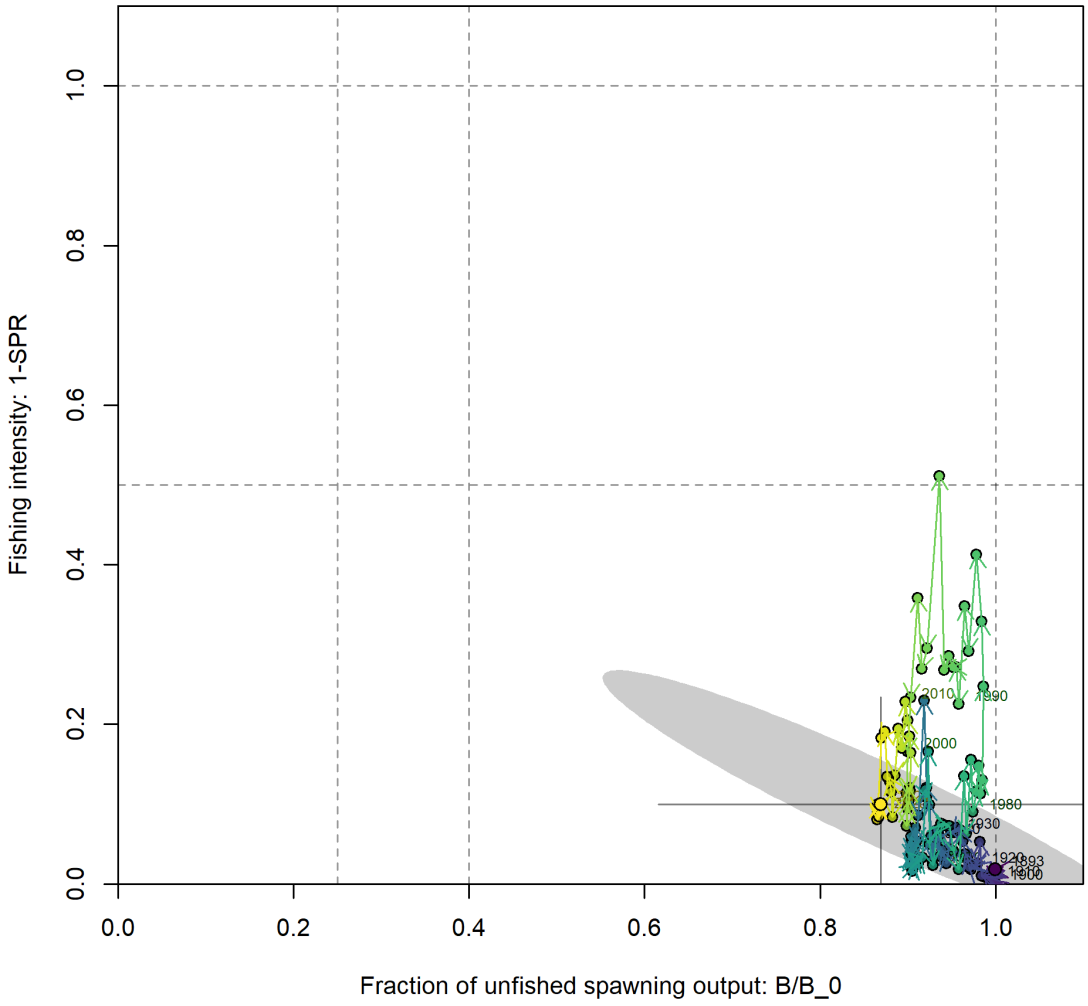


Figure vii: Phase plot of fishing intensity versus fraction unfished. Each point represents the biomass ratio at the start of the year and the relative fishing intensity in that same year. Cooler colors (purple) represent early years and warmer colors (yellow) represent recent years. Lines through the final point show 95% intervals based on the asymptotic uncertainty for each dimension. The shaded ellipse is a 95% region which accounts for the estimated correlation between the two quantities.

Management Performance

The last ten years of total dead catches for RE/BS against the component overfishing limits (OFLs), the acceptable biological catches (ABCs), the annual catch limits (ACLs) are shown in Table vi. In the last ten years, total dead catches of RE/BS have been below the component OFLs for most years, with exception of 2018 and 2019. However, exceeding component OFLs does not indicate overfishing, since the stock is managed as part of a complex.

Table vi: Recent trend in the overfishing limits (OFL), the acceptable biological catches (ABCs), the annual catch limits (ACLs), and the total dead catch (landings + discards) all in metric tons (mt). Specifications are combined across north and south of 40'10.

Year	OFL (mt)	ABC (mt)	ACL (mt)	Catch (mt)
2015	206	188	188	132
2016	211	193	193	149
2017	215	196	196	156
2018	219	200	200	242
2019	222	203	203	227
2020	224	204	204	106
2021	237	196	196	93
2022	238	195	195	117
2023	238	193	193	98
2024	238	195	195	119

Unresolved Problems and Major Uncertainties

The absolute size of RE/BS populations are highly uncertain. Through extensive explorations, we found that stock scale is sensitive to assumptions about the shape of the selectivity curves, especially for the bottom trawl. In the previous assessment, selectivity for all fleets (except for the Triennial Survey) was assumed to be asymptotic. In this assessment, we provided flexibility for the bottom trawl and non-trawl fleets and bottom trawl surveys to estimate dome-shaped selectivity curves. Changes in selectivity assumptions enabled substantially improved fits to length and age composition data in fisheries and surveys, but also resulted in a substantial increase of stock scale.

Stock scale was also sensitive to assumptions about natural mortality. RE/BS is one of the longest lived species of rockfish on the West Coast, with maximum ages of 169 years in this assessment. An individual in Alaska was reported to be 205 years (Munk (2001)), the oldest ever aged rockfish. It is therefore likely that natural mortality for RE/BS is lower than for other rockfish species. With length and age data available only for years after 1994, there is limited ability to monitor the long-term changes of aging cohorts. Therefore, estimates of natural mortality are uncertain. This assessment attempts to capture uncertainty in this parameter and integrate it into the derived biomass estimates by estimating natural mortality for females, while fixing the male natural mortality at the lowest value still supported by the likelihood profile.

Scientific Uncertainty

The model estimated uncertainty (σ) around the 2025 spawning output is 0.68. The uncertainty around the OFL is 0.66. These values underestimate the overall uncertainty as they do not incor-

porate the model structural uncertainty and do not account for any time-varying dynamics other than recruitment. The estimated uncertainty values are lower than the Category 2 default of 1, so all projections will use the Category 2 default.

Decision Table and Harvest Projections

The primary axis of uncertainty used in the decision table is natural mortality. Male natural mortality in the assessment model is fixed at $M = 0.036$, the value informed by likelihood profile and based on a meta-analytical prior that corresponds to the maximum age of 150 years. The natural mortality value for the low state of nature is $M = 0.032$ and for high state of nature is $M = 0.039$.

For the low state of nature the value was selected based in meta-analytic prior to correspond to maximum age of 169 years, which is oldest fish observed in the dataset used in the assessment. For the high state of nature, the value was selected based on the likelihood profile to be higher than in the base model, but still reasonable given the species biology; it corresponds to maximum age of 138 years based on meta-analytic prior.

Twelve-year forecasts were calculated for each state of nature. The 2025 and 2026 catches are fixed at values provided by GMT. For the rest of the years, we used base model forecast catches calculated using the default harvest control rule $P^* = 0.45$, and Category 2 default $\sigma = 1$. The alternative states of nature (Low, Base, and High) are provided in the columns of Table vii, with Spawning Output and Fraction of unfished provided for each state. The sigma value from the decision table for the low state of nature model is 0.83.

Projections of the overfishing limit, acceptable biological catch, and annual catch limit, all based on a P^* of 0.45 and a log-space standard deviation of the overfishing limit (σ) of 1 are included in Table viii. Assumed catches for 2025 and 2026 for this projection were provided by the PFMC Groundfish Management Team, and catches from 2027 onward assume full attainment of the acceptable biological catch.

Table vii: Decision table with 12-year projections. The alternative states of nature ('Low', 'Base', and 'High' as discussed in the text) are provided in the columns, with Spawning Output ('Spawn', in trillions of eggs) and Fraction of unfished spawning output ('Frac') provided for each state.

Mgmt	Year	Catch	Low Spawn	Low Frac	Base Spawn	Base Frac	High Spawn	High Frac
A	2025	155.1	1.98	0.733	4.86	0.872	13.08	0.933
	2026	186.7	1.99	0.734	4.87	0.875	13.13	0.936
	2027	843.9	1.99	0.735	4.89	0.877	13.18	0.939
	2028	825.7	1.91	0.705	4.82	0.865	13.15	0.937
	2029	808.8	1.83	0.677	4.76	0.854	13.12	0.936
	2030	792.2	1.76	0.650	4.70	0.843	13.10	0.934
	2031	776.0	1.69	0.624	4.64	0.833	13.09	0.933
	2032	760.0	1.62	0.598	4.59	0.823	13.07	0.932
	2033	745.2	1.55	0.574	4.53	0.813	13.06	0.931
	2034	729.5	1.49	0.550	4.48	0.804	13.04	0.930
	2035	713.9	1.42	0.527	4.43	0.795	13.02	0.928
	2036	699.4	1.36	0.504	4.38	0.786	13.00	0.927

Table viii: Potential OFLs (mt), ABCs (mt), ACLs (mt), the buffer between the OFL and ABC, estimated spawning output, and fraction unfished with adopted OFLs and ACLs and assumed catch for the first two years of the projection period.

Year	Adopted OFL (mt)	Adopted ACL (mt)	Assumed Catch (mt)	OFL (mt)	Buffer	ABC (mt)	ACL (mt)	Spawning output (trillions of eggs)	Fraction Unfished
2025	238	189	155	—	—	—	—	4.860	0.872
2026	237	187	187	—	—	—	—	4.875	0.875
2027	—	—	—	966	0.874	844	844	4.888	0.877
2028	—	—	—	955	0.865	826	826	4.821	0.865
2029	—	—	—	944	0.857	809	809	4.758	0.854
2030	—	—	—	933	0.849	792	792	4.698	0.843
2031	—	—	—	923	0.841	776	776	4.641	0.833
2032	—	—	—	912	0.833	760	760	4.586	0.823
2033	—	—	—	902	0.826	745	745	4.533	0.813
2034	—	—	—	892	0.818	729	729	4.480	0.804
2035	—	—	—	881	0.810	714	714	4.429	0.795
2036	—	—	—	871	0.803	699	699	4.378	0.786

Research and Data Needs

There are many areas of research that would benefit the understanding and assessment of RE/BS. Below, we identify several of them that we consider particularly important.

- Continued research on distinguishing biology of Rougheye and Blackspotted rockfishes: This assessment reports the status of RE/BS as a pooled complex because it is extremely difficult to separate the catches of each species even in recent data, and attempting to do so would greatly increase the uncertainty in the predictions. Because little is known about the respective biology and catch histories of the two species, it is unclear whether managing them as a complex may place one species at disproportionate risk of overfishing relative to the other. New research presented in this document shows potential differences in maturity between the species. Additional research that will provide insight into the distribution, life history, biological characteristics, and catch and discard profiles of the two species is recommended. Such an endeavor would likely require the efforts of at-sea observers in all fleets, biologists aboard fishery-independent surveys, and port samplers along the entire West Coast, requiring broad, inter-agency collaboration.
- Understanding of coastwide stock structure, connectivity, and distribution: This is a stock assessment for RE/BS off of the west coast of the U.S. and does not consider data from British Columbia or Alaska. Further investigating and comparing the data and predictions from British Columbia and Alaska to determine if there are similarities with the U.S. West Coast observations would help to define the connectivity between Rougheye/Blackspotted Rockfishes north of the U.S.-Canada border.
- Natural mortality: Uncertainty in natural mortality translates into uncertain estimates of status and sustainable fishing levels for RE/BS. The assessment model was able to estimate female natural mortality, consistent with maximum age based meta-analytical prior, but male natural mortality was fixed in the model. Given what seems to be a current population with a deep age structure, the collection of additional age data and further research of the life-history of RE/BS may improve our understanding of RE/BS natural mortality.
- Increasing the number of ageing samples. This assessment increased the number of available aged samples by the thousands, but many more are needed to resolve the age structure, as well as add to our understanding of how the age structure has and is changing over time. This will include the consideration of improving the ageing error of these species, with a consideration towards decreasing the number of ageing error matrices needed, or improving the imprecision of some of the current ageing error matrices. This would necessitate the re-reading of otoliths (in addition to reading new otoliths).
- Developing and applying new age determination techniques, such as Fourier Transform Near-Infrared spectroscopy (FT-NIR): In recent years, progress has been made in using FT-NIR approach for fish age determination. At present, FT-NIR ages for RE/BS have low agreement with traditional age estimates, and further research is needed before they are incorporated into stock assessment. Given the longevity of these species, more age data is needed per year compared to other rockfishes in order to define the age structure. The longevity also makes ageing these species more difficult. More rapid ageing techniques may help achieve the numbers needed to track age structure changes.
- Historical landings and discards, including investigation of fisheries selectivity: Substantial progress has been made in reconstructing historical landings of rockfishes on the U.S. West

Coast, including those for RE/BS. This assessment highlighted the importance of understanding fishery selectivity assumptions associated with removals and how fishery selectivity changes throughout the years. Further understanding and discussion on likely selectivity forms over time would help reduce uncertainty in the estimated scale of the stock.

- Otolith structure may prove to be a distinguishing feature to determine Rougheye from Blackspotted rockfishes (Harris et al. 2019). We encourage more research into this, to assist achieving species-specific identification into the future, and potentially into the past.
- Consider whether the International Pacific Halibut Commission survey may contribute biological samples and possibly an additional index to any future assessments.

Risk Table

A risk table was constructed using the Category 1 stock rubric, but is not included here given this stock assessment is considered Category 2. The risk table can be found in the Appendix.

1 Introduction

Rougheye (*Sebastes aleutianus*) and Blackspotted (*Sebastes melanostictus*) rockfishes are two species that form one management complex of Rougheye/Blackspotted rockfishes (RE/BS).

Rougheye Rockfish are a long-lived rockfish named after a series of 2-10 spines along the lower rim of their eyes. They have also been called Blackthroat or Blacktip Rockfish (Love et al. 2002; Love 2011). Blackspotted Rockfish are distributed in similar locations as Rougheye Rockfish and it is very difficult to visually distinguish the two species. These two species may hybridize on occasion (Love 2011).

It has only been from recent genetic studies that these two separate species have been identified (Hawkins et al. 2005; Gharrett et al. 2006) and have had phenotypic characteristics useful for distinguishing the species in the field identified (Gharrett et al. 2006; Orr and Hawkins 2008). Before then, data were available for one species called Rougheye Rockfish that included Rougheye Rockfish and Blackspotted Rockfish. Due to the difficulty in distinguishing these two species and the lack of historical separation of the species in all of the data, this assessment combines any data for Blackspotted Rockfish with Rougheye Rockfish into RE/BS and provides management advice for the two species combined. These species are also closely related to Shortraker Rockfish (*Sebastes borealis*) and are sometimes difficult to distinguish from Shortraker Rockfish without looking at the gill rakers.

1.1 Stock Structure

There are at least two questions to think about when considering stock structure for RE/BS when doing a stock assessment.

- Since Rougheye and Blackspotted Rockfishes are two different species, can they be separated as two stocks and conduct separate assessments?

Rougheye Rockfish were first described in 1811 as *Perca variabilis* by German zoologist Peter Simon Pallas (Jordan and Evermann 1898), and assigned to various taxa at least 15 times since (Love et al. 2002). Some descriptions noted both light and dark color morphs, which, along with possible confusion with several morphologically similar co-occurring species (e.g., *Sebastes borealis* and *Sebastes melanostomus*), have contributed to the persistent ambiguity in formal descriptions of Rougheye Rockfish (Orr and Hawkins 2008). The first genetic studies conducted in the late 1960s and early 1970s (Tsuyuki et al. 1968; Tsuyuki and Westrheim 1970) observed diversity suggestive of two genetic types within specimens identified as Rougheye Rockfish. Allozyme studies conducted over the next two decades (Seeb 1986; Hawkins et al. 1997; Hawkins et al. 2005) provided additional evidence suggesting two separate genetic types within field-identified Rougheye Rockfish. Genetic variation between the two types, supported by both nuclear and mitochondrial DNA, was determined to be sufficiently conclusive to separate two species: “Type I” and “Type II” Rougheye Rockfish (Gharrett et al. 2005). Meristic and morphometric comparisons of the two species suggested certain characters, such as gill raker counts and length, snout length, anal base length, and pectoral fin base, were significantly different, and in combination could reliably, though not definitively, distinguish between the species (Gharrett et al. 2006). The two separate species

were formally re-described by Orr and Hawkins (2008) with the Type II group retaining *Sebastes aleutianus* and the common name Rougheye Rockfish. Blackspotted Rockfish was proposed as the common name for the Type I group along with the scientific name of *Sebastes melanostictus*, re-establishing nomenclature from one of the species complex's earlier descriptions (Matsubara 1934).

These two species remain difficult to consistently differentiate visually in the catch, thus are still commonly reported and treated as a species complex. Otolith morphometrics (e.g., shape, size, weight) have shown some promise in possibly identifying these species in Alaskan waters (97.3% Blackspotted and 86.2% of Rougheye rockfishes were accurately identified) and possibly using older otoliths to break out historical information by species (Harris et al. 2019). Frey et al. (in prep.) provided insight into the ability of the Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey biologists to identify the two species, with 90% of genetically identified Rougheye Rockfish being correctly identified in the field. When mis-identifications occurred, it was usually a Blackspotted rockfish being mis-identified as a Rougheye Rockfish. There were few mis-identifications when a fish was identified as a Blackspotted rockfish. While this is promising for potential future species-specific data coming from the survey, it does not alleviate the historical problem of separating fishery data into the two species. Frey et al. (in prep.) therefore also considered whether ecological factors like depth or latitude could help separate samples by species. They found that both species occur within the range of this assessment's considered areas (California to Washington), and heavily spatially overlap. Interestingly, there seem to be relative hot spots for these species where one species is more common than the other, and in general, Rougheye Rockfish seems to be more common than Blackspotted Rockfish; however, Blackspotted Rockfish may be the more common of the two in parts of Alaska (Gharrett et al. 2005; Hawkins et al. 2005; Orr and Hawkins 2008).

Despite recent advances in species identification of Rougheye Rockfish and Blackspotted Rockfish as genetically distinct species, there is little ability to separate current or historical fishery data reliably in order to separate these two species into two stocks. Therefore, this assessment maintains a species complex approach, though given absolute presence off the U.S. West Coast, this may be considered more of a Rougheye than a Blackspotted Rockfish stock assessment. We also note that throughout the range of these stocks, all current assessments to this point have maintained a species complex approach. While we treat these species as one assessed stock complex, we recognize and are mindful of the above species distinctions as we conduct our analyses.

- Both species range into Canada and Alaska – are they one stock?

While genetics studies have focused mostly on identification of the two species, little is known about the population structure of either species. This assessment and the 2013 assessment (Hicks et al. 2013) represent the most southerly range of these species. Comparing the absolute abundance of the 2013 assessment to the most current estimates of the Alaskan stocks, the absolute number in this southerly range is much smaller than in the Gulf of Alaska (GOA), but similar to the Bering Sea/Aleutian Island (BSAI) stock (Figure 3). The two smaller stocks have similar trends of decline and stabilization, whereas the higher biomass GOA stock looks to have not dropped at all over the time period considered (Figure 4). In spite of uncertainty in the stock structure, we assume here that the West Coast stocks of RE/BS are distinct management units from those in Alaska.

1.2 Distribution

RE/BS range from northern California up to and throughout Alaska and into Japan (Gharrett et al. 2005; Hawkins et al. 2005; Orr and Hawkins 2008). Both are long-lived (>100 years), with Rougheye Rockfish having the distinction of the oldest ever aged *Sebastes* species at 205 years old (Munk 2001). They both greatly overlap in latitude and depth (shallower than 100 m to at least 439 m), and are generally considered slope rockfish, with an ontogenetic shift from shallower to deeper, and adults commonly found at 360 m (around 200 fathoms). Rougheye seems to be proportionally more abundant when survey samples are genetically identified, and Blackspotted Rockfish tend to be found, on average, deeper than Rougheye Rockfish (Hawkins et al. 2005; Orr and Hawkins 2008).

RE/BS are often associated with structure, such as hard, rocky bottoms and steep habitats. They are rarely found on the deep flats. They can be found alone or in aggregations (Love et al. 2002), with aggregations often differentiated by age. Younger fish may school and are often found in shallower waters on the shelf, juveniles and sub-adults can be found together, and larger fish may form larger aggregations during the autumn and winter.

This assessment treats the U.S. RE/BS resource from the Mexican border to the Canadian border as a single coastwide stock (Figure 1). The U.S.-Canadian border is the northern boundary for the assessed stock, although the basis for this choice is due to political and current management needs rather than the population dynamics. The assessment excludes consideration of the Salish Sea. RE/BS primarily occur in the the northern part of the assessed area (Figure 2).

1.3 Life History

Like all *Sebastes* species, RE/BS give birth to live young. Parturition has been documented between February and June with larvae lengths at parturition are between 4.5-5.3 mm (Love et al. 2002). Dick et al. (2017) showed that rockfishes exhibit a non-proportional relationship of fecundity to weight, with larger individuals producing more eggs than expected only by weight. Although neither Rougheye nor Blackspotted Rockfishes have a species- or subfamily-specific estimate for this relationship, this stock assessment uses the unobserved genus *Sebastes* values to inform fecundity to weight relationship for RE/BS.

A wide range of prey items make up the diet of RE/BS. Crangonid and pandalid shrimps make up the majority of their diets, with larger individuals, greater than 30 cm, feeding upon other fishes (Love 2011). They are also known to feed upon gammarid amphipods, mysids, crabs, polychaetes, and octopuses (Love et al. 2002; Love 2011).

1.4 Ecosystem Considerations

Rougheye Rockfish are one of the larger species of rockfish. They occupy shelf areas when they are young and move into deeper slope waters with age. As they age, they tend to become more solitary, but may form aggregations during the spawning season (Love 2011). Due to a paucity of life-history

data for Rougheye Rockfish, most ecosystem considerations are implied from the understanding of rockfishes in general. Recruitment drivers of RE/BS are not well understood. Patterns in abundance of young-of-year rockfishes often covary through time across species of rockfish (Field et al. 2021) indicating shared responses to oceanographic and ecological conditions which could inform patterns in recruitment for species that are rarely caught in juvenile surveys, such as RE/BS. For species that are primarily located north of Cape Mendocino, 2021 and 2023 indicate good recruitment years (Gasbarro et al. 2025), although it is uncertain how well this trend applies to RE/BS. The specific pathways through which environmental conditions exert influence on RE/BS dynamics are unclear; however, changes in water temperature and currents, the amount and timing of upwelling, and source water variability are all possible drivers.

The largest components of RE/BS diet in Alaska is pandalis and hippolytid shrimp, but amphipods and krill are particularly important for smaller fish (Love 2011). Based on Ecopath foodweb modeling, the highest sources of predation mortality on the functional group Slope Rockfish from greatest to least are: Sablefish, skates, northern fur seals and California sea lions.

1.5 Historical and Current Fishery Information

RE/BS are not targeted by a specific fishery, but are desirable and marketable, thus are typically retained when captured. They are often caught in bottom trawl, mid-water trawl, and longline fisheries. Small numbers have been observed in pot, shrimp, and recreational fisheries.

Longline catches of RE/BS are present from the turn of the century and continue in recent years, targeting Sablefish and halibut.

After many attempts to start trawl fisheries off the West Coast of the U.S. in the late 1800s, the availability of the otter trawl and the diesel engine in the mid-1920s helped the trawl fisheries expand (Douglas and Division 1998). The trawl fisheries became established during World War II when demand increased for bottomfish. A mink food fishery also developed during World War II (Jones and Harry 1961), and post-war catches for rockfishes, including RE/BS, increased (Niska 1976). Between the mid-1960s and mid-1970s, foreign trawl fleets from the former Soviet Union, Japan, Poland, Bulgaria, and East Germany targeted aggregations of Pacific Ocean Perch in the Northeast Pacific Ocean, in the waters off the U.S. West Coast (Love et al. 2002) until the EEZ was implemented in 1977 (Rogers 2003).

Also, large-scale harvesting of Pacific Hake in the U.S. began in late-1960s, when factory trawlers from the Soviet Union and other countries began targeting this stock. RE/BS was commonly caught in this fishery. After the 200 mile U.S. Exclusive Economic Zone was declared in 1977 and a joint-Venture fishery was initiated between U.S. trawlers and Soviet factory trawlers acting as mother-ships (larger, slower ships for fish processing and storage while at sea). By 1989, the U.S. fleet capacity had grown to a level sufficient to harvest the entire quota and no further foreign fishing was allowed.

Since 1977, landings of rockfish were higher until management restrictions were implemented in 2000. RE/BS inhabit deeper water as adults, which were fished less often historically. More

detailed information about the fisheries by state is given in Section 2.1, where the reconstructed catches are discussed. The catches fleet as well as for the Pacific whiting at-sea fleet are shown in Figure 6.

1.6 Summary of Management History and Management Performance

RE/BS has been a small component of groundfish fisheries and catches of RE/BS have been governed by restrictions on assemblages of species, such as Slope Rockfish, of which these species are a member. However, the distribution of fishing effort in areas where RE/BS might be encountered has also been affected by catch restrictions on co-occurring, rebuilding species, as well as associated area closures instituted to promote rebuilding. The first imposed landings limits on a coastwide Sebastes complex (RE/BS being one of the 50 rockfishes in the complex) were instituted in 1983.

This complex was divided in to two management areas north and south of 43°00′ N in 1994. Ongoing concern that shelf and slope rockfishes may be undergoing overfishing led the attempt by Rogers et al. (1996) to describe the status of most rockfishes in the Sebastes complex. RE/BS information content was low. To estimate exploitation rates of Rougheye Rockfish Rogers et al. (1996) assumed fishing mortality was equal to natural mortality and used the AFSC/NWFSC Triennial Shelf Survey to calculate an average biomass. The analysis found that the stock was undergoing very high exploitation rates in both management areas.

The dividing line between the northern and southern management areas was shifted to 40°00′ N latitude in 1999 and the Sebastes complex was subsequently divided into nearshore, shelf, and slope complexes in 2000. Rougheye Rockfish has been managed under trip limits for the minor slope rockfish complex in both north and south management areas since this time.

Table 1 summarizes major management changes since 2000. Some important changes include the implementation of Rockfish Conservation Areas (RCA's) in 2002, the beginning of trawl rationalization in 2011, and the lifting of the RCAs beginning in 2020 with the removal of the trawl RCA in Oregon and California and loosening restrictions in the non-trawl RCAs in 2023 and 2024.

Though managed as part of a complex, OFL contributions for RE/BS were calculated using DB-SRA in 2010 for the 2011-2012 management cycle. DB-SRA results indicated that RE/BS catches had frequently exceeded the OFL contribution estimated using data-poor, catch-only methods and highlighted the need for a more thorough evaluation of RE/BS stock status and sustainable harvest levels using all available data. A full assessment of RE/BS was undertaken in 2013 and indicated the stock complex was above management target levels (Hicks et al. 2013). Recent management performance for RE/BS is provided in Table 2 for north and south of 40°10′. RE/BS is managed as a part of the minor slope rockfish complex.

1.7 Fisheries off Canada and Alaska

RE/BS are distributed throughout Canada and Alaska and are commonly caught in trawl and longline fisheries. Alaska conducts assessments biennially for the Rougheye/Blackspotted complex,

and two have been recently done: one for the Bering Sea and Aluetian Islands (Spencer et al. 2003) and the other for the Gulf of Alaska (Sullivan et al. 2023). Canada completed an assessment in 2020 (Starr and Haigh 2020). The fisheries and assessments for each country are described below.

Rougheye Rockfish have been managed as a bycatch-only species in Alaska since 1991 with catches ranging between 130 and 2,418 mt and peaking in the late 1980s and early 1990s (Sullivan et al. 2023). Generally, about 55-75% of the catch are trawl-caught and 30-45% from hook-and-line (mainly, longline) fisheries. Since 2017, the move to pot gear in the Sablefish fishery has decreased the longline catches. Discards since 2013 have ranged from 11.6% (in 2023) to 45% (in 2018). The Rougheye/Blackspotted complex catch levels generally are between 20% and 60% of the Total Allowable Catch since 2005 when the complex began to be managed separately. The most recent age-structured integrated stock assessments of this complex in the Bering Sea and Aluetian Islands (Spencer et al. 2003) and for the Gulf of Alaska (Sullivan et al. 2023) do not indicate either overfishing or the stocks being overfished.

Canada identified two species of Rougheye Rockfish (Type I and Type II) in 2007 and designated both species of special concern, which means that they may become threatened or endangered because of a combination of biological characteristics and identified threats (COSEWIC 2007). This designation was given because biomass estimates were uncertain and no strong trends were observed, there is evidence of truncation of the age distribution and overall mortality has doubled, it is a long-lived, low-fecundity *Sebastes* species, which is susceptible to population collapse and slow recovery, and because of the difficulty in separating the two species may result in potential impacts on one of the species going unnoticed. Subsequently, the species were identified as Rougheye Rockfish and Blackspotted Rockfish and a management plan was created in 2012 with a goal of sustaining the populations of Rougheye and Blackspotted Rockfishes (Canada 2012). Five high priority and seven low priority actions have been identified to address the threats to the populations and support the management goal.

The first Canadian stock assessment for these species, using a integrated catch-at-age model, was conducted in 2020 (Starr and Haigh 2020) to estimate stock status of two management units of RE/BS (RE/BS north and RE/BS south). The RE/BS north stock was estimated to be in the healthy zone. The RE/BS south stock was likely in the healthy zone, but with an elevated possibility of being in the cautious zone.

2 Data

Data from a wide range of sources were evaluated within this assessment. Data sources included in the assessment model are summarized in Figure 5. Description of each data source used in the model is provided below.

2.1 Fishery-Dependent Data

RE/BS are not currently thought to be targeted by a specific fishery, but are desirable and marketable, thus are typically retained when caught. They are often captured in bottom trawl, mid-water trawl, and longline fisheries. They are also commonly bycaught within the at-sea hake fishery. Small numbers have been observed in pot and shrimp trawl. Recreational catch is inconsequential and not accounted for in this assessment.

RE/BS fishery-dependent data in this assessment are divided among six fleets, which include:

- Fleet 1: Commercial bottom trawl fishery.
- Fleet 2: Dead discard from bottom trawl fishery.
- Fleet 3: Commercial non-trawl (mainly the long-line) fishery.
- Fleet 4: Dead discard from non-trawl fishery.
- Fleet 5: Contemporary mid-water trawl fishery.
- Fleet 6: At-sea hake fishery bycatch.

For the explanation for the chosen fleets and further details on fleet structure, please refer to Section 3.4.3.

2.1.1 Commercial Fishery Landings

Recent and historical fisheries catches were compiled by state and then combined into the fishing fleets used in the assessment. Time series of catches by fleet are reported in Table 3 and shown in Figure 6. The landings by state are given in Table 4 for bottom trawl, Table 5 for non-trawl, and Table 6 for mid-water trawl fleets.

2.1.1.1 Recent landings

Recent commercial landings of RE/BS (2000-2024 for Washington, 1987–2024 for Oregon and 1981–2024 for California,) were obtained from Pacific Fisheries Information Network (PacFIN), a regional fisheries database that manages fishery-dependent information in cooperation with West Coast state agencies and National Marine Fisheries Service (NMFS). Catch data were extracted from PacFIN on April 24, 2025.

2.1.1.2 Historical Landings

Historical landings of RE/BS were reconstructed by state.

The Washington historical landings (1889–2000) of RE/BS were provided by Washington Department of Fish and Wildlife (WDFW), who recently conducted historical catch reconstruction for rockfish species, including RE/BS (Tsou et al. in prep). The three main sources used in this reconstruction included the US Fish Commission Report (UFSC), Washington Bound Volumes, and Washington Statistical Bulletin. The historical species composition was based on the various historical reports and interviews of fishermen and dockside samplers. The landings between 1981 and 2000 were also provided by WDFW (rather than obtained from PacFIN), since WDFW developed and used a improved method for apportioning unidentified rockfish (URCK) category in fish tickets to the individual species landings. This improved approach relaxed the borrowing rules for missing data used in the WDFW species allocation algorithm that feeds into PacFIN (Tsou et al. 2015). New Washington historical landings represent an improvement to the assessment.

The Oregon historical landings (1896–1986) were obtained from Oregon historical catch reconstruction, conducted by Oregon Department of Fish and Wildlife (ODFW) in collaboration with NWFSC (Karnowski et al. 2014). The Oregon landings for the period between 1987 and 1999 were also provided by the ODFW. For that period, Oregon PacFIN landings were supplemented with the additional estimates of RE/BS landings reported within unspecified rockfish market categories (i.e., URCK and POP1; (Fish and Wildlife 2017)).

The California historical landings were informed by several sources. Landings from the most recent "historical" period (between 1969 and 1980) were obtained from the California Cooperative Survey (CalCOM) database. Earlier landing records (between 1931 and 1968) were informed by the rockfish historical catch reconstruction conducted by the Southwest Fisheries Science Center (Ralston et al. 2010).

Comparison of RE/BS historical landings by state and fleet between this and the 2013 assessment is provided in Figure 7. The largest differences in this assessment from the 2013 model are in Washington landings (Figure 10), with newly estimated landings being generally lower than those used in the previous assessment. The new WDFW catch reconstruction completed by WDFW is considered an improvement.

Historical California and Oregon landings did not change substantially (Figure 8 and Figure 9), with the exception of a few years. Discrepancies in California and Oregon non-trawl landings between the 2013 and 2025 assessments are caused by the fact that the non-trawl fleet in the 2013 assessment was limited to only fixed gear, when in 2025 assessment non-trawl fleet includes all non-trawl gear groups. Slight discrepancies in Oregon trawl landings between 1987 and 1999 are from adding previously non-reported landings of RE/BS in the unspecified rockfish market categories (see details above).

The update in historical changes shows only minor differences in model outputs (Figure 38; Figure 39).

2.1.1.3 Bycatch in the Foreign POP Fishery

Between mid-1960s and mid-1970s, foreign trawl fleets from the former Soviet Union, Japan, Poland, Bulgaria and East Germany targeted aggregations of Pacific ocean perch in the Northeast Pacific Ocean, in the waters off the U.S. West Coast (Love et al. 2002). Rogers (2003) estimated removals of rockfish species caught within this foreign POP fishery, including removals of RE/BS. In the assessment, RE/BS bycatch in the foreign POP fishery between 1966 and 1976 as estimated by Rogers (2003) were added to commercial bottom trawl fleet (Table 4).

2.1.1.4 At-Sea Hake Catches

RE/BS has long been bycaught in the fishery for the coastal population of Pacific Hake, which is almost exclusively conducted with mid-water trawls. The Pacific Hake fishery is currently 100% observed by the at-sea hake observer program (A-SHOP) and data on bycatch species, including RE/BS, is being routinely collected.

Annual amounts of RE/BS bycatch (retained and discarded) in the Pacific Hake fishery were obtained from the North Pacific Database Program (NORPAC). That time series covers the period between 1977 and 2024 and include catches by foreign and domestic fisheries as well as removals during the time of Joint Ventures. RE/BS catches within the at-sea hake fishery were treated in the model as a separate fleet (Table 4).

2.1.2 Discards

2.1.2.1 Historical Discards

Historically, little to no discarding was observed for RE/BS.

The historical discard information comes from Pikitch et al. (1988), often referred to as the Pikitch study. The Pikitch study was conducted between 1985 and 1987 between 48°42' and 42°60' N. latitude (Pikitch et al. 1988). Participation in the study was voluntary and included vessels using bottom, mid-water and shrimp trawl gears. Observers of normal fishing operations on commercial vessels collected the data, estimated the total weight of the catch by tow, and recorded the weight of species retained and discarded in the sample.

There are no mid-water trawl records of RE/BSin the Pikitch et al. (1988), and only few fish records of bottom trawl catches, based on which discard rate (discard weight over total weight) for bottom trawl was just 0.09%. Therefore, no historical discard was assumed in the model.

2.1.2.2 Recent Discards

With the introduction of trip limits for rockfish in early 2000, limited discarding has been observed for RE/BSin bottom trawl and non-trawl fisheries.

In 2002, the West Coast Groundfish Observer Program (WCGOP) was implemented on the West Coast of the United States, which began with gathering bycatch and discard information for the limited entry trawl and fixed gear fleets. Observer coverage has expanded to include the California halibut trawl, the nearshore fixed gear and pink shrimp trawl fisheries. Since 2011, trawl fisheries have been managed with catch shares under a system of annual individual fishing quotas (IFQs) for the shoreside sector (i.e., vessels delivering to shoreside processors) and harvest cooperatives for the at-sea hake sectors (catcher-processors who catch and process hake at sea; and motherships, factory processors that take delivery of hake from catcher vessels at sea). Constant monitoring of catch using observers or electronic monitoring (EM) is required to participate in the trawl catch share fishery.

The discard amounts of RE/BS for the period between 2002 and 2023 were obtained from WCGOP by year and fleet (bottom trawl, mid-water trawl and non-trawl), for both the catch share and the non-catch share sector. The discarding amounts of RE/BS within bottom trawl and non-trawl fleets were included in the model as separate fleets.

Mid-water trawl discard was not present in the non-catch share sector and was extremely minimal (virtually non-existant) in the catch-share sector, with discard amounts averaging to 10 kg per year. Therefore, in the model, no discard was assumed for mid-water trawl fleet.

2.1.2.2.1 Bottom Trawl Discards

Bottom trawl discard amounts by year are provided in Table 3 and shown in Figure 6. Prior to 2011, before the start of the IFQ program, the discard of RE/BS ranged between 1 metric ton and 60 metric tons, averaging at 23 metric tons a year. After 2011, the discard has been very low, not exceeding 0.5 metric ton a year. No discard data were available for 2024, and we used the average discard amount for 2019 - 2023 period to approximate 2024 discards for bottom trawl discard fleet.

2.1.2.2.2 Non-Trawl Discard

Non-trawl discard amounts by year are provided in are provided in Table 3 and shown in Figure 6. Non-trawl discard of RE/BS were made in both catch share and non-catch share sectors. Discard amounts in these sectors were combined by year to represent total discard within the fleet. The discards within this fleet ranged between 0.5 metric tons and 35 metric tons, with ten metric tons as average per year. No discard data were available for 2024, and the 2023 discard amount was assumed for 2024 for non-trawl discard fleet.

2.1.3 Fishery Length and Age Data

Length bins from 10 to 80 cm in 2 cm increments were used to summarize the length frequency of the catches in each year. The first length bin includes all observations less than 10 cm and the last bin includes all fish 80 cm and longer. Age distributions included bins from age 1 to age 100, with the last bin including all fish age 100 and above.

2.1.3.1 Commercial Landings Length and Ages

The fishery length and age data for bottom trawl, non-trawl and mid-water trawl fleets, based on samples collected by port samplers, were obtained from the PacFIN Biological Data System (BDS) database and extracted on April 24, 2025. The number of trips and fish sampled for lengths and ages by state and year are summarized in Table 7 through Table 10, by fishing fleet.

Commercial length-frequency distributions were developed for each fleet and year, for which observations were available

Females and males distributions were treated separately, to track sex-specific differences. For each fleet, the raw observations were expanded to the trip level, to account for differences in samples sizes relative catch weights among trips (first stage expansion). The expanded length observations were then further expanded to state level, to account for differences in sampling intensity of RE/BS landings among states combined into a single fleet (second stage expansion). The expansion algorithm can be illustrated with the following equation:

$$N_{b,j,y} = \sum_{s=1}^{s=k} \sum_{t=1}^{t=n} L_{b,j,t} \cdot \left(\frac{LC_t}{SC_t} \right) \cdot \left(\frac{LC_{s,y}}{SC_{s,y}} \right)$$

Where $N_{b,j,y}$ is the number of lengths in each length bin (b) by sex (j) and year (y) within each fleet. $L_{b,j,t}$ represents an individual length sample by bin (b) and sex (j) within an individual fishing trip (t). In the first stage expansion, $L_{b,j,t}$ was multiplied by the ratio of landed catch (LC_t) within that trip (t) to a portion of catch sampled for lengths (SC_t) within the same trip (t). In the second stage expansion, the individual length sample ($L_{b,j,t}$) was multiplied by the ratio of landed catch ($LC_{s,y}$) within individual state (s) and year (y) to catch weights sampled for lengths ($SC_{s,y}$) within the same state (s) and year (y). As the final step, the expanded length samples from the same size bin and sex were summed across all trips and states (combined into a single fleet) within a single year, to obtain the total number of lengths in each length bin by sex, year and fleet ($N_{b,j,y}$). The same calculations were repeated for each length bin, to develop sex specific length frequencies for each fishing fleet by year.

Age distributions were included in the model as conditional-ages-at-length (CAAL) observations. The marginal age compositions were also included, but only for evaluating the implied fits, while the CAAL data were used in the likelihood. The CAAL data were not expanded and were binned according to length, age, sex, and year.

The filtering and processing of the PacFIN length and age composition data were conducted using the pacfintools package in R. The filtering steps included removing samples with missing vital information.

Figure 11 through Figure 17 show length frequencies for bottom trawl, non-trawl and mid-water fleets by year, and Figure 22 through Figure 26 show the commercial CAAL distributions by year for the same fleets.

The initial input values for length compositions in this assessment were calculated as a function of the number of trips and number of fish via the Stewart Method (pers. comm. I. Stewart, International Pacific Halibut Commission (IPHC)). The method is based on analysis of the input and model derived effective sample sizes from West Coast groundfish stock assessments. A piece-wise linear regression was used to estimate the increase in effective sample size per sample based on fish-per-sample and the maximum effective sample size for large numbers of individual fish. The resulting equations are:

$$\text{Input N} = N_{\text{trips}} + 0.138 \cdot \ N_{\text{fish}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \text{ is} < 44$$

$$\text{Input N} = 7.06 \cdot \ N_{\text{trips}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \text{ is} \geq 44$$

The input sample size of CAAL data was set at the number of fish at each length by sex and by year.

2.1.3.1.1 Commercial Discard Lengths

Discard length composition data for both bottom trawl and non-trawl discard fleets were available from WCGOP. The number of trips, hauls and fish sampled for lengths by year are summarized in Table 11, by discard fleet.

Discard length composition data were not sex-specific. Discard raw length observations were expanded to the haul level, to account for differences in catch among hauls (Figure 13 and Figure 16).

The initial input values for length compositions were calculated via the Stewart Method (see above).

No age data were available for discarded fish.

2.1.3.1.2 At-Sea Hake Fishery Length and Age Compositions

The sex-specific length and age data for at-sea hake fleet were collected by the At-Sea Hake Observer Program (ASHOP) and available through NORPAC database (Figure 13 and Figure 16). Age distributions were included in the model as CAAL observations, binned according to length, age, sex, and year (Figure 27 through Figure 28).

The number of hauls and fish sampled by year and used to create length frequency and CAAL distributions are summarized in Table 12.

Input sample sizes for length compositions were based on the number of hauls sampled by year. The input sample size of CAAL data was set at the number of fish at each length by sex and by year.

The marginal age compositions were constructed, but only used in the model for evaluating the implied fits, while the CAAL data were used in the likelihood.

2.2 Fishery-independent data

Data from four fishery-independent surveys were used in this assessment:

- Survey 1: West Coast Groundfish Bottom Trawl Survey (WCGBTS; 2003-2024).
- Survey 2: Triennial (every three years) Survey (1980-2004).
- Survey 3: Alaska Fisheries Science Center (AFSC) Slope Survey (1997, 1999-2001).
- Survey 4: Northwest Fisheries Science Center (NWFSC) Slope Survey (1999-2002).

The surveys temporal and spatial coverage is summarized in Table 14.

Information produced by these surveys included indices of relative abundance (all four surveys), length-frequency distributions (WCGBTS and Triennial survey), and age frequency distributions (WCGBTS).

Only the WCGBTS has new data for this assessment, but new methods were applied to all surveys to develop indices of abundance.

In this assessment, geostatistical models of biomass density were fit to survey data using the R package Species Distribution Models with Template Model Builder (`sdmTMB`) (Anderson et al. 2022).

These models can account for latent spatial factors with a constant spatial Gaussian random field and spatiotemporal deviations to evolve as a random walk Guassian random field (Thorson et al. 2015). Tweedie, delta-binomial, delta-gamma, and mixture distributions, which allow for extreme catch events, were investigated. Results are only shown for the distribution that led to the best model diagnostics, e.g., similar distributions of theoretical normal quantiles and model quantiles, high precision, lack of extreme predictions that are incompatible with the life history, and low Akaike information criterion (AIC). Estimates of biomass from this best model were predicted using a grid based on available survey locations. The {indexwc} R package (Johnson et al. 2025) was used to conduct the analysis and code to reproduce the analysis is available at https://pfmc-assessments.github.io/indexwc/.

Standardized indices for all four surveys overlaid are shown in Figure 32, where each index is rescaled to have mean observation = 1.0.

Description of each survey is provided below; details on methods used to process the data are also discussed.

2.2.1 NWFSC West Coast Groundfish Bottom Trawl Survey

2.2.1.1 Survey Description

The Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey (WCGBTS) is conducted annually since 2003 Table 14. The survey's design and sampling methods are most recently described in detail in Keller et al. (2017). The survey is based on a random-grid design, covering the coastal waters from a depth of 100 to 700 fm (183-1280 m). This design generally uses four industry-chartered vessels per year assigned to a roughly equal number of randomly selected grid cells and divided into two 'passes' of the coast. Two vessels fish from north to south during each pass between late May to early October. This design therefore incorporates both vessel-to-vessel differences in catchability, as well as variance associated with selecting a relatively small number (approximately 700) of possible cells from a very large set of possible cells spread from the Mexican to the Canadian borders.

2.2.1.2 Abundance Index

The data were truncated to depths less than 875 m prior to modeling given that there were zero positive encounters in depths deeper than 875 m. The prediction grid was also truncated to only include available survey locations in depths between 55–875 m to limit extrapolating beyond the data and edge effects.

The chosen model used a delta model with a lognormal distribution for the catch-rate component. A logit-link was used for encounter probability and a log-link for positive catch rates. The response variable was catch (mt) with an offset of area (km^2) to account for differences in effort. Fixed effects were estimated for each year. The following additional covariates were included: pass. Vessel-year effects, which were historically used for index standardization of this survey, were not included because the estimated variance for the random effect was close to zero. Vessel-year effects were more prominent when models did not include spatial effects and instead vessel-year terms accounted for the random selection of commercial vessels used during sampling (Helser et al. 2004; Thorson and Ward 2014).

Spatial variation, but not spatiotemporal variation, was included in either the encounter probability nor the positive catch rate model. Spatial variation was approximated using 200 knots, where more knots led to non-estimable standard errors because the positive encounters are too sparse to support the dense spatial structure.

The biomass estimates produced for this assessment using `sdmTMB` are comparable to the biomass estimates produced in the previous benchmark assessment (Figure 33). The index is relatively flat with high variation (Figure 34).

2.2.1.3 Length and Age Compositions

Table 15 shows the number of lengths and Table 16 shows the number of ages taken by the survey.

Length compositions were separated into males and females. These length compositions were expanded to account for difference in catch among tows, with further expansion based upon the stratification by depth and latitude using the {nwfscSurvey} package in R (Wetzel et al. 2025). The stratification for length data expansions are provided in Table 13.

Age distributions were included in the model as CAAL observations. The marginal age compositions were only used for comparing the implied fits, while the CAAL data were used in the likelihood. The CAAL data were not expanded and were binned according to length, age, sex, and year.

Figure 19 shows WCGBTS length frequencies by year, and Figure 29 through Figure 31 show the WCGBTS length and CAAL distributions by year.

The input sample sizes for length composition data were calculated based on Stewart and Hamel (2014) as Input $N_y = 2.43 \cdot N_{tow}$ where the 2.43 value was estimated for a group of shelf and slope rockfish species.

The input sample size of CAAL data was set at the number of fish at each length by sex and by year.

2.2.2 AFSC/NWFSC West Coast Triennial Shelf Survey

2.2.2.1 Survey Description

The Triennial Survey was first conducted by the AFSC in 1977 and continued until 2004. The survey's design and sampling methods are most recently described in Weinberg et al. (2002). Its basic design was a series of equally-spaced transects from which searches for tows in a specific depth range were initiated.

The survey spatial coverage and timing has changed over the period of survey duration Table 14.

Haul depths ranged from 91–457 m during the 1977 survey with no hauls shallower than 91 m. The surveys in 1980, 1983, and 1986 covered the West Coast south to 36.8°N latitude and a depth range of 55–366 meters. The surveys in 1989 and 1992 covered the same depth range but extended the southern range to 34.5°N (near Point Conception). From 1995 through 2004, the surveys covered the consistent depth range 55–500 meters and surveyed south to 34.5°N. In the final year of the triennial series (2004), the NWFSC conducted the survey and followed very similar protocols as the AFSC, which conducted surveys in all previous years.

All of the surveys were conducted in the mid-summer through early fall: the 1977 survey was conducted from early July through late September; the surveys from 1980 through 1989 ran from mid-July to late September; the 1992 survey spanned from mid-July through early October; the 1995 survey was conducted from early June to late August; the 1998 survey ran from early June through early August; and the 2001 and 2004 surveys were conducted in May-July.

Water hauls (Zimmermann et al. 2001) and tows located in Canadian waters were also excluded from the analysis of this survey. Given the different depths surveyed during 1977, the data from that year were not included in this assessment.

2.2.2.2 Abundance Index

The Triennial Survey was analyzed as an early series (1980–1992) and a late series (1995–2004) to account for change in spatial coverage and survey timing, as RE/BS exhibit ontogenetic movements when individuals gradually shift their distribution toward deeper waters as the grow and mature. Separate catchability parameters were estimated for pre-1995 period and from 1995 forward. Separate selectivity curves were estimated for early and late survey periods as well.

The data for the early series were truncated to depths less than 350 m, and for late series to depths less than 500 m prior to modeling given that there were zero positive encounters in depths deeper than 500 m. The prediction grid was also truncated to only include available survey locations in depths between 55–500 m to limit extrapolating beyond the data and edge effects.

The chosen model used a delta model with a lognormal distribution for the catch-rate component. A logit-link was used for encounter probability and a log-link for positive catch rates. The response variable was catch (mt) with an offset of area (km^2) to account for differences in effort. Fixed effects were estimated for each year. No other covariates were modeled. Vessel-year effects, which were historically used for index standardization of this survey, were not included because the estimated variance for the random effect was close to zero. Vessel-year effects were more prominent when models did not include spatial effects and instead vessel-year terms accounted for the random selection of commercial vessels used during sampling (Helser et al. 2004; Thorson and Ward 2014).

Spatial and spatiotemporal variation were included in the encounter probability but not the positive catch rate model. Spatial variation was approximated using 100 knots, where more knots led to non-estimable standard errors because the positive encounters are too sparse to support the dense spatiotemporal structure.

The estimated index is shown in Figure 35. The index exhibits an increase in biomass from 1995 forward, that corresponds to a change in Triennial Survey depth coverage, when the survey extended to the deeper area Table 14.

2.2.2.3 Length Compositions

Table 15 shows the number of lengths taken by the survey.

Length compositions were separated into males and females. These length compositions were expanded to account for difference in catch among tows, with further expansion based upon the stratification by depth and latitude using the {nwfscSurvey} package in R (Wetzel et al. 2025).

The stratification for length data expansions are provided in Table 13. Figure 20 shows Triennial Survey length frequencies by year,

The input sample sizes for length composition data for all fishery-independent surveys were calculated based on Stewart and Hamel (2014) as Input $N_y = 2.43 \cdot N_{tow}$ where the 2.43 value was estimated for a group of shelf and slope rockfish species.

There are no RE/BS age data from the Triennial Survey.

2.2.3 AFSC Slope Survey

2.2.3.1 Survey Description

The AFSC slope survey was initiated in 1984. The survey methods are described in Lauth (2000). Prior to 1997, the survey was conducted in different latitudinal ranges each year. In this assessment, only data from 1997, 1999, 2000 and 2001 were used – these years were consistent in latitudinal range (from 34°30' N. latitude to the U.S.-Canada border) and depth coverage (183-1280 m; 100-700 fm).

2.2.3.2 Abundance Index

The prediction grid was truncated to only include available survey locations in depths deeper than 183 to limit extrapolating beyond the data and edge effects.

The chosen model used a delta model with a lognormal distribution for the catch-rate component. A logit-link was used for encounter probability and a log-link for positive catch rates. The response variable was catch (mt) with an offset of area (km^2) to account for differences in effort. Fixed effects were estimated for each year. No other covariates were modeled. Vessel-year effects, which were historically used for index standardization of this survey, were not included becausethe estimated variance for the random effect was close to zero. Vessel-year effects were more prominent when models did not include spatial effects and instead vessel-year terms accounted for the random selection of commercial vessels used during sampling (Helser et al. 2004; Thorson and Ward 2014).

Spatial and spatiotemporal variation were not included in either the encounter probability nor the positive catch rate model. Spatial variation was approximated using 100 knots, where more knots led to non-estimable standard errors because the positive encounters are too sparse to support the dense spatiotemporal structure.

The AFSC Slope Survey index is shown in Figure 36. The index is short, and does not exhibits significant change over the four year period.

2.2.3.3 Length Compositions

Table 15 shows the number of lengths taken by the survey.

Length compositions were separated into males and females. These length compositions were expanded to account for difference in catch among tows, with further expansion based upon the stratification by depth and latitude using the {nwfscSurvey} package in R (Wetzel et al. 2025). The stratification for length data expansions are provided in Table 13. Figure 21 shows AFSC Slope Survey length frequencies by year.

The input sample sizes for length composition data for all fishery-independent surveys were calculated based on Stewart and Hamel (2014) as Input $N_y = 2.43 \cdot N_{tow}$ where the 2.43 value was estimated for a group of shelf and slope rockfish species.

There are no RE/BS age data from the AFSC Slope Survey.

2.2.4 NWFSC Slope Survey

2.2.4.1 Survey Description

The NWFSC slope survey was conducted annually from 1999 to 2002. The survey's design and sampling methods are described in Keller et al.(2007). The surveyed area ranged between 34°50' and 48°07' N. latitude, encompassing the U.S. Vancouver, Columbia, Eureka, Monterey INPFC areas, and a portion of the Conception area, and consistently covered depths from 100 to 700 fm (183-1280 m) (Table 13).

2.2.4.2 Abundance Index

The prediction grid was truncated to only include available survey locations in depths deeper than 183 to limit extrapolating beyond the data and edge effects.

The chosen model used a delta model with a lognormal distribution for the catch-rate component. A logit-link was used for encounter probability and a log-link for positive catch rates. The response variable was catch (mt) with an offset of area (km^2) to account for differences in effort. Fixed effects were estimated for each year. No other covariates were modeled. Vessel-year effects, which were historically used for index standardization of this survey, were not included because the estimated variance for the random effect was close to zero. Vessel-year effects were more prominent when models did not include spatial effects and instead vessel-year terms accounted for the random selection of commercial vessels used during sampling (Helser et al. 2004; Thorson and Ward 2014).

Spatial and spatiotemporal variation were not included in either the encounter probability nor the positive catch rate model. Spatial variation was approximated using 100 knots, where more knots

led to non-estimable standard errors because the positive encounters are too sparse to support the dense spatiotemporal structure.

The NWFSC Slope Survey index is shown in Figure 37. The index is short, and, as in case of AFSC SLope Survey, does not exhibits significant change over the four year period.

There are no RE/BS length and age data from the NWFSC Slope Survey. Given that spatial coverage of NWFSC Slope Survey is the same of AFSC Slope Survey, selectivity of the NWFSC SLope Survey was assumed the same as selectivity of AFSC Slope Survey (mirrored in the model).

2.3 Biological Parameters

The major biological inputs to the models are natural mortality, age and growth parameters, weight-length, maturity and stock-recruitment parameters. The following sections outline the treatment of each section. One change from the previous assessment is moving to a two sex from the one-sex specification from 2013. The 2013 stock assessment one-sex specification was based on the observation that the biology of females and males was very similar, thus justifying the simplifying assumption of one sex. The following sections below demonstrates that females and males do generally have similar growth, though there are differences, but may have different natural mortality values. The current assessment will use a two sex configuration that allows for flexibility to set female and male parameters either equal (i.e., functionally equivalent to a one sex model) and or sex-specific. Figure 40 and Figure 41 show that using a two sex configuration with the same life history parameters for females and males is equivalent to the one sex model. Note that the one sex model sums up both female and male biomass, thus why it is twice the size as the two sex female-only spawning output (Figure 41).

2.3.1 Natural Mortality

Natural mortality is a highly influential parameter in age-structured stock assessments. It defines the rate of natural death by age, and thus establishes a stable age-structure and expectation of longevity, and interacts with growth and reproduction to determine stock productivity. It is a very difficult parameter to directly measure, thus empirical relationships based on life history parameters are often used to indirectly determine its value or build prior distributions in belief of what it is in the event we do attempt to estimate it in the model (Cope and Hamel 2022; Hamel and Cope 2022; Maunder et al. 2023). If length and age data are available, it may be possible to estimate it in the model.

An estimate of maximum age tends to be the most reliable life history parameter related to natural mortality to inform its estimation. Cope and Hamel (2022) (The Natural Mortality Tool) provide the most up-to-date examination of the relationship between maximum age and natural mortality

$$M = \frac{5.4}{A_{\max}}$$

where M is natural mortality and $A_{\max}$ is the assumed maximum age. The prior is defined as a lognormal distribution with mean $ln(5.4/A_{\max})$ and standard error = 0.31. This is the equation typically used to estimate a natural mortality point estimate, but is underpinned by the choice of the value of $A_{\max}$. This equation assumes that the proportion of the stable population at this maximum age is 0.4517%. If we take humans as an example, the longest lived human is 122 years. This is not the maximum age, but the oldest ever recorded age. The maximum age that corresponds to 0.4517% of the population is around 100 years. For Rougheye/Blackspotted, the oldest ever aged individual is 205 years with unknown ageing error. We did not consider this as a realistic maximum age.

The 2013 U.S. West Coast stock assessment was based on a single sex model and used a prior built around a mean of 0.034 (corresponding to a maximum age of 163), but estimated natural mortality at 0.042 for sexes combined (maximum age between 128-129 years; Figure 42). The 2023 Gulf of Alaska assessment built a prior conditional on a estimate of natural mortality from their 5 oldest aged individuals that ranged from 126-135 years. This resulted in a mean value of 0.042, similar to the 2013 U.S. West Coast stock assessment. The 2023 Bering Sea/Aleutian Islands assessment used M = 0.05 (assumed longevity of 108), and the recent Canadian assessments considered a range of M values from 0.03 to 0.055 (assumed maximum ages of 180 to 98 years; Figure 42).

Examining the available age data, the oldest 10 individuals range from 139 to 165 and were all males. For females, the 10 oldest individuals range from 130 to 121 years. If those oldest ages were used in the Hamel and Cope (2022) longevity estimator, these ages would correspond to a range of natural mortality values of 0.033 to 0.039 for males, which include the mean of the prior used in the 2013 assessment. For females, it corresponds to natural mortality values of 0.039 to 0.045. All these assume that the sampled population has enough of an age structure still available for sampling, as opposed to having some level of age truncation from the theoretical unfished stable age distribution.

Related to this issue of possible age truncation, applying a catch curve analysis (taking the log of the abundance of numbers of samples in available age classes) on the aggregated ages across all age sources by sex, the total mortality (Natural + Fishing mortality= Total mortality) is 0.046 for females and 0.035 for males, which may indicate the natural mortality could be lower than that estimated in the 2013 assessment, but within the range of values considered in other areas (Figure 43). This also indicates the possibility of estimating sex-specific natural mortality, as natural mortality may differ by sex. The two sex model allows for this type of model specification exploration. Further exploration was done by truncating the upper ages considered, with the assumption that the older ages may also not be sampled fully (i.e., dome-shaped selectivity). We considered both 100 (Figure 44) and 80 (Figure 45) as upper age cut-offs. The less older individuals included, the higher the estimate of total mortality, and thus a higher natural mortality. But we can see a general overestimate of how many older individuals are expected using these higher Z values, thus dome-shapeness does not seem to explain the sampling of these older individuals.

One challenge to estimating natural mortality within the model is the interaction of estimating dome-shaped selectivity with estimating natural mortality. If all fleets assume some level of dome-shaped selectivity, it is difficult to determine if the unseen larger, older individuals are due to natural death or fishing mortality. Typically, at least one major fleet needs to achieve full selectivity for

the larger, older individuals. The 2013 assessment suggested some dome-shaped selectivity in the two major fleets, thus any natural mortality estimates are evaluated depending on the forms of fleet selectivity.

In this assessment, we estimate female natural mortality using the Hamel and Cope (2022) prior, but fix male natural mortality at the value of 0.036, the median of the Hamel and Cope (2022) prior that corresponds to maximum age of 150 years. In runs with natural mortality estimated for both sexes, estimated values were substantially higher and did not align with observed maximum ages and available information on RE/BS life history.

2.3.2 Growth (Length-at-Age)

Age and length data are used to estimate important growth parameters. Figure 46 shows the available age and length data and externally estimated growth curves. Female and male sample sizes are very similar. The WCGBTS clearly and importantly samples the smallest, youngest individuals compared to the other two data sources. This allows for a better estimate of the age at size 0 (t_0) and growth coefficient (k). The female asymptotic size (L_∞) is estimated notably higher from the PacFIN data, though male estimates of Linf are similar across the data sets. The overall externally derived estimates of female and male RE/BS are

$$\text{Females } L_\infty = 59.03 \text{ cm}; \; k = 0.07; \; t_0 = \text{-}2.45$$

$$\text{Males } L_\infty = 56.69 \text{ cm}; \; k = 0.08; \; t_0 = \text{-}2.03$$

The coefficient of variation (CV) of length by age and sex are shown in Figure 47. This is a measure of the variation in length for a given age class. Sample sizes are highest from the youngest ages up to around 70 (females) to 80 (males) years. The smoothed line shows the average response, and indicates similar CVs values for females and males, with the highest at the youngest ages, but generally 0.1. The amount and range of age samples, along with repeated length samples within an age class, allows growth parameters (L_∞, k, t_0, and CVs at age) to be estimated in the model. Ages are conditioned on lengths in the model in order to estimate growth within the model. We also explore sensitivity in growth values by pre-specifying growth to different values.

We note that the growth values being estimated in our data are notably different than those used in Alaska. For instance, the growth parameters for the Bering Sea and Aluetian Islands stock is L_∞ = 51.43, k = 0.06 and t_0 = -3.30 and for the the Gulf of Alaska population (both sexes combined) L_∞ = 54.2 cm, k = 0.07, t_0= -1.5. These growth parameters shows a larger size and faster growth of the West Coast stock complex versus those in Alaska, though the West Coast stock complex is more similar to the GOA complex.

2.3.3 Ageing Bias and Precision

Estimating ages from ageing structures in long-lived, temperate fishes is challenging. Age estimates derived from these structures can be hard to reproduce within and between readers (i.e., imprecision), and may not contain the true age (i.e., bias). Stock assessment outputs can be affected by

bias and imprecision in ageing, thus it is important to quantify and integrate this source of variability when fitting age data in assessments. In Stock Synthesis, this is done by including ageing error matrices that include the mean age (row 1) and standard deviation in age (row 2). Ageing bias is implemented when the inputted mean age deviates from the expected middle age for any given age bin (e.g., 1.75 inputted versus 1.5 being the true age for the age 1 bin); ageing imprecision is given as the standard deviation for each age bin.

There are eight primary readers that provided the available ages, two of which often split the ageing duties. Figure 48 shows which reader assignments are given to each year of ages by data source. Reader 7 is the mix of two readers that shared reading duties within years.

Estimation of ageing error matrices used the approach of Punt et al. (2008). The original package was developed using AD Model Builder (nwfscAgeingError (Thorson et al. 2012)), and was later adapted to Template Model Builder framework (TMB).

The ageing error matrix offers a way to calculate both bias and imprecision in age reads. One of the readers (selected based on readers' experience in age determination of the species) is always considered unbiased, but may be imprecise. Bias relative to the primary reader is given for the second reader. There were three age readers that were assumed to be unbiased. In those cases, 12 model configurations based on different assumptions of imprecision (constant CV, curvilinear standard deviation, or curvilinear CV, along with an option to either share or independently estimate imprecision between readers) were considered. For the other four age readers that could be biased and/or imprecise, thirty-six total model configurations were explored that included the above imprecision models as well as an exploration of the functional form of bias (e.g., no bias, constant coefficient of variation, or non-linear bias) in the second reader.

Model selection criteria included AIC corrected for small sample size (AICc), which converges to AIC when sample sizes are large, and Bayesian Information Criterion (BIC). Both ADMB and TMB were run using an (ageing error shiny app). Model selection was then compared between ADMB and TMB, which did not always agree, so model selection criteria was added across the two modeling approaches to get an overall model selection criteria. Ageing error matrices were also inspected for behavior in the best supported models to make sure outrageously large precision or bias was not chosen (effectively rendering the ages worthless, which is not an assumption of the quality of the ages). Figure 49 and Figure 50 show the bias and imprecision assumptions applied for each ageing error (AE) matrix.

2.3.4 Length-Weight Relationship

Female and male length-weight relationships were determined using data from the PacFIN database, West Coast Groundfish Bottom Trawl Survey, and ASHOP samples. Samples size by sex were: female (N=13839), males (13625), and unknown sex (53). Each of the data sources estimated very similar length-weight relationships (Figure 51).

The resultant sex-specific length-weight relationships are given in Figure 52, with the following individual values:

- Females: $W = 0.00000878L^{3.15}$
- Males: $W = 0.000012L^{3.07}$

These values are very similar to the previous assessment that used a combine sex value of a=0.0000096 and b=3.12 (Figure 52).

2.3.5 Maturity

Maturity for the Rougheye/Blackspotted Rockfish complex was estimated using 473 maturity samples collected from 2015 to 2024 by ODFW and WDFW, as well as by the WCGBTS in California, Oregon, and Washington waters (pers. comm. M. Head, NWFSC). The samples included 194 samples genetically assigned as Rougheye Rockfish, 71 samples genetically assigned as Blackspotted Rockfish, and 208 samples with no genetic assignment. The maturity schedule was assumed to be length-based, as in the 2013 benchmark assessment. This assessment used the functional classification of maturity to describe the maturity schedule, which not only identifies the individuals that are physiologically capable of producing yolk (those that are biologically mature), but also accounts for the occurrence of abortive maturation and skipped spawning, so the functional maturity classification is a more accurate representation of the individuals that may actually spawn in a given year. This is a difference from the 2013 benchmark assessment, which did not explicitly estimate functional maturity, and instead assumed the biological classification of maturity.

Biological maturity and functional maturity observations were fitted in separate models. Biological maturity and functional maturity status observations (0 = immature and 1 = mature) were fitted in a logistic regression model (glm R function, family = binomial, link = "logit"). The estimated model parameters were used to calculate length at 50% maturity (L50; Table 17) and maturity ogives (Figure 53). The delta method was used to calculate 95% confidence intervals of L50 estimates. The estimated L50 (functional maturity; L50 fxn) was 46.53 cm and the estimated slope of the maturity oogive was 0.25. Sensitivities were run using the estimate of biological maturity and the maturity estimate used in the 2013 benchmark assessment. There was little evidence of skipped spawning, so we did not explore fitting the data with a spline model.

Because there are known life history differences between Rougheye Rockfish and Blackspotted Rockfish, maturity was also estimated for each species, using the samples that were genetically assigned to Rougheye Rockfish and Blackspotted Rockfish, respectively, using the same methods as above (Table 17 and Figure 54). Two sensitivities were run using the functional maturity L50 (and slope) estimated for 1) Rougheye Rockfish and 2) Blackspotted Rockfish (which mature at larger sizes on average than Rougheye Rockfish).

Age at 50% maturity was estimated using the same methods as for length at 50% maturity (Table 17 and Figure 55). The differences in age at 50% maturity between species were not trivial, ranging from 12 to almost 13.5 year in both biological and functional maturity estimates. Sensitivities were run using functional age at 50% maturity estimate for the species complex (n = 372) and for each species separately.

2.3.6 Fecundity

The 2013 U.S. West Coast stock assessment assumed that fecundity was proportional to weight. Dick et al. (2017) provided a study on rockfishes showing that rockfishes routinely have a non-proportional relationship of fecundity to weight, with larger individuals producing more eggs than expected only by weight. Neither Rougheye or Blackspotted rockfishes have a species- of subfamily-specific estimate for this relationship, so this stock assessment uses the unobserved Genus Sebastes values of a = 6.538e-06 and b = 4.043 using the $F = aL^b$ relationship. In order to adapt the a parameter for SS3, the equation (a*10^b)/1000000 was used to scale the a parameter to trillions of eggs. This results in a = 7.21847e-11.

2.3.7 Stock-Recruitment Function and Compensation

The Beverton-Holt stock recruit relationship is assumed, as it was in the 2013 assessment, to describe the relationship between spawning biomass and recruitment. The steepness parameter may be considered for estimation, but it is notoriously difficult to estimate in assessment models. The 2013 stock assessment used the previous rockfish steepness mean value of 0.77, but this has subsequently been updated to 0.72, to a value that represents a stock with somewhat lower recruitment compensation. Natural variation in recruitment (i.e., not deterministically taken from the stock-recruit curve) is apparent in the length and age data (as notable length or age classes growing/ageing over time), so deviations in recruitment are estimated.

2.3.8 Sex Ratio

No information on the sex ratio at birth was available so it was assumed to be 1:1.

2.4 Environmental and Ecosystem Data

This stock assessment does not explicitly incorporate trophic interactions, habitat factors or environmental factors into the assessment model. More predation, diet and habitat work, and mechanistic linkages to environmental conditions would be needed to incorporate these elements into the stock assessment and should remain a priority. McClure et al. (2023) report the climate vulnerability for several West Coast groundfishes, including RE/BS. RE/BS demonstrated both high biological sensitivity and high climate exposure risk, to give it an overall high vulnerability score to climate change. This result should also be considered with the fact that, like many rockfishes, periods of low productivity is not unusual to RE/BS and their extended longevity (though admittedly this seems shorter than previously believed and should be reconsidered) has historically allowed them to wait for advantageous productivity periods. Stressors such as habitat degradation and climate change could bring significant challenges to population sustainability. Regardless, no environmental or ecosystem data are directly incorporated into the stock assessment model.

3 Assessment Model

3.1 History of Modeling Approaches

Rougheye Rockfish (not including Blackspotted Rockfish) on the U.S. Pacific Coast was first evaluated in 2010 by Dick and MacCall (2010) using depletion-based stock reduction analysis (DB-SRA), as Category 3 stock. That model estimated the population had greater than a 50% probability of exceeding the estimated proxy overfishing level in 2010 if the harvest remained at the observed levels. DB-SRA estimated a proxy OFL for Rougheye Rockfish of 78.7 mt with a 95% confidence interval between 4.7-587 metric tons.

The first benchmark assessment forRE/BS was conducted in 2013 (Hicks et al. 2013). A 2013 benchmark stock assessment used Stock Synthesis (version 3.24O) integrated statistical catch-at-age model, which is different from the delay-difference model with an assumed stock status prior DB-SRA analysis used in 2010. The stock assessment has been used for management as a Category 2 stock assessment. The 2013 assessment used a substantially updated catch history, indices of abundance, and biological compositions (lengths and ages). The natural mortality value was also updated to be higher value than the one used in the DB-SRA model. The 2013 assessment also assumed logistic selectivity for all fleets and surveys, except for Triennial Shelf Survey, which was allowed to be dome-shaped. With higher natural mortality and asymptotic selectivity assumptions, the 2013 assessment estimated 2013 spawning biomass to be at 47% relative to unfished equilibrium spawning biomass, with a 95% confidence interval between 30.5% - 64.2%. The 2013 spawning biomass was estimated to be 2,552 metric tons, with a 95% confidence interval between 1,024 - 4,081 metric tons.

With this new benchmark assessment, we re-evaluate all the data sources available for RE/BS, analyze new and re-analyze previously used data with current statistical methods and best practices, and re-evaluate modelling assumptions. Detailed description of changes made since 2013 benchmark assessment is provided in Section 3.3.

3.2 Response to Most Recent STAR Panel Recommendations

There were several recommendations from the 2013 STAR panel, broken into two categories

3.2.1 General recommendations

1. *Investigate data-weighting options.* This has been an ongoing research topic in stock assessments over the last several decades (Francis 2011; Thorson et al. 2017; Punt 2017). In this assessment, we use Francis (2011) method, and explore other methods of data weighting within sensitivity analysis described in Section 3.9.1.
2. *A workshop for constructing abundance indices from survey GLMMs.* This is another topic that has developed greatly since this time (Thorson et al. 2015). Spatio-temporal models used in this assessment are described in Section 2.2.
3. *Continue collection of ages.* This had been done, and this assessment benefits from several more years of age data.

4. *Exploring historical catches.* This again has been an ongoing topic and addressed for many of our groundfishes. We use the latest estimates in this assessment.
5. *SSC guidance on decision tables.* Decision table discussion evolve after every stock assessment cycle, and we are using the latest approaches to decision tables in this assessment.
6. *Investigate fishery-independent slope surveys, such as submersibles.* These surveys are still not available for slope species.

3.2.2 Stock-specific recommendations

1. *Collecting additional age data.* This has been done and included in this stock assessment.
2. *Collecting genetic material to explore distinguishing Rougheye and Blackspotted Rockfishes.* This work has been done as was presented earlier in the document when discussing stock structure decisions.
3. *The cause of the re-occurring decrease in sizes around 40cm.* The data continue to exhibit a lack of 35-40cm fish in fleets that catch smaller fish (WCGBTS and Triennial Survey, and bottom trawl discard fleet), creating bimodal distributions of length data (Figure 75). We found that this pattern is not caused by the relative depth distribution of two stocks within the complex, with Rougheye Rockfish being shallower and Blackspotted Rockfish deeper. Figure 56 (pers. comm. P. Frey, NWFSC) shows the length distribution of Rougheye Rockfish and Blackspotted Rockfish identified to species using genetics, and the Rougheye Rockfish still shows a bimodal length distribution. Further analysis reveals that this bimodal length distribution is not limited to RE/BS, but is also evident in multiple other rockfish species. We continue to explore data to understand mechanisms behind this pattern, which are potentially related to accessibility of trawl gear to habitats specific to that size group. In this assessment we were able to fit the bimodal length distribution by allowing surveys' selectivity curves more flexibility, and not fixing it asymptotic as in the previous assessment.
4. *Additional maturity and fecundity studies.* While no fecundity studies are available, updated maturity is presented in Section 2.3.5.
5. *Age validation.* While no age validation study has been completed, the age readers are confident that annuli represent a year's worth of growth. Multiple ages are available and ageing error is characterized in this stock assessment.
6. *Understanding stock structure.* Discussed in the Section 1.1 of this document.
7. *Connectivity of stocks across the species ranges.* This is also discussed in the Section 1.1 of the document.

3.3 Model Changes from the Last Assessment and Bridging Analysis

The last full assessment of RE/BS was conducted in 2013. The 2013 assessment model was the starting point for this assessment. We included a number of improvements related to use of data, model structure and modeling techniques. Below, we describe the most important changes made since the last assessment:

- Upgraded the model to Stock Synthesis 3.30.22.2 version. This is standard practice to capitalize on newly developed features and corrections to older versions as well as improvements in computational efficiency. The list of changes made to Stock Synthesis since 2013 can be found in the model change log. No discernible differences were produce by this change. The status

(Figure 57) and scale (Figure 58) of both models are exactly the same, as are the estimates of within model uncertainty.
- Specified a two-sex model, instead of one-sex model, to allow sex-specific estimation of natural mortality and growth. No discernible differences were produce by this change either (Figure 40 and Figure 41).
- Included bottom trawl and non-trawl discards as separate fleets (see Section 3.4.3 for details), instead of treating them as part of the same fleets as landings. Results did not impact the model output (Figure 59 and Figure 60).
- Split mid-water trawl catches from bottom trawl landings and treat them as a separate fleet (see Section 3.4.3 for details), to account for gradually increasing contribution of mid-water trawl catches. Results did not impact the model output.
- Updated historical and current fishery removals, to include most up to date information. Since 2013 assessment, WDFW completed historical catch reconstruction of rockfish, and newly estimated landings represent improvement. For the period between 1987 and 1999, Oregon PacFIN landings were supplemented with the additional estimates of RE/BSlandings reported within unspecified rockfish market categories. Results did not impact the model output.
- Recalculated survey abundance indices using sdmTMB geostatistical model. Results did not impact the model output.
- Added more biological compositions, mainly in years since 2013, but also some historical ages. Adding more composition data resulted in sight increase in stock scale (Figure 61).
- Updated input sample sizes associated with fisheries and survey length composition data to using a function of number of trips and number of fish (rather than number of trips and number of hauls, as in previous assessment), to follow current best practices and ensure a consistent treatment of fishery and survey input data.
- Updated ageing error matrices.
- Updated weight-length, maturity and fecundity parameters, to include most up to date and improved information.
- Updated spawn-recruit parameters with Beverton-Holt steepness fixed at 0.72, and recruitment variability at 0.5 for consistency with the calculated recruitment variability in the model.
- Assumed natural mortality for males consistent with maximum ages of observed for RE/BS, while estimating female natural mortality using the Hamel and Cope (2022) prior. Previously, natural mortality for both sexes combined was estimated within the model, but estimated value was higher than expected for maximum ages observed for this stock. This change reduced the natural mortality values for both sexes, which resulted in decreased scale of the stock.
- Provided flexibility for the bottom trawl fleet and bottom trawl surveys to estimate dome-shaped selectivity (Figure 141 and Figure 142), previously assumed asymptotic. This change was prompted by the lack of fit to length compositions data. Also, the examination of mean fish lengths by fleet indicated that the bottom trawl fleet capture smaller fish than mid-water trawl and non-trawl gear. This change resulted in a substantial increase of stock scale, and is considered an improvement to the model structure. We also allowed estimated selectivity to vary with time in both the bottom trawl and non-trawl fleets, to account for management changes that can impact selectivity of these fleets.

Bridging analysis was conducted to illustrate the impacts of incremental changes. With the new

fecundity parameters, the 2025 model produces spawning output (in trillions of eggs) rather than spawning biomass (in mt as in 2013 model); so with different metrics, these outputs were no longer comparable between the two models. However, we ran the 2013 model with new fecundity parameters to allow for direct comparison of the results from the bridging runs. The bridging analysis, with the most influential steps done sequentially, is shown in Figure 61 and Figure 62.

This assessment (compared to 2013 assessment) estimates much higher stock scale, primarily, as discussed above, due to changes in treatment of selectivity parameters and relaxing asymptotic selectivity assumptions for the bottom trawl fleet and bottom trawl surveys. Changes in selectivity assumptions allow to substantially improve fits to length and age composition data in fisheries and surveys. The stock scale was also affected by the changes in treatment of natural mortality, bringing the scale down to a lower level compared to the previously used natural mortality assumption.

3.4 General Model Specifications

3.4.1 Modelling Platform

Stock Synthesis statistical catch-at-age modelling framework (Methot and Wetzel 2013), version 3.30.23.1, is used for this assessment. This framework allows the integration of a variety of data types and model specifications. The Stock Assessment Continuum tool (https://github.com/shcaba/SS-DL-tool) was also used to explore model efficiency, likelihood profiling, retrospective analyses, and plotting sensitivities. The companion R package r4ss (version 1.51.0) along with R version 4.4.3 were used to investigate and plot model fits.

3.4.2 Model Structure

This is a sex-specific model. The sex-ratio at birth is assumed to be 1:1. Females and males have separate growth curves (fully estimated within the model) and sex-specific weight-at-length parameters. The model assumes a constant natural mortality of 0.036 for males, while natural mortality for females is estimated based on Hamel and Cope (2022). The length frequency distributions are represented as thirty six 2-cm bins ranging between 10 and 80 cm. Population length bins are defined at a wider 2-cm scale, ranging between 4 and 84 cm. Age data is included as conditional age-at length compositions with bins ranging between 1 and 100 years (Table 18).

The modeling period begins in 1892, and the stock prior to that is assumed to be in an unfished equilibrium condition.

3.4.3 Fleet Definitions

The model is structured to track six fleets and include data from four surveys.

Defining fleets is largely based on differing fleet selectivity (i.e., how the fishery captures fish by length and/or age). In the stock assessment model, selectivity translates into how the removals are

taken via length and/or age out of the population. In this assessment, the following fleet structure is being used to model commercial fishery removals:

- Fleet 1: Commercial bottom trawl fishery.
- Fleet 2: Dead discard from bottom trawl fishery.
- Fleet 3: Commercial non-trawl (mainly the long-line) fishery.
- Fleet 4: Dead discard from non-trawl fishery.
- Fleet 5: Contemporary mid-water trawl fishery.
- Fleet 6: At-sea hake fishery bycatch.

In 2013 assessment (Hicks et al. 2013), fisheries removals were split among three fleets - trawl, hook-and-line and at-sea hake fishery bycatch. For the first two fleets (trawl and hook-and-line), removals were divided between landings and discards, with selectivity and retention curves estimated within the model.

In this assessment, we treat discards in trawl and non-trawl fisheries as separate fleets from landings fleets.

Treating discards as separates fleets from landings provides several advantages, including:

- With separate discard fleets, we can easily track relative amounts of landings and discards within a fishery (they are not being combined into the total catch).
- This approach provides more flexibility to explore different selectivity assumptions for both landed and discarded fish dome-shaped vs asymptotic, mirroring one to the other, etc.
- This approach allows to avoid hard to diagnose issues that come from estimating retention curves (especially with limited amount of data).
- The biological data for landings and discards are collected independently (port sampling vs on-board observers), and using different sampling approaches. Treating landings and discards as separate fleets in the model allows us to weight those data sources separately as well, to balance the representation of samples.

The drawback of treating discards as separate fleets is that it is harder to extrapolate outside the range of data, but given that historical discards are non existing for RE/BS (Section 2.1.2.1), that is not an issue for this stock. The change in treating discards as separate fleets does not impact model results (Figure 59 and Figure 60), regardless of the selectivity form being assumed for the discard fleets. Historically, no discarding was observed for RE/BS (Pikitch et al. 1988), see Section 2.1.2.1 for details. The 2013 assessment estimated zero historical discard for both trawl and fixed gear fleets, based on the available data. In this assessment, therefore, we assume no discard until early 2000, when the first RE/BS was observed after the introduction of trip limits for rockfish.

We also split trawl fishery data into bottom trawl and mid-water trawl fleets. Catch data indicates that contribution of mid-water trawl catches gradually grew over the past 20 years, and now they represent majority of the trawl removals (Figure 6). Length composition data also suggest that selectivity of mid-water trawl gear is likely different from that of bottom trawl, with mid-water trawl fleet selecting larger individuals. Historical information on mid-water catches of RE/BS comes from Pikitch et al. (1988), which has no records of RE/BS mid-water trawl catches, neither retained nor discarded. Also, Oregon historical catch reconstruction (Karnowski et al. 2014) has only one record of 0.0002 metric tons of RE/BS taken in 1985, even though the mid-water trawl

catches had their own market category in Oregon since the early-1980s (Karnowski et al. 2014), and multiple rockfish species are reported as caught by this gear. This information suggest that historically RE/BS mid-water catches were negligible.

As reported in Section 2.2, the following surveys are included in the model:

- Survey 1: West Coast Groundfish Bottom Trawl Survey (WCGBTS; 2003-2024).
- Survey 2: Triennial (every three years) Survey (1980-2004).
- Survey 3: Alaska Fisheries Science Center (AFSC) Slope Survey (1997, 1999-2001).
- Survey 4: Northwest Fisheries Science Center (NWFSC) Slope Survey (1999-2002).

We use length-based selectivity curves for all fleets for this stock assessment model (as was done in the 2013 assessment), as there is no evidence that significant age-based selectivity is occurring. We considered logistic and dome-shaped selectivity options for various combinations of fleets and time periods during model development.

3.4.4 Model Likelihood Components

There are five primary likelihood components for each assessment model:

1. Fit to length composition samples.
2. Fit to age composition samples (all fit as conditional age-at-length).
3. Fit to survey indices of abundance.
4. Penalties on recruitment deviations (specified differently for each model).
5. Prior distribution penalties

In addition, there is a catch component to the likelihood, but catches are essentially fit without error. Additionally, there is a crash penalty that is invoked if true catches would cause the stock to go extinct. The penalty would alter catches to avoid extinction, but any presence of a crash penalty is used as in indication that the model has been mispecified, so this likelihood contribution should always be 0 (Table 21).

3.5 Model Parameters

3.5.1 Estimated and Fixed Parameters

The full list of estimated and fixed parameters is provided in Table 20.

All growth parameters are estimated in the model. The estimated values of growth parameters did not change across the vast majority of explored model scenarios.

Natural mortality (M) is estimated for females and fixed for males. If estimated for both females and males, M for both sexes is estimated higher than expected for ages observed for RE/BS, causing the scale of the population approach the higher end of reasonable values, and thus not a risk-neutral option. In order to balance model fit and reality, a likelihood profile was conducted on natural mortality for males (females M being estimated) in order to find the lowest supported (i.e., within

2 negative log likelihood units) by the data male M value. The profile shows conflicting information in the data, where lengths support higher natural mortality values and ages support lower natural mortality (Figure 65). It is expected that ages would be more informative to natural mortality, which encourages considering just the age component likelihood. Most of the age components are not well informed for natural mortality, though the at-sea hake fishery sampled age data does seem to be informative. This fishery has a logisitic selectivity, thus obtaining large and old individuals. Using this component likelihood, the value of 0.036 for male M is the lowest value supported. The model thus fixes male M to this value and estimates female M.

Length-at-maturity, fecundity-weight, and length-weight relationship were all fixed, as is common practice in Stock Synthesis.

For spawner-recruit curve, steepness (h) is fixed to the rockfish prior of 0.72. Recruitment variability is set at 0.5 and checked for consistency with the calculated recruitment variability in the model. Recruitment deviations were estimated (not constrained to sum to 0) for the full time series. Given the longevity of these species, information on recruitment going deeper into the time series is considered reasonable, even if the actual years or periods of strong versus weak recruitment are not well resolved. We explored numerous model configurations with shorter time series of estimated recruitment deviations prior and during the Stock Assessment Review (STAR) Panel meeting.

3.5.2 Selectivity Assumptions

The selectivity of all fisheries and surveys were estimated using either a logistic or dome-shaped function. Blocks were also added to selectivity curves for the bottom trawl, bottom trawl discard and non-trawl fleets (Figure 141), as well as the Triennial Survey (Figure 142).

Bottom trawl fleet selectivity was allowed to change in 2002, when discard of RE/BS first started, with the introduction of trip limits for rockfish. Selectivity was also allowed to change in 2011 with the start of the IFQ fishery, when bottom trawl discard dropped to minimal level and was comprised of much smaller fish. The bottom trawl discard fleet was also allowed to change in 2011, to reflect a change in size composition of discarded fish with the start of the IFQ program (Section 2.1.2.2).

The non-trawl fleet selectivity was allowed to change in 2011 (also to account for a change associated with the start of the IFQ fishery, in which there is some non-trawl catch), and also in 2020, since the mean length of captured fish exhibited a noticeable increase from 2020 forward (Figure 91). We also explored adding a block to non-trawl selectivity in 2002 (similar to bottom trawl fleet), although this change was ultimately not made for the reference model, since selectivity curves were estimated the same for pre-2002 and post-2002 periods. It should be noted that although we have limited pre-2002 length data for the non-trawl fleet, and mean fish size shows larger uncertainty for that period, the data do not exhibit a clear change mean fish size in 2002 (Figure 91). Also, comparison of length composition data between non-trawl and non-trawl discard fleets indicate that retained and discarded portion of the catch have similar length distributions, which implies that discarding in non-trawl catches that occurred since 2002 were not size-based (Figure 63). For comparison, we do see difference in lengths compositions of retained and discarded fish in bottom trawl catches (Figure 64).

No blocks were added to the non-trawl discard fleet. A large portion of non-trawl catches of RE/BS comes from non-IFQ program catches, and the available length composition data for the non-trawl discard fleet does not show a change associated with the start of the IFQ fishery in 2011 (Figure 92). Adding a block on non-trawl discard selectivity in 2011 resulted in virtually identical selectivity curves being estimated for both periods, and no block assumption for the non-trawl discard fleet was retained for the reference model (Figure 141).

Finally, a block was added to selectivity of the Triennial Survey, to account for change in survey depth coverage in 1995, when the survey extended from 360 meters to 500 meters (Table 14). RE/BS exhibit ontogenetic movements to deeper waters as they age and mature. Therefore, the Triennial Survey is expected to have different selectivity curves between early (pre-1995) and late periods (Figure 142). Separate catchability parameters were estimated for pre-1995 period and from 1995 forward as well.

In an attempt to fit the biological data for RE/BS, we found that the model fits the data from bottom trawl fisheries as well as from bottom trawl surveys substantially better if the selectivity curve was dome-shaped. All fisheries that had final dome-shaped selectivity were given the flexibility to be logistic if it produced a better fit. The mid-water, at-sea hake and the final block of the non-trawl fisheries all required logistic selectivity curve to fit the data. The use of dome-shaped selectivity for the bottom trawl was a major difference from the previous stock assessment. The choice of selectivity for the bottom trawl survey changed the scale and status of the stock and therefore was a major source of uncertainty.

3.5.3 Data Weighting

The method of Francis (2011) was used to re-weight the length and conditional age-at-length composition data against other inputs and likelihood components. The Francis method treats mean length and age as indices, with adjusted input sample size defining the variance around the mean. If the variability around the mean does not encompass model predictions, the data should be down-weighted until predictions fit within the intervals. This method accounts for correlation in the data (i.e., the multinomial distribution), but can be sensitive to years that are outliers, as the amount of down-weighting is applied to all years within a data source, and are not year-specific. Sensitivity runs were conducted to examine different data-weighting treatments: 1) the Dirichlet-Multinomial approach (Thorson et al. 2017), 2) the McAllister-Ianelli Harmonic Mean approach (McAllister and Ianelli 1997), or 3) no additional data-weighting.

The ability to estimate additional variance for indices was allowed to the model to balance fit to indices while acknowledging that variances may be underestimated in the index standardization. Given the large inputted variances and the limited contrast in the index trends, the model did not require further variance estimation. Removal of the index data was explored within sensitivity analysis to demonstrate the limited influence of this data in the model.

3.6 Model Selection and Key Assumptions

The reference model for RE/BS is developed to balance parsimony and realism, and the goal is to estimate a risk-neutral spawning output trajectory and relative stock status for the stocks of RE/BS in state and federal waters off the U.S. West Coast. To achieve the above goals, the model uses different data types and sources to estimate reality, but relies on simplifying assumptions when the data are not informative to parameters. A series of investigative model runs were done to achieve the reference model. Constructing integrated models (i.e., those fitting many data types) takes considerable model exploration using different configurations of the following treatments:

- Data types and weighting;
- Parameter treatments: which parameter can, cannot and do not need to be estimated;
- Phasing of parameter estimation;
- Exploration of local minima vs global minimum (see Section 3.7.1).

Regarding data types, different biological data (i.e., length and/or age composition) without the catch time series (and no additional data weighting) were first included to obtain an understanding of the signal of stock status coming from the data. The length and age only models assume fixed life history values (growth fixed to external estimates, natural mortality assume the reference model values) and constant catch over the entire time series, while estimating the selectivity (either constant or time-varying) of each fleet. Under this constraint, the lengths generally suggest a stock status lower than the reference model, while the ages consider the stock is less depleted than the lengths, and thus more similar to the reference model (Figure 66). Adding selectivity blocks raised the stock status when only lengths were considered, but had little effect once ages were introduced.

Multiple models with alternative periods for estimating recruitment deviations were explored before and during Stock Assessment Review (STAR) Panel. The sensitivity ran presented here is for the model with recruitment deviations estimated only in the recent period (1995 forward). Compared to the base model, this sensitivity ran produced a lower stock status, though it is a much truncated recruitment time series (starting in 1995) compared to the reference model (with recruitment devations estimated thought the start of the modeling period in 1892).

All models are within the uncertainty of the reference model (described in detail below), except the length only model with no selectivity blocks.

Numerous exploratory models that included all data types and a variety of model specifications were subsequently explored and too numerous to fully report. In summary, the estimation of which life history parameters to estimate and fix was liberally explored.

A list of configurations explored, typically in combination with one another, is provided below:

- Estimate or fix M
- Estimate or fix any of the three growth parameters for each sex
- Estimate or fix the stock-recruit relationship
- Estimate or assume constant recruitment. If estimating recruitment, for what years?
- Estimate additional survey variance, and for which survey?
- Logistic or dome-shaped selectivity?
- Estimate or fix selectivity parameters

The biggest uncertainty was in the treatment of sex-specific M and the selectivity of the bottom trawl fishery. The combination of these two sources covered the extent of all other sources of uncertainty observed and presented in Section 3.9.1. The parameters uncertainty is different than the uncertainty derived from data treatment, such as ageing error and data-weighting. While these issues cause large uncertainty in stock scale and status estimates, the choice of treatments are based on the common challenge of balancing information content (i.e., what should the data be informing in the stock assessment) in the data within an integrated statistical frameworks. Those explorations are also provided in Section 3.9.1.

General attributes of the reference model are that indices of abundance are assumed to have log-normal measurement errors. Length compositions and conditional age at length samples are all assumed to follow a multinomial sampling distribution, where the sample size is fixed at the input sample size calculated during compositional example, and where this input sample size is subsequently reweighted to account for additional sources of overdispersion (see below). Recruitment deviations were also estimated are assumed to follow a lognormal distribution, where the standard deviation of this distribution is tuned as noted above.

Sensitivity scenarios and likelihood profiles (on lnR_0, steepness, and natural mortality) were used to explore uncertainty in the above model specifications and are reported in Section 3.9.1 and Section 3.9.2.

3.7 Model Diagnostics

3.7.1 Model Convergence and Acceptability

While there is no definitive measure of model convergence, several measures are routinely applied. These criteria include a low maximum gradient (9.54775×10^{-4}), inversion of the Hessian (passed), acceptable fits to data (passed), and reasonable parameter values (passed).

Model efficiency was explored by doing a short run Bayesian analysis using the Random Walk Metropolis with 2,000 draws, keeping all the draws and examining the fast mixing parameters. Those estimated parameters that do not move much from the initial values slow the model down and are recommended to be fixed at the starting value (Monnahan et al. 2019). No additional parameters were fixed based on this analysis (Figure 67).

An extra effort was given to ensure the model did not rest on a local likelihood minimum. This was done by starting the minimization process from dispersed parameter values away from the maximum likelihood estimates to determine if the approach found a better model fit (i.e., minimum negative log-likelihood value). Starting parameters used a jitter shift value of 0.01 and 0.05. Both jitter scenarios were repeated 100 times with 78 out of 100 (jitter 0.01) and 49 out of 100 (jitter 0.05) runs returned to the reference model likelihood (Figure 68 and Figure 69). Out of the combined 200 jitter runs, a better fit, lower negative log-likelihood model was not found in any of the remaining runs. The reference model did not experience convergence issues when provided reasonable starting values. Through the jittering and likelihood profiles, the present reference model represents the best fit to the data given the assumptions.

3.7.2 Retrospective Analysis

A five-year retrospective analysis was conducted by running the model and sequentially removing one year of data up through minus 5 years(i.e., "Data -1 Years" corresponds to data through 2023 instead of 2024). Retrospective spawning output (Figure 70) and relatives stock status (Figure 71) show a distinct sensitivity to the removal of the recent data. Both the scale and status drop when data from most recent year is removed. Once two years are removed, the model returns to something more similar to the reference model. The large increase in scale is observed when 3 to 5 years of recent data is removed. This general retrospective pattern is conserved across parameter scenarios and data treatments, so it is not only a feature of this particular base model specification. The retrospective patterns do correspond to pattern observed in the fisheries mean age data time series (Figure 108 through Figure 111), where all sources of age data from different fleets show the consistent pattern of decreasing mean age from 2022 to 2023, and an increase in 2024.

These changes in scale and stock status, except for the large increase in scale for the scenarios with 3 to 5 years removed, are within the uncertainty of the reference model (Figure 72). For those peels producing extreme estimates of lnR_0, there is no statistical difference in values of lnR_0 from the base model to the high values (Figure 73). Given low information content on lnR_0 as it gets larger, there is actually no retrospective pattern in scale. The Mohn's rho evaluation of the degree of retrospective pattern show the data peels are below significant levels for stock status. Given the

lack of information on stock status, Mohn's rho is not a useful measure of the retrospective pattern for scale.

The large change in scale in runs when 3 to 5 years of data removed is affected by the presence of the recent block on non-trawl fleet selectivity that spans from 2020 forward and assumes a logistic form, as opposed to the dome-shaped selectivity that precedes it. As the retrospective peel removes data, this can complicate the interpretation of blocks that span the time series of the retrospective analysis. An additional retrospective run was conducted that extended that recent block in time, so it would start the logistic selectivity in 2011 instead of 2020. The model run with the recent block extended showed substantially degrading fits to composition data, but also did not have vast increase in scale in its retrospective runs when 3 to 5 years were removed (Figure 74).

Overall, the retrospective analysis highlighted the importance of the recent data for the assessment as well as poorly informed higher estimates of scale when the population is at or above unfished levels, and the common sensitivity of retrospective analyses when newer blocks span the peels of the retrospective analysis.

3.7.3 Fits to the Data

3.7.3.1 Indices of Abundance

The fits to the 4 available indices of abundance demonstrate little information content in the survey indices (Figure 135 to Figure 138). The are all mostly flat with large uncertainty. Such lack of contrast and high uncertainty in the abundance measure indicate the indices contribute little influence to the model (see data sensitivities section below for more details).

3.7.3.2 Lengths

Fits to the length data are examined based on the Pearson residuals-at-length, the annual mean lengths, and aggregated length composition data for the commercial and recreational fleets. The aggregate fit to each length composition demonstrates acceptable fits to each fleet and survey source (Figure 75). One noticeable behavior is the trade-off in fit between the fit in the bottom trawl fishery versus the fit in the at-sea hake fishery. This current model specification was the best trade off of fits between the two.

Fits to the annual length composition are provided for the following fisheries and surveys:

Fishery
- Bottom trawl (Figure 76 and Figure 77)
- Bottom trawl discard (Figure 78)
- Non-trawl (Figure 79 and Figure 80)
- Non-trawl discard (Figure 81)
- Midwater trawl (Figure 82)

- At-sea hake (Figure 83)

Surveys
- Triennial (Figure 84)
- Alaska slope (Figure 85)
- West Coast Groundfish Bottom Trawl (Figure 86)

Pearson residuals of fits to the fishery (Figure 87) and survey (Figure 88) length data are reasonably small with no distinct patterns.

Model fits to the mean lengths, assuming Francis data-weighting of 1 and blocking patterns, demonstrate fits within the error bars of most years and no strong residual patterns (Figure 89 to Figure 97). A notable observation in the means lengths within blocks generally show a lack of trend, not surprising given how many years an individual may be at its maximum size. This is in contrast with the age data that do show more nuances in age structure trend (see next section on age fits for more detail). This demonstrates the general lack of contrast in the length data.

3.7.3.3 Ages

3.7.3.3.1 Conditional Age at Length

Fits to the sex-specific conditional age at length data are examined based on the age-at-length Pearson residuals, the annual mean ages, and mean age at length by year for the four fishery and one survey source. Pearson residuals were of reasonable size with no distinct patterns (Figure 98 to Figure 107), as most of the residuals were small and not noteworthy and demonstrate the expected shape of the growth curve. There is more contrast in the age data compared to the length data (Figure 108 to Figure 112). While the mean age for fisheries varied by gear selectivity (25-35 years for bottom trawl; 30-40 years for non-trawl; ~40 for midwater trawl; 40-50 years for the at-sea hake fishery), one commonality was the increase in mean age in the last year of the model. This consistent increase in mean age across fisheries with different selectivities is important to remember when interpreting the retrospective pattern of the model. Mean age for the West Coast Groundfish Bottom Trawl survey, which catch much smaller and less larger individuals, fluctuated around 20 and did not show an mean age increase in the final year. Fits to the mean ages by length bins show acceptable fits consistent with model expectations (Figure 113 to Figure 129).

3.7.3.3.2 Marginal Age

Marginal age compositions are not fit in the model, but they are included in order to see how well they fit the reference model without influencing the likelihood (Figure 130 to Figure 134). Marginal length and age composition cannot be used in the same model because of the overlap of fish in both samples. This is why ages conditioned on lengths are often used with the length compositions. But it still stands that age compositions, instead of lengths, could be used. So adding the marginal

age compositions passively (i.e., not contributing to the overall likelihood of the model) can offer insight into how consistent they are with the current model fit. Overall the realized fits are good.

3.8 Model Results

As a supplement to the model results figures included in this report and described below, a full set of diagnostic plots created by the {r4ss} package is available at https://github.com/shcaba/REBS-2025/tree/main/Document/report/ref_model along with the Stock Synthesis input files.

3.8.1 Parameter Estimates

Estimated parameters by category are given in Table 19. The reference model parameter estimates along with asymptotic standard errors are shown in Table 20 and the likelihood components are shown in Table 21. Estimates of derived outputs and reference points and approximate 95 percent asymptotic confidence intervals are provided in Table 22.

The estimate of female natural mortality is higher than the assumed value for males, which fits the expectation given the oldest individuals in the population are all males, and within reason (0.039) given the oldest individual aged female sampled.

Estimated growth curves in this assessment is similar to the growth curve estimated in 2013 assessment (Figure 139), though with some important difference. The estimated L_∞ and k for both sexes were slightly greater and lower than the values estimated externally, respectively. This is not surprising, given external fits assume all variability is in the length at age, while the model incorporates ageing error and selectivity effects. Both females and males reach their maximum size at relatively young ages (< half their presumed longevity), thus possibly limiting the information content of lengths on the underlying age structure.

Estimated ending selectivity curves for each fleet and survey (Figure 140) are a mix of dome-shaped (for bottom trawl gears) and logistic (for mid-water gears) and look plausible given the biology (i.e., as a model convergence check for realism, the selectivity curves must look plausible). The surveys show the greatest degree of dome-shapeness, while the fisheries selectivities included sampling of at least some of the larger individuals. Time-varying selectivity showed mostly the same functional form for each fleet, despite changes in the selectivity, except for the non-trawl fishery, which changed from dome-shaped in the earlier blocks to logistic in the most recent time period (Figure 141 and Figure 142). The realized age selectivity based on the length-based selectivity show even more truncated sampling of older individuals in some of the dome-shaped fleets (Figure 143). Values for the estimated selectivity parameters are in Table 20.

The estimate of initial recruitment (lnR_0) is much higher than the previous assessment (6.98 vs. 6.20). While this is a large increase in the scale of the stock, a value of 6.98 is not unusual for shelf and/or slope rockfish species. The estimate of (lnR_0) for RE/BS is well within the range of other groundfishes in similar habitat (Figure 144). And given this assessment is for two species, the estimate for (lnR_0) is reasonable. There is also a very large variability estimated for this parameter (coefficient of variation = 0.61), thus scale is generally very poorly informed in this model.

3.8.2 Population Trajectory

The predicted spawning output (in trillions of eggs) is provided in Table 23 and plotted in Figure 145. Estimated spawning output shows a decline in the early part of the time series due to poor recruitment, but rise before 1980 from offsetting recruitments (all not well informed), followed by a slight decline during the heaviest period of fishing, though moderated by recruitments in several years over the past 4 decades. The uncertainty around the estimate of spawning output is enormous, highlighting a major feature of the model output.

Relative spawning output never declined below the management target ($SO_{40\%}$) and currently is estimated well above the target (Figure 146; 0.87 in 2025). The uncertainty in stock status also does not support the stock being below the management target of $SO_{40\%}$. This uncertainty is based only on the asymptotic estimation of variance from the base model. Further uncertainty exploration is needed to capture a fuller range of uncertainty (see Sensitivity section).

The time series of estimated annual recruitment deviations are shown in Figure 147. The bias adjustment plot (Figure 148) indicates that the most informed recruitment deviations occur after 1980. While post-1980 is the most informed, the recruitment deviations before that time period, while less assure, are important for the model to prepare the population structure for the upcoming increase in fishing while reconciling weak, but still present, signals in recruitment from the biological compositions that can contain information on recruitment for decades given the long-liveness of these species. Sensitivities to when recruitment estimation begins in the model is shown in the Sensitivity section. Numbers of age-0 individuals indicate those years of particularly strong recruitment (Figure 149). Noticeable recruitment years are seen in 1988, 1993, 1999, 2008, 2010, 2012, and 2017 (Figure 150). This amounts to roughly two notable recruitments per decade. Given this assessment is tracking two species, it is hard to tell whether the species are synchronized or showing their own recruitment pulse in this signal.

3.9 Characterizing uncertainty

3.9.1 Sensitivity Analyses

Sensitivity analyses were conducted to evaluate model sensitivity to alternative data treatment and model specifications.

3.9.1.1 Data treatment sensitivities

Data treatments explored the removal of data types (indices and biological compositions), data weighting options and ageing error treatment.

3.9.1.1.1 Removal of data sources

The following data source sensitivities were explored:

- Remove a single index of abundance (Triennial, Alaska slope, NW slope, WCGBTS, all indices)
- For each fleet and index, including discard fleets, removal of length composition data
- For each fleet and the WCGBTS, removal of age composition data

Likelihood values and estimates of key parameters and derived quantities from each data source removal sensitivity are available in Table 24 to Table 27. Additionally, time series of spawning output and relative spawning output are shown in Figure 151 to Figure 158. Derived quantities relative of all data removal sensitivities to the reference model are summarized in Figure 159. Generally, the removal of indices of abundance decreased both the spawning output and the relative spawning output as compared to the base model (Figure 151 and Figure 152). Of these, the WCGBTS appears to have the most significant impact. Removal of the bottom trawl (bottom trawl + discards) and non-trawl (non-trawl + discards) fishery length compositions decreased the spawning output and the relative spawning output, whereas removal of the mid-water trawl and the at-sea hake length compositions increased the spawning output and relative spawning output (Figure 153 and Figure 154). Of the length composition removals, the most influential data sources appear to be the fishery fleets and removal of the survey length compositions had a limited impact on both spawning output and relative spawning output compared to the base model (Figure 155 and Figure 156). Finally, the removal of any age composition data source decreased the spawning output, with the exception of the mid-water trawl ages, and decreased the relative spawning output (Figure 157 and Figure 158). Again, the WCGBTS appears to be the most influential of the data sources with age composition information.

3.9.1.1.2 Data weighting

The following data weighting sensitivities were explored:

- No data-weighting
- Dirichlet data-weighting

- McAllister-Ianelli data weighting

Likelihood values and estimates of key parameters and derived quantities from each data weighting sensitivity are available in Table 28. Comparison plots for the results relative to the reference model are in Figure 160 and Figure 161. Each data weighting scenario up-weighted the influence of the length data relative to the age data. This resulted in a large drop in the stock scale, but little change in the high stock status. These changes were within the uncertainty of the base model, though at the low end for the stock scale.

3.9.1.1.3 Ageing error

The following ageing error sensitivities were explored:
- No Ageing error for all sources (unbiased and precise ages)
- No ageing error for each source at a time

Likelihood values and estimates of key parameters and derived quantities from each ageing error sensitivity are available in Table 29. Comparison plots for the results relative to the reference model are in Figure 162 and Figure 163. A drop in both stock scale and stock status is generally observed when the ageing error is removed. One notable observation is that the recruitment events become less resolved and variance increases in lengths at age when ages are assumed biased and precise. When the ages are taken as true, all variation between lengths and ages are interpreted in the lengths, while the recruitment must interpret the age composition precisely, thus assigning positive recruitment deviations to years adjacent to strong recruitment years seen in the reference model. Having more positive recruitment can compensate for a lower initial stock size, causing the initial stock size to decrease. All stock scale and status changes were within the uncertainty of the base model.

3.9.1.2 Sensitivities to Model Specification

Model specifications looked at the treatment of life history parameters selectivity and the estimation of recruitment. All scenarios match the reference model specifications in all other aspects unless otherwise stated.

- Life history parameters
  - Natural mortality (M)
    1. Estimate male M
    2. Fix M to 2013 value
    3. Lorenzen age varying M
  - Growth parameters
    4. Fix all growth parameters to external values

  - Reproductive Biology
    5. Proportional fecundity to weight
    6. Functional maturity at age
    7. Functional maturity at length for Blackspotted Rockfish
    8. Functional maturity at length for Rougheye Rockfish
    9. Biological maturity at length

Summaries of the model results for these sensitivities are presented in Table 30 and Table 31, Figure 164 and Figure 165. Additionally, the scale comparisons minus the estimation of male M scenario is provided in Figure 166 as that model scenario showed such higher estimates of scale to obscure all other models. Note also that the proportional fecundity scale measure is in metric tons, not trillions of eggs, and thus are not comparable in scale to the other models.

None of the sensitivities were found to be outside of the reference model uncertainty for scale or stock status (Figure 165). In particular, the stock status was highly conserved over these sensitivities, while both the initial and final stock scales were more sensitive (but still within the uncertainty of the reference model). In general, higher natural mortality assumptions reduced the stock scale when the bottom trawl and non-trawl fisheries were dome-shaped, as did the fixing of growth to the external model estimates. For reproductive biology, scale decreased if either age at maturity of functional length at maturity for Blackspotted Rockfish only was used. But scale increased if either functional maturity for Rougheye Rockfish only or biological maturity was used. The reference model, a mix of both species maturity at length, settled the scale in between each individual species-specific functional maturity model. For this long-lived species and future consideration, age may be a more precise determination of maturity (because there is a wide range of lengths per age) than length; however, age data is more limited and further information is encouraged to build this relationship.

- Recruitment estimation
    13. No recruitment estimation
    14. Estimate from 1940 onward
    15. Estimate from 1980 onward

Likelihood values and estimates of key parameters and derived quantities from each sensitivity are available in Table 32 and Table 33. Comparison plots for the results relative to the reference model are in Figure 167 and Figure 168. Few (starting in 1980) or no recruitment deviation estimation leads to larger stock scale required to make up for the catch history and lack of recruitment compensation. There is a drop in stocks status when starting recruitment deviations in 1940, but more similar to the reference model. Stock status is steady in these scenarios and all uncertainty is included in the reference model uncertainty (Figure 168).

- Selectivity
    16. Logistic selectivity for all fisheries and time blocks
    17. Logistic selectivity for bottom trawl fishery
    18. Logistic selectivity for non-trawl fishery

The model is much more sensitive to the assumption that fishery selectivity for the bottom trawl and/or non-trawl are logistic. These produce the most sensitive of all the explored alternative models scenarios in both scale (lower) and stock status. In all of these instances, the uncertainty is outside that of the reference model Figure 168. The reason these are less likely scenarios can be seen in the notably degraded fits to the bottom trawl and/or non-trawl length compositions (Figure 169). This supports the choice for the change in the reference model from the previous stock assessment to consider dome-shaped selectivity for those two fisheries. Given the only scenarios to fall below the low uncertainty treat the bottom trawl as logistic selectivity, it is a good candidate for a lower state of nature (and not a risk neutral model).

3.9.2 Likelihood profiles

Likelihood profiles were conducted for the the log of initial recruitment ($\ln(R_0)$), steepness (h), and female male natural mortality (M) with female natural mortality estimated. Likelihood profiles were conducted by fixing the featured parameter(s) at specific values across a range of values and estimating all remaining parameters. A likelihood profile offers insight into model sensitivity to changing model parameter values, while providing an additional way to describe uncertainty in the parameter by identifying the range of parameters within 1.96 likelihood units of the reference model.

3.9.2.1 Initial unfished recruitment (lnR_0)

The profile on the assumption of lnR_0 (that sets the initial scale of the population) demonstrates the data and current model specification support value of lnR_0 greater than 6.25, with a steep increase in likelihood difference as lnR_0 goes lower (Figure 170). The is the expectant increase in scale across increasing lnR_0 values for both initial and ending spawning output. The final spawning output goes down quicker than the initial spawning output, leading to a lower stock status. Even at very low lnR_0 values, the stock does not drop below the target reference stock status.

The component likelihoods show a clear conflict in the length and age data, with lengths pulling for lower lnR_0 values and ages for higher lnR_0 values (Figure 171). While this is a consistent signal in the ages, the individual length sources also show conflict, with the bottom trawl length data pulling for higher lnR_0 values.

3.9.2.2 Steepness (h)

The profile on the assumption of h (defining productivity of the stock) demonstrates the data and current model specification do not demonstrate support for a particular steepness value (Figure 172). The change in scale and stock status is small and mostly flat through a large range of h values. The lack of information on h is seen across the data likelihood components (Figure 173). Given the strong signal of a health stock with little contrast in historical population trajectory, these are expected results. This strongly supports the pre-specifying of this value, but also demonstrates the low sensitivity to pre-specifying this value.

3.9.2.3 Male Natural Mortality (M)

The profile on the assumption of male M (while still estimating female M) demonstrates the data and current model specification support a higher value of male M than what is being used in the reference model (Figure 174). This uncertainty has a much larger expression in the scale than in the stock status, and one major reason the model estimated uncertainty in scale is so large. It is also a reason why only female M was estimated. Comparing the sex-specific values of M, females are always higher than males (Figure 175). Regarding stock status, there were no explored M values that caused the stock to go below the target reference point.

The component likelihoods show a some conflict in the length and age data, with lengths (mostly the non-trawl lengths; most of the other length contain no information) pulling for higher M values and ages for lower M values (Figure 176). As noted when building the reference model, ages are believed to contain more information on natural mortality than lengths. Consider that component likelihood profile, the reference model value for male M is the lowest support by the age data, and was chosen to avoid the fast increasing scale estimates. The integrated assessment approach does not allow for ages only to define the estimation of M, and thus the choice to pre-specify one M value and estimate the other in order to anchor to compensate for the incursion of the length data signal in the estimation of M.

3.9.3 Summary of Sources of Uncertainty and States of Nature

Over the many different sources of potential uncertainty, patterns in how these sources affect scale and status emerge (Table 34). These sources highlight conflicts in data and selectivity assumptions, while also emphasizing key uncertainty in natural mortality. Specifically, there are many ways to make the reference model at a higher or lower scale and/or stock status (Table 34). In building states of nature and around this risk neutral reference model, two key axes of uncertainty are based around the treatment of natural mortality and selectivity. Additionally, one could control states of nature via the lnR_0 parameter, as it is a direct measure of scale, which is highly uncertain. When choosing among these option, modifying selectivities ultimately compromised fits to the data. By changing the lnR_0, the model starts at a different stock scale, but uses the same productivity assumptions. When using different pre-specified male M values (while continuing to estimate female M), it changes both the scale, the stable age structure, and the productivity of the stock into the future. Given the multidimensional influence on the population by M, we use the following male M values to define high and low states of nature. The high state uses 0.039 as the male M value (supported by the M profile) which provided a reasonable coverage of the high scale and stock status. For the low state of nature, the male M associated with the oldest aged (169) sampled male was used ($M = 0.032$). These produce a very wide set of uncertainties around both scale and stock status (Figure 177). If these are treated as an ensemble, with high and low states of nature assuming a weight of 12.5% and the reference model the remaining 75%, the uncertainty range can be expressed as one model output (Figure 178 and Figure 179).

3.9.4 Unresolved Problems and Major Uncertainties

The absolute size of RE/BS populations are highly uncertain. RE/BS is relatively lightly exploited stock, most likely because RE/BS is associated with steep slopes and boulder habitats, difficult to access with bottom trawl gears. Plus, it occurs in the northern part of the assessed area (off Oregon and Washington), and is only rarely taken by fisheries in California. Given this relatively light exploitation, we did not observe large contrasts in the stock dynamics. Such contrast created by periods of notable depletion (i.e., "one-way trip"), followed by recovery (i.e., "two-way trip") provide more information about population productivity and scale. The more the uncertainty in the current stock status includes the probability of being at or above unfished levels, the uncertainty in the scale greatly increases. This is illustrated by reducing the male M value down to 0.033 from 0.036, a change that reduces how much probability is at or above unfished conditions in the current year (Figure 180). This change also reduces the uncertainty (i.e., "sigma") in the OFL from 0.66 in the reference model to 0.45 in the model assuming 0.033 for male M. This tendency to have high uncertainty in scale is a common feature of models with such high stock status estimates (Thorson and Cope 2017).

This assessment increased the number of available ages greatly, but given the deep age structure still existing in the population, the number of age samples needed to reduce uncertainty in estimated stock scale and status in much higher than most other groundfishes. Many more ages are needed in the currently examined years, as well as additional years, to reduce the inherent uncertainty in the stock assessment. Additionally, the simple fact that the current within model uncertainty includes population stocks status that may be at or exceed unfished levels greatly inflates the uncertainty in the estimate of stock scale. More ages may refine the estimate of stock scale, decreasing the chance of including an unfished stock within uncertainty intervals, and thus reducing over uncertainty in stock scale.

Through extensive explorations, we found that stock scale is sensitive to assumptions about shape of the selectivity curves, especially for the bottom trawl, as well as the choice of blocking selectivity. In the previous assessment all fleets (except for Triennial Survey) were assumed asymptotic. In this assessment, we provide flexibility for the bottom trawl and non-trawl fleets and bottom trawl surveys to estimate dome-shaped selectivity curves. Changes in selectivity assumptions enabled substantially improved fits to length and age composition data in fisheries and surveys, but also resulted in a substantial increase of stock scale. The most recent selectivity block for the non-trawl fishery also created aberrant retrospective patterns. Given the overall non-target, but still valuable, nature of these species, selectivity patterns may change for both regulatory and market reasons. This increases uncertainty of projections, as current projections assume the selectivity patterns in the final year of the model will hold for the entirety of the projection period.

Stock scale is also sensitive to assumptions about natural mortality. RE/BS is one of the longest lived species of rockfish on the West Coast, with maximum ages of 169 years in this assessment. Individuals as old as 205 years are reported in literature. It is therefore likely that natural mortality for RE/BS is lower than for other rockfish species. With length and age data available only for years after 1994, there is limited ability to monitor the long-term changes of aging cohorts. Therefore, estimates of natural mortality are uncertain. This assessment attempts to capture uncertainty in this parameter and integrate it into the derived biomass estimates by estimating natural mortality for females, while fixing the male natural mortality at the value from meta-analytical study.

4 Management

4.1 Reference Points

Reference points were calculated using the estimated fishery selectivity and removals in the most recent year of the model (2024, Table 22). Reference points were based on the rockfish $F_{MSY\%}$ proxy ($SPR_{50\%}$), target relative biomass (40%), and estimated selectivity and catch for each fleet (Table 22). The proxy MSY values of management quantities are by definition more conservative compared to the estimated MSY and MSY relative to 40% of unfished spawning output because of the assumed steepness value. Sustainable total yield, removals, using the proxy $SPR_{50\%}$ is 519.31 mt. The spawning output equivalent to 40% of the unfished spawning output ($SO_{40\%}$) calculated using the SPR target ($SPR_{50\%}$) was 2.48651 trillions of eggs.

The 2025 spawning output relative to unfished equilibrium spawning output, based on the 2024 fishing year, is 87%, above the management target of 40% of unfished spawning output (Figure 146). The fishing intensity, $1 - SPR$, was below or just slightly above harvest rate limit ($SPR_{50\%}$) from the mid-1980s through the 1990s. Removals since 2000 have been below the point estimate of potential long-term yields calculated using an $SPR_{50\%}$ reference point (Table 23 and Figure 182). The equilibrium estimates of yield relative to biomass based on a steepness value fixed at 0.72 are provided in Figure 183, where vertical dashed lines indicate the estimate of fraction unfished at the start of 2025 (current) and the estimated management targets calculated based on the relative target biomass (B target), the SPR target, and the maximum sustainable yield (MSY).

The relative biomass and the ratio of the estimated SPR to the management target ($SPR_{50\%}$) across all model years are shown in Figure 184 where cooler colors (purple) represent early years and warmer colors (yellow) represent recent years. The stock status has not decreased below the target relative biomass, and fishing intensity (except for in 1995) has been below the target fishing intensity based on $SPR_{50\%}$.

4.2 Management performance

The last ten years total dead catches for RE/BS against the component overfishing limits (OFLs), the acceptable biological catches (ABCs), the annual catch limits (ACLs) are shown in Table 35. In the last ten years, total dead catches of RE/BS have been below the component OFLs for most years, with exception of 2018 and 2019. However, exceeding component OFLs does not indicate overfishing, since the stock is managed as part of a complex.

4.3 Decision Table and Harvest Projections

The primary axis of uncertainty used in the decision table is natural mortality (see Summary of Sources of Uncertainty and States of Nature section for more details). Male natural mortality in the assessment model is fixed at $M = 0.036$, the value informed by likelihood profile and based on a meta-analytic prior that corresponds to the maximum age of 150 years. The male natural mortality for the low state of nature is $M = 0.032$ and for high state of nature is $M = 0.039$.

The male natural mortality value for the low state of nature was selected based on the Hamel and Cope (2022) M estimator to correspond to maximum age of 169 years, which is oldest fish observed in the dataset used in the assessment. The male natural mortality value for the high state of nature was selected based on likelihood profile to be higher than the value in the base model, but still reasonable givent the species biology; it corresponds to maximum age of 138 years based on Hamel and Cope (2022) M estimator.

Twelve-year forecasts were calculated for each state of nature. The 2025 and 2026 catches are fixed at values provided by GMT. For the rest of the years, we used base model forecast catches calculated using the default harvest control rule $P^* = 0.45$, and Category 2 default $\sigma = 1$. The alternative states of nature (Low, Base, and High) are provided in the columns of Table 36, with Spawning Output and Fraction of unfished provided for each state. The sigma value from the decision table for the low state of nature model is 0.83.

The RE/BS assessment is being considered as a Category 2 assessment with a $P^* = 0.45$, $\sigma = 1$ and a time-varying buffer applied to set the ABC below the OFL. These multipliers are also combined with the rockfish MSY proxy of SPR_{50} and the 40-10 harvest control rule to calculate OFLs and ACLs. Projections of the overfishing limit, acceptable biological catch, and annual catch limit, all based on a P^* of 0.45 and a log-space standard deviation of the overfishing limit (σ) of 1 are included in Table 37. Assumed catches for 2025 and 2026 for this projection were provided by the PFMC Groundfish Management Team, and catches from 2027 onward assume full attainment of the acceptable biological catch.

4.4 Evaluation of Scientific Uncertainty

The model estimated uncertainty (σ) around the 2025 spawning output is 0.68. The uncertainty around the OFL is 0.66. These values underestimate the overall uncertainty as they do not incorporate the model structural uncertainty and do not account for any time-varying dynamics other than recruitment. The estimated uncertainty values are lower than the Category 2 default of 1, so all projections will use Category 2 default. The alternative states of nature used to bracket uncertainty in the decision table assist with encapsulating model structure uncertainty.

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7 Tables

Table 1: Major management actions since 2000 that have impacted the management of the Rougheye/Blackspotted complex.

Year	Management Action
2000	Minor slope rockfish complex formed north and south of 40° 10 N and is subject to bi-monthly vessel limits. New limited entry trawl gear restrictions implemented for large footrope trawl gear, small footrope trawl gear, and midwater trawl gear.
2002	Rockfish Conservation Areas (RCA) established. Large footrope gear prohibited inside 275 m. Open access trip limits revised for the minor slope rockfish complex.
2005	Selective flatfish trawl required shoreward of the RCA north of 40° 10 N
2006	Ammendment 19 established essential fish habitat (EFH) boundaries and conservation areas.
2007	Seasonal changes of trawl RCA boundaries and periodic closures within certain latitude boundaries (e.g., north of Cape Alava at 48°10 N. latitude to the U.S.- Canada border) started in 2007.
2011	Trawl rationalization began, establishing the IFQ fishery.
2015	Canary rockfish rebuilt; increased attainment of mid-water rockfishes when implemented in 2017.
2020	Trawl RCA off OR and CA removed (WA RCA remained in place)
2023	Non-bottom contact hook and line gear allowed in non-trawl RCA south of WA-OR border.
2024	Multiple non-trawl RCA south of WA-OR border rule updates, ultimately pushing fixed gear effort onto the shelf/slope.

Table 2: Recent trend in the overfishing limits (OFL), the acceptable biological catches (ABCs), the annual catch limits (ACLs), and the total dead catch (landings + discards) all in metric tons (mt) for the Rougheye/Blackspotted complex north and south of 40'10.

	North of 40'10'			South of 40'10'			Combined			
	OFL (mt)	ABC (mt)	ACL (mt)	OFL (mt)	ABC (mt)	ACL (mt)	OFL (mt)	ABC (mt)	ACL (mt)	Catch (mt)
2015	201.9	184.3	184.3	4.1	3.8	3.8	206	188.1	188.1	132.1
2016	206.8	188.8	188.8	4.2	3.9	3.9	211	192.7	192.7	149.0
2017	210.7	192.4	192.4	4.3	3.9	3.9	215	196.3	196.3	156.0
2018	214.6	195.9	195.9	4.4	4.0	4.0	219	199.9	199.9	241.5
2019	217.6	198.7	198.7	4.4	4.0	4.0	222	202.7	202.7	226.6
2020	219.5	200.4	200.4	4.5	4.1	4.1	224	204.5	204.5	106.1
2021	232.3	191.8	191.8	4.7	3.9	3.9	237	195.8	195.8	92.8
2022	233.2	190.8	190.8	4.8	3.9	3.9	238	194.7	194.7	117.4
2023	233.2	188.9	188.9	4.8	3.9	3.9	238	192.8	192.8	97.6
2024	233.2	190.8	190.8	4.8	3.9	3.9	238	194.7	194.7	118.9

Table 3: Landings in metric tons (mt) by year for each fleet.

Year	Total (mt)	Trawl (mt)	Trawl Discard (mt)	Non-trawl (mt)	Non-trawl discard (mt)	Midwater trawl (mt)	At-sea-Hake (mt)
1891	0	0	0	0	0	0	0
1892	19	0	0	19	0	0	0
1893	19	0	0	19	0	0	0
1894	19	0	0	19	0	0	0
1895	5	0	0	5	0	0	0
1896	1	0	0	1	0	0	0
1897	1	0	0	1	0	0	0
1898	1	0	0	1	0	0	0
1899	1	0	0	1	0	0	0
1900	2	0	0	2	0	0	0
1901	2	0	0	2	0	0	0
1902	3	0	0	3	0	0	0
1903	3	0	0	3	0	0	0
1904	4	0	0	4	0	0	0
1905	4	0	0	4	0	0	0
1906	4	0	0	4	0	0	0
1907	5	0	0	5	0	0	0
1908	8	0	0	8	0	0	0
1909	6	0	0	6	0	0	0
1910	6	0	0	6	0	0	0
1911	7	0	0	7	0	0	0
1912	7	0	0	7	0	0	0
1913	8	0	0	8	0	0	0
1914	8	0	0	8	0	0	0
1915	10	0	0	10	0	0	0
1916	9	0	0	9	0	0	0
1917	10	0	0	10	0	0	0
1918	55	0	0	55	0	0	0
1919	26	0	0	26	0	0	0
1920	23	0	0	23	0	0	0
1921	23	0	0	23	0	0	0
1922	18	0	0	18	0	0	0
1923	20	0	0	20	0	0	0
1924	32	0	0	32	0	0	0
1925	38	0	0	38	0	0	0
1926	54	0	0	54	0	0	0
1927	69	0	0	69	0	0	0
1928	72	0	0	72	0	0	0
1929	66	0	0	66	0	0	0
1930	67	0	0	67	0	0	0
1931	44	0	0	44	0	0	0
1932	25	0	0	25	0	0	0
1933	35	0	0	35	0	0	0
1934	42	0	0	42	0	0	0

1935	34	0	0	34	0	0	0
1936	61	0	0	61	0	0	0
1937	53	0	0	53	0	0	0
1938	55	0	0	55	0	0	0
1939	28	0	0	28	0	0	0
1940	60	1	0	59	0	0	0
1941	102	1	0	101	0	0	0
1942	126	2	0	124	0	0	0
1943	258	7	0	251	0	0	0
1944	85	11	0	74	0	0	0
1945	50	20	0	30	0	0	0
1946	69	11	0	58	0	0	0
1947	42	7	0	35	0	0	0
1948	44	5	0	39	0	0	0
1949	31	5	0	26	0	0	0
1950	52	6	0	46	0	0	0
1951	59	6	0	53	0	0	0
1952	38	6	0	32	0	0	0
1953	21	5	0	16	0	0	0
1954	36	6	0	30	0	0	0
1955	32	6	0	26	0	0	0
1956	21	8	0	13	0	0	0
1957	35	9	0	26	0	0	0
1958	15	7	0	8	0	0	0
1959	23	7	0	16	0	0	0
1960	23	10	0	13	0	0	0
1961	26	11	0	15	0	0	0
1962	32	14	0	18	0	0	0
1963	24	13	0	11	0	0	0
1964	31	11	0	20	0	0	0
1965	31	23	0	8	0	0	0
1966	117	111	0	6	0	0	0
1967	108	98	0	10	0	0	0
1968	172	165	0	7	0	0	0
1969	50	25	0	25	0	0	0
1970	23	19	0	4	0	0	0
1971	68	67	0	1	0	0	0
1972	76	75	0	1	0	0	0
1973	75	69	0	6	0	0	0
1974	76	58	0	18	0	0	0
1975	43	35	0	5	0	0	3
1976	19	16	0	2	0	0	1
1977	166	1	0	164	0	0	1
1978	69	33	0	36	0	0	0
1979	185	63	0	121	0	0	1
1980	99	56	0	43	0	0	0
1981	131	61	0	68	0	0	2
1982	167	99	0	68	0	0	0
1983	126	55	0	70	0	0	1
1984	144	75	0	67	0	0	2

1985	298	139	0	158	0	0	1
1986	428	154	0	273	0	0	1
1987	570	198	0	368	0	0	4
1988	351	173	0	162	0	0	16
1989	418	287	0	131	0	0	0
1990	244	167	0	76	0	0	1
1991	299	235	0	59	0	0	5
1992	306	186	0	110	0	0	10
1993	327	166	0	159	0	0	2
1994	306	127	0	173	0	0	6
1995	744	165	0	576	0	0	3
1996	339	127	0	204	0	0	8
1997	303	107	0	186	0	0	10
1998	441	110	0	313	0	0	18
1999	256	81	0	166	0	0	9
2000	183	79	0	29	0	4	71
2001	114	74	0	18	0	1	21
2002	74	31	14	27	1	0	1
2003	100	58	15	23	2	0	2
2004	115	58	3	34	5	1	14
2005	137	45	1	50	5	0	36
2006	127	48	12	59	1	0	7
2007	187	60	27	59	10	2	29
2008	219	54	29	56	3	1	76
2009	228	67	45	104	1	2	9
2010	263	79	60	71	25	6	22
2011	210	53	0	63	9	4	81
2012	244	47	0	74	20	49	54
2013	156	64	0	59	12	3	18
2014	91	34	0	37	10	4	6
2015	133	31	0	47	14	19	22
2016	150	31	0	60	13	16	30
2017	155	22	0	59	34	2	38
2018	242	16	0	47	15	3	161
2019	226	22	0	39	31	9	125
2020	106	10	0	24	1	29	42
2021	92	10	0	21	2	21	38
2022	118	12	0	19	3	19	65
2023	96	13	0	19	0	26	38
2024	118	10	0	10	0	69	29

7.1 Data

Table 4: Landings in metric tons for bottom trawl fleet by state and bycatch within POP historical fishery.

Year	California	Oregon	Washington	POP Fishery Bycatch	Total
1932	0	0	0	0	0
1933	0	0	0	0	0
1934	0	0	0	0	0
1935	0	0	0	0	0
1936	0	0	0	0	0
1937	0	0	0	0	0
1938	0	0	0	0	0
1939	0	0	0	0	0
1940	0	0	0	0	1
1941	0	1	0	0	1
1942	0	1	0	0	2
1943	0	5	2	0	7
1944	0	9	3	0	11
1945	0	14	6	0	20
1946	0	8	3	0	11
1947	0	5	1	0	7
1948	0	3	2	0	5
1949	0	3	1	0	5
1950	0	4	2	0	6
1951	0	4	2	0	6
1952	0	5	1	0	6
1953	0	3	1	0	5
1954	0	4	2	0	6
1955	0	4	2	0	6
1956	0	6	2	0	8
1957	0	7	2	0	9
1958	0	6	2	0	7
1959	0	5	1	0	7
1960	0	7	3	0	10
1961	0	7	4	0	11
1962	0	8	6	0	14
1963	0	6	7	0	13
1964	0	6	6	0	11
1965	0	17	7	0	23
1966	0	7	6	98	111
1967	0	7	6	85	98
1968	0	4	114	47	165
1969	0	9	2	15	25
1970	0	0	1	17	19
1971	0	11	7	49	67
1972	0	6	1	68	75
1973	0	3	4	63	69
1974	0	2	11	45	58
1975	0	4	4	27	35

1976	0	0	3	12	16
1977	0	0	0	0	1
1978	0	28	6	0	33
1979	0	16	47	0	63
1980	0	30	26	0	56
1981	0	45	16	0	61
1982	0	52	47	0	99
1983	0	44	11	0	55
1984	0	45	30	0	75
1985	0	96	44	0	139
1986	0	137	17	0	154
1987	1	132	66	0	198
1988	0	144	29	0	173
1989	0	240	46	0	287
1990	2	154	11	0	167
1991	1	213	21	0	235
1992	2	155	29	0	186
1993	0	164	3	0	166
1994	7	115	5	0	127
1995	5	113	48	0	165
1996	2	97	29	0	127
1997	0	71	36	0	107
1998	1	89	21	0	110
1999	0	60	21	0	81
2000	2	56	21	0	79
2001	0	64	10	0	74
2002	0	22	8	0	31
2003	1	47	10	0	58
2004	0	51	8	0	58
2005	0	38	7	0	45
2006	0	35	13	0	48
2007	1	50	10	0	60
2008	0	45	8	0	54
2009	0	51	15	0	67
2010	0	63	16	0	79
2011	0	43	10	0	53
2012	0	32	15	0	47
2013	1	54	8	0	64
2014	0	27	7	0	34
2015	0	30	1	0	31
2016	0	28	3	0	31
2017	0	20	2	0	22
2018	1	15	1	0	16
2019	1	21	1	0	22
2020	0	10	0	0	10
2021	0	9	1	0	10
2022	0	10	1	0	12
2023	0	13	0	0	13
2024	0	10	0	0	10

Table 5: Landings in metric tons for non-trawl fleet by state.

Year	California	Oregon	Washington	Total
1892	0	19	0	19
1893	0	19	0	19
1894	0	19	0	19
1895	0	5	0	5
1896	0	1	0	1
1897	0	1	0	1
1898	0	1	0	1
1899	0	1	0	1
1900	0	2	0	2
1901	0	2	0	2
1902	0	3	0	3
1903	0	3	0	3
1904	0	4	0	4
1905	0	4	0	4
1906	0	4	0	4
1907	0	5	0	5
1908	0	5	3	8
1909	0	6	0	6
1910	0	6	0	6
1911	0	7	0	7
1912	0	7	0	7
1913	0	8	0	8
1914	0	8	0	8
1915	0	9	2	10
1916	0	9	0	9
1917	0	10	0	10
1918	0	10	45	55
1919	0	11	15	26
1920	0	11	12	23
1921	0	12	11	23
1922	0	12	6	18
1923	0	13	8	20
1924	0	13	19	32
1925	0	14	24	38
1926	0	14	40	54
1927	0	15	54	69
1928	0	24	48	72
1929	0	38	28	66
1930	0	32	35	67
1931	0	26	17	44
1932	0	10	15	25
1933	0	14	20	35
1934	0	16	26	42
1935	0	15	18	34
1936	0	34	27	61
1937	0	33	20	53

1938	0	31	24	55
1939	0	10	19	28
1940	0	37	22	59
1941	0	61	39	101
1942	0	87	36	124
1943	0	235	15	251
1944	0	42	32	74
1945	0	16	14	30
1946	0	23	35	58
1947	0	17	18	35
1948	0	24	15	39
1949	0	8	18	26
1950	0	19	27	46
1951	0	14	39	53
1952	0	6	26	32
1953	0	6	10	16
1954	0	9	21	30
1955	0	6	19	26
1956	0	5	7	13
1957	0	11	14	26
1958	0	3	4	8
1959	0	6	10	16
1960	0	2	11	13
1961	0	9	7	15
1962	0	10	7	18
1963	0	6	5	11
1964	0	14	6	20
1965	0	3	5	8
1966	0	3	3	6
1967	0	8	2	10
1968	0	6	1	7
1969	0	21	4	25
1970	0	4	0	4
1971	0	1	0	1
1972	0	1	0	1
1973	0	6	0	6
1974	0	18	0	18
1975	0	5	0	5
1976	0	2	0	2
1977	0	152	12	164
1978	0	20	16	36
1979	0	66	55	121
1980	0	19	23	43
1981	2	51	15	68
1982	0	51	17	68
1983	0	53	17	70
1984	0	39	28	67
1985	0	71	87	158
1986	0	185	88	273
1987	9	245	114	368

1988	0	103	60	162
1989	0	98	33	131
1990	0	51	24	76
1991	0	34	25	59
1992	1	63	46	110
1993	0	34	125	159
1994	7	39	127	173
1995	1	131	444	576
1996	1	85	119	204
1997	0	47	139	186
1998	1	86	226	313
1999	0	41	125	166
2000	1	2	26	29
2001	2	2	13	18
2002	1	4	23	27
2003	1	3	18	23
2004	0	2	31	34
2005	3	6	40	50
2006	2	5	52	59
2007	3	6	49	59
2008	1	11	44	56
2009	5	21	77	104
2010	2	22	46	71
2011	2	20	40	63
2012	5	23	45	74
2013	3	19	37	59
2014	3	6	29	37
2015	1	14	32	47
2016	3	16	41	60
2017	0	13	46	59
2018	0	7	39	47
2019	1	8	30	39
2020	1	11	13	24
2021	1	9	12	21
2022	1	4	14	19
2023	5	5	9	19
2024	2	2	5	10

Table 6: Landings in metric tons for mid-water trawl fleet by state.

Year	California	Oregon	Washington	Total
1985	0	0	0	0
1986	0	0	0	0
1987	0	0	0	0
1988	0	0	0	0
1989	0	0	0	0
1990	0	0	0	0
1991	0	0	0	0
1992	0	0	0	0
1993	0	0	0	0
1994	0	0	0	0
1995	0	0	0	0
1996	0	0	0	0
1997	0	0	0	0
1998	0	0	0	0
1999	0	0	0	0
2000	0	2	3	4
2001	0	0	1	1
2002	0	0	0	0
2003	0	0	0	0
2004	0	0	1	1
2005	0	0	0	0
2006	0	0	0	0
2007	0	0	2	2
2008	0	0	1	1
2009	0	0	2	2
2010	0	3	3	6
2011	0	3	1	4
2012	0	42	7	49
2013	0	3	0	3
2014	0	2	2	4
2015	0	12	7	19
2016	0	11	4	16
2017	0	1	1	2
2018	0	1	1	3
2019	0	4	5	9
2020	0	13	16	29
2021	0	11	10	21
2022	0	7	11	19
2023	0	13	13	26
2024	0	43	27	69

Table 7: Summary of fishery sampling effort (number of trips and fish sampled) by state used to create length frequency distributions of the bottom trawl fleet.

Year	N Trips CA	N Fish CA	N Trips OR	N Fish OR	N Trips WA	N Fish WA	Input N
1995	3	4	1	22	0	0	8
1996	6	15	2	44	0	0	16
1997	1	1	1	24	0	0	5
1998	0	0	0	0	24	509	94
1999	2	3	1	33	19	404	83
2000	4	11	1	12	28	573	115
2001	1	1	5	111	18	334	86
2002	3	3	1	5	26	378	83
2003	4	6	8	46	31	794	160
2004	1	1	20	318	13	300	119
2005	1	1	20	258	9	184	91
2006	5	5	29	254	9	297	120
2007	13	17	53	815	21	722	301
2008	15	32	42	659	14	673	259
2009	11	16	65	891	14	448	277
2010	8	12	60	711	8	354	225
2011	9	12	37	386	16	263	153
2012	15	25	46	409	18	612	223
2013	11	15	45	515	7	195	163
2014	11	15	61	507	7	113	167
2015	12	20	63	778	15	382	253
2016	19	28	42	631	8	144	180
2017	19	38	76	728	8	87	221
2018	14	19	61	650	12	169	203
2019	21	59	81	730	7	92	231
2020	3	3	51	381	9	101	130
2021	15	33	53	353	11	135	151
2022	6	19	33	373	11	230	136
2023	6	6	20	254	8	296	111
2024	21	38	23	357	22	569	199

Table 8: Summary of fishery sampling effort (number of trips and fish sampled) by state used to create length frequency distributions of the non-trawl fleet.

Year	N Trips CA	N Fish CA	N Trips OR	N Fish OR	N Trips WA	N Fish WA	Input N
1996	0	0	5	123	0	0	22
1998	0	0	2	44	11	678	92
1999	0	0	3	69	10	392	77
2000	1	9	1	23	0	0	6
2001	0	0	1	24	5	62	18
2002	2	13	0	0	17	268	58
2003	2	7	1	2	50	967	188
2004	0	0	0	0	33	741	135
2005	13	57	5	22	42	1167	232
2006	9	113	10	177	49	1323	291
2007	4	9	5	88	27	747	152
2008	8	47	7	121	34	953	204
2009	11	92	17	257	27	1115	257
2010	12	93	38	499	21	742	255
2011	15	60	44	544	32	1034	317
2012	4	17	34	318	27	847	228
2013	4	26	27	488	29	919	258
2014	1	2	24	176	31	882	202
2015	0	0	47	342	33	927	255
2016	3	15	49	459	53	1236	341
2017	0	0	61	441	73	1061	341
2018	0	0	88	477	93	1293	425
2019	0	0	68	379	117	1456	438
2020	1	1	40	242	33	489	175
2021	1	10	34	232	83	931	280
2022	0	0	53	344	90	881	312
2023	3	10	25	190	73	871	249
2024	27	102	29	162	65	731	258

Table 9: Summary of fishery sampling effort (number of trips and fish sampled) by state used to create length frequency distributions of the mid-water trawl fleet.

Year	N Trips OR	N Fish OR	Input N
2000	1	28	5
2008	2	13	4
2010	3	48	10
2011	4	8	5
2012	19	460	82
2013	4	29	8
2014	9	19	12
2015	32	324	77
2016	16	147	36
2017	9	63	18
2018	6	44	12
2019	8	24	11
2020	15	124	32
2021	32	178	57
2022	17	154	38
2023	20	237	53
2024	26	327	71

Table 10: Summary of fishery sampling effort (number of trips and fish sampled) by state used to create conditional ages-at-length compositions.

Year	Fleet	N Trips OR	N Fish OR	N Trips WA	N Fish WA
2008	Bottom Trawl	38	630	0	0
2009	Bottom Trawl	0	0	3	87
2010	Bottom Trawl	0	0	7	217
2011	Bottom Trawl	36	384	2	39
2012	Bottom Trawl	0	0	9	191
2013	Bottom Trawl	0	0	2	66
2017	Bottom Trawl	49	257	0	0
2021	Bottom Trawl	39	172	0	0
2022	Bottom Trawl	26	174	0	0
2023	Bottom Trawl	20	253	0	0
2024	Bottom Trawl	22	182	6	202
2008	Non-trawl	4	51	3	41
2009	Non-trawl	0	0	10	406
2010	Non-trawl	0	0	17	562
2011	Non-trawl	1	3	9	234
2012	Non-trawl	0	0	22	710
2013	Non-trawl	0	0	6	179
2017	Non-trawl	39	118	0	0
2021	Non-trawl	31	132	0	0
2022	Non-trawl	37	160	0	0
2023	Non-trawl	25	190	0	0
2024	Non-trawl	25	77	21	278
2011	Midwater Trawl	4	8	0	0
2017	Midwater Trawl	8	25	0	0
2021	Midwater Trawl	25	95	0	0
2022	Midwater Trawl	15	66	0	0
2023	Midwater Trawl	20	235	0	0
2024	Midwater Trawl	25	141	0	0

Table 11: Summary of fishery sampling effort (number of trips, number of hauls and fish sampled) used to create length frequency distributions of discard fleets.

Year	Fleet	N Fish	N Hauls	N Trips	Input N
2004	Bottom Trawl Discard	51	10	7	14
2005	Bottom Trawl Discard	36	20	16	21
2006	Bottom Trawl Discard	88	26	18	30
2007	Bottom Trawl Discard	456	123	40	103
2008	Bottom Trawl Discard	1104	324	95	247
2009	Bottom Trawl Discard	1026	295	101	243
2010	Bottom Trawl Discard	655	166	49	139
2011	Bottom Trawl Discard	27	14	14	18
2012	Bottom Trawl Discard	92	39	24	37
2013	Bottom Trawl Discard	115	46	27	43
2014	Bottom Trawl Discard	60	30	23	31
2015	Bottom Trawl Discard	5	4	4	5
2016	Bottom Trawl Discard	18	8	7	9
2019	Bottom Trawl Discard	14	4	3	5
2020	Bottom Trawl Discard	10	4	4	5
2022	Bottom Trawl Discard	13	6	6	8
2023	Bottom Trawl Discard	24	5	5	8
2004	Non-trawl Discard	22	5	3	6
2005	Non-trawl Discard	202	21	7	35
2006	Non-trawl Discard	34	10	4	9
2007	Non-trawl Discard	92	26	9	22
2008	Non-trawl Discard	33	18	9	14
2009	Non-trawl Discard	19	11	9	12
2010	Non-trawl Discard	180	49	16	41
2011	Non-trawl Discard	400	100	12	67
2012	Non-trawl Discard	395	114	18	73
2013	Non-trawl Discard	112	26	5	20
2014	Non-trawl Discard	108	26	8	23
2015	Non-trawl Discard	254	52	15	50
2016	Non-trawl Discard	154	39	16	37
2017	Non-trawl Discard	340	55	17	64
2018	Non-trawl Discard	320	60	19	63
2019	Non-trawl Discard	753	123	21	125
2020	Non-trawl Discard	21	6	5	8
2021	Non-trawl Discard	49	11	9	16
2022	Non-trawl Discard	76	22	8	18
2023	Non-trawl Discard	39	11	8	13

Table 12: Summary of fishery sampling effort (number of hauls and fish sampled) used to create length frequency distributions and CAAL of At-sea Hake fleet.

Year	N Hauls	N Lengths	N Ages
2003	66	338	0
2004	425	2132	0
2005	461	3102	0
2006	305	1029	0
2007	572	5135	0
2008	893	7547	555
2009	284	1093	0
2010	380	1956	0
2011	1092	8672	508
2012	591	5176	0
2013	446	2233	0
2014	278	744	283
2015	424	2044	0
2016	794	3092	507
2017	507	2746	0
2018	524	2900	0
2019	317	2488	311
2020	189	1213	185
2021	282	1356	262
2022	519	2363	450
2023	260	776	373
2024	306	898	221

Table 13: Stratifications used for generate survey length compositions.

Survey	Stratum Name	Depth Low (m)	Depth High (m)	Latitude Low (° N)	Latitude High (° N)
WCGBTS	Shallow OR	55	183	42	46
	Middle OR	183	350	42	46
	Deep OR	350	549	42	46
	Shallow WA	55	183	46	49
	Middle WA	183	350	46	49
	Deep WA	350	549	46	49
Triennial early	Shallow	55	183	42	49
	Deep	183	350	42	49
Triennial late	Shallow	55	183	42	49
	Deep	183	500	42	49
AFSC Slope	Shallow	183	549	42	46
	Deep	183	549	46	49

Table 14: Spatial and temporal coverage of surveys used in this assessment.

Survey	Year	Latitudes Low	Latitude High	Depths Low (m)	Depths High (m)
WCGBTS	2003	32° 34' N	48° 27' N	55	1,280
WCGBTS	2004	32° 34' N	48° 27' N	55	1,280
WCGBTS	2005	32° 34' N	48° 27' N	55	1,280
WCGBTS	2006	32° 34' N	48° 27' N	55	1,280
WCGBTS	2007	32° 34' N	48° 27' N	55	1,280
WCGBTS	2008	32° 34' N	48° 27' N	55	1,280
WCGBTS	2009	32° 34' N	48° 27' N	55	1,280
WCGBTS	2010	32° 34' N	48° 27' N	55	1,280
WCGBTS	2011	32° 34' N	48° 27' N	55	1,280
WCGBTS	2012	32° 34' N	48° 27' N	55	1,280
WCGBTS	2013	32° 34' N	48° 27' N	55	1,280
WCGBTS	2014	32° 34' N	48° 27' N	55	1,280
WCGBTS	2015	32° 34' N	48° 27' N	55	1,280
WCGBTS	2016	32° 34' N	48° 27' N	55	1,280
WCGBTS	2017	32° 34' N	48° 27' N	55	1,280
WCGBTS	2018	32° 34' N	48° 27' N	55	1,280
WCGBTS	2019	32° 34' N	48° 27' N	55	1,280
WCGBTS	2021	32° 34' N	48° 27' N	55	1,280
WCGBTS	2022	32° 34' N	48° 27' N	55	1,280
WCGBTS	2023	32° 34' N	48° 27' N	55	1,280
WCGBTS	2024	32° 34' N	48° 27' N	55	1,280
AFSC/NWFSC Triennial	1977	34° 00' N	Canadian border	91	457
AFSC/NWFSC Triennial	1980	36° 48' N	49° 15' N	55	366
AFSC/NWFSC Triennial	1983	36° 48' N	49° 15' N	55	366
AFSC/NWFSC Triennial	1986	36° 48' N	Canadian border	55	366
AFSC/NWFSC Triennial	1989	36° 30' N	49° 40' N	55	366
AFSC/NWFSC Triennial	1992	36° 30' N	49° 40' N	55	366
AFSC/NWFSC Triennial	1995	36° 30' N	49° 40' N	55	500
AFSC/NWFSC Triennial	1998	36° 30' N	49° 40' N	55	500
AFSC/NWFSC Triennial	2001	36° 30' N	49° 40' N	55	500
AFSC/NWFSC Triennial	2004	34° 30' N	Canadian border	55	500
AFSC Slope	1988	44° 05' N	45° 30' N	182	1,280
AFSC Slope	1990	44° 30' N	40° 30' N	182	1,280
AFSC Slope	1991	38° 20' N	40° 30' N	182	1,280
AFSC Slope	1992	45° 30' N	Canadian border	182	1,280
AFSC Slope	1993	43° 00' N	45° 30' N	182	1,280
AFSC Slope	1995	40° 30' N	43° 00' N	182	1,280
AFSC Slope	1996	43° 00' N	Canadian border	182	1,280
AFSC Slope	1997	34° 00' N	Canadian border	182	1,280
AFSC Slope	1999	34° 00' N	Canadian border	182	1,280
AFSC Slope	2000	34° 00' N	Canadian border	182	1,280
AFSC Slope	2001	34° 00' N	Canadian border	182	1,280
NWFSC Slope	1999	34° 50' N	48° 10' N	182	1,280
NWFSC Slope	2000	34° 50' N	48° 10' N	182	1,280
NWFSC Slope	2001	34° 50' N	48° 10' N	182	1,280
NWFSC Slope	2002	34° 50' N	48° 10' N	182	1,280

Table 15: Summary of surveys' sampling effort (number of hauls and fish sampled) used to create length frequency distributions.

Year	Survey	N Hauls	N Fish	Input N
2003	WCGBTS	33	111	80
2004	WCGBTS	24	111	58
2005	WCGBTS	27	259	65
2006	WCGBTS	34	99	82
2007	WCGBTS	35	106	85
2008	WCGBTS	35	120	85
2009	WCGBTS	26	125	63
2010	WCGBTS	29	89	70
2011	WCGBTS	29	113	70
2012	WCGBTS	21	82	51
2013	WCGBTS	21	67	51
2014	WCGBTS	20	39	39
2015	WCGBTS	35	181	85
2016	WCGBTS	31	103	75
2017	WCGBTS	26	173	63
2018	WCGBTS	25	97	60
2019	WCGBTS	10	57	24
2021	WCGBTS	29	139	70
2022	WCGBTS	19	41	41
2023	WCGBTS	28	78	68
2024	WCGBTS	28	59	59
1980	Triennial	2	70	4
1986	Triennial	10	94	24
1989	Triennial	24	276	58
1992	Triennial	17	290	41
1995	Triennial	54	432	131
1998	Triennial	49	240	119
2001	Triennial	50	287	121
2004	Triennial	46	315	111
1997	AFSC Slope	10	32	24
1999	AFSC Slope	11	25	25
2000	AFSC Slope	13	128	31
2001	AFSC Slope	10	99	24

Table 16: Summary of WCGBTS sampling effort (number of hauls and fish sampled) used to create conditional ages-at-length distributions.

Year	Survey	N Hauls	N Fish	Input N
2003	WCGBTS	17	56	56
2004	WCGBTS	24	74	74
2005	WCGBTS	27	139	139
2006	WCGBTS	31	94	94
2007	WCGBTS	35	105	105
2008	WCGBTS	35	119	119
2009	WCGBTS	24	93	93
2010	WCGBTS	29	89	89
2011	WCGBTS	27	110	110
2012	WCGBTS	19	78	78
2013	WCGBTS	21	67	67
2014	WCGBTS	11	22	22
2015	WCGBTS	34	169	169
2016	WCGBTS	31	103	103
2017	WCGBTS	25	128	128
2018	WCGBTS	25	97	97
2019	WCGBTS	10	57	57
2021	WCGBTS	28	138	138
2022	WCGBTS	19	41	41
2023	WCGBTS	27	76	76
2024	WCGBTS	28	59	59

Table 17: Length and age at biological (L50 bio, A50 bio) and functional maturity (L50 fxn, A50 fxn) for the Rougheye and Blackspotted rockfish complex (RE/BS), and genetically confirmed Rougheye and Blackspotted separately. Only certain maturity determinations were used in this analysis.

Data used	n(length)	L50 bio	L50 fxn	n(age)	A50 bio	A50 fxn
RE/BS all data	473	42.92 (1.28)	46.53 (1.11)	372	21.23 (2.05)	26.02 (2.12)
RE/BS genetically confirmed	265	43.98 (1.86)	46.83 (1.64)	258	19.45 (2.16)	21.85 (2.14)
Rougheye Rockfish	194	39.86 (2.18)	43.57 (2.02)	188	13.89 (1.77)	15.80 (1.84)
Blackspotted Rockfish	71	49.46 (2.09)	51.45 (2.35)	70	26.18 (4.40)	29.27 (3.75)

7.2 Model Details

Table 18: Specifications and structure of the model.

Section	Configuration
Maximum model age	140
Sexes	Females, males
Population bins	4-84 cm by 2 cm bins
Summary biomass (mt) age	26+
Number of areas	1
Number of seasons	1
Number of growth patterns	1
Start year	1892
End year	2024
Data length bins	10-80 cm by 2 cm bins
Data age bins	1-100 by 1 year

Table 19: Estimated parameters in the model.

Type	Count
Natural Mortality (M)	1
M time-variation	0
Growth mean	6
Growth variability	4
Growth time-variation	0
Stock-recruit	1
Stock-recruit variation	0
Rec. dev. time series	133
Rec. dev. initial age	0
Rec. dev. forecast	12
Index	1
Index time-variation	1
Size selectivity	30
Size selectivity time-variation	24
Retention	0
Retention time-variation	0
Age selectivity	0
Age selectivity time-variation	0

Table 20: Parameter estimates, estimation phase, parameter bounds, estimation status, estimated standard deviation (SD), prior information [distribution(mean, SD)] used in the base model.

Label	Value	Phase	Bounds	Status	SD	Prior
NatM_uniform_Fem_GP_1	0.0391	1	(0.001, 0.2)	ok	0.000834	lognormal(0.034, 0.310)
L_at_Amin_Fem_GP_1	-3.1	2	(-100, 25)	ok	0.62	none
L_at_Amax_Fem_GP_1	60.1	2	(40, 90)	ok	0.351	none
VonBert_K_Fem_GP_1	0.0785	2	(0.01, 0.15)	ok	0.00179	none
CV_young_Fem_GP_1	0.0513	2	(1e-06, 1)	ok	0.0143	none
CV_old_Fem_GP_1	0.0936	2	(1e-06, 1)	ok	0.00305	none
Wtlen_1_Fem_GP_1	8.78e-06	-3	(-3, 3)	fixed	0	none
Wtlen_2_Fem_GP_1	3.15	-3	(-3, 4)	fixed	0	none
Mat50%_Fem_GP_1	46.5	-3	(1, 60)	fixed	0	none
Mat_slope_Fem_GP_1	-0.254	-3	(-30, 3)	fixed	0	none
Eggs_scalar_Fem_GP_1	7.22e-11	-3	(-3, 3)	fixed	0	none
Eggs_exp_len_Fem_GP_1	4.04	-3	(-3, 5)	fixed	0	none
NatM_uniform_Mal_GP_1	0.036	-2	(0.001, 0.2)	fixed	0	lognormal(0.034, 0.310)
L_at_Amin_Mal_GP_1	-2.67	2	(-100, 25)	ok	1.05	none
L_at_Amax_Mal_GP_1	57.8	2	(40, 90)	ok	0.315	none
VonBert_K_Mal_GP_1	0.0837	2	(0.01, 0.15)	ok	0.00253	none
CV_young_Mal_GP_1	0.0912	2	(1e-06, 1)	ok	0.0197	none
CV_old_Mal_GP_1	0.085	2	(1e-06, 1)	ok	0.00296	none
Wtlen_1_Mal_GP_1	1.18e-05	-3	(-3, 3)	fixed	0	none
Wtlen_2_Mal_GP_1	3.07	-3	(-3, 4)	fixed	0	none
CohortGrowDev	1	-4	(0, 1)	fixed	0	none
FracFemale_GP_1	0.5	-5	(1e-06, 1)	fixed	0	none
SR_LN(R0)	6.98	1	(1, 15)	ok	0.613	none
SR_BH_steep	0.72	-3	(0.25, 0.99)	fixed	0	beta(0.718, 0.152)
SR_sigmaR	0.5	-4	(0, 2)	fixed	0	none
SR_regime	0	-4	(-5, 5)	fixed	0	none
SR_autocorr	0	-99	(0, 0)	fixed	0	none
Main_RecrDev_1892	-0.0793	1	(-5, 5)	dev	0.481	normal(0.00, 0.50)
Main_RecrDev_1893	-0.081	1	(-5, 5)	dev	0.481	normal(0.00, 0.50)

Main_RecrDev_1894	-0.0827	1	(-5, 5)	dev	0.48	normal(0.00, 0.50)
Main_RecrDev_1895	-0.0844	1	(-5, 5)	dev	0.48	normal(0.00, 0.50)
Main_RecrDev_1896	-0.086	1	(-5, 5)	dev	0.479	normal(0.00, 0.50)
Main_RecrDev_1897	-0.0876	1	(-5, 5)	dev	0.479	normal(0.00, 0.50)
Main_RecrDev_1898	-0.0891	1	(-5, 5)	dev	0.479	normal(0.00, 0.50)
Main_RecrDev_1899	-0.0906	1	(-5, 5)	dev	0.478	normal(0.00, 0.50)
Main_RecrDev_1900	-0.092	1	(-5, 5)	dev	0.478	normal(0.00, 0.50)
Main_RecrDev_1901	-0.0933	1	(-5, 5)	dev	0.478	normal(0.00, 0.50)
Main_RecrDev_1902	-0.0945	1	(-5, 5)	dev	0.477	normal(0.00, 0.50)
Main_RecrDev_1903	-0.0956	1	(-5, 5)	dev	0.477	normal(0.00, 0.50)
Main_RecrDev_1904	-0.0965	1	(-5, 5)	dev	0.477	normal(0.00, 0.50)
Main_RecrDev_1905	-0.0974	1	(-5, 5)	dev	0.477	normal(0.00, 0.50)
Main_RecrDev_1906	-0.0981	1	(-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1907	-0.0986	1	(-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1908	-0.099	1	(-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1909	-0.0991	1	(-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1910	-0.0991	1	(-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1911	-0.0989	1	(-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1912	-0.0985	1	(-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1913	-0.0979	1	(-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1914	-0.097	1	(-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1915	-0.0958	1	(-5, 5)	dev	0.477	normal(0.00, 0.50)
Main_RecrDev_1916	-0.0944	1	(-5, 5)	dev	0.477	normal(0.00, 0.50)
Main_RecrDev_1917	-0.0927	1	(-5, 5)	dev	0.477	normal(0.00, 0.50)
Main_RecrDev_1918	-0.0906	1	(-5, 5)	dev	0.478	normal(0.00, 0.50)
Main_RecrDev_1919	-0.0883	1	(-5, 5)	dev	0.478	normal(0.00, 0.50)
Main_RecrDev_1920	-0.0857	1	(-5, 5)	dev	0.479	normal(0.00, 0.50)
Main_RecrDev_1921	-0.0828	1	(-5, 5)	dev	0.479	normal(0.00, 0.50)
Main_RecrDev_1922	-0.0796	1	(-5, 5)	dev	0.48	normal(0.00, 0.50)
Main_RecrDev_1923	-0.0761	1	(-5, 5)	dev	0.48	normal(0.00, 0.50)
Main_RecrDev_1924	-0.0725	1	(-5, 5)	dev	0.481	normal(0.00, 0.50)
Main_RecrDev_1925	-0.0688	1	(-5, 5)	dev	0.482	normal(0.00, 0.50)
Main_RecrDev_1926	-0.065	1	(-5, 5)	dev	0.482	normal(0.00, 0.50)
Main_RecrDev_1927	-0.0612	1	(-5, 5)	dev	0.483	normal(0.00, 0.50)
Main_RecrDev_1928	-0.0575	1	(-5, 5)	dev	0.484	normal(0.00, 0.50)
Main_RecrDev_1929	-0.054	1	(-5, 5)	dev	0.484	normal(0.00, 0.50)
Main_RecrDev_1930	-0.0508	1	(-5, 5)	dev	0.485	normal(0.00, 0.50)
Main_RecrDev_1931	-0.0479	1	(-5, 5)	dev	0.485	normal(0.00, 0.50)
Main_RecrDev_1932	-0.0454	1	(-5, 5)	dev	0.486	normal(0.00, 0.50)

Main_RecrDev_1933	-0.0432	1	(-5, 5)	dev	0.486	normal(0.00, 0.50)
Main_RecrDev_1934	-0.0414	1	(-5, 5)	dev	0.486	normal(0.00, 0.50)
Main_RecrDev_1935	-0.0397	1	(-5, 5)	dev	0.486	normal(0.00, 0.50)
Main_RecrDev_1936	-0.038	1	(-5, 5)	dev	0.487	normal(0.00, 0.50)
Main_RecrDev_1937	-0.0362	1	(-5, 5)	dev	0.487	normal(0.00, 0.50)
Main_RecrDev_1938	-0.034	1	(-5, 5)	dev	0.487	normal(0.00, 0.50)
Main_RecrDev_1939	-0.0312	1	(-5, 5)	dev	0.488	normal(0.00, 0.50)
Main_RecrDev_1940	-0.0275	1	(-5, 5)	dev	0.489	normal(0.00, 0.50)
Main_RecrDev_1941	-0.0228	1	(-5, 5)	dev	0.49	normal(0.00, 0.50)
Main_RecrDev_1942	-0.0166	1	(-5, 5)	dev	0.491	normal(0.00, 0.50)
Main_RecrDev_1943	-0.00879	1	(-5, 5)	dev	0.492	normal(0.00, 0.50)
Main_RecrDev_1944	0.000913	1	(-5, 5)	dev	0.495	normal(0.00, 0.50)
Main_RecrDev_1945	0.0127	1	(-5, 5)	dev	0.497	normal(0.00, 0.50)
Main_RecrDev_1946	0.0269	1	(-5, 5)	dev	0.5	normal(0.00, 0.50)
Main_RecrDev_1947	0.0435	1	(-5, 5)	dev	0.504	normal(0.00, 0.50)
Main_RecrDev_1948	0.0626	1	(-5, 5)	dev	0.509	normal(0.00, 0.50)
Main_RecrDev_1949	0.0841	1	(-5, 5)	dev	0.514	normal(0.00, 0.50)
Main_RecrDev_1950	0.108	1	(-5, 5)	dev	0.521	normal(0.00, 0.50)
Main_RecrDev_1951	0.133	1	(-5, 5)	dev	0.527	normal(0.00, 0.50)
Main_RecrDev_1952	0.16	1	(-5, 5)	dev	0.535	normal(0.00, 0.50)
Main_RecrDev_1953	0.186	1	(-5, 5)	dev	0.542	normal(0.00, 0.50)
Main_RecrDev_1954	0.211	1	(-5, 5)	dev	0.549	normal(0.00, 0.50)
Main_RecrDev_1955	0.232	1	(-5, 5)	dev	0.556	normal(0.00, 0.50)
Main_RecrDev_1956	0.249	1	(-5, 5)	dev	0.561	normal(0.00, 0.50)
Main_RecrDev_1957	0.259	1	(-5, 5)	dev	0.564	normal(0.00, 0.50)
Main_RecrDev_1958	0.264	1	(-5, 5)	dev	0.566	normal(0.00, 0.50)
Main_RecrDev_1959	0.263	1	(-5, 5)	dev	0.565	normal(0.00, 0.50)
Main_RecrDev_1960	0.257	1	(-5, 5)	dev	0.563	normal(0.00, 0.50)
Main_RecrDev_1961	0.247	1	(-5, 5)	dev	0.559	normal(0.00, 0.50)
Main_RecrDev_1962	0.232	1	(-5, 5)	dev	0.554	normal(0.00, 0.50)
Main_RecrDev_1963	0.212	1	(-5, 5)	dev	0.547	normal(0.00, 0.50)
Main_RecrDev_1964	0.187	1	(-5, 5)	dev	0.539	normal(0.00, 0.50)
Main_RecrDev_1965	0.157	1	(-5, 5)	dev	0.53	normal(0.00, 0.50)
Main_RecrDev_1966	0.126	1	(-5, 5)	dev	0.522	normal(0.00, 0.50)
Main_RecrDev_1967	0.0973	1	(-5, 5)	dev	0.514	normal(0.00, 0.50)
Main_RecrDev_1968	0.075	1	(-5, 5)	dev	0.508	normal(0.00, 0.50)
Main_RecrDev_1969	0.0598	1	(-5, 5)	dev	0.503	normal(0.00, 0.50)
Main_RecrDev_1970	0.05	1	(-5, 5)	dev	0.5	normal(0.00, 0.50)
Main_RecrDev_1971	0.0427	1	(-5, 5)	dev	0.497	normal(0.00, 0.50)

Main_RecrDev_1972	0.0368	1	(-5, 5)	dev	0.495	normal(0.00, 0.50)
Main_RecrDev_1973	0.0359	1	(-5, 5)	dev	0.493	normal(0.00, 0.50)
Main_RecrDev_1974	0.041	1	(-5, 5)	dev	0.492	normal(0.00, 0.50)
Main_RecrDev_1975	0.0428	1	(-5, 5)	dev	0.492	normal(0.00, 0.50)
Main_RecrDev_1976	0.056	1	(-5, 5)	dev	0.492	normal(0.00, 0.50)
Main_RecrDev_1977	0.0762	1	(-5, 5)	dev	0.493	normal(0.00, 0.50)
Main_RecrDev_1978	0.107	1	(-5, 5)	dev	0.495	normal(0.00, 0.50)
Main_RecrDev_1979	0.108	1	(-5, 5)	dev	0.492	normal(0.00, 0.50)
Main_RecrDev_1980	0.0982	1	(-5, 5)	dev	0.484	normal(0.00, 0.50)
Main_RecrDev_1981	0.0849	1	(-5, 5)	dev	0.476	normal(0.00, 0.50)
Main_RecrDev_1982	0.0216	1	(-5, 5)	dev	0.466	normal(0.00, 0.50)
Main_RecrDev_1983	0.0283	1	(-5, 5)	dev	0.459	normal(0.00, 0.50)
Main_RecrDev_1984	0.18	1	(-5, 5)	dev	0.457	normal(0.00, 0.50)
Main_RecrDev_1985	0.168	1	(-5, 5)	dev	0.436	normal(0.00, 0.50)
Main_RecrDev_1986	-0.0211	1	(-5, 5)	dev	0.438	normal(0.00, 0.50)
Main_RecrDev_1987	0.124	1	(-5, 5)	dev	0.462	normal(0.00, 0.50)
Main_RecrDev_1988	0.656	1	(-5, 5)	dev	0.388	normal(0.00, 0.50)
Main_RecrDev_1989	0.221	1	(-5, 5)	dev	0.438	normal(0.00, 0.50)
Main_RecrDev_1990	-0.114	1	(-5, 5)	dev	0.416	normal(0.00, 0.50)
Main_RecrDev_1991	0.0338	1	(-5, 5)	dev	0.394	normal(0.00, 0.50)
Main_RecrDev_1992	0.152	1	(-5, 5)	dev	0.393	normal(0.00, 0.50)
Main_RecrDev_1993	0.303	1	(-5, 5)	dev	0.365	normal(0.00, 0.50)
Main_RecrDev_1994	0.0223	1	(-5, 5)	dev	0.353	normal(0.00, 0.50)
Main_RecrDev_1995	-0.49	1	(-5, 5)	dev	0.351	normal(0.00, 0.50)
Main_RecrDev_1996	-0.618	1	(-5, 5)	dev	0.342	normal(0.00, 0.50)
Main_RecrDev_1997	-0.606	1	(-5, 5)	dev	0.345	normal(0.00, 0.50)
Main_RecrDev_1998	-0.271	1	(-5, 5)	dev	0.35	normal(0.00, 0.50)
Main_RecrDev_1999	0.546	1	(-5, 5)	dev	0.268	normal(0.00, 0.50)
Main_RecrDev_2000	0.185	1	(-5, 5)	dev	0.34	normal(0.00, 0.50)
Main_RecrDev_2001	0.108	1	(-5, 5)	dev	0.316	normal(0.00, 0.50)
Main_RecrDev_2002	-0.22	1	(-5, 5)	dev	0.338	normal(0.00, 0.50)
Main_RecrDev_2003	-0.526	1	(-5, 5)	dev	0.373	normal(0.00, 0.50)
Main_RecrDev_2004	-0.0514	1	(-5, 5)	dev	0.362	normal(0.00, 0.50)
Main_RecrDev_2005	0.0358	1	(-5, 5)	dev	0.37	normal(0.00, 0.50)
Main_RecrDev_2006	-0.214	1	(-5, 5)	dev	0.411	normal(0.00, 0.50)
Main_RecrDev_2007	0.221	1	(-5, 5)	dev	0.391	normal(0.00, 0.50)
Main_RecrDev_2008	0.576	1	(-5, 5)	dev	0.356	normal(0.00, 0.50)
Main_RecrDev_2009	0.0815	1	(-5, 5)	dev	0.427	normal(0.00, 0.50)
Main_RecrDev_2010	0.646	1	(-5, 5)	dev	0.332	normal(0.00, 0.50)

Main_RecrDev_2011	0.0451	1	(-5, 5)	dev	0.383	normal(0.00, 0.50)
Main_RecrDev_2012	1.04	1	(-5, 5)	dev	0.273	normal(0.00, 0.50)
Main_RecrDev_2013	-0.0418	1	(-5, 5)	dev	0.371	normal(0.00, 0.50)
Main_RecrDev_2014	-0.365	1	(-5, 5)	dev	0.397	normal(0.00, 0.50)
Main_RecrDev_2015	-0.445	1	(-5, 5)	dev	0.422	normal(0.00, 0.50)
Main_RecrDev_2016	-0.172	1	(-5, 5)	dev	0.429	normal(0.00, 0.50)
Main_RecrDev_2017	0.737	1	(-5, 5)	dev	0.381	normal(0.00, 0.50)
Main_RecrDev_2018	0.25	1	(-5, 5)	dev	0.416	normal(0.00, 0.50)
Main_RecrDev_2019	0.132	1	(-5, 5)	dev	0.413	normal(0.00, 0.50)
Main_RecrDev_2020	-0.22	1	(-5, 5)	dev	0.44	normal(0.00, 0.50)
Main_RecrDev_2021	-0.138	1	(-5, 5)	dev	0.465	normal(0.00, 0.50)
Main_RecrDev_2022	-0.0462	1	(-5, 5)	dev	0.491	normal(0.00, 0.50)
Main_RecrDev_2023	-0.00315	1	(-5, 5)	dev	0.499	normal(0.00, 0.50)
Late_RecrDev_2024	0	5	(-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2025	0	5	(-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2026	0	5	(-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2027	0	5	(-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2028	0	5	(-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2029	0	5	(-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2030	0	5	(-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2031	0	5	(-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2032	0	5	(-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2033	0	5	(-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2034	0	5	(-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2035	0	5	(-5, 5)	dev	0.5	normal(0.00, 0.50)
ForeRecr_2036	0	5	(-5, 5)	dev	0.5	normal(0.00, 0.50)
LnQ_base_TRIENNIAL(7)	-1.47	1	(-10, 2)	ok	0.734	none
LnQ_base_AK_SLOPE(8)	-3.1	-1	(-15, 15)	fixed	0	none
LnQ_base_NW_SLOPE(9)	-2.03	-1	(-15, 15)	fixed	0	none
LnQ_base_WCGBTS(10)	-2.6	-1	(-15, 15)	fixed	0	none
LnQ_base_TRIENNIAL(7)_BLK3repl_1892	-2.26	1	(-10, 2)	ok	0.763	none
Size_DblN_peak_BOTTOM_TRAWL(1)	49.3	3	(15, 79)	ok	1.02	none
Size_DblN_top_logit_BOTTOM_TRAWL(1)	-11.5	-4	(-15, 20)	fixed	0	none
Size_DblN_ascend_se_BOTTOM_TRAWL(1)	4.57	3	(-15, 12)	ok	0.207	none

Size_DblN_descend_se_-BOTTOM_TRAWL(1)	2.95	4	(-15, 20)	ok	0.695	none
Size_DblN_start_logit_-BOTTOM_TRAWL(1)	-999	-3	(-1000, 20)	fixed	0	none
Size_DblN_end_logit_-BOTTOM_TRAWL(1)	-0.638	4	(-15, 20)	ok	0.345	none
Size_DblN_peak_BOTTOM_-TRAWL_DISCARD(2)	25.3	3	(15, 79)	ok	5.37	none
Size_DblN_top_logit_-BOTTOM_TRAWL_-DISCARD(2)	-15	-4	(-15, 20)	fixed	0	none
Size_DblN_ascend_se_-BOTTOM_TRAWL_-DISCARD(2)	4.89	3	(-15, 12)	ok	2.42	none
Size_DblN_descend_se_-BOTTOM_TRAWL_-DISCARD(2)	3.84	4	(-15, 20)	ok	1.49	none
Size_DblN_start_logit_-BOTTOM_TRAWL_-DISCARD(2)	-15	-3	(-15, 20)	fixed	0	none
Size_DblN_end_logit_-BOTTOM_TRAWL_-DISCARD(2)	-3.81	4	(-15, 20)	ok	1.31	none
Size_DblN_peak_NON_-TRAWL(3)	50.3	3	(15, 70)	ok	1.25	none
Size_DblN_top_logit_NON_-TRAWL(3)	-15	-4	(-15, 20)	fixed	0	none
Size_DblN_ascend_se_NON_-TRAWL(3)	3.86	3	(-15, 12)	ok	0.296	none
Size_DblN_descend_se_NON_-TRAWL(3)	20	-4	(-15, 20)	fixed	0	none
Size_DblN_start_logit_NON_-TRAWL(3)	-999	-3	(-1000, 20)	fixed	0	none
Size_DblN_end_logit_NON_-TRAWL(3)	4.6	-4	(-15, 20)	fixed	0	none
Size_DblN_peak_NON_-TRAWL_DISCARD(4)	49.9	3	(15, 70)	ok	1.5	none
Size_DblN_top_logit_NON_-TRAWL_DISCARD(4)	-15	-4	(-15, 20)	fixed	0	none

Size_DblN_ascend_se_NON_-TRAWL_DISCARD(4)	3.75	3	(-15, 12)	ok	0.44	none
Size_DblN_descend_se_NON_-TRAWL_DISCARD(4)	2.66	4	(-15, 20)	ok	0.951	none
Size_DblN_start_logit_NON_-TRAWL_DISCARD(4)	-999	-3	(-1000, 20)	fixed	0	none
Size_DblN_end_logit_NON_-TRAWL_DISCARD(4)	-0.191	4	(-15, 20)	ok	0.419	none
Size_DblN_peak_-MIDWATER_TRAWL(5)	52.2	3	(15, 79)	ok	2.31	none
Size_DblN_top_logit_-MIDWATER_TRAWL(5)	-15	-4	(-15, 20)	fixed	0	none
Size_DblN_ascend_se_-MIDWATER_TRAWL(5)	4.57	3	(-15, 12)	ok	0.383	none
Size_DblN_descend_se_-MIDWATER_TRAWL(5)	20	-4	(-15, 20)	fixed	0	none
Size_DblN_start_logit_-MIDWATER_TRAWL(5)	-999	-3	(-1000, 20)	fixed	0	none
Size_DblN_end_logit_-MIDWATER_TRAWL(5)	-999	-4	(-1000, 20)	fixed	0	none
Size_DblN_peak_AT_SEA_-HAKE(6)	49.7	3	(15, 70)	ok	1.41	none
Size_DblN_top_logit_AT_-SEA_HAKE(6)	-15	-4	(-15, 20)	fixed	0	none
Size_DblN_ascend_se_AT_-SEA_HAKE(6)	3.59	3	(-15, 12)	ok	0.419	none
Size_DblN_descend_se_AT_-SEA_HAKE(6)	20	-4	(-15, 20)	fixed	0	none
Size_DblN_start_logit_AT_-SEA_HAKE(6)	-999	-2	(-1000, 20)	fixed	0	none
Size_DblN_end_logit_AT_-SEA_HAKE(6)	-999	-4	(-1000, 20)	fixed	0	none
Size_DblN_peak_-TRIENNIAL(7)	21.8	3	(13, 50)	ok	1.94	none
Size_DblN_top_logit_-TRIENNIAL(7)	-8.6	-4	(-15, 20)	fixed	0	none
Size_DblN_ascend_se_-TRIENNIAL(7)	3.53	3	(-15, 12)	ok	0.587	none

Size_DblN_descend_se_-TRIENNIAL(7)	3.95	4	(-15, 20)	ok	0.553	none
Size_DblN_start_logit_-TRIENNIAL(7)	-999	-2	(-1000, 20)	fixed	0	none
Size_DblN_end_logit_-TRIENNIAL(7)	-2.58	4	(-15, 20)	ok	0.321	none
Size_DblN_peak_AK_-SLOPE(8)	37.3	3	(13, 50)	ok	2.38	none
Size_DblN_top_logit_AK_-SLOPE(8)	-15	-4	(-15, 20)	fixed	0	none
Size_DblN_ascend_se_AK_-SLOPE(8)	4.94	3	(-15, 12)	ok	0.425	none
Size_DblN_descend_se_AK_-SLOPE(8)	4.63	4	(-15, 20)	ok	0.381	none
Size_DblN_start_logit_AK_-SLOPE(8)	-999	-2	(-1000, 20)	fixed	0	none
Size_DblN_end_logit_AK_-SLOPE(8)	-10.5	4	(-15, 20)	ok	64.5	none
Size_DblN_peak_WCGBTS(10)	21.1	3	(13, 50)	ok	3.75	none
Size_DblN_top_logit_-WCGBTS(10)	-15	-4	(-15, 20)	fixed	0	none
Size_DblN_ascend_se_-WCGBTS(10)	3.39	3	(-15, 12)	ok	1.07	none
Size_DblN_descend_se_-WCGBTS(10)	4.64	4	(-15, 20)	ok	1.05	none
Size_DblN_start_logit_-WCGBTS(10)	-999	-2	(-1000, 20)	fixed	0	none
Size_DblN_end_logit_-WCGBTS(10)	-0.832	4	(-15, 20)	ok	0.311	none
Size_DblN_peak_BOTTOM_-TRAWL(1)_BLK4repl_1892	44.7	3	(15, 70)	ok	2.95	none
Size_DblN_peak_BOTTOM_-TRAWL(1)_BLK4repl_2002	47.6	3	(15, 70)	ok	1.07	none
Size_DblN_ascend_se_-BOTTOM_TRAWL(1)_-BLK4repl_1892	5.03	3	(-15, 12)	ok	0.51	none
Size_DblN_ascend_se_-BOTTOM_TRAWL(1)_-BLK4repl_2002	4.1	3	(-15, 12)	ok	0.306	none

Size_DblN_descend_se_-BOTTOM_TRAWL(1)_-BLK4repl_1892	2.65	4	(-15, 20)	ok	1.7	none
Size_DblN_descend_se_-BOTTOM_TRAWL(1)_-BLK4repl_2002	2.75	4	(-15, 20)	ok	0.751	none
Size_DblN_end_logit_-BOTTOM_TRAWL(1)_-BLK4repl_1892	-1.59	4	(-15, 20)	ok	0.584	none
Size_DblN_end_logit_-BOTTOM_TRAWL(1)_-BLK4repl_2002	-0.933	4	(-15, 20)	ok	0.324	none
Size_DblN_peak_BOTTOM_-TRAWL_DISCARD(2)_-BLK1repl_1892	47.7	3	(15, 79)	ok	2.49	none
Size_DblN_ascend_se_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	6.32	3	(-15, 12)	ok	0.626	none
Size_DblN_descend_se_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	3.01	4	(-15, 20)	ok	1.19	none
Size_DblN_end_logit_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	-1.7	4	(-15, 20)	ok	0.77	none
Size_DblN_peak_NON_-TRAWL(3)_BLK2repl_1892	46.8	3	(15, 70)	ok	0.484	none
Size_DblN_peak_NON_-TRAWL(3)_BLK2repl_2011	49.5	3	(15, 70)	ok	0.556	none
Size_DblN_ascend_se_NON_-TRAWL(3)_BLK2repl_1892	3.05	3	(-15, 12)	ok	0.207	none
Size_DblN_ascend_se_NON_-TRAWL(3)_BLK2repl_2011	3.81	3	(-15, 12)	ok	0.154	none
Size_DblN_descend_se_NON_-TRAWL(3)_BLK2repl_1892	3.17	4	(-15, 20)	ok	0.242	none
Size_DblN_descend_se_NON_-TRAWL(3)_BLK2repl_2011	2.32	4	(-15, 20)	ok	0.52	none
Size_DblN_end_logit_NON_-TRAWL(3)_BLK2repl_1892	-2.28	4	(-15, 20)	ok	0.258	none

Size_DblN_end_logit_NON_-TRAWL(3)_BLK2repl_2011	-0.625	4	(-15, 20)	ok	0.194	none
Size_DblN_peak_-TRIENNIAL(7)_BLK3repl_1892	17.4	3	(13, 50)	ok	2.64	none
Size_DblN_ascend_se_-TRIENNIAL(7)_BLK3repl_1892	2.09	3	(-15, 12)	ok	1.39	none
Size_DblN_descend_se_-TRIENNIAL(7)_BLK3repl_1892	5.1	4	(-15, 20)	ok	0.636	none
Size_DblN_end_logit_-TRIENNIAL(7)_BLK3repl_1892	-4.28	4	(-15, 20)	ok	1.69	none

Table 21: Likelihood components by source.

Label	Total
TOTAL	7,333.9
Catch	0.0
Equil catch	0.0
Survey	-26.8
Length comp	574.8
Age comp	6,783.5
Recruitment	2.3
InitEQ Regime	0.0
Forecast Recruitment	0.0
Parm priors	0.1
Parm softbounds	0.0
Parm devs	0.0
Crash Pen	0.0

7.3 Model Outputs

Table 22: Summary of reference points and management quantities, including estimates of the 95 percent confidence intervals. SO is spawning output (in trillions of eggs), SPR is the spawning potential ratio, and MSY is maximum sustainable yield.

Reference Point	Estimate	Lower Interval	Upper Interval
Unfished Spawning output	5.573	<1	12.328
Unfished Age 26+ Biomass (mt)	33,189	<1	73,425
Unfished Recruitment (R0)	1,077	<1	2,371
2025 Spawning output	4.860	<1	12.124
2025 Fraction Unfished	0.872	0.617	1.127
Reference Points Based SO40%	—	—	—
Proxy Spawning output SO40%	2.229	<1	4.931
SPR Resulting in SO40%	0.458	0.458	0.458
Exploitation Rate Resulting in SO40%	0.048	0.045	0.051
Yield with SPR Based On SO40% (mt)	545	<1	1,200
Reference Points Based on SPR Proxy for MSY	—	—	—
Proxy Spawning output (SPR50)	2.487	<1	5.500
SPR50	0.500	—	—
Exploitation Rate Corresponding to SPR50	0.040	0.038	0.042
Yield with SPR50 at SO SPR (mt)	519	<1	1,142
Reference Points Based on Estimated MSY Values	—	—	—
Spawning output at MSY (SO MSY)	1.477	<1	3.270
SPR MSY	0.337	0.334	0.339
Exploitation Rate Corresponding to SPR MSY	0.085	0.079	0.090
MSY (mt)	585	<1	1,285

Table 23: Time series of population estimates from the base model.

Year	Total Biomass (mt)	Spawning output	Total Biomass 26+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	1-SPR	Exploitation Rate
1892	47083.9	6.000	33189.4	1.000	997	19	0.018	0.001
1893	47062.1	6.000	33176.0	1.000	995	19	0.018	0.001
1894	47039.3	6.000	33162.3	0.999	993	19	0.018	0.001
1895	47014.7	6.000	33148.1	0.999	992	5	0.005	0.000
1896	47003.5	6.000	33143.4	0.999	990	1	0.001	0.000
1897	46992.9	6.000	33141.1	0.999	989	1	0.001	0.000
1898	46978.1	6.000	33138.8	0.999	987	1	0.001	0.000
1899	46959.0	6.000	33136.7	0.998	986	1	0.001	0.000
1900	46934.1	6.000	33134.3	0.998	984	2	0.002	0.000
1901	46903.3	6.000	33131.6	0.998	983	2	0.002	0.000
1902	46866.5	6.000	33128.8	0.998	982	3	0.002	0.000
1903	46823.7	6.000	33125.9	0.998	981	3	0.003	0.000
1904	46775.1	6.000	33122.9	0.998	980	4	0.003	0.000
1905	46720.8	6.000	33120.1	0.998	979	4	0.004	0.000
1906	46661.2	6.000	33117.2	0.997	978	4	0.004	0.000
1907	46596.6	6.000	33114.5	0.997	978	5	0.005	0.000
1908	46527.4	6.000	33111.6	0.996	977	8	0.008	0.000
1909	46451.2	6.000	33106.7	0.996	977	6	0.006	0.000
1910	46374.0	6.000	33103.2	0.995	977	6	0.006	0.000
1911	46293.5	6.000	33099.3	0.994	977	7	0.007	0.000
1912	46210.0	6.000	33095.0	0.992	977	7	0.007	0.000
1913	46124.0	6.000	33090.2	0.991	978	8	0.008	0.000
1914	46035.9	6.000	33085.0	0.989	978	8	0.008	0.000
1915	45946.0	6.000	33079.3	0.988	979	10	0.010	0.000
1916	45853.0	5.000	33072.1	0.986	981	9	0.009	0.000
1917	45760.8	5.000	33065.5	0.984	982	10	0.010	0.000
1918	45667.9	5.000	32988.9	0.982	984	55	0.053	0.002
1919	45524.5	5.000	32878.6	0.979	986	26	0.025	0.001
1920	45415.0	5.000	32787.6	0.977	988	23	0.023	0.001
1921	45309.6	5.000	32697.5	0.975	991	23	0.023	0.001
1922	45206.3	5.000	32606.9	0.972	994	18	0.018	0.001
1923	45110.5	5.000	32519.4	0.970	997	20	0.020	0.001
1924	45014.5	5.000	32430.0	0.968	1001	32	0.031	0.001

1925	44907.9	5.000	32332.4	0.965	1004	38	0.037	0.001
1926	44797.4	5.000	32230.3	0.963	1008	54	0.053	0.002
1927	44671.7	5.000	32116.6	0.960	1011	69	0.067	0.002
1928	44533.5	5.000	31992.6	0.956	1015	72	0.070	0.002
1929	44396.1	5.000	31866.7	0.953	1018	66	0.065	0.002
1930	44269.9	5.000	31745.2	0.950	1021	67	0.066	0.002
1931	44147.5	5.000	31623.7	0.946	1023	44	0.044	0.001
1932	44056.3	5.000	31519.4	0.944	1026	25	0.025	0.001
1933	43991.2	5.000	31429.9	0.942	1028	35	0.035	0.001
1934	43920.0	5.000	31335.3	0.939	1029	42	0.042	0.001
1935	43845.7	5.000	31237.4	0.937	1031	34	0.034	0.001
1936	43785.7	5.000	31147.6	0.935	1032	61	0.060	0.002
1937	43700.7	5.000	31041.7	0.933	1034	53	0.053	0.002
1938	43629.6	5.000	30944.1	0.930	1036	56	0.055	0.002
1939	43561.2	5.000	30848.4	0.928	1038	28	0.029	0.001
1940	43528.0	5.000	30775.1	0.927	1042	59	0.059	0.002
1941	43465.3	5.000	30684.8	0.925	1047	102	0.099	0.003
1942	43360.4	5.000	30569.0	0.922	1053	125	0.120	0.004
1943	43234.3	5.000	30440.0	0.918	1061	257	0.229	0.008
1944	42966.6	5.000	30222.7	0.912	1071	85	0.086	0.003
1945	42897.6	5.000	30125.3	0.910	1083	50	0.054	0.002
1946	42873.8	5.000	30056.5	0.909	1098	69	0.070	0.002
1947	42834.5	5.000	29977.4	0.907	1116	41	0.043	0.001
1948	42832.3	5.000	29920.5	0.906	1138	44	0.045	0.001
1949	42833.4	5.000	29866.1	0.905	1163	31	0.032	0.001
1950	42856.7	5.000	29826.0	0.905	1190	53	0.054	0.002
1951	42863.4	5.000	29776.9	0.904	1221	59	0.059	0.002
1952	42872.5	5.000	29729.8	0.903	1254	38	0.039	0.001
1953	42914.6	5.000	29702.9	0.903	1287	20	0.021	0.001
1954	42987.4	5.000	29694.6	0.904	1319	36	0.037	0.001
1955	43055.7	5.000	29683.4	0.904	1348	32	0.033	0.001
1956	43142.6	5.000	29681.7	0.904	1370	20	0.022	0.001
1957	43257.6	5.000	29693.7	0.905	1385	35	0.036	0.001
1958	43373.5	5.000	29701.5	0.905	1391	15	0.016	0.001
1959	43529.1	5.000	29726.2	0.906	1390	22	0.023	0.001
1960	43694.4	5.000	29748.9	0.908	1382	23	0.024	0.001
1961	43877.5	5.000	29774.5	0.909	1369	26	0.027	0.001
1962	44075.3	5.000	29800.6	0.911	1349	32	0.033	0.001
1963	44284.0	5.000	29825.9	0.912	1323	23	0.024	0.001

1964	44518.0	5.000	29859.2	0.915	1290	32	0.032	0.001
1965	44756.5	5.000	29889.6	0.917	1252	31	0.033	0.001
1966	45007.3	5.000	29925.6	0.920	1214	117	0.118	0.004
1967	45172.5	5.000	29923.6	0.921	1180	108	0.108	0.004
1968	45350.9	5.000	29929.2	0.923	1154	172	0.166	0.006
1969	45459.8	5.000	29909.1	0.925	1137	51	0.049	0.002
1970	45698.2	5.000	29950.5	0.929	1126	22	0.023	0.001
1971	45963.2	5.000	30017.2	0.934	1119	68	0.067	0.002
1972	46171.9	5.000	30073.8	0.938	1113	76	0.075	0.003
1973	46360.5	5.000	30138.7	0.942	1112	75	0.073	0.002
1974	46538.0	5.000	30218.4	0.947	1119	77	0.073	0.003
1975	46699.6	5.000	30312.4	0.952	1121	43	0.041	0.001
1976	46884.1	5.000	30442.8	0.958	1137	19	0.018	0.001
1977	47079.9	5.000	30607.7	0.964	1161	166	0.135	0.005
1978	47098.9	5.000	30702.9	0.967	1198	69	0.063	0.002
1979	47211.6	5.000	30883.5	0.972	1199	185	0.155	0.006
1980	47184.1	5.000	31017.5	0.974	1185	99	0.090	0.003
1981	47240.3	5.000	31220.4	0.978	1165	131	0.116	0.004
1982	47250.5	5.000	31415.7	0.981	1089	167	0.148	0.005
1983	47212.0	5.000	31598.8	0.983	1092	126	0.112	0.004
1984	47209.9	5.000	31799.8	0.985	1265	144	0.129	0.005
1985	47180.5	5.000	31984.2	0.986	1245	299	0.247	0.009
1986	46973.3	5.000	32061.1	0.984	1026	428	0.329	0.013
1987	46618.4	5.000	32029.9	0.978	1180	571	0.413	0.018
1988	46101.9	5.000	31874.4	0.969	1998	351	0.292	0.011
1989	45831.5	5.000	31826.3	0.965	1288	418	0.348	0.013
1990	45493.3	5.000	31712.6	0.958	916	244	0.225	0.008
1991	45355.7	5.000	31661.4	0.955	1057	299	0.272	0.009
1992	45166.2	5.000	31544.3	0.951	1185	306	0.272	0.010
1993	44974.8	5.000	31380.7	0.946	1371	327	0.286	0.010
1994	44765.0	5.000	31174.1	0.941	1031	306	0.268	0.010
1995	44585.0	5.000	30956.8	0.936	617	745	0.511	0.024
1996	43920.9	5.000	30429.1	0.922	542	339	0.295	0.011
1997	43708.3	5.000	30161.5	0.916	549	303	0.269	0.010
1998	43527.3	5.000	29910.1	0.911	766	441	0.358	0.015
1999	43180.8	5.000	29565.4	0.904	1734	256	0.234	0.009
2000	43021.5	5.000	29347.8	0.900	1208	183	0.166	0.006
2001	42941.9	5.000	29177.1	0.898	1118	114	0.114	0.004
2002	42922.2	5.000	29075.6	0.899	805	74	0.072	0.003

2003	42937.0	5.000	29016.9	0.900	593	99	0.094	0.003
2004	42918.1	5.000	28977.2	0.901	953	115	0.104	0.004
2005	42874.2	5.000	28938.0	0.902	1040	138	0.120	0.005
2006	42798.0	5.000	28886.3	0.903	810	127	0.117	0.004
2007	42720.5	5.000	28848.1	0.903	1252	187	0.164	0.006
2008	42573.4	5.000	28728.9	0.902	1785	218	0.185	0.008
2009	42392.0	5.000	28602.2	0.900	1089	228	0.204	0.008
2010	42196.0	5.000	28625.6	0.897	1915	261	0.229	0.009
2011	41976.8	5.000	28617.8	0.893	1049	210	0.170	0.007
2012	41845.5	5.000	28464.1	0.889	2824	244	0.194	0.009
2013	41704.7	5.000	28413.6	0.885	966	156	0.136	0.005
2014	41687.5	5.000	29079.4	0.883	703	91	0.083	0.003
2015	41772.3	5.000	29234.8	0.881	652	132	0.115	0.005
2016	41844.7	5.000	29064.7	0.879	861	149	0.129	0.005
2017	41921.5	5.000	28997.5	0.877	2147	156	0.134	0.005
2018	42005.4	5.000	29029.0	0.874	1326	242	0.190	0.008
2019	42027.2	5.000	29142.7	0.870	1184	227	0.182	0.008
2020	42080.1	5.000	28996.6	0.866	837	106	0.091	0.004
2021	42269.7	5.000	28616.1	0.865	913	93	0.080	0.003
2022	42478.7	5.000	28190.3	0.866	1006	117	0.099	0.004
2023	42664.6	5.000	27757.0	0.867	1056	98	0.084	0.004
2024	42866.0	5.000	27525.2	0.869	1064	119	0.100	0.004
2025	43039.4	5.000	28081.0	0.872	1065	155	0.127	0.006
2026	43166.1	5.000	28180.0	0.875	1065	187	0.148	0.007
2027	43251.0	5.000	28183.7	0.877	1065	844	0.462	0.030
2028	42687.5	5.000	27441.1	0.865	1064	826	0.459	0.030
2029	42139.3	5.000	26557.1	0.854	1062	809	0.457	0.030
2030	41605.4	5.000	25992.6	0.843	1061	792	0.454	0.030
2031	41085.7	5.000	25518.1	0.833	1059	776	0.452	0.030
2032	40580.6	5.000	24886.0	0.823	1058	760	0.449	0.031
2033	40090.6	5.000	24613.1	0.813	1056	745	0.447	0.030
2034	39615.3	4.000	24747.7	0.804	1055	729	0.444	0.029
2035	39156.5	4.000	24365.6	0.795	1054	714	0.441	0.029
2036	38714.6	4.000	24599.6	0.786	1052	699	0.439	0.028

7.4 Sensitivity Analyses

Table 24: Base model sensitivity to the removal of data sources (indices).

Label	Base	- Triennial	- AK Slope	-NW slope	- WCGBTS	No indices
Diff. in likelihood from base model						
Total	0	-15.45	-52.03	1.04	-2058.16	-2161.34
Index	0	7.779	0.411	1.032	17.579	-8.01
Length comp	0	-21.986	-52.007	0	-92.25	-173.434
Age comp	0	-0.12	-0.24	0	-1976.52	-1973.38
Recruitment	0	-1.13	-0.21	-0.001	-6.997	-6.552
Parm priors	0	0.001	0.006	0	0.001	0.007
Estimates of key parameters						
Recruitment unfished thousands	1077.35	920.223	1055.03	1073.53	667.8	627.775
log(R0)	6.982	6.825	6.961	6.979	6.504	6.442
NatM uniform Female	0.039	0.039	0.039	0.039	0.039	0.039
NatM uniform Male	0.036	0.036	0.036	0.036	0.036	0.036
L at Amax Female	60.1	60.1	60.1	60.1	61.9	62.3
L at Amax Male	57.8	57.8	57.8	57.8	58.7	58.8
Estimates of derived quantities						
Unfished age 26+ bio 1000 mt	33.189	28.365	32.378	33.071	20.523	19.216
B0 trillions of eggs	5.573	4.764	5.421	5.553	3.434	3.218
B2025 trillions of eggs	4.86	3.967	4.693	4.838	2.551	2.304
Fraction unfished 2025	0.872	0.833	0.866	0.871	0.743	0.716
Fishing intensity 2024	0.1	0.12	0.102	0.1	0.183	0.2
Catchability for WCGBTS	0.075	0.09	0.076	0.075	NA	37.946

Table 25: Base model sensitivity to the removal of data sources (length compositions by fleet).

Label	Base	- bottom trawl	- non-trawl	- mid-water trawl	- ASHOP	- Triennial	- AK slope	- NW slope	- WCGBTS
Diff. in likelihood from base model									
Total	0	-130.63	-251.33	-59.3	-26.55	-25.25	-52.49	0.01	-83.81
Index	0	1.268	0.219	-0.117	0.005	-2.616	-0.048	0	0.02
Length comp	0	-116.271	-222.756	-58.144	-25.248	-22.233	-51.94	0	-82.401
Age comp	0	-13	-26.82	-0.63	-1.39	0.26	-0.29	0	-1.49
Recruitment	0	-2.531	-1.933	-0.42	0.076	-0.673	-0.226	0	0.066
Parm priors	0	-0.111	-0.064	0.005	-0.004	0	0.005	0	-0.006
Estimates of key parameters									
Recruitment unfished millions	1.077	0.268	0.393	1.509	1.599	0.952	1.063	1.077	1.148
log(R0)	6.982	5.59	5.974	7.319	7.377	6.859	6.969	6.982	7.046
NatM uniform Female	0.039	0.034	0.037	0.039	0.039	0.039	0.039	0.039	0.039
NatM uniform Male	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
L at Amax Female	60.1	60.2	59.1	60.2	60.5	60.1	60.1	60.1	60.1
L at Amax Male	57.8	57.6	57.4	58	58.2	57.8	57.8	57.8	57.9
Estimates of derived quantities									
Unfished age 26+ bio 1000 mt	33.189	9.401	12.376	46.655	50.186	29.351	32.623	33.189	35.59
B0 trillions of eggs	5.573	1.757	2.108	7.821	8.504	4.931	5.462	5.573	6.005
B2025 trillions of eggs	4.86	0.609	1.172	7.217	7.838	4.152	4.737	4.86	5.328
Fraction unfished 2025	0.872	0.347	0.556	0.923	0.922	0.842	0.867	0.872	0.887
Fishing intensity 2024	0.1	0.544	0.321	0.073	0.064	0.115	0.101	0.1	0.092
Catchability for WCGBTS	0.075	0.34	0.237	0.052	0.048	0.086	0.076	0.075	0.069

Table 26: Base model sensitivity to the removal of data sources (length compositions by source).

Label	Base	- fishery	- survey	no lengths
Diff. in likelihood from base model				
Total	0	-454.01	-162.74	-616.56
Index	0	1.07	-3.926	-1.946
Length comp	0	-415.38	-157.7	-574.802
Age comp	0	-37.09	-0.45	-37.83
Recruitment	0	-2.662	-0.674	-2.972
Parm priors	0	0.036	-0.001	0.975
Estimates of key parameters				
Recruitment unfished thousands	1077.35	361.632	1028.83	816.125
log(R0)	6.982	5.891	6.936	6.705
NatM uniform Female	0.039	0.04	0.039	0.053
NatM uniform Male	0.036	0.036	0.036	0.036
L at Amax Female	60.1	57.4	60.2	56.1
L at Amax Male	57.8	56.5	57.9	56.8
Estimates of derived quantities				
Unfished age 26+ bio 1000 mt	33.189	9.973	31.806	17.384
B0 trillions of eggs	5.573	1.518	5.355	1.77
B2025 trillions of eggs	4.86	0.714	4.61	1.311
Fraction unfished 2025	0.872	0.47	0.861	0.741
Fishing intensity 2024	0.1	0.404	0.105	0.161
Catchability for WCGBTS	0.075	0.293	6.495	0.224

Table 27: Base model sensitivity to the removal of data sources (age compositions by fleet).

Label	Base	- bottom trawl	- non-trawl	- mid-water trawl	- ASHOP	- WGCBTS	- fishery	no ages
Diff. in likelihood from base model								
Total	0	-467.49	-332.86	-182.78	-3886.09	-1988.28	-4868.14	-6839.43
Index	0	0.219	0.016	0.09	-0.461	0.005	-0.207	-1.073
Length comp	0	-0.578	-2.264	0.085	-30.735	-5.666	-37.1	-48.777
Age comp	0	-467.57	-330.26	-183.29	-3854.05	-1975.71	-4829.47	-6783.5
Recruitment	0	0.43	-0.359	0.33	-0.821	-6.927	-1.329	-5.997
Parm priors	0	-0.001	-0.003	-0.003	-0.03	0.007	-0.045	-0.092
Estimates of key parameters								
Recruitment unfished thousands	1077.35	915.363	1137.35	1048.32	484.845	664.269	501.966	637.826
log(R0)	6.982	6.819	7.036	6.955	6.184	6.499	6.219	6.458
NatM uniform Female	0.039	0.039	0.039	0.039	0.038	0.039	0.038	0.036
NatM uniform Male	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
L at Amax Female	60.1	60	60	60.1	59.6	61.7	58.4	55.6
L at Amax Male	57.8	57.7	57.7	57.8	57.4	58.7	56.9	54.5
Estimates of derived quantities								
Unfished age 26+ bio 1000 mt	33.189	28.248	34.973	32.369	15.163	20.331	15.658	19.062
B0 trillions of eggs	5.573	4.765	5.881	5.454	2.619	3.385	3.913	3.3
B2025 trillions of eggs	4.86	3.921	5.114	4.706	1.849	2.489	1.72	2.432
Fraction unfished 2025	0.872	0.823	0.87	0.863	0.706	0.735	0.44	0.737
Fishing intensity 2024	0.1	0.12	0.095	0.103	0.231	0.185	0.169	0.167
Catchability for WCGBTS	0.075	0.09	0.071	0.077	0.204	0.094	0.213	0.179

Table 28: Likelihood values and estimates of key parameters and derived quantities from each data weighting sensitivity.

Label	Type	Reference	No data weighting	McAllister & Ianelli	Dirichlet
AIC					
	AIC	15,093.86	43,301.40	17,672.56	71,789.20
	deltaAIC	0.00	28,207.54	2,578.70	56,695.34
Survey likelihood					
	ALL	-26.81	-27.29	-27.44	-27.28
	TRIENNIAL	-7.76	-7.97	-8.15	-7.94
	AK_SLOPE	-0.53	-0.56	-0.55	-0.56
	NW_SLOPE	-1.03	-1.03	-1.04	-1.03
	WCGBTS	-17.49	-17.73	-17.70	-17.74
Lt likelihood					
	ALL	574.80	3,390.67	1,911.44	9,927.86
	BOTTOM_TRAWL	79.11	603.67	316.55	2,082.76
	BOTTOM_TRAWL_DISCARD	27.15	310.72	48.27	591.79
	NON_TRAWL	179.64	580.12	301.83	1,987.26
	NON_TRAWL_DISCARD	46.63	188.12	116.18	462.50
	MIDWATER_TRAWL	58.94	147.40	118.79	492.65
	AT_SEA_HAKE	25.42	670.51	323.76	2,156.43
	TRIENNIAL	22.43	135.04	85.56	451.23
	AK_SLOPE	52.31	52.49	52.48	138.45
	NW_SLOPE	0.00	0.00	0.00	0.00
	WCGBTS	83.19	702.60	548.01	1,564.78
Age likelihood					
	ALL	6,783.50	18,052.20	6,726.97	25,665.50
	BOTTOM_TRAWL	464.26	4,116.95	1,274.69	5,974.47
	BOTTOM_TRAWL_DISCARD	0.00	0.00	0.00	0.00
	NON_TRAWL	331.37	4,013.67	1,089.13	5,922.91
	NON_TRAWL_DISCARD	0.00	0.00	0.00	0.00
	MIDWATER_TRAWL	182.47	1,186.38	559.07	1,538.07
	AT_SEA_HAKE	3,847.50	5,317.75	1,597.42	8,053.07
	TRIENNIAL	0.00	0.00	0.00	0.00
	AK_SLOPE	0.00	0.00	0.00	0.00

	NW_SLOPE	0.00	0.00	0.00	0.00
	WCGBTS	1,957.89	3,417.43	2,206.67	4,176.94
Parameters					
	NatM_uniform_Fem_GP_1	0.04	0.04	0.04	0.04
	L_at_Amin_Fem_GP_1	-3.10	-1.88	-3.27	-1.60
	L_at_Amax_Fem_GP_1	60.08	59.82	59.23	59.76
	VonBert_K_Fem_GP_1	0.08	0.08	0.08	0.08
	CV_young_Fem_GP_1	0.05	0.08	0.04	0.08
	CV_old_Fem_GP_1	0.09	0.10	0.10	0.10
	Wtlen_1_Fem_GP_1	0.00	0.00	0.00	0.00
	Wtlen_2_Fem_GP_1	3.15	3.15	3.15	3.15
	Mat50%_Fem_GP_1	46.53	46.53	46.53	46.53
	Mat_slope_Fem_GP_1	-0.25	-0.25	-0.25	-0.25
	Eggs_scalar_Fem_GP_1	0.00	0.00	0.00	0.00
	Eggs_exp_len_Fem_GP_1	4.04	4.04	4.04	4.04
	NatM_uniform_Mal_GP_1	0.04	0.04	0.04	0.04
	L_at_Amin_Mal_GP_1	-2.67	-0.98	-2.80	-0.71
	L_at_Amax_Mal_GP_1	57.83	57.81	57.35	57.73
	VonBert_K_Mal_GP_1	0.08	0.08	0.09	0.08
	CV_young_Mal_GP_1	0.09	0.11	0.07	0.11
	CV_old_Mal_GP_1	0.08	0.09	0.09	0.09
	Wtlen_1_Mal_GP_1	0.00	0.00	0.00	0.00
	Wtlen_2_Mal_GP_1	3.07	3.07	3.07	3.07
	CohortGrowDev	1.00	1.00	1.00	1.00
	FracFemale_GP_1	0.50	0.50	0.50	0.50
	SR_LN(R0)	6.98	6.29	6.29	6.23
	SR_BH_steep	0.72	0.72	0.72	0.72
	SR_sigmaR	0.50	0.50	0.50	0.50
	SR_regime	0.00	0.00	0.00	0.00
	SR_autocorr	0.00	0.00	0.00	0.00
	LnQ_base_TRIENNIAL(7)	-1.47	-1.09	-0.90	-1.04
	LnQ_base_AK_SLOPE(8)	-3.10	-2.80	-2.74	-2.74
	LnQ_base_NW_SLOPE(9)	-2.03	-1.74	-1.68	-1.69
	LnQ_base_WCGBTS(10)	-2.60	-1.84	-1.73	-1.79
	LnQ_base_TRIENNIAL(7)_BLK3repl_1892	-2.26	-2.06	-1.94	-2.02
	Size_DblN_peak_BOTTOM_TRAWL(1)	49.34	49.49	49.62	49.76
	Size_DblN_top_logit_BOTTOM_TRAWL(1)	-11.52	-11.52	-11.52	-11.52

Size_DblN_ascend_se_BOTTOM_-TRAWL(1)	4.57	4.75	4.76	4.77
Size_DblN_descend_se_BOTTOM_-TRAWL(1)	2.95	2.87	2.93	2.84
Size_DblN_start_logit_BOTTOM_-TRAWL(1)	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_BOTTOM_-TRAWL(1)	-0.64	-0.22	-0.16	-0.13
Size_DblN_peak_BOTTOM_TRAWL_-DISCARD(2)	25.26	24.65	24.82	24.82
Size_DblN_top_logit_BOTTOM_-TRAWL_DISCARD(2)	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_BOTTOM_-TRAWL_DISCARD(2)	4.89	4.75	4.78	4.60
Size_DblN_descend_se_BOTTOM_-TRAWL_DISCARD(2)	3.84	3.80	3.80	3.71
Size_DblN_start_logit_BOTTOM_-TRAWL_DISCARD(2)	-15.00	-15.00	-15.00	-15.00
Size_DblN_end_logit_BOTTOM_-TRAWL_DISCARD(2)	-3.81	-4.13	-4.09	-3.44
Size_DblN_peak_NON_TRAWL(3)	50.28	50.26	50.73	50.66
Size_DblN_top_logit_NON_TRAWL(3)	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_NON_TRAWL(3)	3.86	4.01	4.04	4.05
Size_DblN_descend_se_NON_TRAWL(3)	20.00	20.00	20.00	20.00
Size_DblN_start_logit_NON_TRAWL(3)	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_NON_TRAWL(3)	4.60	4.60	4.60	4.60
Size_DblN_peak_NON_TRAWL_-DISCARD(4)	49.95	51.33	51.43	51.69
Size_DblN_top_logit_NON_TRAWL_-DISCARD(4)	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_NON_TRAWL_-DISCARD(4)	3.75	4.08	4.10	4.15
Size_DblN_descend_se_NON_TRAWL_-DISCARD(4)	2.66	1.88	1.86	1.59
Size_DblN_start_logit_NON_TRAWL_-DISCARD(4)	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_NON_TRAWL_-DISCARD(4)	-0.19	0.34	0.45	0.44
Size_DblN_peak_MIDWATER_TRAWL(5)	52.18	54.04	54.72	54.85

Size_DblN_top_logit_MIDWATER_-TRAWL(5)	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_MIDWATER_-TRAWL(5)	4.57	4.87	4.92	4.94
Size_DblN_descend_se_MIDWATER_-TRAWL(5)	20.00	20.00	20.00	20.00
Size_DblN_start_logit_MIDWATER_-TRAWL(5)	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_MIDWATER_-TRAWL(5)	-999.00	-999.00	-999.00	-999.00
Size_DblN_peak_AT_SEA_HAKE(6)	49.71	51.29	51.71	51.62
Size_DblN_top_logit_AT_SEA_HAKE(6)	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_AT_SEA_HAKE(6)	3.59	3.85	3.93	3.89
Size_DblN_descend_se_AT_SEA_HAKE(6)	20.00	20.00	20.00	20.00
Size_DblN_start_logit_AT_SEA_HAKE(6)	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_AT_SEA_HAKE(6)	-999.00	-999.00	-999.00	-999.00
Size_DblN_peak_TRIENNIAL(7)	21.78	21.79	21.46	21.87
Size_DblN_top_logit_TRIENNIAL(7)	-8.60	-8.60	-8.60	-8.60
Size_DblN_ascend_se_TRIENNIAL(7)	3.53	3.56	3.46	3.58
Size_DblN_descend_se_TRIENNIAL(7)	3.95	3.79	3.82	3.76
Size_DblN_start_logit_TRIENNIAL(7)	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_TRIENNIAL(7)	-2.58	-2.27	-2.38	-2.21
Size_DblN_peak_AK_SLOPE(8)	37.29	38.04	37.40	38.40
Size_DblN_top_logit_AK_SLOPE(8)	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_AK_SLOPE(8)	4.94	5.02	5.04	5.06
Size_DblN_descend_se_AK_SLOPE(8)	4.63	4.75	4.87	4.69
Size_DblN_start_logit_AK_SLOPE(8)	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_AK_SLOPE(8)	-10.48	-10.15	-10.06	-4.05
Size_DblN_peak_WCGBTS(10)	21.09	21.46	21.56	21.55
Size_DblN_top_logit_WCGBTS(10)	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_WCGBTS(10)	3.39	3.56	3.55	3.59
Size_DblN_descend_se_WCGBTS(10)	4.64	4.42	4.41	4.35
Size_DblN_start_logit_WCGBTS(10)	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_WCGBTS(10)	-0.83	-1.01	-1.01	-0.94
Size_DblN_peak_BOTTOM_TRAWL(1)_-BLK4repl_1892	44.71	45.85	46.24	45.99
Size_DblN_peak_BOTTOM_TRAWL(1)_-BLK4repl_2002	47.64	48.70	50.06	48.95

Size_DblN_ascend_se_BOTTOM_-TRAWL(1)_BLK4repl_1892	5.03	5.10	5.19	5.10
Size_DblN_ascend_se_BOTTOM_-TRAWL(1)_BLK4repl_2002	4.10	4.22	4.49	4.24
Size_DblN_descend_se_BOTTOM_-TRAWL(1)_BLK4repl_1892	2.65	2.15	1.84	2.05
Size_DblN_descend_se_BOTTOM_-TRAWL(1)_BLK4repl_2002	2.75	2.30	-0.18	2.16
Size_DblN_end_logit_BOTTOM_-TRAWL(1)_BLK4repl_1892	-1.59	-1.07	-0.89	-1.01
Size_DblN_end_logit_BOTTOM_-TRAWL(1)_BLK4repl_2002	-0.93	-0.34	-0.15	-0.26
Size_DblN_peak_BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	47.68	48.66	48.48	47.32
Size_DblN_ascend_se_BOTTOM_-TRAWL_DISCARD(2)_BLK1repl_1892	6.32	6.76	6.93	7.17
Size_DblN_descend_se_BOTTOM_-TRAWL_DISCARD(2)_BLK1repl_1892	3.01	2.86	2.93	2.36
Size_DblN_end_logit_BOTTOM_-TRAWL_DISCARD(2)_BLK1repl_1892	-1.70	-1.16	-1.08	-0.26
Size_DblN_peak_NON_TRAWL(3)_-BLK2repl_1892	46.77	47.32	47.35	47.42
Size_DblN_peak_NON_TRAWL(3)_-BLK2repl_2011	49.49	50.04	50.10	50.23
Size_DblN_ascend_se_NON_TRAWL(3)_-BLK2repl_1892	3.05	3.13	3.16	3.15
Size_DblN_ascend_se_NON_TRAWL(3)_-BLK2repl_2011	3.81	3.97	3.99	3.99
Size_DblN_descend_se_NON_TRAWL(3)_-BLK2repl_1892	3.17	3.15	3.19	3.13
Size_DblN_descend_se_NON_TRAWL(3)_-BLK2repl_2011	2.32	1.88	1.85	1.77
Size_DblN_end_logit_NON_TRAWL(3)_-BLK2repl_1892	-2.28	-1.84	-1.75	-1.79
Size_DblN_end_logit_NON_TRAWL(3)_-BLK2repl_2011	-0.62	-0.16	-0.08	-0.07
Size_DblN_peak_TRIENNIAL(7)_-BLK3repl_1892	17.36	17.27	17.03	17.32

	Size_DblN_ascend_se_TRIENNIAL(7)_-BLK3repl_1892	2.09	2.13	2.01	2.16
	Size_DblN_descend_se_TRIENNIAL(7)_-BLK3repl_1892	5.10	5.13	5.17	5.12
	Size_DblN_end_logit_TRIENNIAL(7)_-BLK3repl_1892	-4.28	-3.50	-3.58	-3.41
	ln(DM_theta)_Len_P1				5.98
	ln(DM_theta)_Len_P2				1.12
	ln(DM_theta)_Len_P3				5.19
	ln(DM_theta)_Len_P4				5.63
	ln(DM_theta)_Len_P5				5.78
	ln(DM_theta)_Len_P6				5.41
	ln(DM_theta)_Len_P7				4.77
	ln(DM_theta)_Len_P8				4.24
	ln(DM_theta)_Len_P9				4.59
	ln(DM_theta)_Age_P10				7.80
	ln(DM_theta)_Age_P11				7.64
	ln(DM_theta)_Age_P12				6.86
	ln(DM_theta)_Age_P13				7.50
	ln(DM_theta)_Age_P14				8.98
Derived quantities					
	SB0	5.57	2.73	2.70	2.53
	SSB_2025	4.86	2.52	2.24	2.28
	Bratio_2025	0.87	0.92	0.83	0.90
	MSY_SPR	519.31	258.17	260.76	242.60
	F_SPR	0.04	0.04	0.04	0.04

Table 29: Likelihood values and estimates of key parameters and derived quantities from each ageing error sensitivity.

Label	Type	Reference	No ageing error	No trawl AE	No non-trawl AE	No midwater AE	No ASHOP AE	No WCGBTS AE
AIC								
	AIC	15,093.86	14,838.12	15,071.72	15,086.94	15,099.04	15,077.40	14,954.82
	deltaAIC	0.00	-255.74	-22.14	-6.92	5.18	-16.46	-139.04
Survey likelihood								
	ALL	-26.81	-25.49	-26.60	-26.74	-26.76	-26.05	-26.00
	TRIENNIAL	-7.76	-6.92	-7.60	-7.77	-7.72	-7.22	-7.22
	AK_SLOPE	-0.53	-0.47	-0.52	-0.51	-0.53	-0.50	-0.50
	NW_SLOPE	-1.03	-1.01	-1.03	-1.02	-1.03	-1.02	-1.02
	WCGBTS	-17.49	-17.10	-17.46	-17.44	-17.48	-17.31	-17.26
Survey lambda								
Lt likelihood								
	ALL	574.80	581.07	574.53	573.23	575.15	582.96	585.36
	BOTTOM_TRAWL	79.11	80.01	78.98	78.77	79.14	79.57	80.82
	BOTTOM_TRAWL_DISCARD	27.15	27.19	27.12	27.08	27.14	27.08	27.14
	NON_TRAWL	179.64	177.06	177.86	178.30	179.84	179.99	181.51
	NON_TRAWL_DISCARD	46.63	46.60	46.44	46.49	46.64	46.91	46.90
	MIDWATER_TRAWL	58.94	58.47	58.73	58.48	58.91	58.82	59.15
	AT_SEA_HAKE	25.42	26.70	25.15	24.84	25.49	26.85	26.54
	TRIENNIAL	22.43	25.78	24.01	23.16	22.42	25.73	25.14
	AK_SLOPE	52.31	53.38	53.01	53.06	52.29	53.04	53.29
	NW_SLOPE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	WCGBTS	83.19	85.86	83.25	83.05	83.26	84.98	84.88
Age likelihood								
	ALL	6,783.50	6,641.80	6,773.06	6,781.02	6,785.56	6,764.30	6,696.84
	BOTTOM_TRAWL	464.26	450.06	447.39	463.75	464.92	469.80	460.46
	BOTTOM_TRAWL_DISCARD	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	NON_TRAWL	331.37	324.77	332.27	323.64	331.55	332.18	328.35
	NON_TRAWL_DISCARD	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	MIDWATER_TRAWL	182.47	186.06	181.89	181.81	185.22	186.59	183.16

	AT_SEA_HAKE	3,847.50	3,794.07	3,848.03	3,847.43	3,846.76	3,796.19	3,852.55
	TRIENNIAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	AK_SLOPE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	NW_SLOPE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	WCGBTS	1,957.89	1,886.85	1,963.47	1,964.40	1,957.12	1,979.54	1,872.32
Parameters								
	NatM_uniform_Fem_GP_1	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	L_at_Amin_Fem_GP_1	-3.10	-2.29	-2.66	-2.51	-3.14	-3.29	-1.98
	L_at_Amax_Fem_GP_1	60.08	59.94	60.10	60.07	60.08	59.77	60.27
	VonBert_K_Fem_GP_1	0.08	0.08	0.08	0.08	0.08	0.08	0.08
	CV_young_Fem_GP_1	0.05	0.16	0.05	0.05	0.05	0.12	0.14
	CV_old_Fem_GP_1	0.09	0.10	0.09	0.10	0.09	0.09	0.09
	Wtlen_1_Fem_GP_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Wtlen_2_Fem_GP_1	3.15	3.15	3.15	3.15	3.15	3.15	3.15
	Mat50%_Fem_GP_1	46.53	46.53	46.53	46.53	46.53	46.53	46.53
	Mat_slope_Fem_GP_1	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25
	Eggs_scalar_Fem_GP_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Eggs_exp_len_Fem_GP_1	4.04	4.04	4.04	4.04	4.04	4.04	4.04
	NatM_uniform_Mal_GP_1	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	L_at_Amin_Mal_GP_1	-2.67	-2.03	-1.84	-1.70	-2.78	-2.82	-1.67
	L_at_Amax_Mal_GP_1	57.83	57.78	57.87	57.84	57.82	57.72	58.02
	VonBert_K_Mal_GP_1	0.08	0.08	0.08	0.08	0.08	0.09	0.08
	CV_young_Mal_GP_1	0.09	0.19	0.10	0.10	0.09	0.16	0.17
	CV_old_Mal_GP_1	0.08	0.09	0.09	0.09	0.08	0.09	0.08
	Wtlen_1_Mal_GP_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Wtlen_2_Mal_GP_1	3.07	3.07	3.07	3.07	3.07	3.07	3.07
	CohortGrowDev	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	FracFemale_GP_1	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	SR_LN(R0)	6.98	6.41	6.78	6.72	6.96	6.91	6.55
	SR_BH_steep	0.72	0.72	0.72	0.72	0.72	0.72	0.72
	SR_sigmaR	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	SR_regime	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	SR_autocorr	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	LnQ_base_TRIENNIAL(7)	-1.47	-0.76	-1.26	-1.14	-1.44	-1.35	-1.03
	LnQ_base_AK_SLOPE(8)	-3.10	-2.35	-2.89	-2.84	-3.07	-2.92	-2.57
	LnQ_base_NW_SLOPE(9)	-2.03	-1.26	-1.82	-1.76	-2.00	-1.84	-1.49
	LnQ_base_WCGBTS(10)	-2.60	-2.02	-2.40	-2.36	-2.58	-2.53	-2.18

LnQ_base_TRIENNIAL(7)_-BLK3repl_1892	-2.26	-1.75	-2.09	-2.05	-2.24	-2.19	-1.87
Size_DblN_peak_BOTTOM_-TRAWL(1)	49.34	49.64	49.49	49.54	49.34	49.33	49.46
Size_DblN_top_logit_-BOTTOM_TRAWL(1)	-11.52	-11.52	-11.52	-11.52	-11.52	-11.52	-11.52
Size_DblN_ascend_se_-BOTTOM_TRAWL(1)	4.57	4.49	4.55	4.54	4.56	4.53	4.51
Size_DblN_descend_se_-BOTTOM_TRAWL(1)	2.95	2.97	2.95	2.92	2.95	2.97	2.95
Size_DblN_start_logit_-BOTTOM_TRAWL(1)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-BOTTOM_TRAWL(1)	-0.64	-0.68	-0.61	-0.59	-0.64	-0.71	-0.69
Size_DblN_peak_BOTTOM_-TRAWL_DISCARD(2)	25.26	25.81	25.31	25.36	25.33	25.61	25.77
Size_DblN_top_logit_-BOTTOM_TRAWL_-DISCARD(2)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_-BOTTOM_TRAWL_-DISCARD(2)	4.89	4.57	4.84	4.86	4.89	4.70	4.58
Size_DblN_descend_se_-BOTTOM_TRAWL_-DISCARD(2)	3.84	3.76	3.83	3.82	3.83	3.80	3.72
Size_DblN_start_logit_-BOTTOM_TRAWL_-DISCARD(2)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_end_logit_-BOTTOM_TRAWL_-DISCARD(2)	-3.81	-3.62	-3.73	-3.68	-3.81	-3.78	-3.75
Size_DblN_peak_NON_-TRAWL(3)	50.28	50.72	50.49	50.63	50.28	50.36	50.18
Size_DblN_top_logit_NON_-TRAWL(3)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_NON_-TRAWL(3)	3.86	3.80	3.86	3.86	3.85	3.82	3.77
Size_DblN_descend_se_NON_-TRAWL(3)	20.00	20.00	20.00	20.00	20.00	20.00	20.00

Size_DblN_start_logit_NON_-TRAWL(3)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_NON_-TRAWL(3)	4.60	4.60	4.60	4.60	4.60	4.60	4.60
Size_DblN_peak_NON_-TRAWL_DISCARD(4)	49.95	50.04	50.07	50.06	49.93	49.78	50.01
Size_DblN_top_logit_NON_-TRAWL_DISCARD(4)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_NON_-TRAWL_DISCARD(4)	3.75	3.72	3.76	3.75	3.74	3.70	3.74
Size_DblN_descend_se_NON_-TRAWL_DISCARD(4)	2.66	2.69	2.64	2.64	2.67	2.72	2.66
Size_DblN_start_logit_NON_-TRAWL_DISCARD(4)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_NON_-TRAWL_DISCARD(4)	-0.19	-0.24	-0.16	-0.14	-0.20	-0.29	-0.26
Size_DblN_peak_-MIDWATER_TRAWL(5)	52.18	52.47	52.46	52.53	52.16	52.02	52.07
Size_DblN_top_logit_-MIDWATER_TRAWL(5)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_-MIDWATER_TRAWL(5)	4.57	4.49	4.57	4.56	4.56	4.52	4.48
Size_DblN_descend_se_-MIDWATER_TRAWL(5)	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Size_DblN_start_logit_-MIDWATER_TRAWL(5)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-MIDWATER_TRAWL(5)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_peak_AT_SEA_-HAKE(6)	49.71	49.75	49.88	49.92	49.69	49.46	49.65
Size_DblN_top_logit_AT_-SEA_HAKE(6)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_AT_-SEA_HAKE(6)	3.59	3.55	3.61	3.61	3.59	3.55	3.55
Size_DblN_descend_se_AT_-SEA_HAKE(6)	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Size_DblN_start_logit_AT_-SEA_HAKE(6)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00

Size_DblN_end_logit_AT_-SEA_HAKE(6)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_peak_-TRIENNIAL(7)	21.78	21.95	21.96	21.91	21.78	21.97	22.01
Size_DblN_top_logit_-TRIENNIAL(7)	-8.60	-8.60	-8.60	-8.60	-8.60	-8.60	-8.60
Size_DblN_ascend_se_-TRIENNIAL(7)	3.53	3.61	3.60	3.58	3.52	3.61	3.61
Size_DblN_descend_se_-TRIENNIAL(7)	3.95	3.93	3.90	3.88	3.95	3.97	3.93
Size_DblN_start_logit_-TRIENNIAL(7)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-TRIENNIAL(7)	-2.58	-2.56	-2.55	-2.59	-2.59	-2.62	-2.49
Size_DblN_peak_AK_-SLOPE(8)	37.29	36.69	37.31	36.85	37.26	36.73	37.30
Size_DblN_top_logit_AK_-SLOPE(8)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_AK_-SLOPE(8)	4.94	4.85	4.97	4.97	4.94	4.84	4.90
Size_DblN_descend_se_AK_-SLOPE(8)	4.63	4.70	4.65	4.73	4.63	4.65	4.64
Size_DblN_start_logit_AK_-SLOPE(8)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_AK_-SLOPE(8)	-10.48	-10.28	-10.39	-10.54	-10.48	-10.34	-10.47
Size_DblN_peak_WCGBTS(10)	21.09	21.57	21.34	21.38	21.08	20.79	21.39
Size_DblN_top_logit_-WCGBTS(10)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_-WCGBTS(10)	3.39	3.48	3.46	3.47	3.39	3.31	3.46
Size_DblN_descend_se_-WCGBTS(10)	4.64	4.44	4.55	4.55	4.65	4.74	4.49
Size_DblN_start_logit_-WCGBTS(10)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-WCGBTS(10)	-0.83	-0.48	-0.73	-0.68	-0.83	-0.78	-0.59
Size_DblN_peak_BOTTOM_-TRAWL(1)_BLK4repl_1892	44.71	44.60	44.88	45.18	44.69	44.11	44.77

Size_DblN_peak_BOTTOM_-TRAWL(1)_BLK4repl_2002	47.64	47.61	47.72	47.65	47.62	47.45	47.70
Size_DblN_ascend_se_-BOTTOM_TRAWL(1)_-BLK4repl_1892	5.03	5.06	5.05	5.13	5.03	4.99	5.03
Size_DblN_ascend_se_-BOTTOM_TRAWL(1)_-BLK4repl_2002	4.10	4.06	4.11	4.13	4.10	4.06	4.05
Size_DblN_descend_se_-BOTTOM_TRAWL(1)_-BLK4repl_1892	2.65	2.63	2.55	2.40	2.65	2.88	2.59
Size_DblN_descend_se_-BOTTOM_TRAWL(1)_-BLK4repl_2002	2.75	2.76	2.74	2.76	2.75	2.76	2.74
Size_DblN_end_logit_-BOTTOM_TRAWL(1)_-BLK4repl_1892	-1.59	-1.36	-1.46	-1.37	-1.59	-1.68	-1.45
Size_DblN_end_logit_-BOTTOM_TRAWL(1)_-BLK4repl_2002	-0.93	-0.96	-0.89	-0.86	-0.94	-1.03	-0.98
Size_DblN_peak_BOTTOM_-TRAWL_DISCARD(2)_-BLK1repl_1892	47.68	47.79	47.75	47.61	47.65	47.52	48.04
Size_DblN_ascend_se_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	6.32	6.33	6.29	6.23	6.32	6.35	6.39
Size_DblN_descend_se_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	3.01	2.99	3.00	3.03	3.02	3.02	2.92
Size_DblN_end_logit_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	-1.70	-1.72	-1.66	-1.66	-1.71	-1.79	-1.70
Size_DblN_peak_NON_-TRAWL(3)_BLK2repl_1892	46.77	46.74	46.83	46.81	46.76	46.61	46.81
Size_DblN_peak_NON_-TRAWL(3)_BLK2repl_2011	49.49	49.57	49.57	49.57	49.48	49.40	49.57
Size_DblN_ascend_se_NON_-TRAWL(3)_BLK2repl_1892	3.05	3.02	3.06	3.07	3.05	3.01	3.02

	Size_DblN_ascend_se_NON_-TRAWL(3)_BLK2repl_2011	3.81	3.79	3.80	3.79	3.81	3.79	3.81
	Size_DblN_descend_se_NON_-TRAWL(3)_BLK2repl_1892	3.17	3.19	3.18	3.19	3.17	3.18	3.16
	Size_DblN_descend_se_NON_-TRAWL(3)_BLK2repl_2011	2.32	2.39	2.31	2.29	2.33	2.39	2.35
	Size_DblN_end_logit_NON_-TRAWL(3)_BLK2repl_1892	-2.28	-2.29	-2.25	-2.22	-2.29	-2.35	-2.31
	Size_DblN_end_logit_NON_-TRAWL(3)_BLK2repl_2011	-0.62	-0.66	-0.60	-0.59	-0.63	-0.71	-0.67
	Size_DblN_peak_-TRIENNIAL(7)_BLK3repl_1892	17.36	17.69	17.69	17.68	17.33	17.71	17.72
	Size_DblN_ascend_se_-TRIENNIAL(7)_BLK3repl_1892	2.09	2.15	2.16	2.18	2.08	2.14	2.14
	Size_DblN_descend_se_-TRIENNIAL(7)_BLK3repl_1892	5.10	4.86	5.01	5.04	5.10	4.92	4.94
	Size_DblN_end_logit_-TRIENNIAL(7)_BLK3repl_1892	-4.28	-3.70	-4.06	-4.10	-4.27	-3.94	-3.89
Derived quantities								
	SB0	5.57	3.05	4.48	4.20	5.48	5.19	3.56
	SSB_2025	4.86	2.08	3.69	3.39	4.75	4.34	2.67
	Bratio_2025	0.87	0.68	0.82	0.81	0.87	0.84	0.75
	MSY_SPR	519.31	297.00	420.44	395.51	510.27	496.29	336.93
	F_SPR	0.04	0.04	0.04	0.04	0.04	0.04	0.04

Table 30: Likelihood values and estimates of key parameters and derived quantities from each life history parameter sensitivity (natural mortality and growth).

Label	Type	Reference	Est male M	Fixed M 2013	Lorenzen M	Fixed growth ext
AIC						
	AIC	15,093.86	15,086.58	15,103.66	15,123.28	15,580.02
	deltaAIC	0.00	-7.28	9.80	29.42	486.16
Survey likelihood						
	ALL	-26.81	-27.07	-26.66	-26.73	-27.02
	TRIENNIAL	-7.76	-8.05	-7.64	-7.64	-7.98
	AK_SLOPE	-0.53	-0.54	-0.52	-0.52	-0.53
	NW_SLOPE	-1.03	-1.03	-1.03	-1.03	-1.03
	WCGBTS	-17.49	-17.45	-17.47	-17.54	-17.48
Lt likelihood						
	ALL	574.80	573.19	585.01	573.77	605.79
	BOTTOM_TRAWL	79.11	79.75	78.31	79.70	82.67
	BOTTOM_TRAWL_DISCARD	27.15	27.18	27.24	27.09	28.35
	NON_TRAWL	179.64	178.16	188.32	179.56	194.51
	NON_TRAWL_DISCARD	46.63	46.71	47.17	46.47	48.93
	MIDWATER_TRAWL	58.94	58.49	59.97	58.80	59.11
	AT_SEA_HAKE	25.42	25.03	25.98	24.56	23.50
	TRIENNIAL	22.43	22.40	22.40	22.38	25.37
	AK_SLOPE	52.31	52.19	52.92	51.87	52.86
	NW_SLOPE	0.00	0.00	0.00	0.00	0.00
	WCGBTS	83.19	83.29	82.70	83.35	90.48
Age likelihood						
	ALL	6,783.50	6,781.99	6,779.34	6,795.57	6,981.02
	BOTTOM_TRAWL	464.26	463.72	464.13	466.53	462.65
	BOTTOM_TRAWL_DISCARD	0.00	0.00	0.00	0.00	0.00
	NON_TRAWL	331.37	330.63	331.04	332.26	331.60
	NON_TRAWL_DISCARD	0.00	0.00	0.00	0.00	0.00
	MIDWATER_TRAWL	182.47	182.42	182.21	183.33	183.77
	AT_SEA_HAKE	3,847.50	3,848.16	3,843.85	3,853.81	3,862.55
	TRIENNIAL	0.00	0.00	0.00	0.00	0.00

	AK_SLOPE	0.00	0.00	0.00	0.00	0.00
	NW_SLOPE	0.00	0.00	0.00	0.00	0.00
	WCGBTS	1,957.89	1,957.05	1,958.11	1,959.63	2,140.45
Parameters						
	NatM_uniform_Fem_GP_1	0.04	0.04	0.04		0.04
	L_at_Amin_Fem_GP_1	-3.10	-3.03	-3.19	-2.63	0.00
	L_at_Amax_Fem_GP_1	60.08	60.08	59.84	60.03	59.03
	VonBert_K_Fem_GP_1	0.08	0.08	0.08	0.08	0.07
	CV_young_Fem_GP_1	0.05	0.05	0.05	0.05	0.13
	CV_old_Fem_GP_1	0.09	0.09	0.09	0.09	0.09
	Wtlen_1_Fem_GP_1	0.00	0.00	0.00	0.00	0.00
	Wtlen_2_Fem_GP_1	3.15	3.15	3.15	3.15	3.15
	Mat50%_Fem_GP_1	46.53	46.53	46.53	46.53	46.53
	Mat_slope_Fem_GP_1	-0.25	-0.25	-0.25	-0.25	-0.25
	Eggs_scalar_Fem_GP_1	0.00	0.00	0.00	0.00	0.00
	Eggs_exp_len_Fem_GP_1	4.04	4.04	4.04	4.04	4.04
	NatM_uniform_Mal_GP_1	0.04	0.04	0.04		0.04
	L_at_Amin_Mal_GP_1	-2.67	-2.67	-2.38	-5.08	1.71
	L_at_Amax_Mal_GP_1	57.83	57.76	57.87	57.52	56.69
	VonBert_K_Mal_GP_1	0.08	0.08	0.08	0.09	0.08
	CV_young_Mal_GP_1	0.09	0.09	0.09	0.09	0.19
	CV_old_Mal_GP_1	0.08	0.08	0.09	0.08	0.08
	Wtlen_1_Mal_GP_1	0.00	0.00	0.00	0.00	0.00
	Wtlen_2_Mal_GP_1	3.07	3.07	3.07	3.07	3.07
	CohortGrowDev	1.00	1.00	1.00	1.00	1.00
	FracFemale_GP_1	0.50	0.50	0.50	0.50	0.50
	SR_LN(R0)	6.98	10.82	6.85	7.37	6.77
	SR_BH_steep	0.72	0.72	0.72	0.72	0.72
	SR_sigmaR	0.50	0.50	0.50	0.50	0.50
	SR_regime	0.00	0.00	0.00	0.00	0.00
	SR_autocorr	0.00	0.00	0.00	0.00	0.00
	LnQ_base_TRIENNIAL(7)	-1.47	-5.24	-1.27	-1.20	-1.57
	LnQ_base_AK_SLOPE(8)	-3.10	-6.82	-2.89	-2.71	-3.12
	LnQ_base_NW_SLOPE(9)	-2.03	-5.76	-1.83	-1.64	-2.06
	LnQ_base_WCGBTS(10)	-2.60	-6.39	-2.40	-2.26	-2.57
	LnQ_base_TRIENNIAL(7)_BLK3repl_1892	-2.26	-5.93	-2.08	-2.09	-2.27

Size_DblN_peak_BOTTOM_-TRAWL(1)	49.34	49.42	49.50	49.31	50.17
Size_DblN_top_logit_-BOTTOM_TRAWL(1)	-11.52	-11.52	-11.52	-11.52	-11.52
Size_DblN_ascend_se_-BOTTOM_TRAWL(1)	4.57	4.56	4.56	4.55	4.65
Size_DblN_descend_se_-BOTTOM_TRAWL(1)	2.95	2.93	2.86	2.93	1.86
Size_DblN_start_logit_-BOTTOM_TRAWL(1)	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-BOTTOM_TRAWL(1)	-0.64	-0.60	-0.53	-0.60	0.28
Size_DblN_peak_BOTTOM_-TRAWL_DISCARD(2)	25.26	25.39	25.38	25.73	26.10
Size_DblN_top_logit_-BOTTOM_TRAWL_-DISCARD(2)	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_-BOTTOM_TRAWL_-DISCARD(2)	4.89	4.88	4.88	4.75	7.86
Size_DblN_descend_se_-BOTTOM_TRAWL_-DISCARD(2)	3.84	3.82	3.82	3.78	3.70
Size_DblN_start_logit_-BOTTOM_TRAWL_-DISCARD(2)	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_end_logit_-BOTTOM_TRAWL_-DISCARD(2)	-3.81	-3.74	-3.74	-3.69	-3.47
Size_DblN_peak_NON_-TRAWL(3)	50.28	50.39	50.56	50.24	51.68
Size_DblN_top_logit_NON_-TRAWL(3)	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_NON_-TRAWL(3)	3.86	3.86	3.87	3.86	4.02
Size_DblN_descend_se_NON_-TRAWL(3)	20.00	20.00	20.00	20.00	20.00
Size_DblN_start_logit_NON_-TRAWL(3)	-999.00	-999.00	-999.00	-999.00	-999.00

Size_DblN_end_logit_NON_-TRAWL(3)	4.60	4.60	4.60	4.60	4.60
Size_DblN_peak_NON_-TRAWL_DISCARD(4)	49.95	49.99	50.05	49.94	51.10
Size_DblN_top_logit_NON_-TRAWL_DISCARD(4)	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_NON_-TRAWL_DISCARD(4)	3.75	3.75	3.75	3.74	3.95
Size_DblN_descend_se_NON_-TRAWL_DISCARD(4)	2.66	2.64	2.59	2.64	1.71
Size_DblN_start_logit_NON_-TRAWL_DISCARD(4)	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_NON_-TRAWL_DISCARD(4)	-0.19	-0.15	-0.10	-0.14	0.70
Size_DblN_peak_-MIDWATER_TRAWL(5)	52.18	52.36	52.64	52.19	55.82
Size_DblN_top_logit_-MIDWATER_TRAWL(5)	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_-MIDWATER_TRAWL(5)	4.57	4.57	4.59	4.56	4.89
Size_DblN_descend_se_-MIDWATER_TRAWL(5)	20.00	20.00	20.00	20.00	20.00
Size_DblN_start_logit_-MIDWATER_TRAWL(5)	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-MIDWATER_TRAWL(5)	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_peak_AT_SEA_-HAKE(6)	49.71	49.78	49.92	49.81	51.50
Size_DblN_top_logit_AT_-SEA_HAKE(6)	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_AT_-SEA_HAKE(6)	3.59	3.60	3.61	3.60	3.84
Size_DblN_descend_se_AT_-SEA_HAKE(6)	20.00	20.00	20.00	20.00	20.00
Size_DblN_start_logit_AT_-SEA_HAKE(6)	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_AT_-SEA_HAKE(6)	-999.00	-999.00	-999.00	-999.00	-999.00

Size_DblN_peak_-TRIENNIAL(7)	21.78	21.89	21.83	22.14	22.70
Size_DblN_top_logit_-TRIENNIAL(7)	-8.60	-8.60	-8.60	-8.60	-8.60
Size_DblN_ascend_se_-TRIENNIAL(7)	3.53	3.54	3.54	3.52	4.09
Size_DblN_descend_se_-TRIENNIAL(7)	3.95	3.95	3.93	3.90	3.72
Size_DblN_start_logit_-TRIENNIAL(7)	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-TRIENNIAL(7)	-2.58	-2.54	-2.55	-2.37	-2.23
Size_DblN_peak_AK_-SLOPE(8)	37.29	37.34	37.35	37.79	37.43
Size_DblN_top_logit_AK_-SLOPE(8)	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_AK_-SLOPE(8)	4.94	4.92	4.95	4.92	4.97
Size_DblN_descend_se_AK_-SLOPE(8)	4.63	4.62	4.64	4.61	4.71
Size_DblN_start_logit_AK_-SLOPE(8)	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_AK_-SLOPE(8)	-10.48	-10.52	-10.15	-10.49	-10.60
Size_DblN_peak_WCGBTS(10)	21.09	21.29	21.34	21.92	22.02
Size_DblN_top_logit_-WCGBTS(10)	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_-WCGBTS(10)	3.39	3.43	3.45	3.50	4.28
Size_DblN_descend_se_-WCGBTS(10)	4.64	4.60	4.54	4.54	4.10
Size_DblN_start_logit_-WCGBTS(10)	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-WCGBTS(10)	-0.83	-0.73	-0.74	-0.61	-0.57
Size_DblN_peak_BOTTOM_-TRAWL(1)_BLK4repl_1892	44.71	44.39	44.74	45.24	45.42
Size_DblN_peak_BOTTOM_-TRAWL(1)_BLK4repl_2002	47.64	47.64	47.73	47.72	48.25

Size_DblN_ascend_se_-BOTTOM_TRAWL(1)_-BLK4repl_1892	5.03	4.98	5.03	5.03	5.08
Size_DblN_ascend_se_-BOTTOM_TRAWL(1)_-BLK4repl_2002	4.10	4.09	4.11	4.10	4.11
Size_DblN_descend_se_-BOTTOM_TRAWL(1)_-BLK4repl_1892	2.65	2.84	2.67	2.23	2.13
Size_DblN_descend_se_-BOTTOM_TRAWL(1)_-BLK4repl_2002	2.75	2.73	2.68	2.69	1.92
Size_DblN_end_logit_-BOTTOM_TRAWL(1)_-BLK4repl_1892	-1.59	-1.79	-1.59	-1.13	-1.11
Size_DblN_end_logit_-BOTTOM_TRAWL(1)_-BLK4repl_2002	-0.93	-0.92	-0.86	-0.86	-0.33
Size_DblN_peak_BOTTOM_-TRAWL_DISCARD(2)_-BLK1repl_1892	47.68	47.74	47.79	47.78	48.58
Size_DblN_ascend_se_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	6.32	6.25	6.30	6.16	6.34
Size_DblN_descend_se_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	3.01	2.98	2.98	2.97	2.63
Size_DblN_end_logit_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	-1.70	-1.68	-1.65	-1.63	-1.08
Size_DblN_peak_NON_-TRAWL(3)_BLK2repl_1892	46.77	46.76	46.82	46.84	47.08
Size_DblN_peak_NON_-TRAWL(3)_BLK2repl_2011	49.49	49.54	49.60	49.49	51.00
Size_DblN_ascend_se_NON_-TRAWL(3)_BLK2repl_1892	3.05	3.04	3.05	3.05	3.08
Size_DblN_ascend_se_NON_-TRAWL(3)_BLK2repl_2011	3.81	3.81	3.81	3.80	4.02

	Size_DblN_descend_se_NON_-TRAWL(3)_BLK2repl_1892	3.17	3.18	3.16	3.16	3.01
	Size_DblN_descend_se_NON_-TRAWL(3)_BLK2repl_2011	2.32	2.29	2.21	2.28	-13.02
	Size_DblN_end_logit_NON_-TRAWL(3)_BLK2repl_1892	-2.28	-2.29	-2.23	-2.19	-1.75
	Size_DblN_end_logit_NON_-TRAWL(3)_BLK2repl_2011	-0.62	-0.59	-0.54	-0.59	0.03
	Size_DblN_peak_-TRIENNIAL(7)_BLK3repl_1892	17.36	17.50	17.40	17.66	17.19
	Size_DblN_ascend_se_-TRIENNIAL(7)_BLK3repl_1892	2.09	2.13	2.10	2.16	2.02
	Size_DblN_descend_se_-TRIENNIAL(7)_BLK3repl_1892	5.10	5.16	5.08	5.19	5.12
	Size_DblN_end_logit_-TRIENNIAL(7)_BLK3repl_1892	-4.28	-4.46	-4.20	-4.04	-4.04
	NatM_Lorenzen_Fem_GP_1				0.04	
	NatM_Lorenzen_Mal_GP_1				0.04	
	Eggs/kg_inter_Fem_GP_1					
	Eggs/kg_slope_wt_Fem_GP_1					
Derived quantities						
	SB0	5.57	212.82	4.17	3.60	3.99
	SSB_2025	4.86	205.46	3.39	2.99	3.69
	Bratio_2025	0.87	0.97	0.81	0.83	0.93
	MSY_SPR	519.31	21,656.80	446.67	306.86	416.46
	F_SPR	0.04	0.05	0.04	0.04	0.04

Table 31: Likelihood values and estimates of key parameters and derived quantities from each life history parameter sensitivity (reproductive biology).

Label	Type	Reference	Prop fecund	Fxn mat age	Fxn mat Bspot	Fxn mat Reye	Biological mat
AIC							
	AIC	15,093.86	15,093.90	15,093.94	15,093.90	15,093.86	15,093.86
	deltaAIC	0.00	0.04	0.08	0.04	0.00	0.00
Survey likelihood							
	ALL	-26.81	-26.81	-26.81	-26.81	-26.81	-26.81
	TRIENNIAL	-7.76	-7.76	-7.76	-7.76	-7.76	-7.76
	AK_SLOPE	-0.53	-0.53	-0.53	-0.53	-0.53	-0.53
	NW_SLOPE	-1.03	-1.03	-1.03	-1.03	-1.03	-1.03
	WCGBTS	-17.49	-17.49	-17.49	-17.49	-17.49	-17.49
Lt likelihood							
	ALL	574.80	574.83	574.82	574.81	574.80	574.80
	BOTTOM_TRAWL	79.11	79.10	79.11	79.11	79.11	79.11
	BOTTOM_TRAWL_DISCARD	27.15	27.15	27.15	27.15	27.15	27.15
	NON_TRAWL	179.64	179.66	179.65	179.65	179.64	179.64
	NON_TRAWL_DISCARD	46.63	46.62	46.62	46.62	46.63	46.63
	MIDWATER_TRAWL	58.94	58.95	58.95	58.94	58.94	58.94
	AT_SEA_HAKE	25.42	25.42	25.42	25.42	25.41	25.41
	TRIENNIAL	22.43	22.42	22.42	22.43	22.43	22.42
	AK_SLOPE	52.31	52.30	52.30	52.31	52.31	52.30
	NW_SLOPE	0.00	0.00	0.00	0.00	0.00	0.00
	WCGBTS	83.19	83.19	83.19	83.19	83.19	83.19
Age likelihood							
	ALL	6,783.50	6,783.49	6,783.50	6,783.50	6,783.49	6,783.49
	BOTTOM_TRAWL	464.26	464.25	464.26	464.26	464.26	464.26
	BOTTOM_TRAWL_DISCARD	0.00	0.00	0.00	0.00	0.00	0.00
	NON_TRAWL	331.37	331.38	331.38	331.38	331.37	331.37
	NON_TRAWL_DISCARD	0.00	0.00	0.00	0.00	0.00	0.00
	MIDWATER_TRAWL	182.47	182.47	182.47	182.47	182.47	182.47
	AT_SEA_HAKE	3,847.50	3,847.50	3,847.49	3,847.49	3,847.50	3,847.50
	TRIENNIAL	0.00	0.00	0.00	0.00	0.00	0.00

	AK_SLOPE	0.00	0.00	0.00	0.00	0.00	0.00
	NW_SLOPE	0.00	0.00	0.00	0.00	0.00	0.00
	WCGBTS	1,957.89	1,957.88	1,957.90	1,957.90	1,957.89	1,957.90
Parameters							
	NatM_uniform_Fem_GP_1	0.04	0.04	0.04	0.04	0.04	0.04
	L_at_Amin_Fem_GP_1	-3.10	-3.10	-3.10	-3.10	-3.10	-3.10
	L_at_Amax_Fem_GP_1	60.08	60.08	60.08	60.08	60.08	60.08
	VonBert_K_Fem_GP_1	0.08	0.08	0.08	0.08	0.08	0.08
	CV_young_Fem_GP_1	0.05	0.05	0.05	0.05	0.05	0.05
	CV_old_Fem_GP_1	0.09	0.09	0.09	0.09	0.09	0.09
	Wtlen_1_Fem_GP_1	0.00	0.00	0.00	0.00	0.00	0.00
	Wtlen_2_Fem_GP_1	3.15	3.15	3.15	3.15	3.15	3.15
	Mat50%_Fem_GP_1	46.53	46.53	26.02	51.45	43.57	42.92
	Mat_slope_Fem_GP_1	-0.25	-0.25	-0.13	-0.29	-0.43	-0.26
	Eggs_scalar_Fem_GP_1	0.00		0.00	0.00	0.00	0.00
	Eggs_exp_len_Fem_GP_1	4.04		4.04	4.04	4.04	4.04
	NatM_uniform_Mal_GP_1	0.04	0.04	0.04	0.04	0.04	0.04
	L_at_Amin_Mal_GP_1	-2.67	-2.68	-2.67	-2.67	-2.67	-2.67
	L_at_Amax_Mal_GP_1	57.83	57.83	57.83	57.83	57.83	57.83
	VonBert_K_Mal_GP_1	0.08	0.08	0.08	0.08	0.08	0.08
	CV_young_Mal_GP_1	0.09	0.09	0.09	0.09	0.09	0.09
	CV_old_Mal_GP_1	0.08	0.08	0.08	0.08	0.08	0.08
	Wtlen_1_Mal_GP_1	0.00	0.00	0.00	0.00	0.00	0.00
	Wtlen_2_Mal_GP_1	3.07	3.07	3.07	3.07	3.07	3.07
	CohortGrowDev	1.00	1.00	1.00	1.00	1.00	1.00
	FracFemale_GP_1	0.50	0.50	0.50	0.50	0.50	0.50
	SR_LN(R0)	6.98	6.99	6.98	6.98	6.98	6.98
	SR_BH_steep	0.72	0.72	0.72	0.72	0.72	0.72
	SR_sigmaR	0.50	0.50	0.50	0.50	0.50	0.50
	SR_regime	0.00	0.00	0.00	0.00	0.00	0.00
	SR_autocorr	0.00	0.00	0.00	0.00	0.00	0.00
	LnQ_base_TRIENNIAL(7)	-1.47	-1.48	-1.48	-1.47	-1.47	-1.47
	LnQ_base_AK_SLOPE(8)	-3.10	-3.11	-3.10	-3.10	-3.10	-3.10
	LnQ_base_NW_SLOPE(9)	-2.03	-2.04	-2.03	-2.03	-2.03	-2.03
	LnQ_base_WCGBTS(10)	-2.60	-2.61	-2.60	-2.60	-2.60	-2.60
	LnQ_base_TRIENNIAL(7)_BLK3repl_1892	-2.26	-2.27	-2.26	-2.26	-2.26	-2.26

Size_DblN_peak_BOTTOM_-TRAWL(1)	49.34	49.34	49.34	49.34	49.34	49.34
Size_DblN_top_logit_-BOTTOM_TRAWL(1)	-11.52	-11.52	-11.52	-11.52	-11.52	-11.52
Size_DblN_ascend_se_-BOTTOM_TRAWL(1)	4.57	4.57	4.57	4.57	4.57	4.57
Size_DblN_descend_se_-BOTTOM_TRAWL(1)	2.95	2.95	2.95	2.95	2.95	2.95
Size_DblN_start_logit_-BOTTOM_TRAWL(1)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-BOTTOM_TRAWL(1)	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64
Size_DblN_peak_BOTTOM_-TRAWL_DISCARD(2)	25.26	25.26	25.26	25.26	25.26	25.26
Size_DblN_top_logit_-BOTTOM_TRAWL_-DISCARD(2)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_-BOTTOM_TRAWL_-DISCARD(2)	4.89	4.89	4.89	4.89	4.89	4.89
Size_DblN_descend_se_-BOTTOM_TRAWL_-DISCARD(2)	3.84	3.84	3.84	3.84	3.84	3.84
Size_DblN_start_logit_-BOTTOM_TRAWL_-DISCARD(2)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_end_logit_-BOTTOM_TRAWL_-DISCARD(2)	-3.81	-3.82	-3.81	-3.81	-3.81	-3.81
Size_DblN_peak_NON_-TRAWL(3)	50.28	50.27	50.28	50.28	50.28	50.28
Size_DblN_top_logit_NON_-TRAWL(3)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_NON_-TRAWL(3)	3.86	3.86	3.86	3.86	3.86	3.86
Size_DblN_descend_se_NON_-TRAWL(3)	20.00	20.00	20.00	20.00	20.00	20.00
Size_DblN_start_logit_NON_-TRAWL(3)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00

Size_DblN_end_logit_NON_-TRAWL(3)	4.60	4.60	4.60	4.60	4.60	4.60
Size_DblN_peak_NON_-TRAWL_DISCARD(4)	49.95	49.95	49.95	49.95	49.95	49.95
Size_DblN_top_logit_NON_-TRAWL_DISCARD(4)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_NON_-TRAWL_DISCARD(4)	3.75	3.75	3.75	3.75	3.75	3.75
Size_DblN_descend_se_NON_-TRAWL_DISCARD(4)	2.66	2.66	2.66	2.66	2.66	2.66
Size_DblN_start_logit_NON_-TRAWL_DISCARD(4)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_NON_-TRAWL_DISCARD(4)	-0.19	-0.19	-0.19	-0.19	-0.19	-0.19
Size_DblN_peak_-MIDWATER_TRAWL(5)	52.18	52.17	52.18	52.18	52.18	52.18
Size_DblN_top_logit_-MIDWATER_TRAWL(5)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_-MIDWATER_TRAWL(5)	4.57	4.57	4.57	4.57	4.57	4.57
Size_DblN_descend_se_-MIDWATER_TRAWL(5)	20.00	20.00	20.00	20.00	20.00	20.00
Size_DblN_start_logit_-MIDWATER_TRAWL(5)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-MIDWATER_TRAWL(5)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_peak_AT_SEA_-HAKE(6)	49.71	49.71	49.71	49.71	49.71	49.71
Size_DblN_top_logit_AT_-SEA_HAKE(6)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_AT_-SEA_HAKE(6)	3.59	3.59	3.59	3.59	3.59	3.59
Size_DblN_descend_se_AT_-SEA_HAKE(6)	20.00	20.00	20.00	20.00	20.00	20.00
Size_DblN_start_logit_AT_-SEA_HAKE(6)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_AT_-SEA_HAKE(6)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00

Size_DblN_peak_-TRIENNIAL(7)	21.78	21.78	21.78	21.78	21.79	21.79
Size_DblN_top_logit_-TRIENNIAL(7)	-8.60	-8.60	-8.60	-8.60	-8.60	-8.60
Size_DblN_ascend_se_-TRIENNIAL(7)	3.53	3.52	3.53	3.53	3.53	3.53
Size_DblN_descend_se_-TRIENNIAL(7)	3.95	3.95	3.95	3.95	3.95	3.95
Size_DblN_start_logit_-TRIENNIAL(7)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-TRIENNIAL(7)	-2.58	-2.58	-2.58	-2.58	-2.58	-2.58
Size_DblN_peak_AK_-SLOPE(8)	37.29	37.29	37.29	37.29	37.29	37.29
Size_DblN_top_logit_AK_-SLOPE(8)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_AK_-SLOPE(8)	4.94	4.94	4.94	4.94	4.94	4.94
Size_DblN_descend_se_AK_-SLOPE(8)	4.63	4.63	4.63	4.63	4.63	4.63
Size_DblN_start_logit_AK_-SLOPE(8)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_AK_-SLOPE(8)	-10.48	-10.48	-10.48	-10.48	-10.48	-10.48
Size_DblN_peak_WCGBTS(10)	21.09	21.09	21.09	21.09	21.09	21.09
Size_DblN_top_logit_-WCGBTS(10)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_-WCGBTS(10)	3.39	3.39	3.39	3.39	3.39	3.39
Size_DblN_descend_se_-WCGBTS(10)	4.64	4.65	4.64	4.64	4.64	4.64
Size_DblN_start_logit_-WCGBTS(10)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-WCGBTS(10)	-0.83	-0.83	-0.83	-0.83	-0.83	-0.83
Size_DblN_peak_BOTTOM_-TRAWL(1)_BLK4repl_1892	44.71	44.70	44.71	44.71	44.71	44.71
Size_DblN_peak_BOTTOM_-TRAWL(1)_BLK4repl_2002	47.64	47.64	47.64	47.64	47.64	47.64

Size_DblN_ascend_se_-BOTTOM_TRAWL(1)_-BLK4repl_1892	5.03	5.03	5.03	5.03	5.03	5.03
Size_DblN_ascend_se_-BOTTOM_TRAWL(1)_-BLK4repl_2002	4.10	4.10	4.10	4.10	4.10	4.10
Size_DblN_descend_se_-BOTTOM_TRAWL(1)_-BLK4repl_1892	2.65	2.65	2.65	2.65	2.65	2.65
Size_DblN_descend_se_-BOTTOM_TRAWL(1)_-BLK4repl_2002	2.75	2.75	2.75	2.75	2.75	2.75
Size_DblN_end_logit_-BOTTOM_TRAWL(1)_-BLK4repl_1892	-1.59	-1.59	-1.59	-1.59	-1.59	-1.59
Size_DblN_end_logit_-BOTTOM_TRAWL(1)_-BLK4repl_2002	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93
Size_DblN_peak_BOTTOM_-TRAWL_DISCARD(2)_-BLK1repl_1892	47.68	47.67	47.67	47.67	47.68	47.68
Size_DblN_ascend_se_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	6.32	6.32	6.32	6.32	6.32	6.32
Size_DblN_descend_se_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	3.01	3.01	3.01	3.01	3.01	3.01
Size_DblN_end_logit_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	-1.70	-1.70	-1.70	-1.70	-1.70	-1.70
Size_DblN_peak_NON_-TRAWL(3)_BLK2repl_1892	46.77	46.77	46.77	46.77	46.77	46.77
Size_DblN_peak_NON_-TRAWL(3)_BLK2repl_2011	49.49	49.49	49.49	49.49	49.49	49.49
Size_DblN_ascend_se_NON_-TRAWL(3)_BLK2repl_1892	3.05	3.05	3.05	3.05	3.05	3.05
Size_DblN_ascend_se_NON_-TRAWL(3)_BLK2repl_2011	3.81	3.81	3.81	3.81	3.81	3.81

	Size_DblN_descend_se_NON_-TRAWL(3)_BLK2repl_1892	3.17	3.17	3.17	3.17	3.17	3.17
	Size_DblN_descend_se_NON_-TRAWL(3)_BLK2repl_2011	2.32	2.32	2.32	2.32	2.32	2.32
	Size_DblN_end_logit_NON_-TRAWL(3)_BLK2repl_1892	-2.28	-2.28	-2.28	-2.28	-2.28	-2.28
	Size_DblN_end_logit_NON_-TRAWL(3)_BLK2repl_2011	-0.62	-0.63	-0.63	-0.63	-0.62	-0.62
	Size_DblN_peak_-TRIENNIAL(7)_BLK3repl_1892	17.36	17.36	17.36	17.35	17.36	17.36
	Size_DblN_ascend_se_-TRIENNIAL(7)_BLK3repl_1892	2.09	2.09	2.09	2.09	2.09	2.09
	Size_DblN_descend_se_-TRIENNIAL(7)_BLK3repl_1892	5.10	5.11	5.10	5.11	5.10	5.10
	Size_DblN_end_logit_-TRIENNIAL(7)_BLK3repl_1892	-4.28	-4.29	-4.28	-4.28	-4.28	-4.28
	NatM_Lorenzen_Fem_GP_1						
	NatM_Lorenzen_Mal_GP_1						
	Eggs/kg_inter_Fem_GP_1		1.00				
	Eggs/kg_slope_wt_Fem_GP_1		0.00				
Derived quantities							
	SB0	5.57	18,434.60	4.87	4.81	6.10	6.00
	SSB_2025	4.86	16,181.90	4.21	4.14	5.36	5.28
	Bratio_2025	0.87	0.88	0.86	0.86	0.88	0.88
	MSY_SPR	519.31	539.52	477.13	493.99	533.83	534.04
	F_SPR	0.04	0.04	0.03	0.04	0.04	0.04

Table 32: Likelihood values and estimates of key parameters and derived quantities from each recruitment and selectivity sensitivity (recruitment deviations).

Label	Type	Reference	No recdevs	1920 recdevs	1930 recdevs	1940 recdevs	1950 recdevs	1960 recdevs
AIC								
	AIC	15,093.86	14,899.80	15,039.02	15,019.32	14,999.42	14,979.52	14,962.52
	deltaAIC	0.00	-194.06	-54.84	-74.54	-94.44	-114.34	-131.34
Survey likelihood								
	ALL	-26.81	-26.63	-26.80	-26.79	-26.79	-26.79	-26.88
	TRIENNIAL	-7.76	-7.45	-7.74	-7.73	-7.73	-7.73	-7.83
	AK_SLOPE	-0.53	-0.52	-0.53	-0.53	-0.53	-0.53	-0.53
	NW_SLOPE	-1.03	-1.02	-1.03	-1.03	-1.03	-1.03	-1.03
	WCGBTS	-17.49	-17.63	-17.50	-17.50	-17.50	-17.50	-17.49
Lt likelihood								
	ALL	574.80	590.54	574.96	575.00	575.02	575.03	575.34
	BOTTOM_TRAWL	79.11	80.14	79.07	79.06	79.06	79.06	78.99
	BOTTOM_TRAWL_DISCARD	27.15	28.13	27.15	27.14	27.14	27.14	27.14
	NON_TRAWL	179.64	179.73	179.77	179.81	179.81	179.82	180.09
	NON_TRAWL_DISCARD	46.63	47.02	46.62	46.61	46.61	46.61	46.64
	MIDWATER_TRAWL	58.94	60.49	58.98	58.99	59.00	59.00	59.06
	AT_SEA_HAKE	25.42	27.05	25.45	25.47	25.48	25.48	25.50
	TRIENNIAL	22.43	28.29	22.42	22.42	22.42	22.42	22.41
	AK_SLOPE	52.31	53.05	52.31	52.32	52.32	52.32	52.33
	NW_SLOPE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	WCGBTS	83.19	86.66	83.18	83.17	83.17	83.17	83.17
Lt lambda								
	ALL							
Age likelihood								
	ALL	6,783.50	6,817.83	6,783.97	6,784.01	6,783.99	6,784.02	6,785.82
	BOTTOM_TRAWL	464.26	464.96	464.34	464.35	464.35	464.35	464.34
	BOTTOM_TRAWL_DISCARD	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	NON_TRAWL	331.37	335.01	331.48	331.50	331.52	331.53	331.71
	NON_TRAWL_DISCARD	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	MIDWATER_TRAWL	182.47	182.04	182.50	182.50	182.48	182.47	182.30

	AT_SEA_HAKE	3,847.50	3,860.10	3,847.68	3,847.63	3,847.58	3,847.63	3,849.67
	TRIENNIAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	AK_SLOPE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	NW_SLOPE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	WCGBTS	1,957.89	1,975.72	1,957.97	1,958.02	1,958.07	1,958.05	1,957.80
Age lambda								
	ALL							
Parameters								
	NatM_uniform_Fem_GP_1	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	L_at_Amin_Fem_GP_1	-3.10	-3.34	-3.10	-3.10	-3.10	-3.10	-3.11
	L_at_Amax_Fem_GP_1	60.08	60.11	60.08	60.08	60.08	60.08	60.08
	VonBert_K_Fem_GP_1	0.08	0.08	0.08	0.08	0.08	0.08	0.08
	CV_young_Fem_GP_1	0.05	0.04	0.05	0.05	0.05	0.05	0.05
	CV_old_Fem_GP_1	0.09	0.09	0.09	0.09	0.09	0.09	0.09
	Wtlen_1_Fem_GP_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Wtlen_2_Fem_GP_1	3.15	3.15	3.15	3.15	3.15	3.15	3.15
	Mat50%_Fem_GP_1	46.53	46.53	46.53	46.53	46.53	46.53	46.53
	Mat_slope_Fem_GP_1	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25
	Eggs_scalar_Fem_GP_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Eggs_exp_len_Fem_GP_1	4.04	4.04	4.04	4.04	4.04	4.04	4.04
	NatM_uniform_Mal_GP_1	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	L_at_Amin_Mal_GP_1	-2.67	-3.63	-2.68	-2.68	-2.68	-2.68	-2.70
	L_at_Amax_Mal_GP_1	57.83	57.82	57.83	57.83	57.83	57.83	57.84
	VonBert_K_Mal_GP_1	0.08	0.09	0.08	0.08	0.08	0.08	0.08
	CV_young_Mal_GP_1	0.09	0.06	0.09	0.09	0.09	0.09	0.09
	CV_old_Mal_GP_1	0.08	0.09	0.09	0.09	0.09	0.09	0.09
	Wtlen_1_Mal_GP_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Wtlen_2_Mal_GP_1	3.07	3.07	3.07	3.07	3.07	3.07	3.07
	CohortGrowDev	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	FracFemale_GP_1	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	SR_LN(R0)	6.98	8.27	6.92	6.90	6.89	6.89	7.09
	SR_BH_steep	0.72	0.72	0.72	0.72	0.72	0.72	0.72
	SR_sigmaR	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	SR_regime	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	SR_autocorr	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	LnQ_base_TRIENNIAL(7)	-1.47	-2.82	-1.42	-1.41	-1.39	-1.40	-1.59
	LnQ_base_AK_SLOPE(8)	-3.10	-4.26	-3.05	-3.03	-3.02	-3.03	-3.21

LnQ_base_NW_SLOPE(9)	-2.03	-3.20	-1.98	-1.97	-1.95	-1.96	-2.14
LnQ_base_WCGBTS(10)	-2.60	-3.80	-2.54	-2.52	-2.51	-2.51	-2.71
LnQ_base_TRIENNIAL(7)_-BLK3repl_1892	-2.26	-3.46	-2.22	-2.20	-2.19	-2.19	-2.36
Size_DblN_peak_BOTTOM_-TRAWL(1)	49.34	49.32	49.34	49.33	49.33	49.33	49.32
Size_DblN_top_logit_-BOTTOM_TRAWL(1)	-11.52	-11.52	-11.52	-11.52	-11.52	-11.52	-11.52
Size_DblN_ascend_se_-BOTTOM_TRAWL(1)	4.57	4.66	4.57	4.57	4.57	4.57	4.57
Size_DblN_descend_se_-BOTTOM_TRAWL(1)	2.95	3.04	2.95	2.95	2.95	2.95	2.95
Size_DblN_start_logit_-BOTTOM_TRAWL(1)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-BOTTOM_TRAWL(1)	-0.64	-0.68	-0.64	-0.64	-0.64	-0.64	-0.64
Size_DblN_peak_BOTTOM_-TRAWL_DISCARD(2)	25.26	23.61	25.26	25.25	25.25	25.25	25.25
Size_DblN_top_logit_-BOTTOM_TRAWL_-DISCARD(2)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_-BOTTOM_TRAWL_-DISCARD(2)	4.89	4.82	4.89	4.89	4.89	4.89	4.89
Size_DblN_descend_se_-BOTTOM_TRAWL_-DISCARD(2)	3.84	4.07	3.84	3.84	3.84	3.84	3.84
Size_DblN_start_logit_-BOTTOM_TRAWL_-DISCARD(2)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_end_logit_-BOTTOM_TRAWL_-DISCARD(2)	-3.81	-4.06	-3.82	-3.82	-3.82	-3.82	-3.83
Size_DblN_peak_NON_-TRAWL(3)	50.28	50.20	50.27	50.27	50.26	50.26	50.24
Size_DblN_top_logit_NON_-TRAWL(3)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_NON_-TRAWL(3)	3.86	4.00	3.86	3.86	3.86	3.86	3.86

Size_DblN_descend_se_NON_-TRAWL(3)	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Size_DblN_start_logit_NON_-TRAWL(3)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_NON_-TRAWL(3)	4.60	4.60	4.60	4.60	4.60	4.60	4.60
Size_DblN_peak_NON_-TRAWL_DISCARD(4)	49.95	50.08	49.94	49.94	49.94	49.94	49.93
Size_DblN_top_logit_NON_-TRAWL_DISCARD(4)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_NON_-TRAWL_DISCARD(4)	3.75	3.79	3.75	3.75	3.75	3.75	3.75
Size_DblN_descend_se_NON_-TRAWL_DISCARD(4)	2.66	2.65	2.66	2.66	2.66	2.66	2.67
Size_DblN_start_logit_NON_-TRAWL_DISCARD(4)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_NON_-TRAWL_DISCARD(4)	-0.19	-0.24	-0.19	-0.19	-0.20	-0.20	-0.20
Size_DblN_peak_-MIDWATER_TRAWL(5)	52.18	52.17	52.17	52.16	52.16	52.16	52.13
Size_DblN_top_logit_-MIDWATER_TRAWL(5)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_-MIDWATER_TRAWL(5)	4.57	4.66	4.57	4.57	4.57	4.57	4.57
Size_DblN_descend_se_-MIDWATER_TRAWL(5)	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Size_DblN_start_logit_-MIDWATER_TRAWL(5)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-MIDWATER_TRAWL(5)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_peak_AT_SEA_-HAKE(6)	49.71	49.57	49.71	49.71	49.70	49.70	49.69
Size_DblN_top_logit_AT_-SEA_HAKE(6)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_AT_-SEA_HAKE(6)	3.59	3.58	3.59	3.59	3.59	3.59	3.59
Size_DblN_descend_se_AT_-SEA_HAKE(6)	20.00	20.00	20.00	20.00	20.00	20.00	20.00

Size_DblN_start_logit_AT_-SEA_HAKE(6)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_AT_-SEA_HAKE(6)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_peak_-TRIENNIAL(7)	21.78	22.07	21.78	21.77	21.77	21.77	21.78
Size_DblN_top_logit_-TRIENNIAL(7)	-8.60	-8.60	-8.60	-8.60	-8.60	-8.60	-8.60
Size_DblN_ascend_se_-TRIENNIAL(7)	3.53	3.58	3.52	3.52	3.52	3.52	3.52
Size_DblN_descend_se_-TRIENNIAL(7)	3.95	3.99	3.95	3.95	3.95	3.95	3.95
Size_DblN_start_logit_-TRIENNIAL(7)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-TRIENNIAL(7)	-2.58	-2.56	-2.59	-2.59	-2.59	-2.59	-2.59
Size_DblN_peak_AK_-SLOPE(8)	37.29	36.47	37.29	37.29	37.29	37.29	37.29
Size_DblN_top_logit_AK_-SLOPE(8)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_AK_-SLOPE(8)	4.94	4.68	4.94	4.94	4.95	4.95	4.94
Size_DblN_descend_se_AK_-SLOPE(8)	4.63	4.65	4.63	4.63	4.63	4.63	4.63
Size_DblN_start_logit_AK_-SLOPE(8)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_AK_-SLOPE(8)	-10.48	-10.08	-10.48	-10.48	-10.48	-10.48	-10.48
Size_DblN_peak_WCGBTS(10)	21.09	20.65	21.08	21.07	21.07	21.07	21.05
Size_DblN_top_logit_-WCGBTS(10)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_-WCGBTS(10)	3.39	3.24	3.39	3.39	3.39	3.39	3.38
Size_DblN_descend_se_-WCGBTS(10)	4.64	4.69	4.65	4.65	4.65	4.65	4.66
Size_DblN_start_logit_-WCGBTS(10)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-WCGBTS(10)	-0.83	-1.05	-0.84	-0.84	-0.84	-0.84	-0.84

Size_DblN_peak_BOTTOM_-TRAWL(1)_BLK4repl_1892	44.71	42.95	44.74	44.75	44.76	44.76	44.69
Size_DblN_peak_BOTTOM_-TRAWL(1)_BLK4repl_2002	47.64	47.51	47.64	47.64	47.64	47.64	47.63
Size_DblN_ascend_se_-BOTTOM_TRAWL(1)_-BLK4repl_1892	5.03	4.77	5.03	5.04	5.04	5.04	5.03
Size_DblN_ascend_se_-BOTTOM_TRAWL(1)_-BLK4repl_2002	4.10	4.01	4.10	4.11	4.11	4.11	4.10
Size_DblN_descend_se_-BOTTOM_TRAWL(1)_-BLK4repl_1892	2.65	3.35	2.63	2.62	2.62	2.62	2.64
Size_DblN_descend_se_-BOTTOM_TRAWL(1)_-BLK4repl_2002	2.75	2.75	2.75	2.75	2.75	2.75	2.75
Size_DblN_end_logit_-BOTTOM_TRAWL(1)_-BLK4repl_1892	-1.59	-1.86	-1.56	-1.54	-1.54	-1.54	-1.57
Size_DblN_end_logit_-BOTTOM_TRAWL(1)_-BLK4repl_2002	-0.93	-1.05	-0.93	-0.94	-0.94	-0.94	-0.94
Size_DblN_peak_BOTTOM_-TRAWL_DISCARD(2)_-BLK1repl_1892	47.68	47.89	47.67	47.67	47.67	47.67	47.66
Size_DblN_ascend_se_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	6.32	6.24	6.32	6.32	6.33	6.32	6.32
Size_DblN_descend_se_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	3.01	2.93	3.01	3.01	3.02	3.02	3.02
Size_DblN_end_logit_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	-1.70	-1.76	-1.70	-1.70	-1.70	-1.70	-1.71
Size_DblN_peak_NON_-TRAWL(3)_BLK2repl_1892	46.77	46.61	46.77	46.77	46.77	46.77	46.76
Size_DblN_peak_NON_-TRAWL(3)_BLK2repl_2011	49.49	49.62	49.49	49.49	49.49	49.49	49.48

	Size_DblN_ascend_se_NON_-TRAWL(3)_BLK2repl_1892	3.05	2.98	3.05	3.05	3.05	3.05	3.05
	Size_DblN_ascend_se_NON_-TRAWL(3)_BLK2repl_2011	3.81	3.83	3.81	3.81	3.81	3.81	3.81
	Size_DblN_descend_se_NON_-TRAWL(3)_BLK2repl_1892	3.17	3.18	3.17	3.17	3.17	3.17	3.17
	Size_DblN_descend_se_NON_-TRAWL(3)_BLK2repl_2011	2.32	2.35	2.32	2.33	2.33	2.33	2.33
	Size_DblN_end_logit_NON_-TRAWL(3)_BLK2repl_1892	-2.28	-2.39	-2.28	-2.28	-2.28	-2.28	-2.29
	Size_DblN_end_logit_NON_-TRAWL(3)_BLK2repl_2011	-0.62	-0.64	-0.63	-0.63	-0.63	-0.63	-0.63
	Size_DblN_peak_-TRIENNIAL(7)_BLK3repl_1892	17.36	17.15	17.34	17.34	17.34	17.34	17.37
	Size_DblN_ascend_se_-TRIENNIAL(7)_BLK3repl_1892	2.09	1.94	2.08	2.08	2.08	2.08	2.09
	Size_DblN_descend_se_-TRIENNIAL(7)_BLK3repl_1892	5.10	5.07	5.10	5.11	5.11	5.11	5.11
	Size_DblN_end_logit_-TRIENNIAL(7)_BLK3repl_1892	-4.28	-4.20	-4.28	-4.29	-4.29	-4.29	-4.33
	Size_DblN_peak_BOTTOM_-TRAWL(1)_BLK2repl_1892							
	Size_DblN_peak_BOTTOM_-TRAWL(1)_BLK2repl_2011							
	Size_DblN_ascend_se_-BOTTOM_TRAWL(1)_-BLK2repl_1892							
	Size_DblN_ascend_se_-BOTTOM_TRAWL(1)_-BLK2repl_2011							
Derived quantities								
	SB0	5.57	20.04	5.24	5.12	5.04	5.07	6.15
	SSB_2025	4.86	19.03	4.60	4.50	4.44	4.47	5.49
	Bratio_2025	0.87	0.95	0.88	0.88	0.88	0.88	0.89
	MSY_SPR	519.31	1,878.45	489.66	478.55	471.32	474.66	575.86
	F_SPR	0.04	0.04	0.04	0.04	0.04	0.04	0.04

Table 33: Likelihood values and estimates of key parameters and derived quantities from each recruitment and selectivity sensitivity (recruitment deviations and fishery selectivity).

Label	Type	Reference	1970 recdevs	1980 recdevs	Logistic fisheries	Logistic btrawl	Logistic nontrawl
AIC							
	AIC	15,093.86	14,947.26	14,927.38	15,393.42	15,185.00	15,357.78
	deltaAIC	0.00	-146.60	-166.48	299.56	91.14	263.92
Survey likelihood							
	ALL	-26.81	-27.06	-27.07	-27.18	-26.73	-26.74
	TRIENNIAL	-7.76	-8.00	-8.01	-8.22	-7.75	-7.80
	AK_SLOPE	-0.53	-0.55	-0.55	-0.54	-0.52	-0.52
	NW_SLOPE	-1.03	-1.04	-1.04	-1.03	-1.03	-1.02
	WCGBTS	-17.49	-17.47	-17.47	-17.39	-17.43	-17.39
Lt likelihood							
	ALL	574.80	576.90	577.15	702.11	617.52	684.17
	BOTTOM_TRAWL	79.11	78.69	78.65	106.01	123.64	82.67
	BOTTOM_TRAWL_DISCARD	27.15	27.12	27.12	27.68	27.31	27.65
	NON_TRAWL	179.64	181.18	181.32	275.95	181.87	283.07
	NON_TRAWL_DISCARD	46.63	46.67	46.67	49.95	47.56	49.53
	MIDWATER_TRAWL	58.94	59.46	59.52	58.58	57.36	58.39
	AT_SEA_HAKE	25.42	25.87	25.93	24.94	22.45	24.43
	TRIENNIAL	22.43	22.37	22.39	21.72	21.97	21.71
	AK_SLOPE	52.31	52.32	52.32	52.57	52.39	52.54
	NW_SLOPE	0.00	0.00	0.00	0.00	0.00	0.00
	WCGBTS	83.19	83.22	83.23	84.69	82.96	84.17
Lt lambda							
	ALL						
Age likelihood							
	ALL	6,783.50	6,788.24	6,788.05	6,818.04	6,793.09	6,811.75
	BOTTOM_TRAWL	464.26	464.16	464.14	462.88	463.81	462.88
	BOTTOM_TRAWL_DISCARD	0.00	0.00	0.00	0.00	0.00	0.00
	NON_TRAWL	331.37	331.74	331.73	333.46	331.62	333.12
	NON_TRAWL_DISCARD	0.00	0.00	0.00	0.00	0.00	0.00
	MIDWATER_TRAWL	182.47	182.24	182.24	180.88	181.84	181.00

	AT_SEA_HAKE	3,847.50	3,852.18	3,851.98	3,884.77	3,858.45	3,878.34
	TRIENNIAL	0.00	0.00	0.00	0.00	0.00	0.00
	AK_SLOPE	0.00	0.00	0.00	0.00	0.00	0.00
	NW_SLOPE	0.00	0.00	0.00	0.00	0.00	0.00
	WCGBTS	1,957.89	1,957.92	1,957.96	1,956.05	1,957.36	1,956.40
Age lambda							
	ALL						
Parameters							
	NatM_uniform_Fem_GP_1	0.04	0.04	0.04	0.04	0.04	0.04
	L_at_Amin_Fem_GP_1	-3.10	-3.15	-3.15	-3.43	-3.13	-3.37
	L_at_Amax_Fem_GP_1	60.08	60.10	60.11	57.59	59.16	57.83
	VonBert_K_Fem_GP_1	0.08	0.08	0.08	0.08	0.08	0.08
	CV_young_Fem_GP_1	0.05	0.05	0.05	0.03	0.04	0.03
	CV_old_Fem_GP_1	0.09	0.09	0.09	0.10	0.10	0.10
	Wtlen_1_Fem_GP_1	0.00	0.00	0.00	0.00	0.00	0.00
	Wtlen_2_Fem_GP_1	3.15	3.15	3.15	3.15	3.15	3.15
	Mat50%_Fem_GP_1	46.53	46.53	46.53	46.53	46.53	46.53
	Mat_slope_Fem_GP_1	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25
	Eggs_scalar_Fem_GP_1	0.00	0.00	0.00	0.00	0.00	0.00
	Eggs_exp_len_Fem_GP_1	4.04	4.04	4.04	4.04	4.04	4.04
	NatM_uniform_Mal_GP_1	0.04	0.04	0.04	0.04	0.04	0.04
	L_at_Amin_Mal_GP_1	-2.67	-2.76	-2.76	-4.06	-2.95	-3.86
	L_at_Amax_Mal_GP_1	57.83	57.90	57.91	55.23	56.91	55.49
	VonBert_K_Mal_GP_1	0.08	0.08	0.08	0.09	0.09	0.09
	CV_young_Mal_GP_1	0.09	0.09	0.09	0.05	0.08	0.05
	CV_old_Mal_GP_1	0.08	0.08	0.08	0.09	0.09	0.09
	Wtlen_1_Mal_GP_1	0.00	0.00	0.00	0.00	0.00	0.00
	Wtlen_2_Mal_GP_1	3.07	3.07	3.07	3.07	3.07	3.07
	CohortGrowDev	1.00	1.00	1.00	1.00	1.00	1.00
	FracFemale_GP_1	0.50	0.50	0.50	0.50	0.50	0.50
	SR_LN(R0)	6.98	8.28	8.59	6.07	6.20	6.05
	SR_BH_steep	0.72	0.72	0.72	0.72	0.72	0.72
	SR_sigmaR	0.50	0.50	0.50	0.50	0.50	0.50
	SR_regime	0.00	0.00	0.00	0.00	0.00	0.00
	SR_autocorr	0.00	0.00	0.00	0.00	0.00	0.00
	LnQ_base_TRIENNIAL(7)	-1.47	-2.81	-3.14	-0.35	-0.55	-0.35
	LnQ_base_AK_SLOPE(8)	-3.10	-4.42	-4.74	-2.15	-2.25	-2.12

LnQ_base_NW_SLOPE(9)	-2.03	-3.36	-3.68	-1.09	-1.18	-1.05
LnQ_base_WCGBTS(10)	-2.60	-3.95	-4.27	-1.47	-1.68	-1.45
LnQ_base_TRIENNIAL(7)_-BLK3repl_1892	-2.26	-3.51	-3.83	-1.09	-1.35	-1.17
Size_DblN_peak_BOTTOM_-TRAWL(1)	49.34	49.21	49.20	50.79	49.15	52.27
Size_DblN_top_logit_-BOTTOM_TRAWL(1)	-11.52	-11.52	-11.52	-15.00	-15.00	-11.52
Size_DblN_ascend_se_-BOTTOM_TRAWL(1)	4.57	4.57	4.57	4.64	4.52	4.84
Size_DblN_descend_se_-BOTTOM_TRAWL(1)	2.95	2.97	2.97	20.00	20.00	-1.21
Size_DblN_start_logit_-BOTTOM_TRAWL(1)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-BOTTOM_TRAWL(1)	-0.64	-0.69	-0.69	-999.00	-999.00	0.96
Size_DblN_peak_BOTTOM_-TRAWL_DISCARD(2)	25.26	25.19	25.18	25.46	25.45	25.51
Size_DblN_top_logit_-BOTTOM_TRAWL_-DISCARD(2)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_-BOTTOM_TRAWL_-DISCARD(2)	4.89	4.90	4.90	5.04	4.92	5.03
Size_DblN_descend_se_-BOTTOM_TRAWL_-DISCARD(2)	3.84	3.86	3.86	3.73	3.78	3.72
Size_DblN_start_logit_-BOTTOM_TRAWL_-DISCARD(2)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_end_logit_-BOTTOM_TRAWL_-DISCARD(2)	-3.81	-3.87	-3.88	-3.40	-3.57	-3.41
Size_DblN_peak_NON_-TRAWL(3)	50.28	50.06	50.03	54.17	51.61	53.76
Size_DblN_top_logit_NON_-TRAWL(3)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_NON_-TRAWL(3)	3.86	3.85	3.85	4.25	3.96	4.20

Size_DblN_descend_se_NON_-TRAWL(3)	20.00	20.00	20.00	20.00	20.00	20.00
Size_DblN_start_logit_NON_-TRAWL(3)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_NON_-TRAWL(3)	4.60	4.60	4.60	-999.00	4.60	-999.00
Size_DblN_peak_NON_-TRAWL_DISCARD(4)	49.95	49.85	49.83	51.62	51.08	51.58
Size_DblN_top_logit_NON_-TRAWL_DISCARD(4)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_NON_-TRAWL_DISCARD(4)	3.75	3.74	3.74	3.98	3.94	3.98
Size_DblN_descend_se_NON_-TRAWL_DISCARD(4)	2.66	2.69	2.69	1.25	1.94	1.32
Size_DblN_start_logit_NON_-TRAWL_DISCARD(4)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_NON_-TRAWL_DISCARD(4)	-0.19	-0.24	-0.24	2.24	0.42	1.76
Size_DblN_peak_-MIDWATER_TRAWL(5)	52.18	51.86	51.82	62.40	55.02	60.55
Size_DblN_top_logit_-MIDWATER_TRAWL(5)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_-MIDWATER_TRAWL(5)	4.57	4.55	4.55	5.33	4.79	5.20
Size_DblN_descend_se_-MIDWATER_TRAWL(5)	20.00	20.00	20.00	20.00	20.00	20.00
Size_DblN_start_logit_-MIDWATER_TRAWL(5)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-MIDWATER_TRAWL(5)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_peak_AT_SEA_-HAKE(6)	49.71	49.56	49.54	54.30	51.18	53.68
Size_DblN_top_logit_AT_-SEA_HAKE(6)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_AT_-SEA_HAKE(6)	3.59	3.58	3.58	4.22	3.79	4.13
Size_DblN_descend_se_AT_-SEA_HAKE(6)	20.00	20.00	20.00	20.00	20.00	20.00

Size_DblN_start_logit_AT_-SEA_HAKE(6)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_AT_-SEA_HAKE(6)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_peak_-TRIENNIAL(7)	21.78	21.79	21.79	21.82	21.82	21.83
Size_DblN_top_logit_-TRIENNIAL(7)	-8.60	-8.60	-8.60	-8.60	-8.60	-8.60
Size_DblN_ascend_se_-TRIENNIAL(7)	3.53	3.52	3.52	3.53	3.54	3.54
Size_DblN_descend_se_-TRIENNIAL(7)	3.95	3.97	3.97	3.80	3.87	3.81
Size_DblN_start_logit_-TRIENNIAL(7)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-TRIENNIAL(7)	-2.58	-2.60	-2.60	-2.34	-2.47	-2.34
Size_DblN_peak_AK_-SLOPE(8)	37.29	37.27	37.26	37.03	37.30	37.16
Size_DblN_top_logit_AK_-SLOPE(8)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_AK_-SLOPE(8)	4.94	4.93	4.93	4.96	4.97	4.96
Size_DblN_descend_se_AK_-SLOPE(8)	4.63	4.62	4.62	4.85	4.71	4.82
Size_DblN_start_logit_AK_-SLOPE(8)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_AK_-SLOPE(8)	-10.48	-10.37	-10.38	-10.30	-10.51	-10.34
Size_DblN_peak_WCGBTS(10)	21.09	20.89	20.87	21.50	21.61	21.51
Size_DblN_top_logit_-WCGBTS(10)	-15.00	-15.00	-15.00	-15.00	-15.00	-15.00
Size_DblN_ascend_se_-WCGBTS(10)	3.39	3.34	3.34	3.49	3.52	3.49
Size_DblN_descend_se_-WCGBTS(10)	4.64	4.74	4.75	4.14	4.31	4.15
Size_DblN_start_logit_-WCGBTS(10)	-999.00	-999.00	-999.00	-999.00	-999.00	-999.00
Size_DblN_end_logit_-WCGBTS(10)	-0.83	-0.89	-0.90	-0.44	-0.59	-0.43

Size_DblN_peak_BOTTOM_-TRAWL(1)_BLK4repl_1892	44.71	44.41	44.37			45.69
Size_DblN_peak_BOTTOM_-TRAWL(1)_BLK4repl_2002	47.64	47.56	47.55			49.00
Size_DblN_ascend_se_-BOTTOM_TRAWL(1)_-BLK4repl_1892	5.03	4.99	4.99			5.13
Size_DblN_ascend_se_-BOTTOM_TRAWL(1)_-BLK4repl_2002	4.10	4.10	4.10			4.24
Size_DblN_descend_se_-BOTTOM_TRAWL(1)_-BLK4repl_1892	2.65	2.81	2.83			1.72
Size_DblN_descend_se_-BOTTOM_TRAWL(1)_-BLK4repl_2002	2.75	2.77	2.78			-12.73
Size_DblN_end_logit_-BOTTOM_TRAWL(1)_-BLK4repl_1892	-1.59	-1.74	-1.77			-0.76
Size_DblN_end_logit_-BOTTOM_TRAWL(1)_-BLK4repl_2002	-0.93	-0.98	-0.98			0.21
Size_DblN_peak_BOTTOM_-TRAWL_DISCARD(2)_-BLK1repl_1892	47.68	47.58	47.57	48.71	48.12	48.69
Size_DblN_ascend_se_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	6.32	6.31	6.31	6.36	6.33	6.36
Size_DblN_descend_se_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	3.01	3.03	3.03	2.60	2.87	2.63
Size_DblN_end_logit_-BOTTOM_TRAWL_-DISCARD(2)_BLK1repl_1892	-1.70	-1.75	-1.75	-0.65	-1.30	-0.75
Size_DblN_peak_NON_-TRAWL(3)_BLK2repl_1892	46.77	46.71	46.71	45.83	47.05	45.74
Size_DblN_peak_NON_-TRAWL(3)_BLK2repl_2011	49.49	49.42	49.41	50.02	50.02	49.84

	Size_DblN_ascend_se_NON_-TRAWL(3)_BLK2repl_1892	3.05	3.04	3.04	2.98	3.11	2.96
	Size_DblN_ascend_se_NON_-TRAWL(3)_BLK2repl_2011	3.81	3.81	3.81	3.91	3.86	3.88
	Size_DblN_descend_se_NON_-TRAWL(3)_BLK2repl_1892	3.17	3.18	3.18		3.10	
	Size_DblN_descend_se_NON_-TRAWL(3)_BLK2repl_2011	2.32	2.36	2.36		1.73	
	Size_DblN_end_logit_NON_-TRAWL(3)_BLK2repl_1892	-2.28	-2.33	-2.34		-1.88	
	Size_DblN_end_logit_NON_-TRAWL(3)_BLK2repl_2011	-0.62	-0.67	-0.67		-0.10	
	Size_DblN_peak_-TRIENNIAL(7)_BLK3repl_1892	17.36	17.44	17.42	16.94	17.32	16.95
	Size_DblN_ascend_se_-TRIENNIAL(7)_BLK3repl_1892	2.09	2.11	2.10	1.88	2.06	1.90
	Size_DblN_descend_se_-TRIENNIAL(7)_BLK3repl_1892	5.10	5.11	5.13	5.17	5.09	5.13
	Size_DblN_end_logit_-TRIENNIAL(7)_BLK3repl_1892	-4.28	-4.39	-4.41	-4.73	-4.43	-4.42
	Size_DblN_peak_BOTTOM_-TRAWL(1)_BLK2repl_1892				47.94	46.60	
	Size_DblN_peak_BOTTOM_-TRAWL(1)_BLK2repl_2011				51.07	49.15	
	Size_DblN_ascend_se_-BOTTOM_TRAWL(1)_-BLK2repl_1892				4.89	4.84	
	Size_DblN_ascend_se_-BOTTOM_TRAWL(1)_-BLK2repl_2011				4.79	4.68	
Derived quantities							
	SB0	5.57	20.25	27.84	1.81	2.36	1.80
	SSB_2025	4.86	19.89	27.72	1.04	1.51	1.01
	Bratio_2025	0.87	0.98	1.00	0.57	0.64	0.56
	MSY_SPR	519.31	1,890.37	2,597.69	205.97	238.45	202.59
	F_SPR	0.04	0.04	0.04	0.05	0.04	0.05

Table 34: Summary of uncertainty sources and how they influence stock scale and relative status.

Source	Source.option	Change	Scale	Status
Nautral mortlality		Increase	Up	Up
Bottom Trawl Selectivity				
	Logistic		Down	Down
	Dome-shaped		Up	Up
Ageing Error		Less bias and imprecision	Down	Same
Data weighting				
	Lengths	Higher weight	Down	Down
	Ages	Higher weight	Up	Up
	WCGBTS Index	Removed	Down	Down
Recruitment estimation		Estimate fewer years	Up	Up

7.5 Management Quantities

Table 35: Recent trend in the overfishing limits (OFL), the acceptable biological catches (ABCs), the annual catch limits (ACLs), and the total dead catch (landings + discards) all in metric tons (mt). Specifications are combined across north and south of 40'10.

Year	OFL (mt)	ABC (mt)	ACL (mt)	Catch (mt)
2015	206	188.1	188.1	132.1
2016	211	192.7	192.7	149.0
2017	215	196.3	196.3	156.0
2018	219	199.9	199.9	241.5
2019	222	202.7	202.7	226.6
2020	224	204.5	204.5	106.1
2021	237	195.8	195.8	92.8
2022	238	194.7	194.7	117.4
2023	238	192.8	192.8	97.6
2024	238	194.7	194.7	118.9

Table 36: Decision table with 12-year projections. The alternative states of nature ('Low', 'Base', and 'High' as discussed in the text) are provided in the columns, with Spawning Output ('Spawn', in trillions of eggs) and Fraction of unfished spawning output ('Frac') provided for each state.

Mgmt	Year	Catch	Low Spawn	Low Frac	Base Spawn	Base Frac	High Spawn	High Frac
A	2025	155.1	1.98	0.733	4.86	0.872	13.08	0.933
	2026	186.7	1.99	0.734	4.87	0.875	13.13	0.936
	2027	843.9	1.99	0.735	4.89	0.877	13.18	0.939
	2028	825.7	1.91	0.705	4.82	0.865	13.15	0.937
	2029	808.8	1.83	0.677	4.76	0.854	13.12	0.936
	2030	792.2	1.76	0.650	4.70	0.843	13.10	0.934
	2031	776.0	1.69	0.624	4.64	0.833	13.09	0.933
	2032	760.0	1.62	0.598	4.59	0.823	13.07	0.932
	2033	745.2	1.55	0.574	4.53	0.813	13.06	0.931
	2034	729.5	1.49	0.550	4.48	0.804	13.04	0.930
	2035	713.9	1.42	0.527	4.43	0.795	13.02	0.928
	2036	699.4	1.36	0.504	4.38	0.786	13.00	0.927

Table 37: Potential OFLs (mt), ABCs (mt), ACLs (mt), the buffer between the OFL and ABC, estimated spawning output, and fraction unfished with adopted OFLs and ACLs and assumed catch for the first two years of the projection period.

Year	Adopted OFL (mt)	Adopted ACL (mt)	Assumed Catch (mt)	OFL (mt)	Buffer	ABC (mt)	ACL (mt)	Spawning output (trillions of eggs)	Fraction Unfished
2025	238	189	155	—	—	—	—	4.860	0.872
2026	237	187	187	—	—	—	—	4.875	0.875
2027	—	—	—	966	0.874	844	844	4.888	0.877
2028	—	—	—	955	0.865	826	826	4.821	0.865
2029	—	—	—	944	0.857	809	809	4.758	0.854
2030	—	—	—	933	0.849	792	792	4.698	0.843
2031	—	—	—	923	0.841	776	776	4.641	0.833
2032	—	—	—	912	0.833	760	760	4.586	0.823
2033	—	—	—	902	0.826	745	745	4.533	0.813
2034	—	—	—	892	0.818	729	729	4.480	0.804
2035	—	—	—	881	0.810	714	714	4.429	0.795
2036	—	—	—	871	0.803	699	699	4.378	0.786

8 Figures

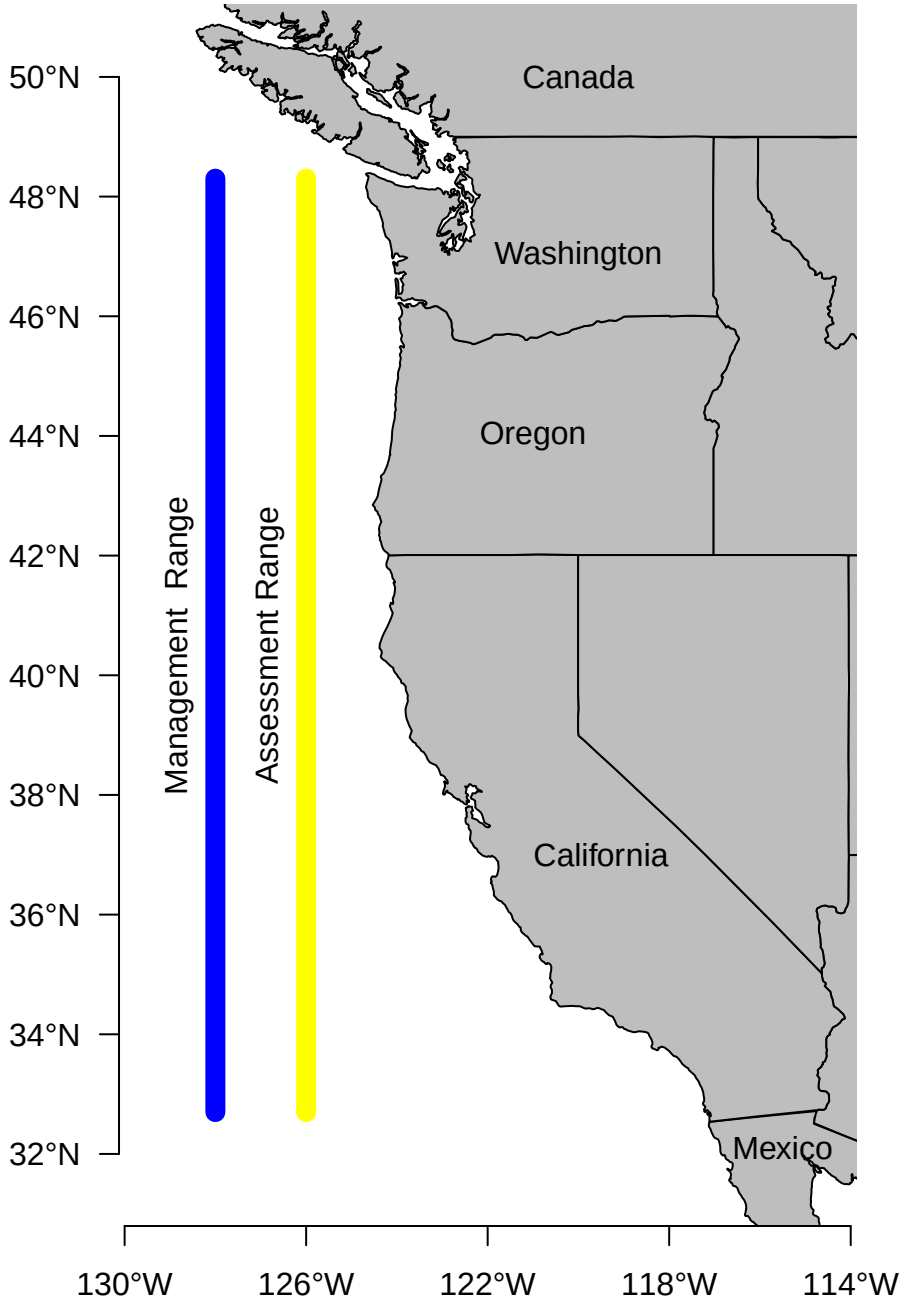


Figure 1: Map of the assessment area.

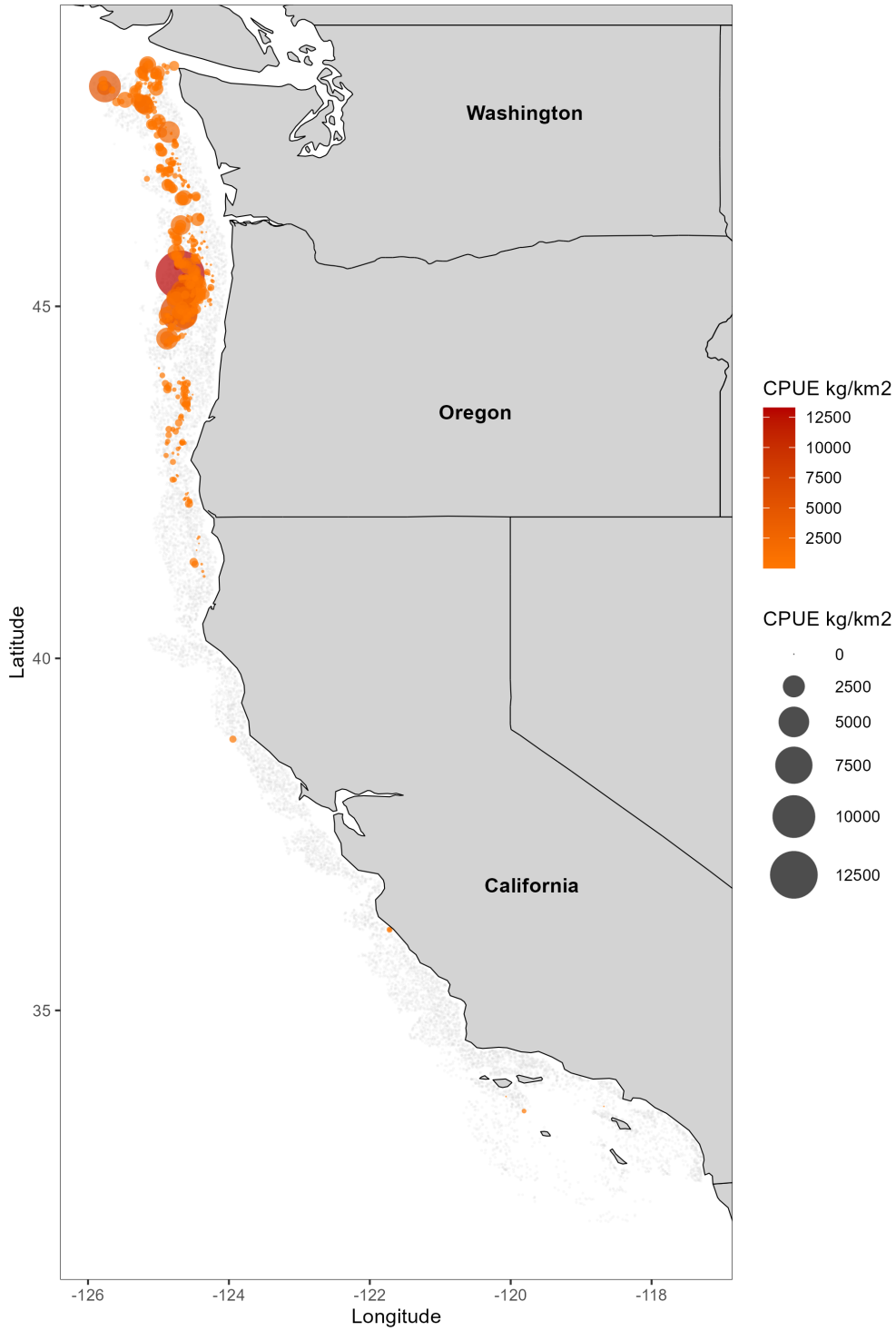


Figure 2: Rougheye/Blackspotted Rockfishes 2003-2024 WCGBTS CPUE map.

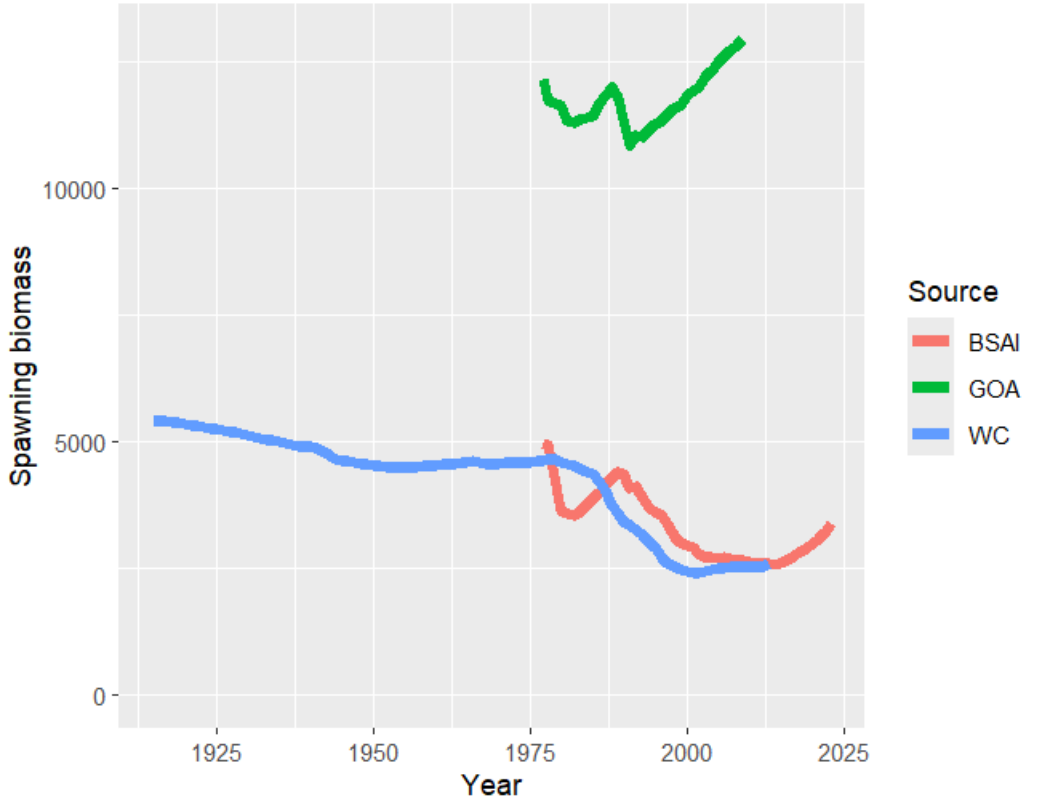


Figure 3: Estimates of biomass for the Rougheye/Blackspotted rockfish complex from the two most recent Alaska (Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska (GOA)) and the 2013 U.S. West Coast stock assessment.

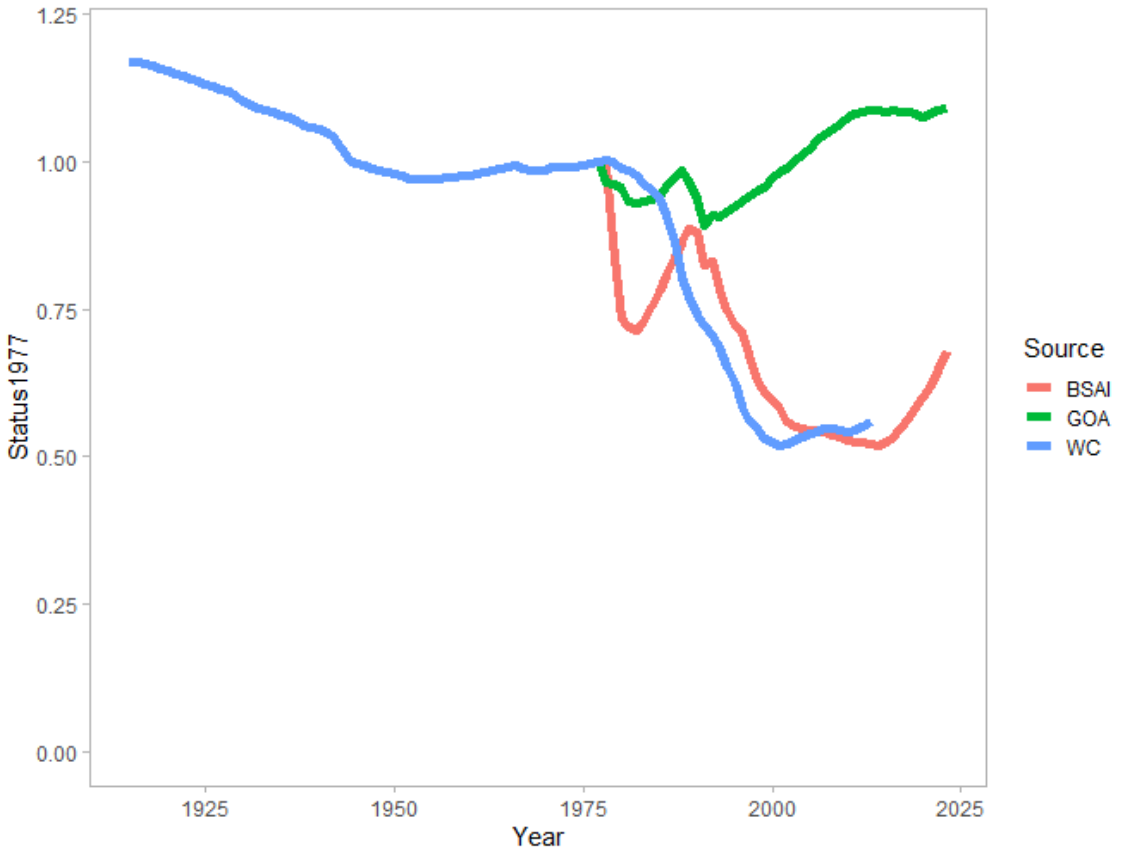


Figure 4: Estimates of fraction unfished relative to 1977 (the common year in all stock assessments compared) for the Rougheye/Blackspotted rockfish complex from the two most recent Alaska (Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska (GOA)) and the 2013 U.S. West Coast stock assessment.

8.1 Data

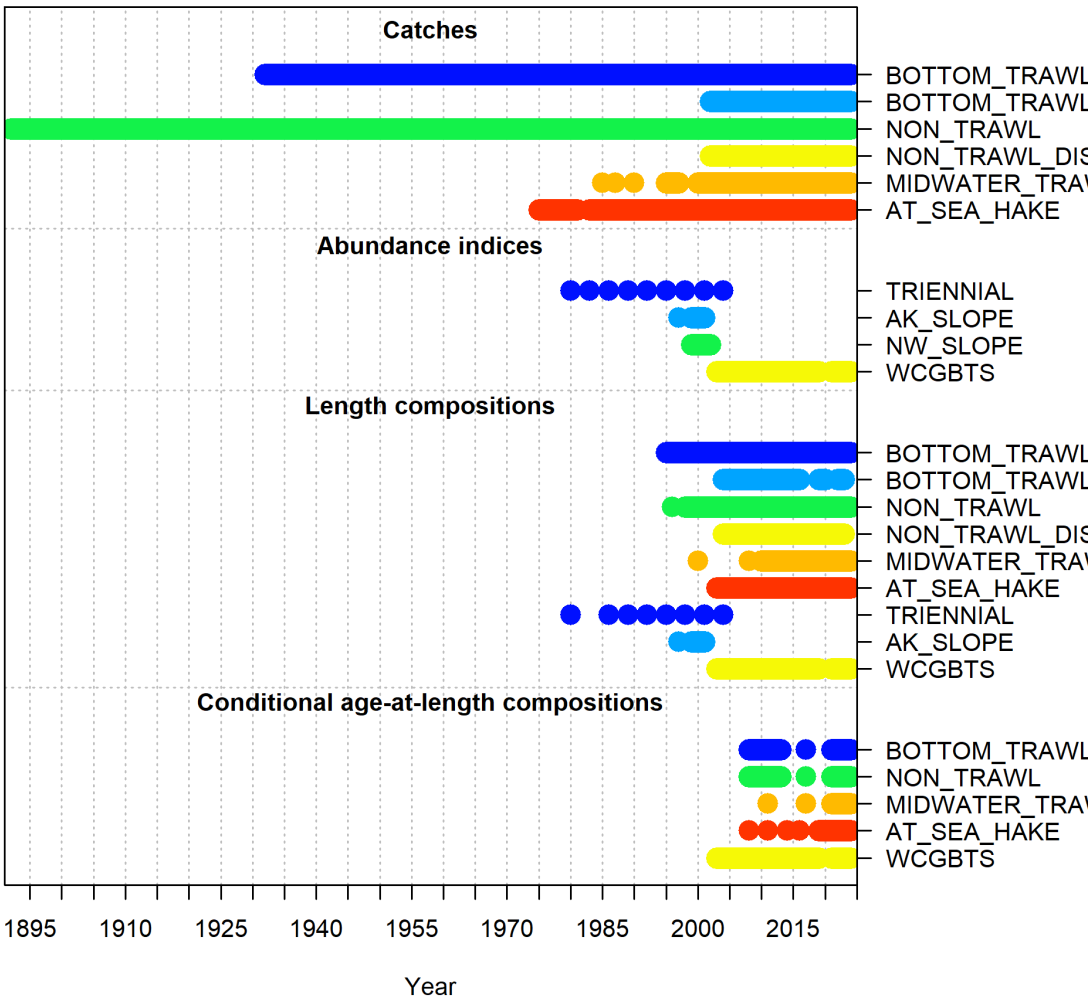


Figure 5: Data sources by year used in the assessment.

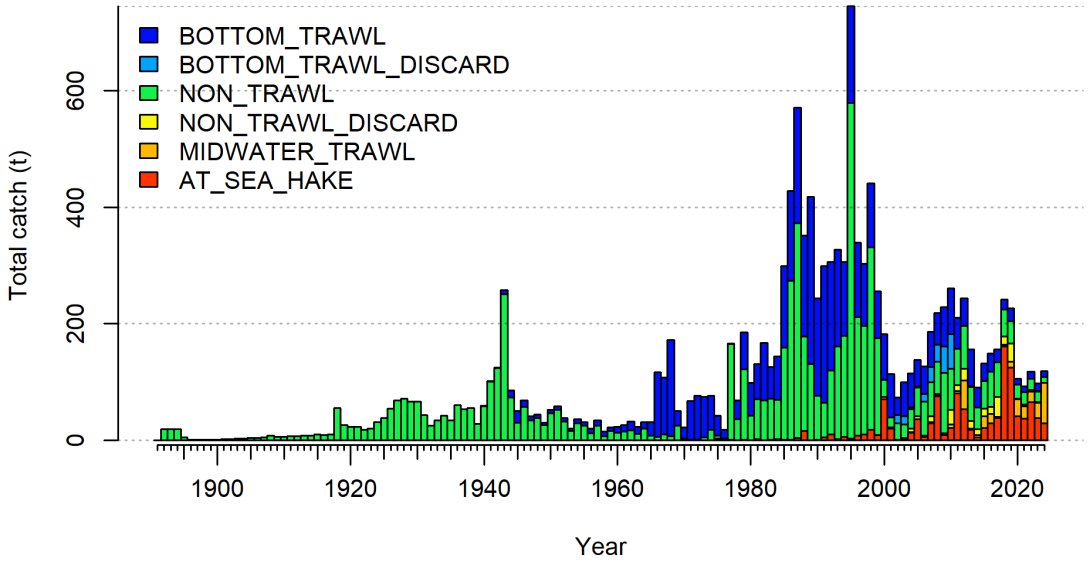


Figure 6: Time series of catches by fleet.

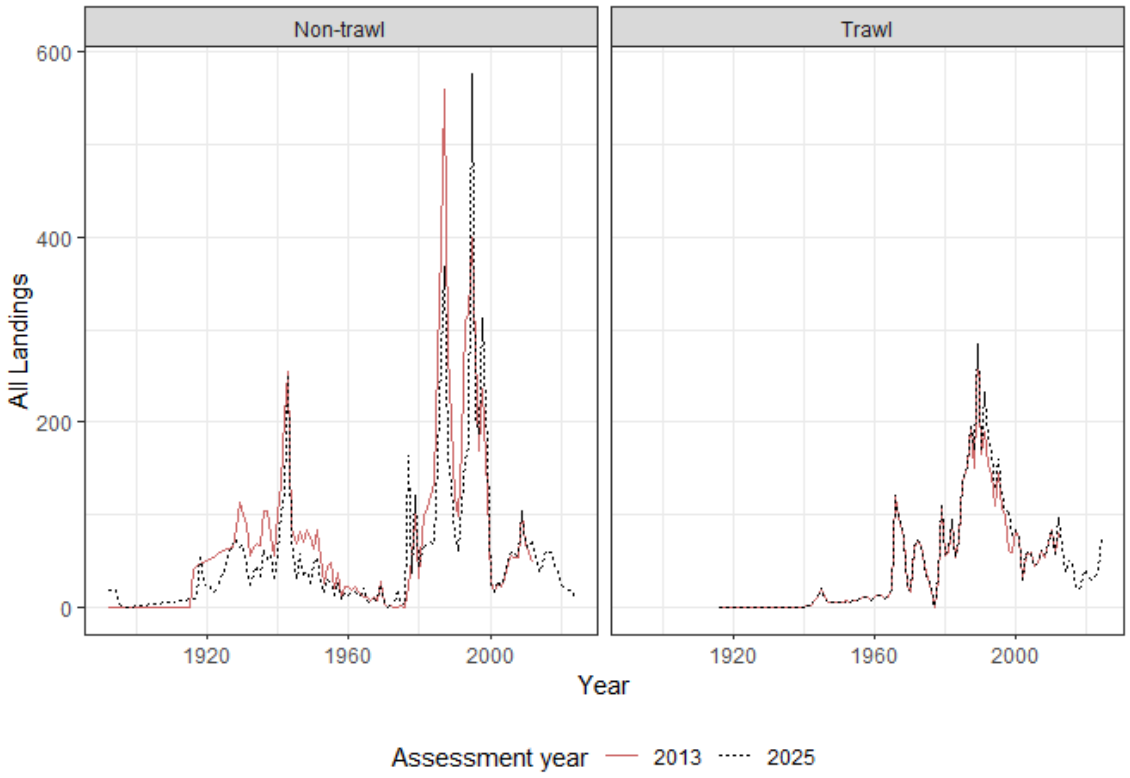


Figure 7: Landings (metric tons) across all states for non-trawl and trawl fisheries compared between the 2013 assessment and updated landings for the 2025 stock assessment model.

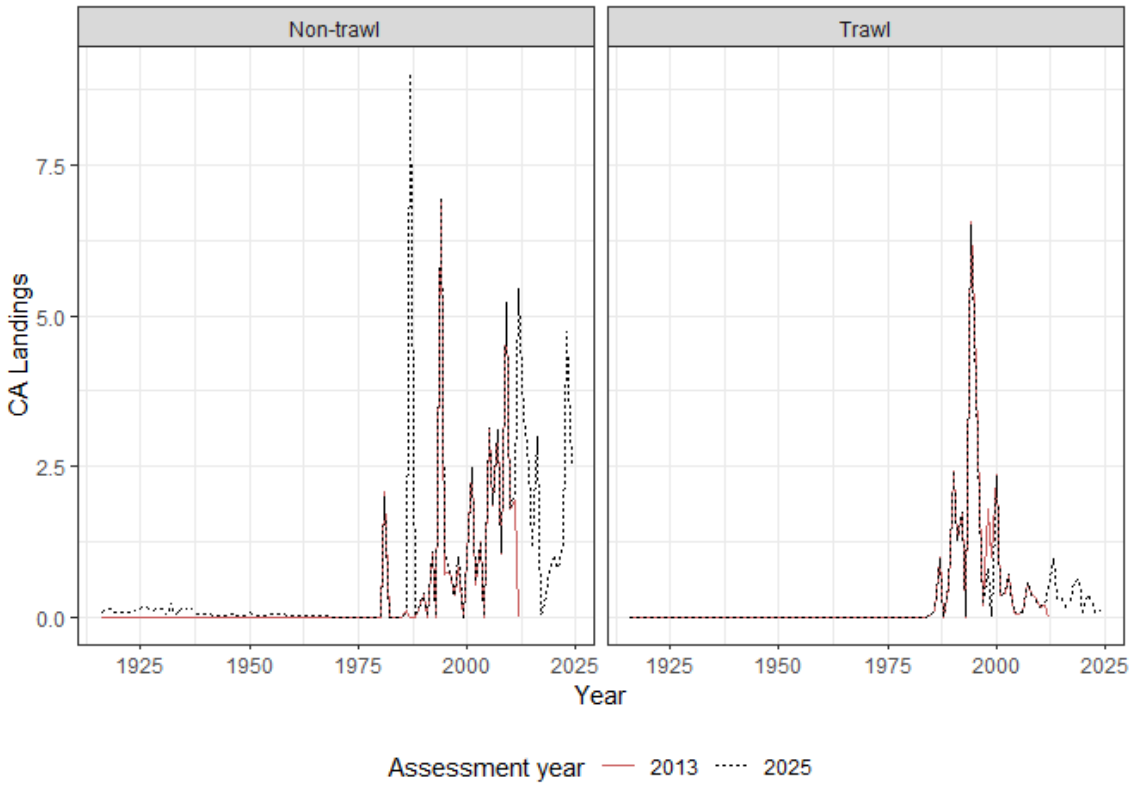


Figure 8: California state landings (metric tons) for non-trawl and trawl fisheries compared between the 2013 assessment and updated landings for the 2025 stock assessment model.

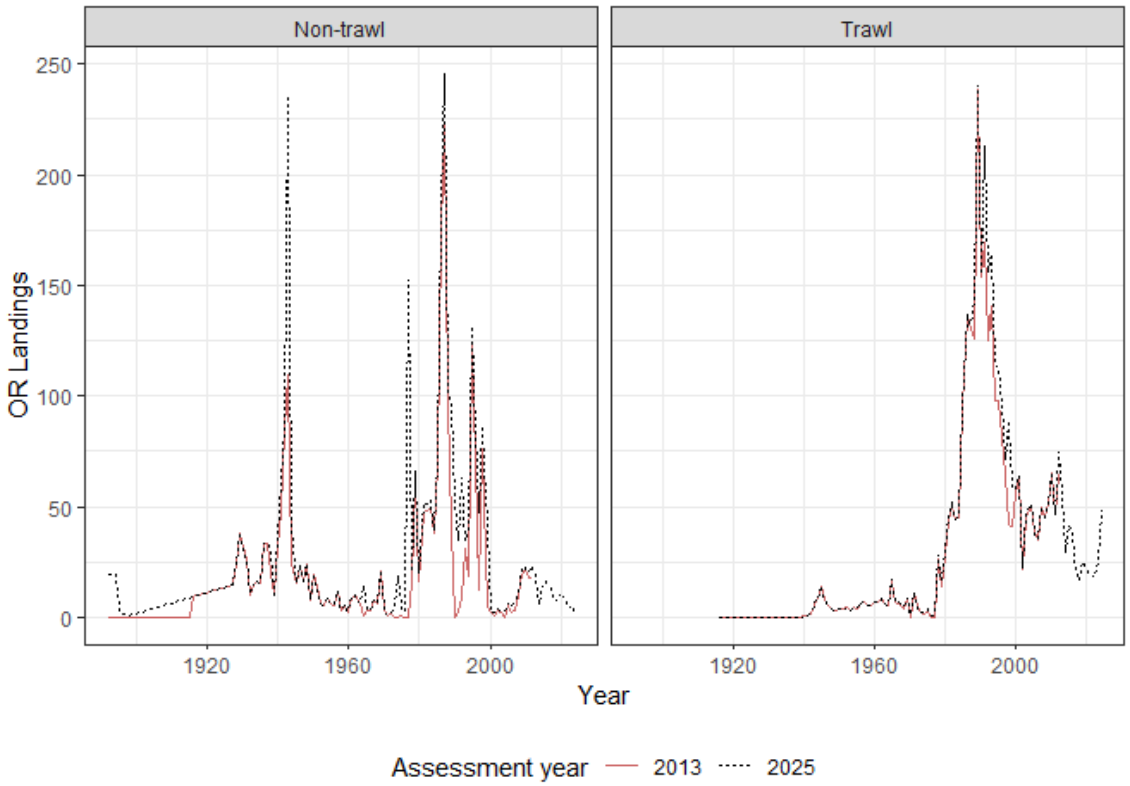


Figure 9: Oregon state landings (metric tons) for non-trawl and trawl fisheries compared between the 2013 assessment and updated landings for the 2025 stock assessment model.

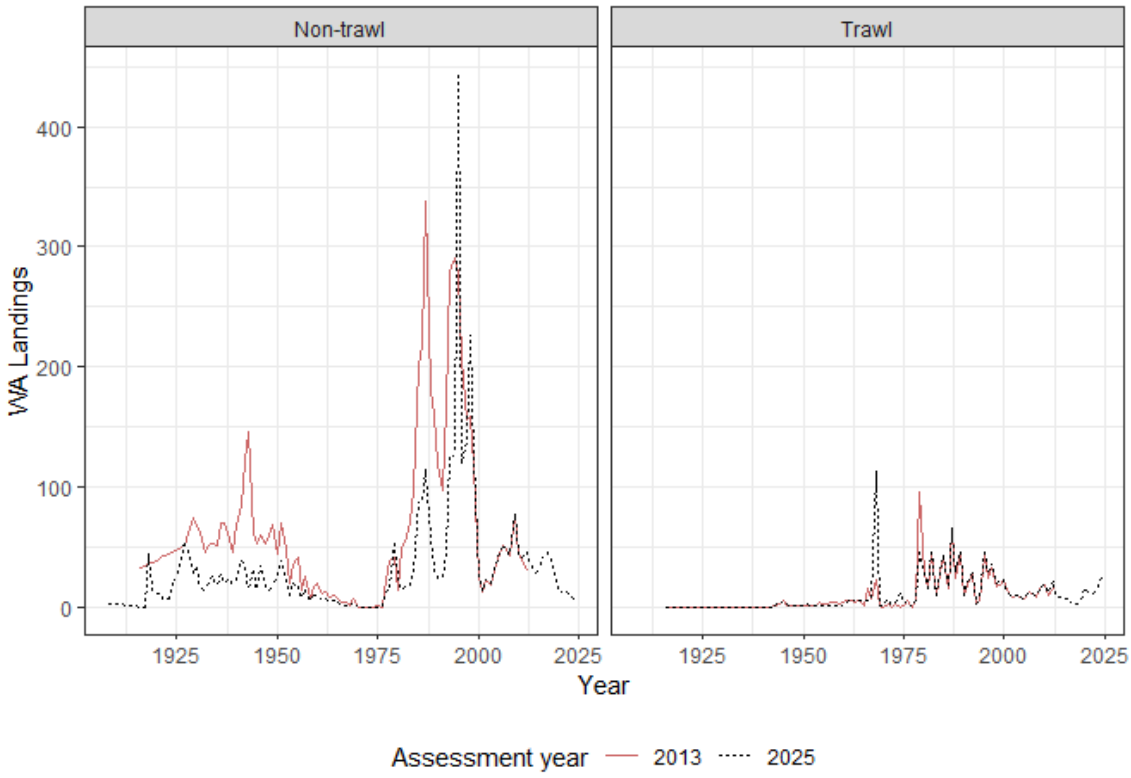


Figure 10: Washington state landings (metric tons) for non-trawl and trawl fisheries compared between the 2013 assessment and updated landings for the 2025 stock assessment model.

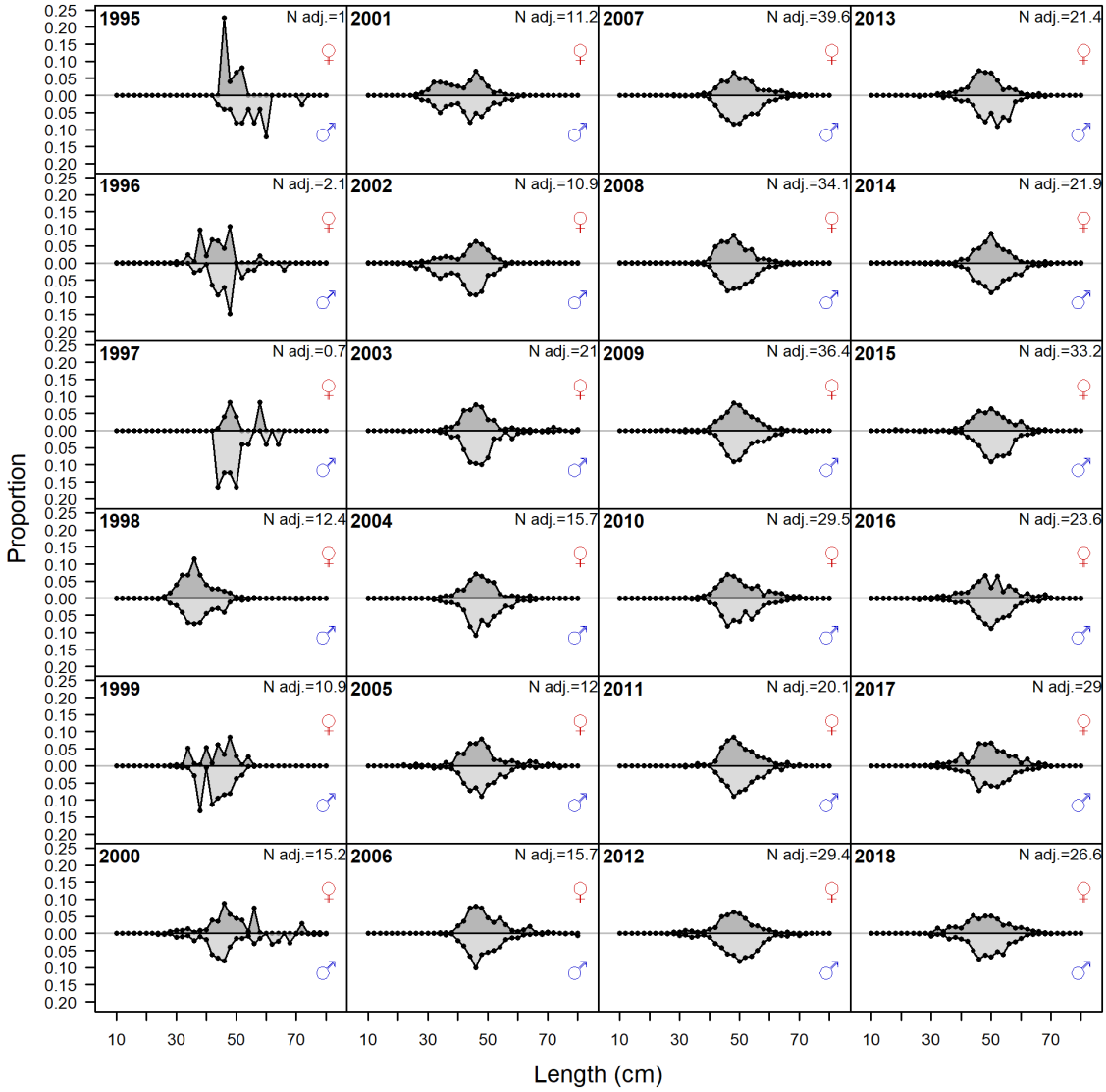


Figure 11: Length composition data for bottom trawl fleet.

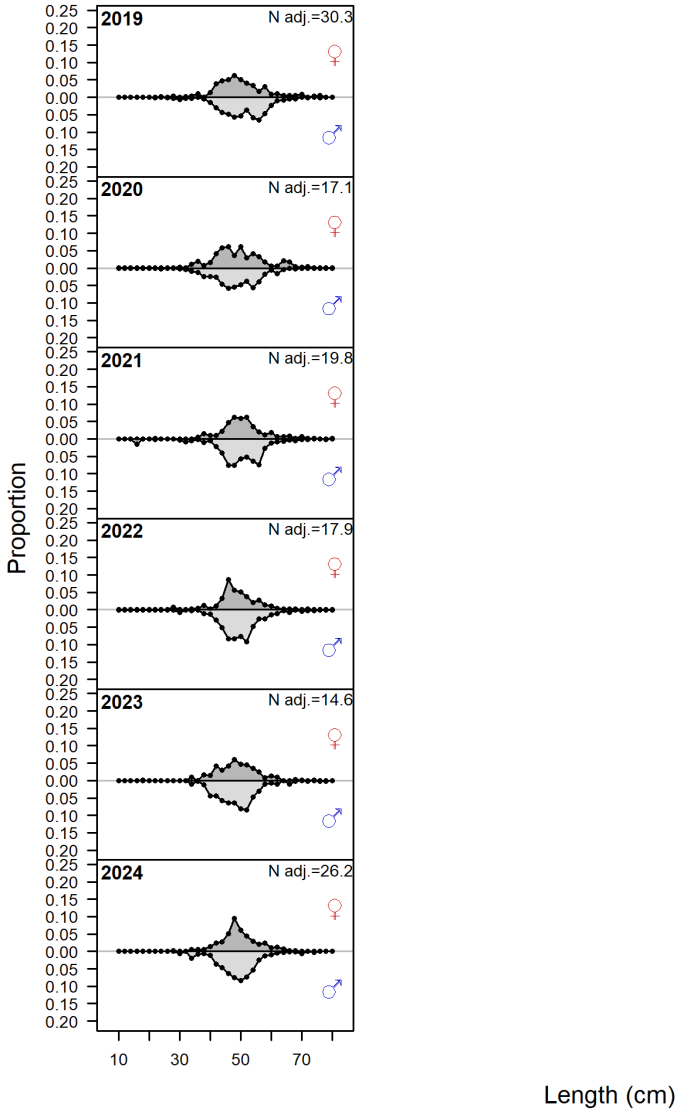


Figure 12: Length composition data for bottom trawl fleet, continued.

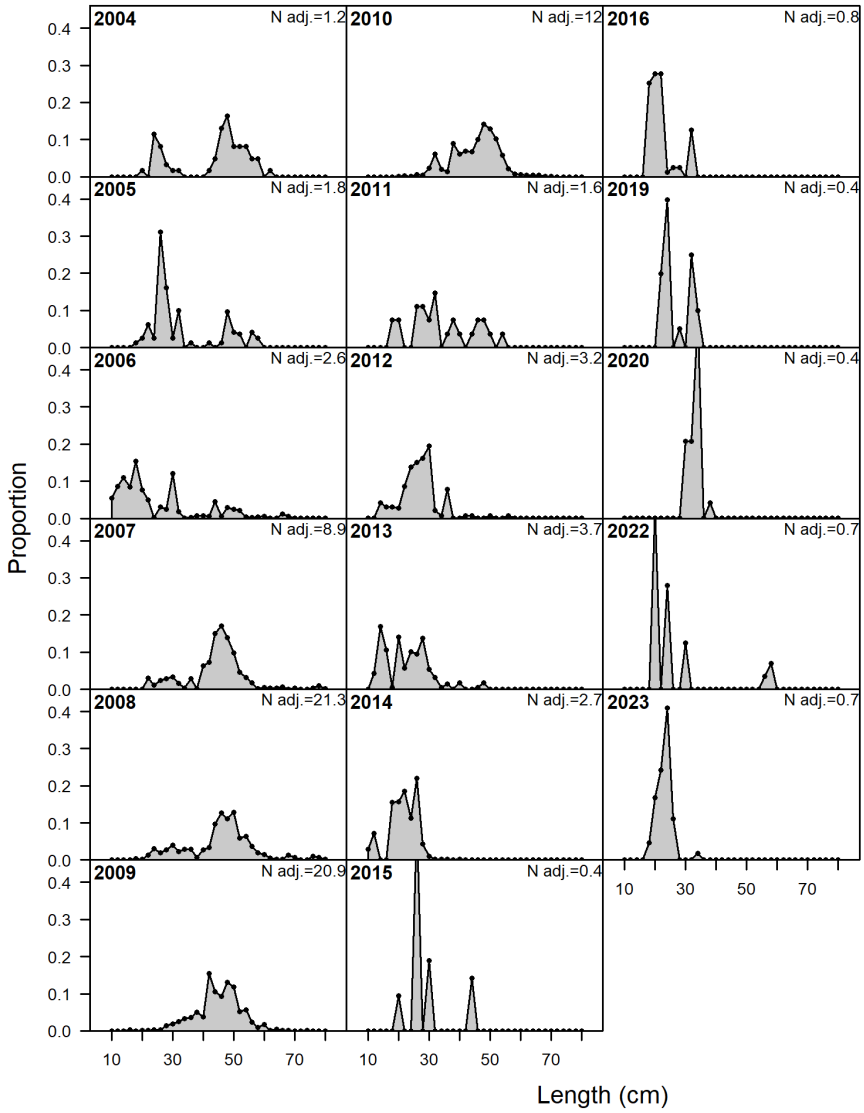


Figure 13: Length composition data for bottom trawl discard fleet.

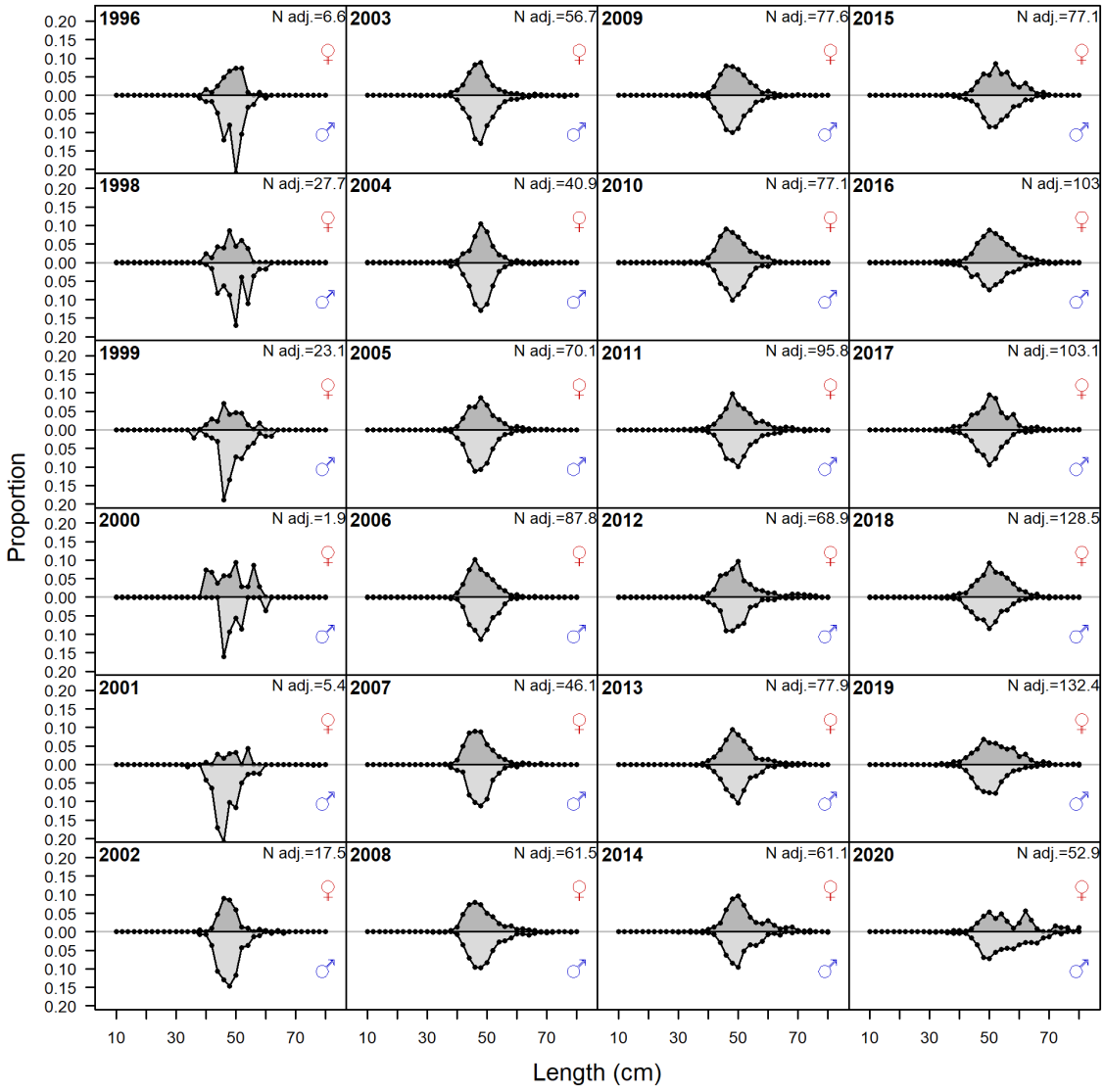


Figure 14: Length composition data for non-trawl fleet.

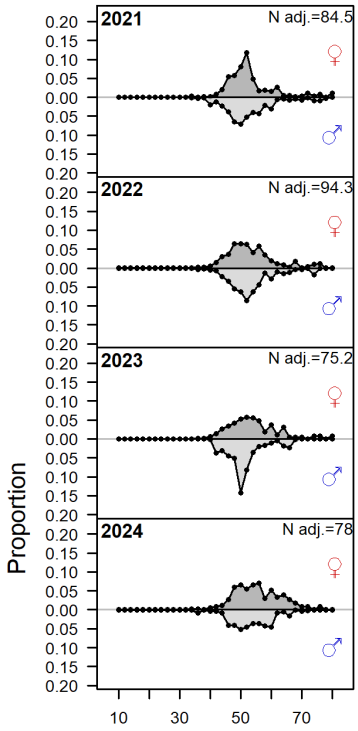


Figure 15: Length composition data for non-trawl fleet, continued.

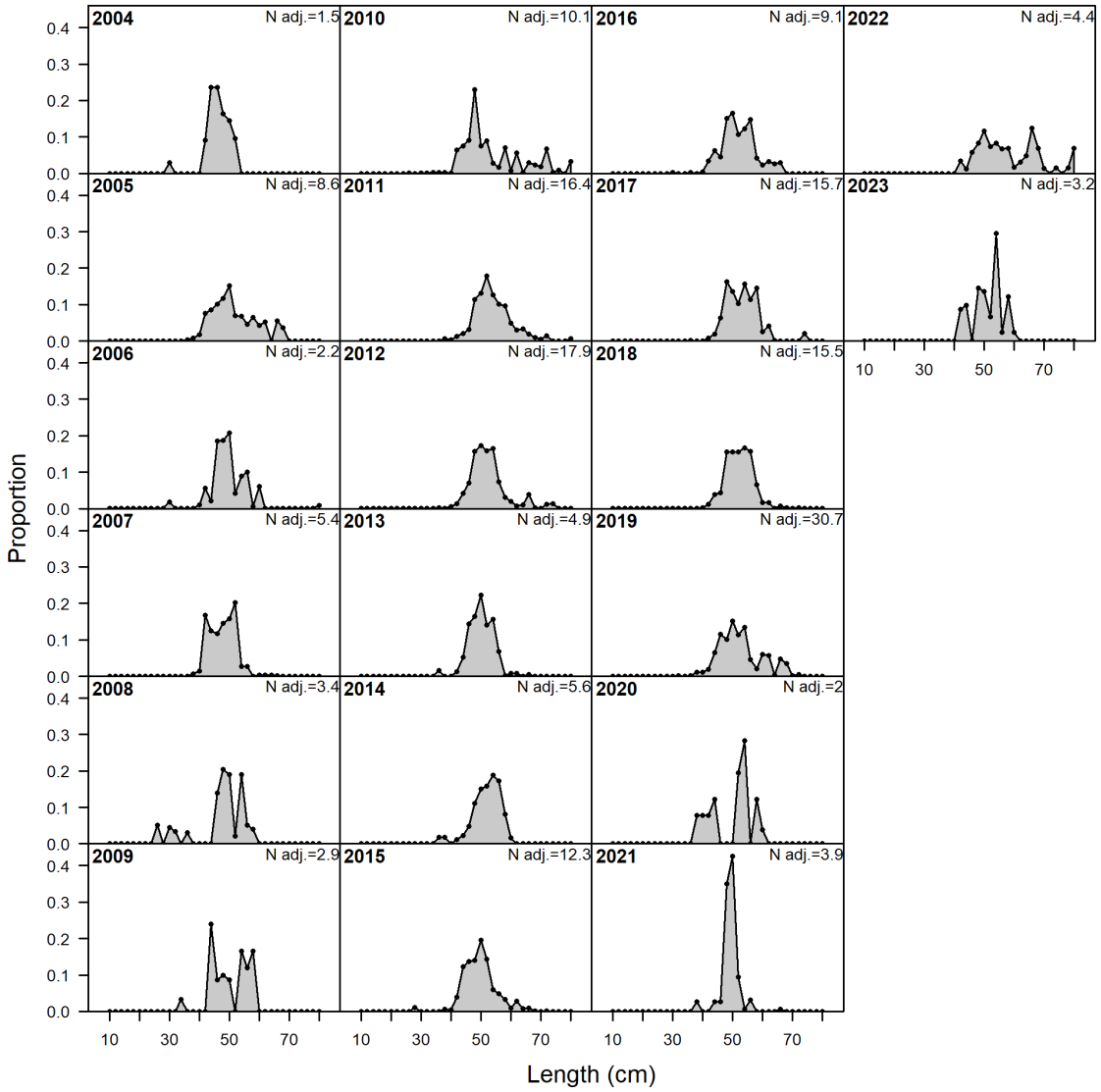


Figure 16: Length composition data for non-trawl discard fleet.

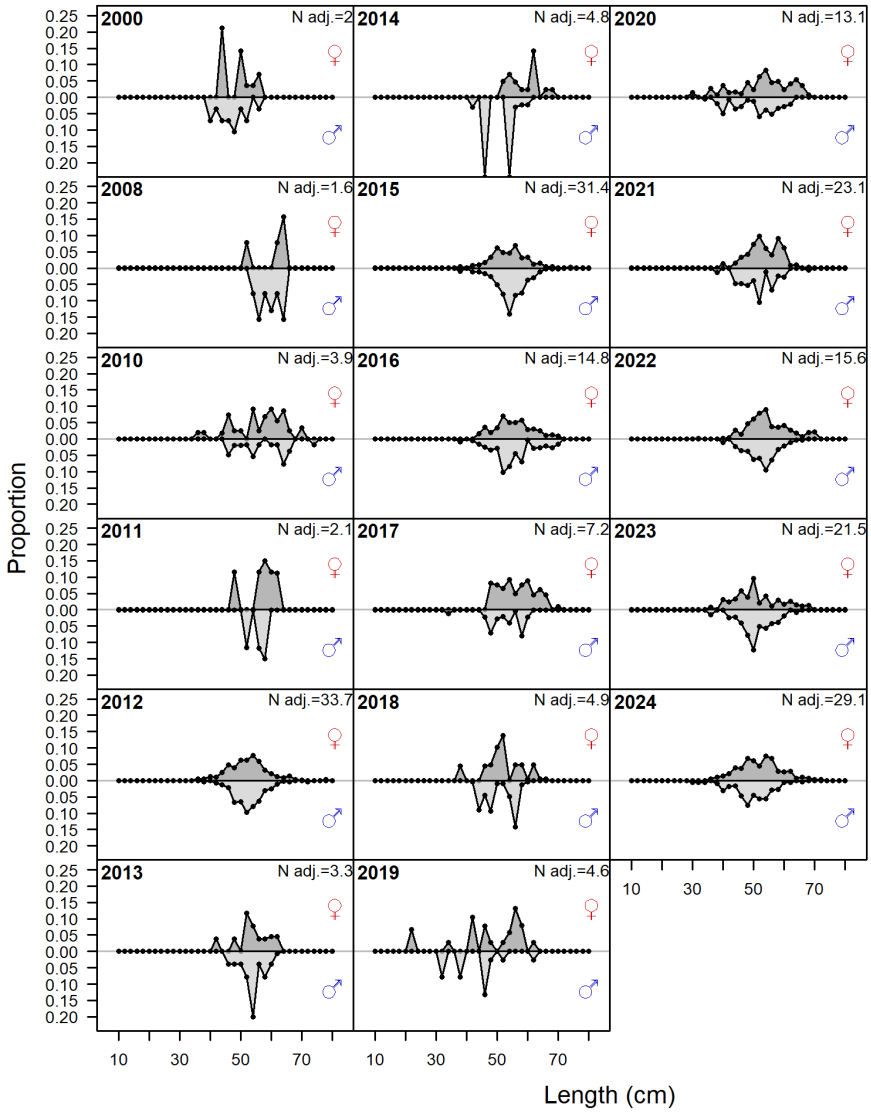


Figure 17: Length composition data for mid-water trawl fleet.

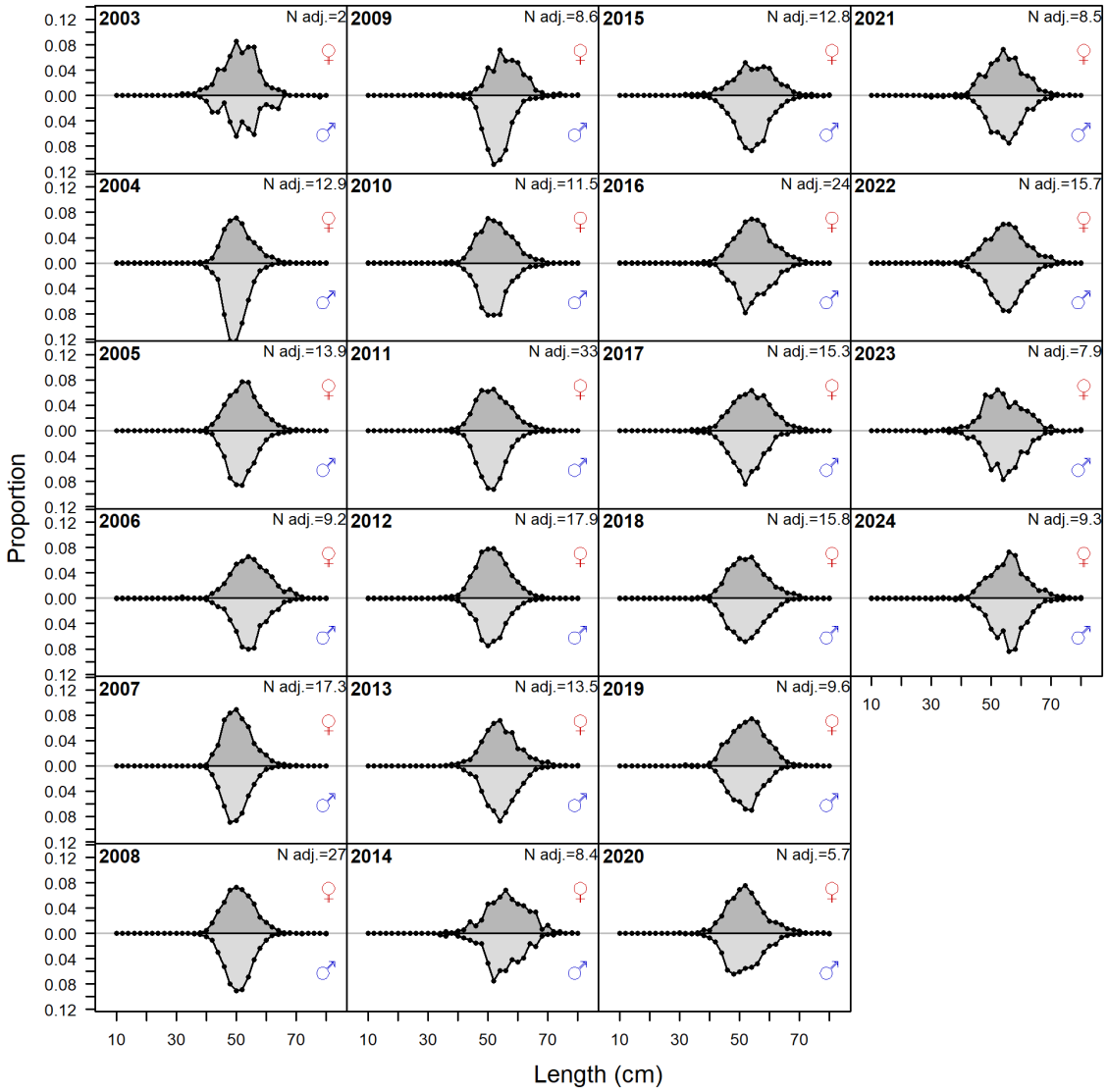


Figure 18: Length composition data for at-sea hake fleet.

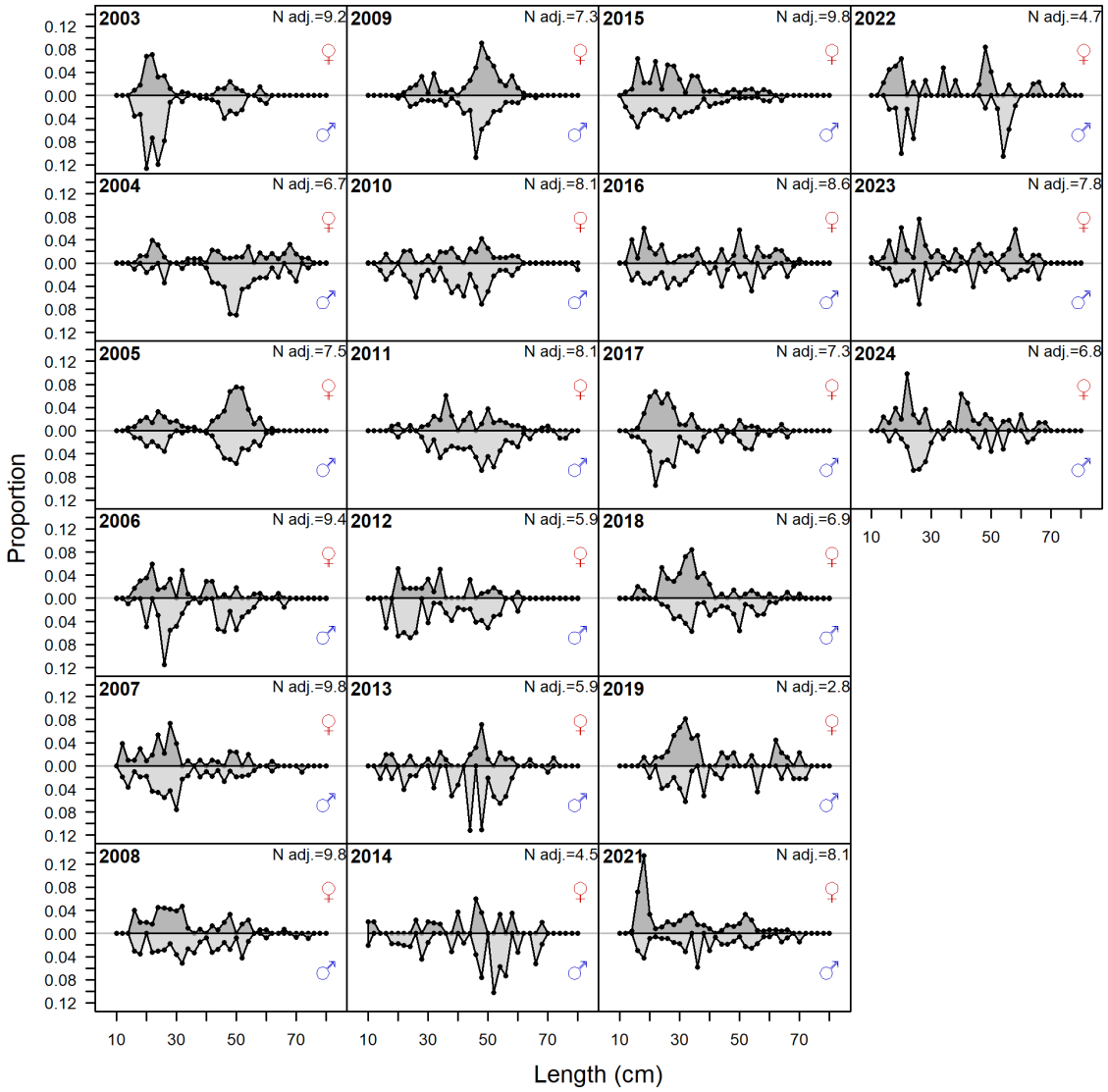


Figure 19: Length composition data for the West Coast Groundfish Bottom Trawl Survey (WCGBTS).

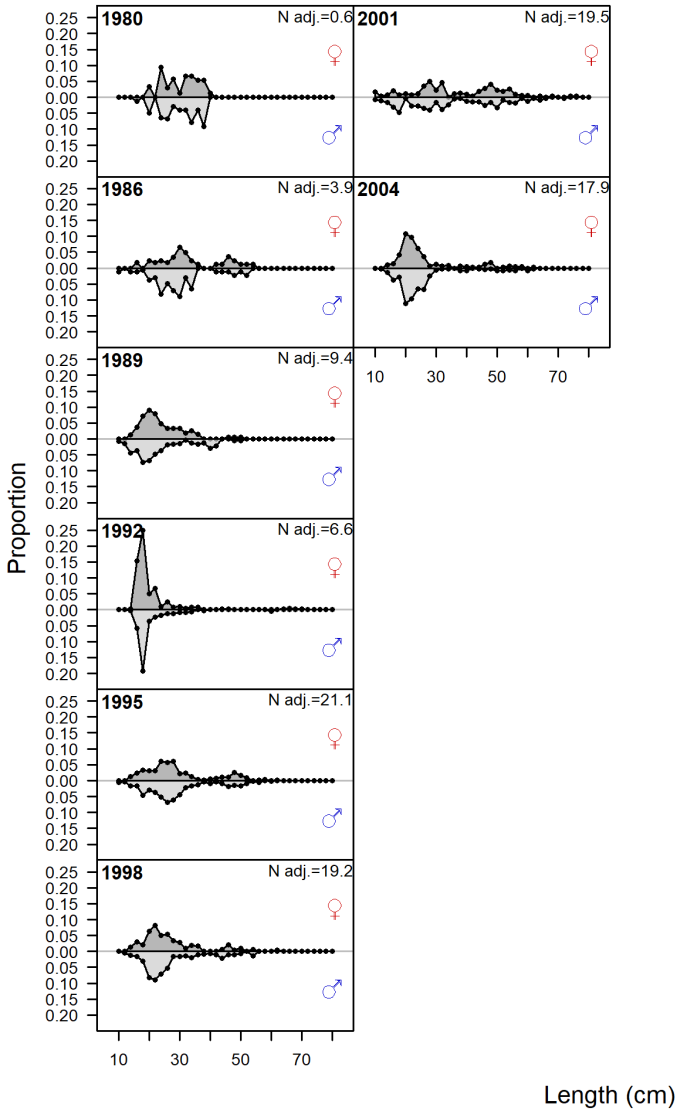


Figure 20: Length composition data for Triennial Survey.

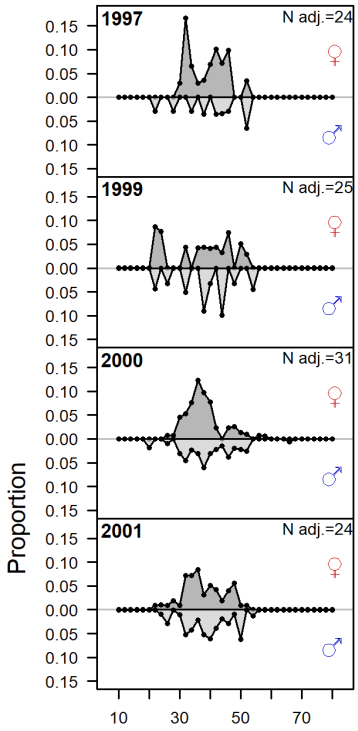


Figure 21: Length composition data for AFSC Slope Survey.

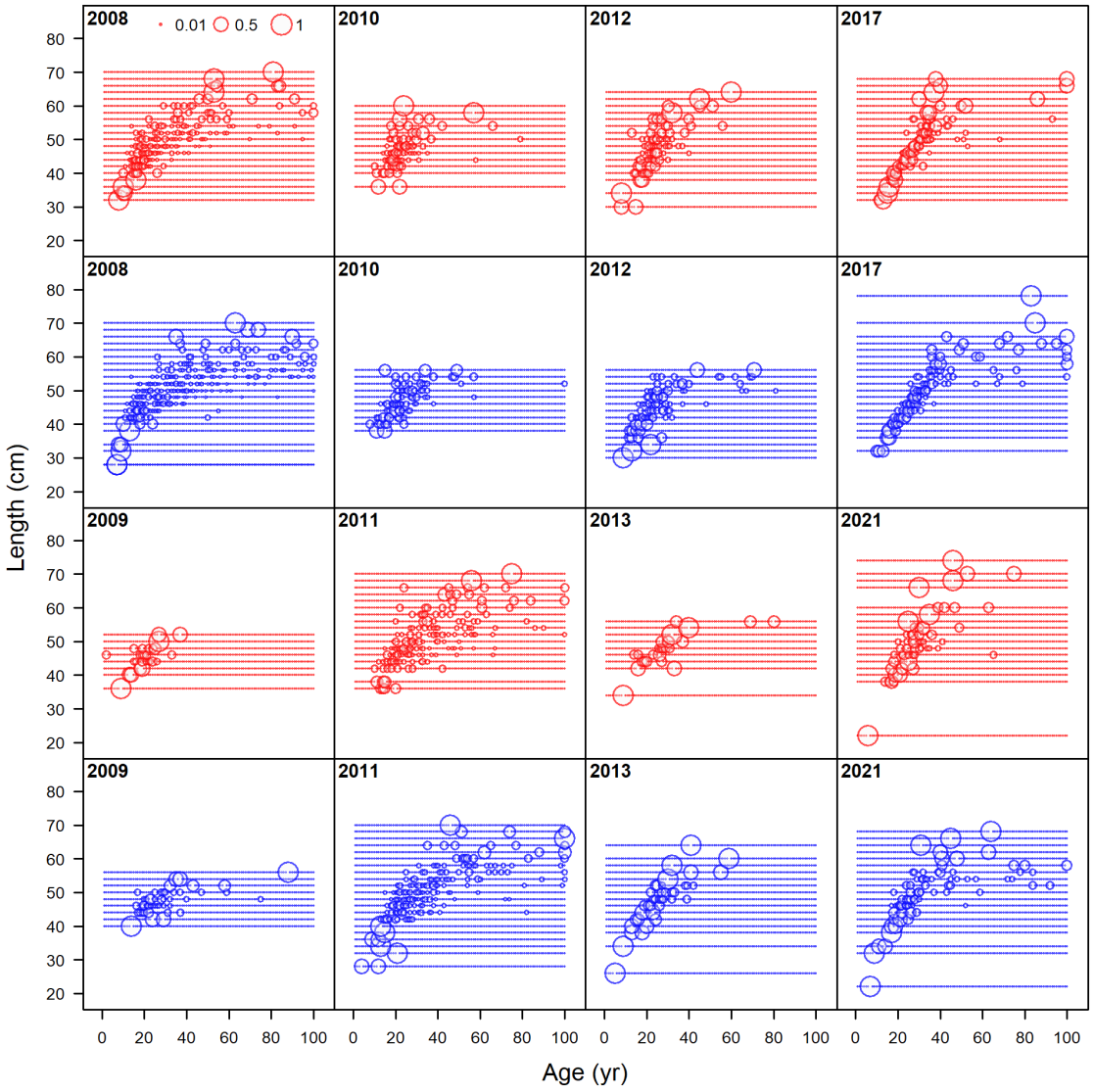


Figure 22: Length composition data for bottom trawl fleet.

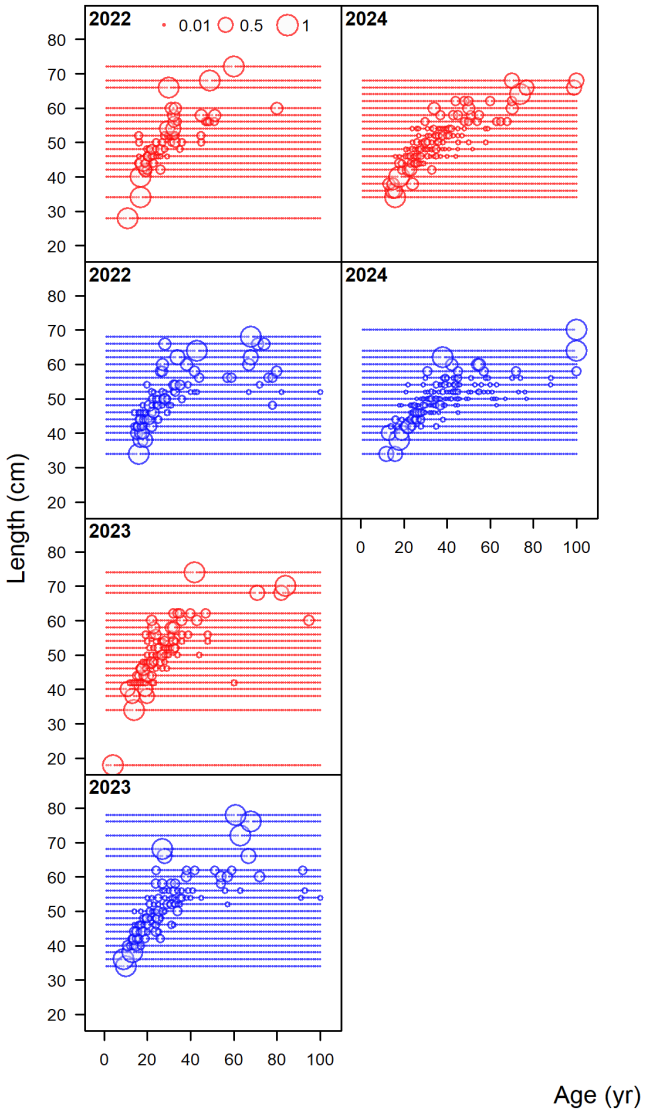


Figure 23: Length composition data for bottom trawl fleet, continued.

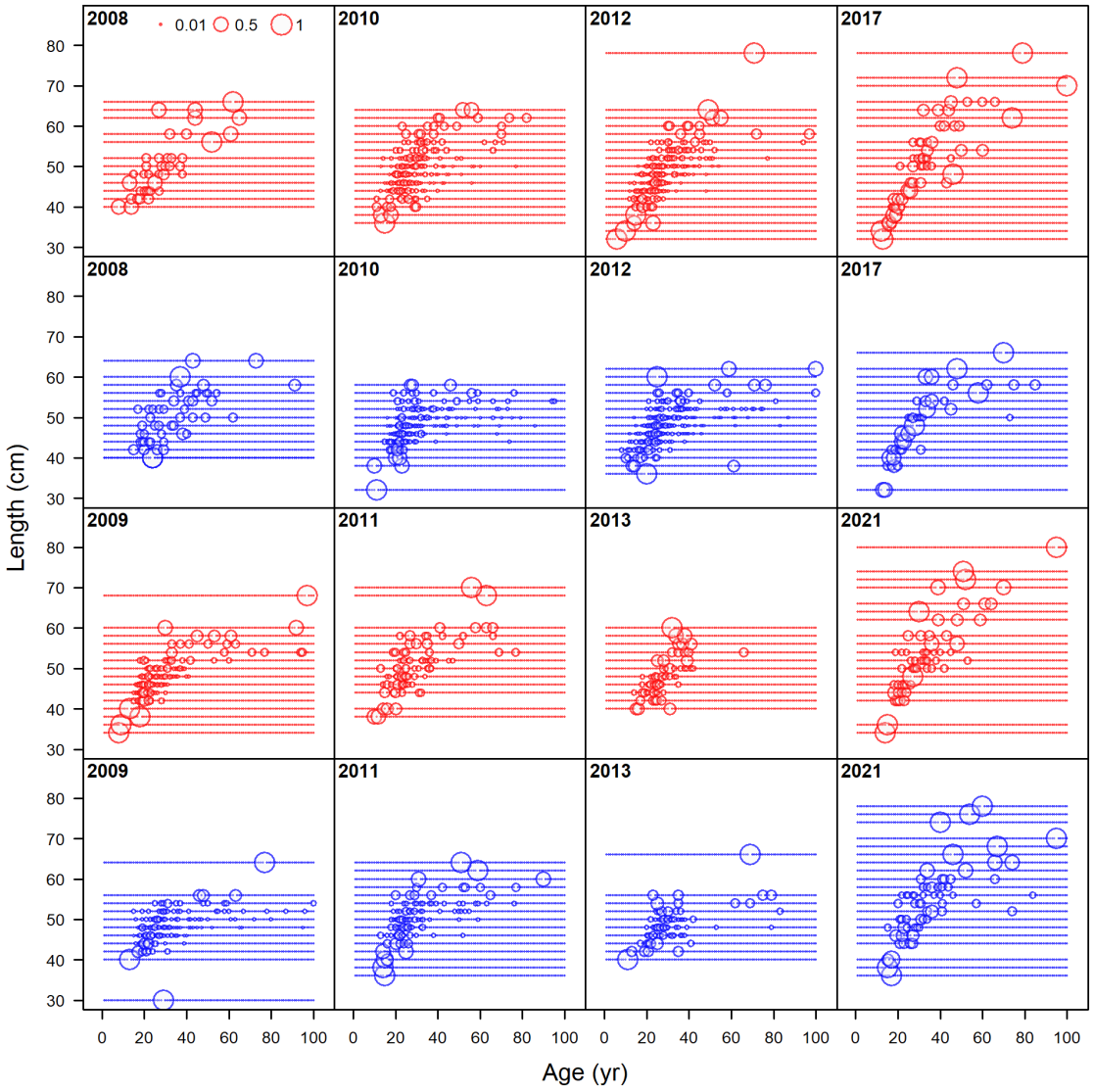


Figure 24: Conditional ages-at-length composition data for non-trawl fleet.

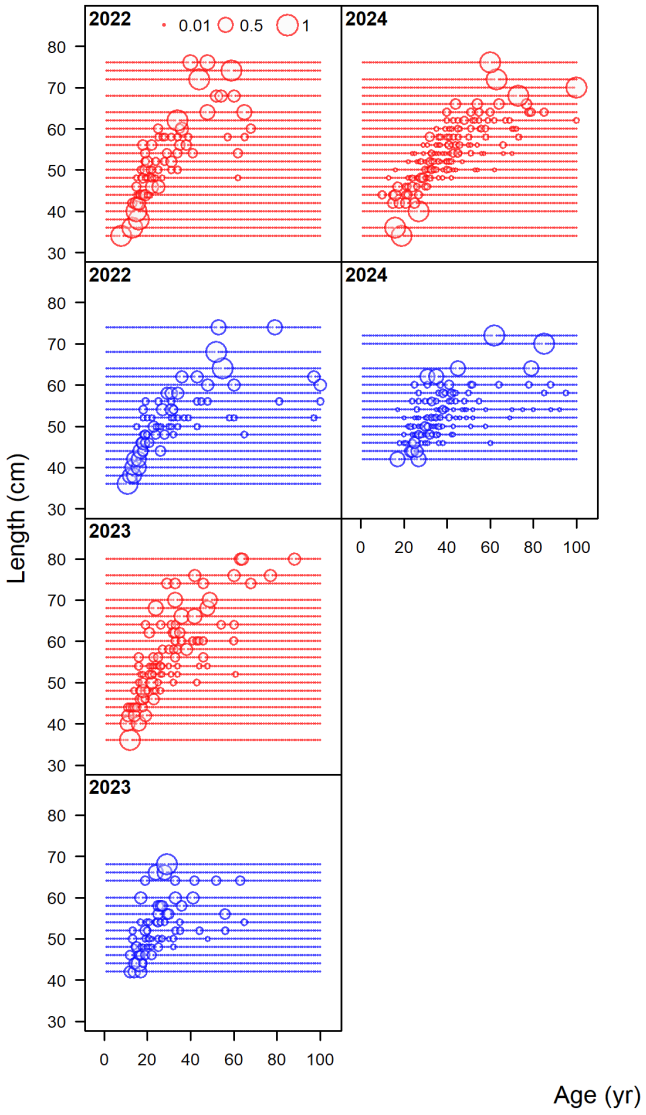


Figure 25: Conditional ages-at-length composition data for non-trawl fleet, continued.

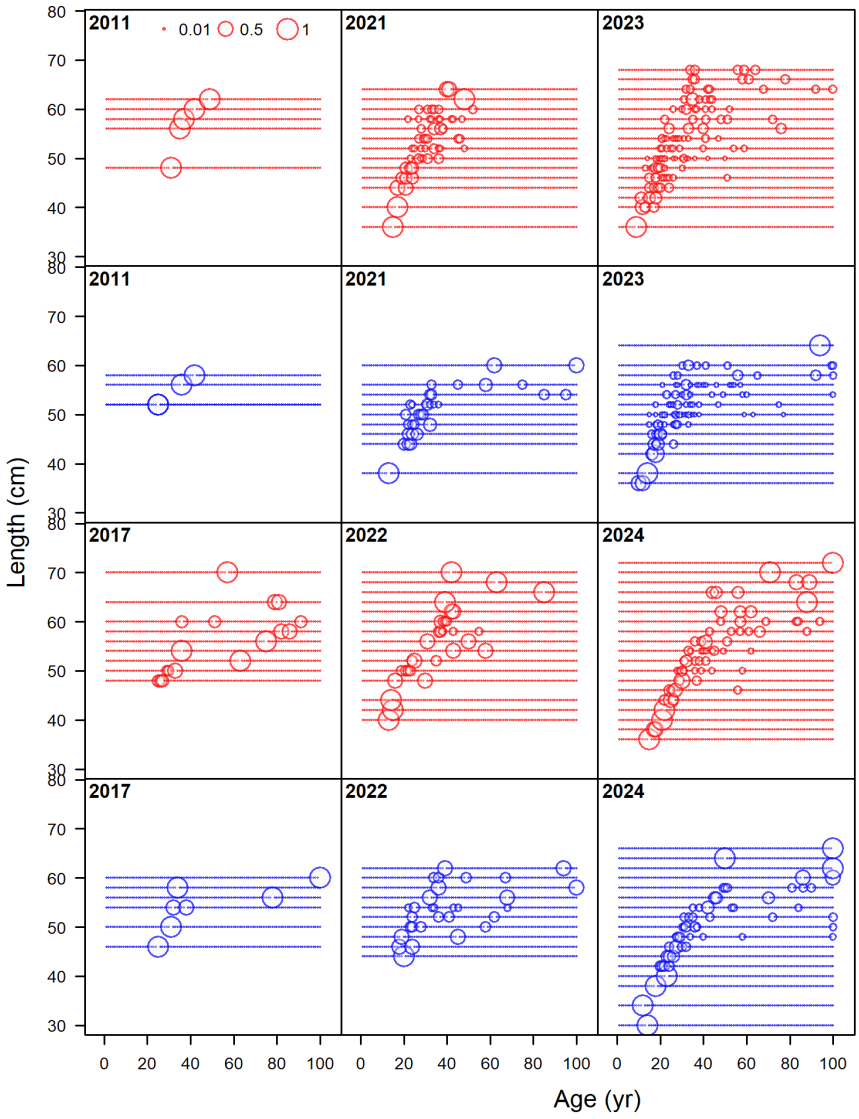


Figure 26: Conditional ages-at-length composition data for Midwater trawl fleet.

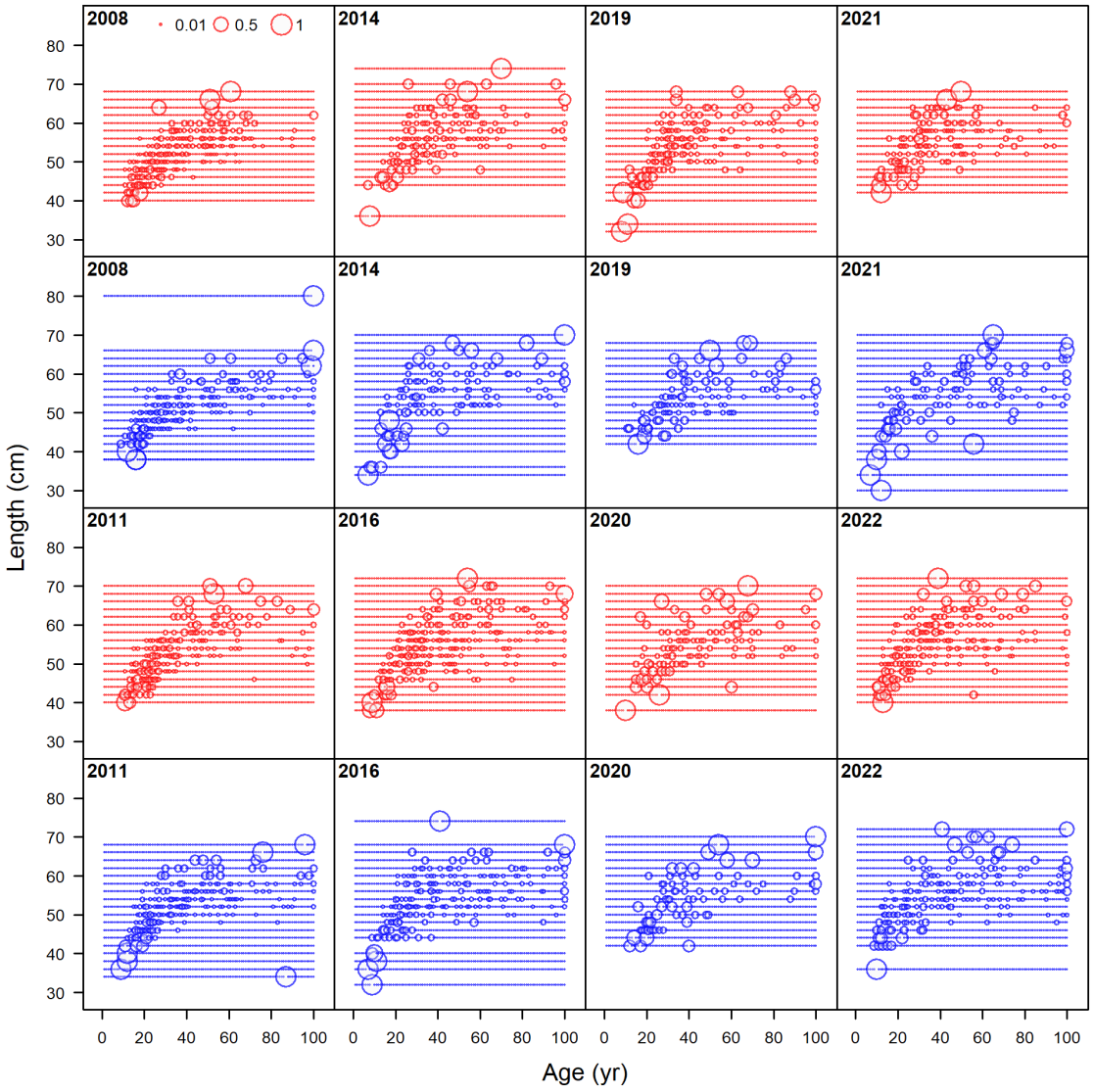


Figure 27: Conditional ages-at-length composition data for at-sea hake fleet.

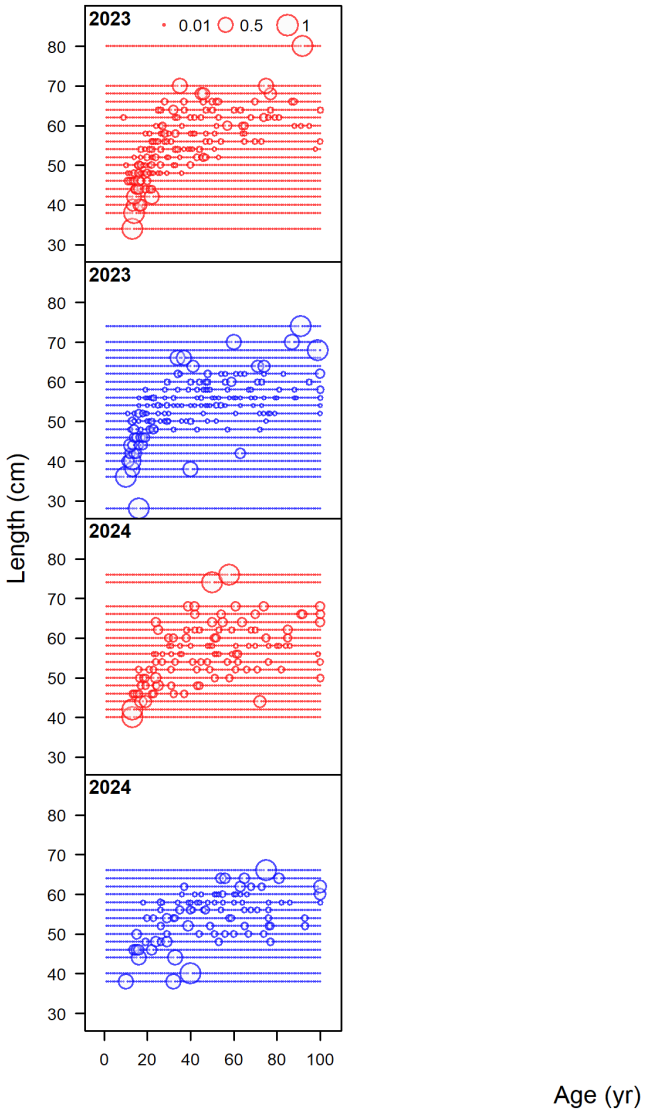


Figure 28: Conditional ages-at-length composition data for at-sea hake fleet, continued.

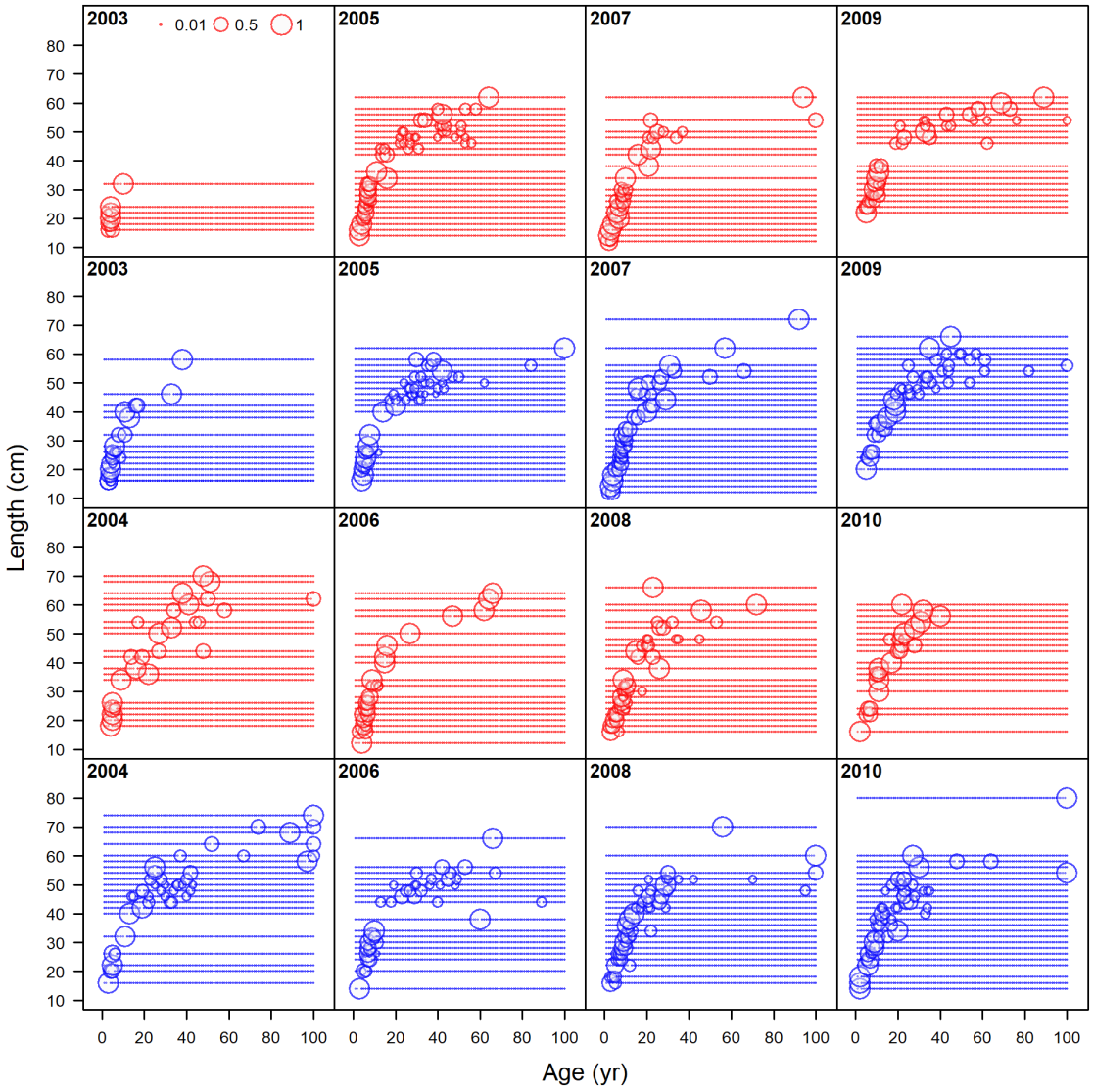


Figure 29: Conditional ages-at-length composition data for the West Coast Groundfish Bottom Trawl Survey (WCGBTS).

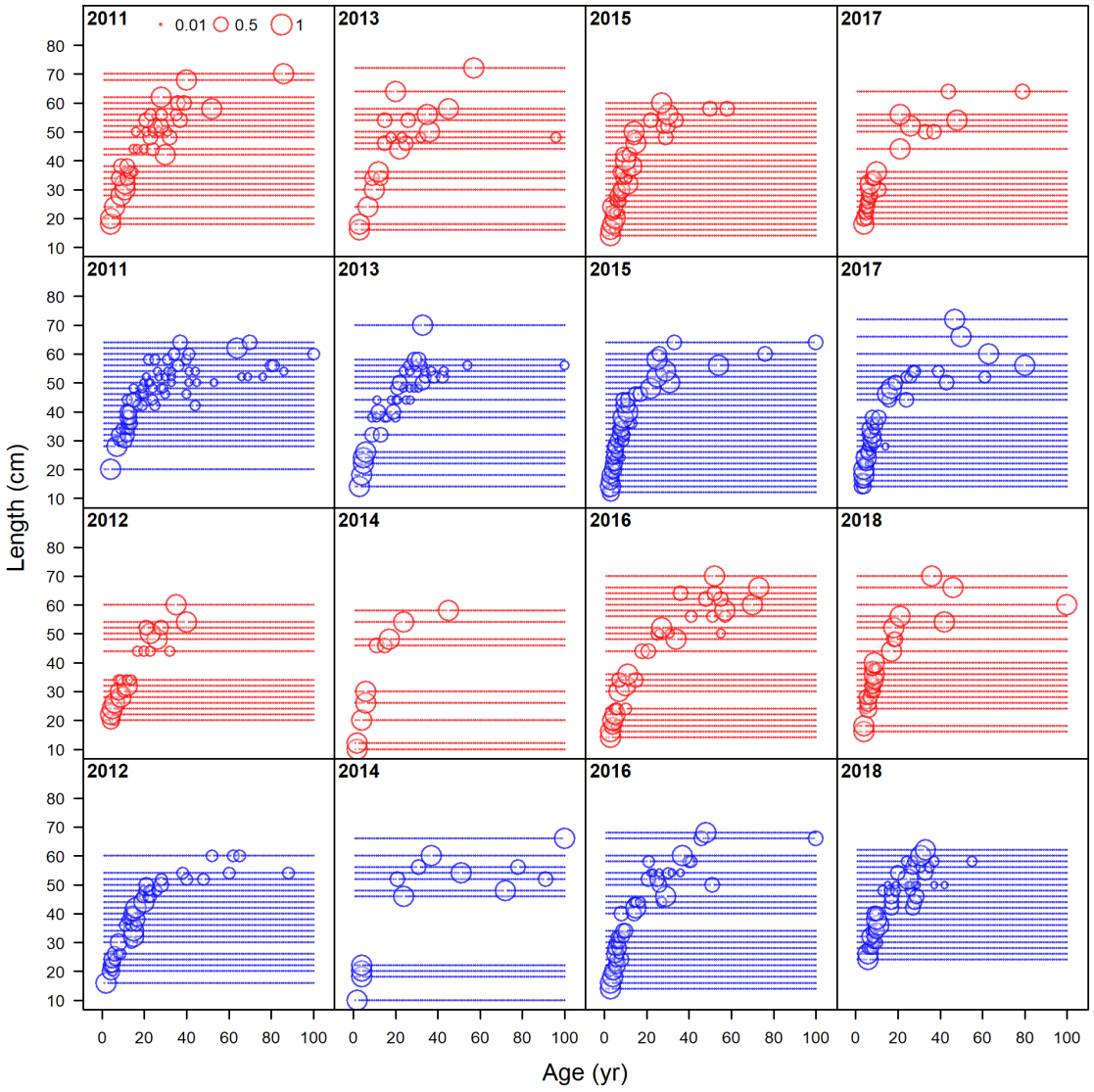


Figure 30: Conditional ages-at-length composition data for the West Coast Groundfish Bottom Trawl Survey (WCGBTS), continued.

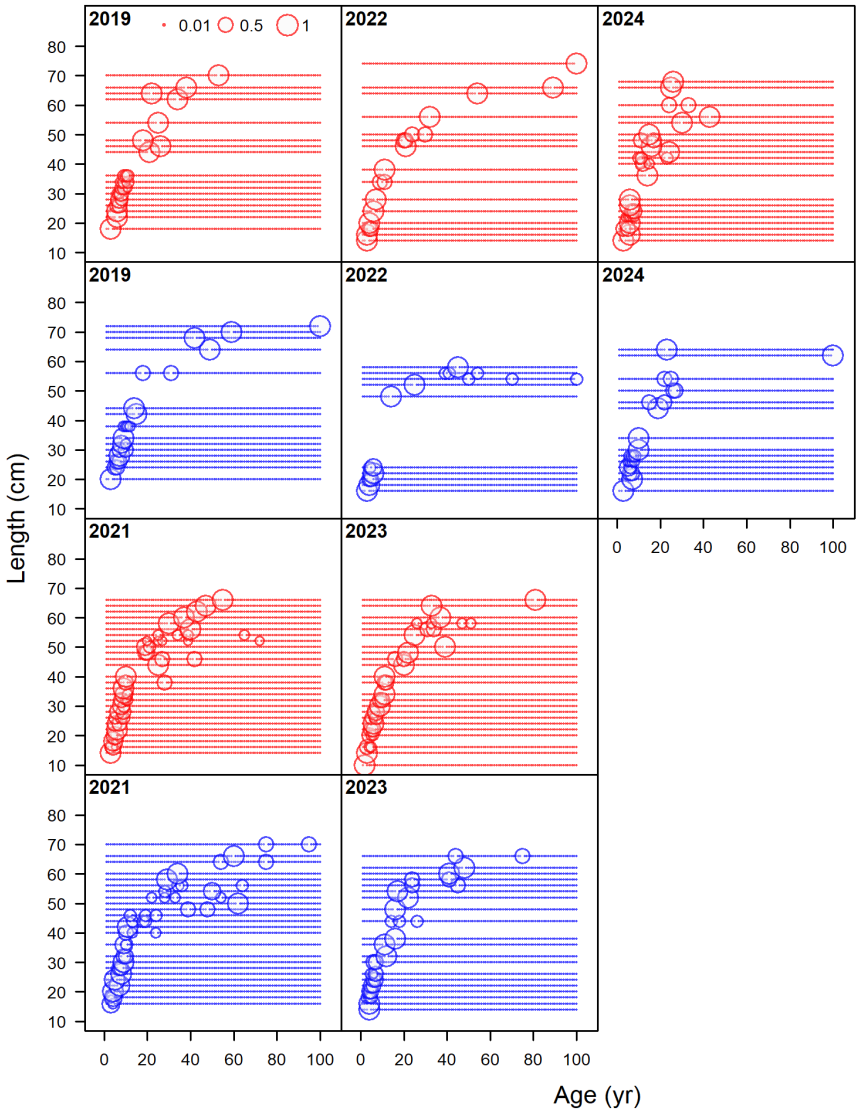


Figure 31: Conditional ages-at-length composition data for the West Coast Groundfish Bottom Trawl Survey (WCGBTS), continued.

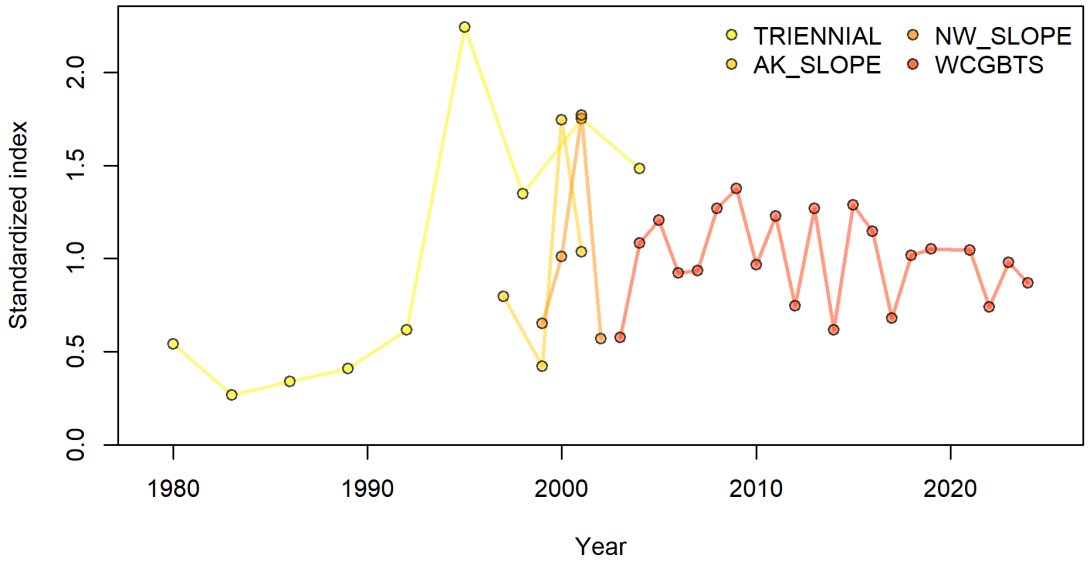


Figure 32: Standardized survey indices used in the assessment.

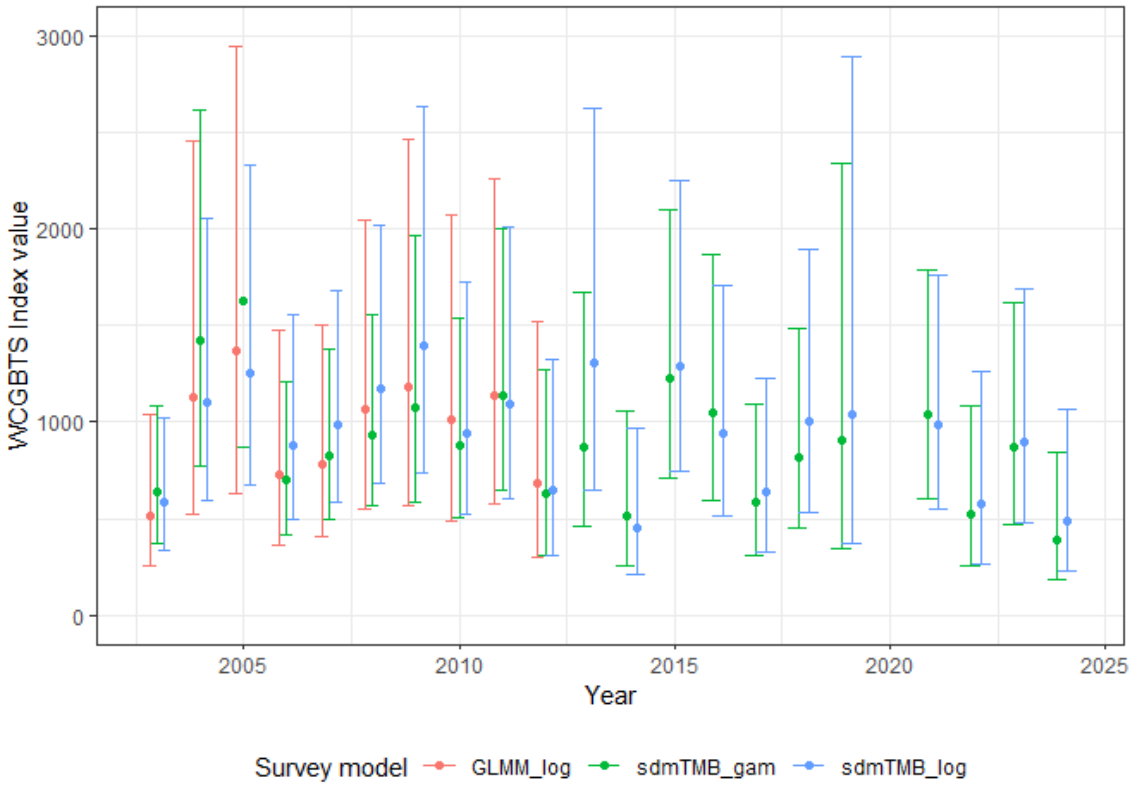


Figure 33: Comparison of the West Coast Groundfish Bottom Trawl Survey (WCGBTS) index from the previous assessment (GLMM) and the WCGBTS index of abundance used in this assessment (sdmTMB, lognormal distribution).

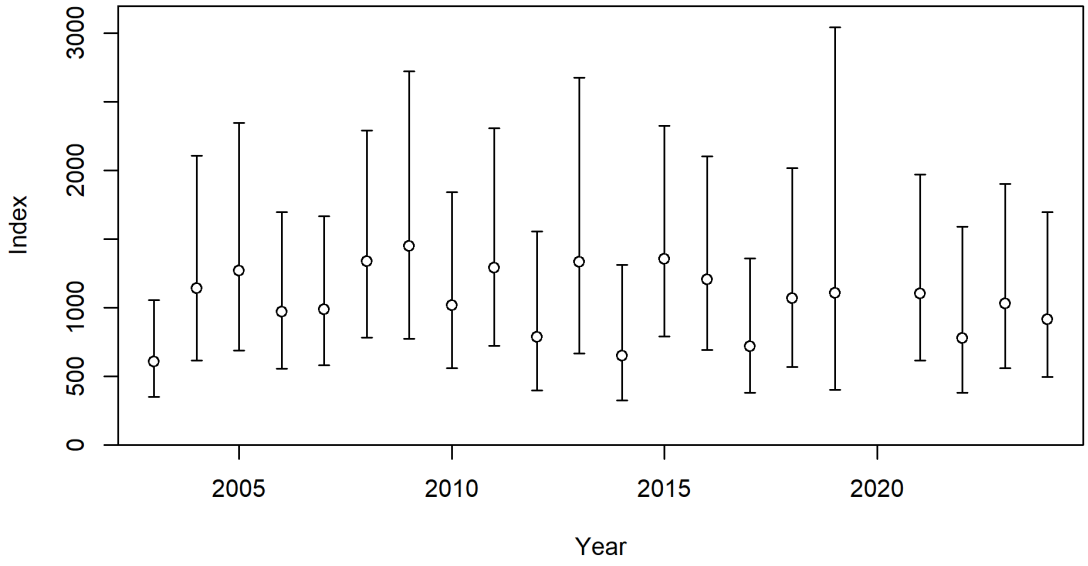


Figure 34: West Coast Groundfish Bottom Trawl Survey (WCGBTS) index.

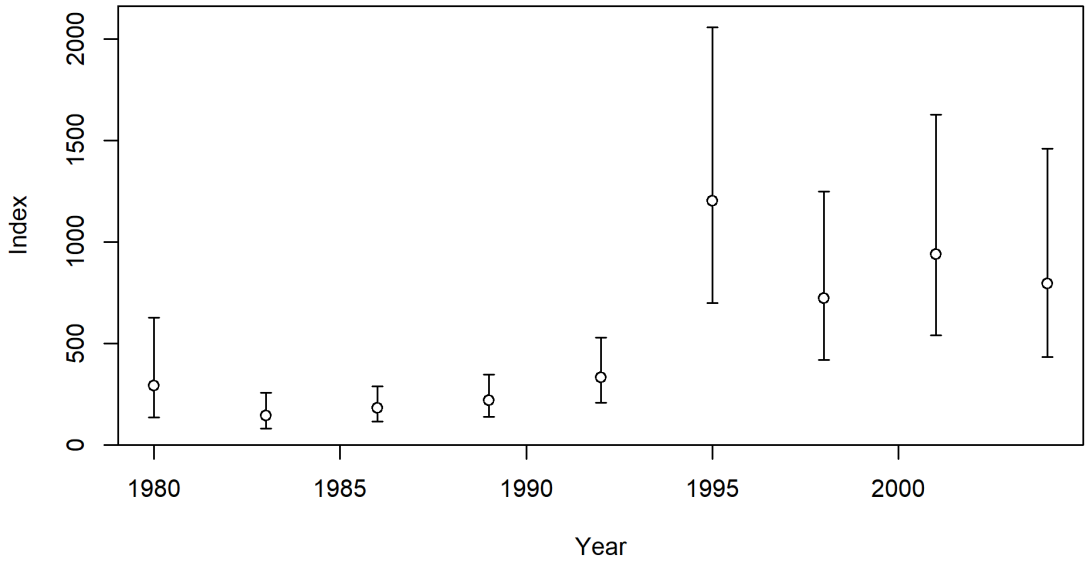


Figure 35: Triennial Survey index.

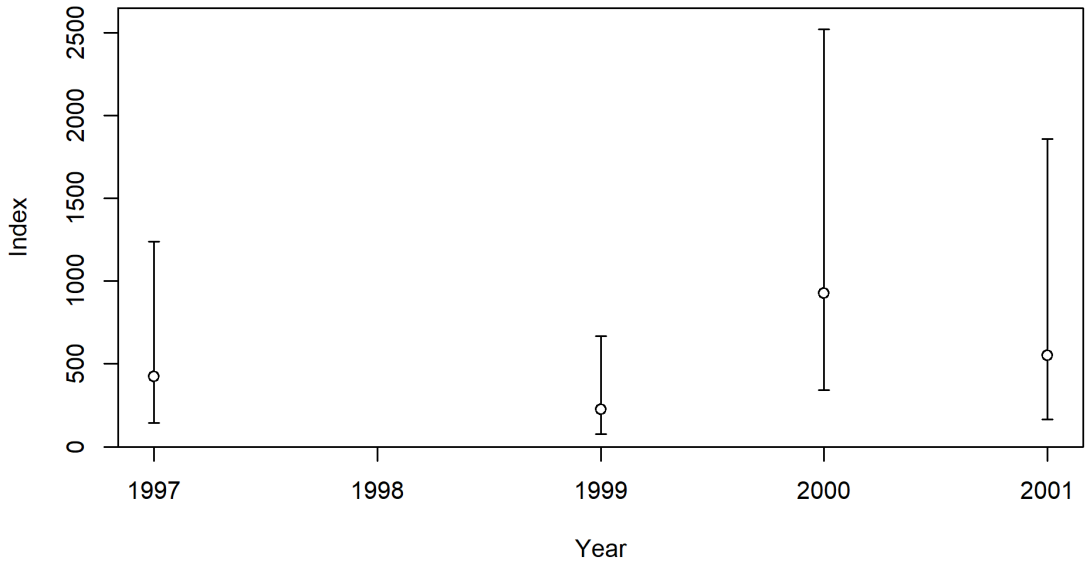


Figure 36: AFSC Slope Survey index.

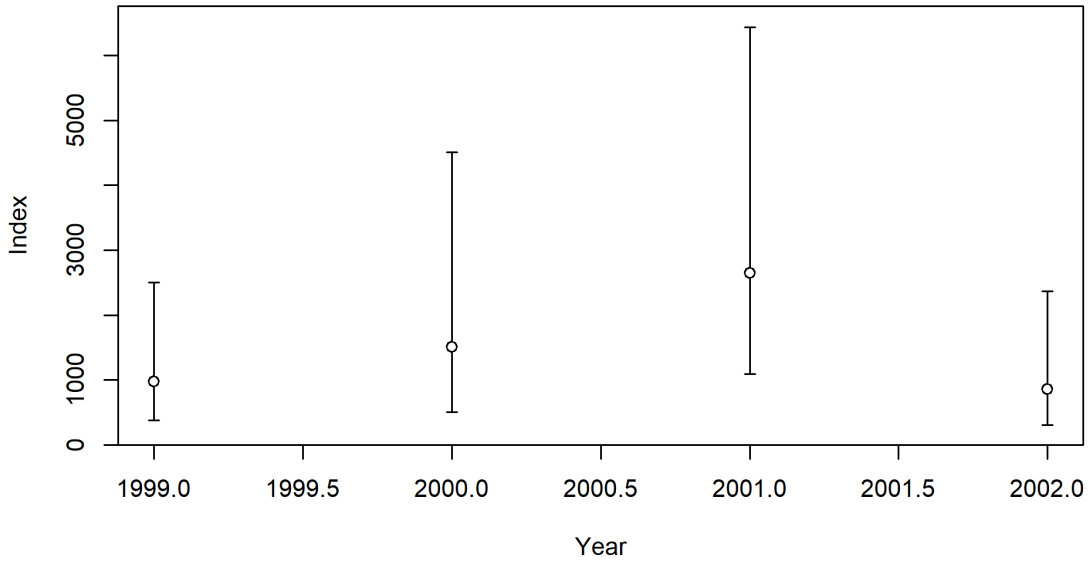


Figure 37: NWFSC Slope Survey index.

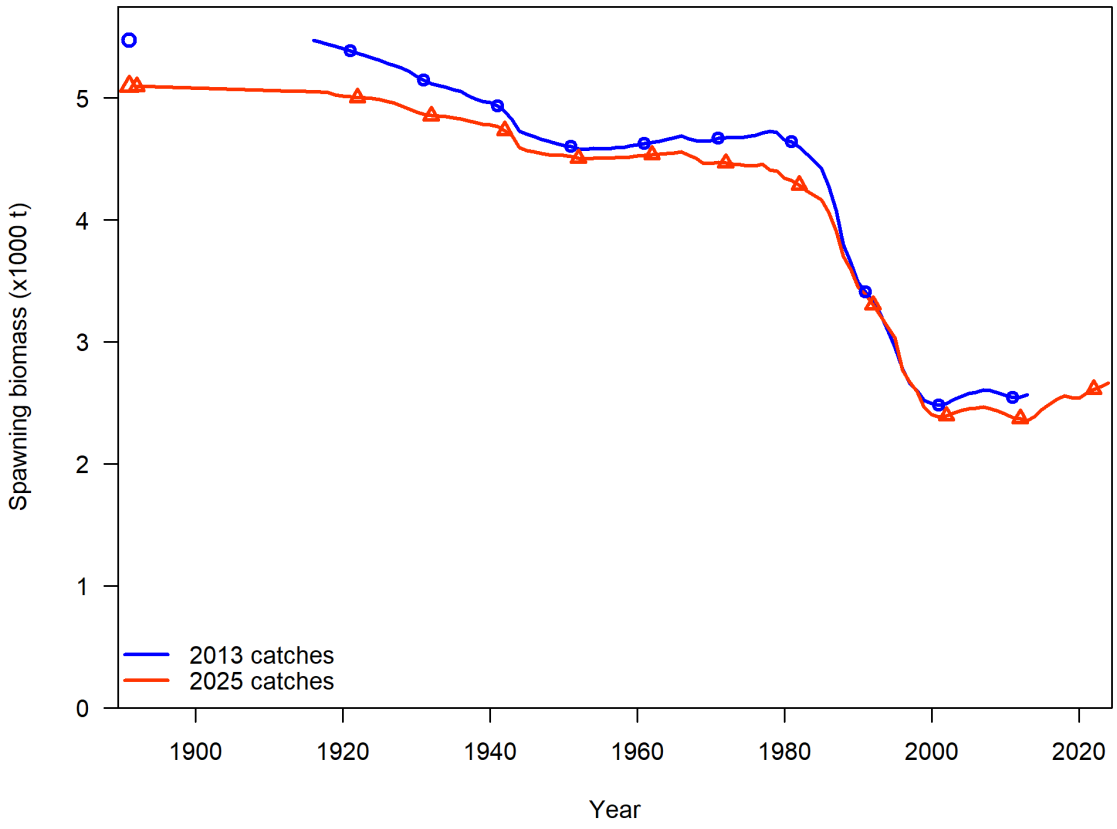


Figure 38: Comparison of spawning biomass between 2013 Rougheye/Blackspotted Rockfishes assessment model and model with updated/extended catches used in 2025 assessment.

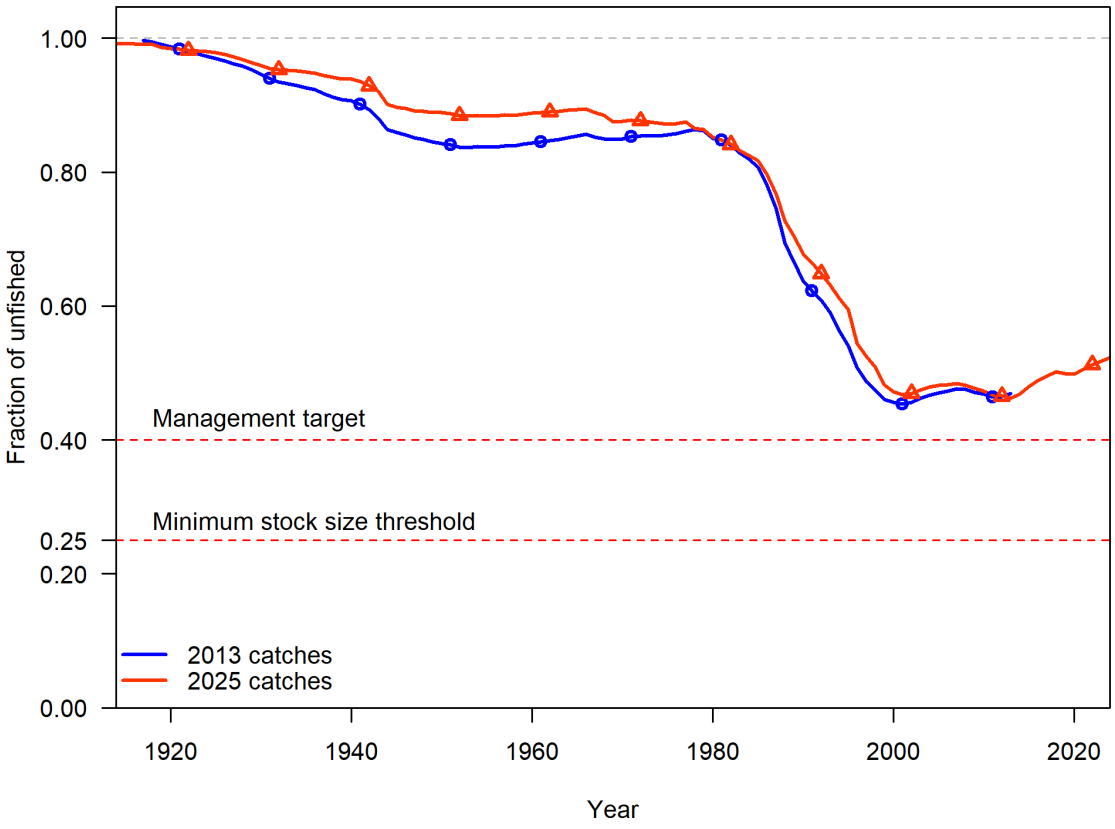


Figure 39: Comparison of fraction unfished between 2013 Rougheye/Blackspotted Rockfishes assessment model and model with updated/extended catches used in 2025 assessment.

8.2 Biology

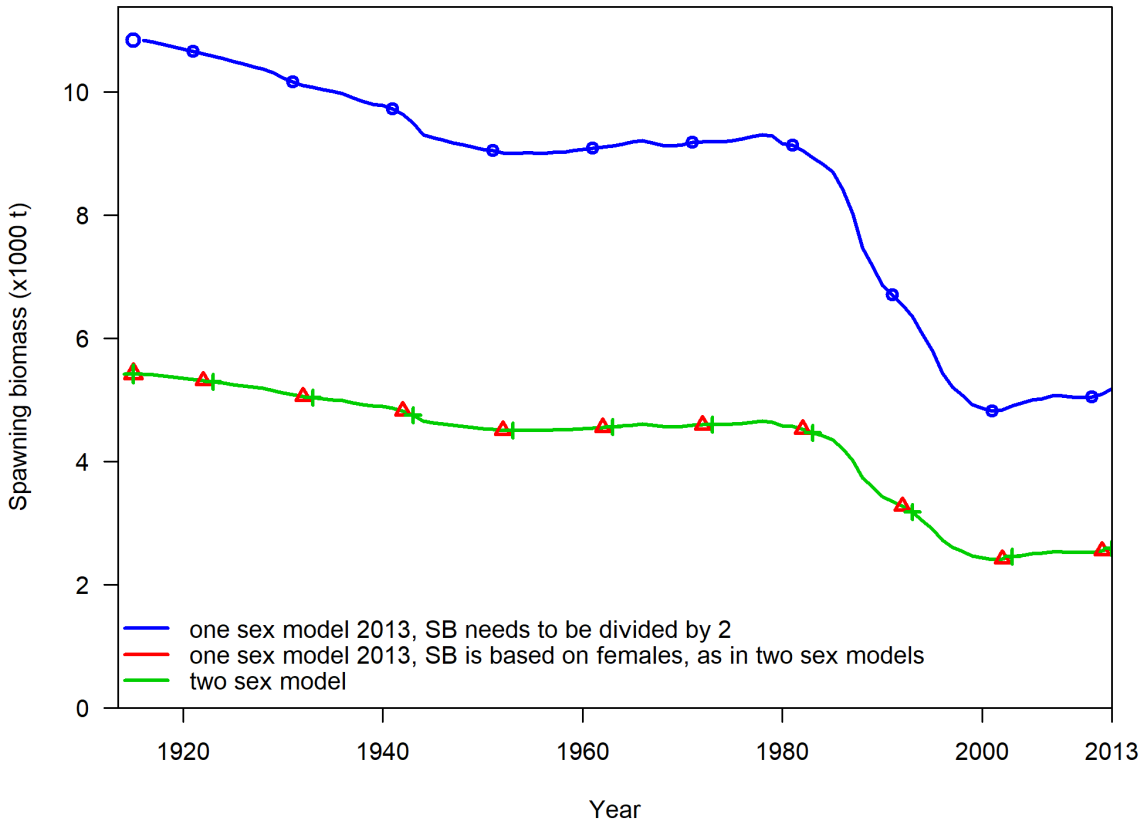


Figure 40: Comparison of spawning biomass using the 1 sex and 2 sexes set to equal values models based on the 2013 Rougheye/Blackspotted Rockfishes assessment data. The 1 sex model has double the biomass because it includes both females and males.

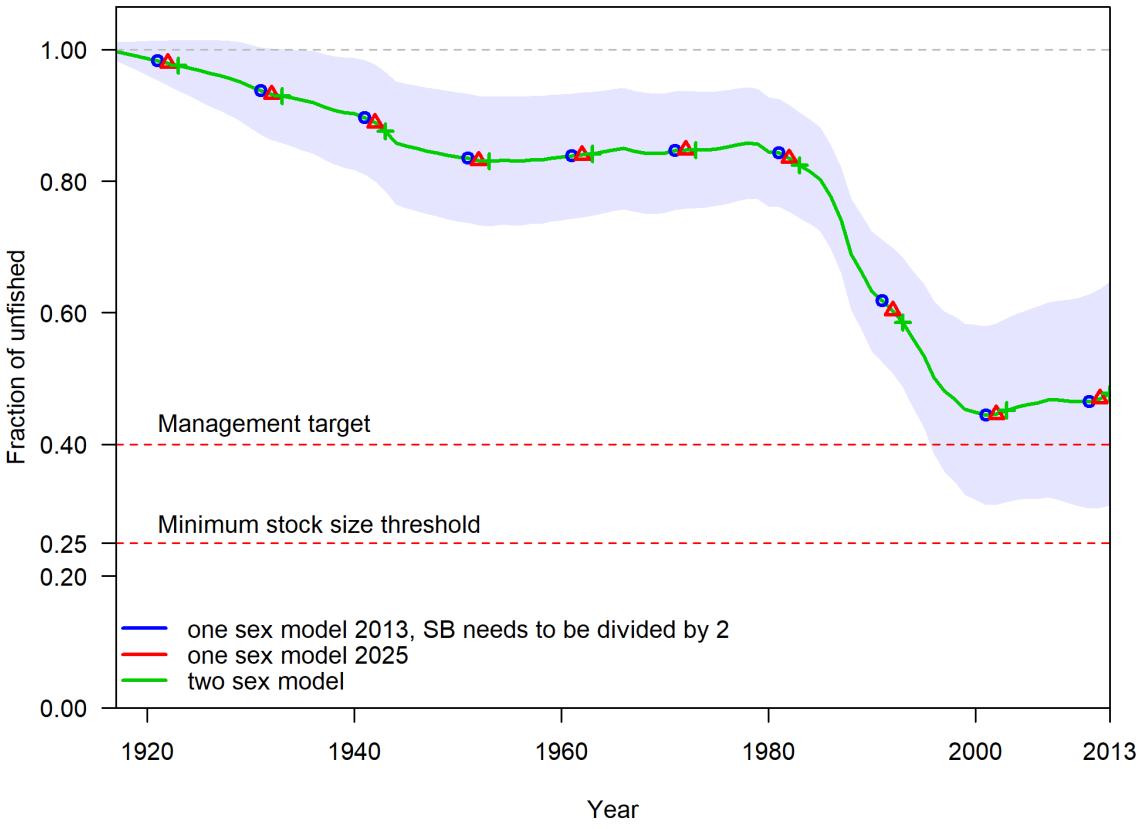


Figure 41: Comparison of fraction unfished using the 1 sex and 2 sexes set to equal values models based on the 2013 Rougheye/Blackspotted Rockfishes assessment data.

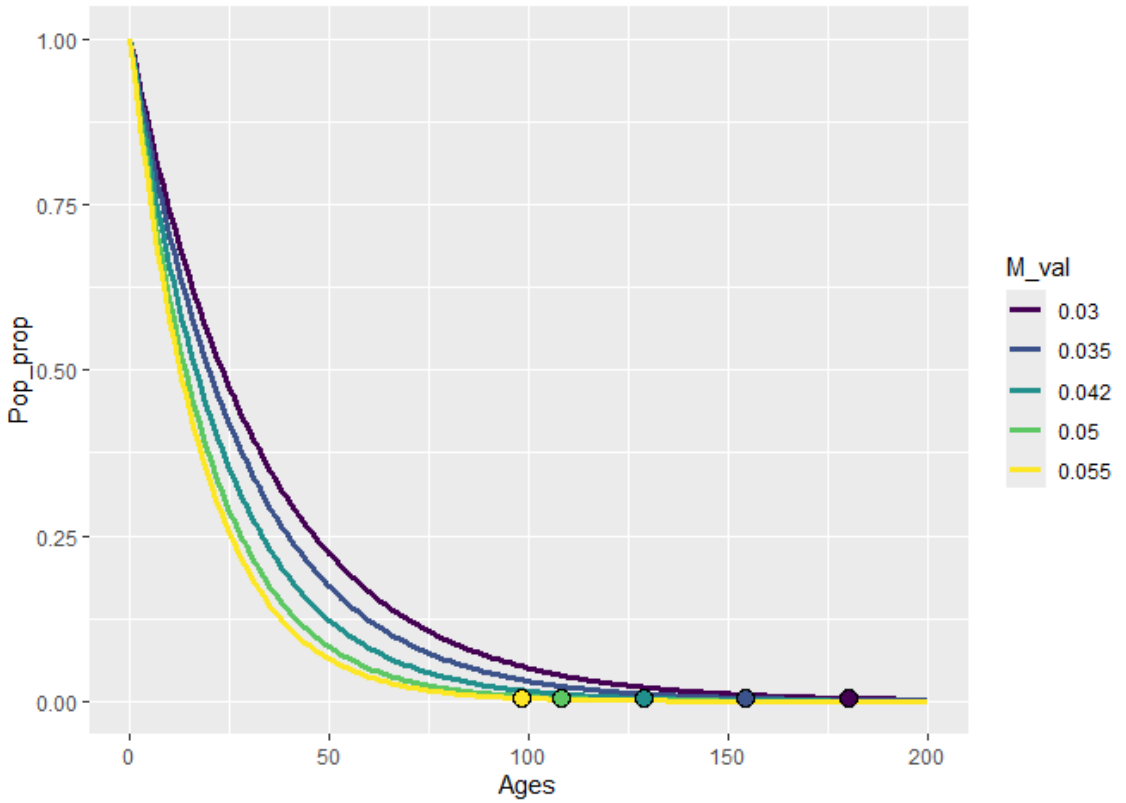


Figure 42: Natural mortality curves by age in years for values of natural mortality used in various Rougheye/Blackspotted Rockfish stock assessments. Dots indicate the range of assumed maximum ages using the equation from Hamel and Cope 2022.

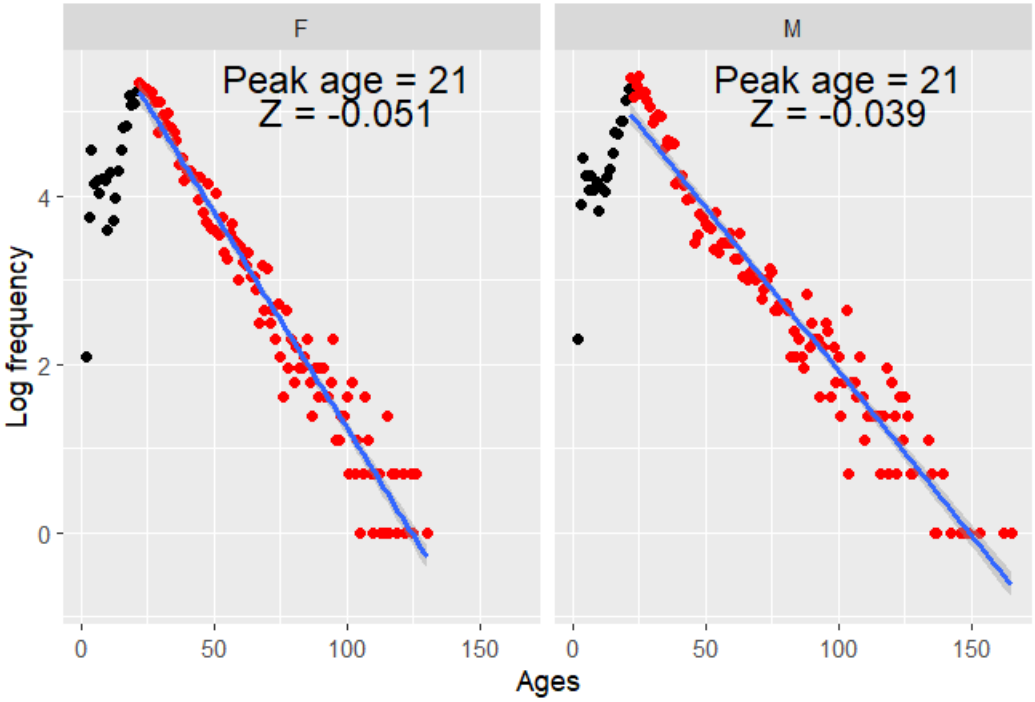


Figure 43: Catch curve (log abundance by age) analysis on aggregated ages over all age sources by sex (black points). The peak selected age was 21 for both sexes, so the linear model was run from age 21 until the oldest age (red points). The slope of the linear model is equal to the estimate of an aggregate total mortality (Z).

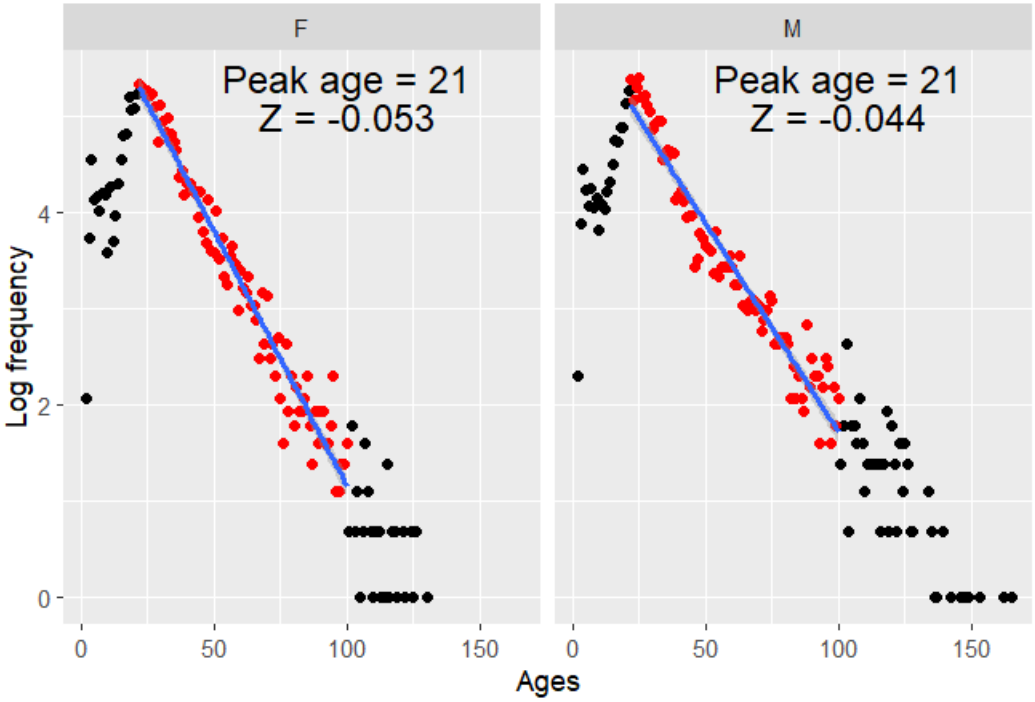


Figure 44: Catch curve (log abundance by age) analysis on aggregated ages over all age sources by sex (black points). The peak selected age was 21 for both sexes with a max age of 100, so the linear model was run from age 21 until age 100 (red points). The slope of the linear model is equal to the estimate of an aggregate total mortality (Z).

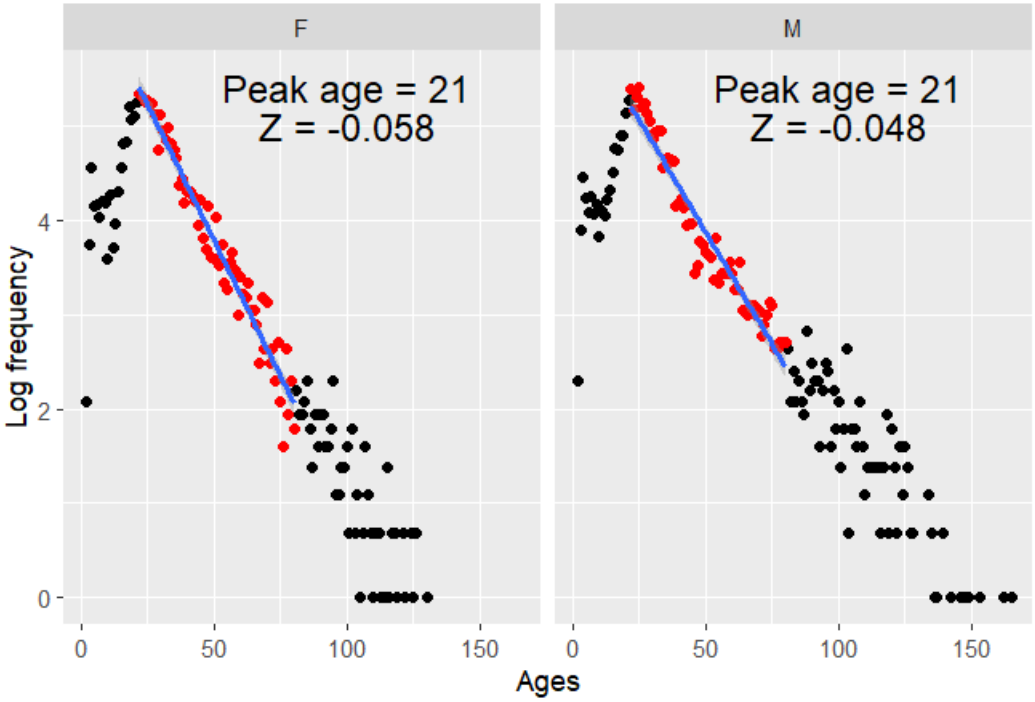


Figure 45: Catch curve (log abundance by age) analysis on aggregated ages over all age sources by sex (black points). The peak selected age was 21 for both sexes with a max age of 80, so the linear model was run from age 21 until age 80 (red points). The slope of the linear model is equal to the estimate of an aggregate total mortality (Z).

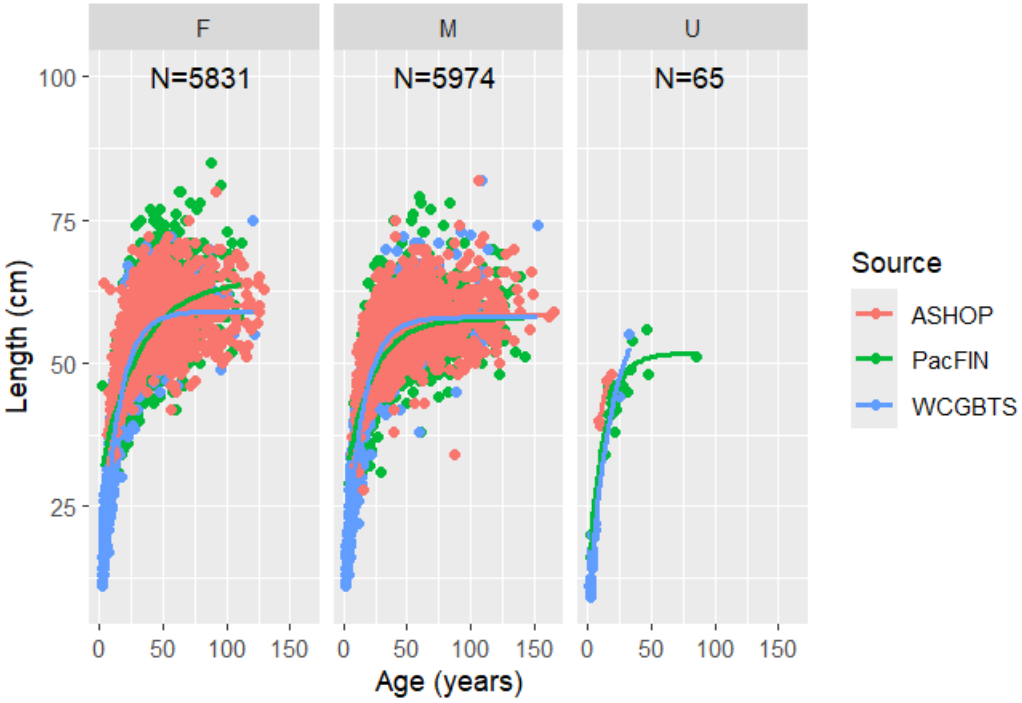


Figure 46: Age and length data, with fitted von Bertalanffy growth curves, by sex and data source for the Rougheye/Blackspotted rockfish complex. Sample sizes (N) are also provided.

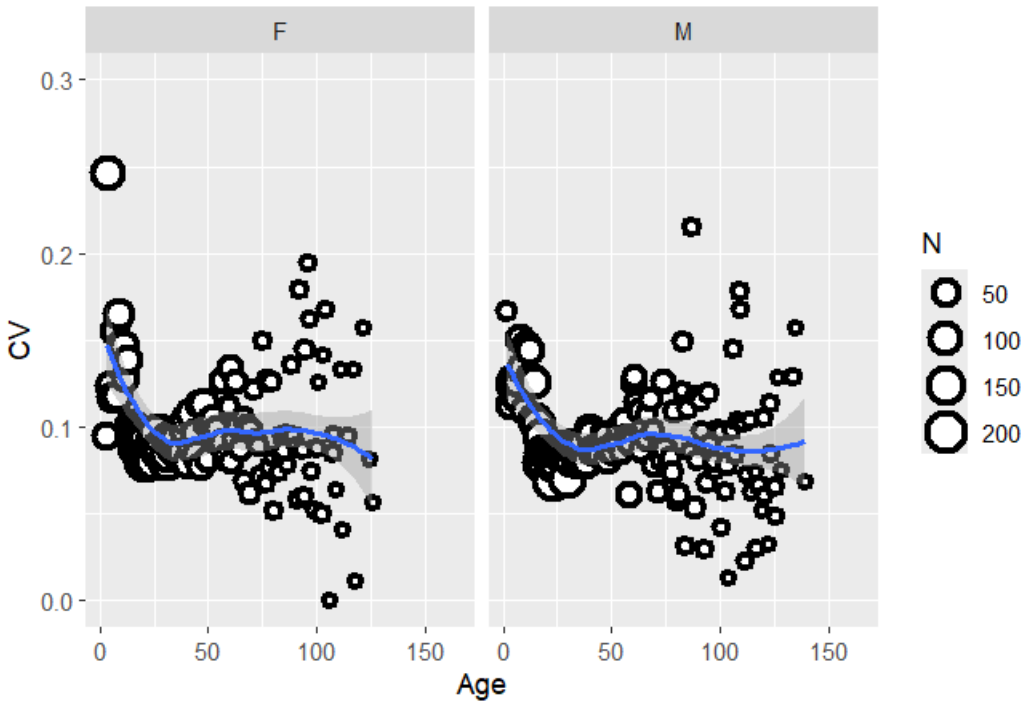


Figure 47: Coefficient of variation by age and sex for all sources of Rougheye/Blackspotted rockfishes ages. Sample sizes (N) are also indicated by size of the point. The line is a smoothed loess (polynomial) line that gives a moving average of CV by age and sex.

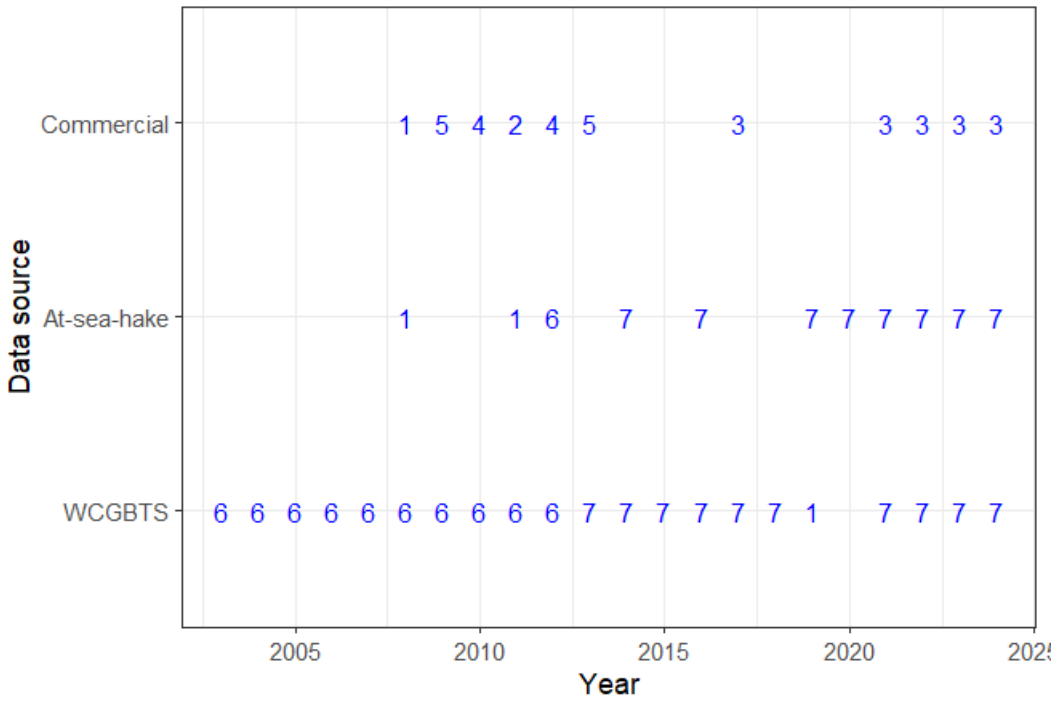


Figure 48: Ageing error matrix assignments by year and data source. The number indicates which ageing error matrix was used for conditional ages within those years and data sources. 'Commercial' is a combination of all commercial fleets.

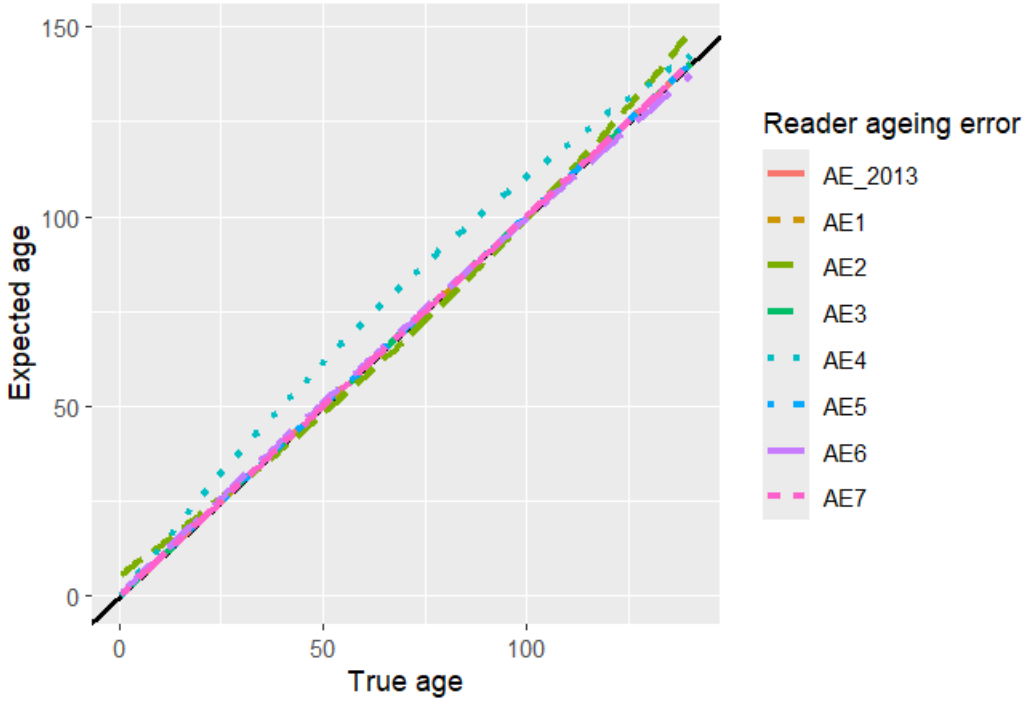


Figure 49: Estimated bias used for each of the seven ageing error matrices.

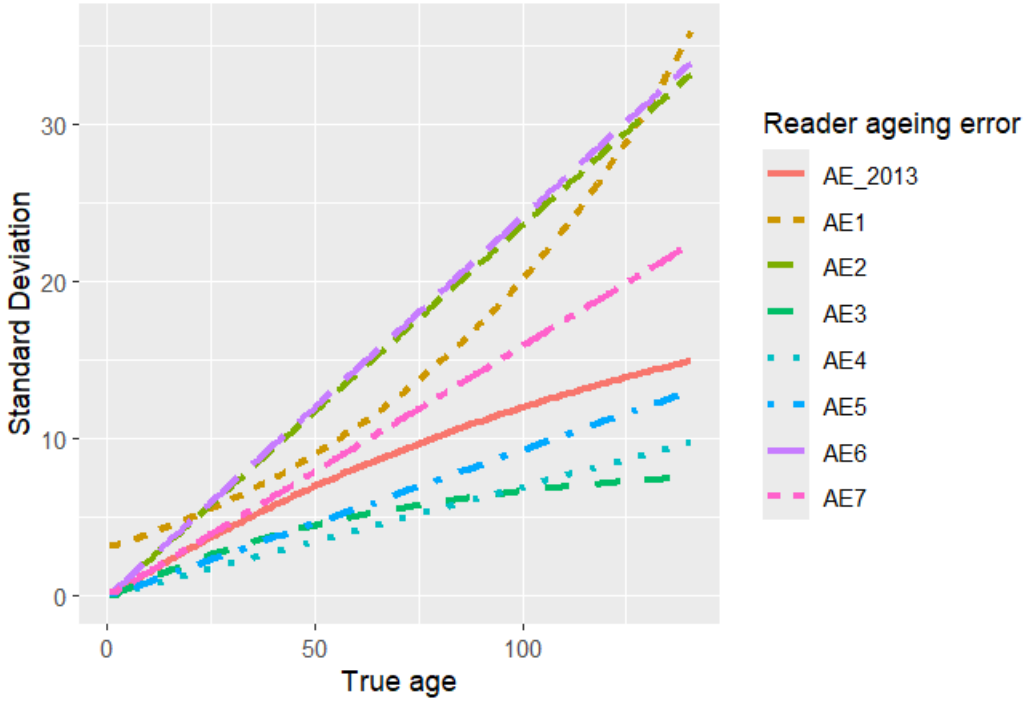


Figure 50: Estimated imprecision (as a standard deviation) used for each of the seven ageing error matrices.

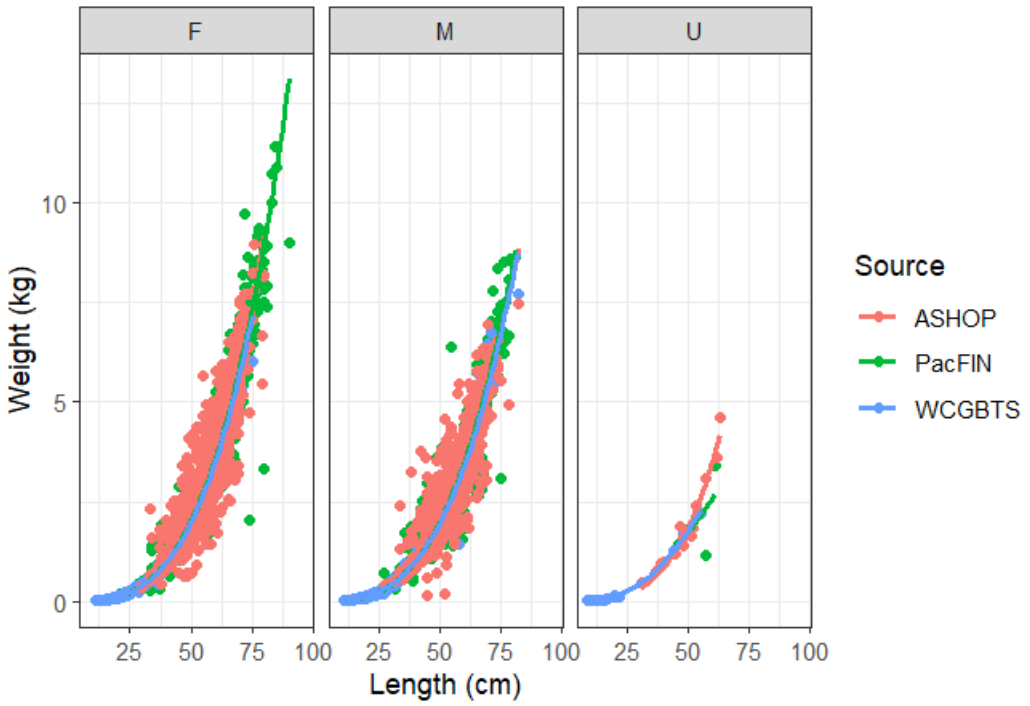


Figure 51: Length and weight samples by sex and data source. Lines are the power function fits by data source.

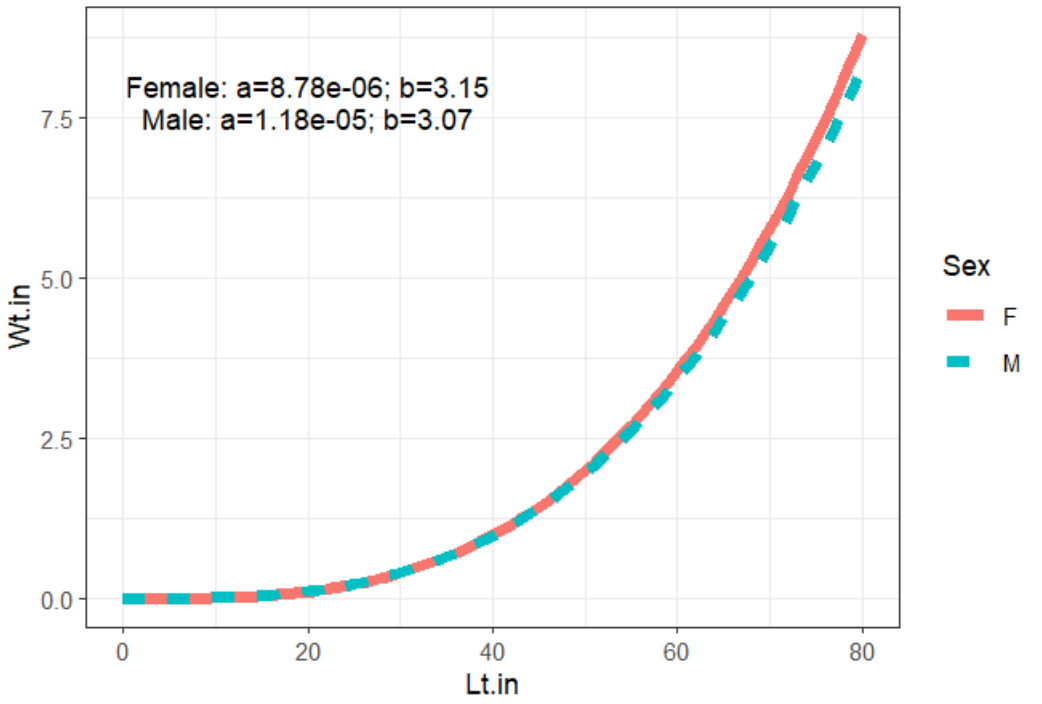


Figure 52: Realized length and weight relationships for female and male Rougheye/Blackspotted Rockfishes.

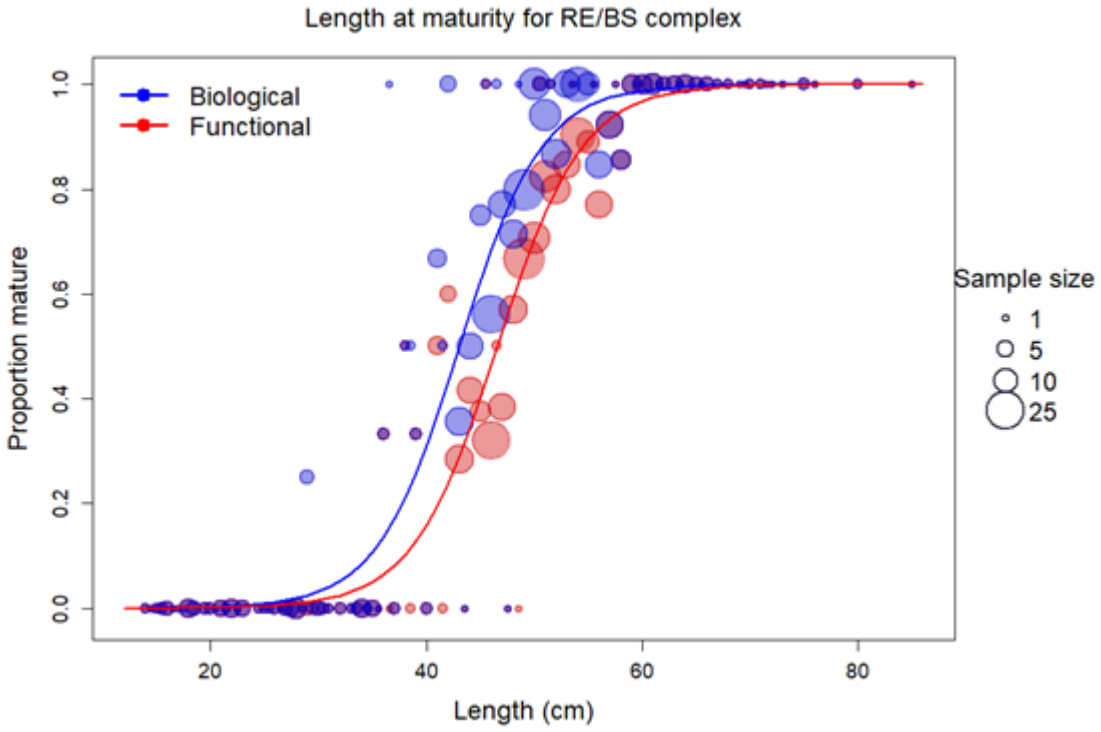


Figure 53: Proportion of mature fish by length when using biological versus functional maturity criteria.

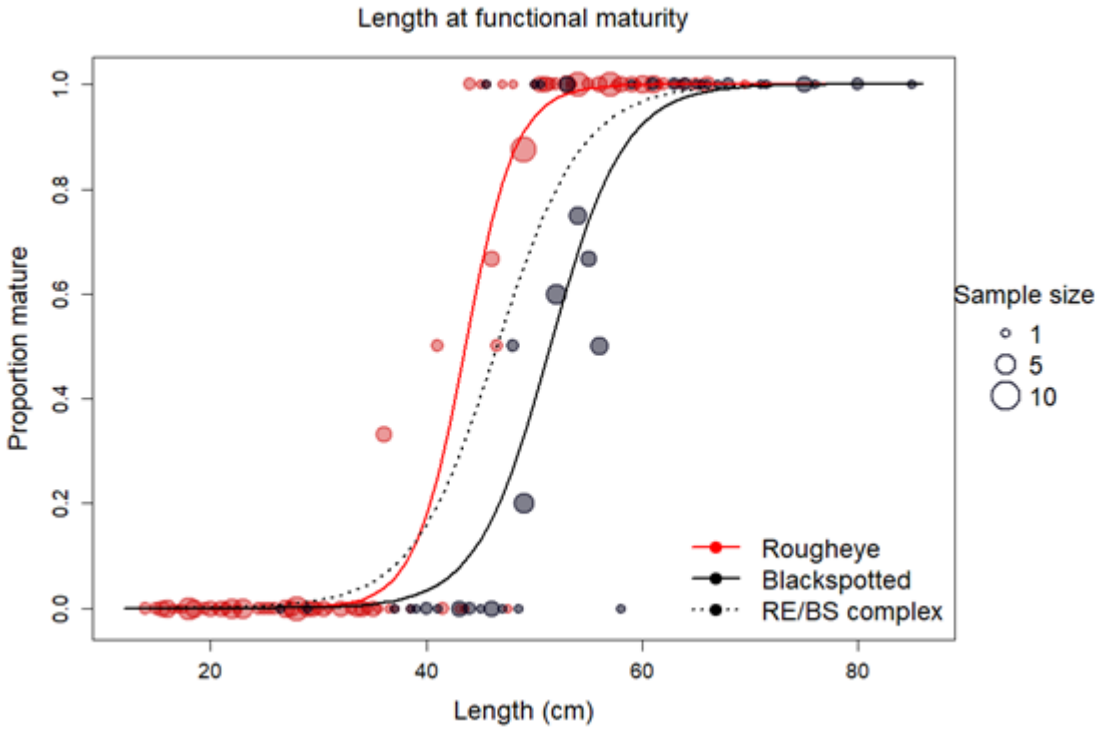


Figure 54: Proportion of mature fish by length for the Rougheye/Blackspotted rockfishes complex and by species.

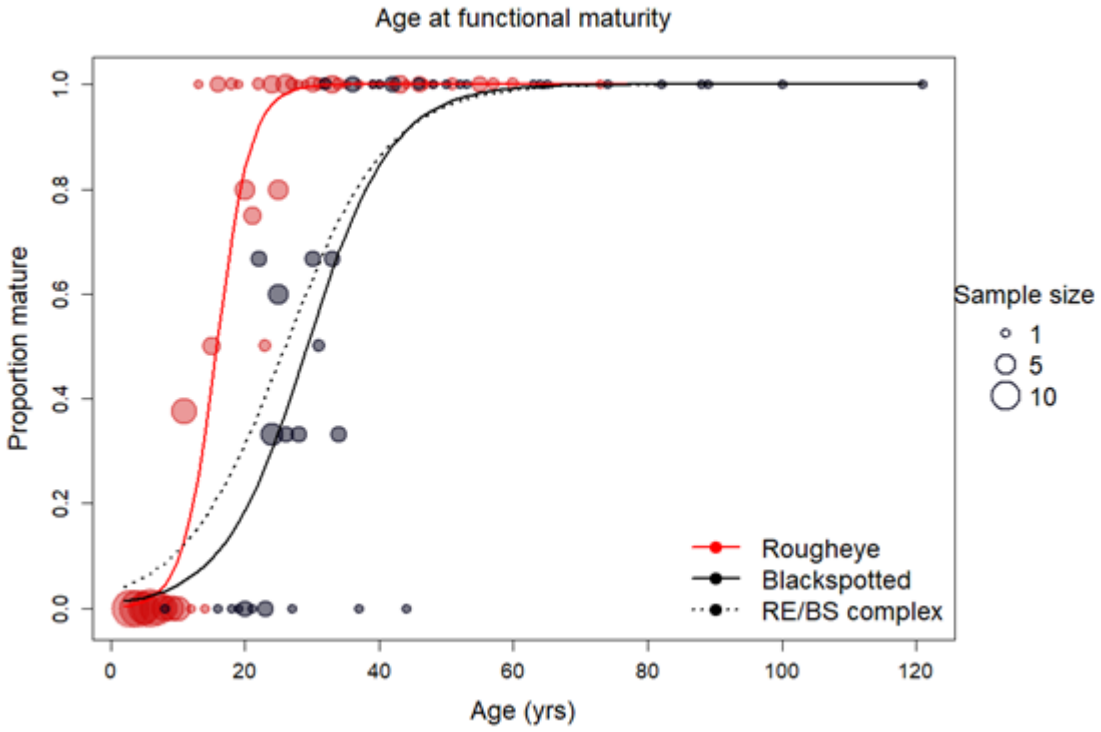


Figure 55: Proportion of mature fish by age for the Rougheye/Blackspotted rockfishes complex and by species.

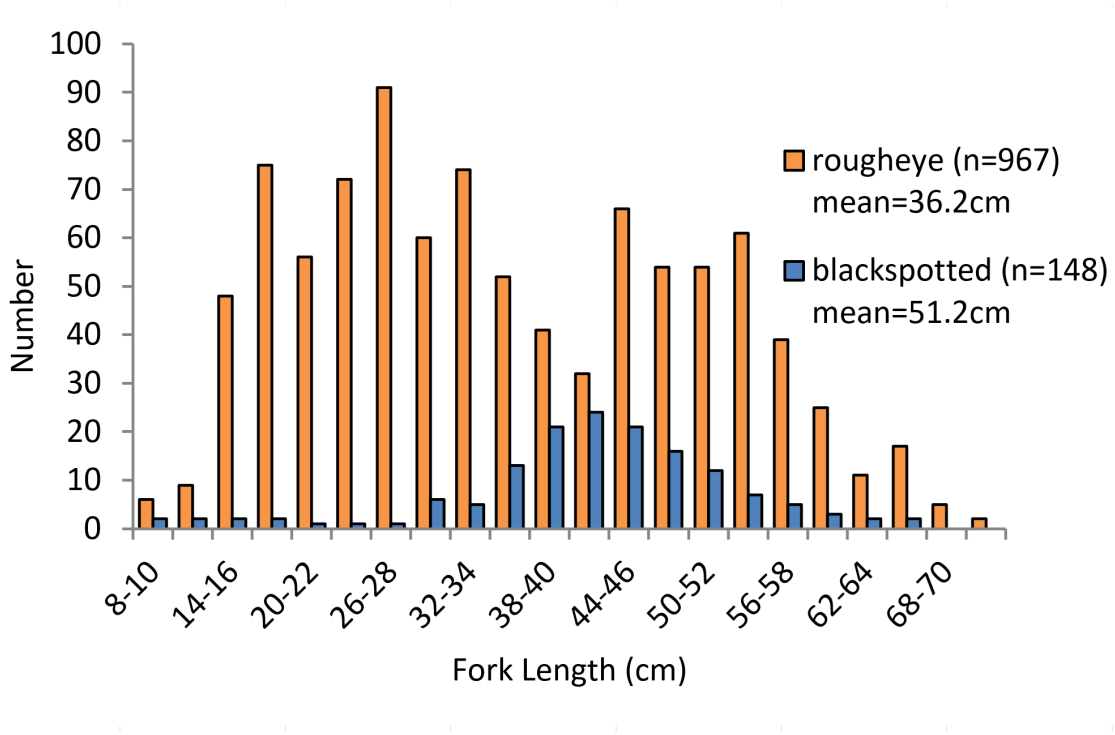


Figure 56: Length distribution of Rougheye Rockfish and Blackspotted Rockfish identified to species using genetics (pers. comm. P. Frey, NWFSC).

8.3 Model Bridging

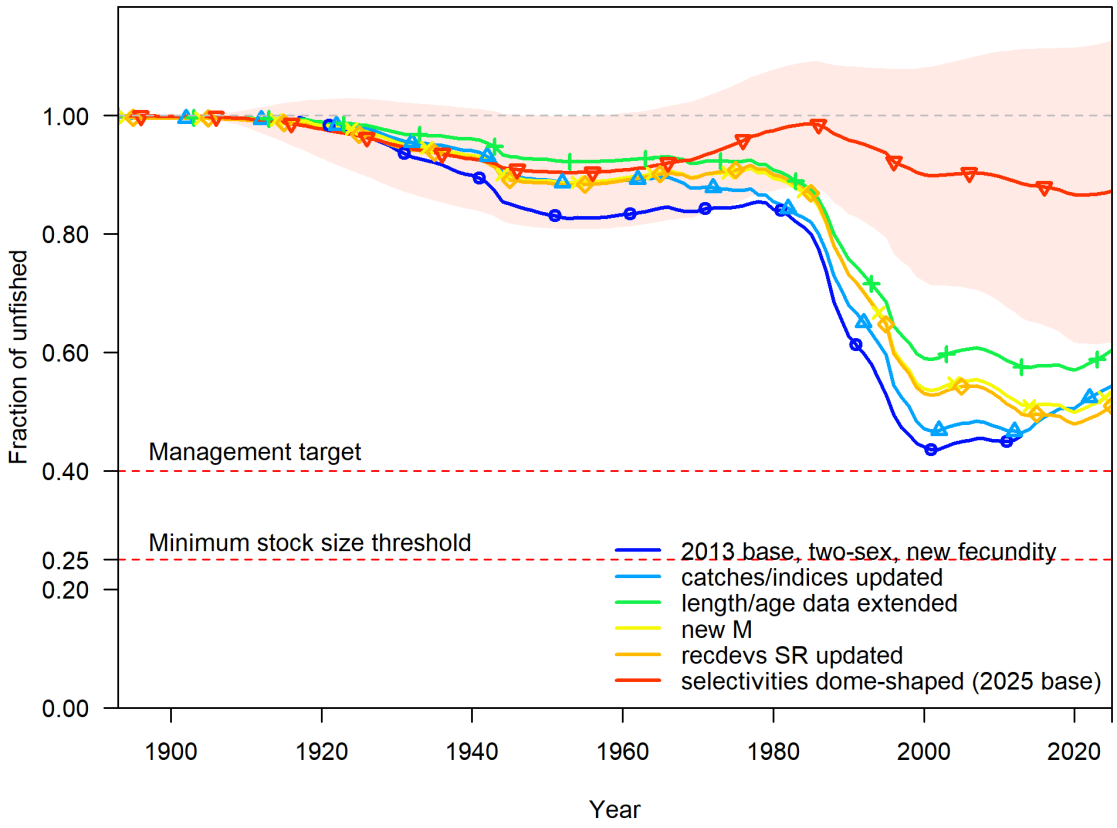


Figure 57: Estimates of relative stock size (current spawning output/unfished spawning output) for the Rougheye/Blackspotted rockfish complex in U.S. west coast waters from the 2013 assessment, and compared to the using the same data in the newest version of SS3 (3.30.22.2).

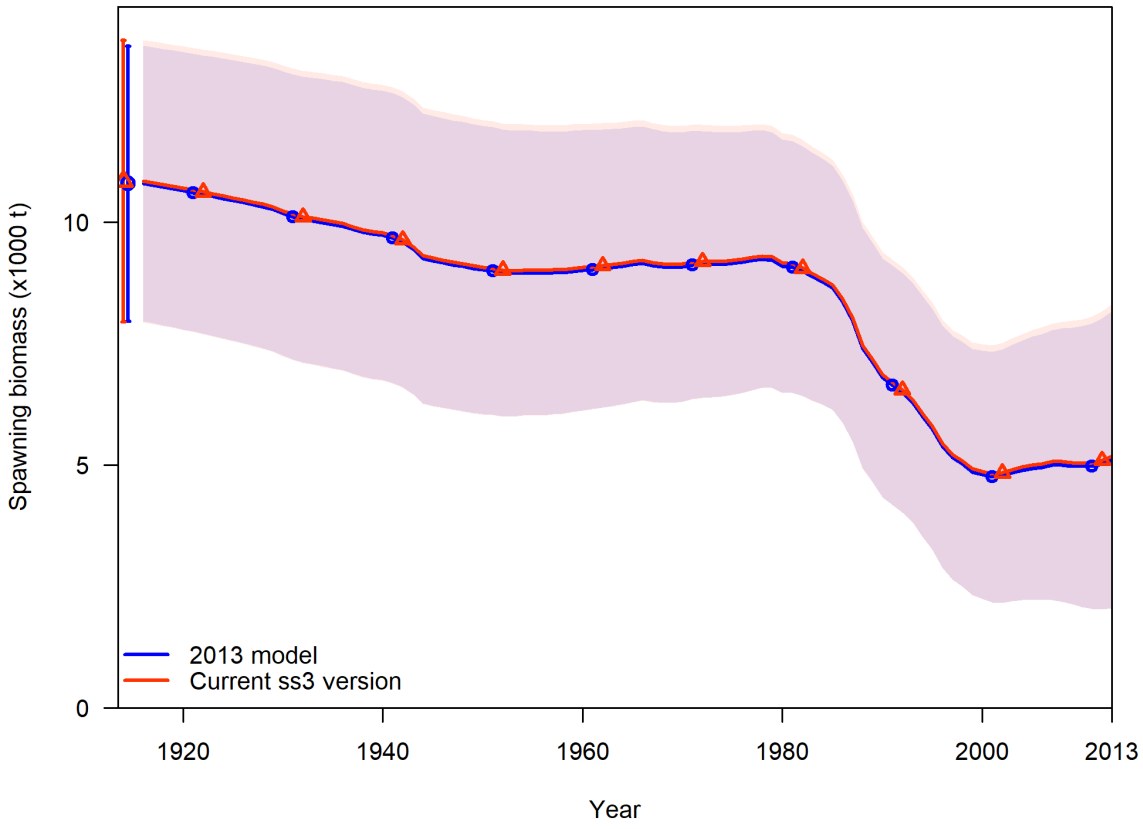


Figure 58: Estimates of spawning biomass for the Rougheye/Blackspotted rockfish complex in U.S. west coast waters from the 2013 assessment, and compared to the same data in the newest version of SS3 (3.30.22.2). Shading denotes 95% confidence intervals. Shading denotes 95% confidence intervals.

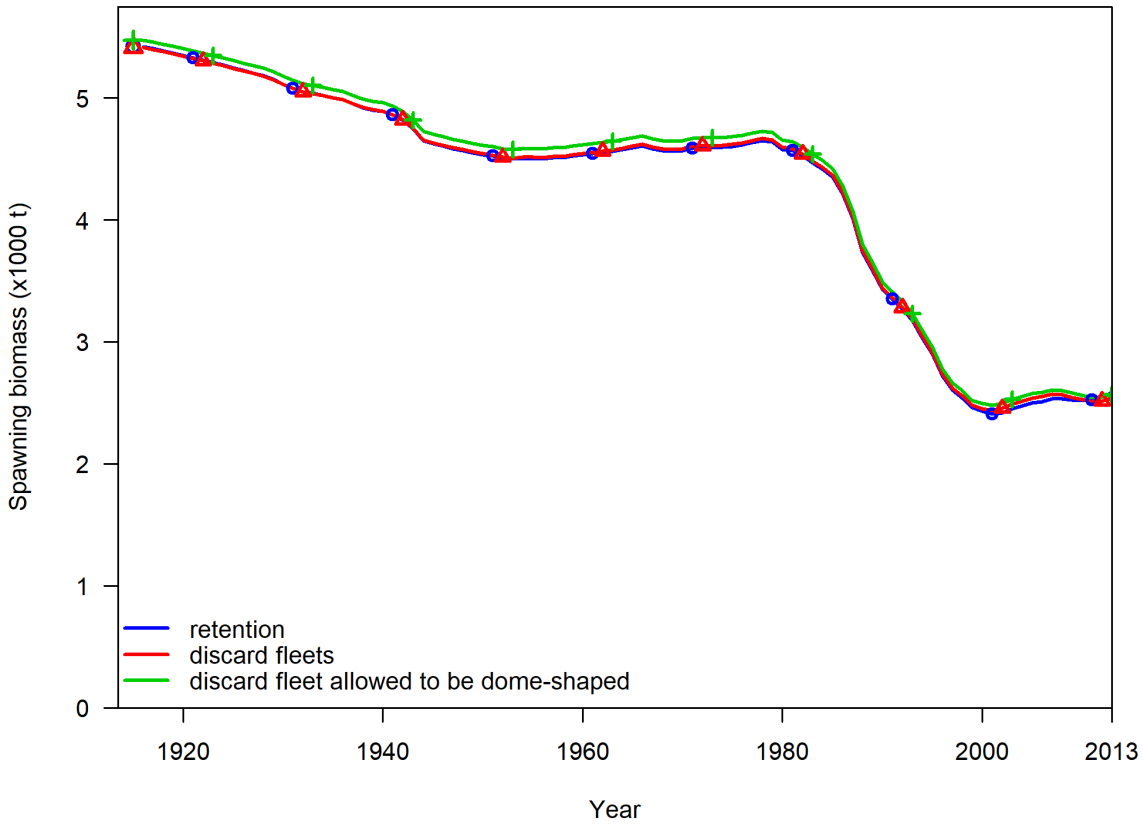


Figure 59: Comparison of spawning biomass using retention curves or discard fleets using the 2013 Rougheye/Blackspotted Rockfishes assessment.

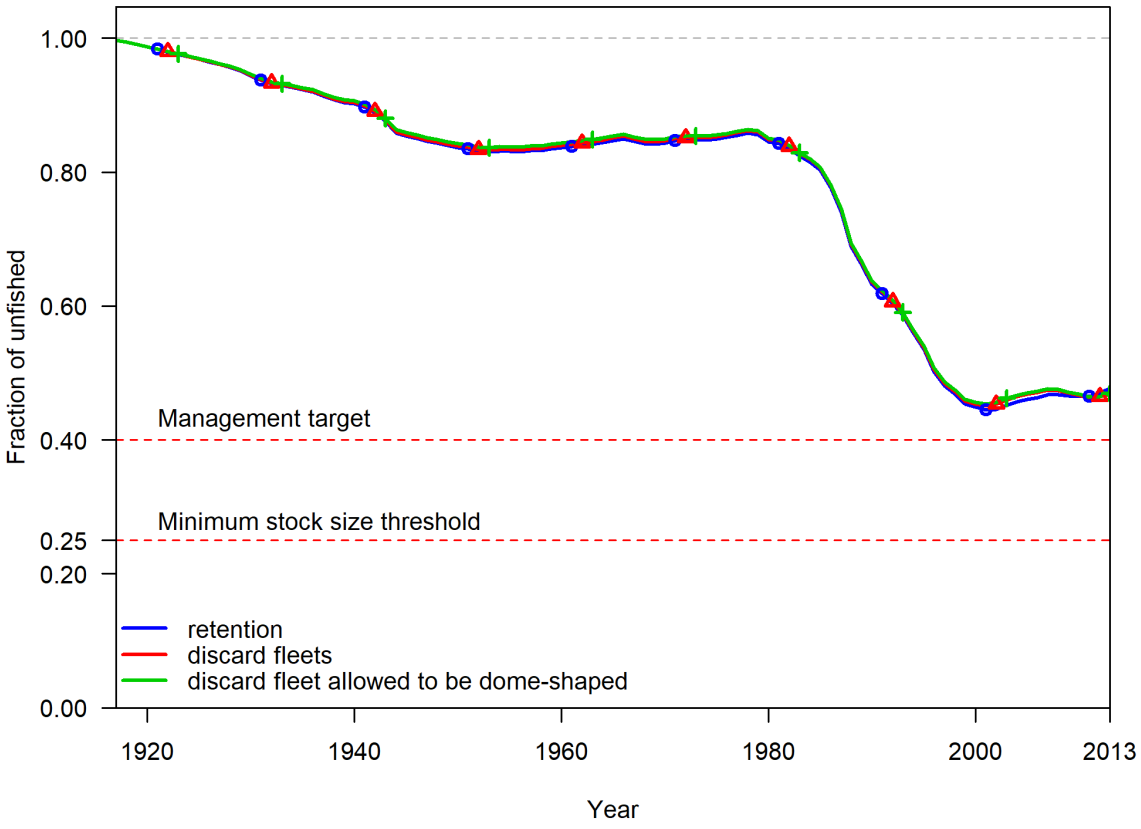


Figure 60: Comparison of fraction unfished (relative spawning biomass) using retention curves or discard fleets using the 2013 Rougheye/Blackspotted Rockfishes assessment.

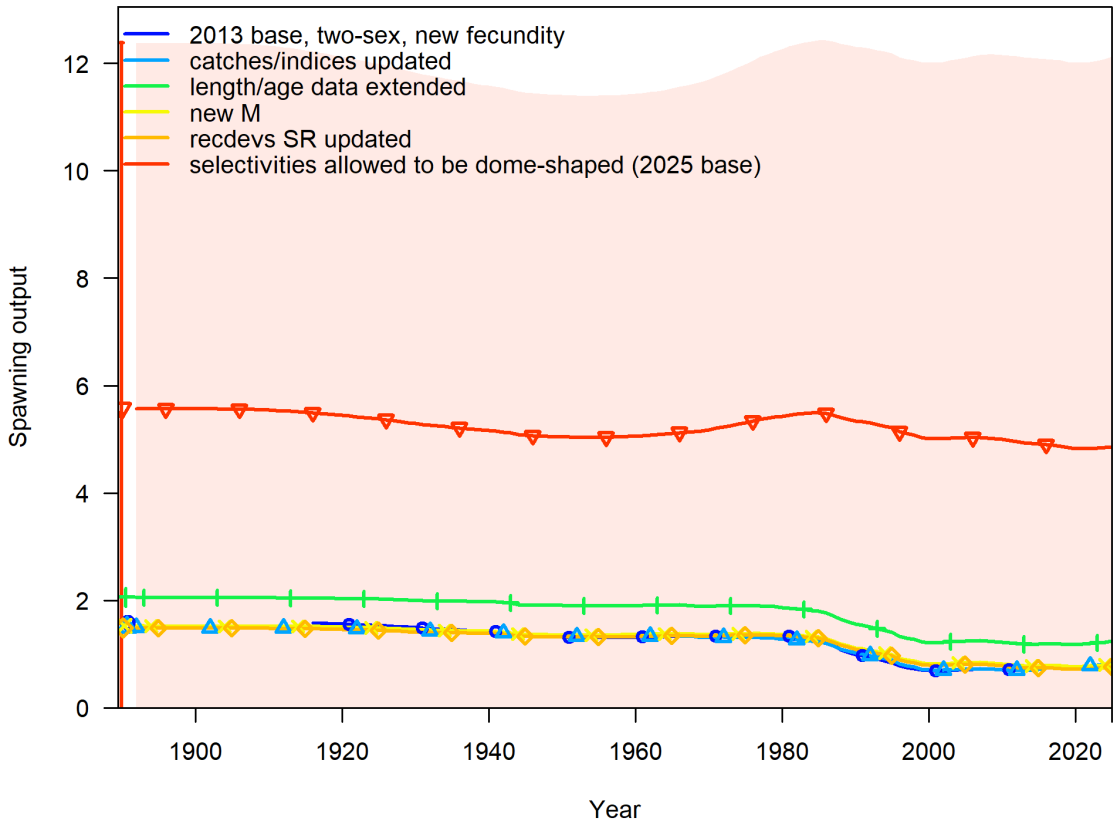


Figure 61: Time series of estimated spawning output (trillions of eggs) for bridging analysis.

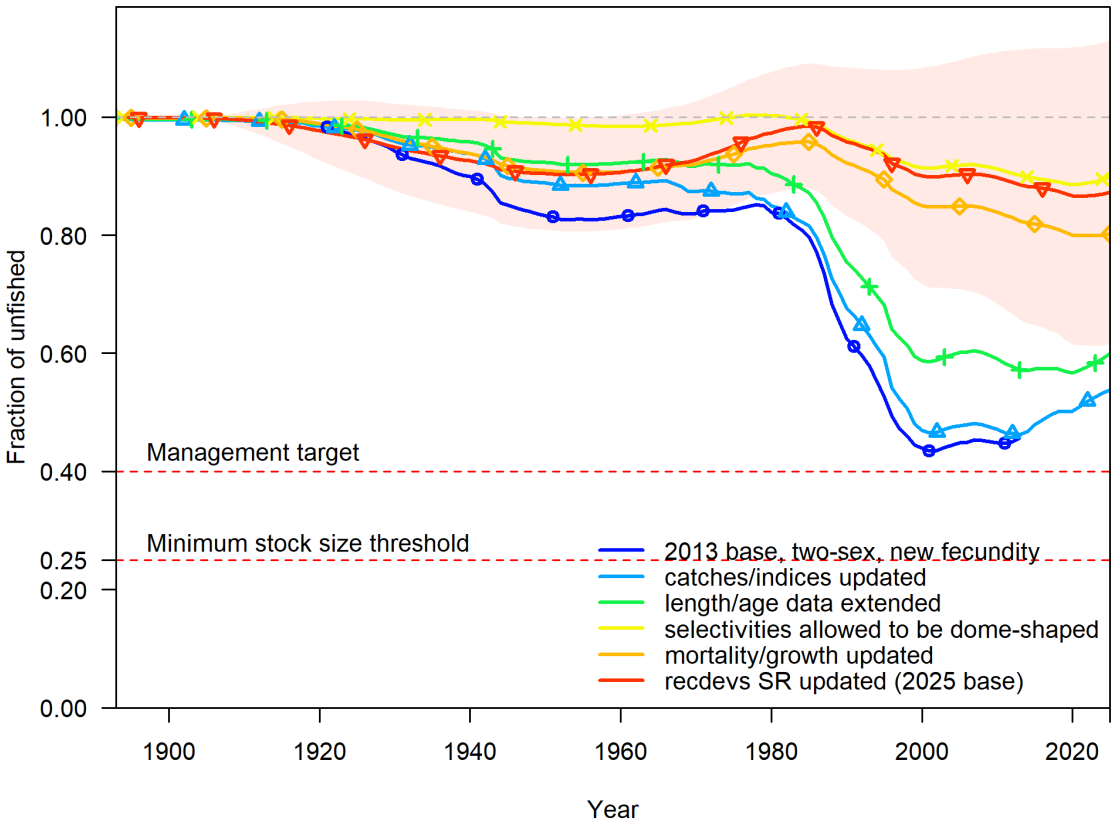


Figure 62: Time series of fraction of unfished spawning output for bridging analysis.

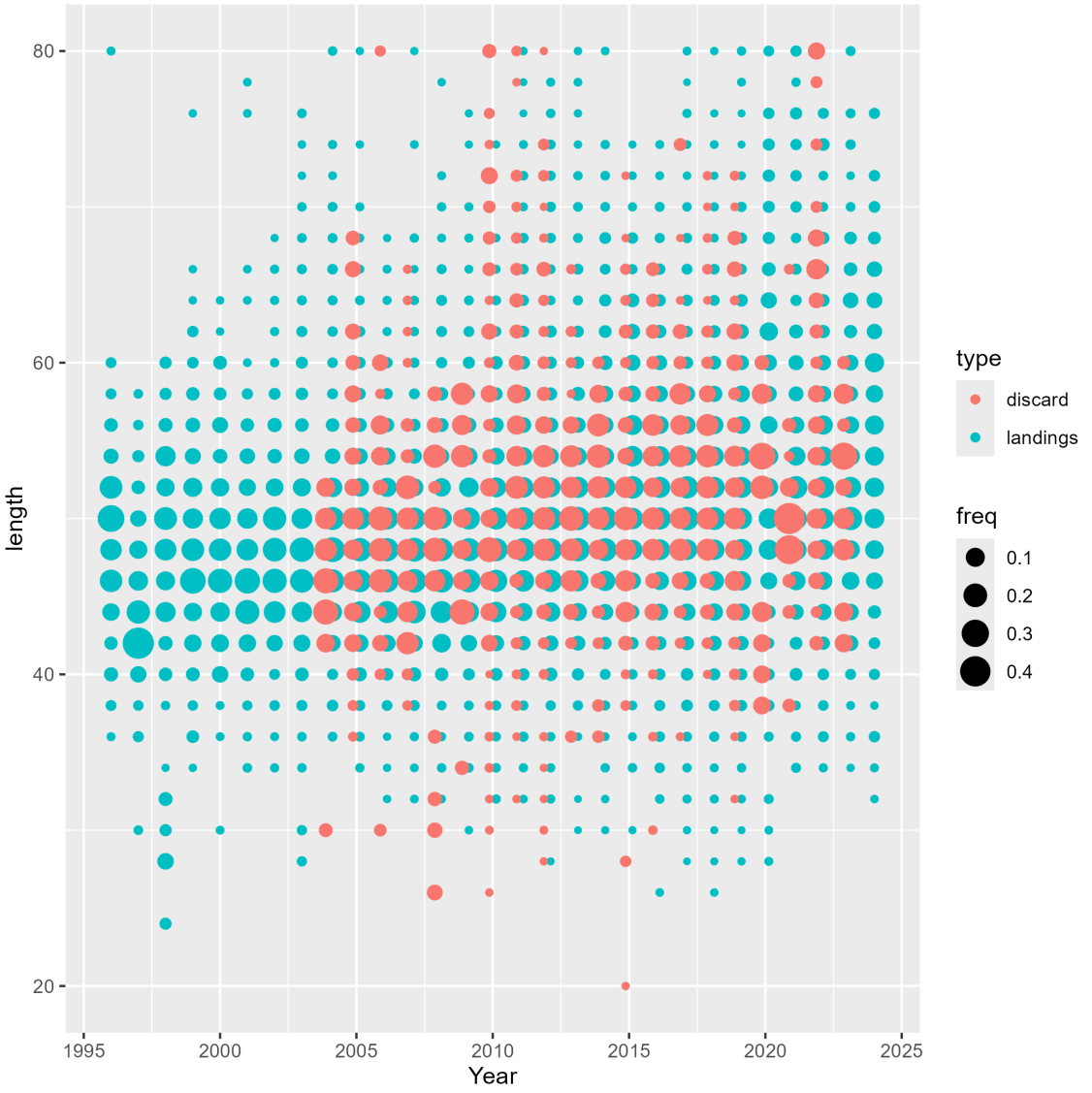


Figure 63: Comparison of length compositions (lengths in cm) between non-trawl and non-trawl discard fleets, sexes combined.

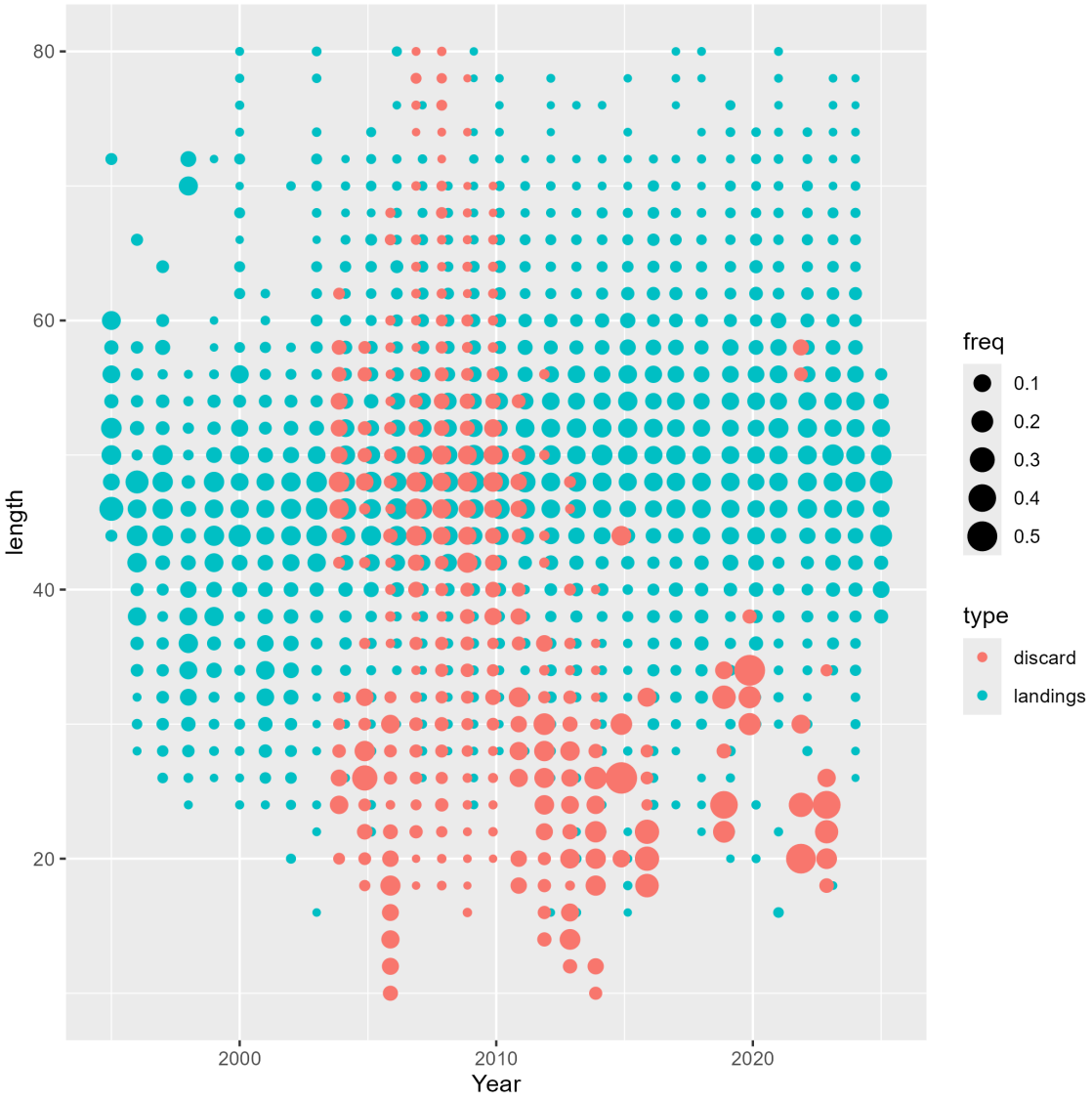


Figure 64: Comparison of length compositions (lengths in cm) between trawl and trawl discard fleets, sexes combined.

8.4 Model Diagnostics

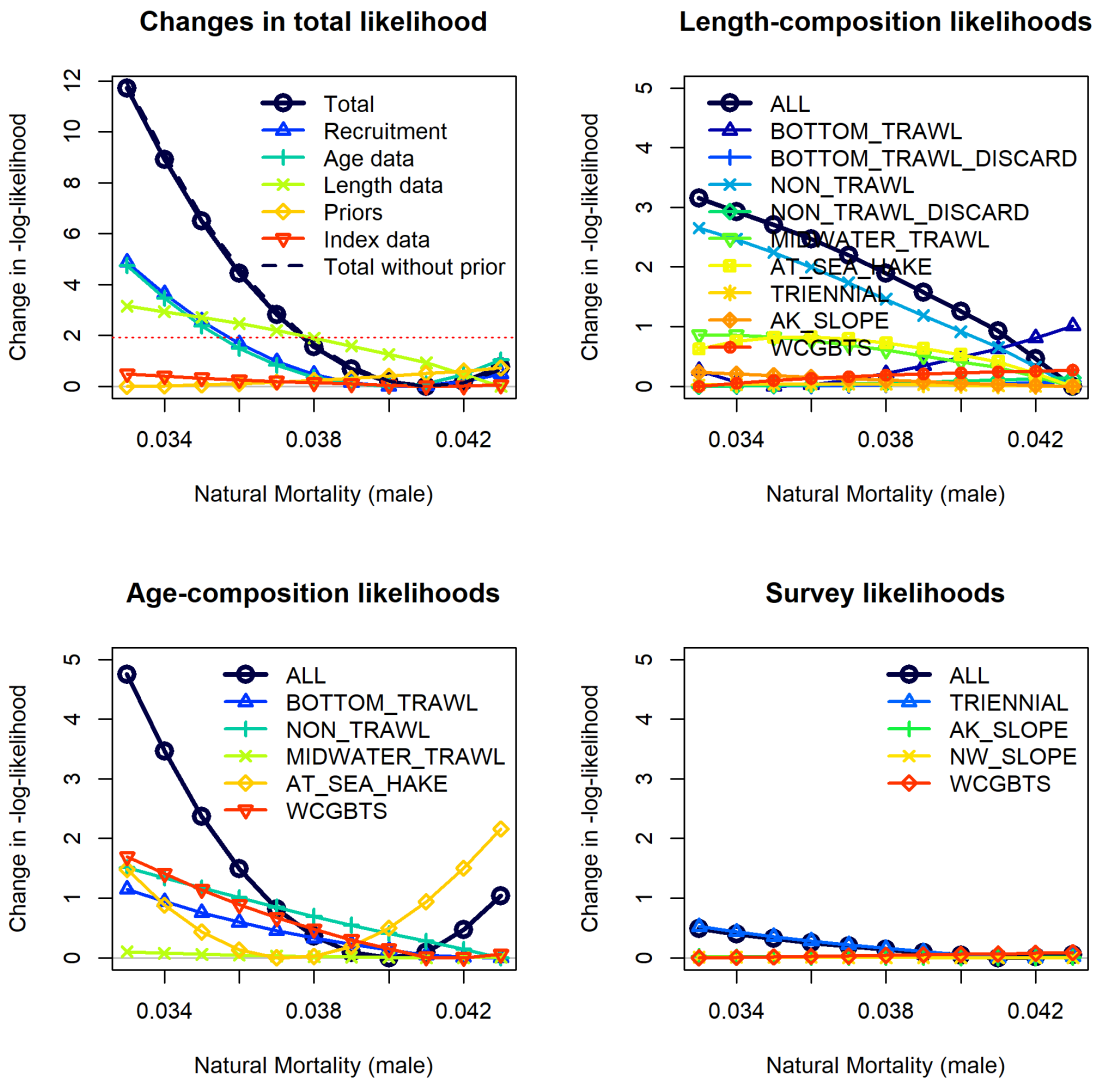


Figure 65: Likelihood profile and component likelihoods used to establish a fixed value for male natural mortality.

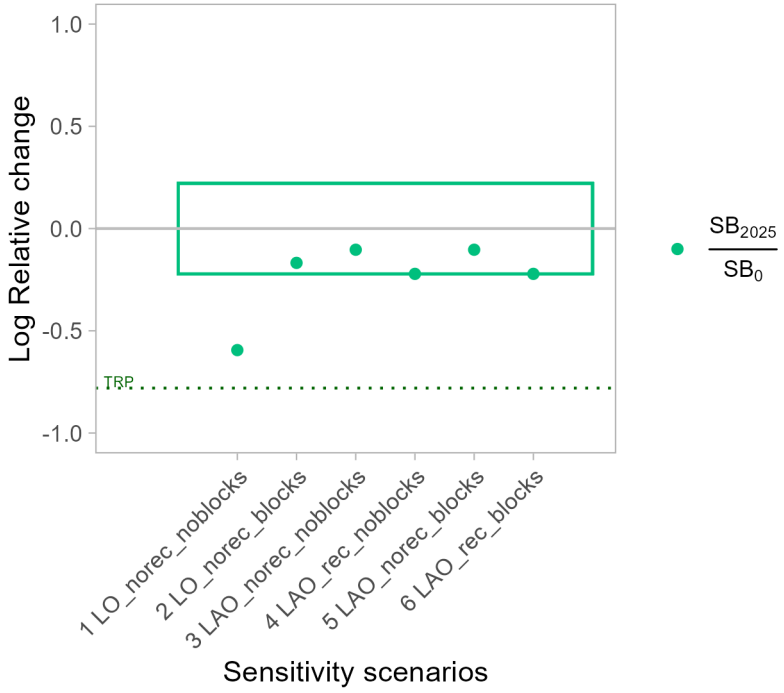


Figure 66: Log relative change (log((Model_sensi-Model_ref)/Model_ref)) in length and/or age only scenarios for relative stock status. Box indicates 95 percent confidence interval of the reference model.

8.5 Model Convergence

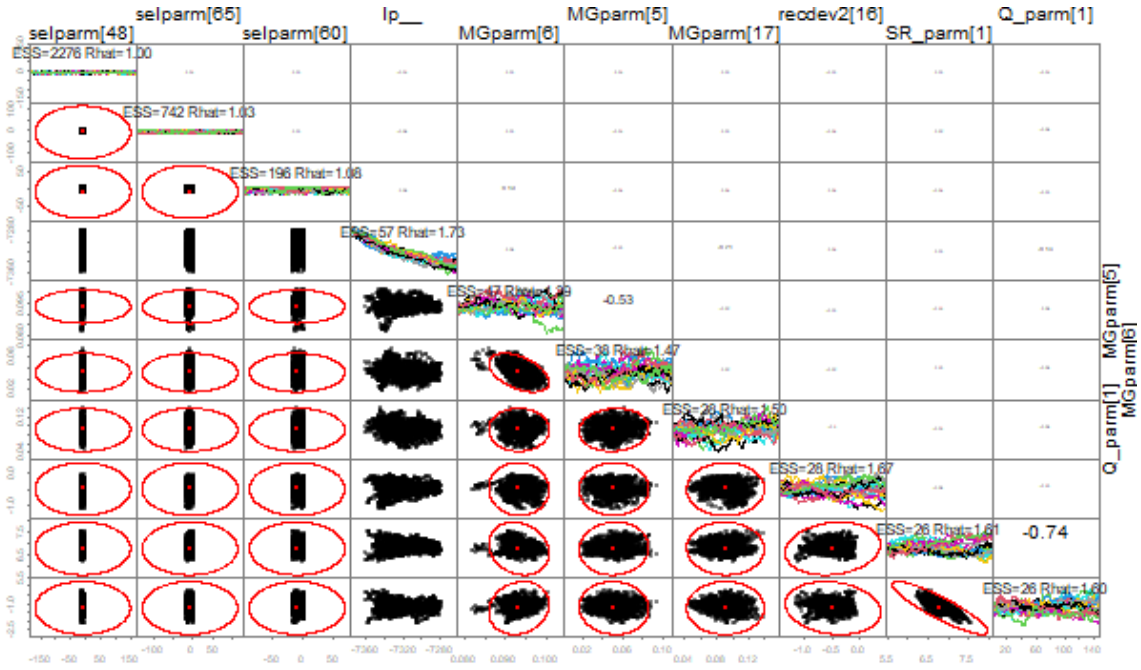


Figure 67: Pairs plots of the fastest mixing parameters from running 2000 posterior draws (keeping every draw) using the random walk Metropolis algorithm. Parameters that show little to no movement are recommended to be fixed to improve model speed and efficiency.

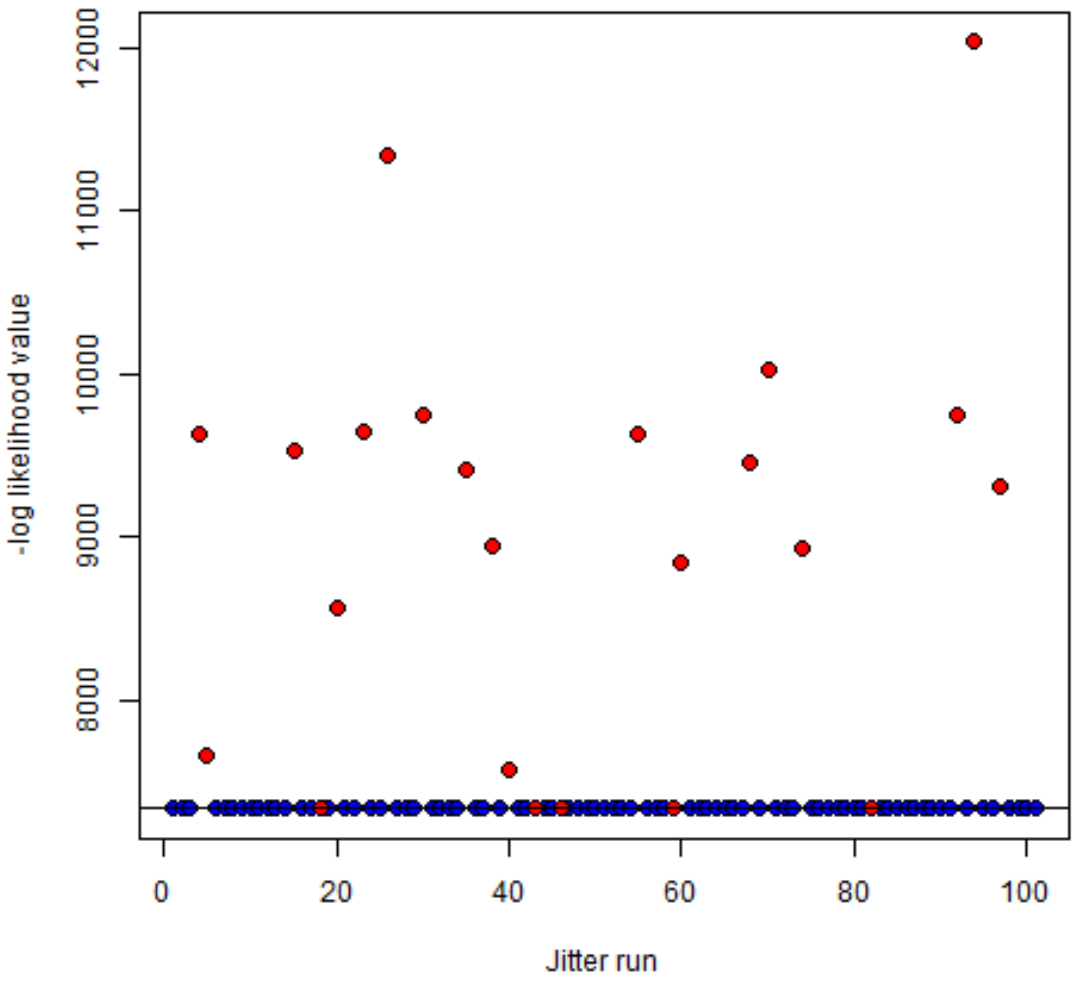


Figure 68: Jitter runs (using a value of 0.01) for the reference model, with jitter run number on the x-axis and -log likelihood value on the y-axis. Blue dot are models that match the likelihood value of the reference model, while red dots deviate from the reference model. All red dots are above the blue dots, indicating no better fit to the reference model was found.

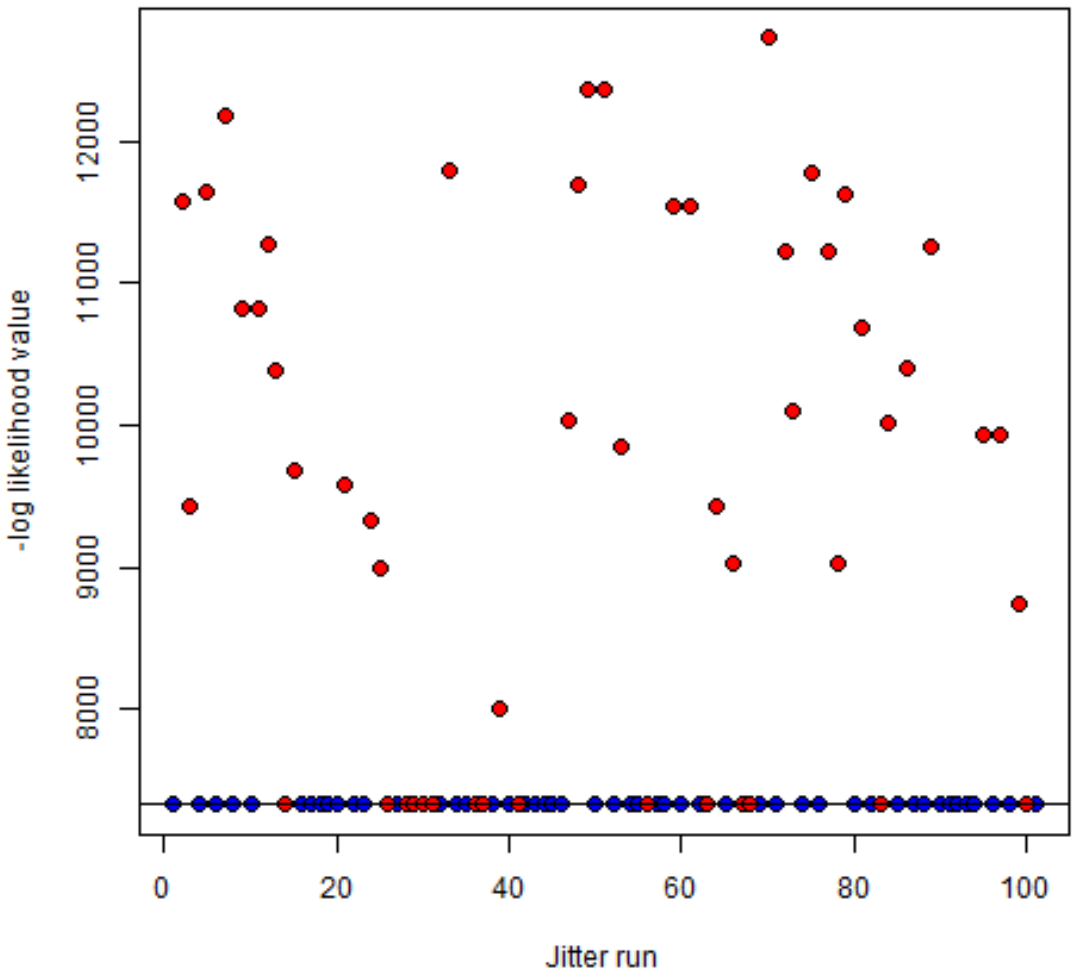


Figure 69: Jitter runs (using a value of 0.05) for the reference model, with jitter run number on the x-axis and -log likelihood value on the y-axis. Blue dot are models that match the likelihood value of the reference model, while red dots deviate from the reference model. All red dots are above the blue dots, indicating no better fit to the reference model was found.

8.6 Retrospecitve Analysis

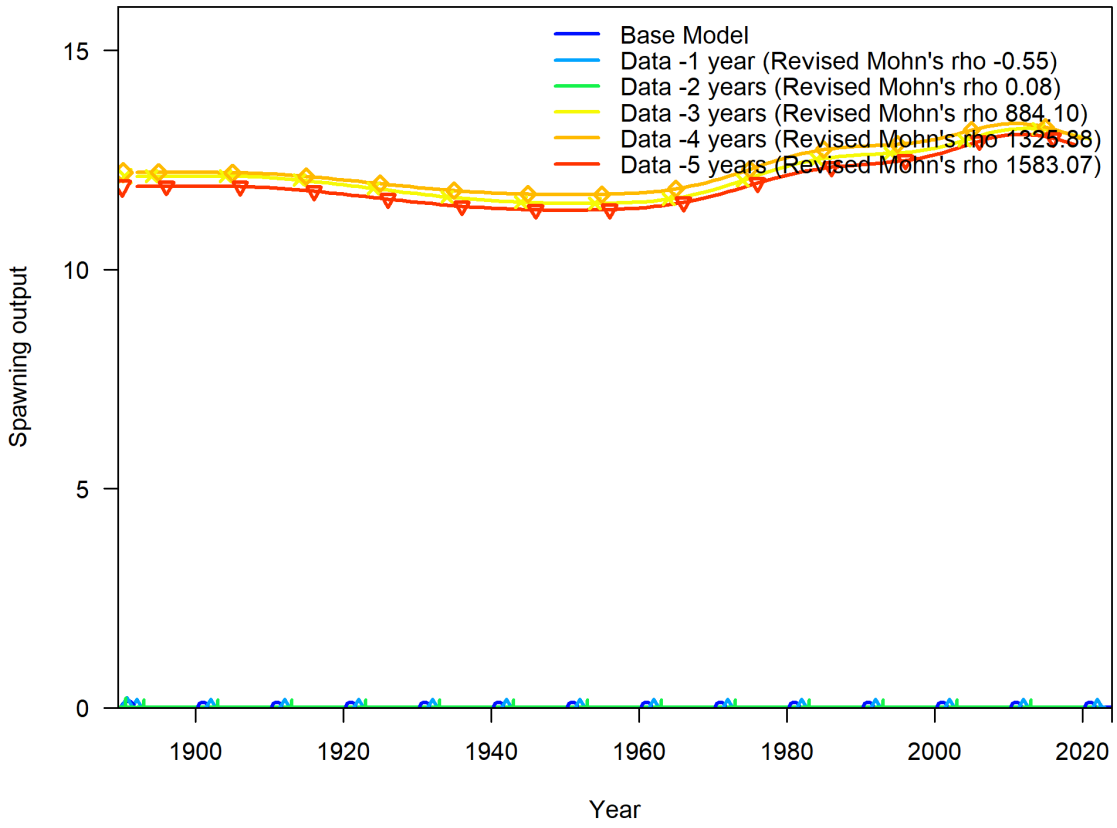


Figure 70: Change in the estimate of spawning output (quadrillions of eggs) when the five most recent years of data area removed sequentially.

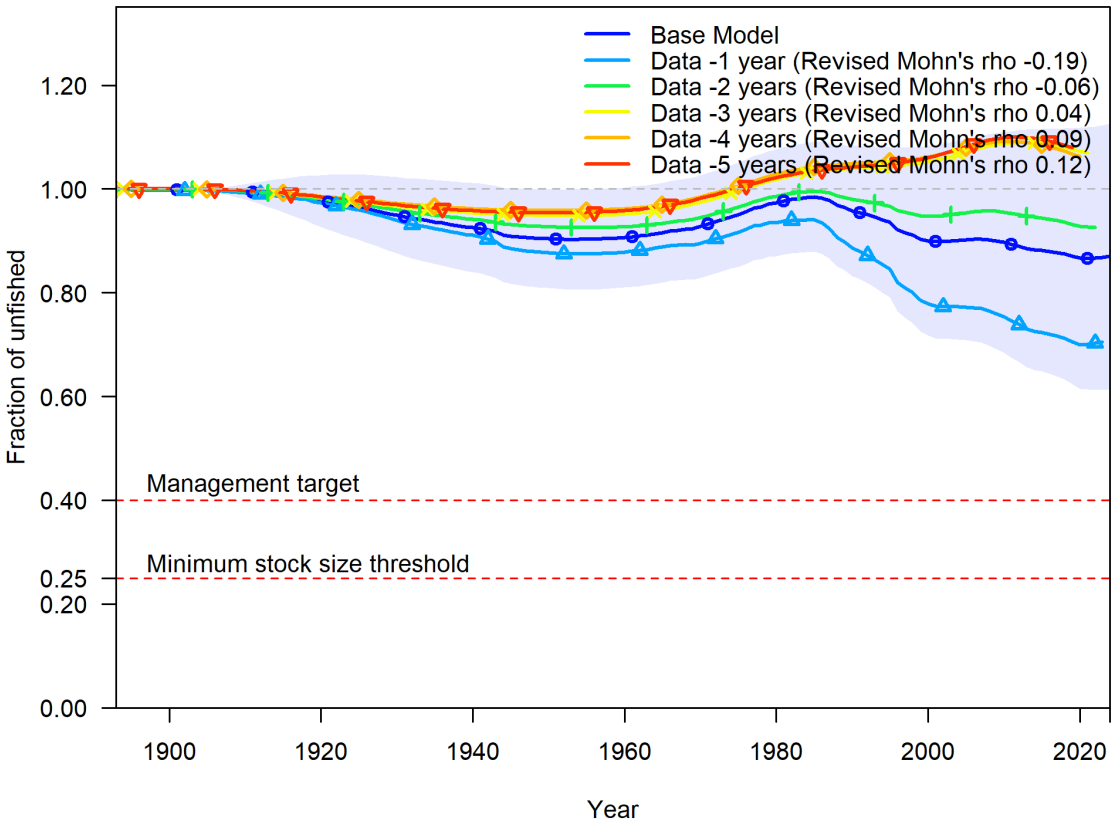


Figure 71: Change in the estimate of relative stock status (fraction unfished) when the five most recent years of data area removed sequentially.

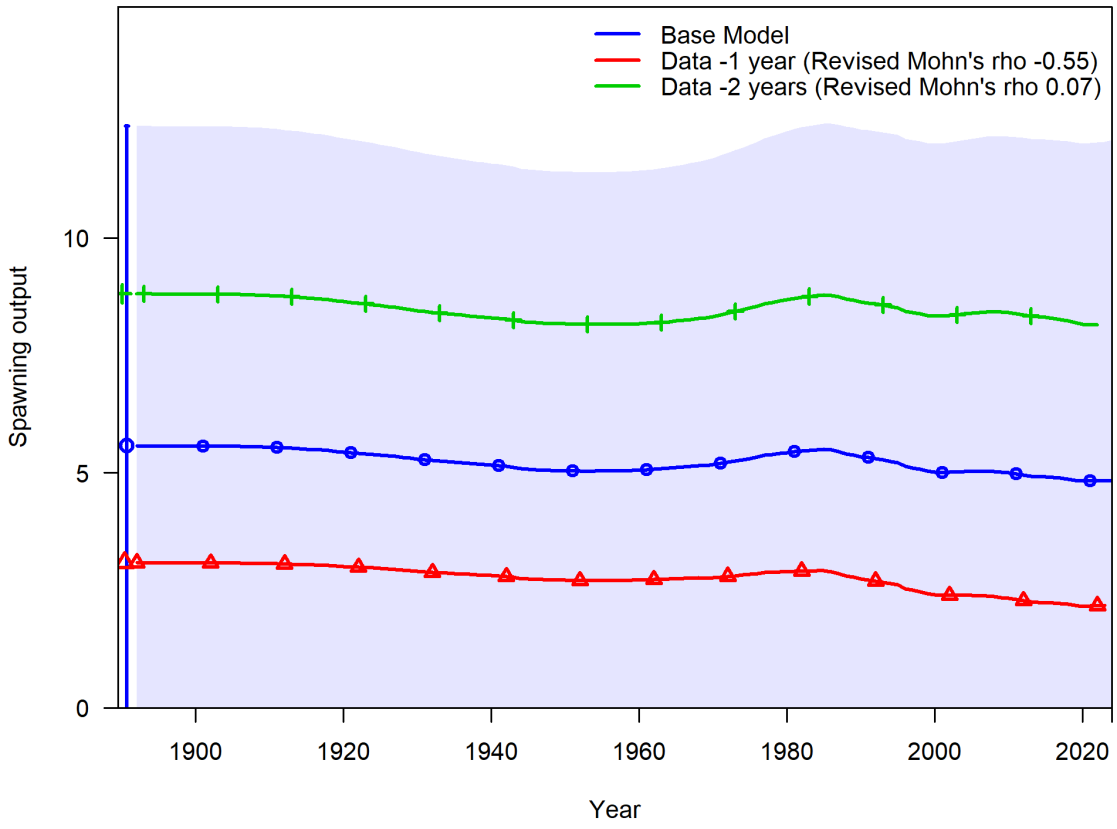


Figure 72: Change in the estimate of spawning output (quadrillions of eggs) when the two most recent years of data area removed sequentially. Uncertainty envelopes are also provided for the reference model.

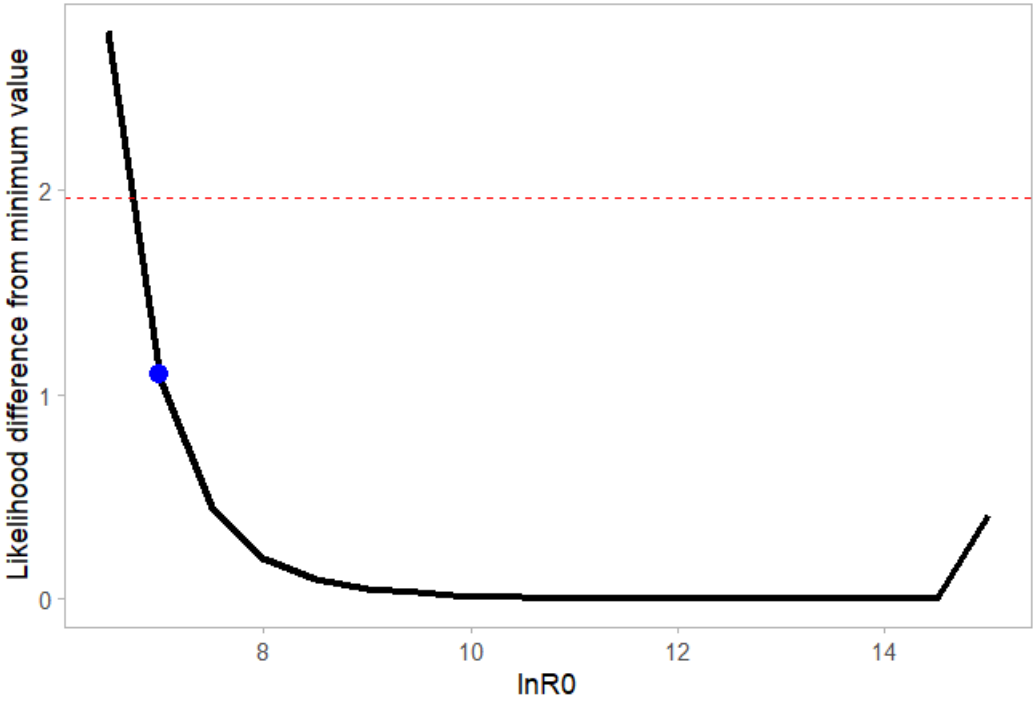


Figure 73: Initial recruitment (lnR_0) likelihood profile (change in the negative log-likelihood across a range of $lnR0$ values) and derived quantities for the retrospective -3 years model. Red line in the top left figure indicates the significance level in likelihood difference. Blue dot is the reference model value.

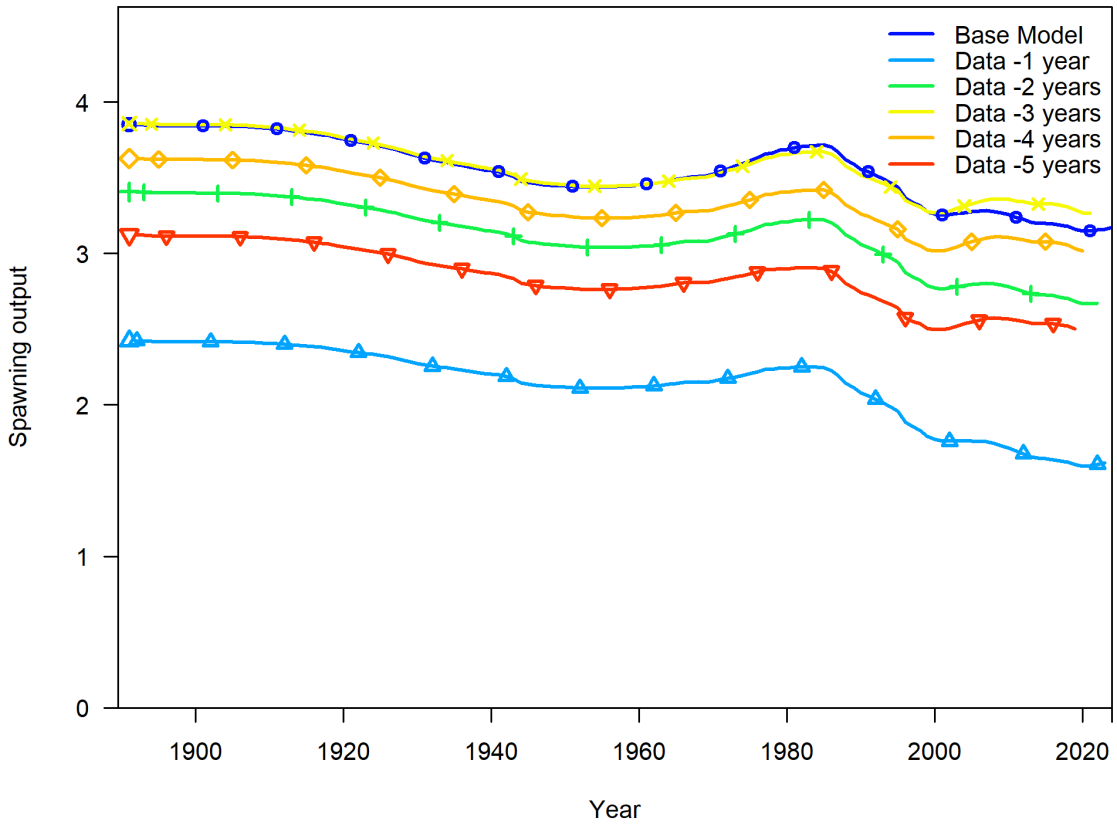


Figure 74: Change in the estimate of spawning output (trillions of eggs) when the five most recent years of data area removed sequentially in the model with the most recent block on non-trawl fleet selelctivity extended to start in 2011 (instead of 2020). Base model in this plot labels the model with modified block, not the assessment base model.

8.7 Model Fits to Data

8.7.1 Lengths

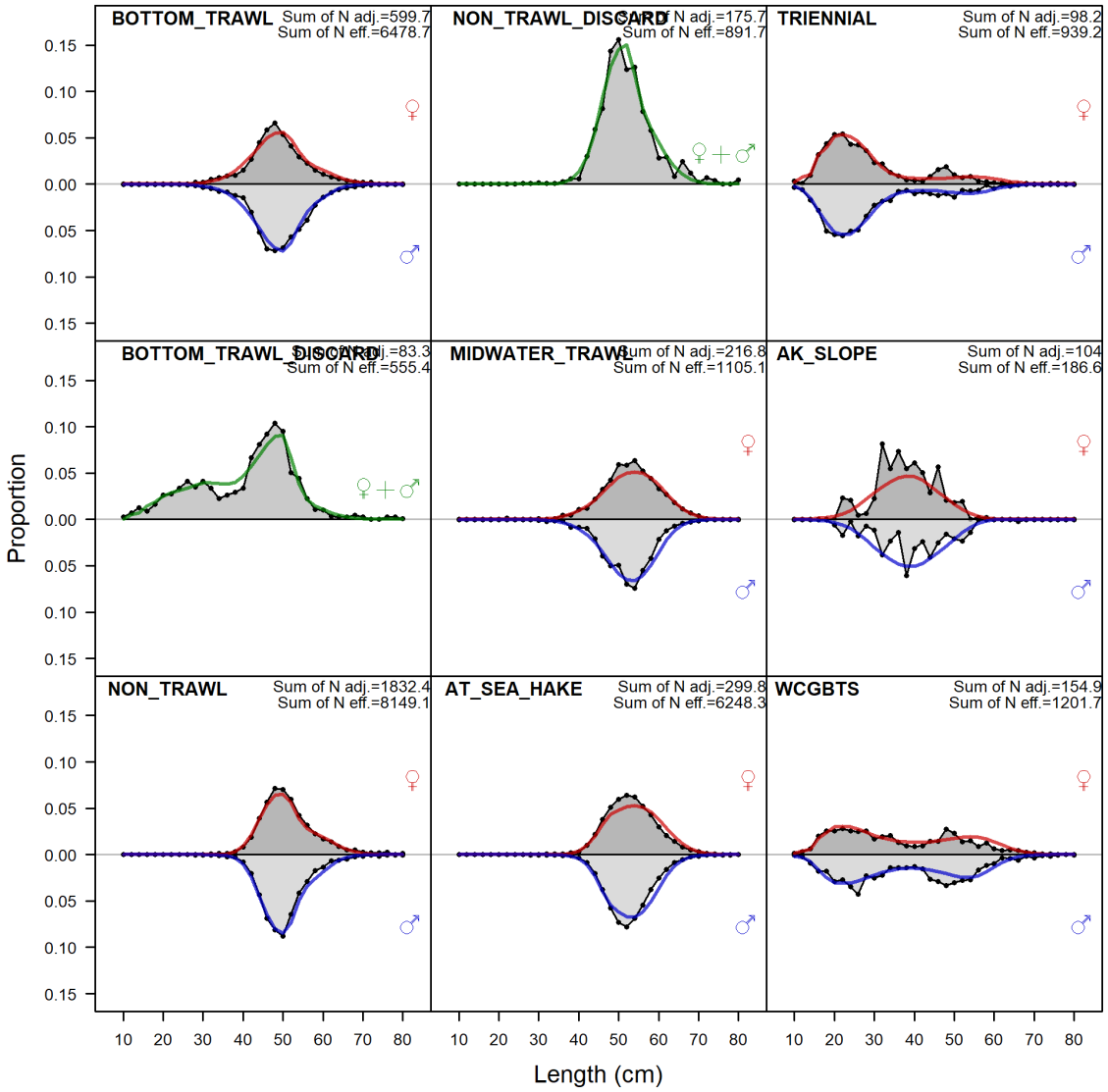


Figure 75: Model fit to aggregated length (cm) compositions over all years.

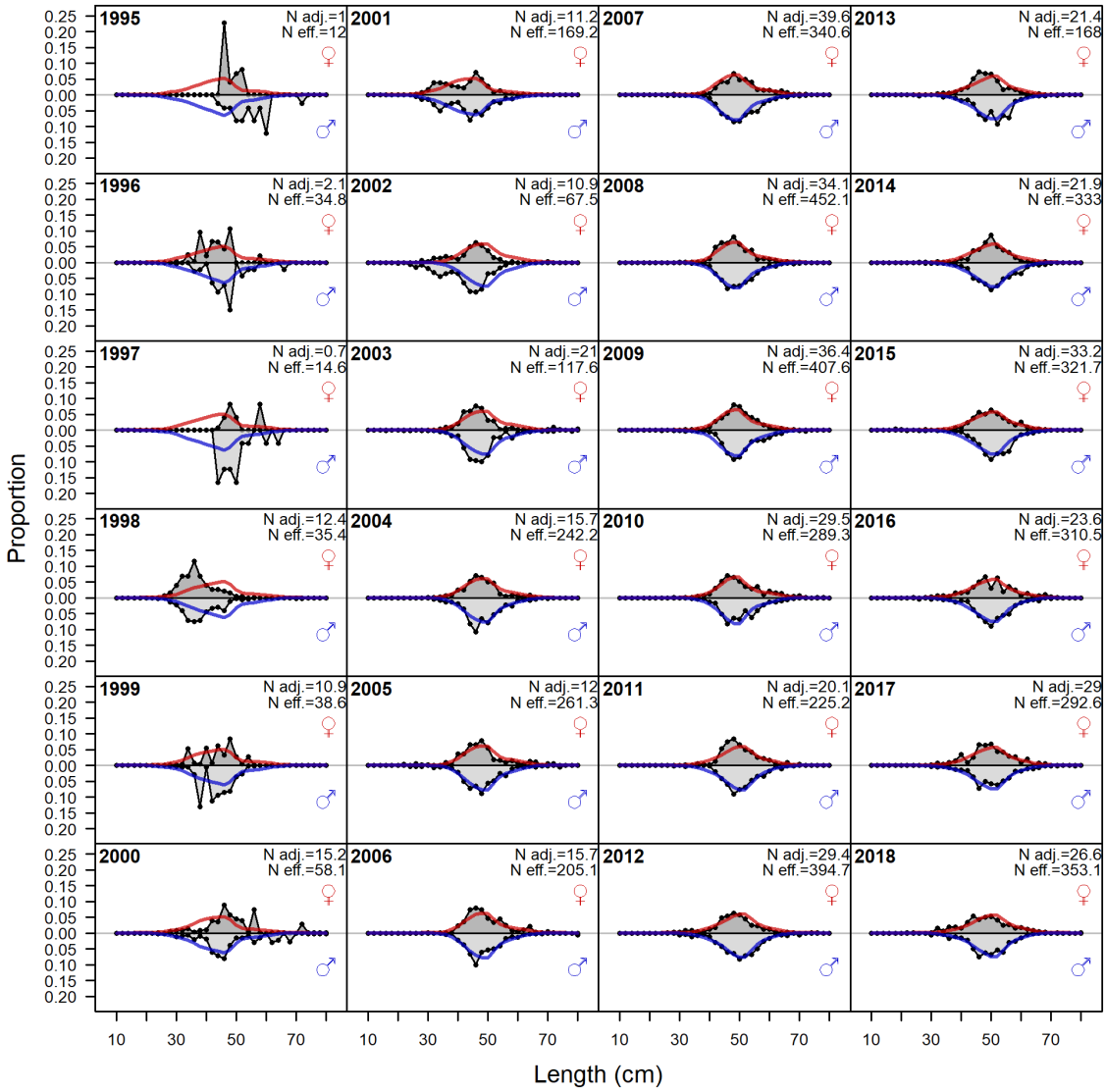


Figure 76: Observed (gray density plot) and expected (density lines by sex) length compositions by year for the bottom trawl fishery in years available between 1995-2018.'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

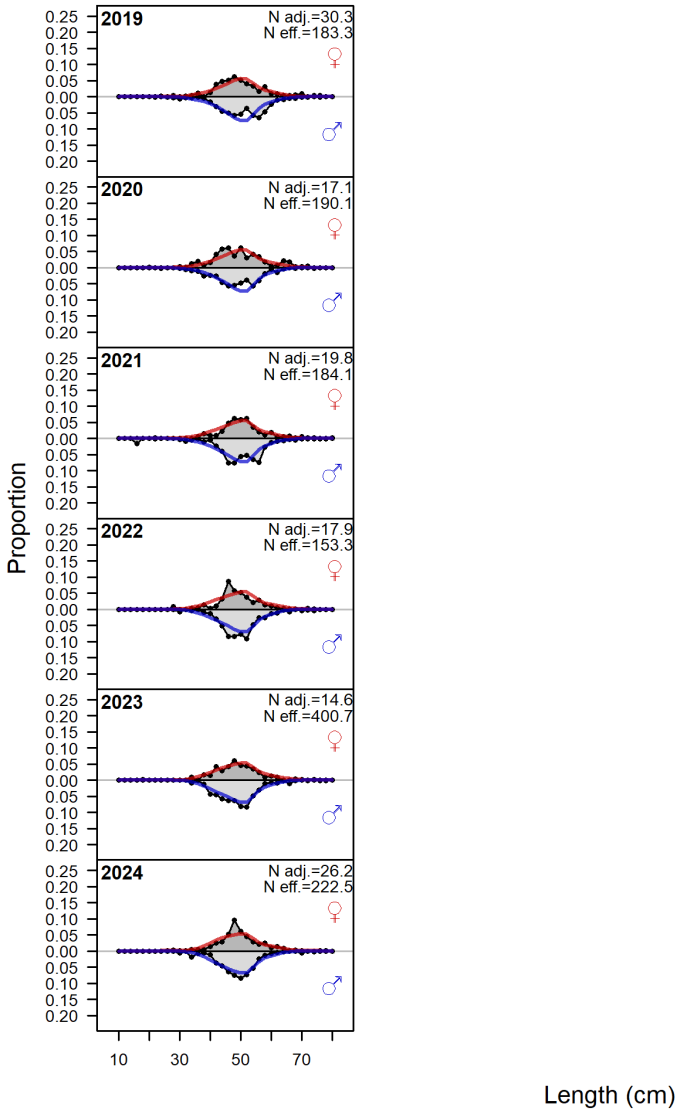


Figure 77: Observed (gray density plot) and expected (density lines by sex) length compositions by year for the bottom trawl fishery in years available between 2019-2024.'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

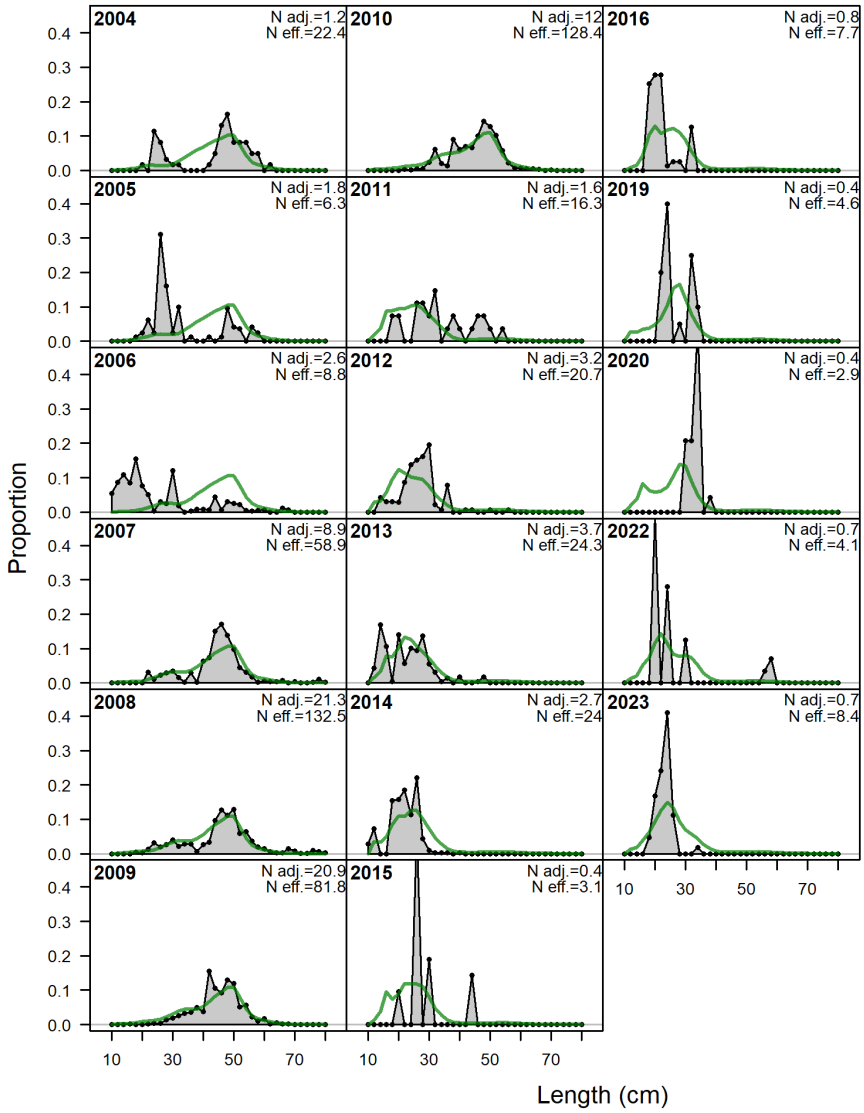


Figure 78: Observed (gray density plot) and expected (density lines) length compositions by year for the bottom trawl discard fishery in years available between 2004-2023.'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

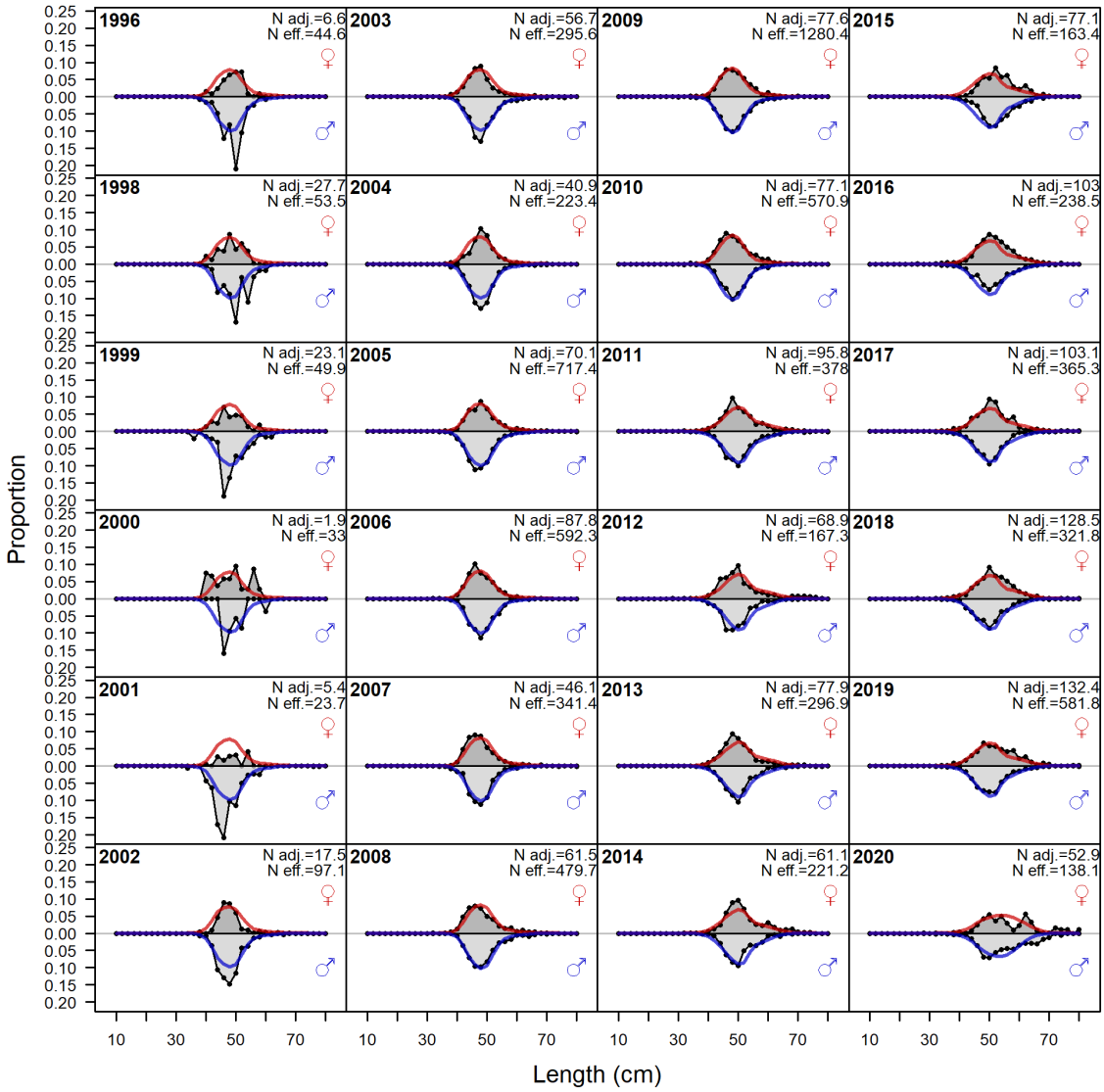


Figure 79: Observed (gray density plot) and expected (density lines by sex) length compositions by year for the non-trawl fishery in years available between 1996-2020.'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

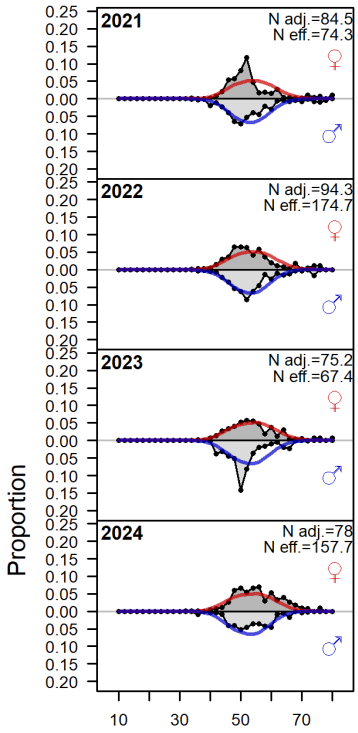


Figure 80: Observed (gray density plot) and expected (density lines by sex) length compositions by year for the non-trawl fishery in years available between 2021-2024.'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

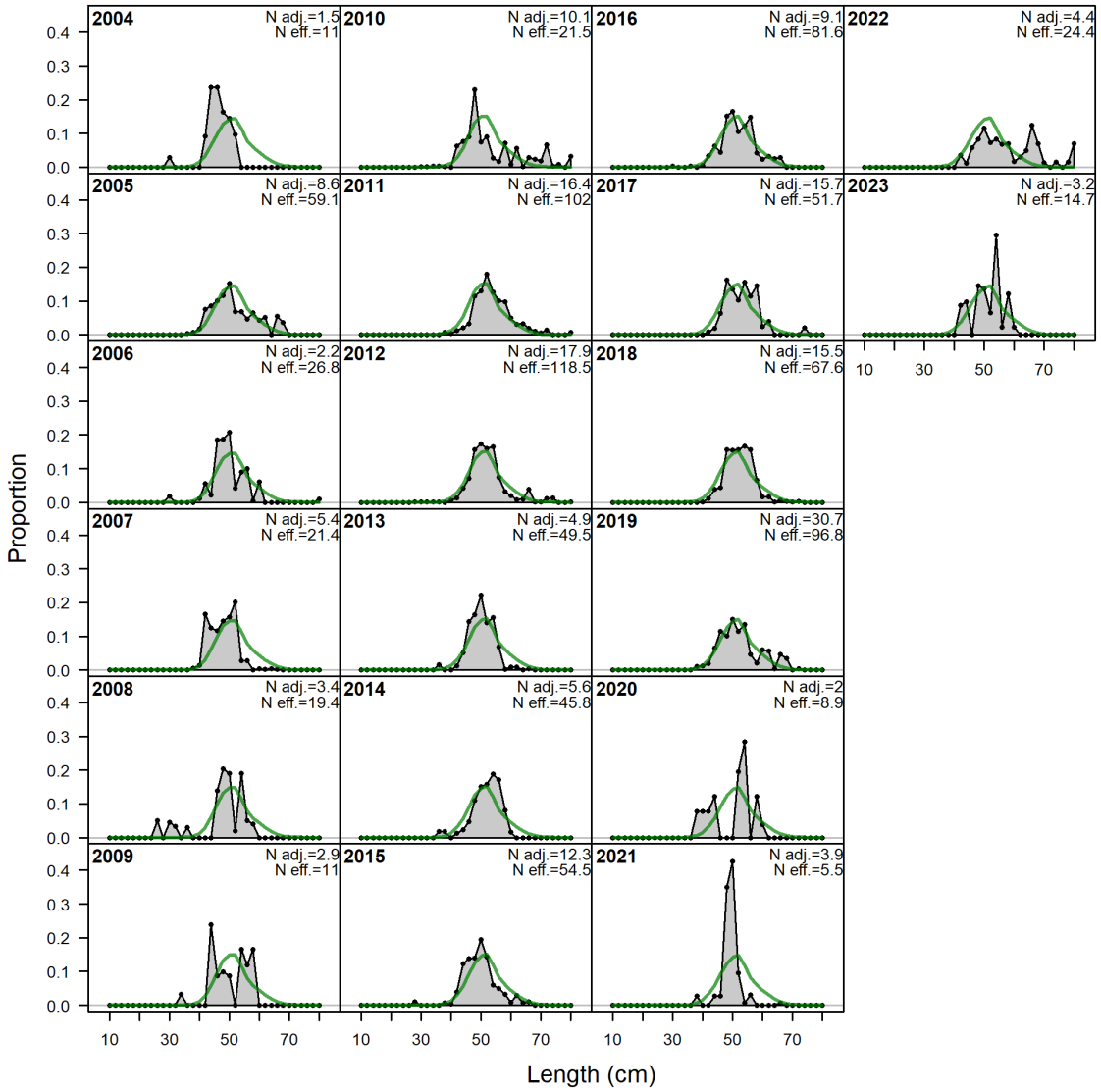


Figure 81: Observed (gray density plot) and expected (density lines) length compositions by year for the midwater trawl fishery in years available between 2004-2024.'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

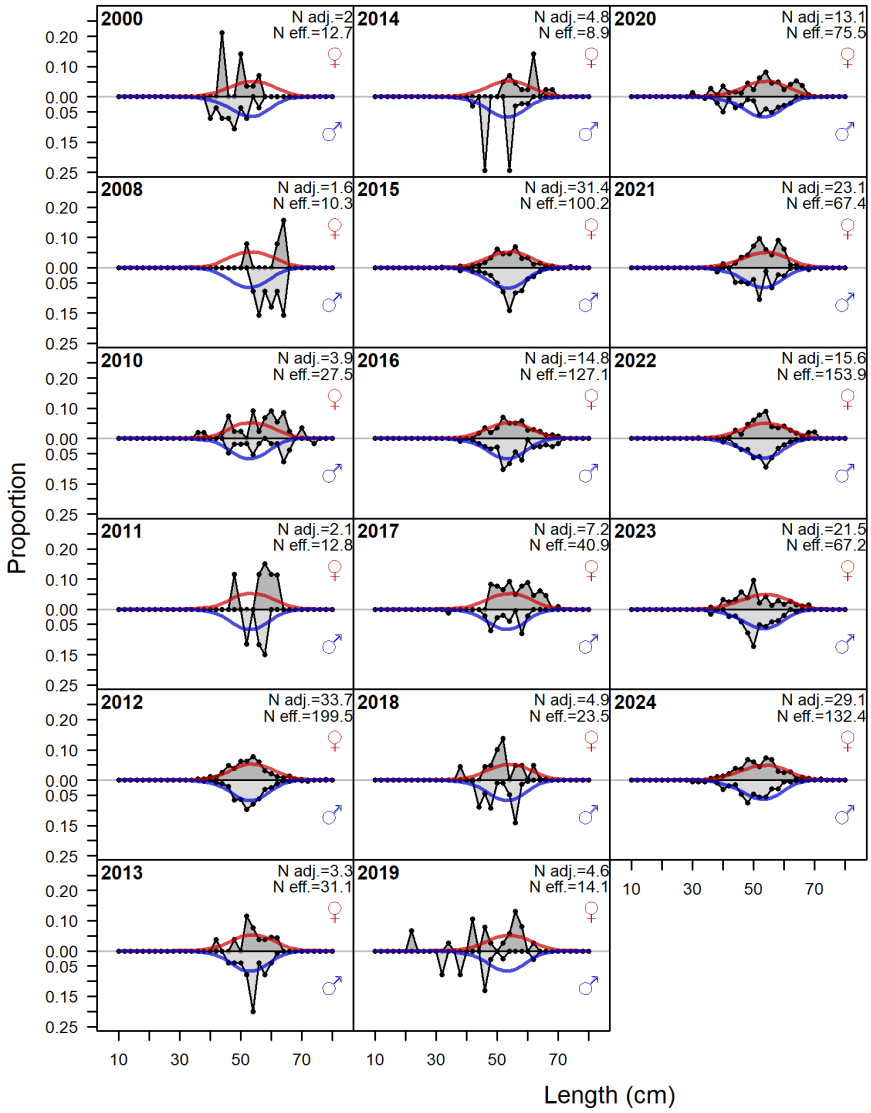


Figure 82: Observed (gray density plot) and expected (density lines by sex) length compositions by year for the non-trawl discard fishery in years available between 2000-2023.'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

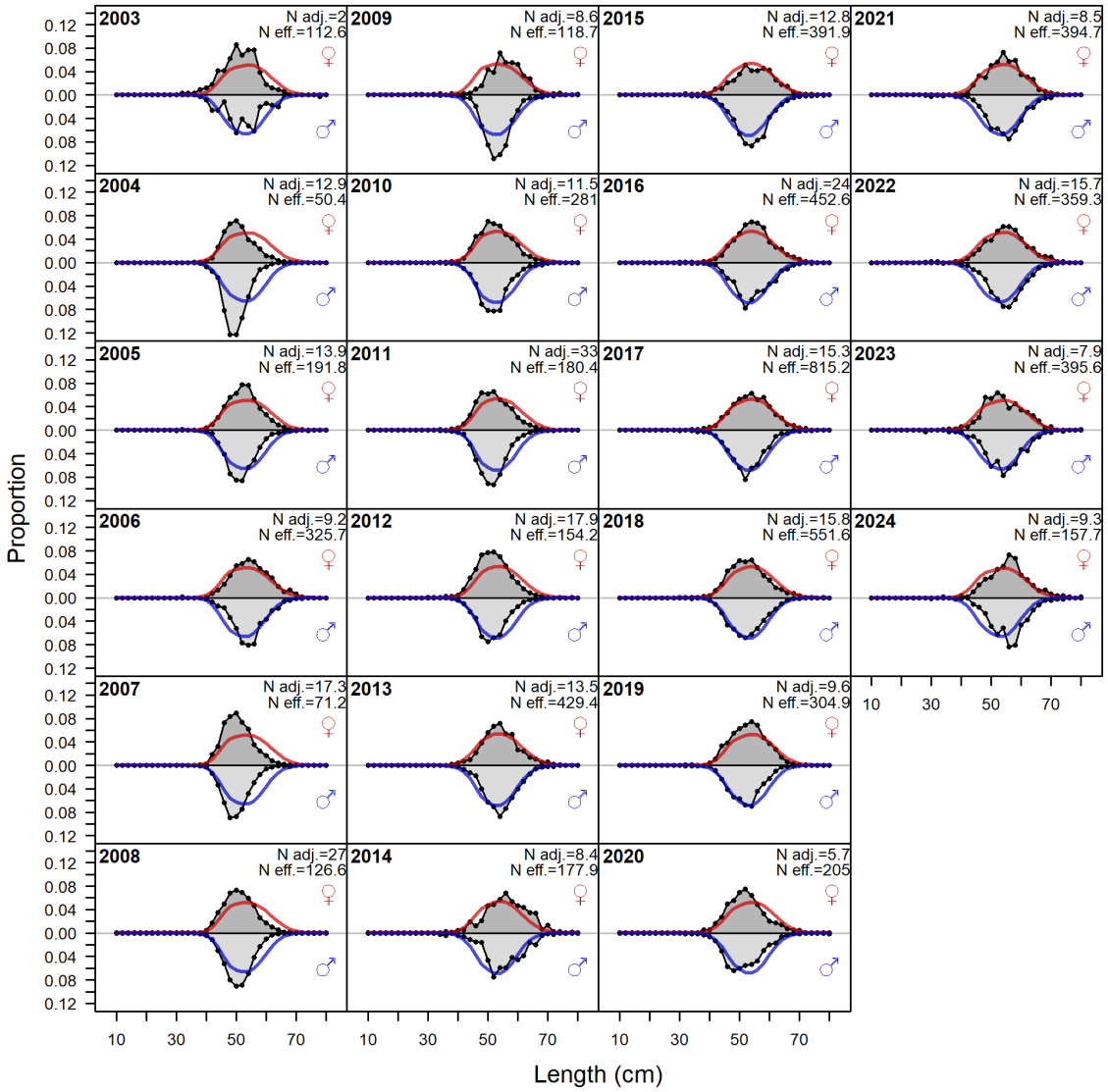


Figure 83: Observed (gray density plot) and expected (density lines by sex) length compositions by year for the at-sea-hake fishery in years available between 2003-2024.'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

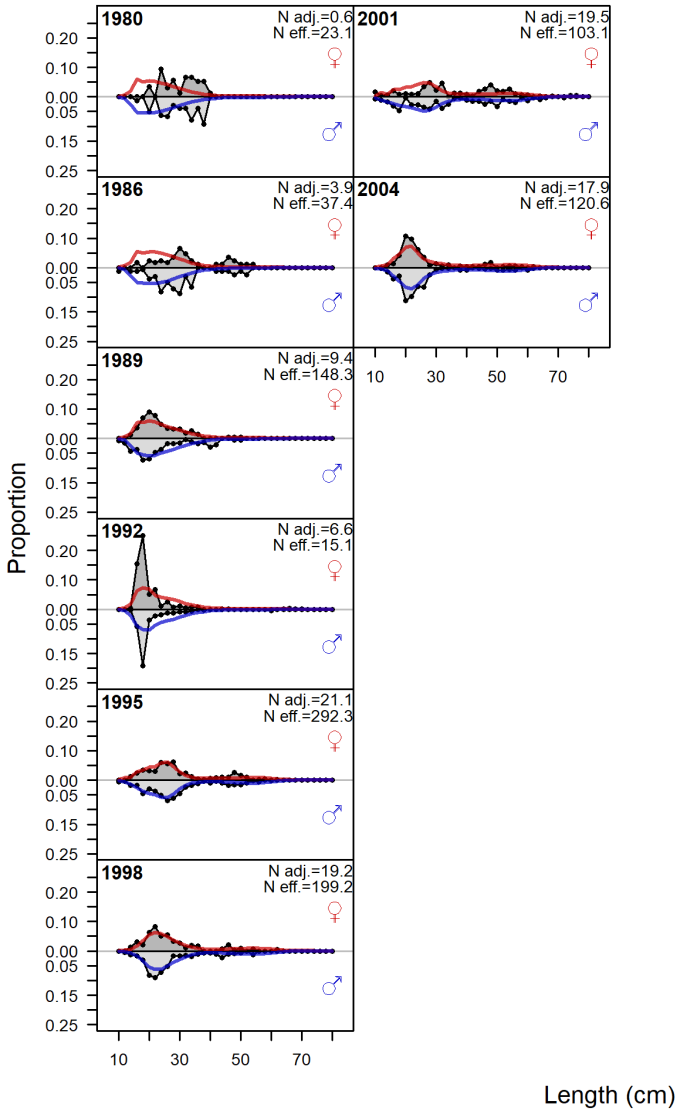


Figure 84: Observed (gray density plot) and expected (density lines by sex) length compositions by year for the Triennial Bottom Trawl Survey in years available between 1980-2004.'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

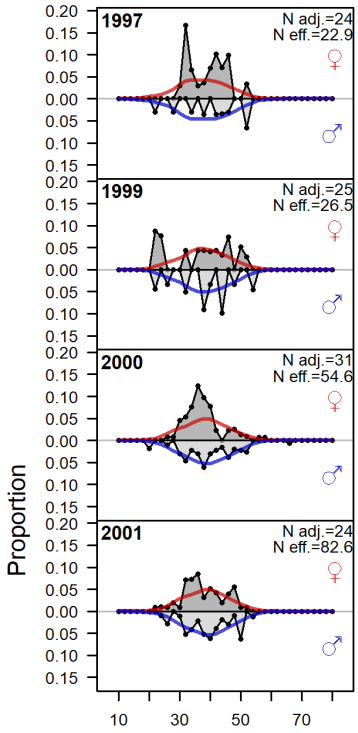


Figure 85: Observed (gray density plot) and expected (density lines by sex) length compositions by year for the Alaskan Slope Bottom Trawl Survey in years available between 1997-2001.'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

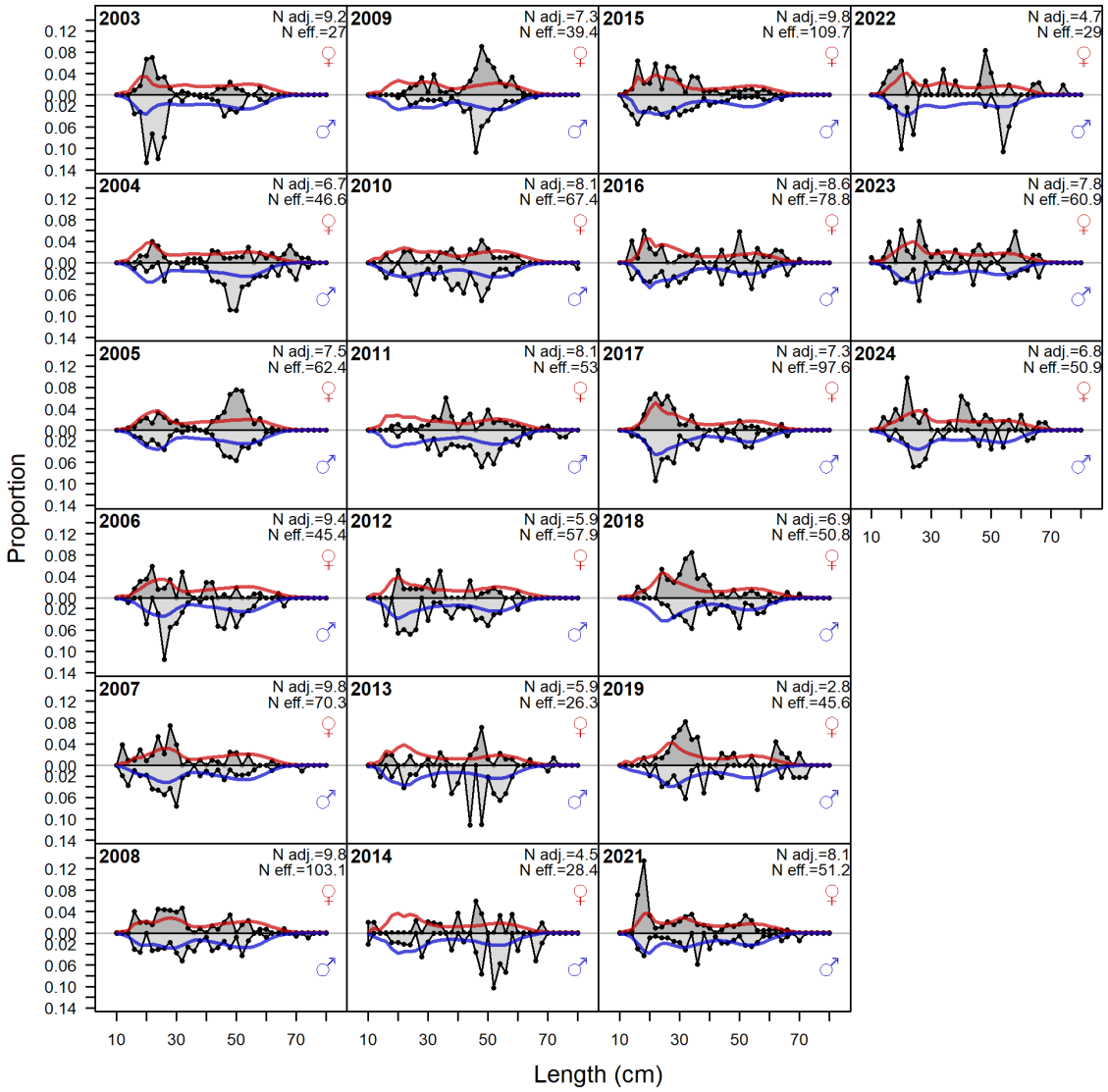


Figure 86: Observed (gray density plot) and expected (density lines by sex) length compositions by year for the West Coast Groundfish Bottom Trawl Survey in years available between 1980-2004.'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

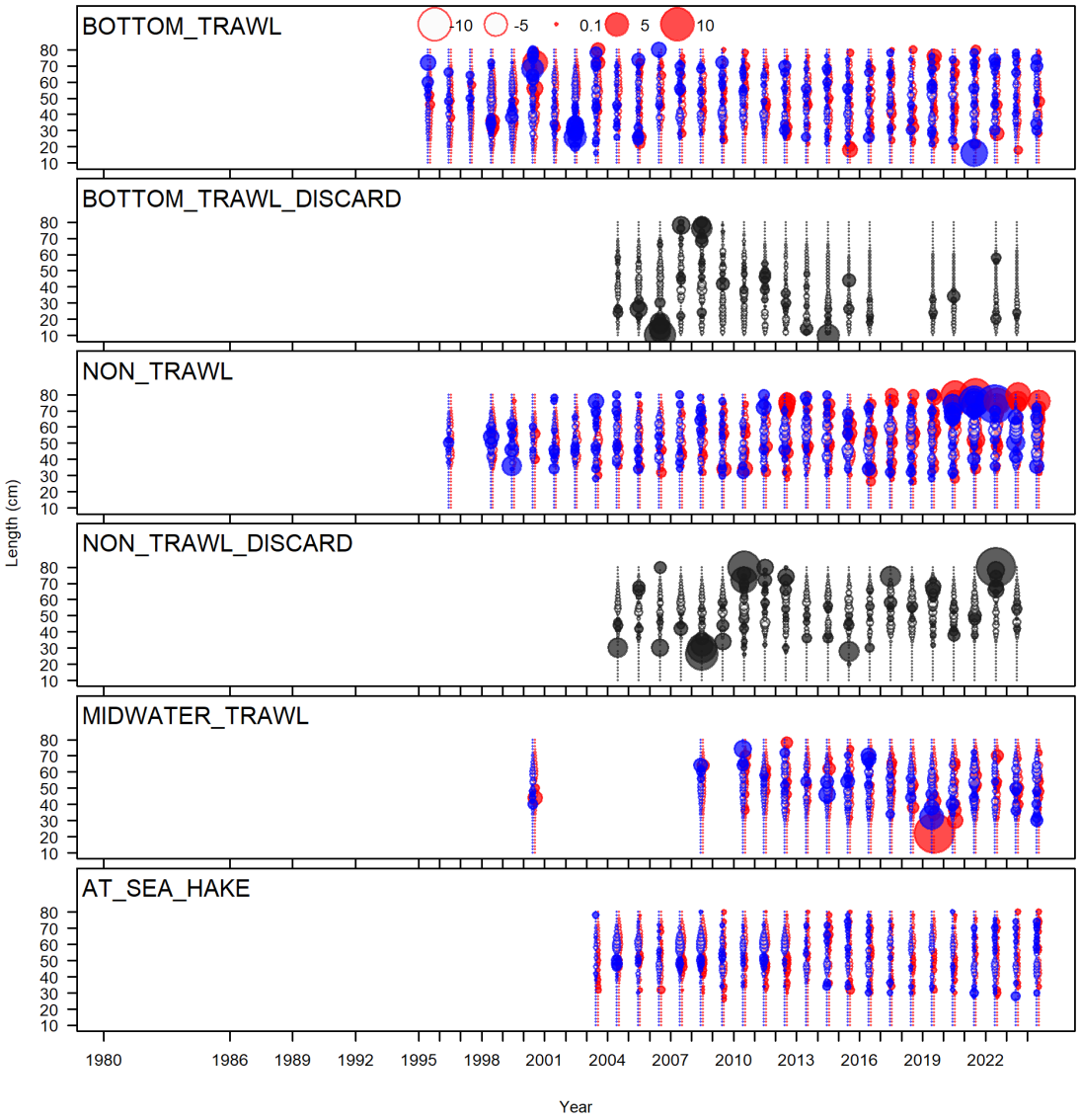


Figure 87: Pearson residuals of length fits for each fishing fleet. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

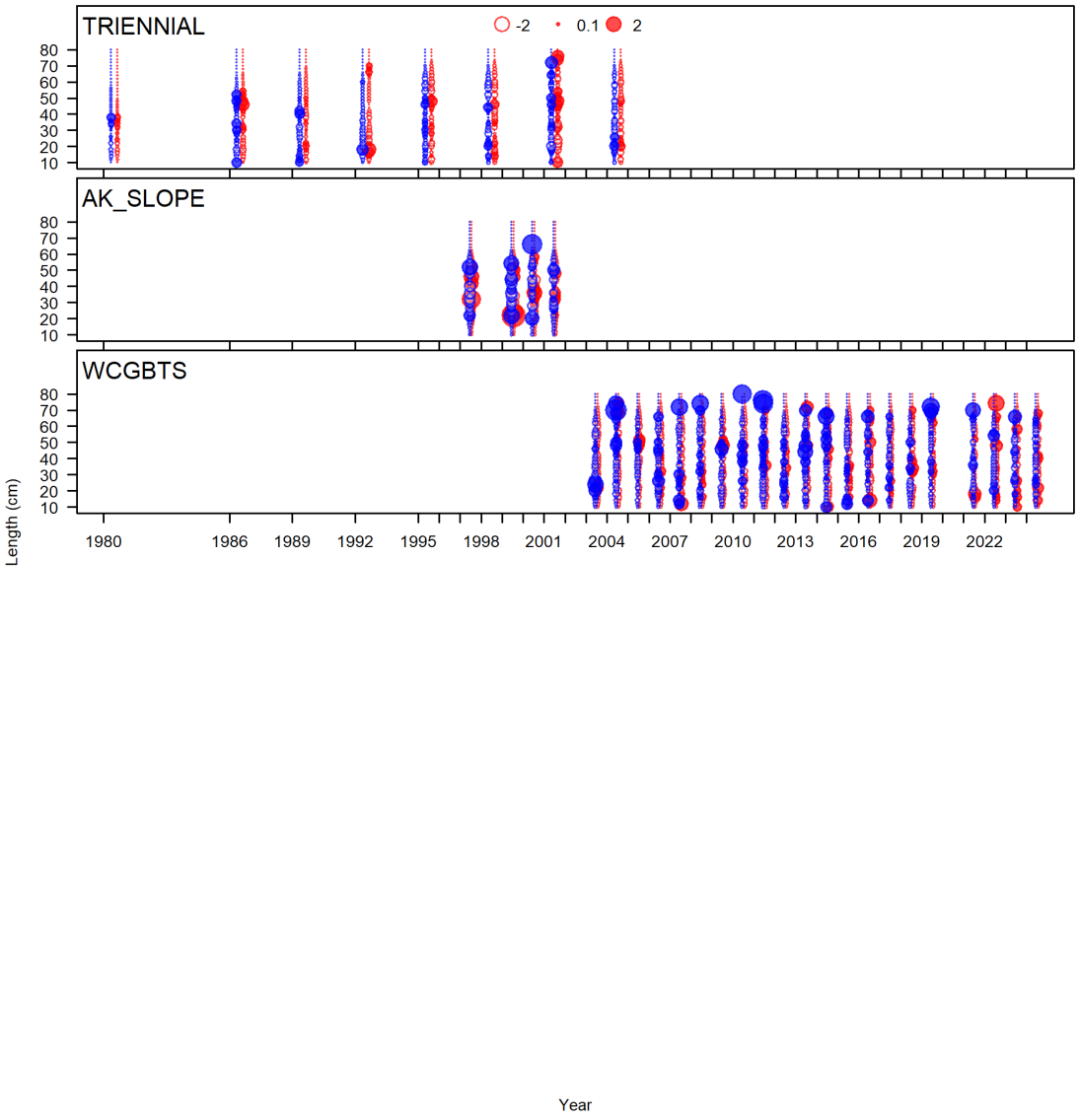


Figure 88: Pearson residuals of length fits for each survey. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

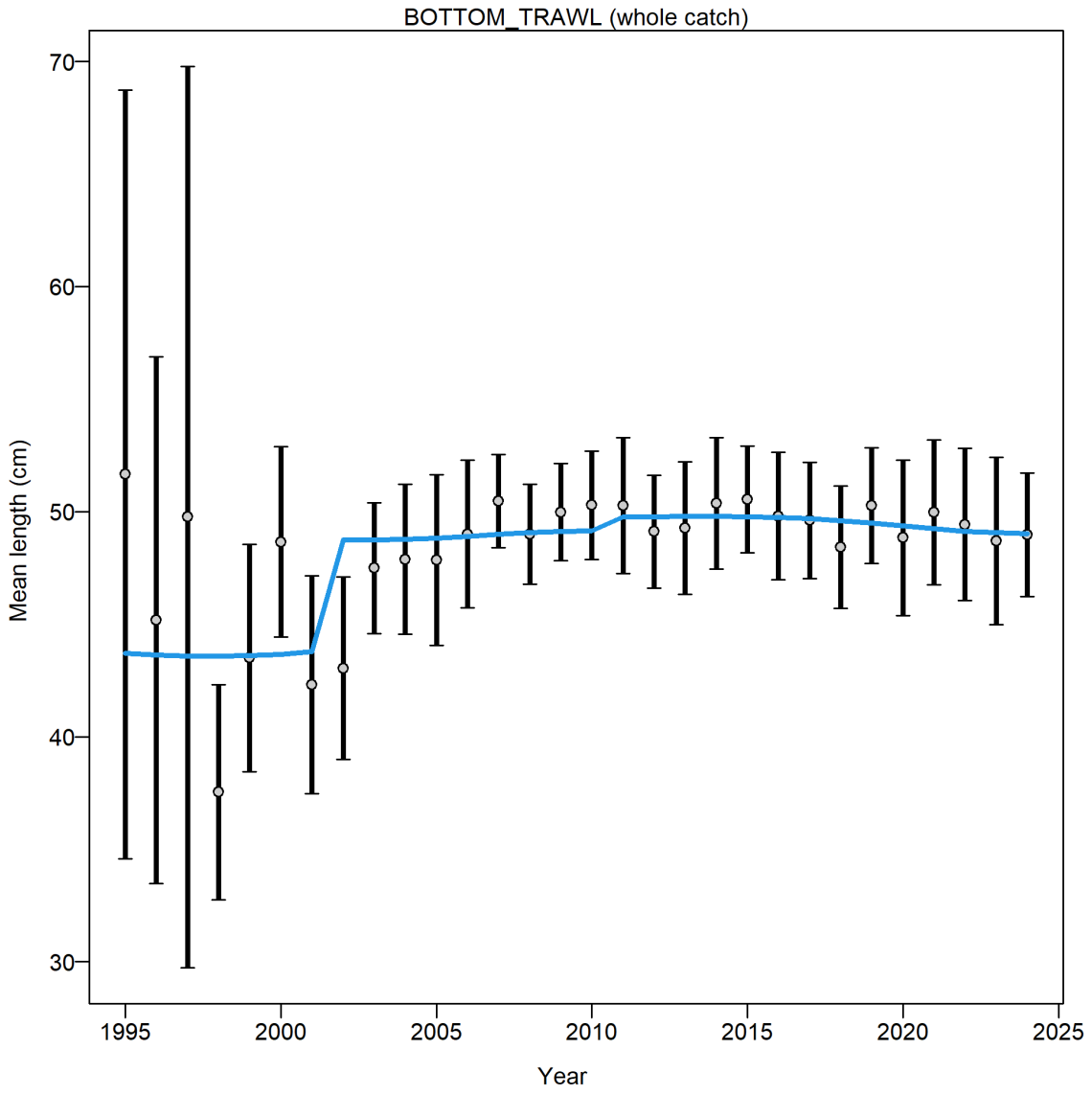


Figure 89: Mean length (cm) index from the bottom trawl fishery with 95 percent confidence intervals based on sample sizes and data weighting.

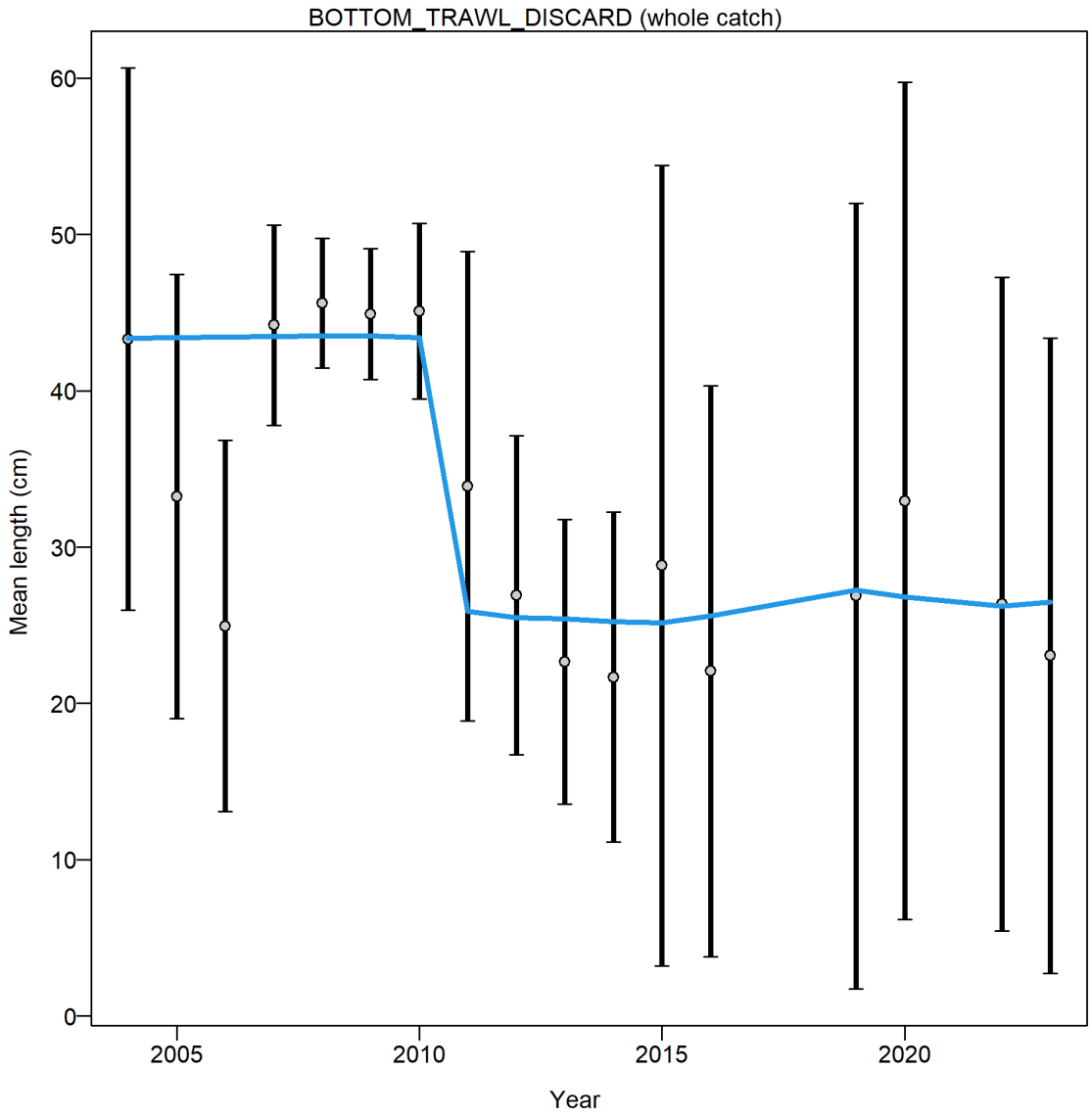


Figure 90: Mean length (cm) index from the bottom trawl discard fishery with 95 percent confidence intervals based on sample sizes and data weighting.

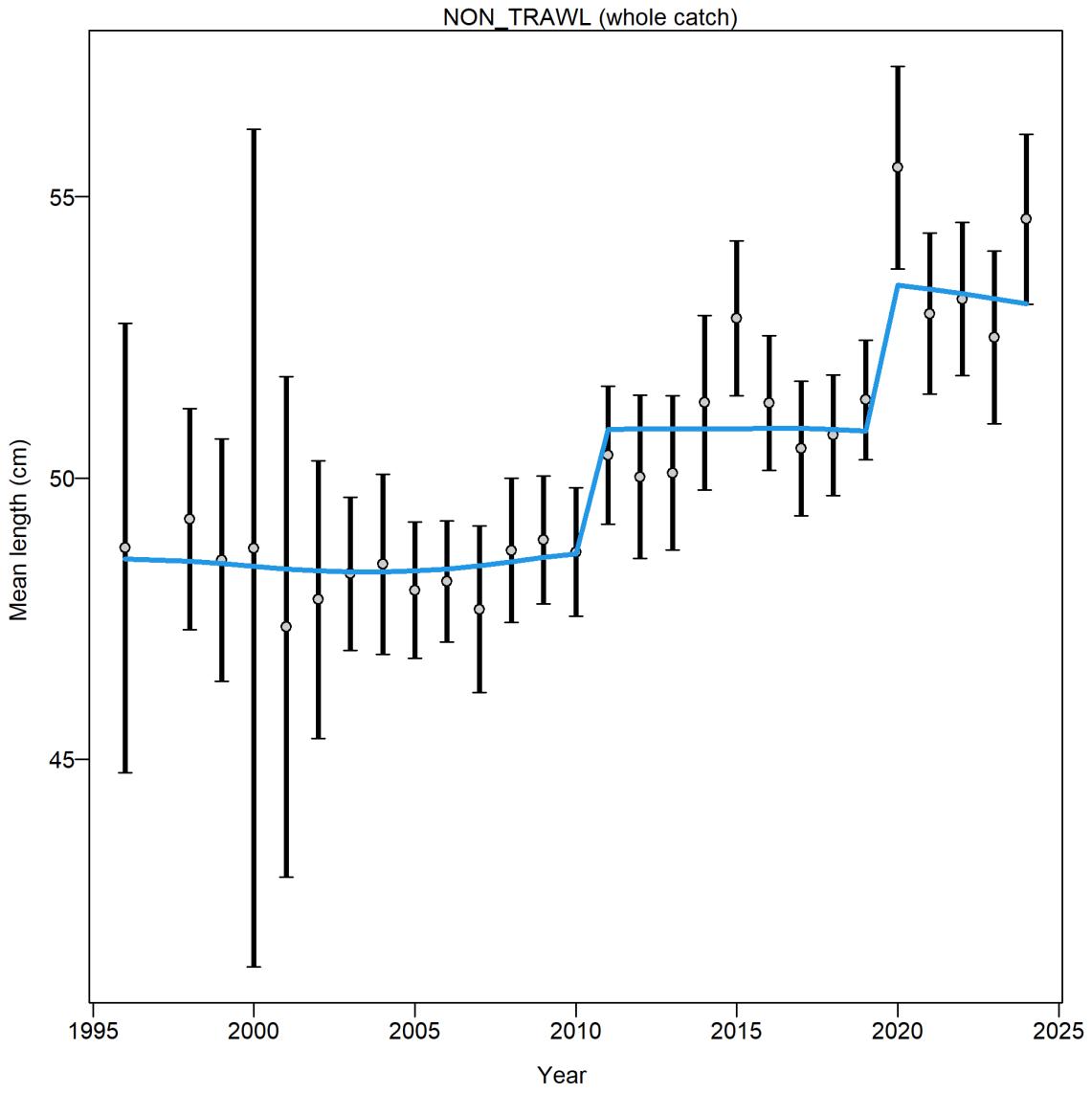


Figure 91: Mean length (cm) index from the non-trawl fishery with 95 percent confidence intervals based on sample sizes and data weighting.

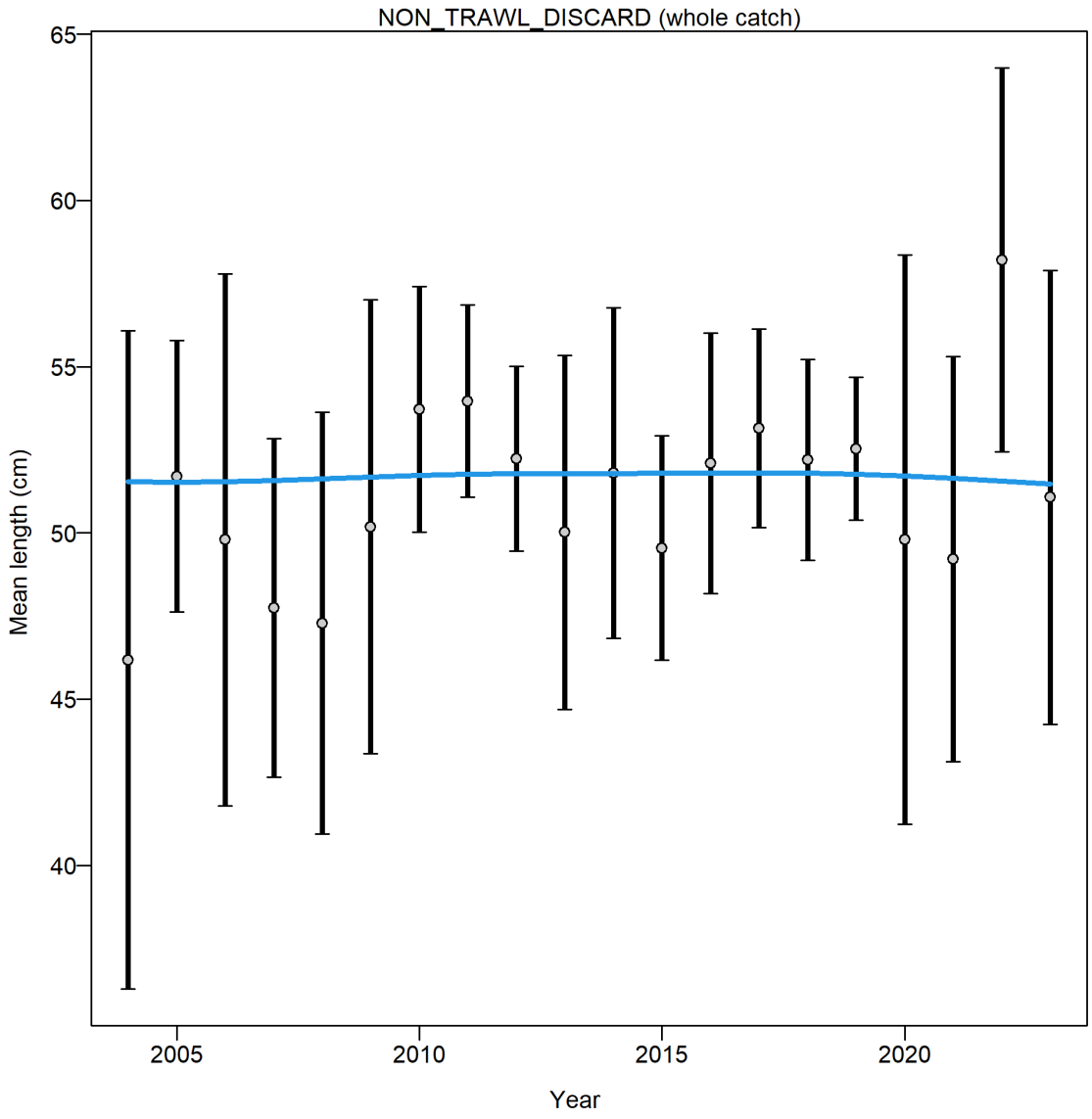


Figure 92: Mean length (cm) index from the non-trawl discard fishery with 95 percent confidence intervals based on sample sizes and data weighting.

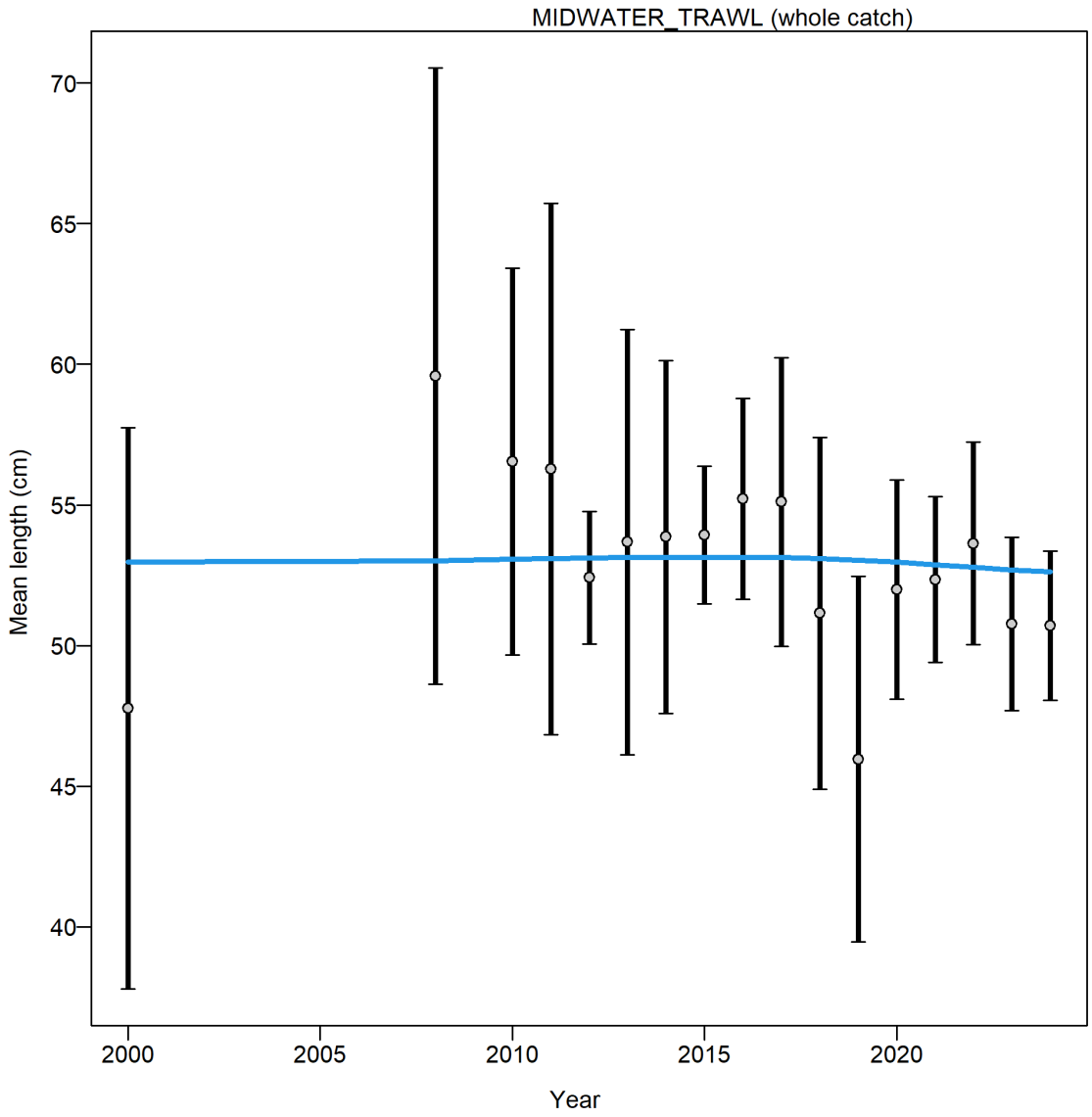


Figure 93: Mean length (cm) index from the midwater trawl fishery with 95 percent confidence intervals based on sample sizes and data weighting.

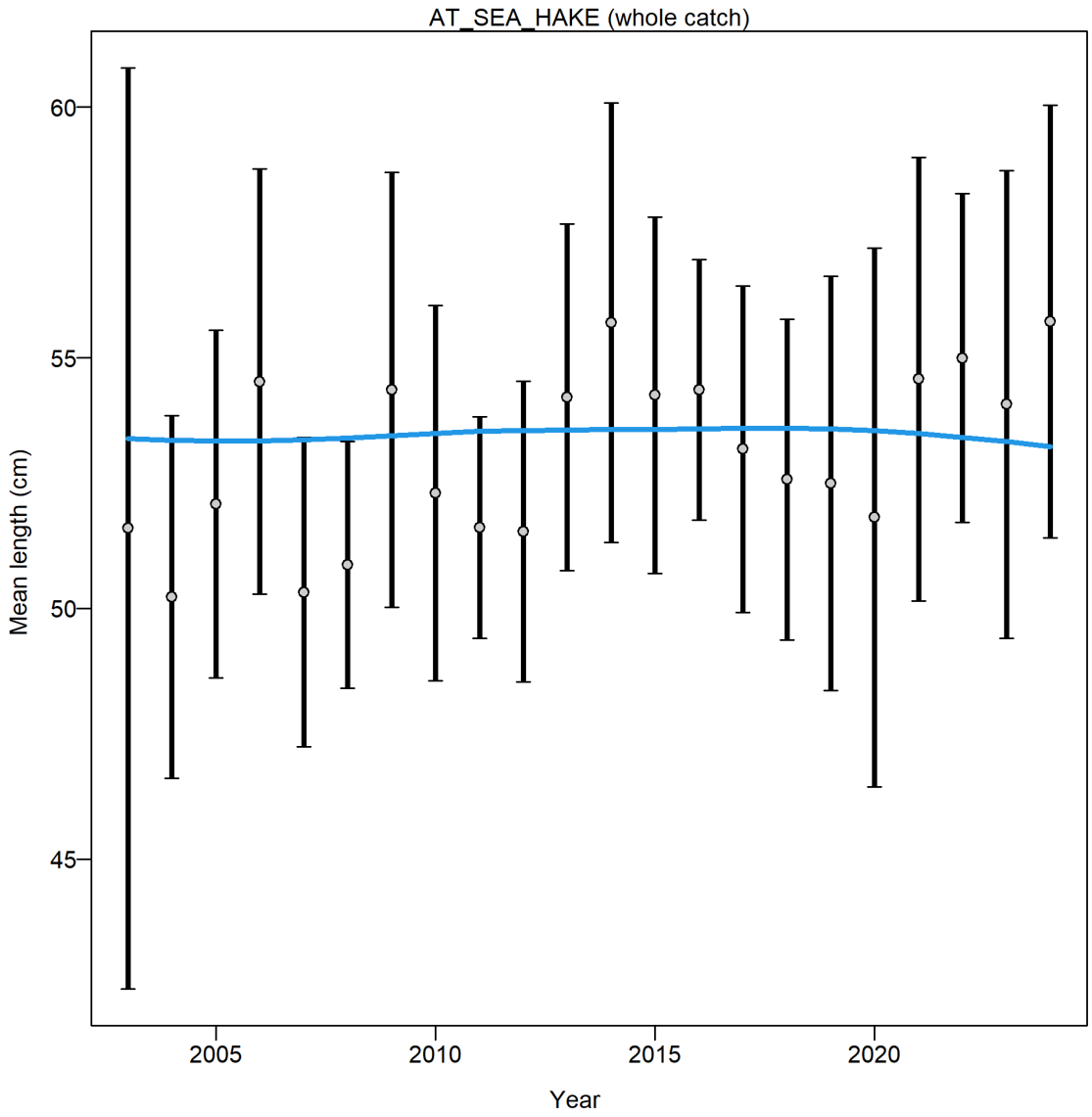


Figure 94: Mean length (cm) index from the at-sea-hake fishery with 95 percent confidence intervals based on sample sizes and data weighting.

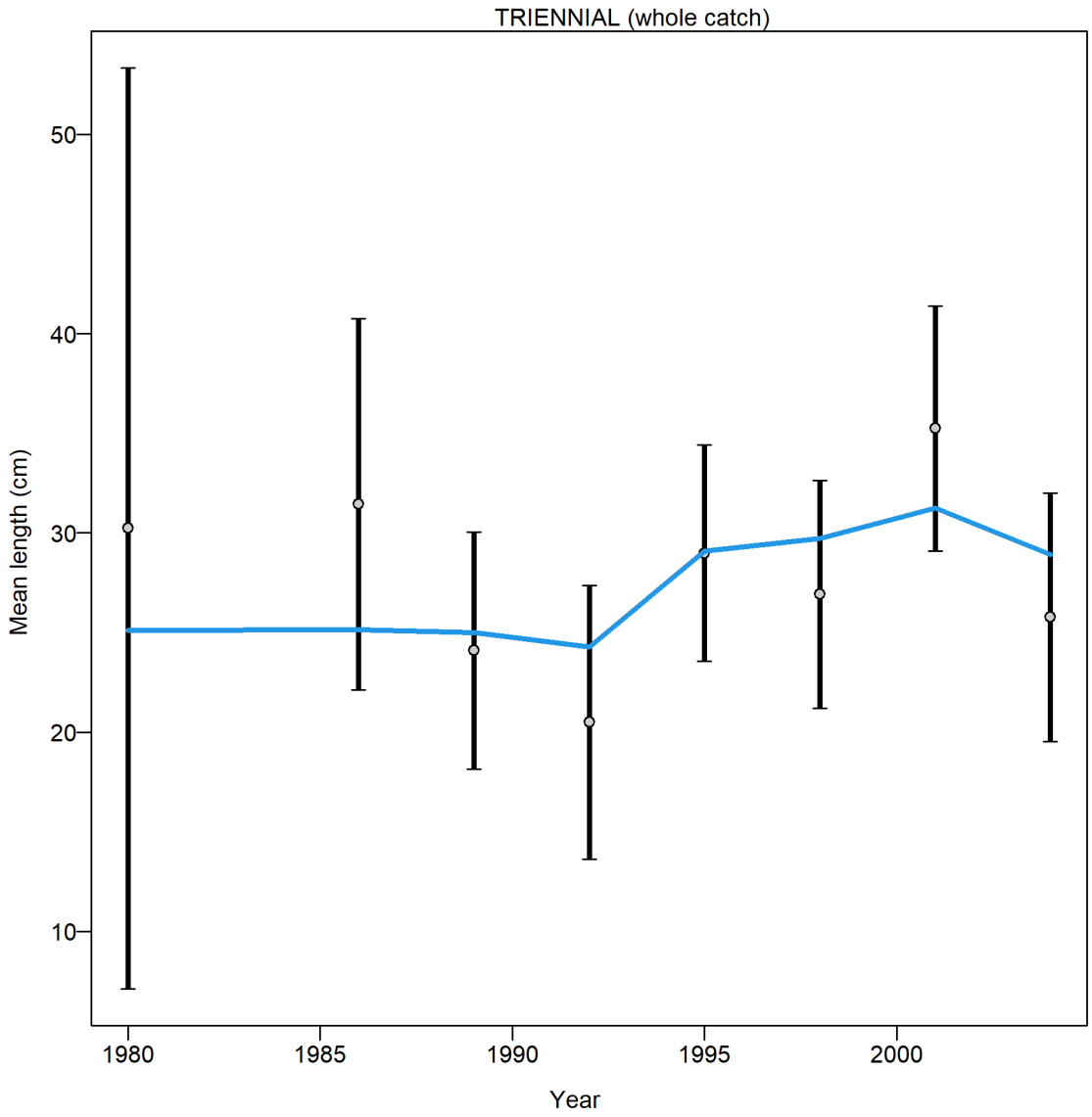


Figure 95: Mean length (cm) index from the Triennial survey with 95 percent confidence intervals based on sample sizes and data weighting.

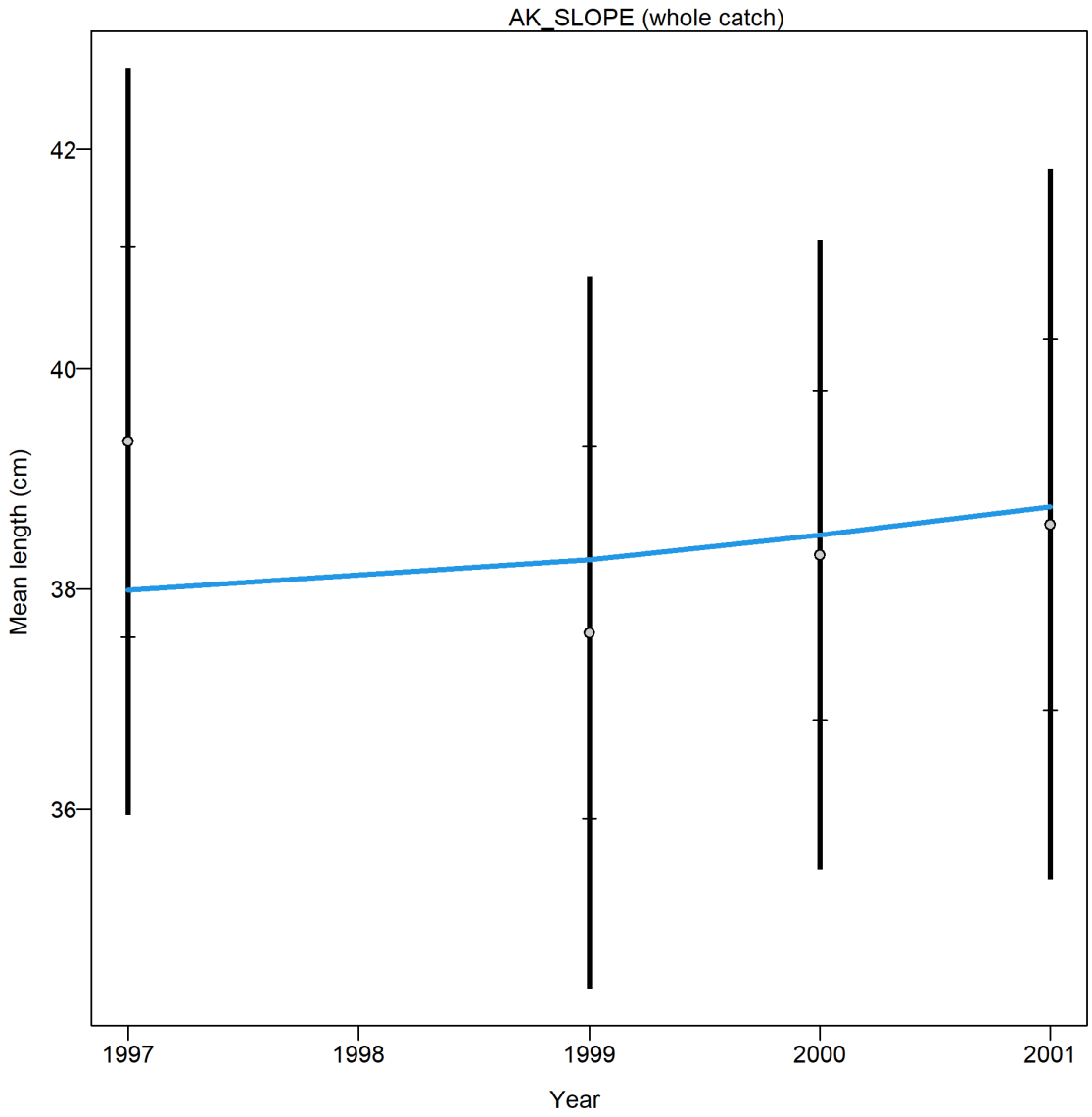


Figure 96: Mean length (cm) index from the Alaskan slope survey with 95 percent confidence intervals based on sample sizes and data weighting.

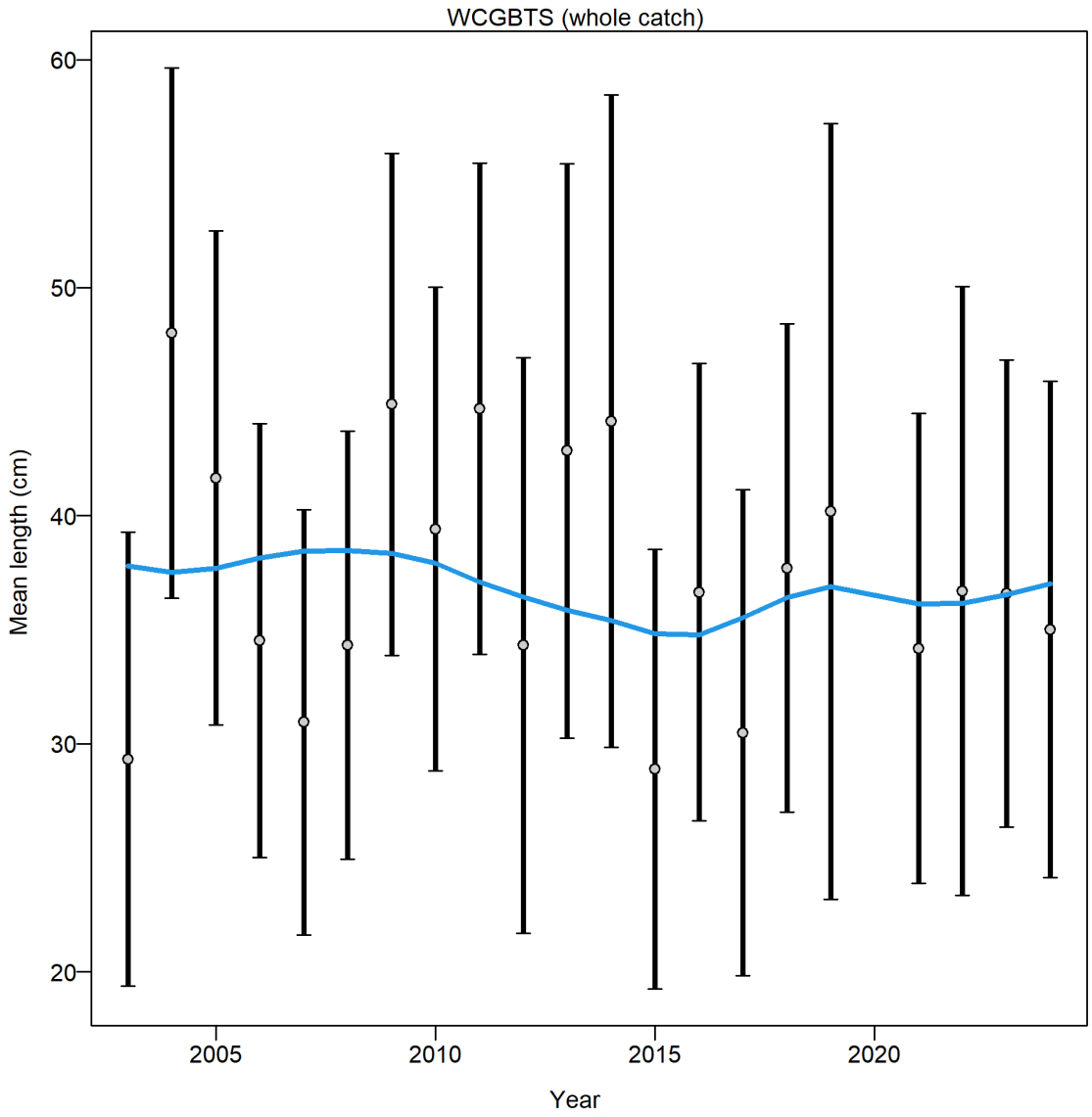


Figure 97: Mean length (cm) index from the West Coast Groundfish Bottom Trawl survey with 95 percent confidence intervals based on sample sizes and data weighting.

8.7.2 Ages

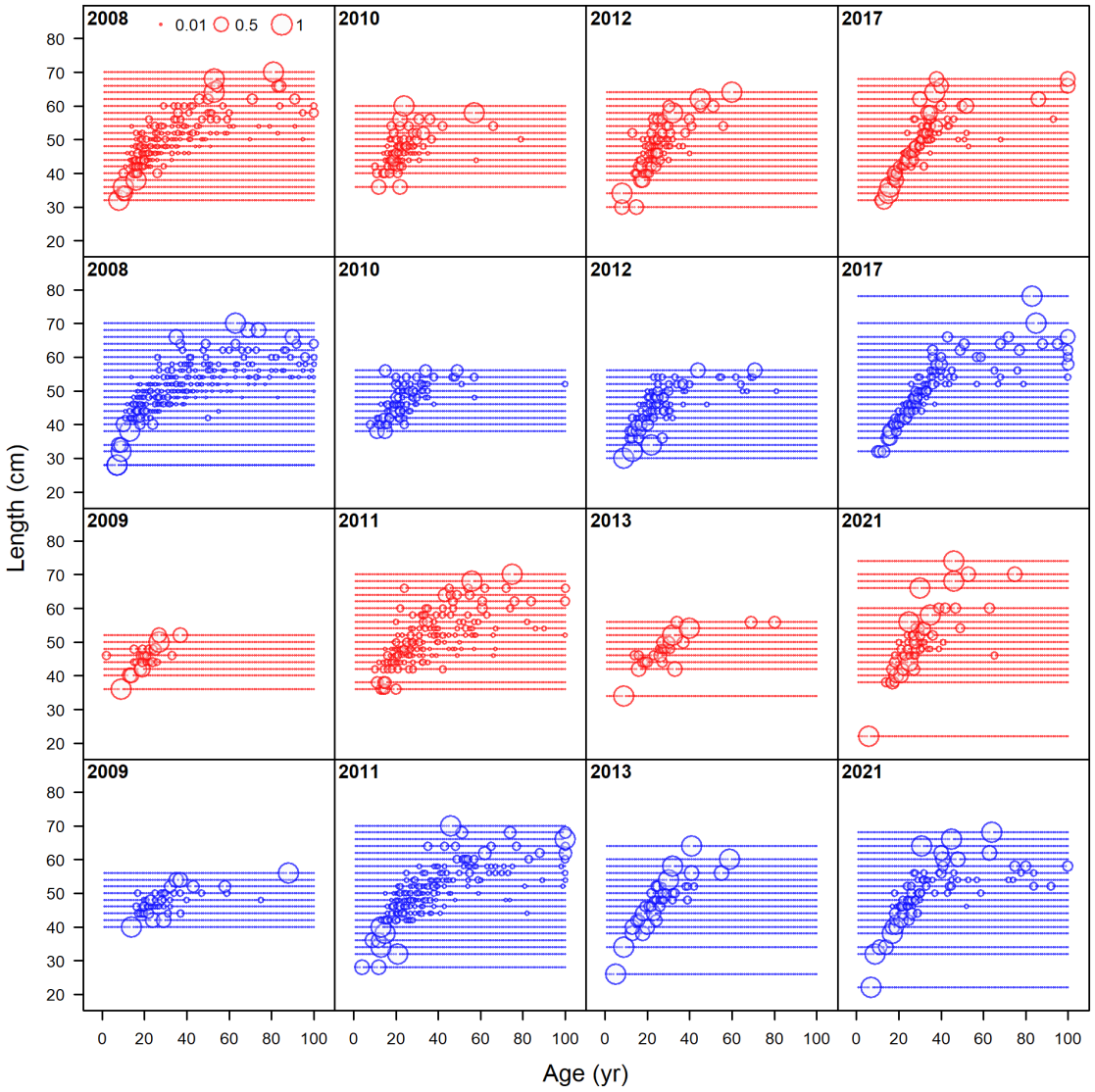


Figure 98: Pearson residuals of conditional age at length fits for the bottom trawl fishery in the years 2008-2021. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

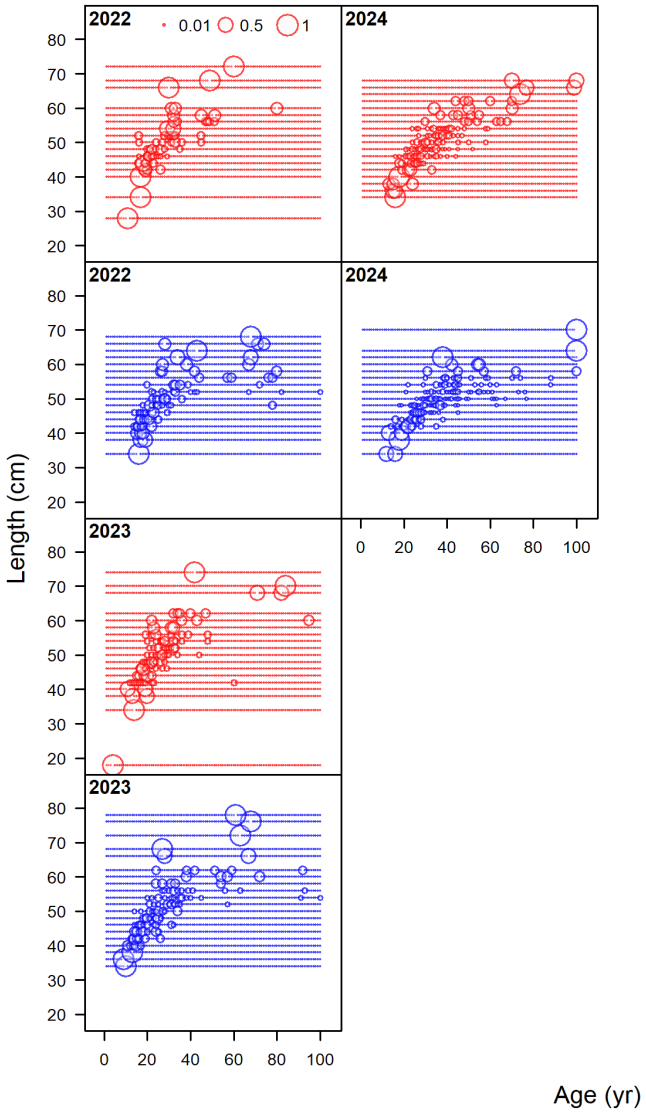


Figure 99: Pearson residuals of conditional age at length fits for the bottom trawl fishery in the years 2022-2024. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

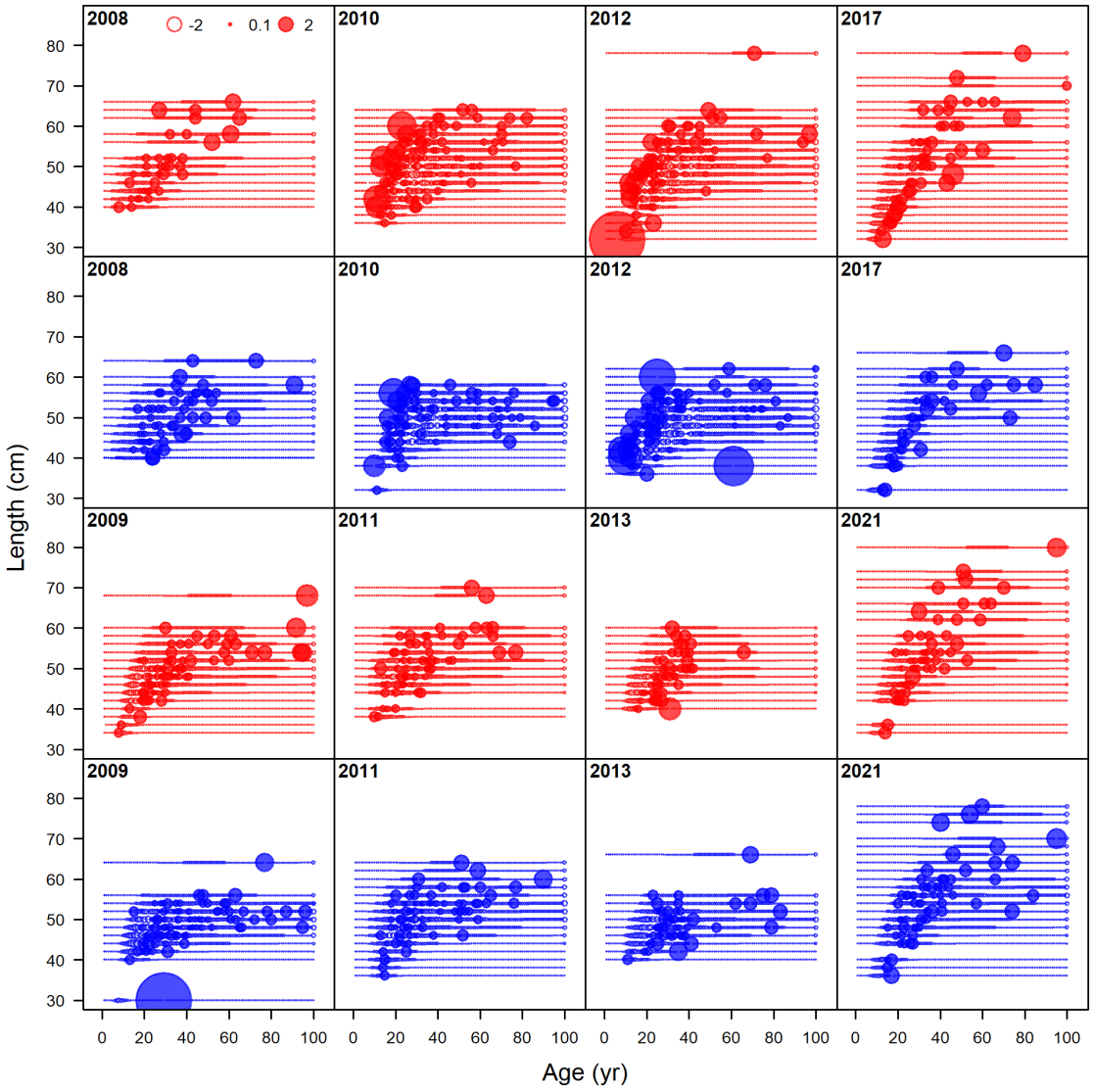


Figure 100: Pearson residuals of conditional age at length fits for the non-trawl fishery in the years 2008-2021. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

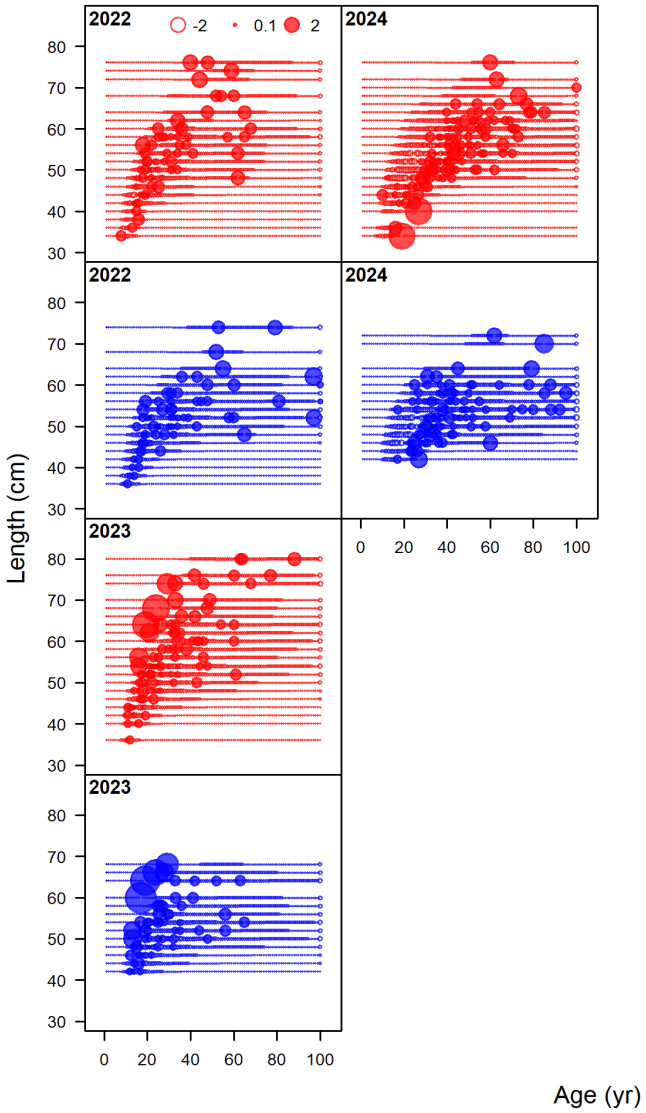


Figure 101: Pearson residuals of conditional age at length fits for the non-trawl fishery in the years 2022-2024. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

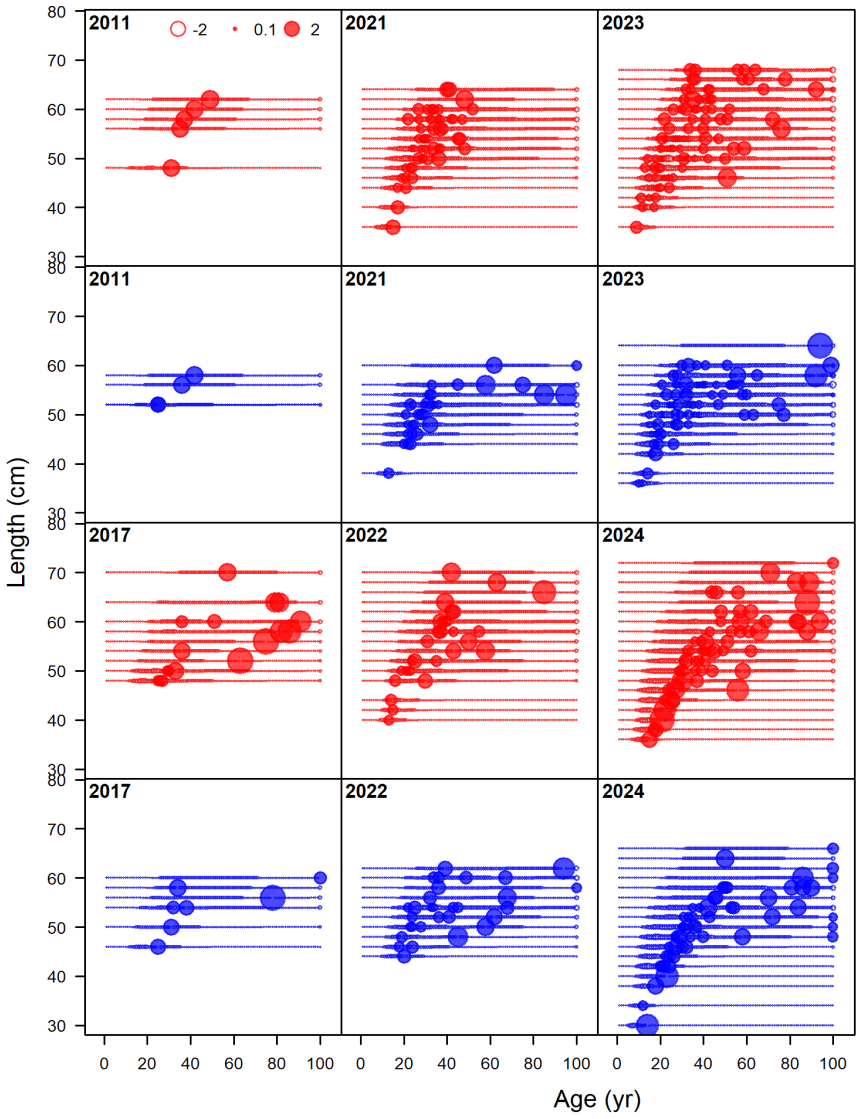


Figure 102: Pearson residuals of conditional age at length fits for the midwater trawl fishery. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

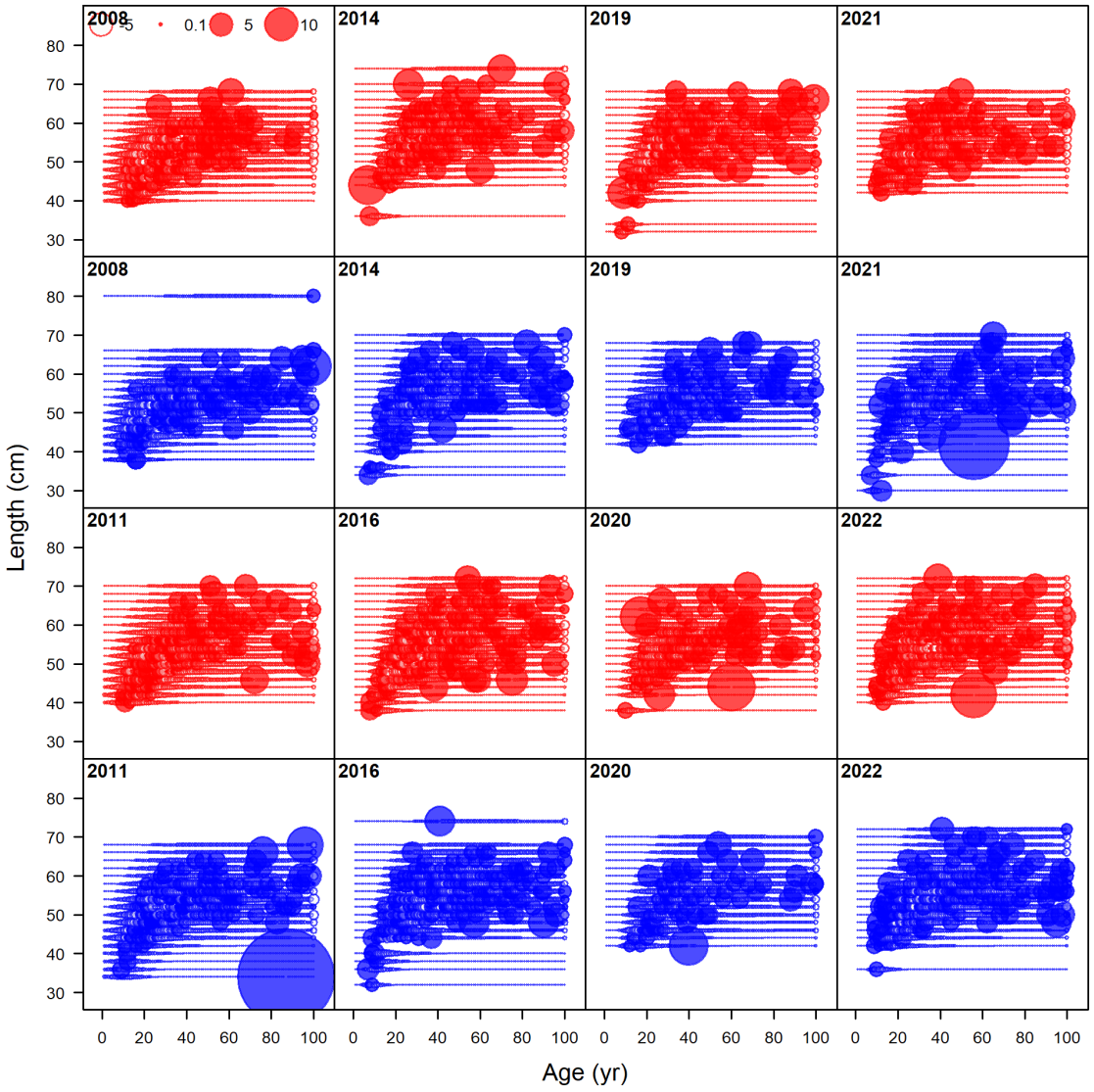


Figure 103: Pearson residuals of conditional age at length fits for the at-sea-hake fishery in the years 2008-2022. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

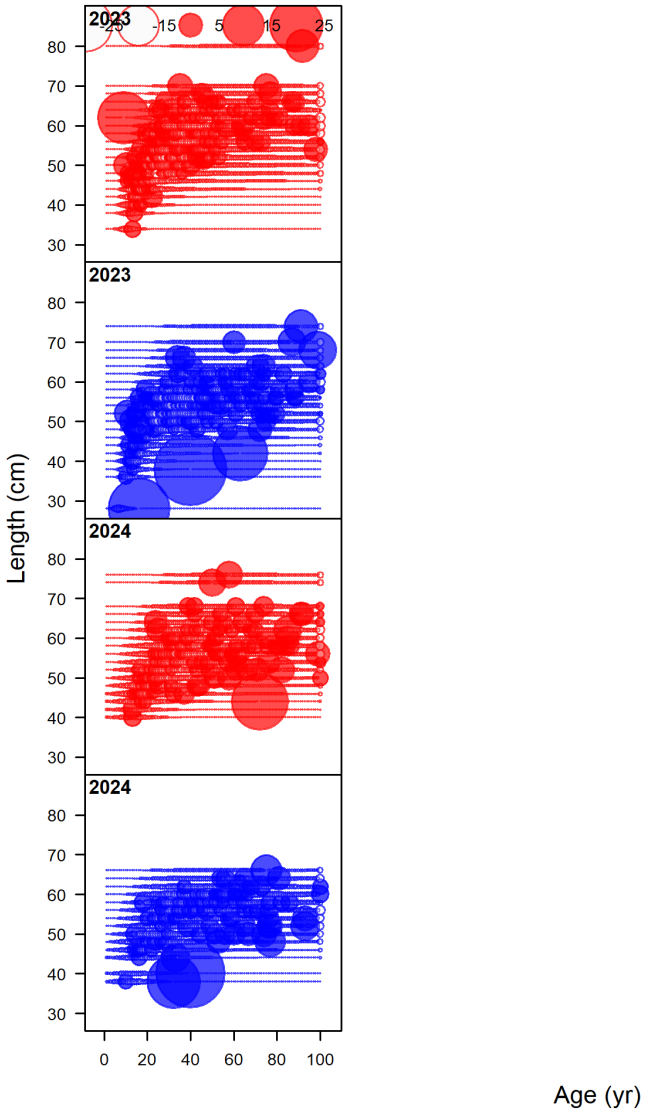


Figure 104: Pearson residuals of conditional age at length fits for the at-sea-hake fishery in the years 2023-2024. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

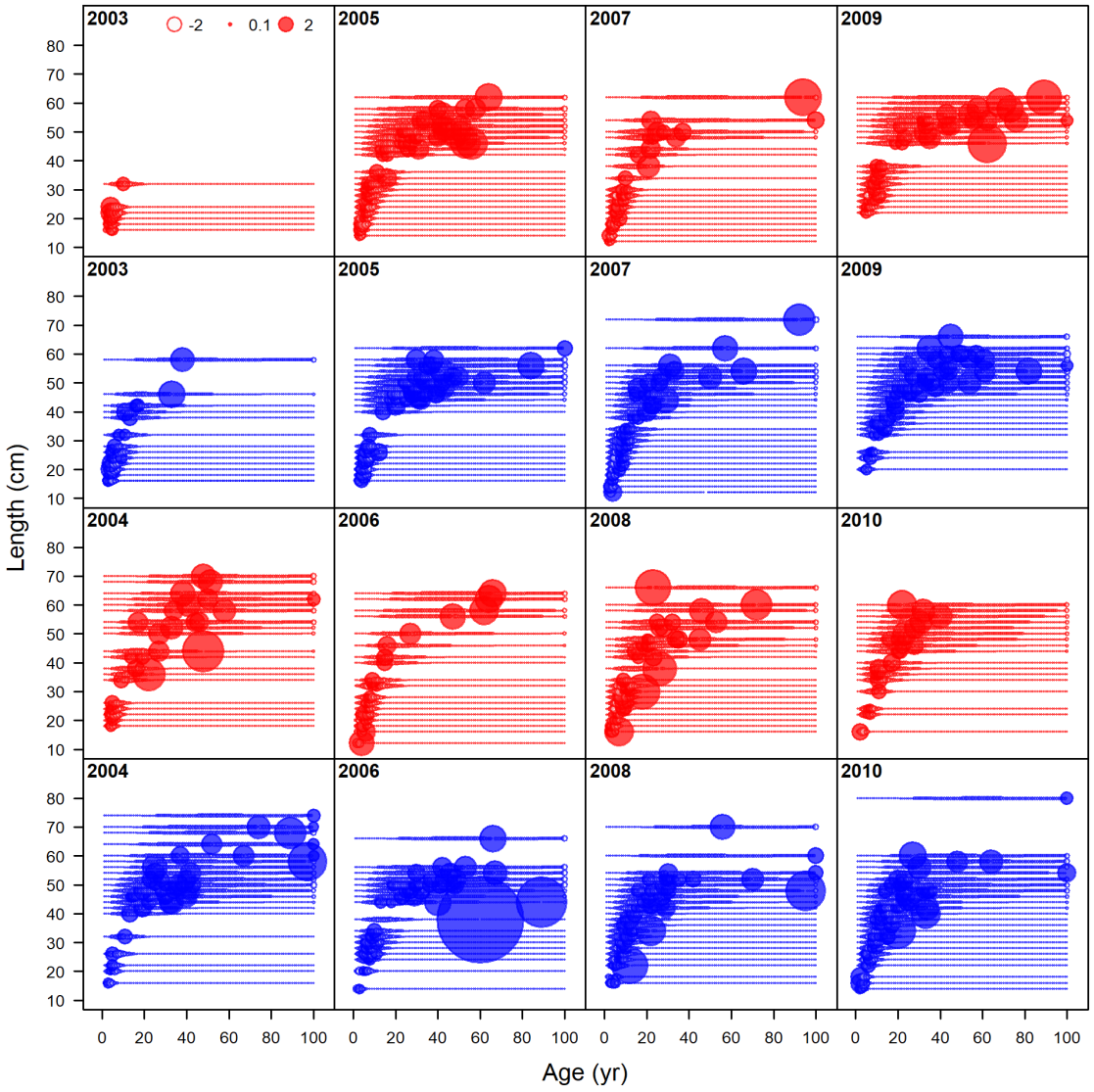


Figure 105: Pearson residuals of conditional age at length fits for the West Coast Groundfish Bottom Trawl survey in the years 2003-2010. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

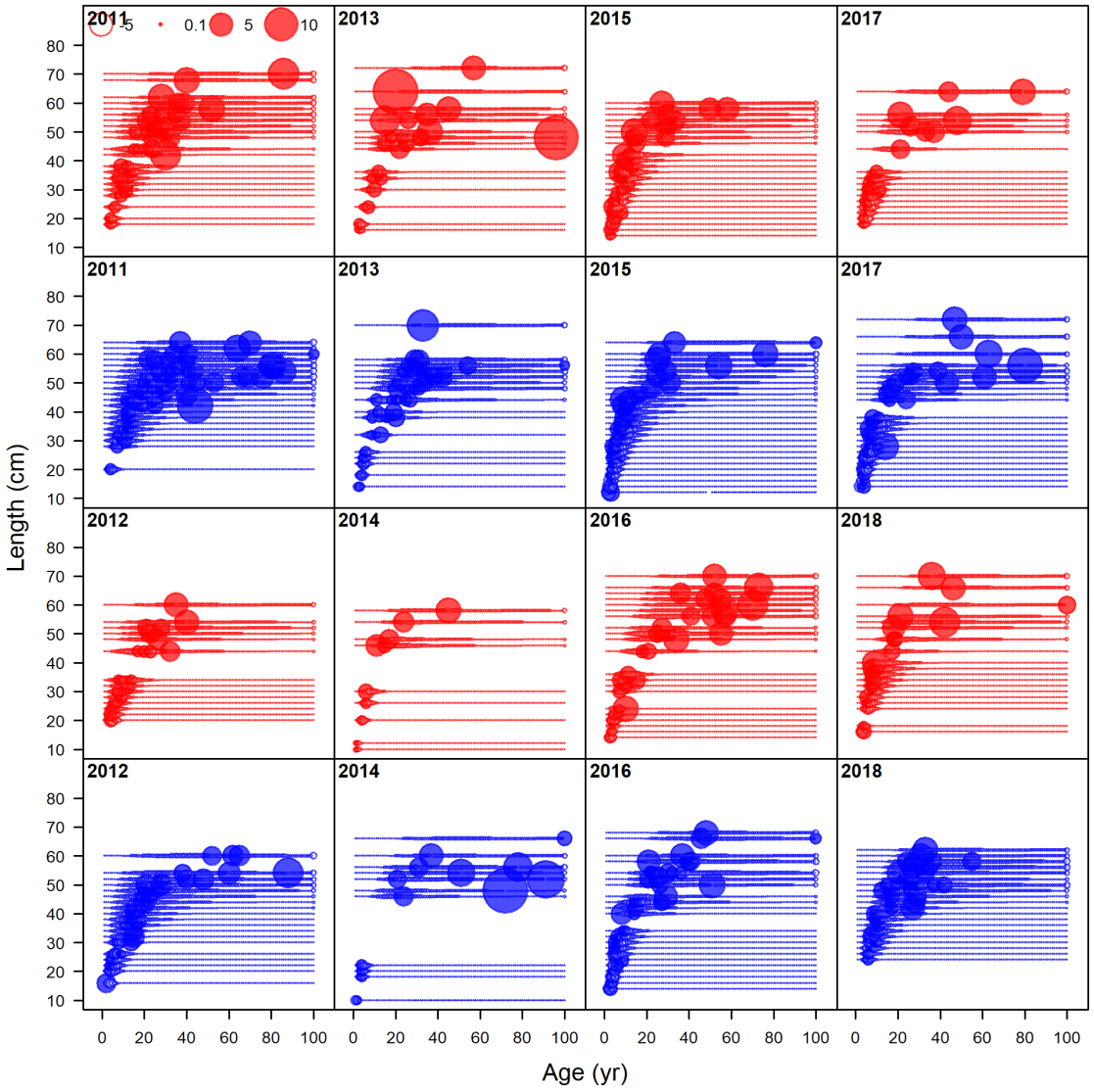


Figure 106: Pearson residuals of conditional age at length fits for the West Coast Groundfish Bottom Trawl survey in the years 2011-2018. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

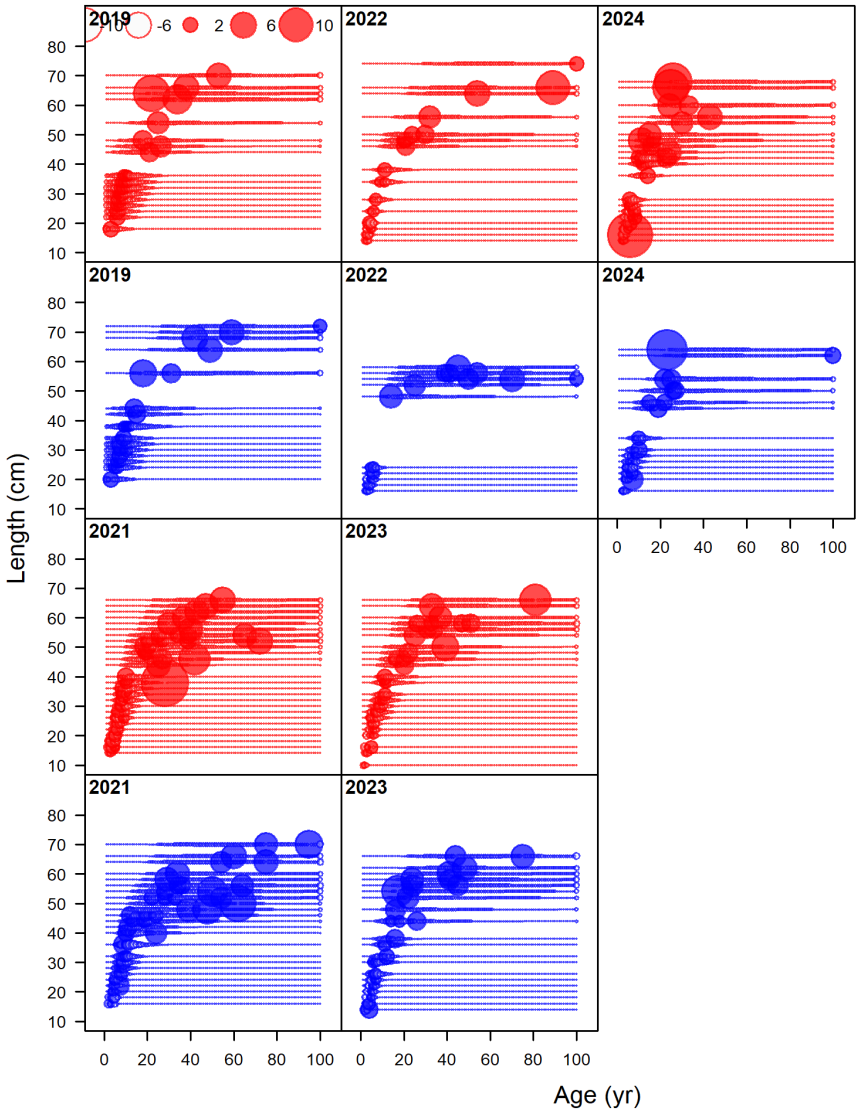


Figure 107: Pearson residuals of conditional age at length fits for the West Coast Groundfish Bottom Trawl survey in the years 2019-2024. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

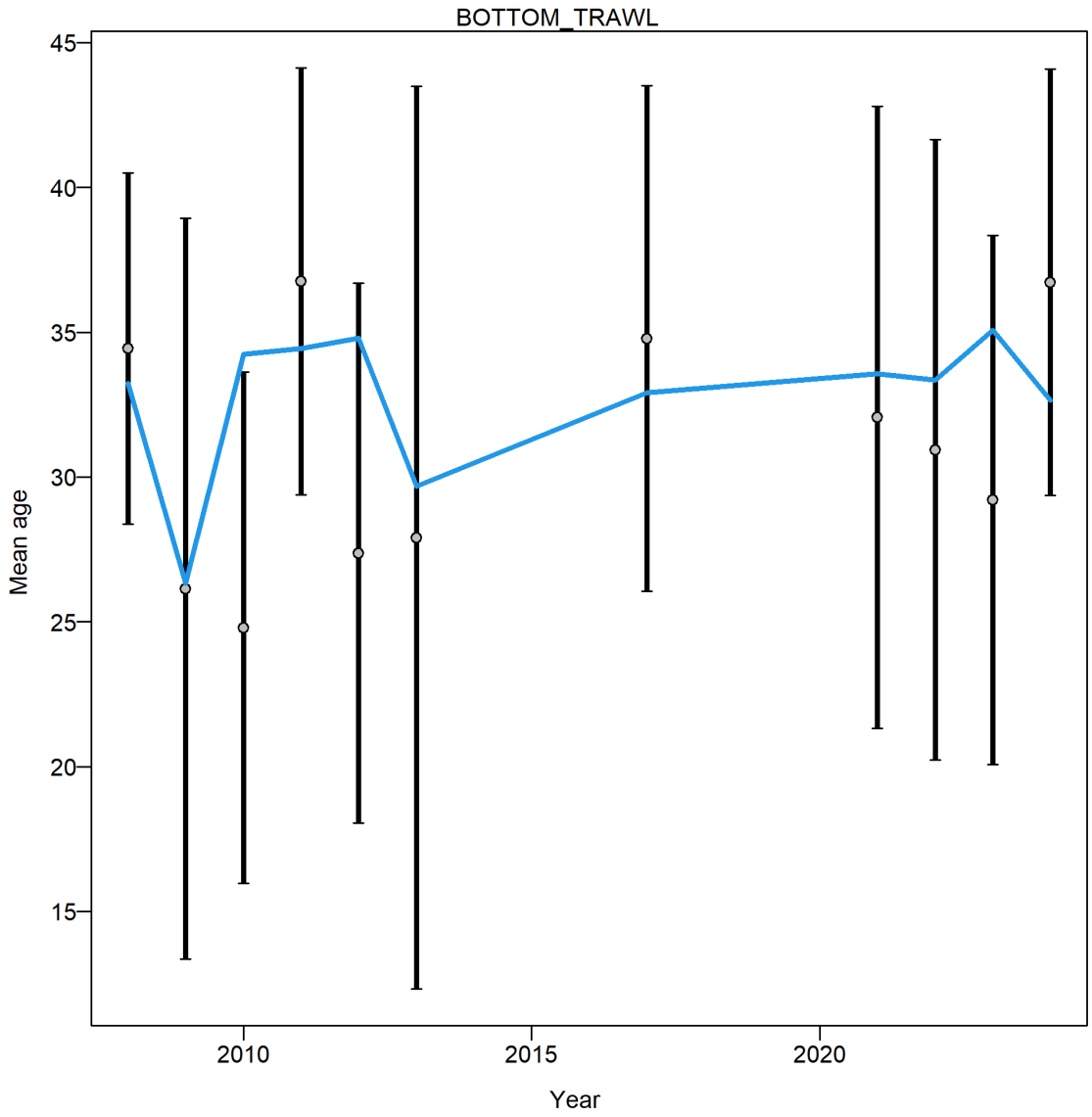


Figure 108: Mean age from conditional age-at-length data for the bottom trawl fishery with 95% confidence intervals based on current samples sizes and data weighting.

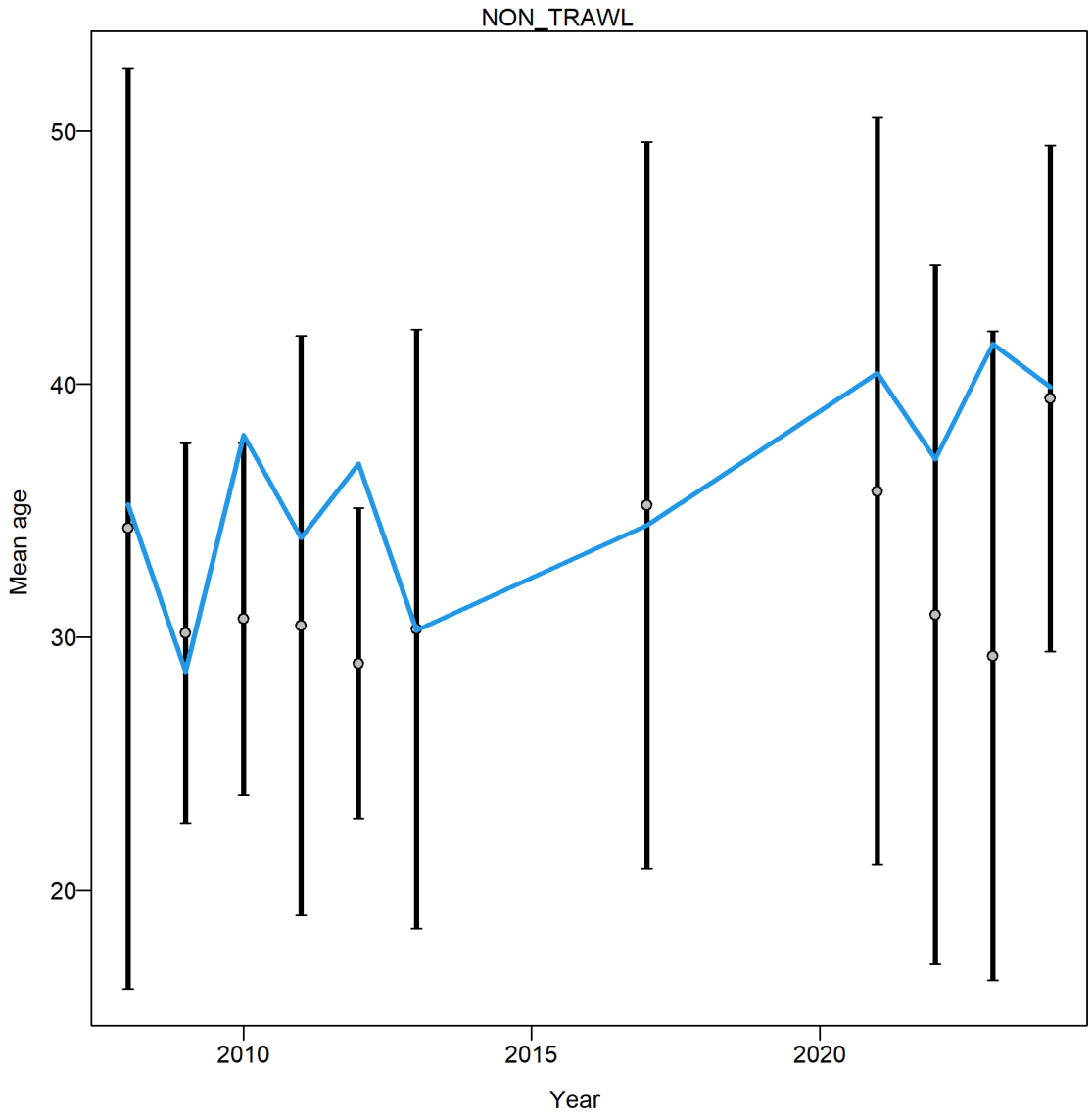


Figure 109: Mean age from conditional age-at-length data for the non-trawl fishery with 95% confidence intervals based on current samples sizes and data weighting.

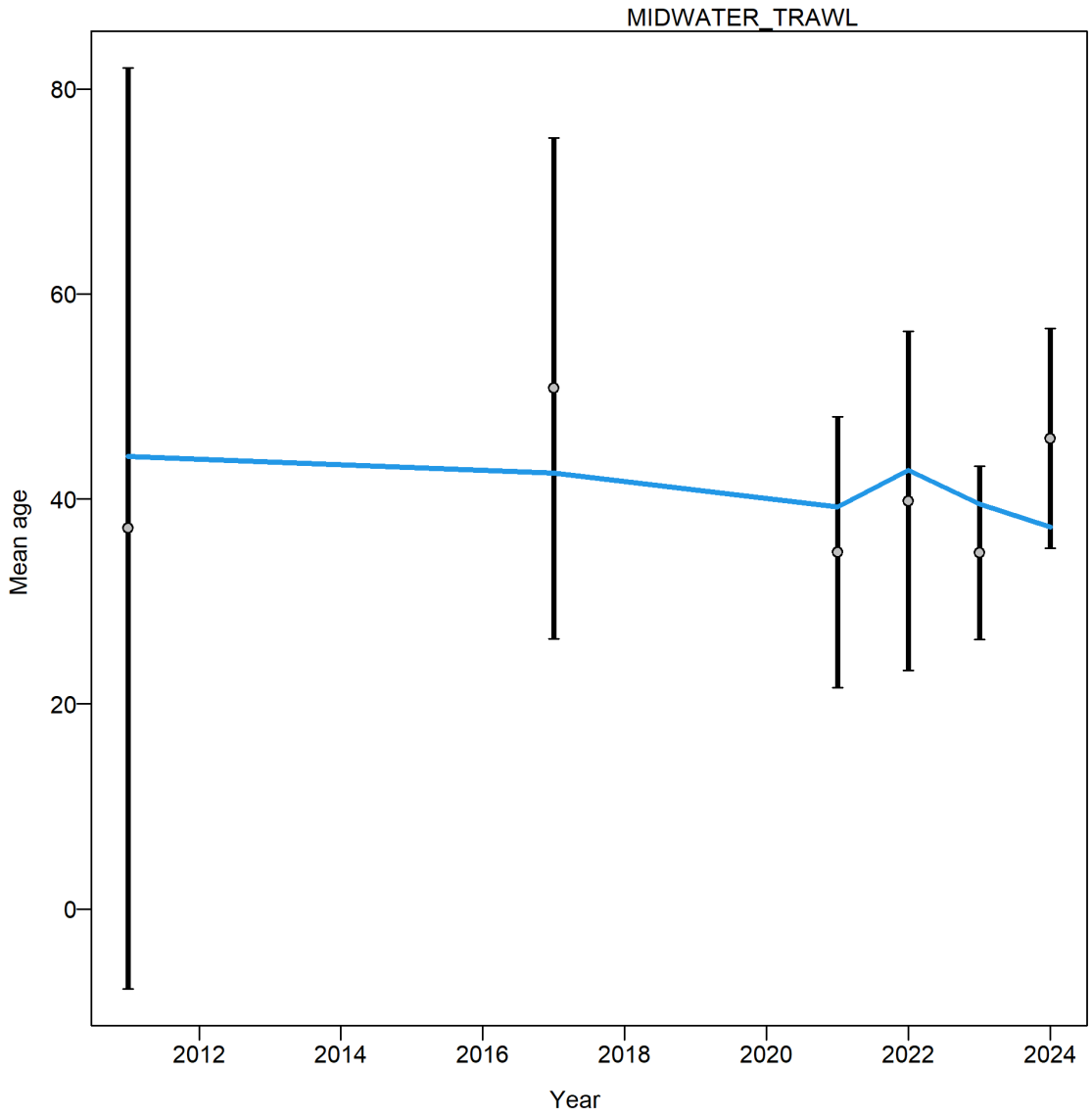


Figure 110: Mean age from conditional age-at-length data for the midwater trawl fishery with 95% confidence intervals based on current samples sizes and data weighting.

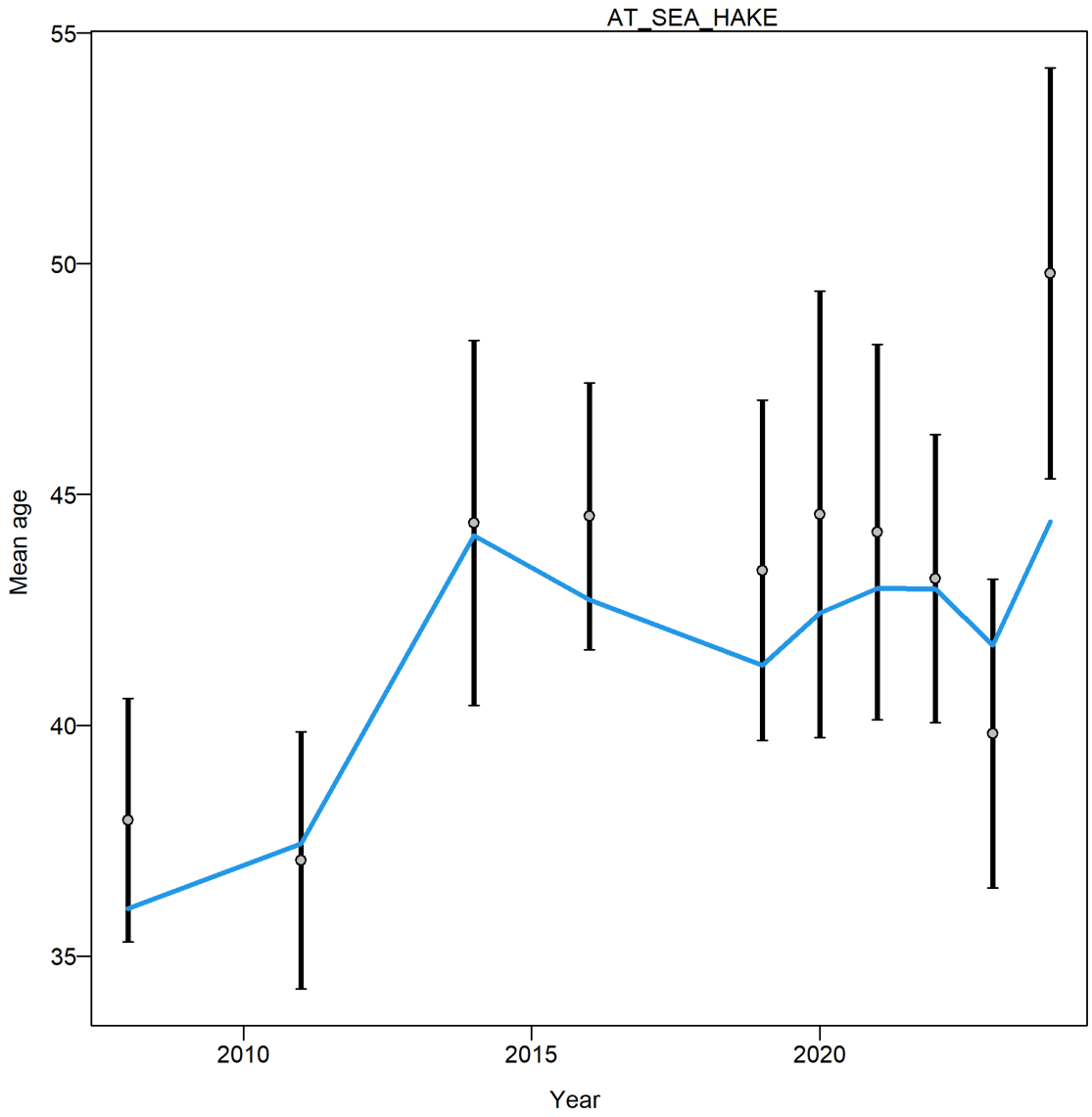


Figure 111: Mean age from conditional age-at-length data for the at-sea-hake fishery with 95% confidence intervals based on current samples sizes and data weighting.

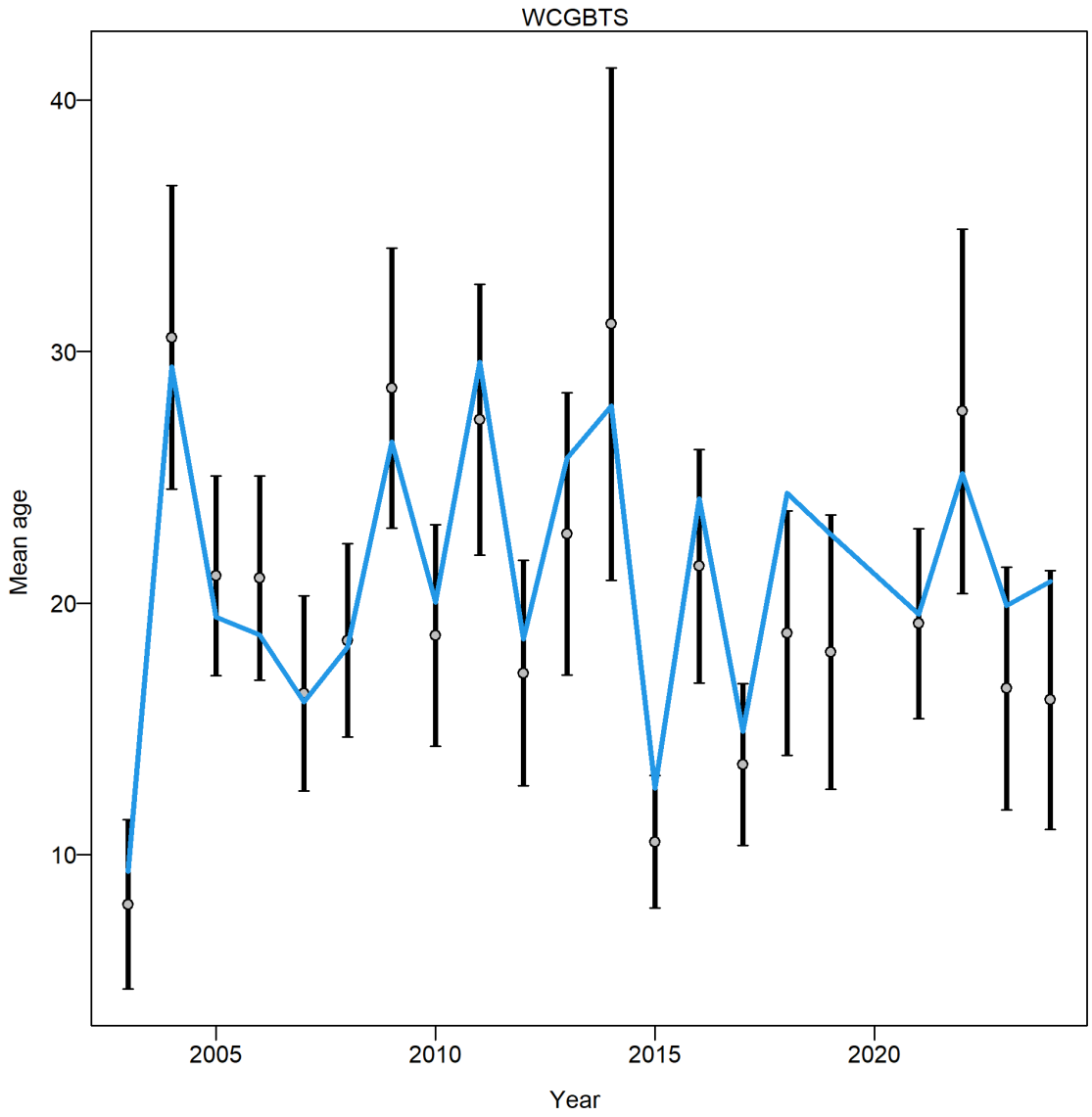


Figure 112: Mean age from conditional age-at-length data for the West Coast Groundfish Bottom Trawl survey with 95% confidence intervals based on current samples sizes and data weighting.

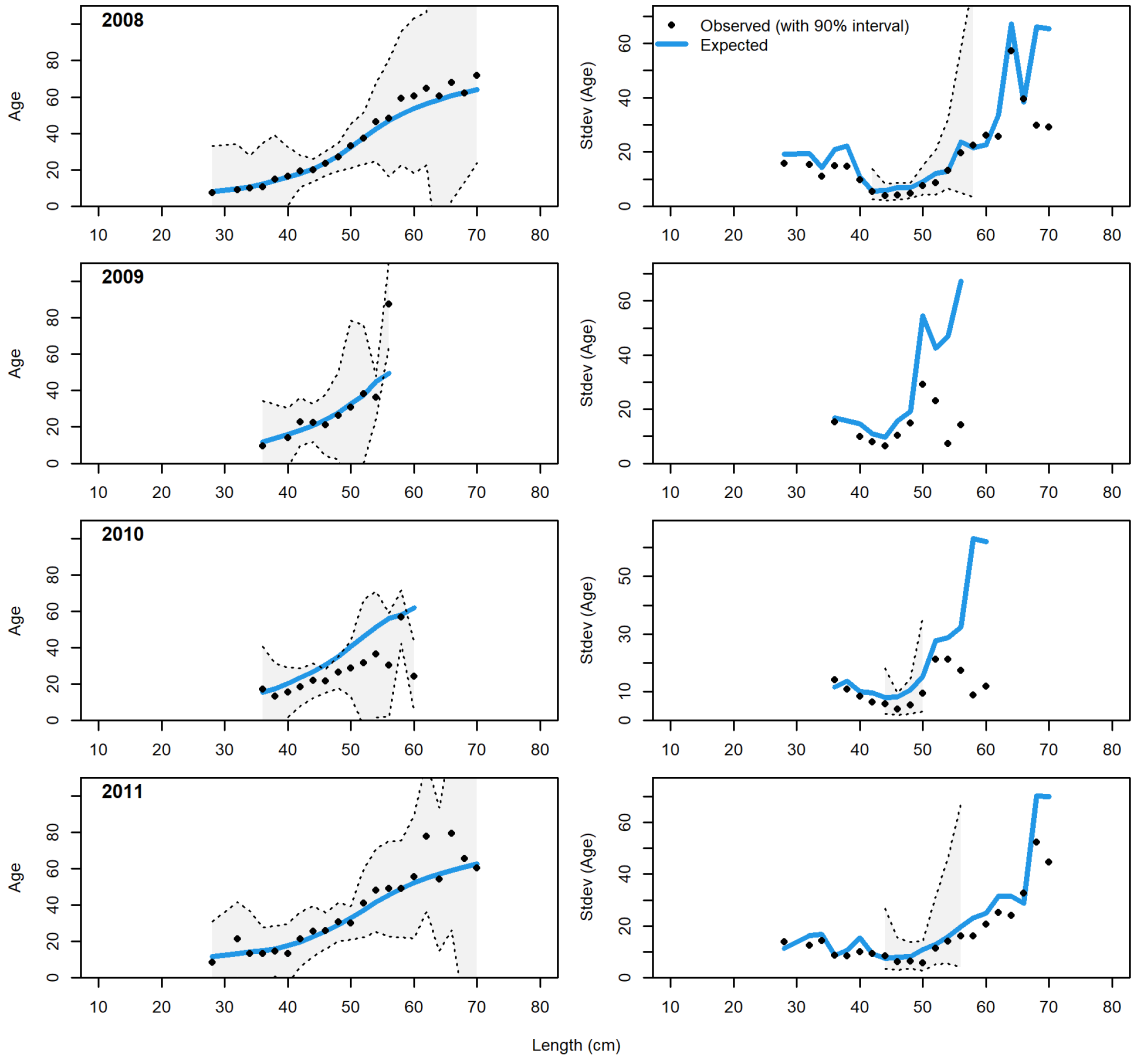


Figure 113: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the bottom trawl fishery in years 2008-2011. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

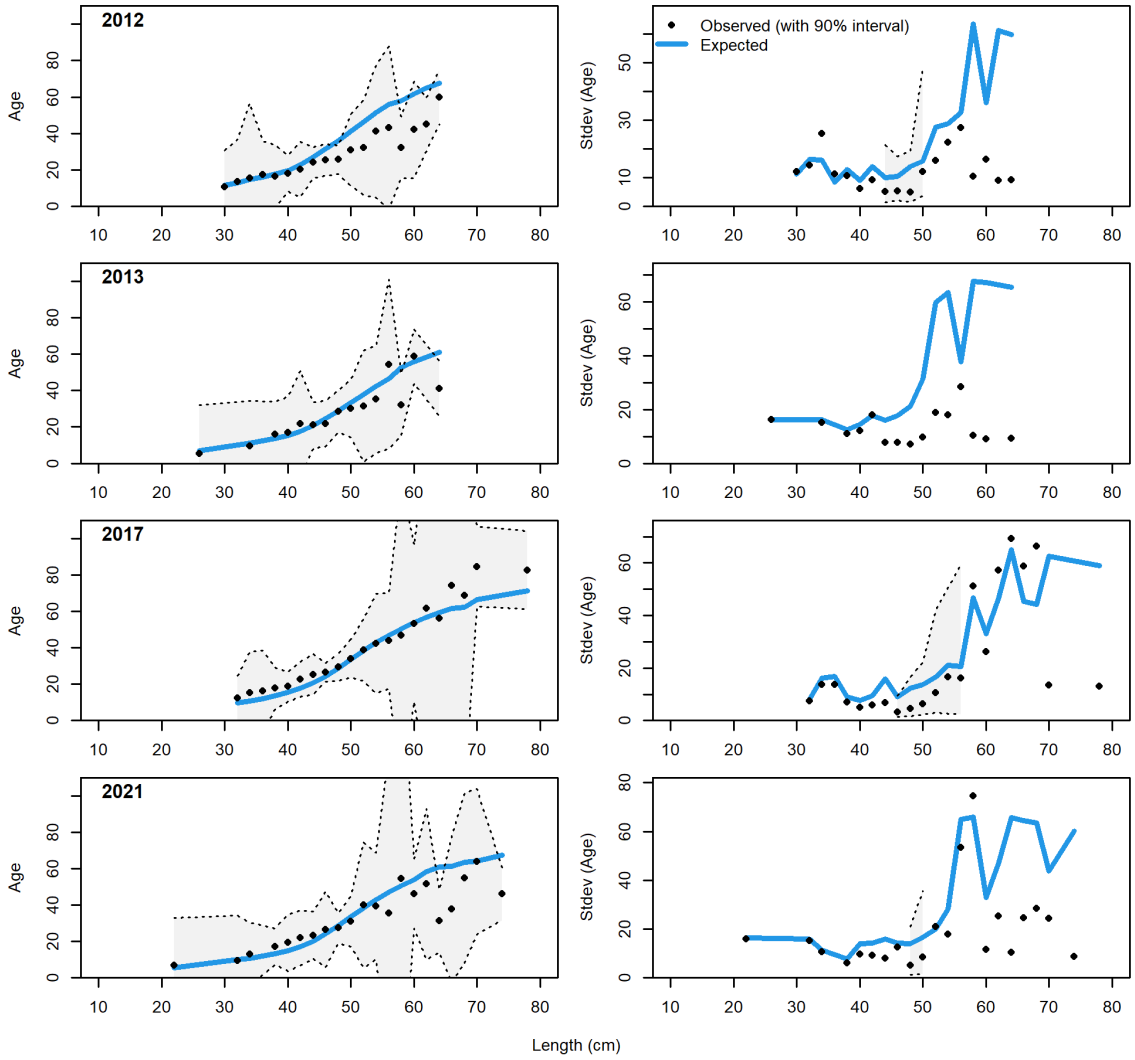


Figure 114: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the bottom trawl fishery in years 2012-2021. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

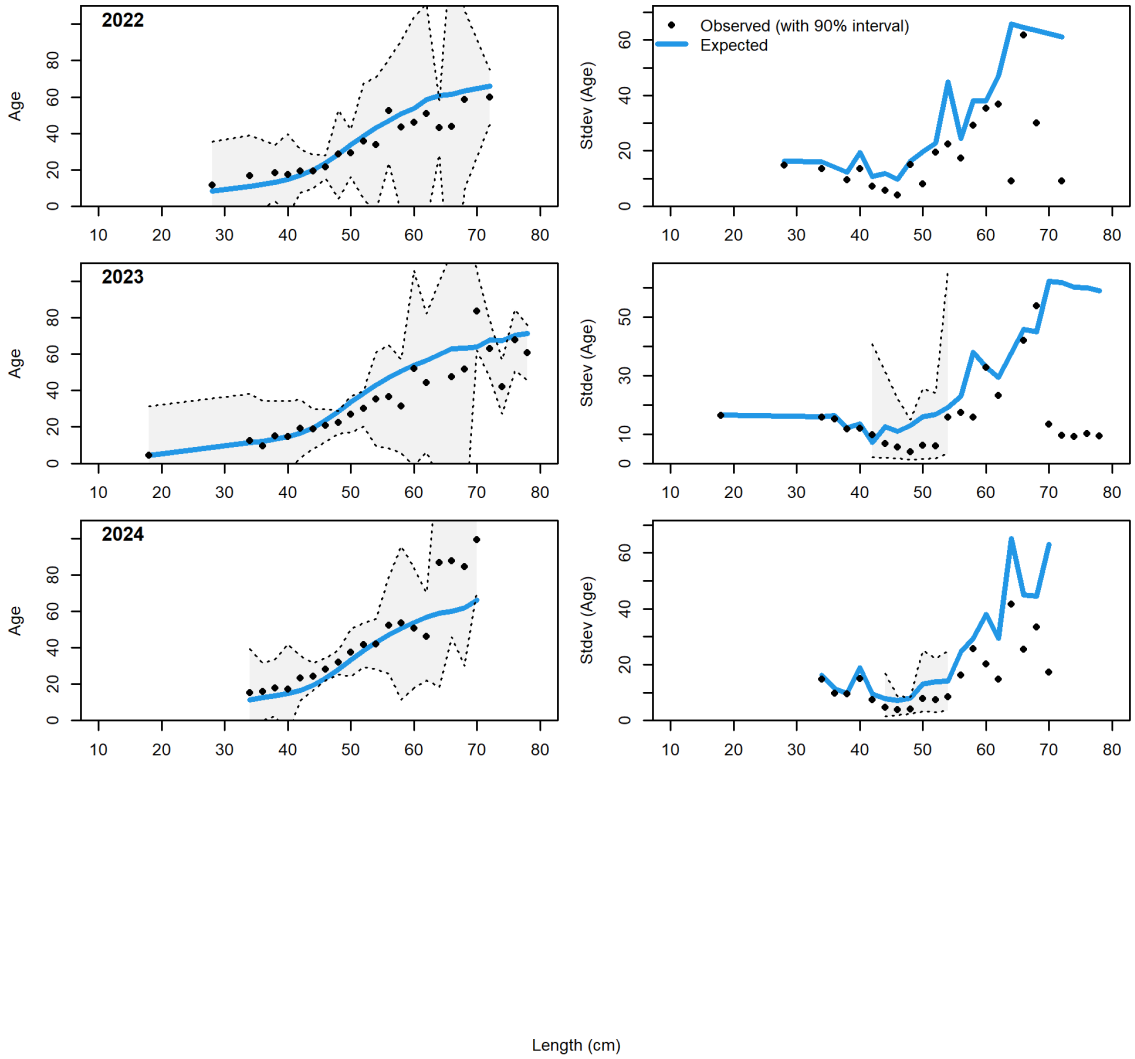


Figure 115: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the bottom trawl fishery in years 2022-2024. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

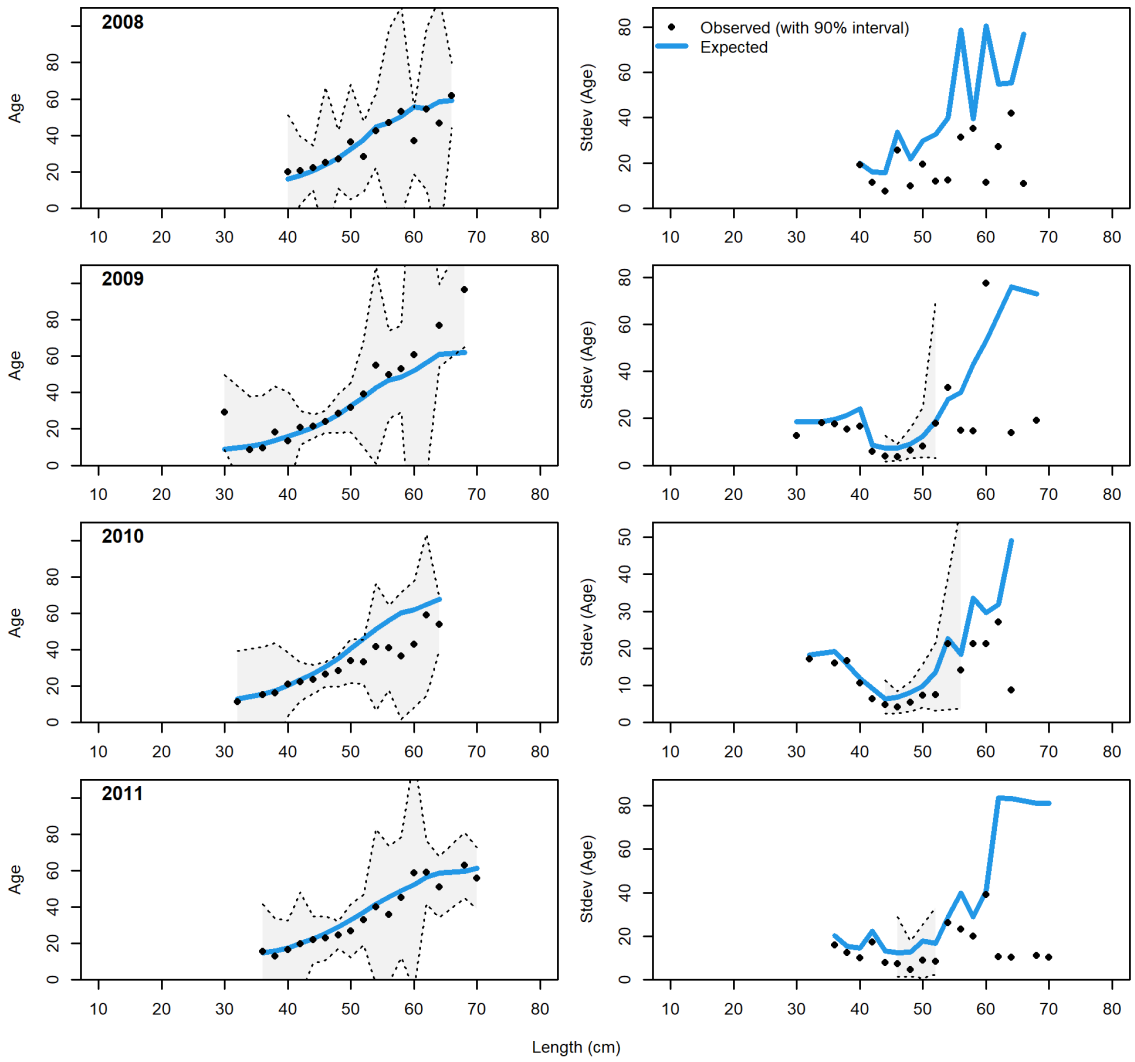


Figure 116: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the non-trawl fishery in years 2008-2011. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

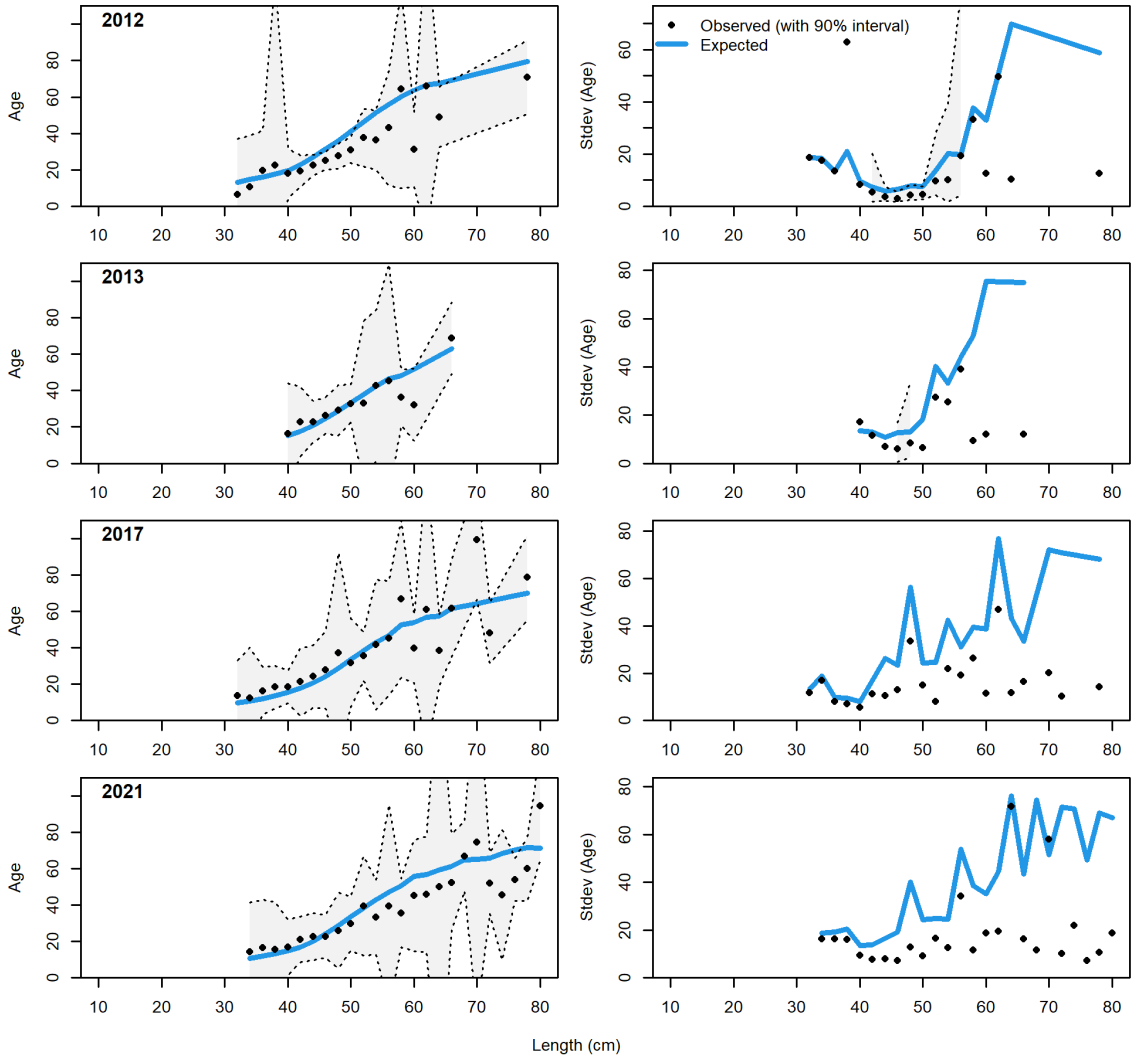


Figure 117: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the non-trawl fishery in years 2012-2021. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

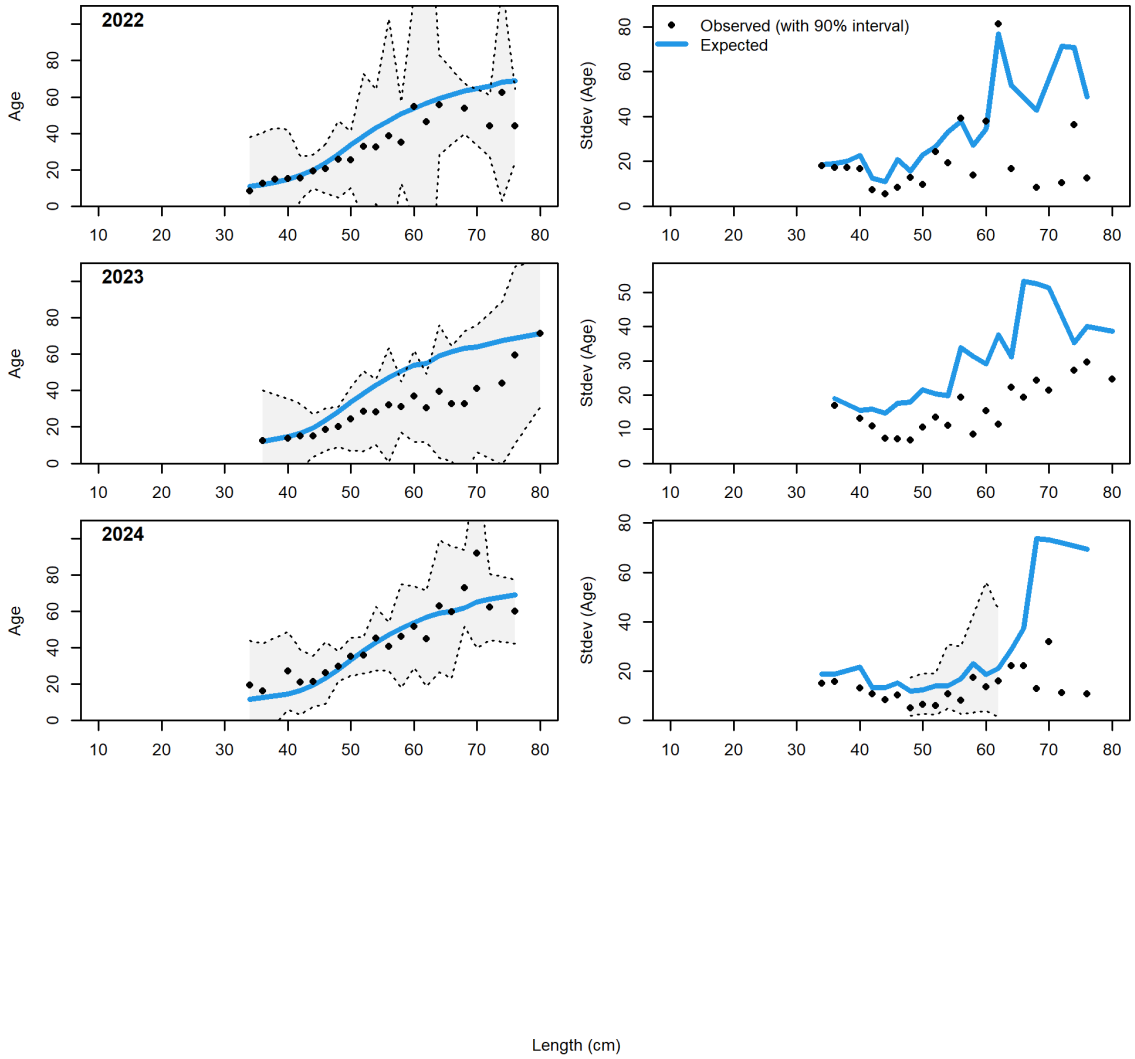


Figure 118: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the non-trawl fishery in years 2022-2024. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

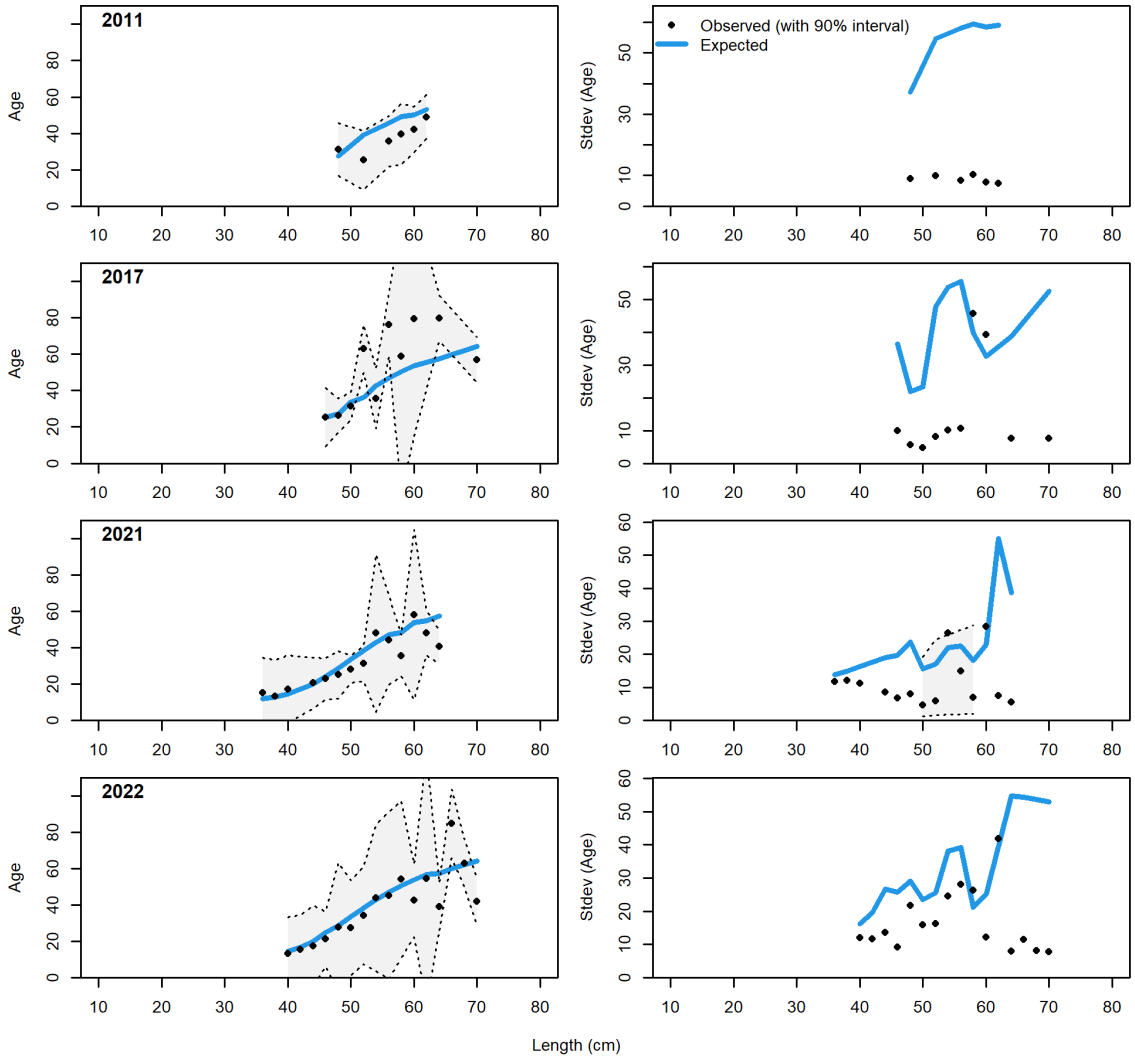


Figure 119: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the midwater trawl fishery in years 2011-2022. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

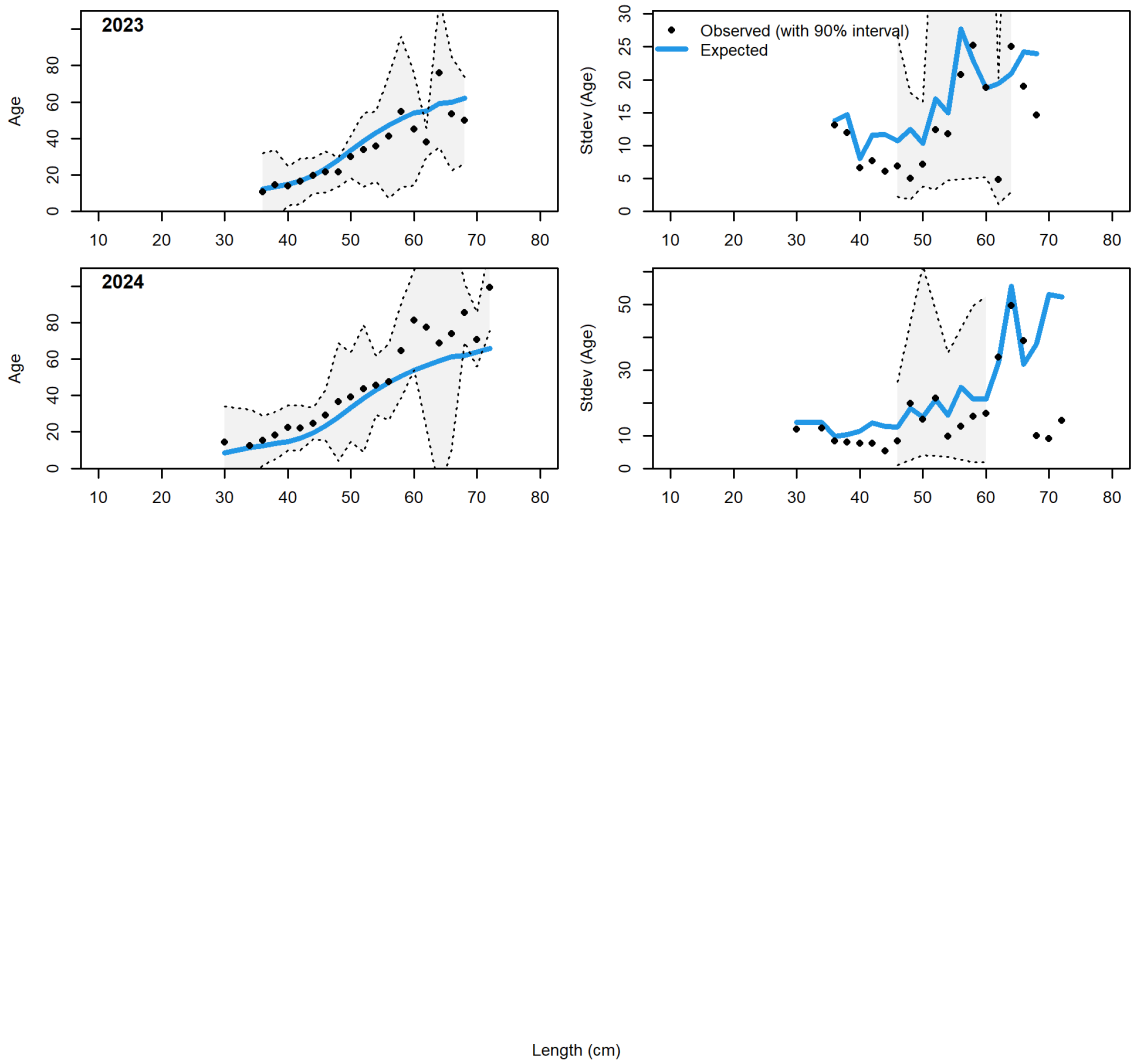


Figure 120: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the non-trawl fishery in years 2023-2024. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

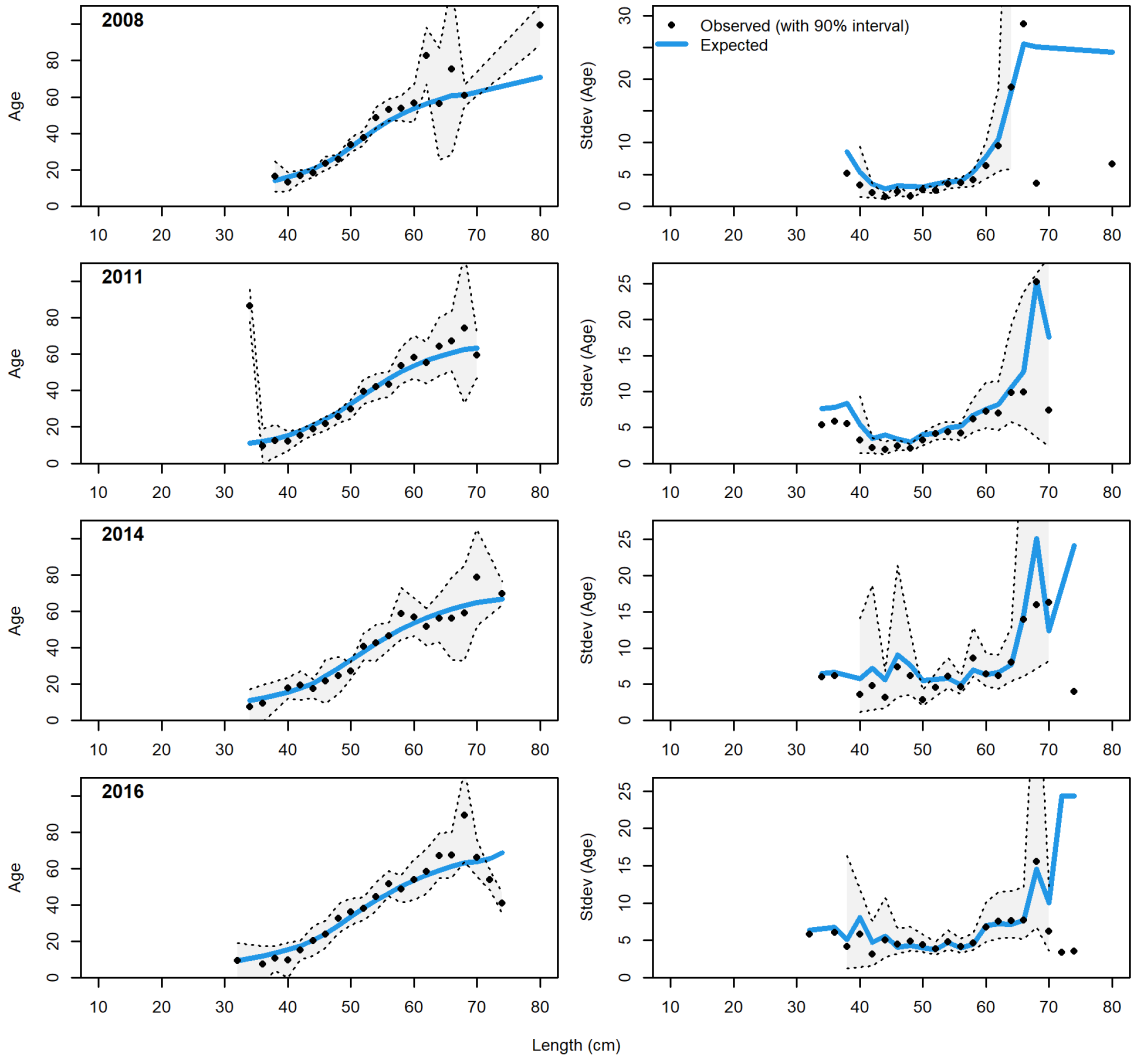


Figure 121: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the at-sea-hake fishery in years 2008-2016. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

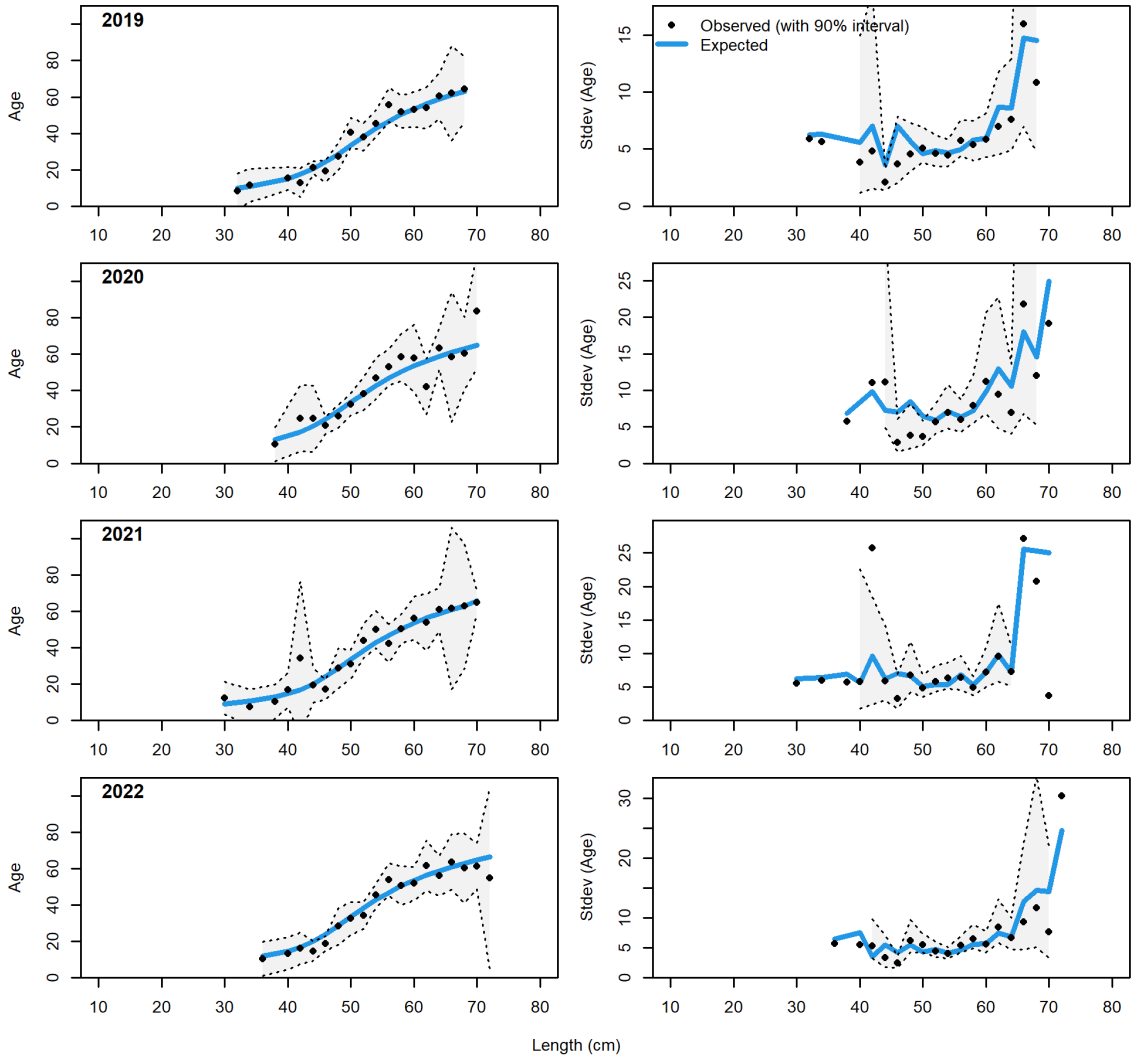


Figure 122: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the at-sea-hake fishery in years 2019-2022. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

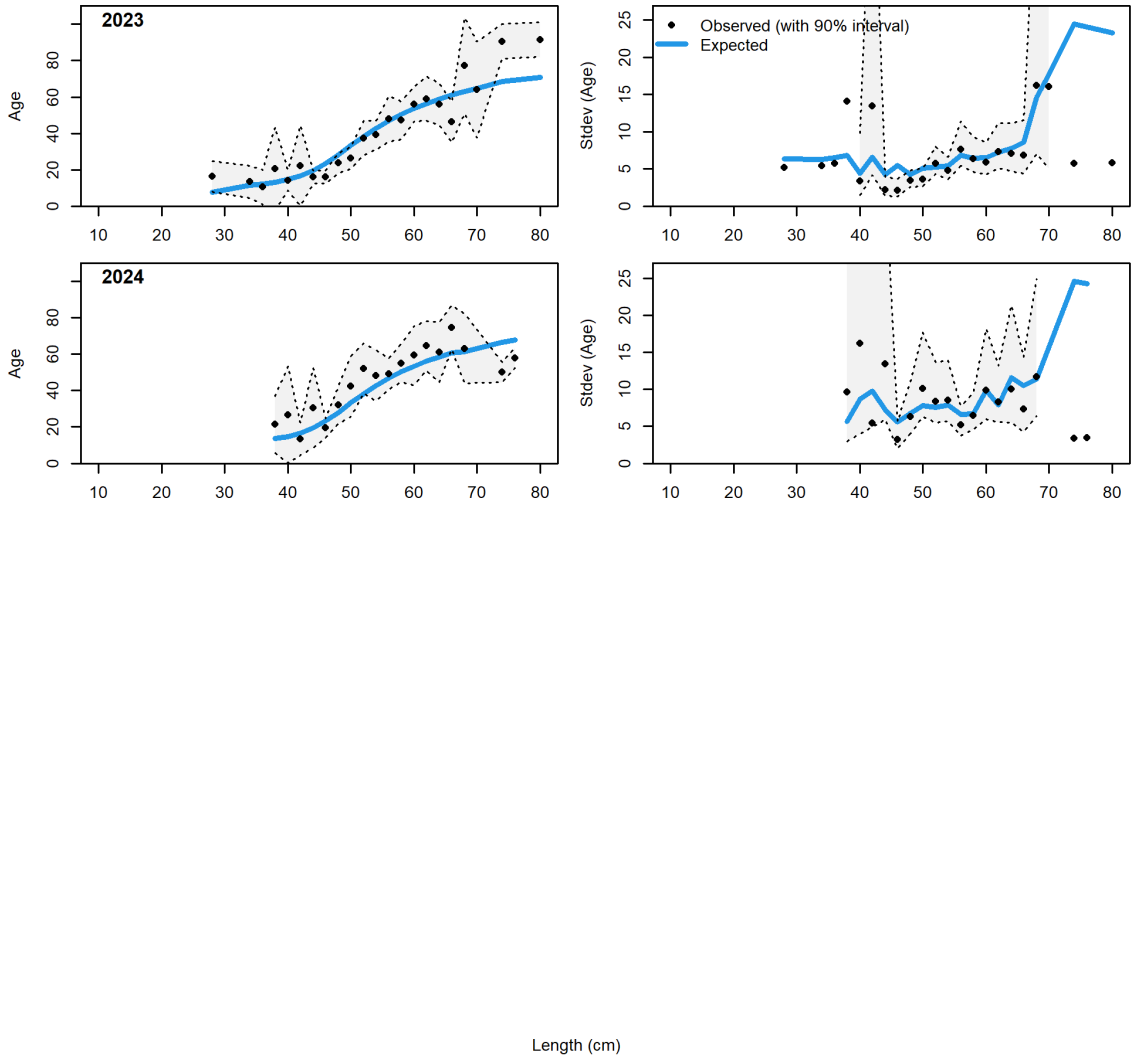


Figure 123: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the at-sea-hake fishery in years 2023-2024. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

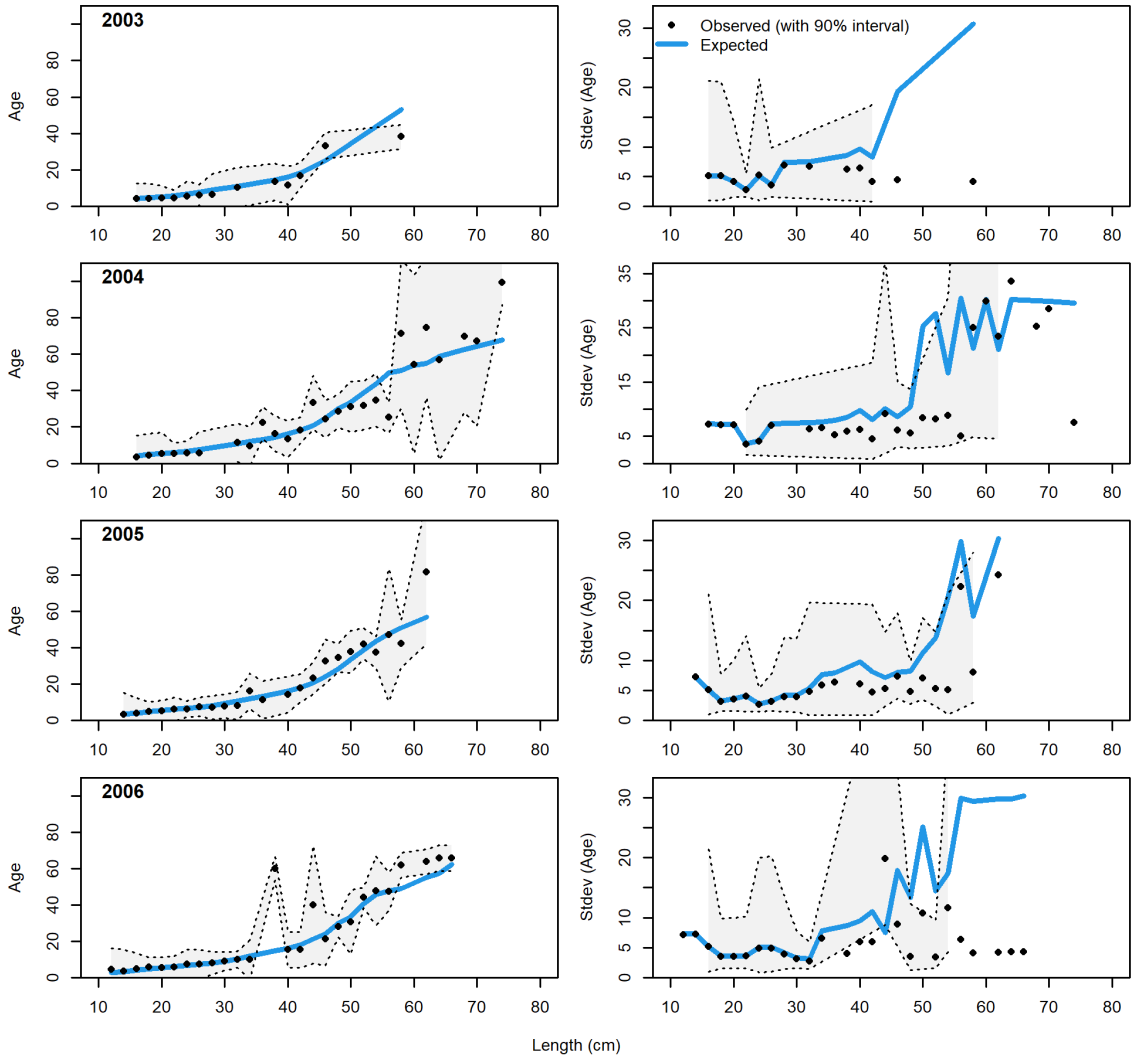


Figure 124: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the West Coast Groundfish Bottom Trawl survey in years 2003-2006. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

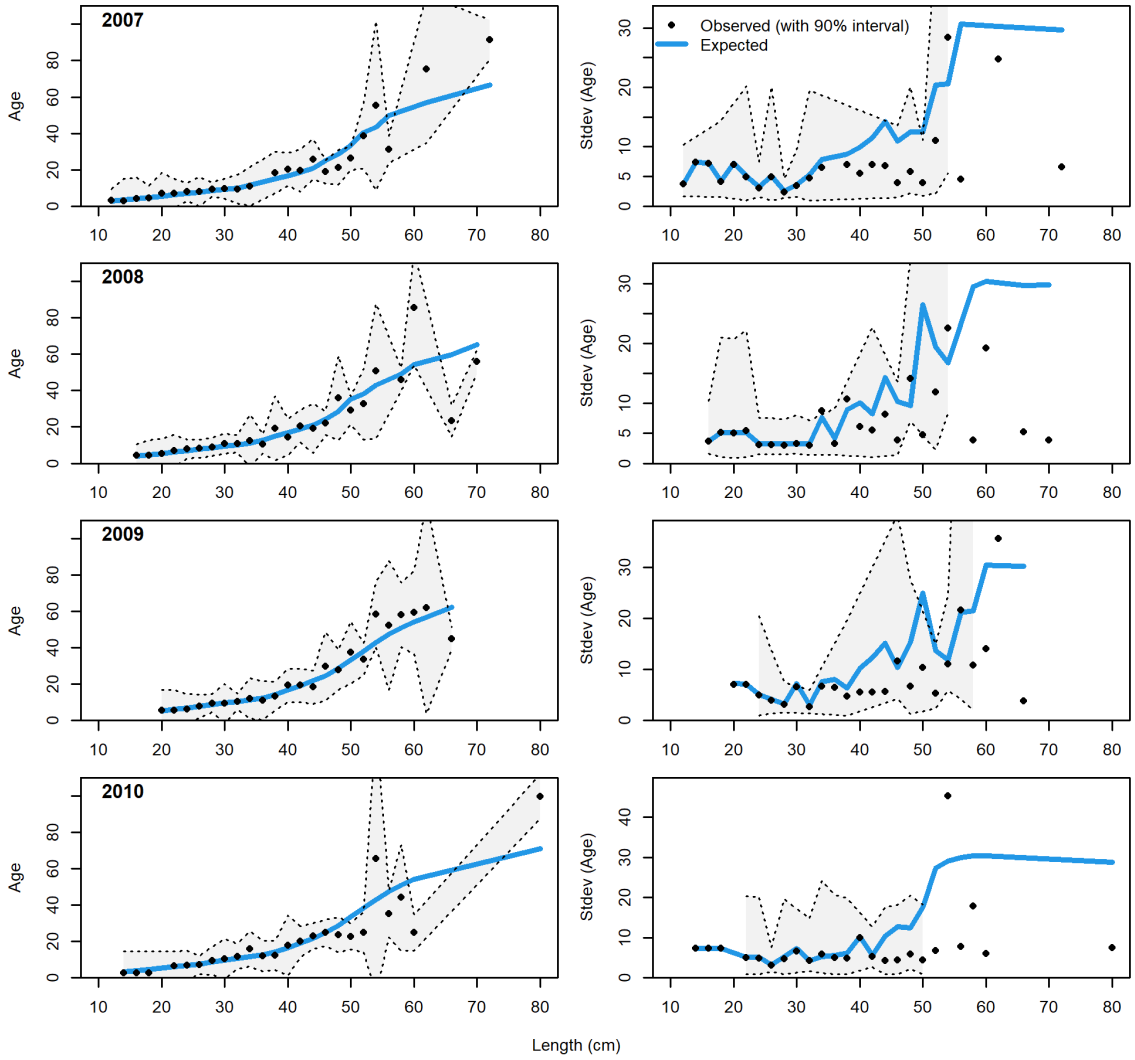


Figure 125: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the West Coast Groundfish Bottom Trawl survey in years 2007-2010. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

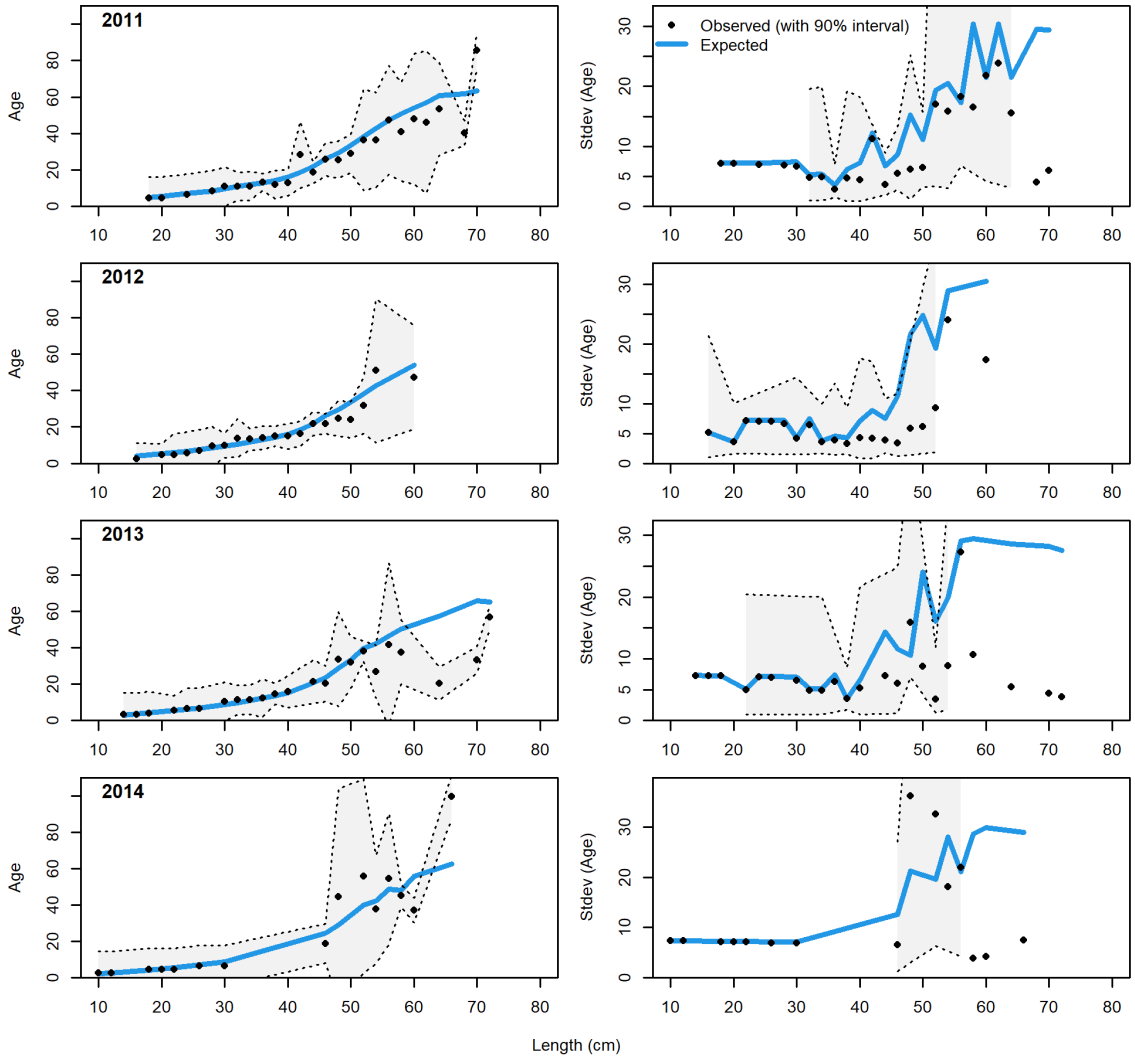


Figure 126: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the West Coast Groundfish Bottom Trawl survey in years 2011-2014. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

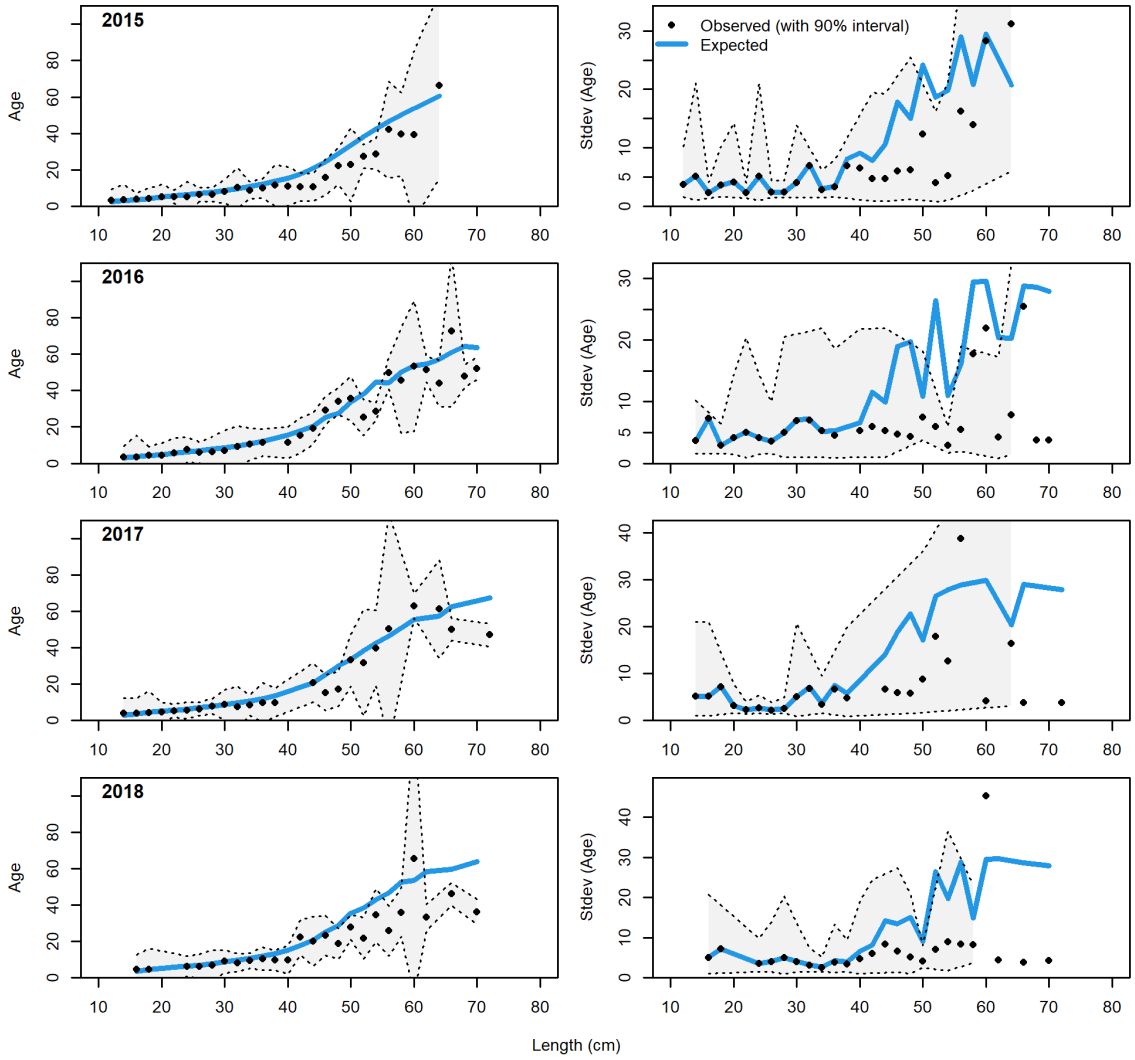


Figure 127: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the West Coast Groundfish Bottom Trawl survey in years 2015-2018. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

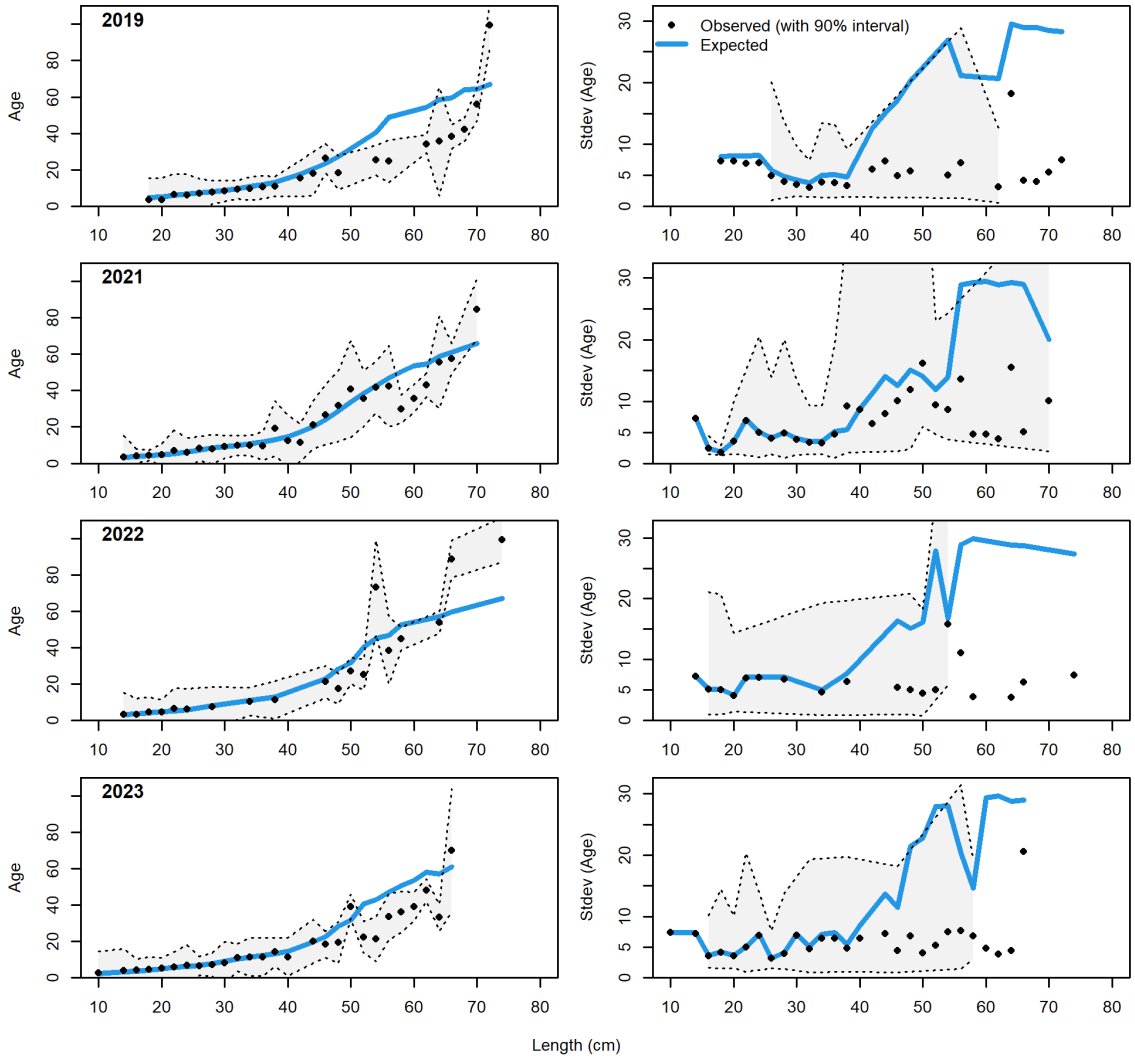


Figure 128: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the West Coast Groundfish Bottom Trawl survey in years 2019-2023. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

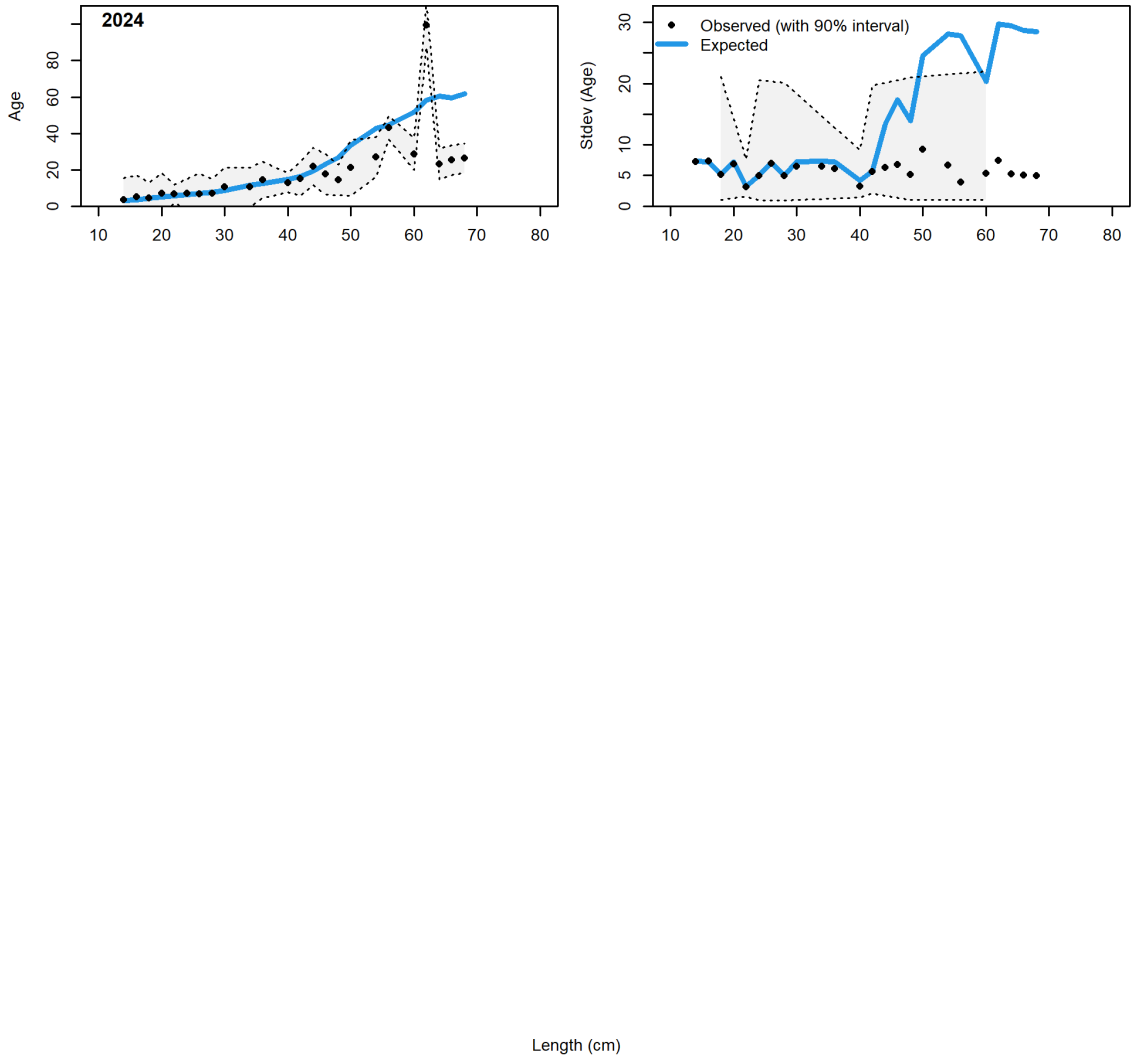


Figure 129: Conditional age at length plot showing mean age (left panels) and standard deviation (right panels) for the West Coast Groundfish Bottom Trawl survey in 2024. The CIs are 90% based on adding 1.64 SE of mean to the data for the left panels and the standard error of mean age at length (obs. and exp.) with 90% CIs based on the chi-square distribution.

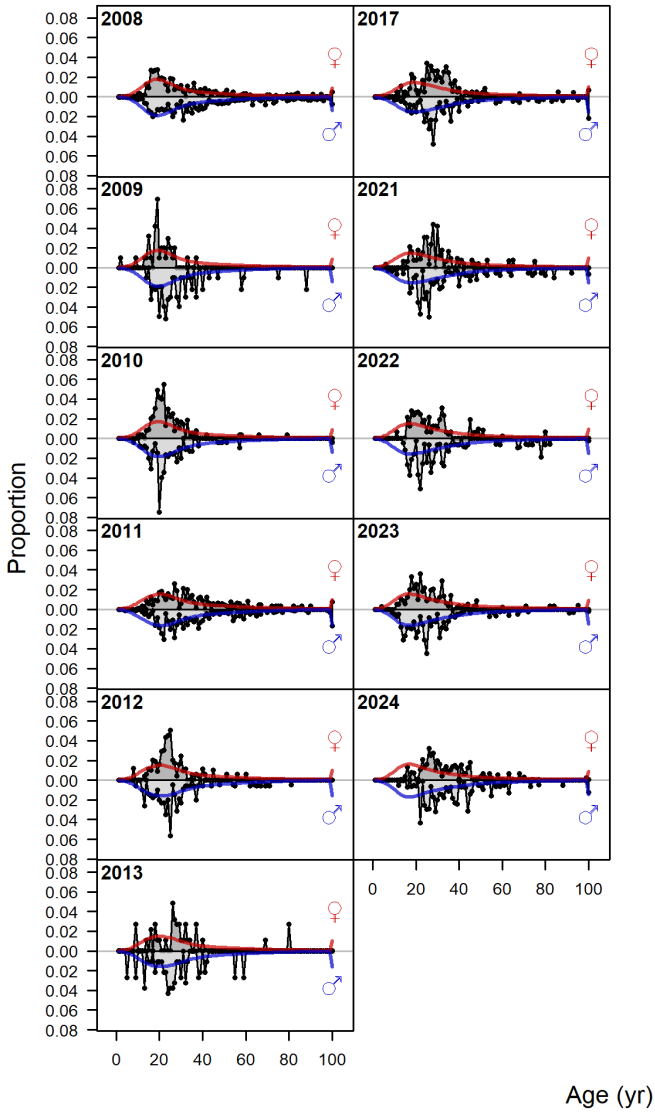


Figure 130: Realized fits (lines) to the marginal age composition data (density) for the bottom trawl fishery.

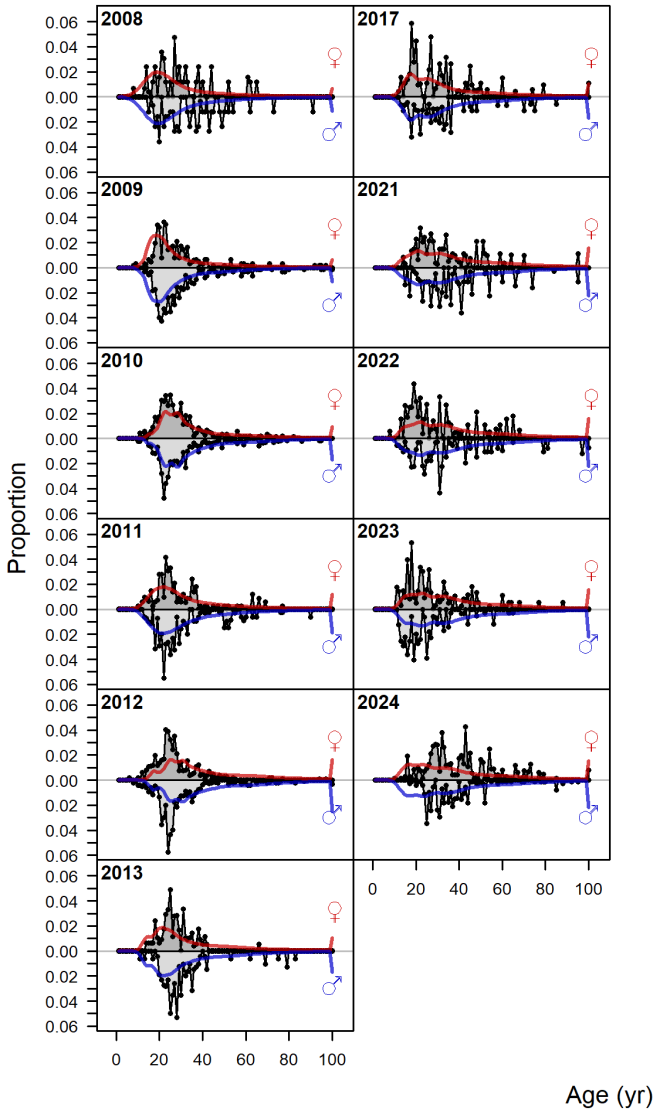


Figure 131: Realized fits (lines) to the marginal age composition data (density) for the non-trawl fishery.

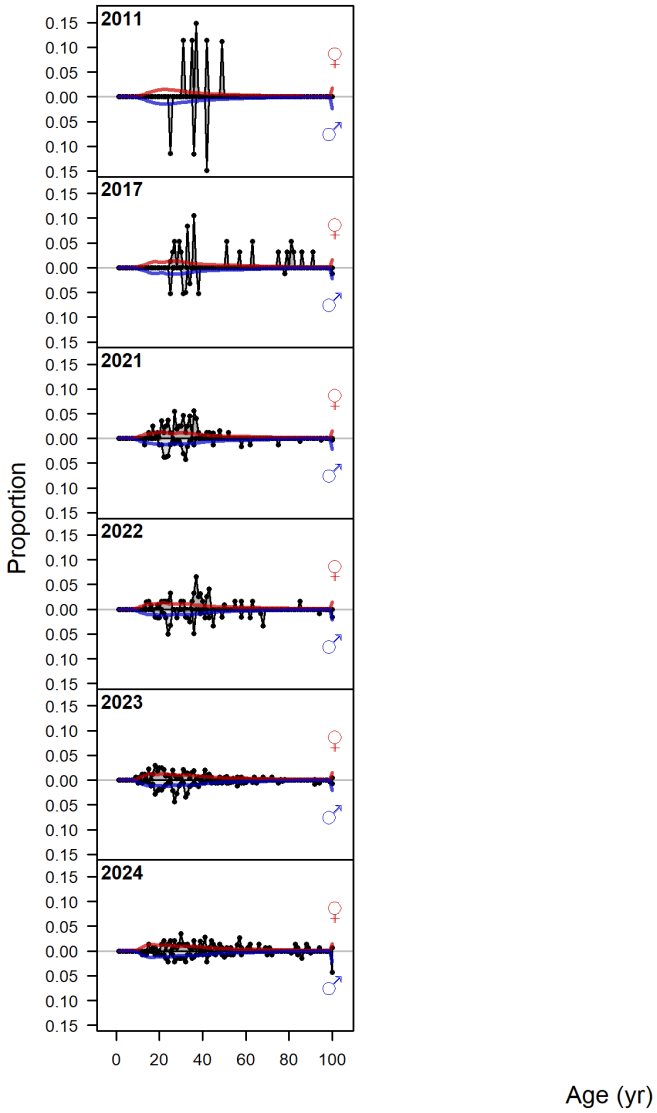


Figure 132: Realized fits (lines) to the marginal age composition data (density) for the midwater trawl fishery.

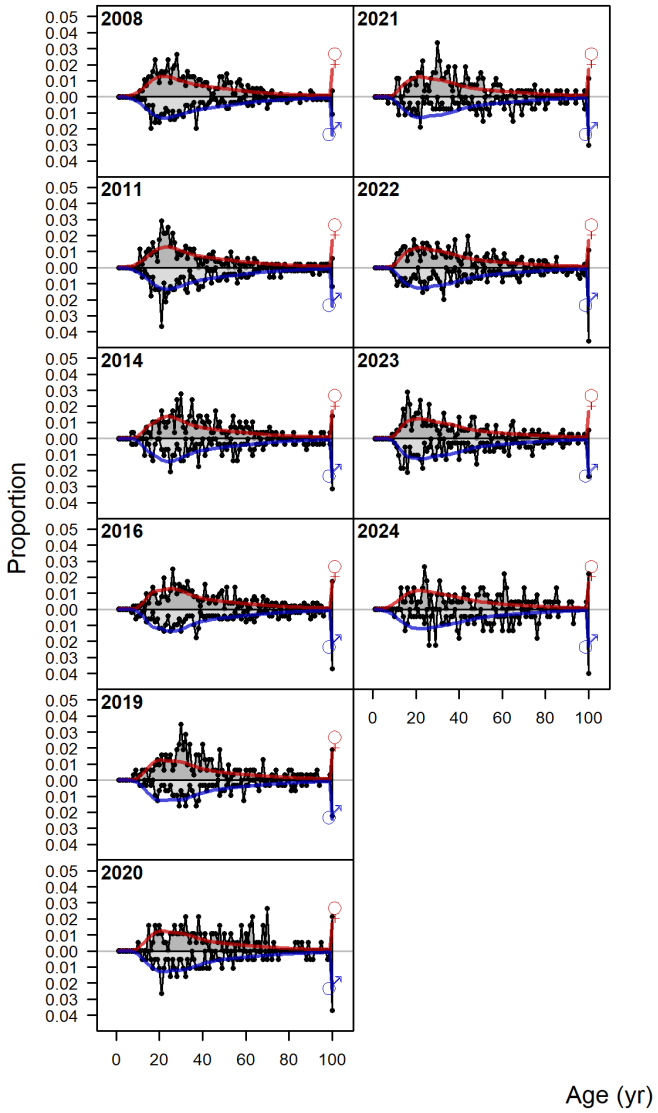


Figure 133: Realized fits (lines) to the marginal age composition data (density) for the at-sea-hake fishery.

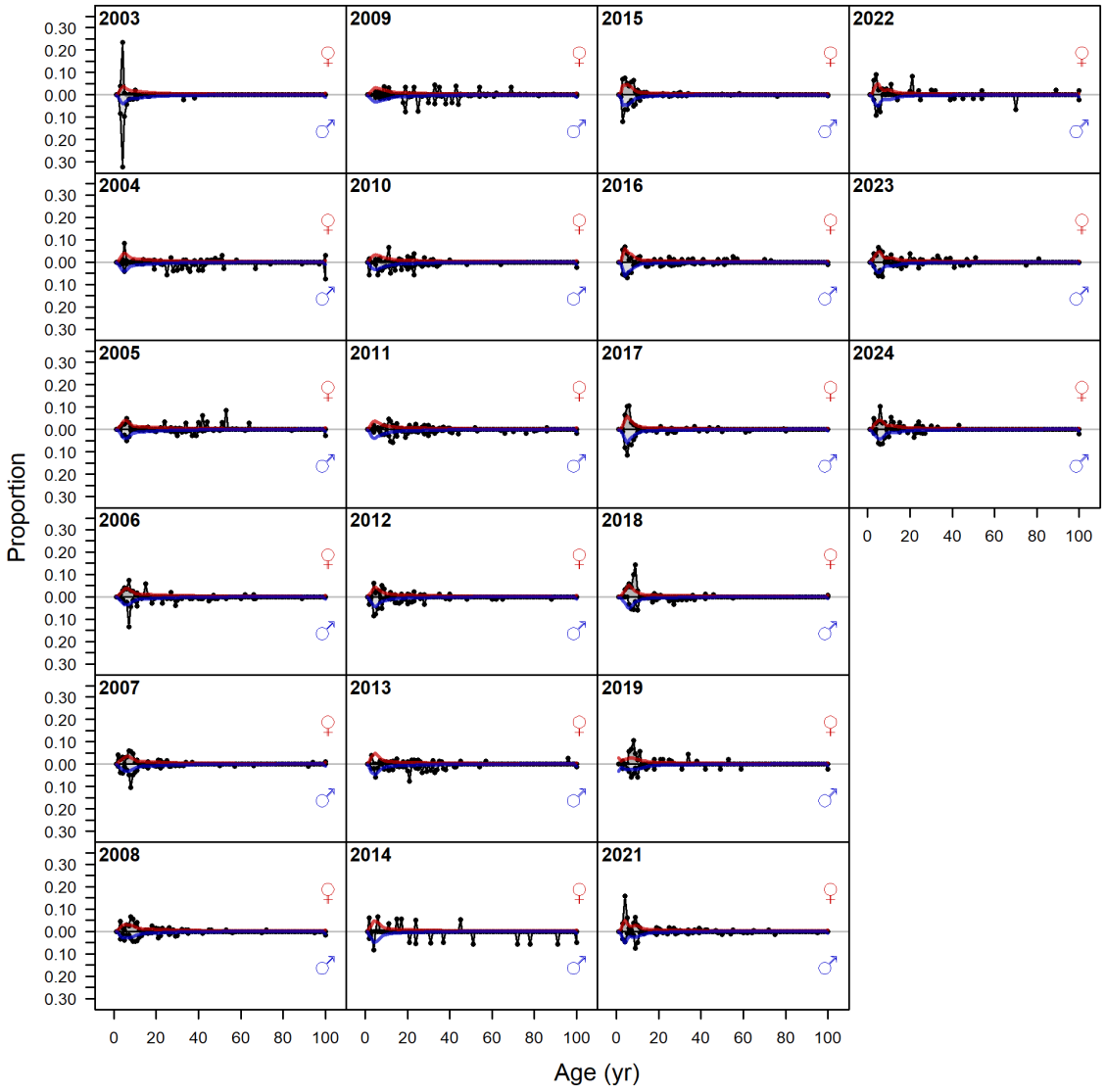


Figure 134: Realized fits (lines) to the marginal age composition data (density) for the West Coast Groundfish Bottom Trawl survey.

8.7.3 Indices of Abundance

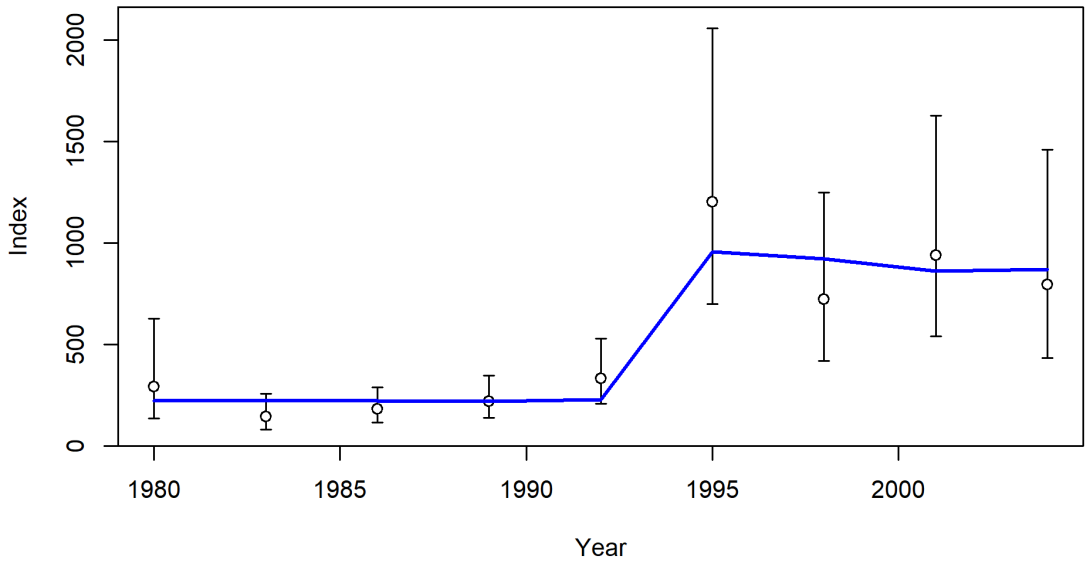


Figure 135: Fit to index data for Triennial survey. Lines indicate 95% uncertainty interval around index values based on the assumption of lognormal error.

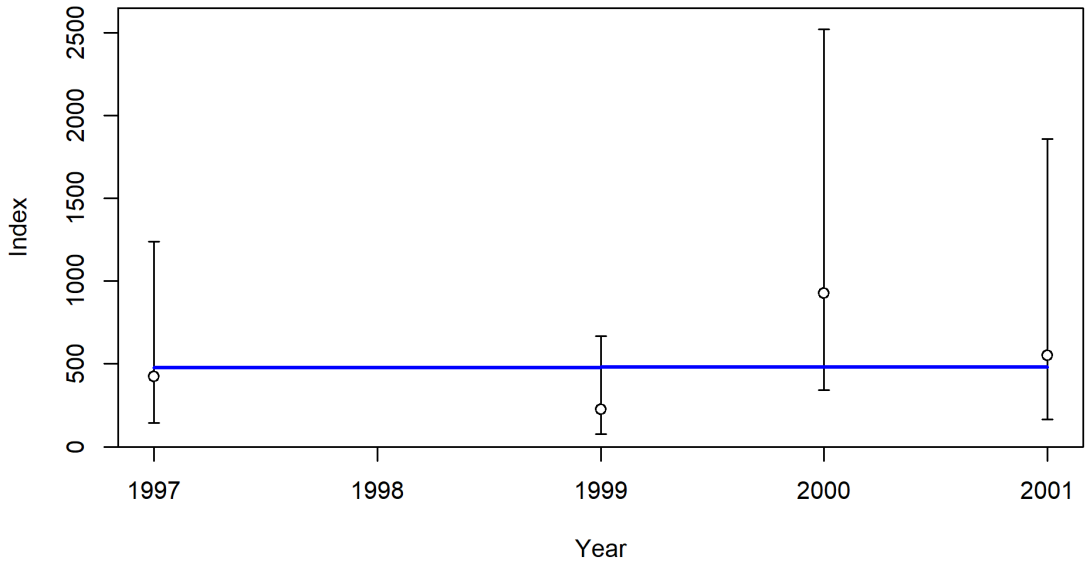


Figure 136: Fit to index data for the Alaska Slope survey. Lines indicate 95% uncertainty interval around index values based on the assumption of lognormal error.

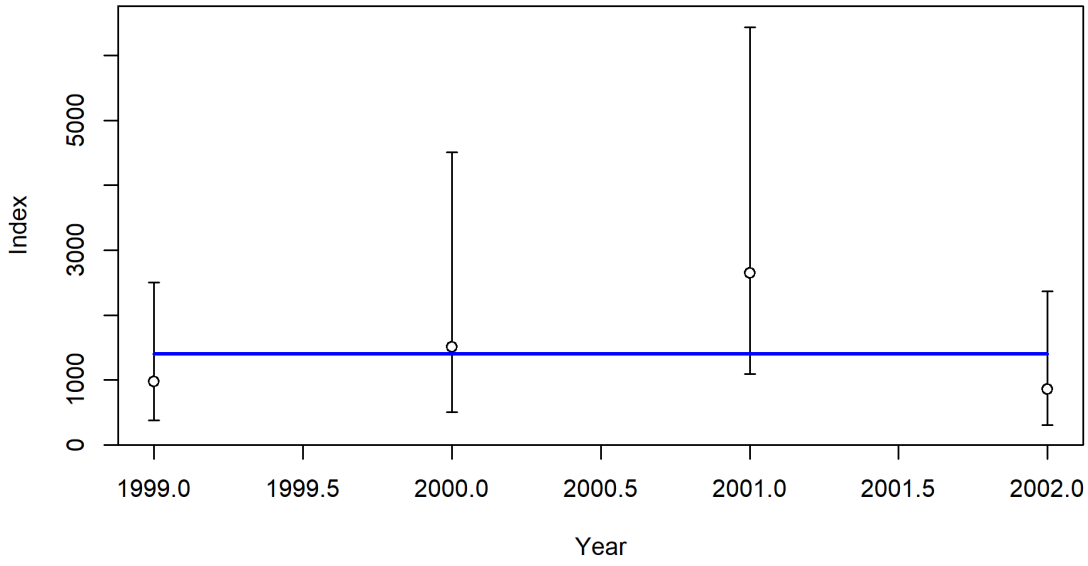


Figure 137: Fit to index data for Northwest Fisheries Science Center Slope survey. Lines indicate 95% uncertainty interval around index values based on the assumption of lognormal error.

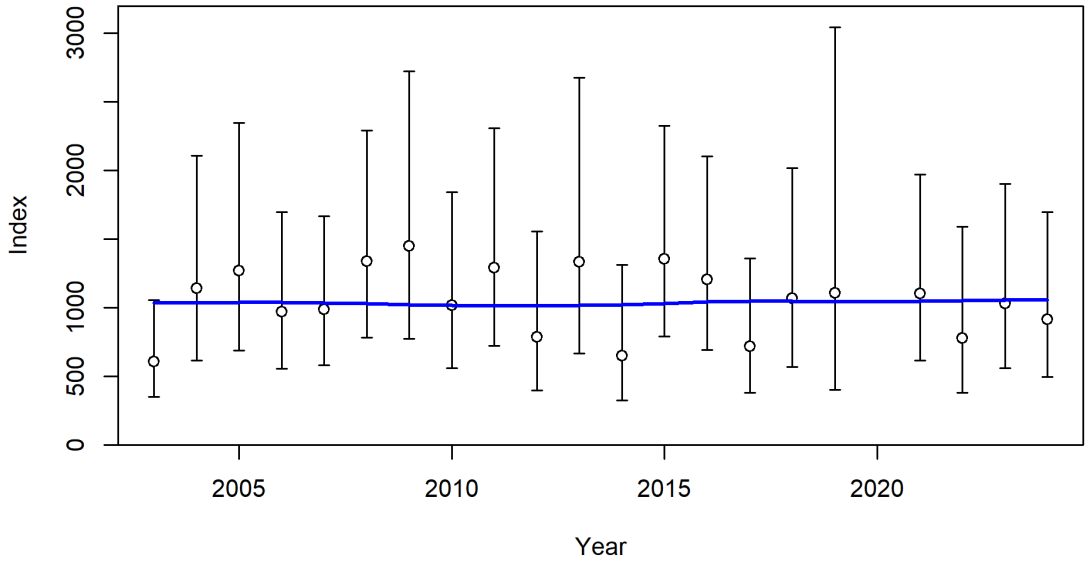


Figure 138: Fit to index data for West Coast Groundfish Bottom Trawl survey. Lines indicate 95% uncertainty interval around index values based on the assumption of lognormal error.

8.8 Parameter Estimates

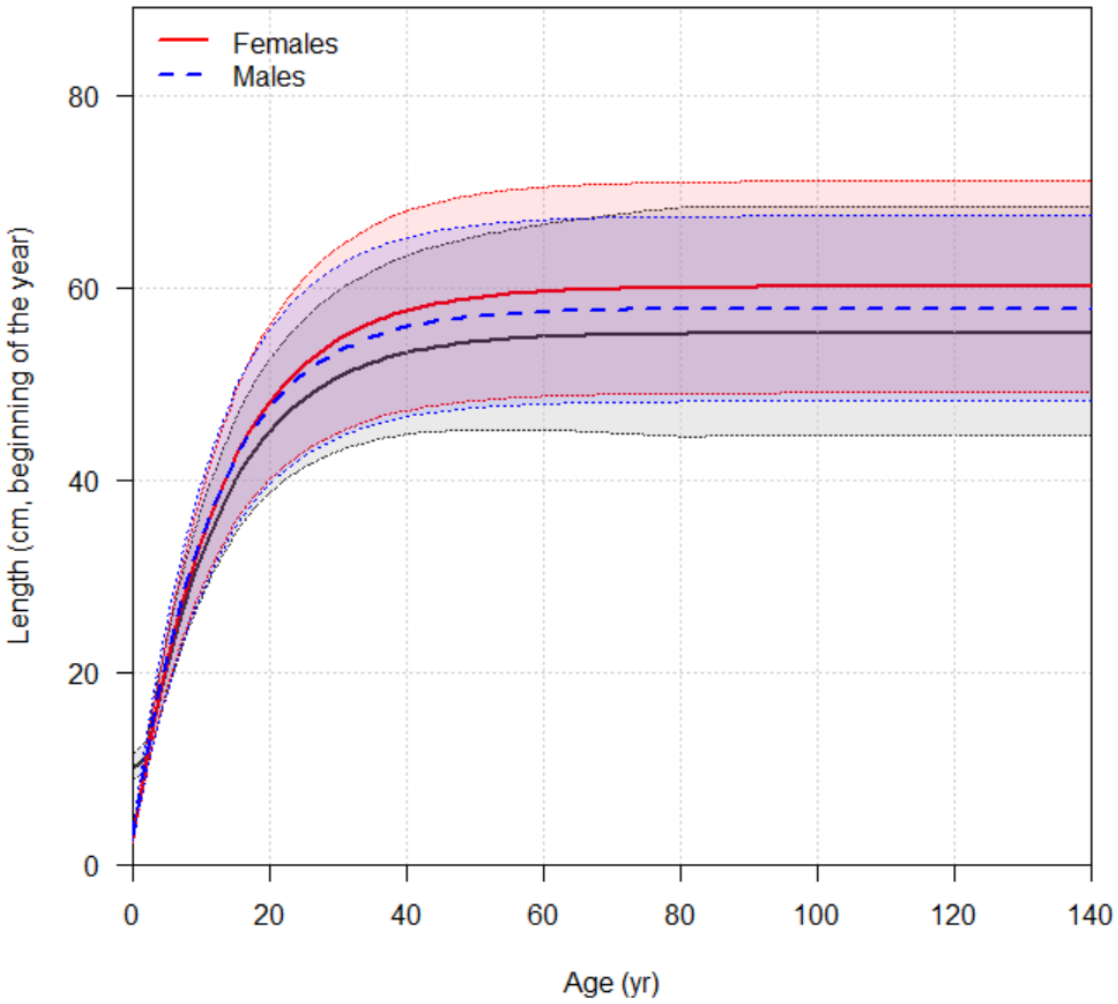


Figure 139: Estimated age and growth relatioship in the reference model. Shaded area indicates 95% distribution of length at age around estimated growth curve. Black curve is the estimated growth curve from the 2013 model.

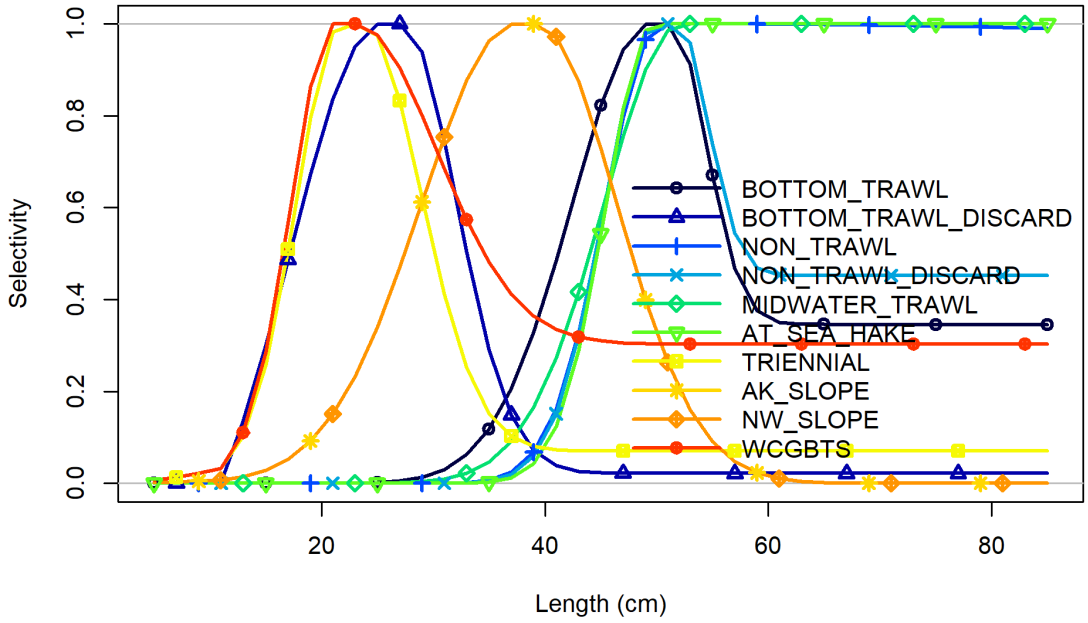


Figure 140: Ending selectivity at length for each fishery and survey.

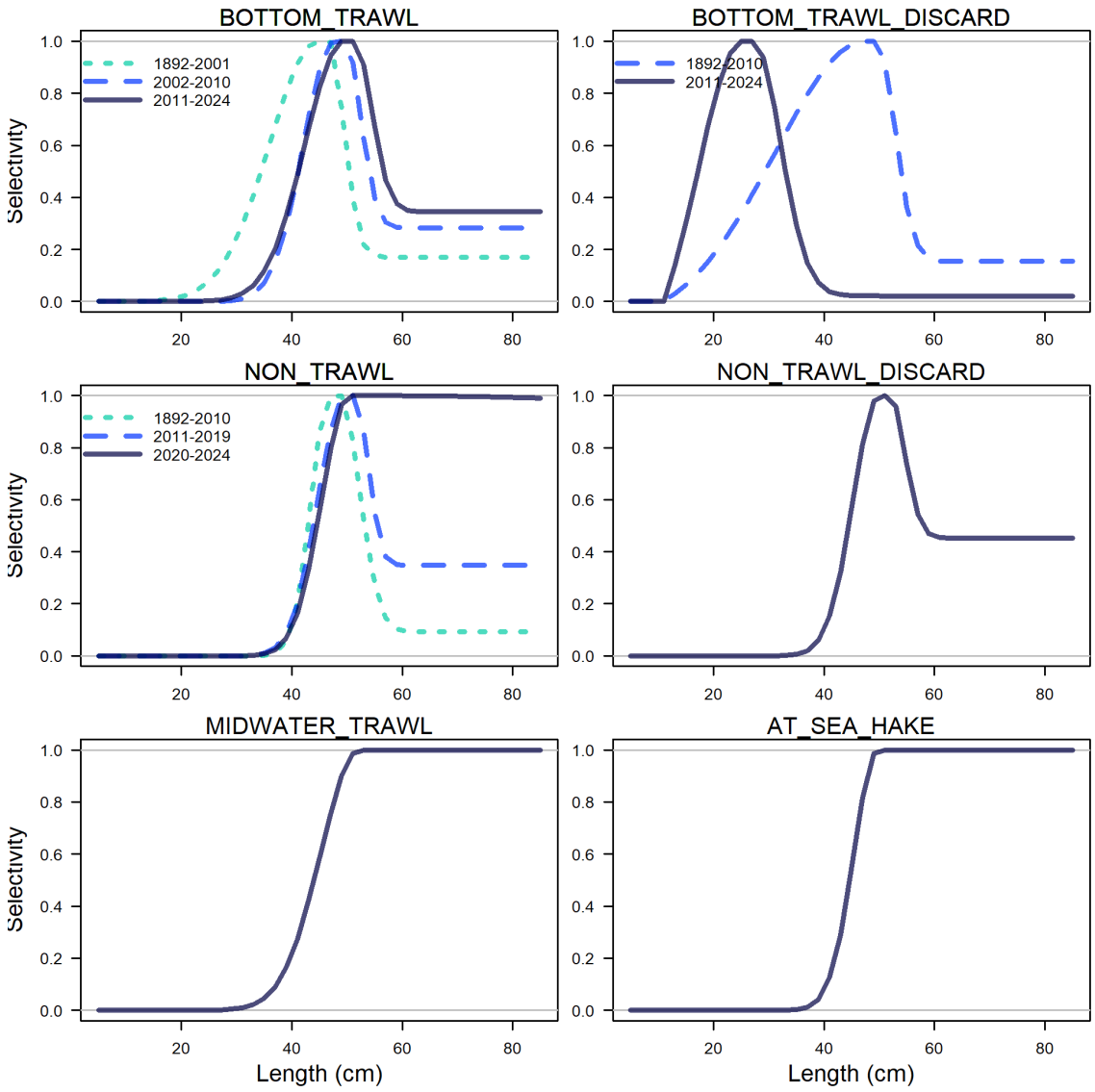


Figure 141: Time-varying selectivity for fishery fleets with time blocks.

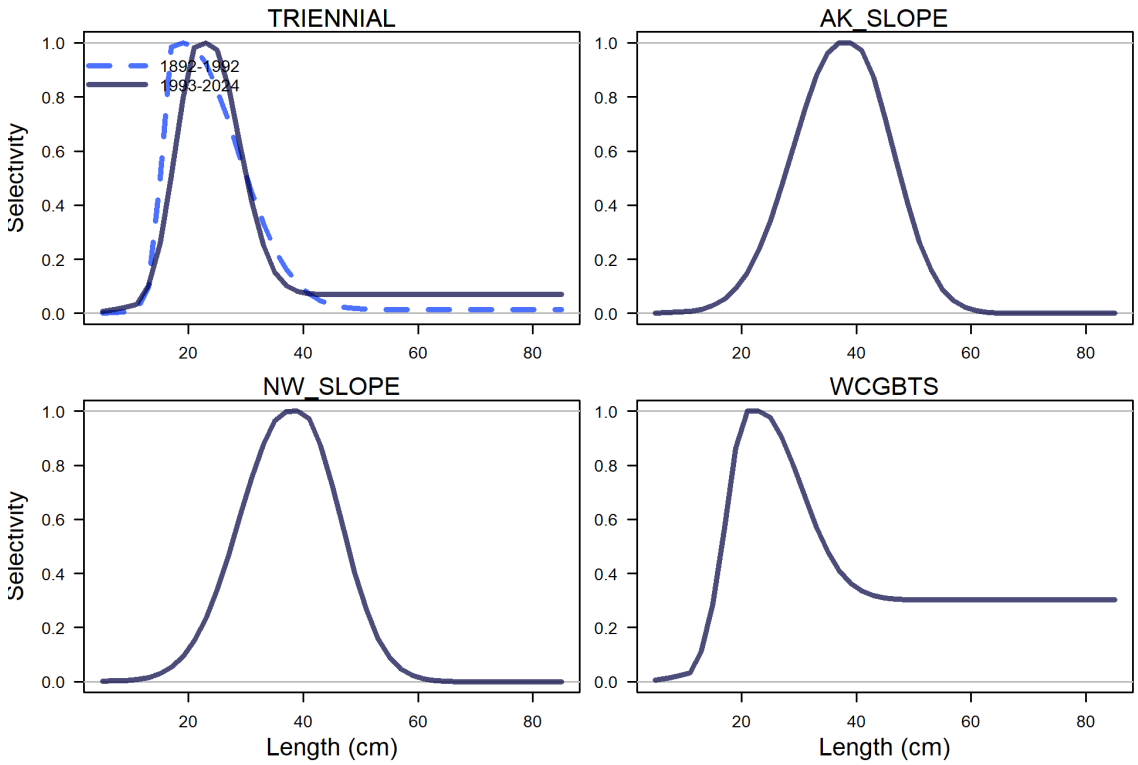


Figure 142: Time-varying selectivity for surveys with time blocks.

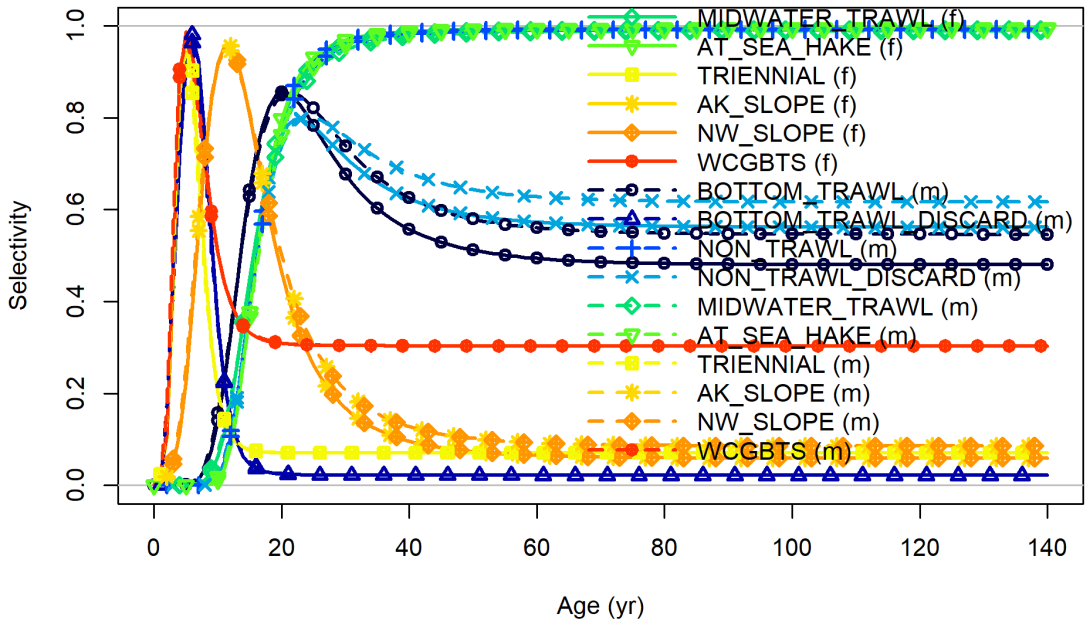


Figure 143: Ending selectivity at age derived from lengths for each fishery and survey.

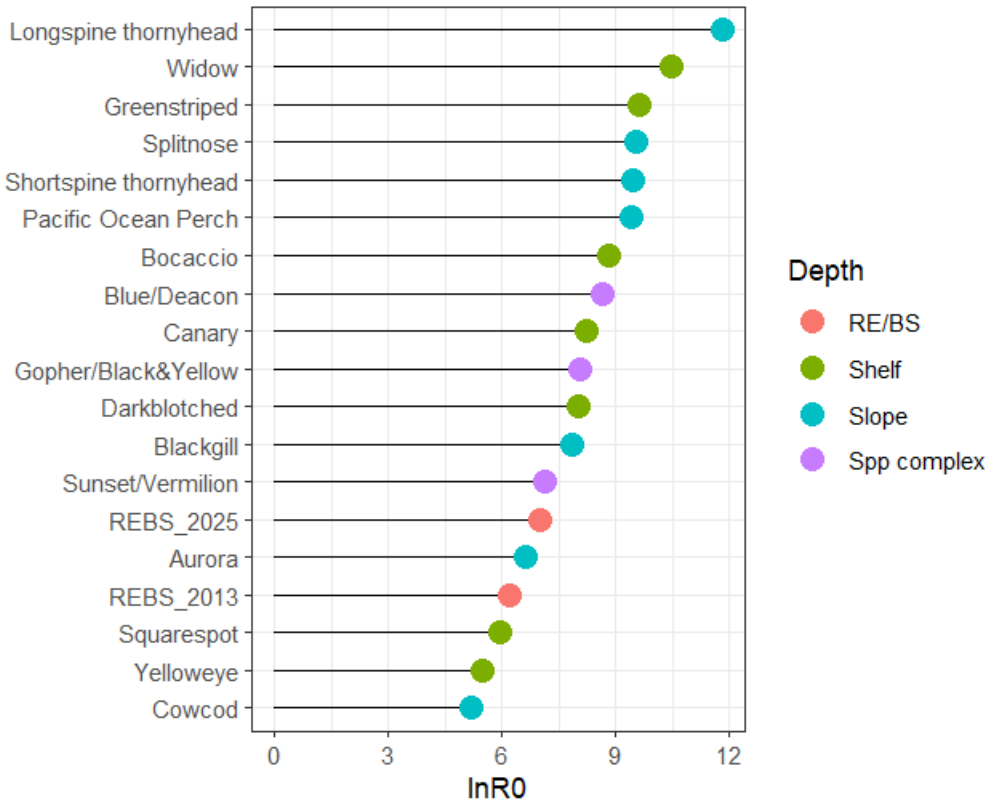


Figure 144: Estimated unfished recruitment (lnR0) for several assessed shelf and slope rockfishes.

8.9 Model Derived Outputs

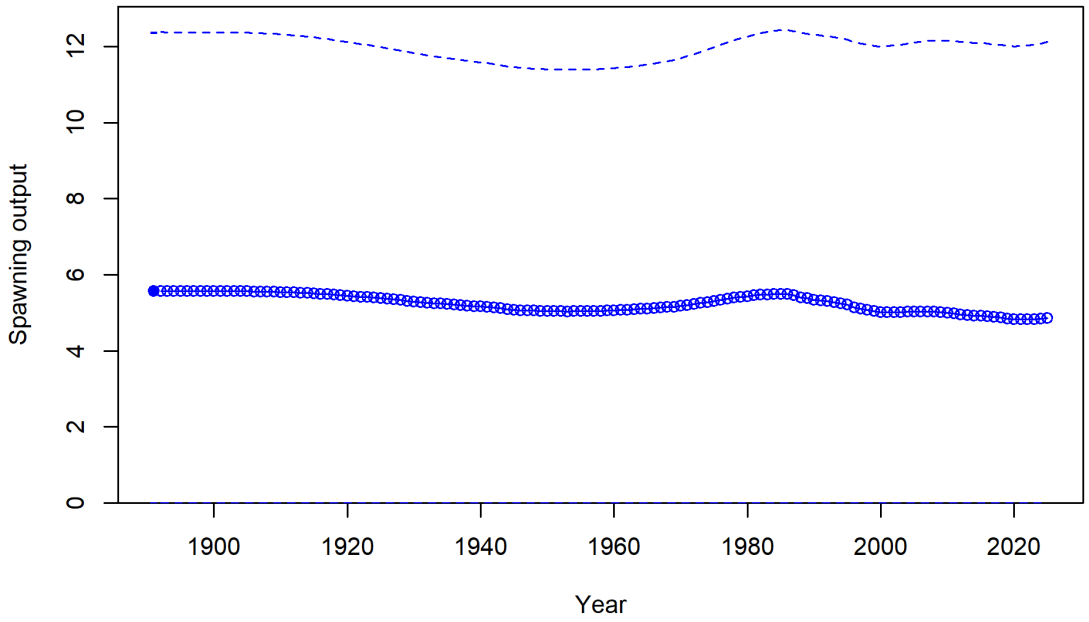


Figure 145: Estimated time series of spawning output (in millions of eggs) for the reference model.

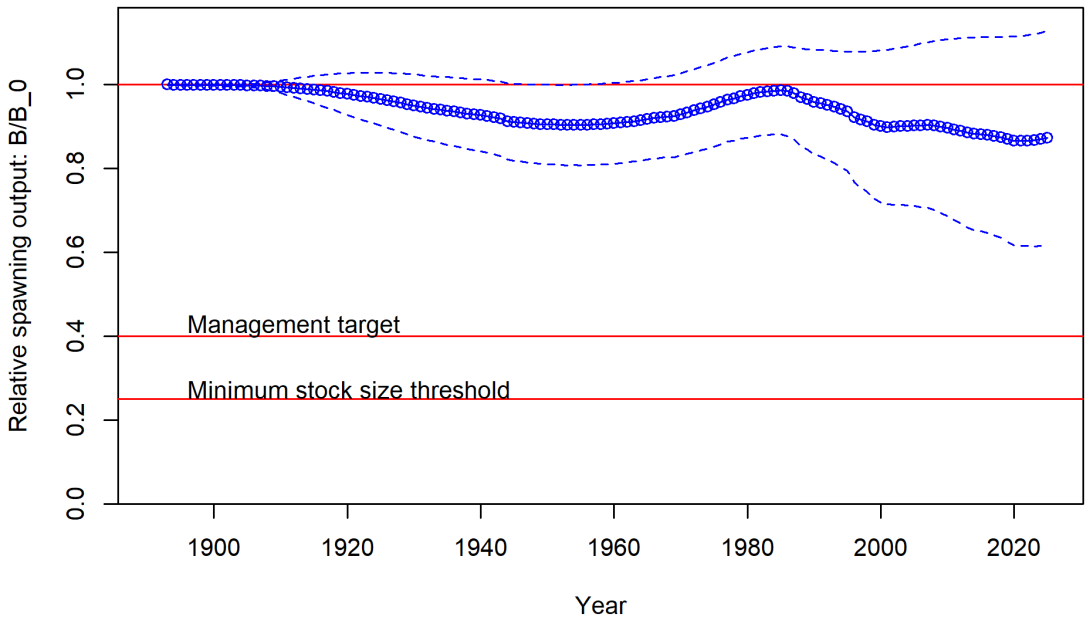


Figure 146: Estimated time series of fraction of unfished spawning output for the reference model.

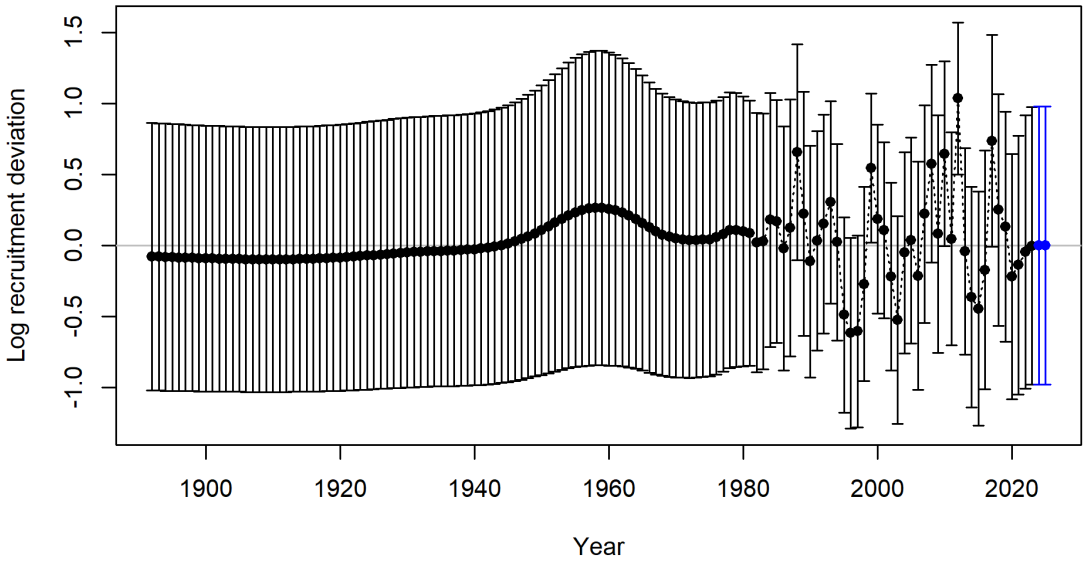


Figure 147: Estimated time series of recruitment deviations for the reference model.

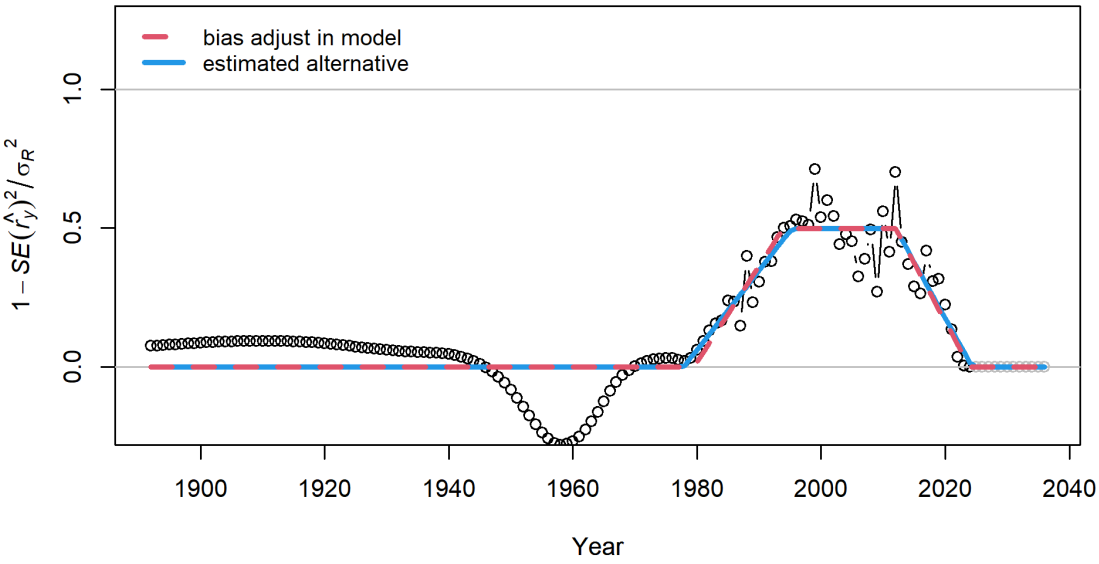


Figure 148: Bias adjustment applied to the recruitment deviations (red line). Points are transformed variances relative to the assumed variance of recruitment.

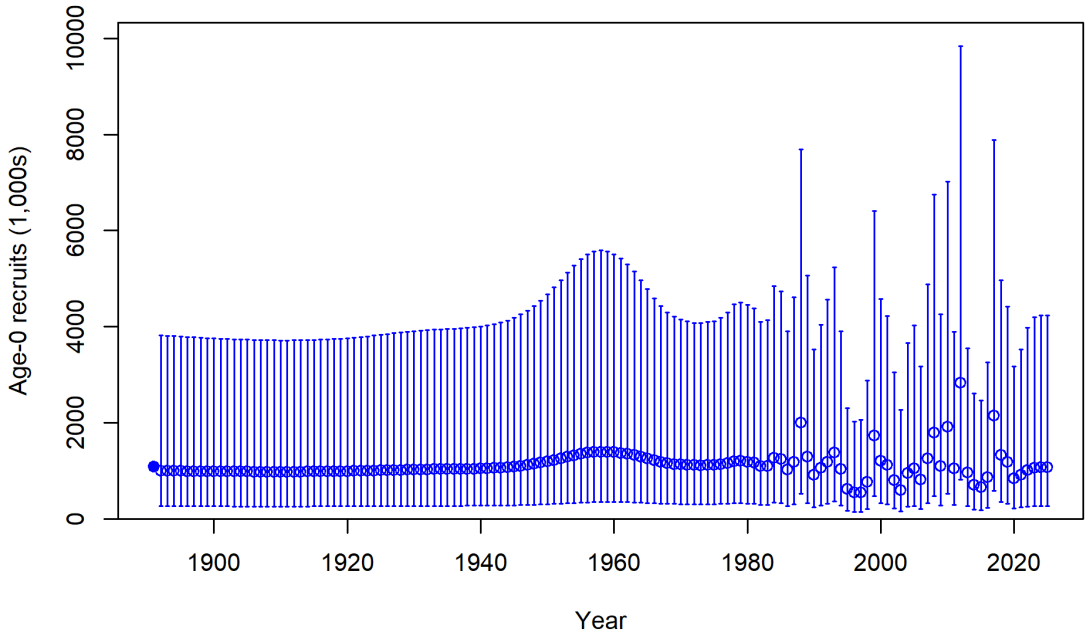


Figure 149: Estimated time series of age-0 recruits for the reference model.

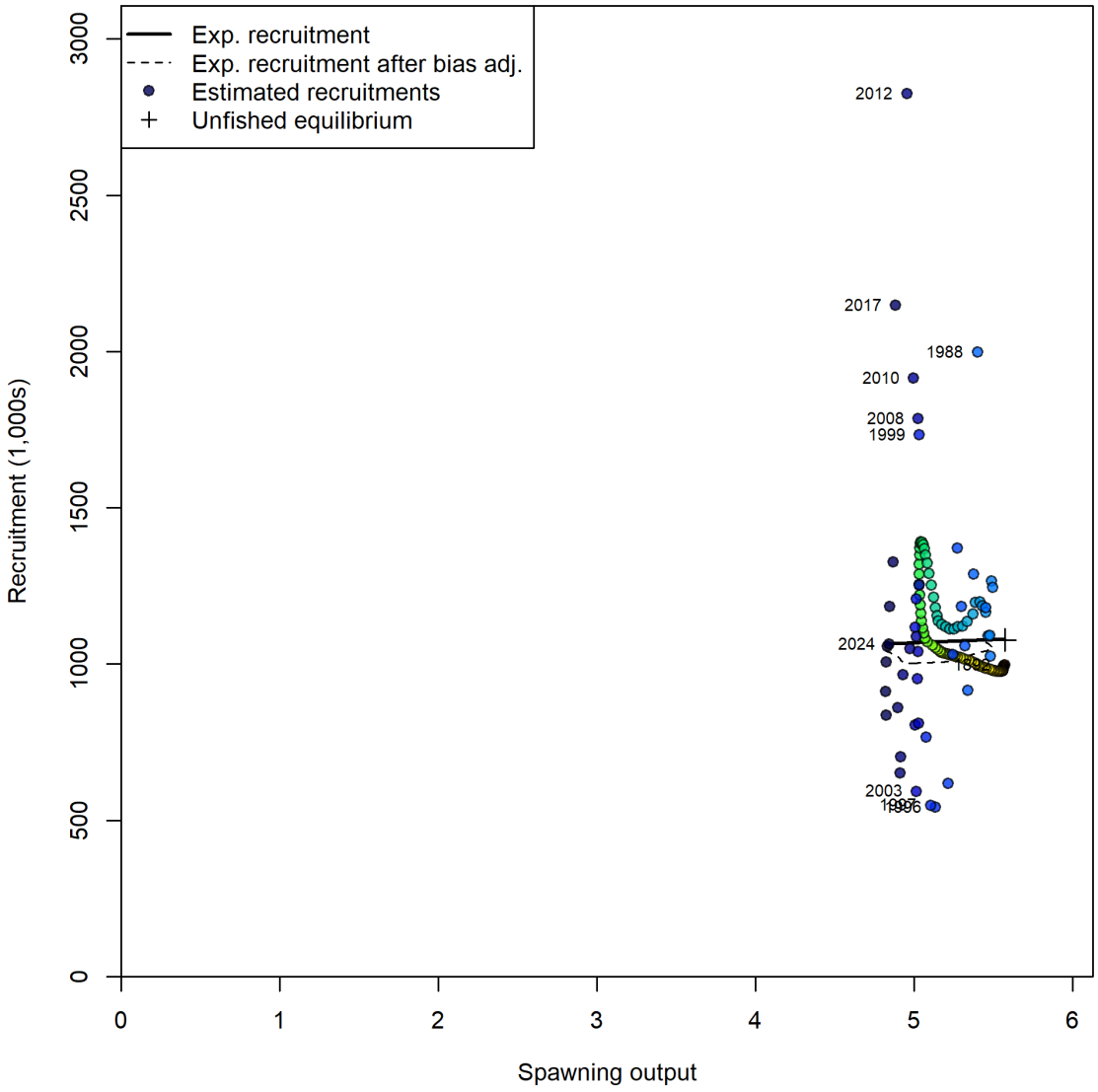


Figure 150: Stock-recruit curve with labels on first, last, and years with (log) deviations > 0.5. Point colors indicate year, with warmer colors indicating earlier years and cooler colors in showing later years.

8.10 Sensitivity Analyses

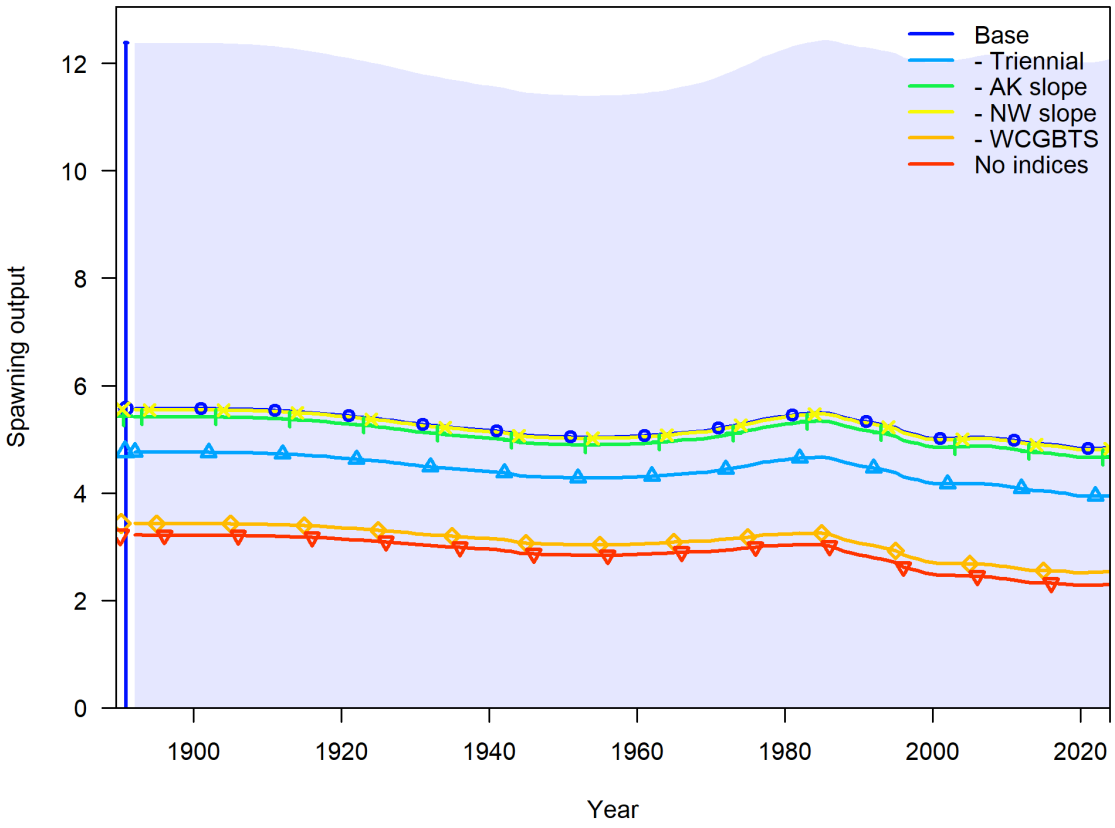


Figure 151: Spawning output (trillions of eggs) across data removal sensitivities (indices).

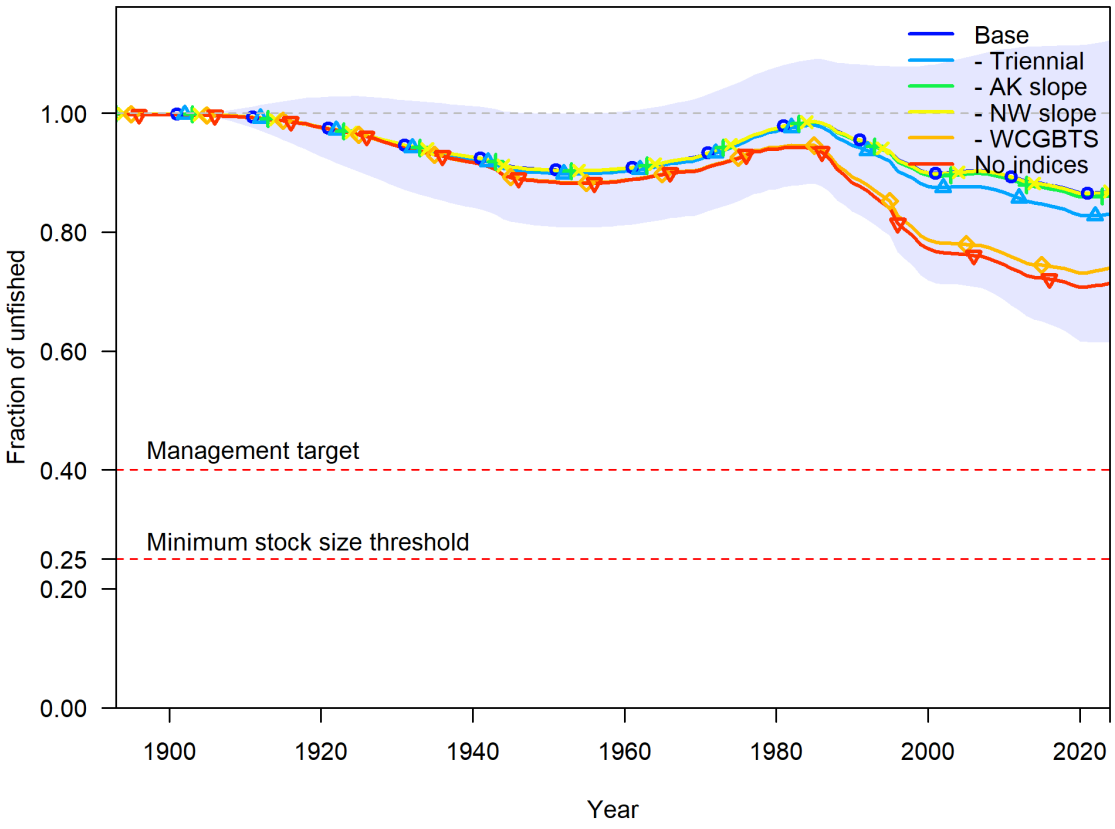


Figure 152: Relative spawning output (fraction unfished) across data removal sensitivities (indices).

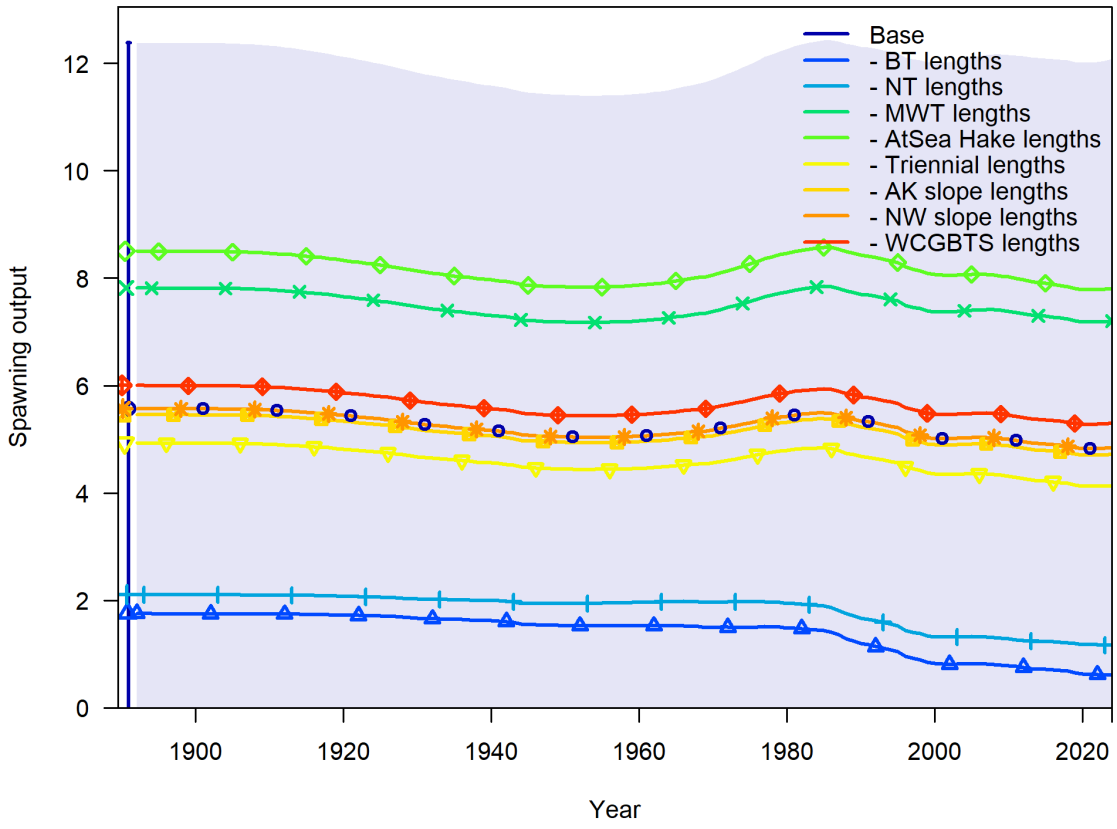


Figure 153: Spawning output (trillions of eggs) across data removal sensitivities (length compositions by fleet).

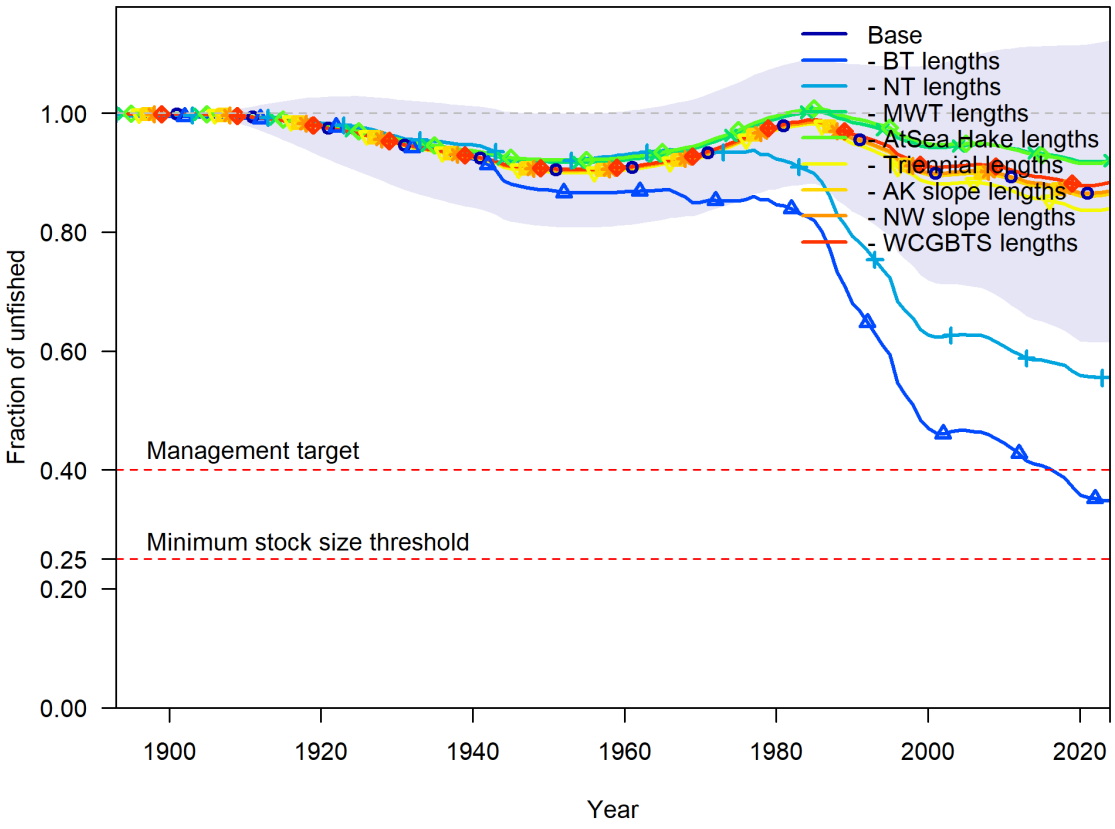


Figure 154: Relative spawning output (fraction unfished) across data removal sensitivities (length compositions by fleet).

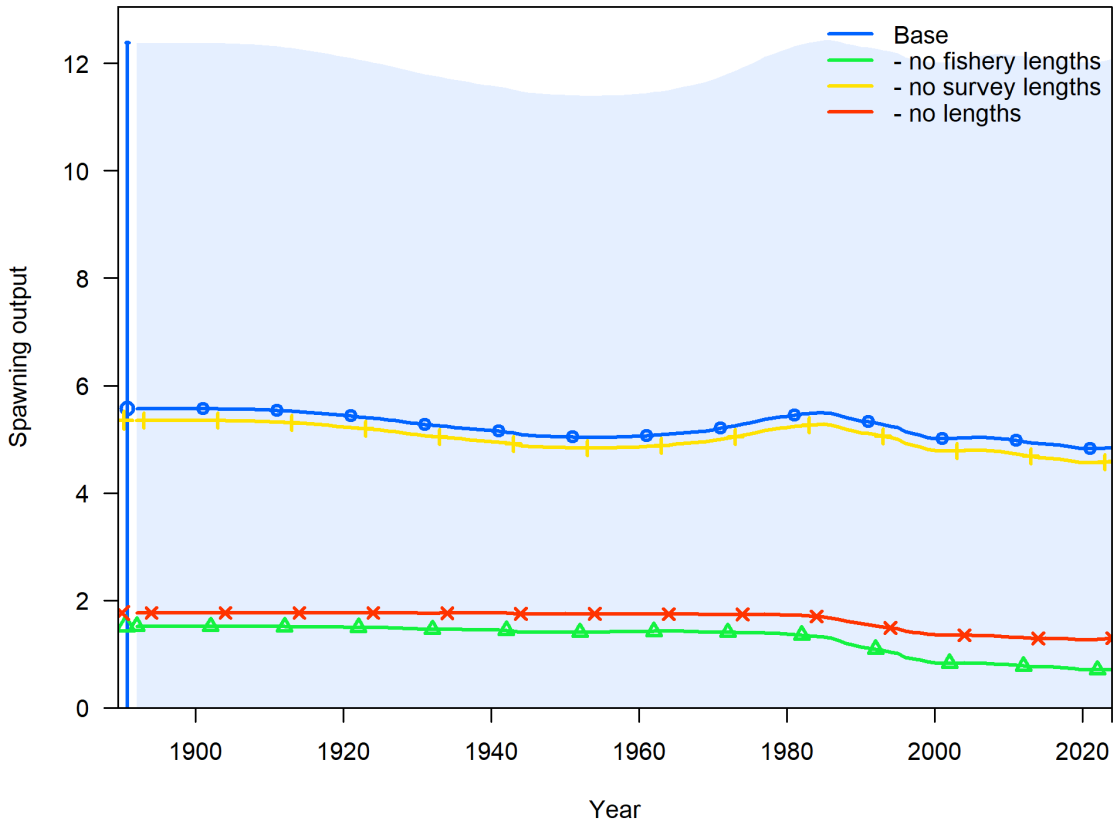


Figure 155: Spawning output (trillions of eggs) across data removal sensitivities (length compositions by source).

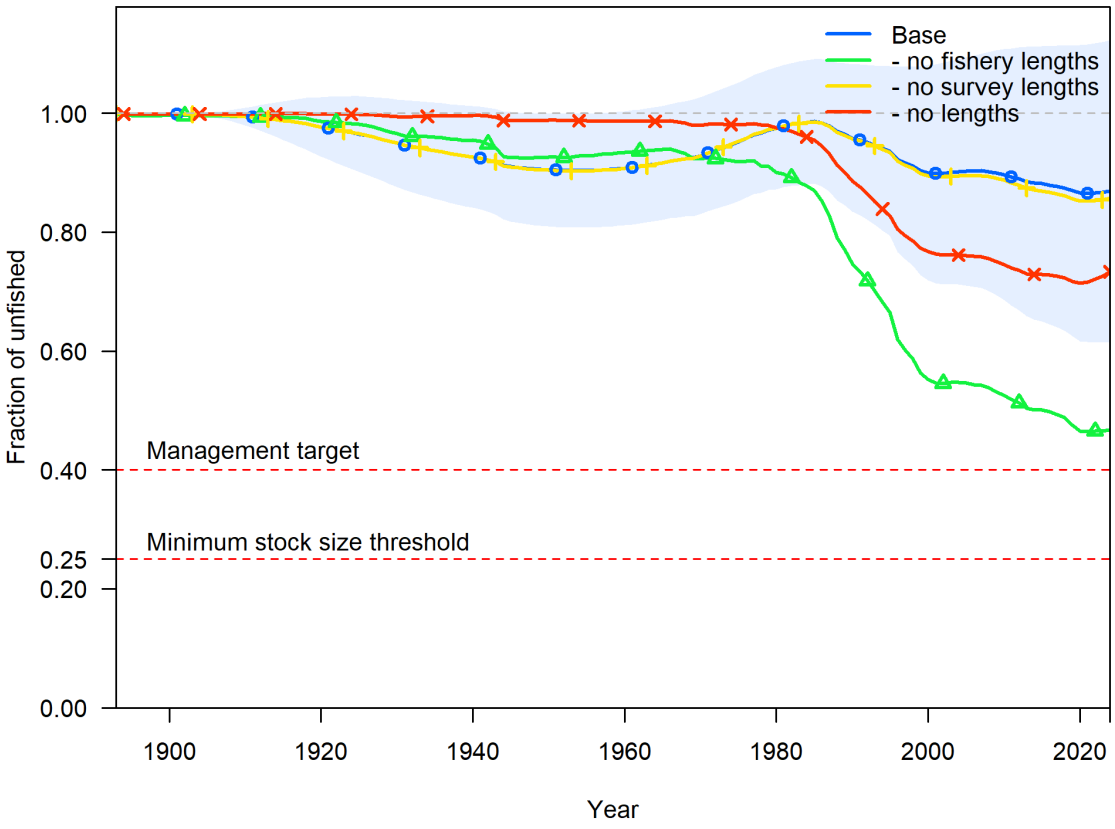


Figure 156: Relative spawning output (fraction unfished) across data removal sensitivities (length compositions by source).

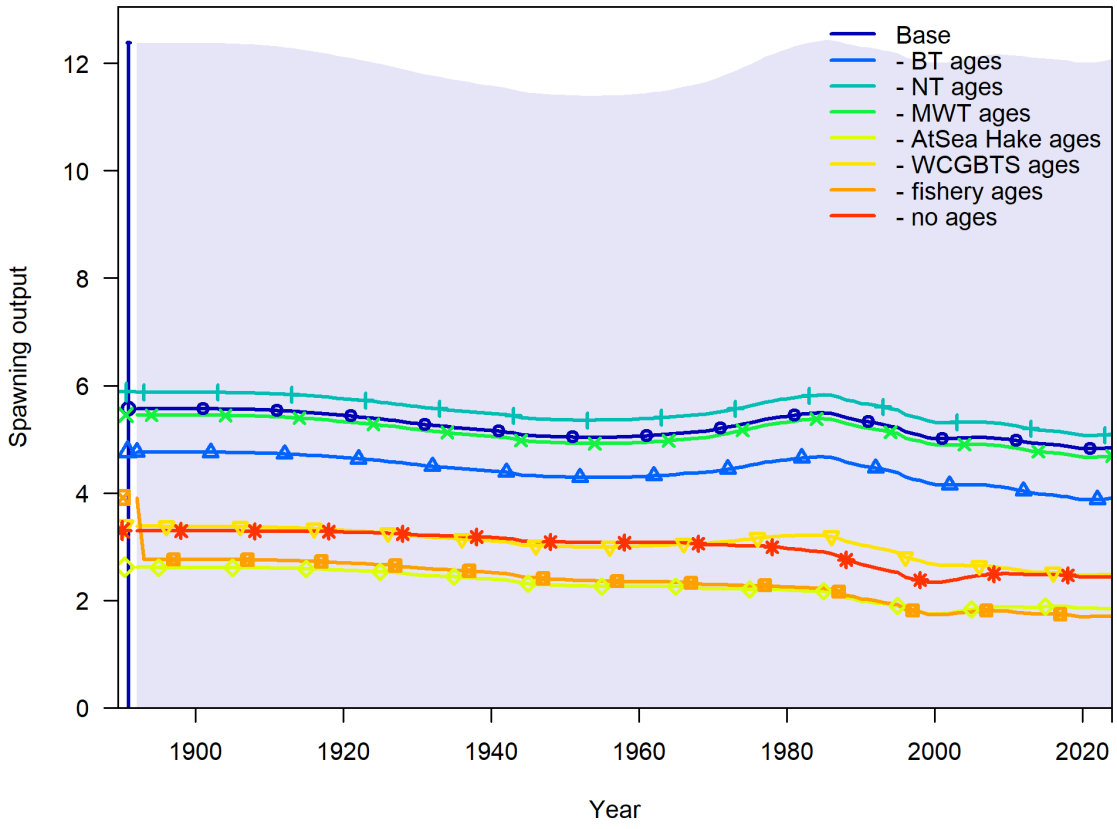


Figure 157: Spawning output (trillions of eggs) across data removal sensitivities (age compositions by fleet).

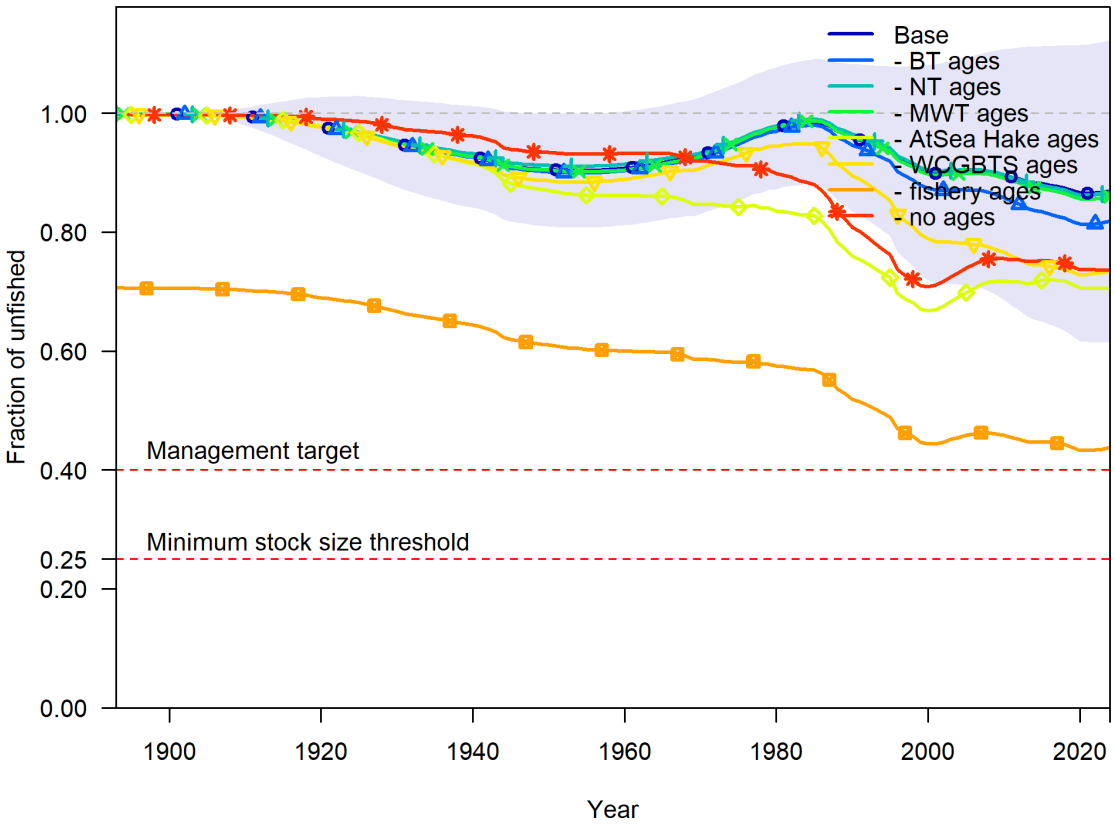


Figure 158: Relative spawning output (fraction unfished) across data removal sensitivities (age compositions by fleet).

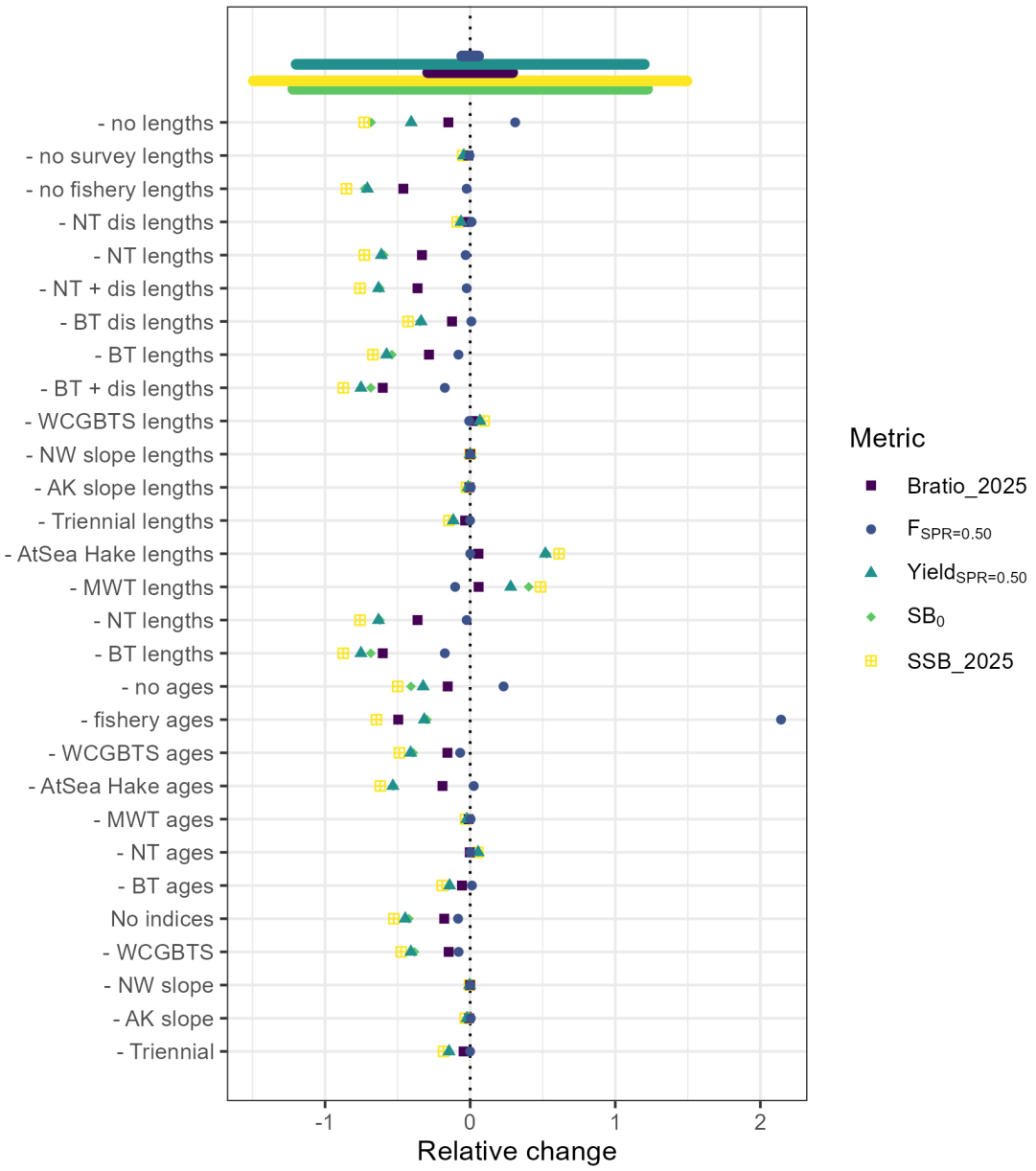


Figure 159: Relative change in management quantities across models conducted as sensitivities (removal of data sources).

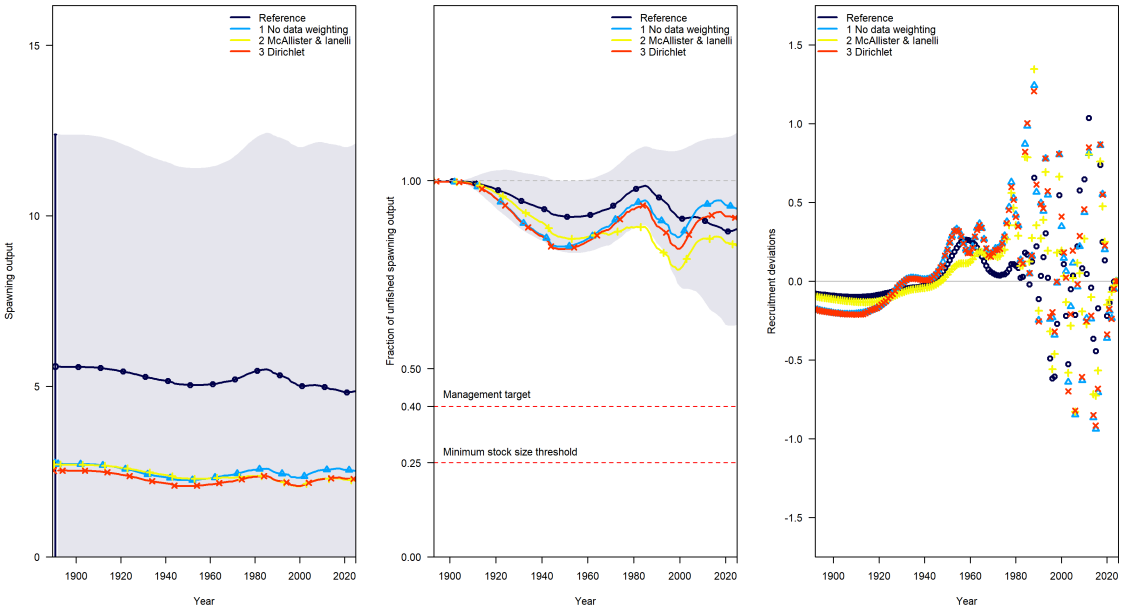


Figure 160: Comparison of spawning output (trillions of eggs; left panel), relative stock status (middle panel) and recruitment estimation (right panel) for models under different data weighting scenarios. The reference model uses the Francis method.

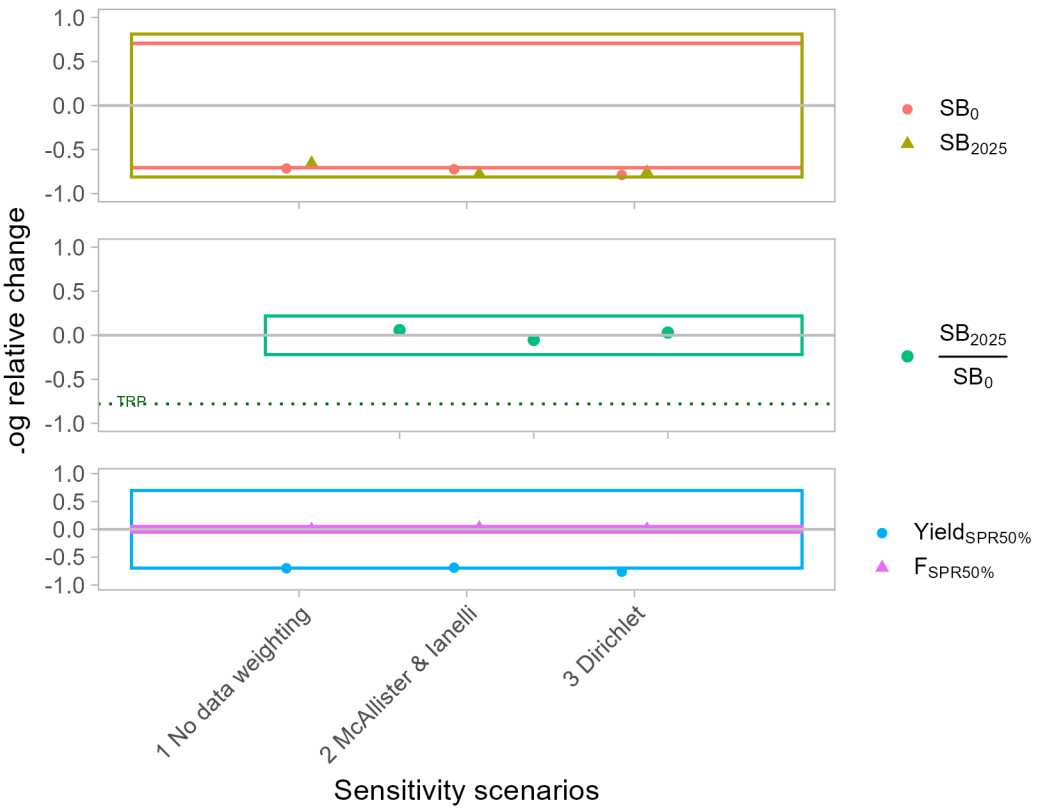


Figure 161: Log relative change (log((Model_sensi-Model_ref)/Model_ref)) in data weighting treatment for 5 derived quantities. Colored boxes indicate 95 percent confidence interval of the reference model. See 'Sensitivity Analysis' section for more details on each scenario.

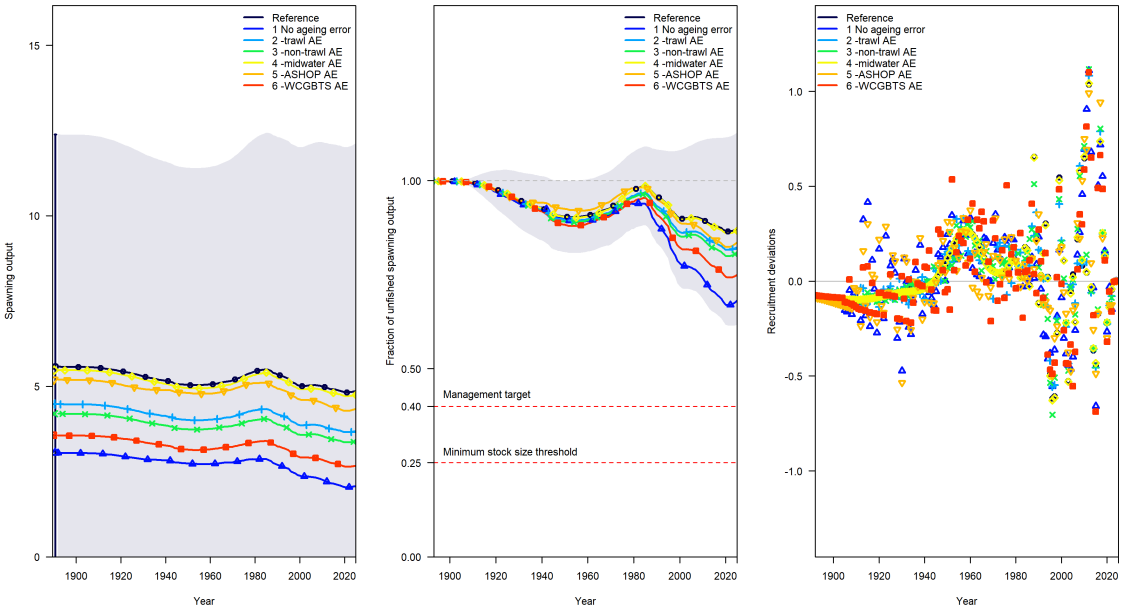


Figure 162: Comparison of spawning output (trillions of eggs; left panel), relative stock status (middle panel) and recruitment estimation (right panel) for models under different ageing error scenarios. The reference model uses ageing error matrices for all age sources.

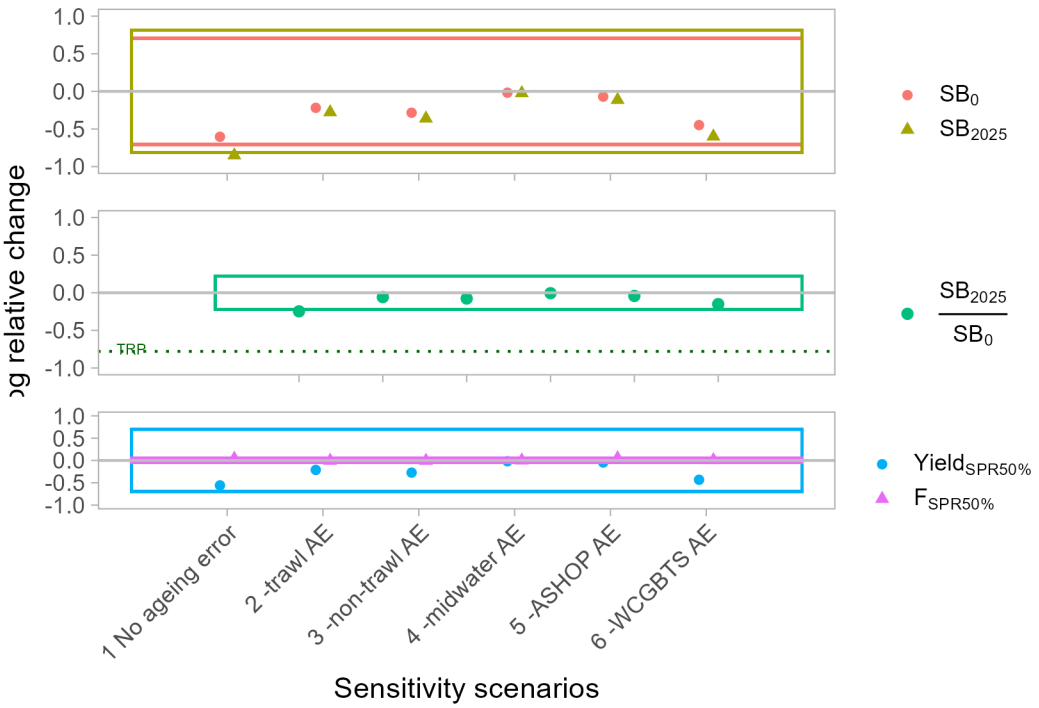


Figure 163: Log relative change (log((Model_sensi-Model_ref)/Model_ref)) in ageing error scenarios for 5 derived quantities. Colored boxes indicate 95 percent confidence interval of the reference model. See 'Sensitivity Analysis' section for more details on each scenario.

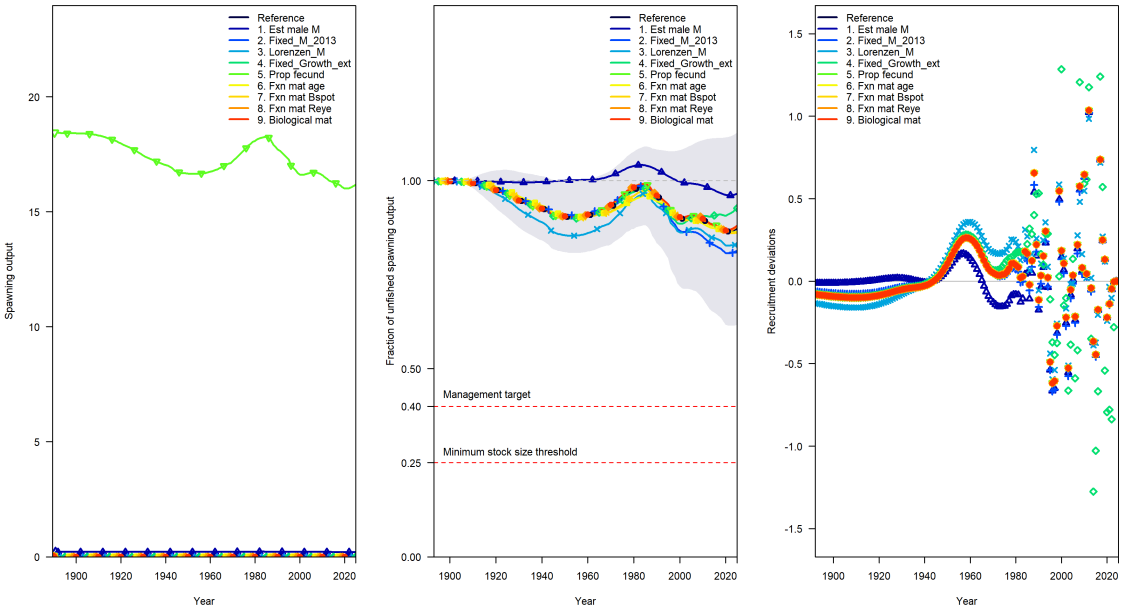


Figure 164: Comparison of spawning output (trillions of eggs; left panel), relative stock status (middle panel) and recruitment estimation (right panel) for models under different natural mortality, growth and reproductive biology scenarios.

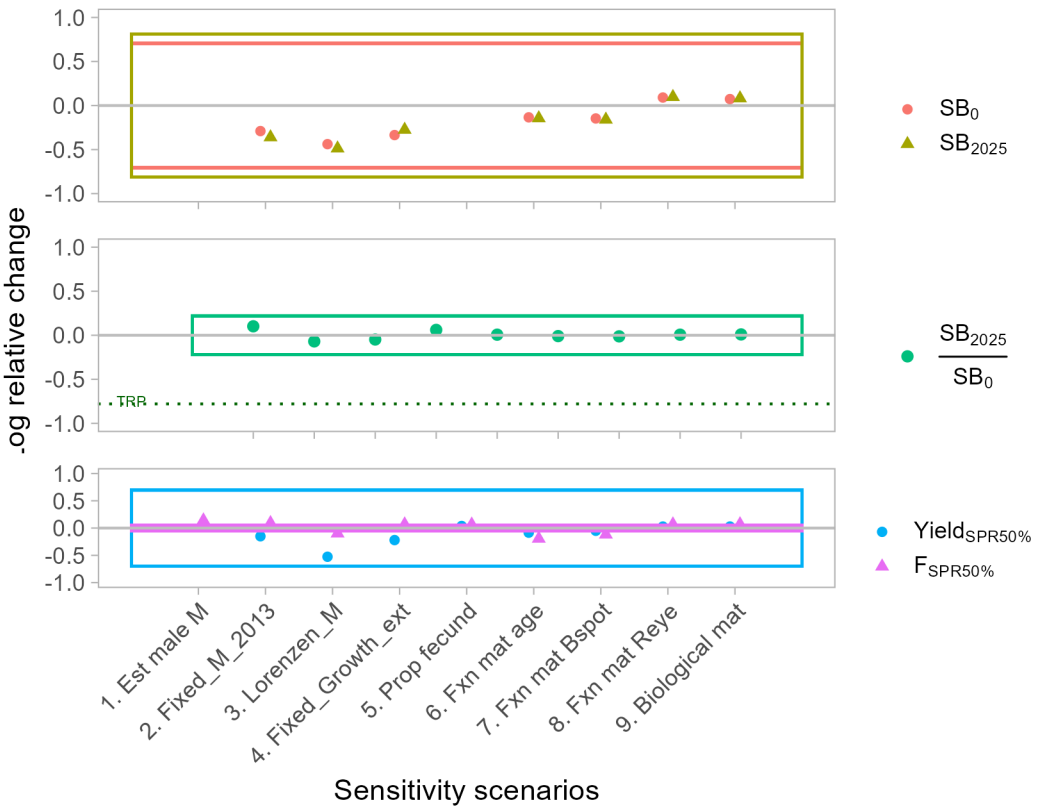


Figure 165: Log relative change (log((Model_sensi-Model_ref)/Model_ref)) in natural mortality, growth and reproductive biology scenarios for 5 derived quantities. Colored boxes indicate 95 percent confidence interval of the reference model. See 'Sensitivity Analysis' section for more details on each scenario.

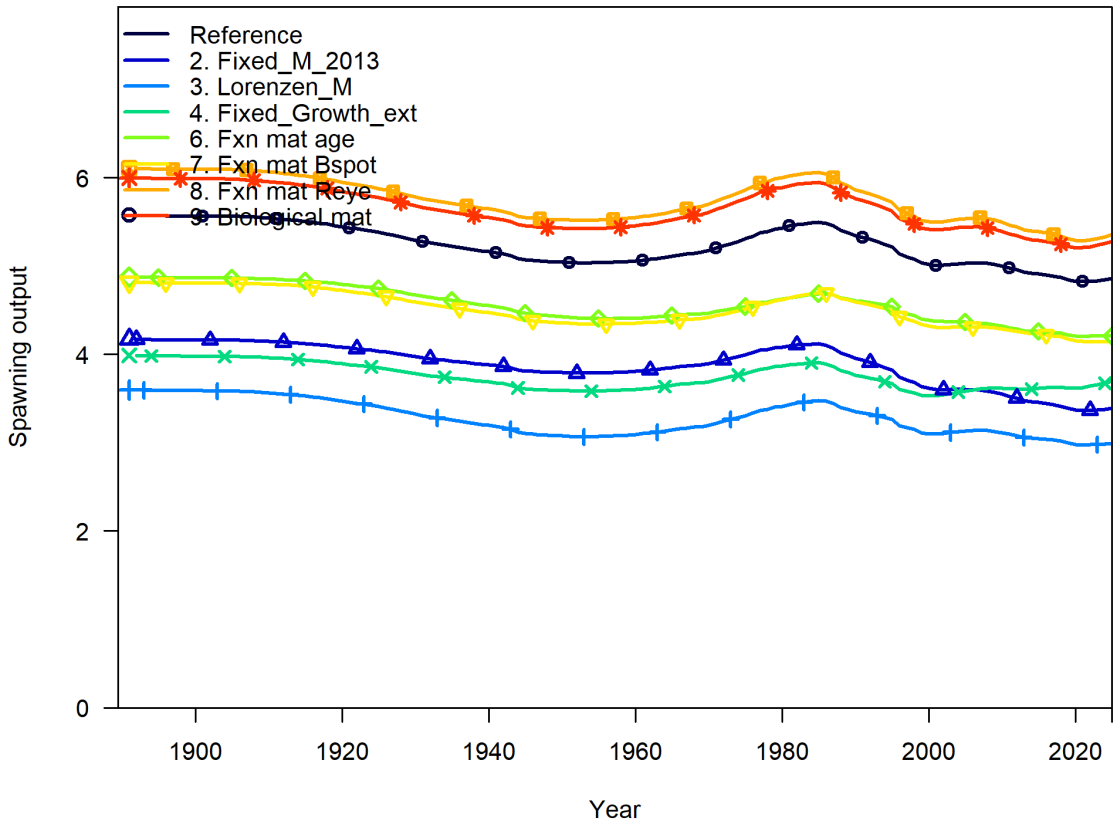


Figure 166: Comparison of spawning output (trillions of eggs) for models under different natural mortality, growth and reproductive biology scenarios. This comparison excludes the model estimating natural mortality, as the scale goes extremely high, and the weight proportional to fecundity scenario, as it is on a different scale than the other models.

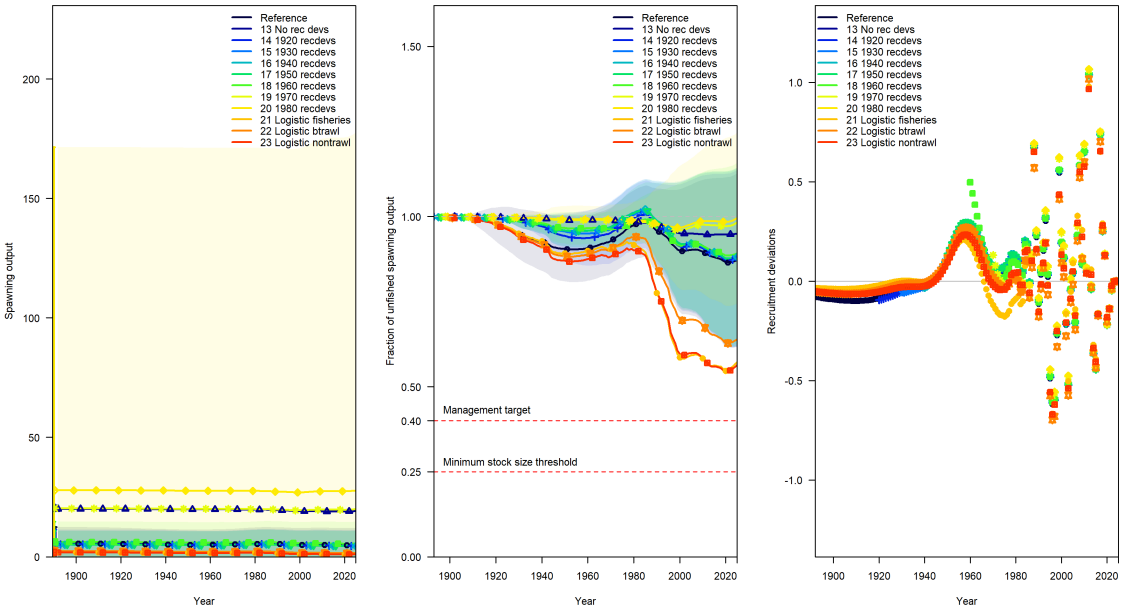


Figure 167: Comparison of spawning output (trillions of eggs; left panel), relative stock status (middle panel) and recruitment estimation (right panel) for models under different recruitment and selectivity scenarios.

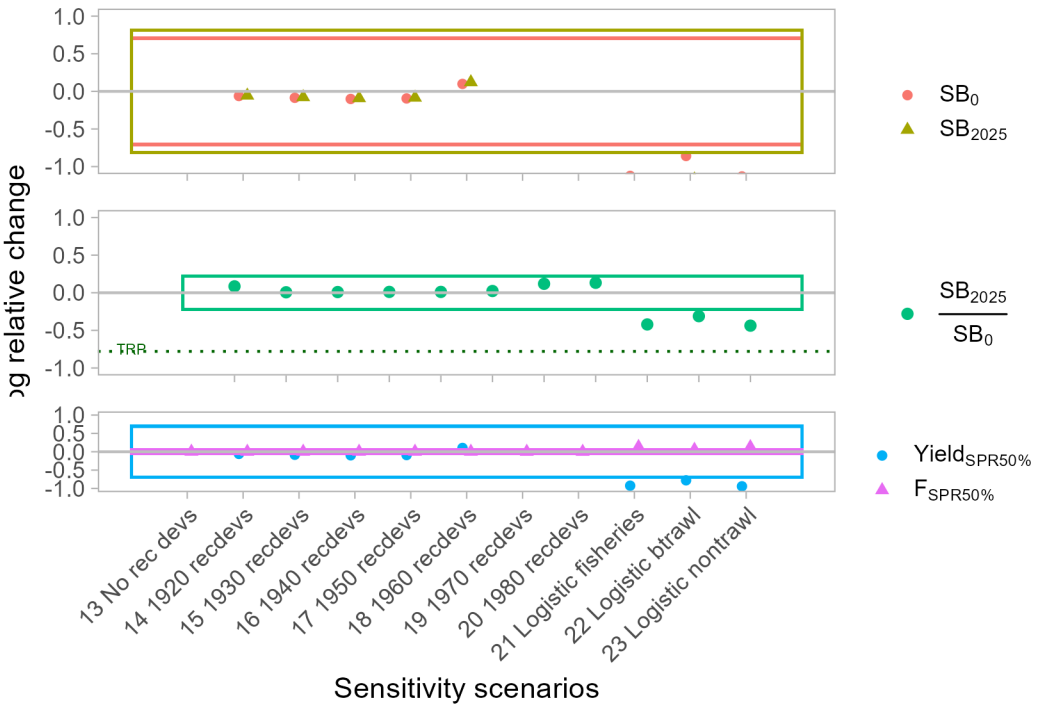


Figure 168: Log relative change (log((Model_sensi-Model_ref)/Model_ref)) in recruitment and selectivity scenarios for 5 derived quantities. Colored boxes indicate 95 percent confidence interval of the reference model. See 'Sensitivity Analysis' section for more details on each scenario.

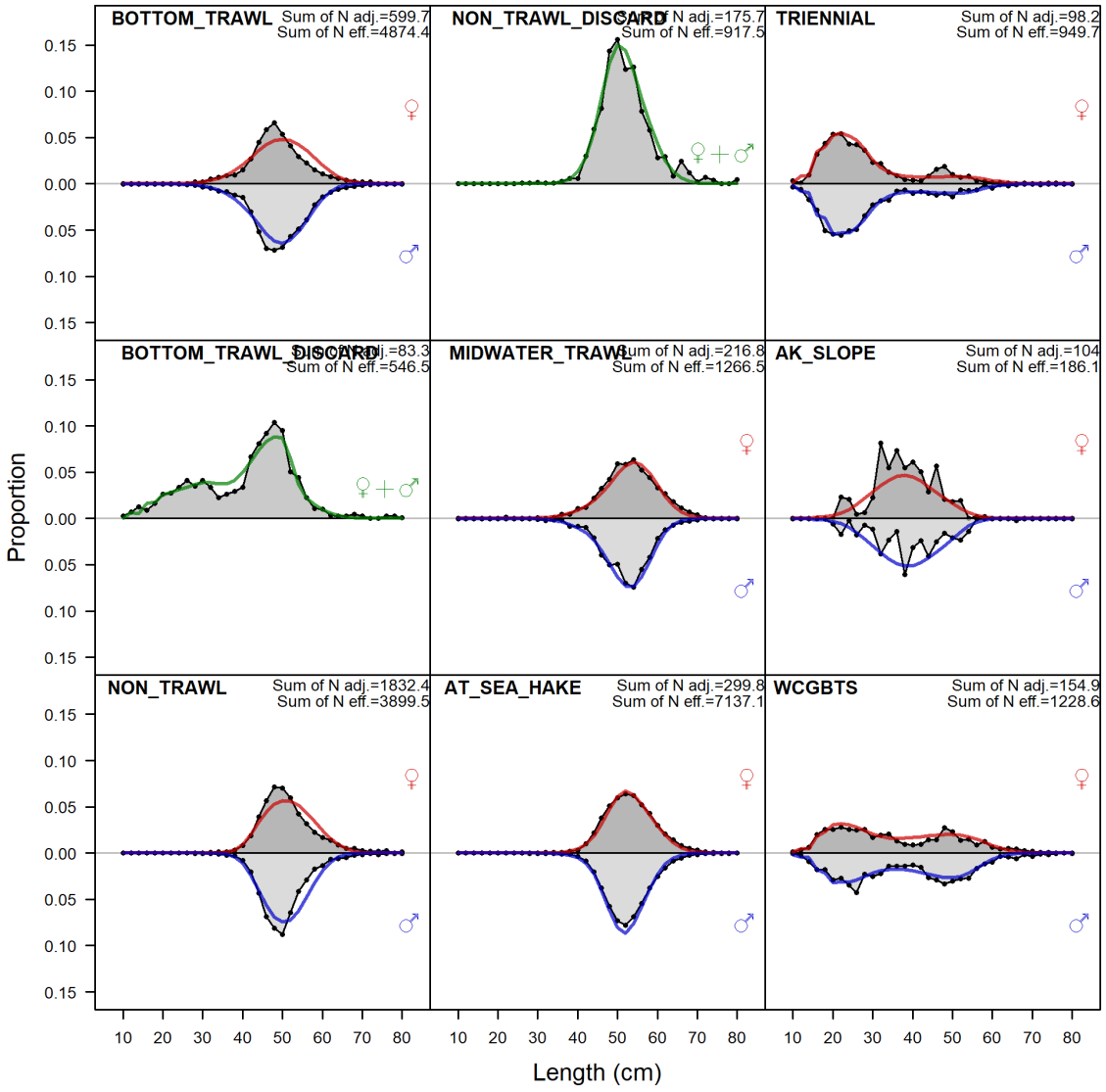


Figure 169: Aggregate fit to length compositions for the scenario that assume logistic selectivity for all fisheries and time blocks.

8.11 Likelihood Profiles

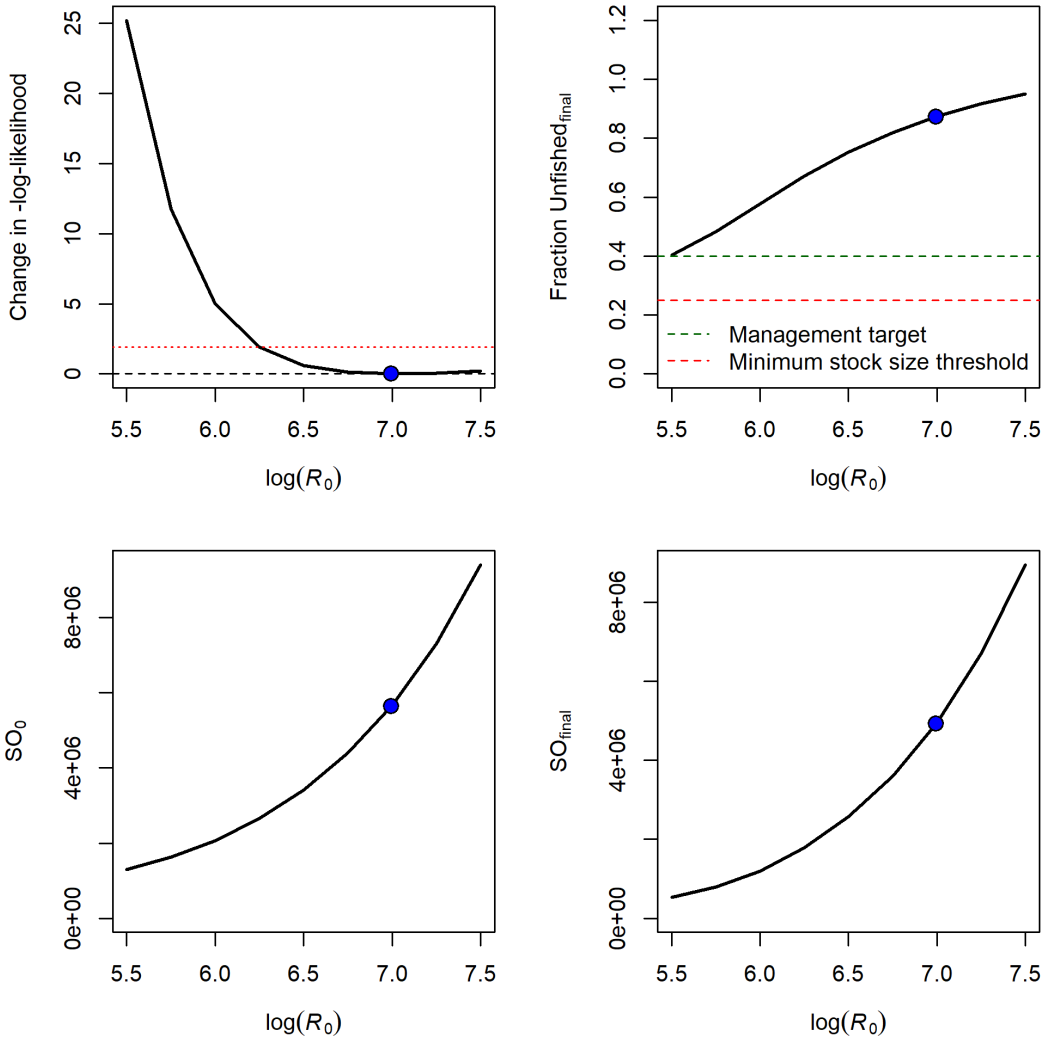


Figure 170: Initial recruitment (lnR_0) likelihood profile (change in the negative log-likelihood across a range of $ln(R0)$ values) and derived quantities. Red line in the top left figure indicates the significance level in likelihood difference.

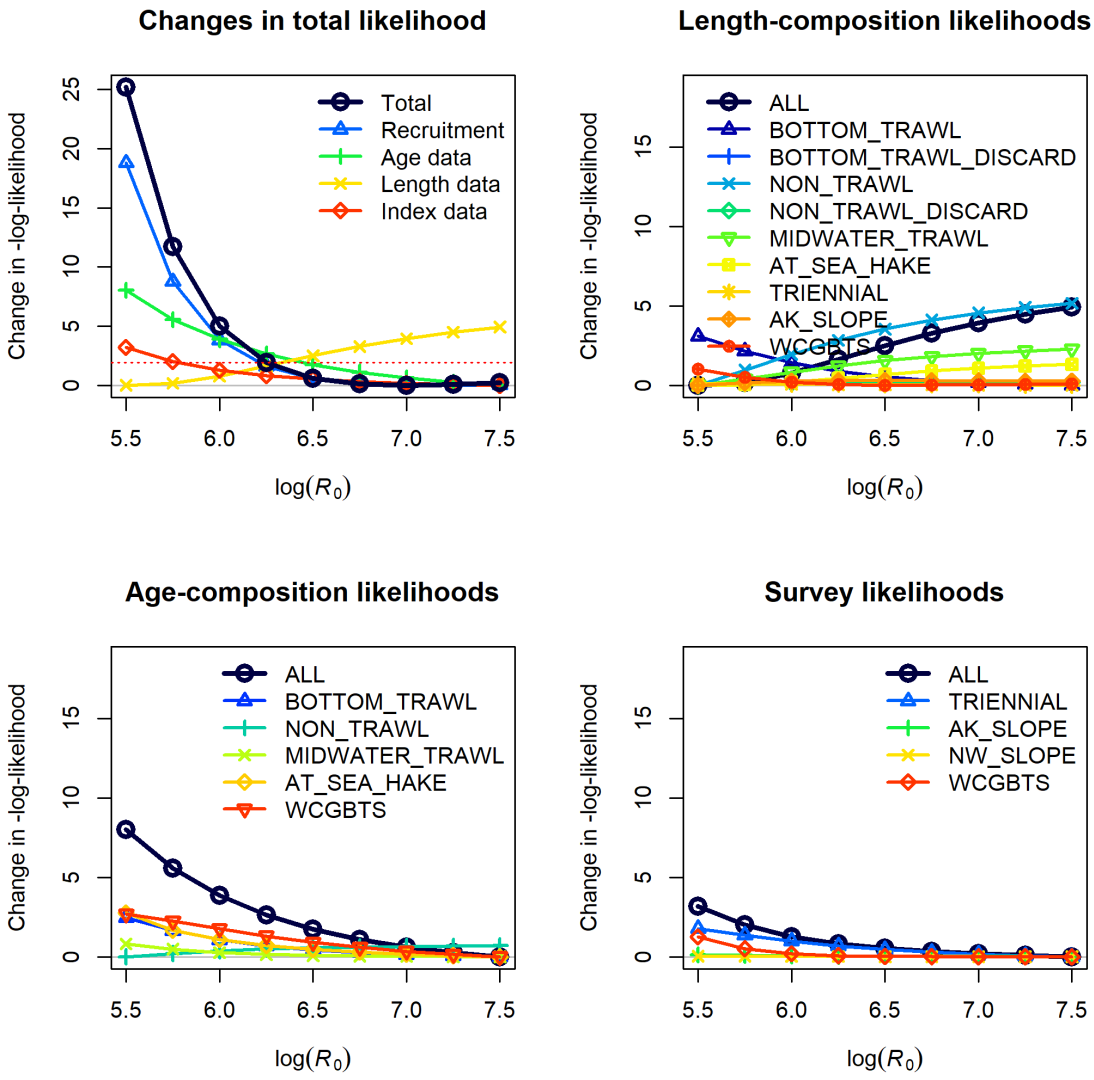


Figure 171: Initial recruitment ($ln(R0)$) likelihood profile for each of the likelihood components.

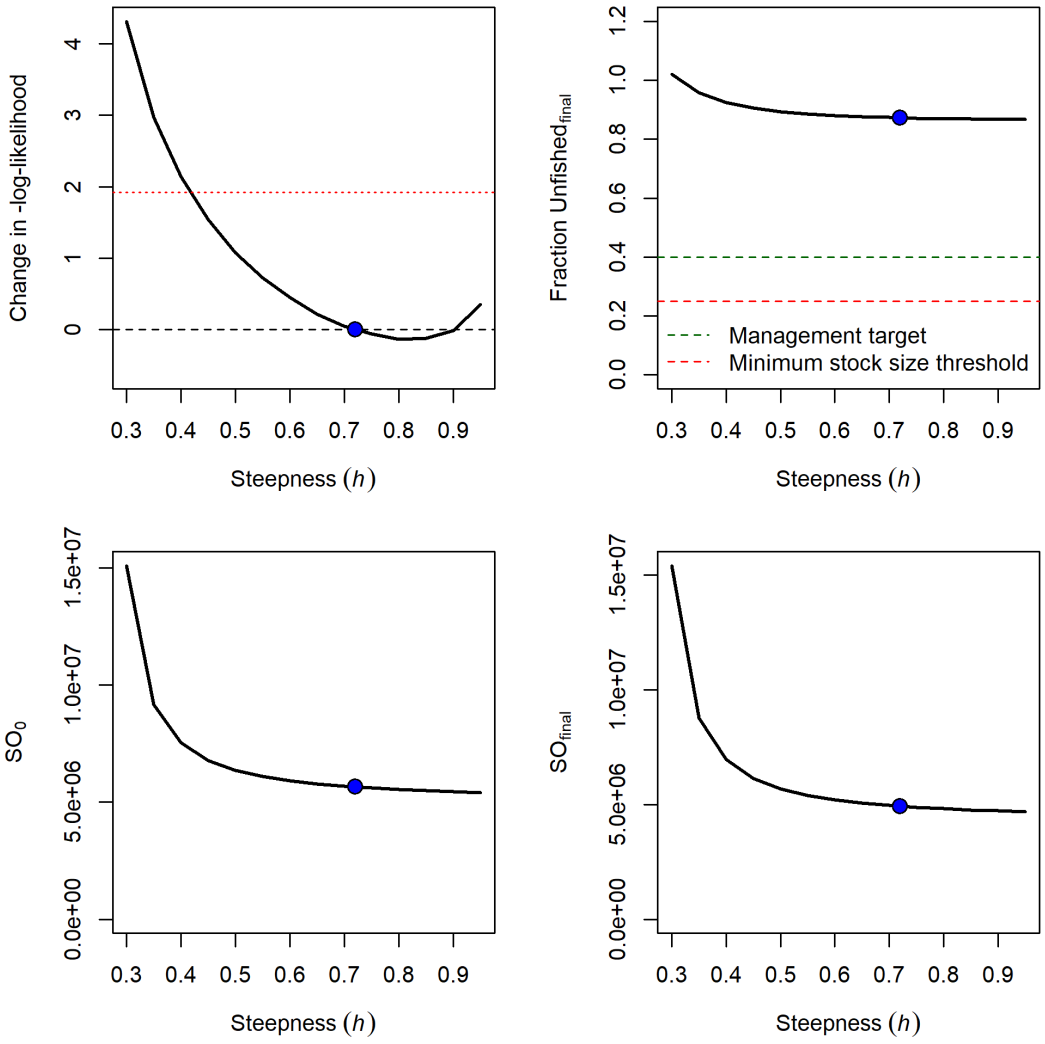


Figure 172: Steepness (h) likelihood profile (change in the negative log-likelihood across a range of h values) and derived quantities. Red line in the top left figure indicates the significance level in likelihood difference.

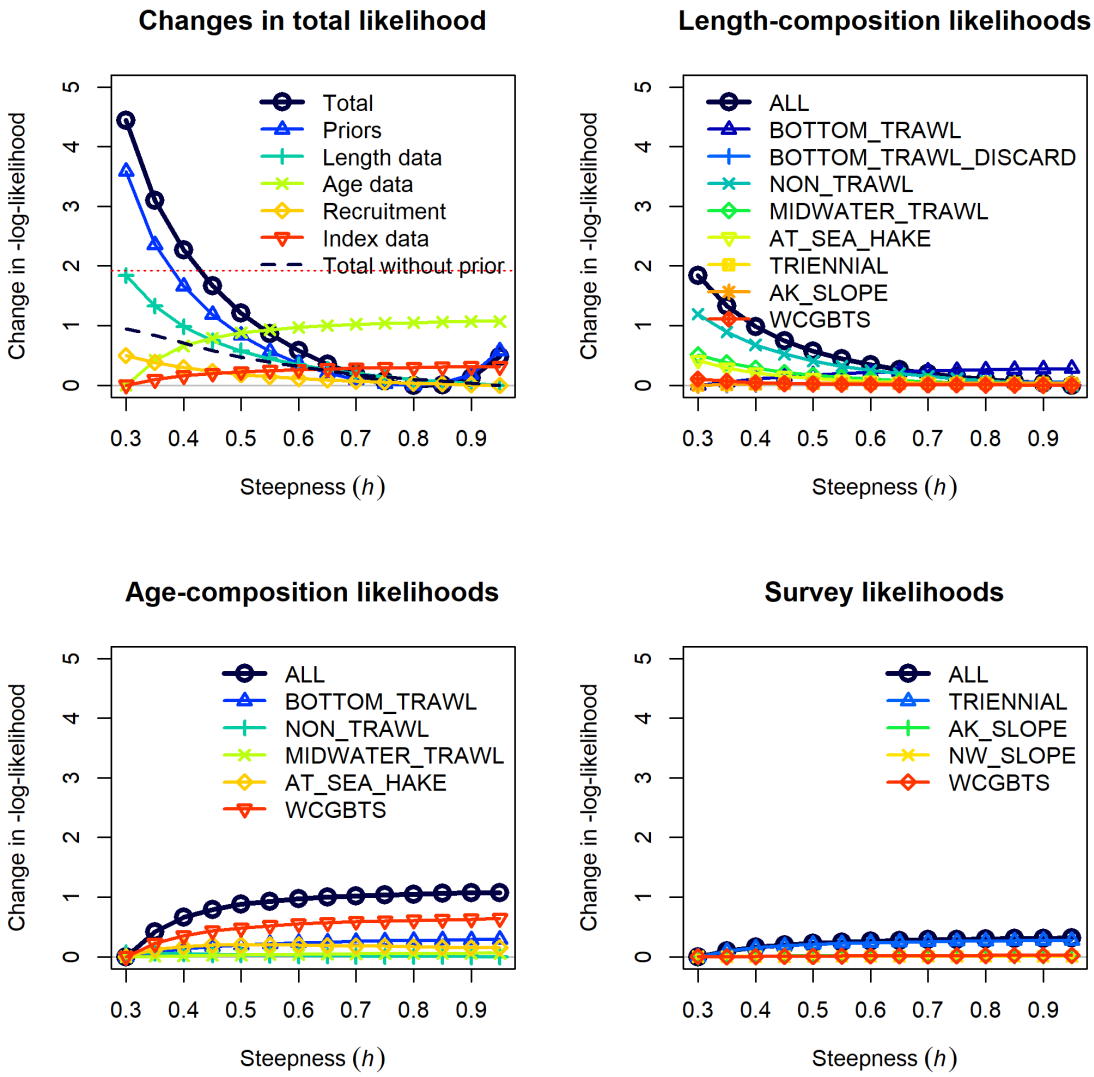


Figure 173: Steepness (h) likelihood profile for each of the likelihood components.

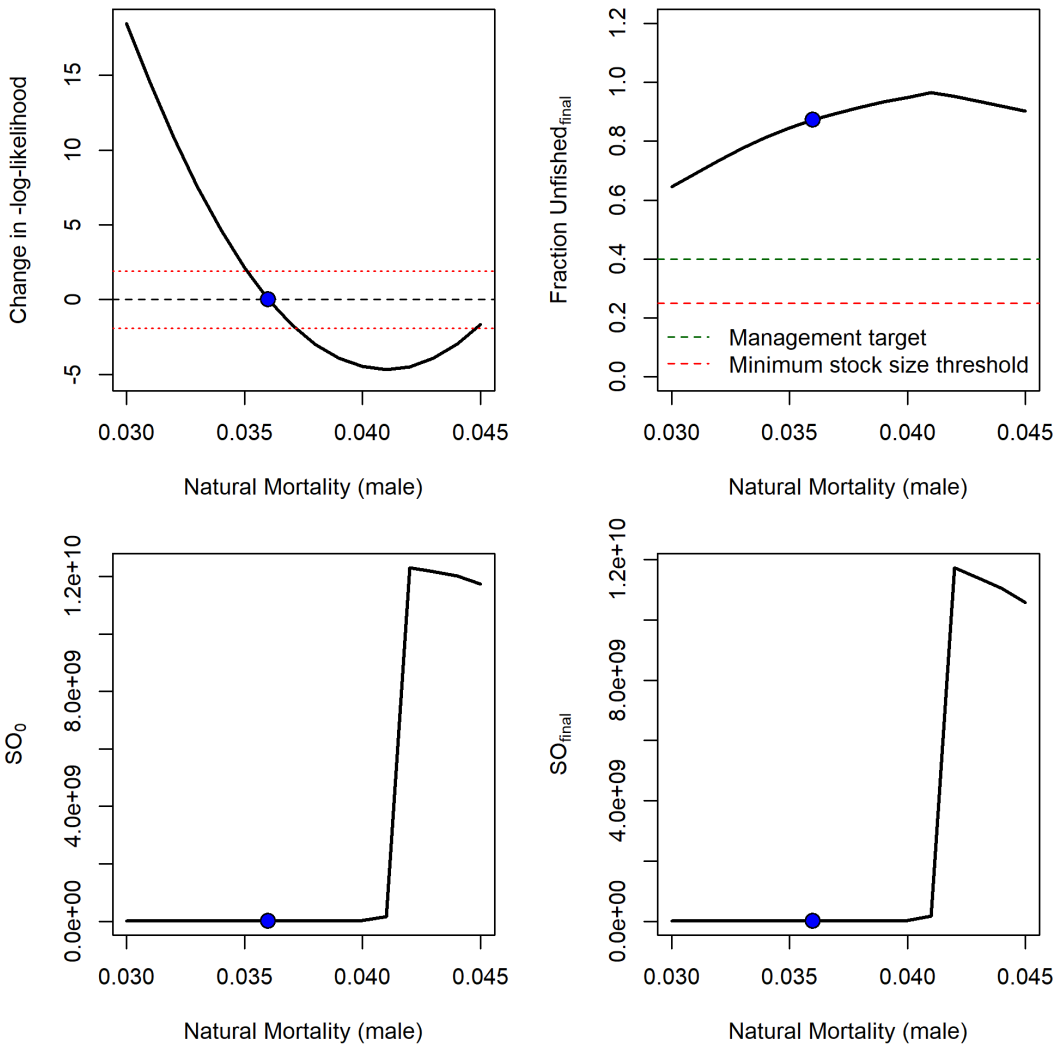


Figure 174: Male natural mortality (M) likelihood profile (change in the negative log-likelihood across a range of male M values) and derived quantities. Red line in the top left figure indicates the significance level in likelihood difference.

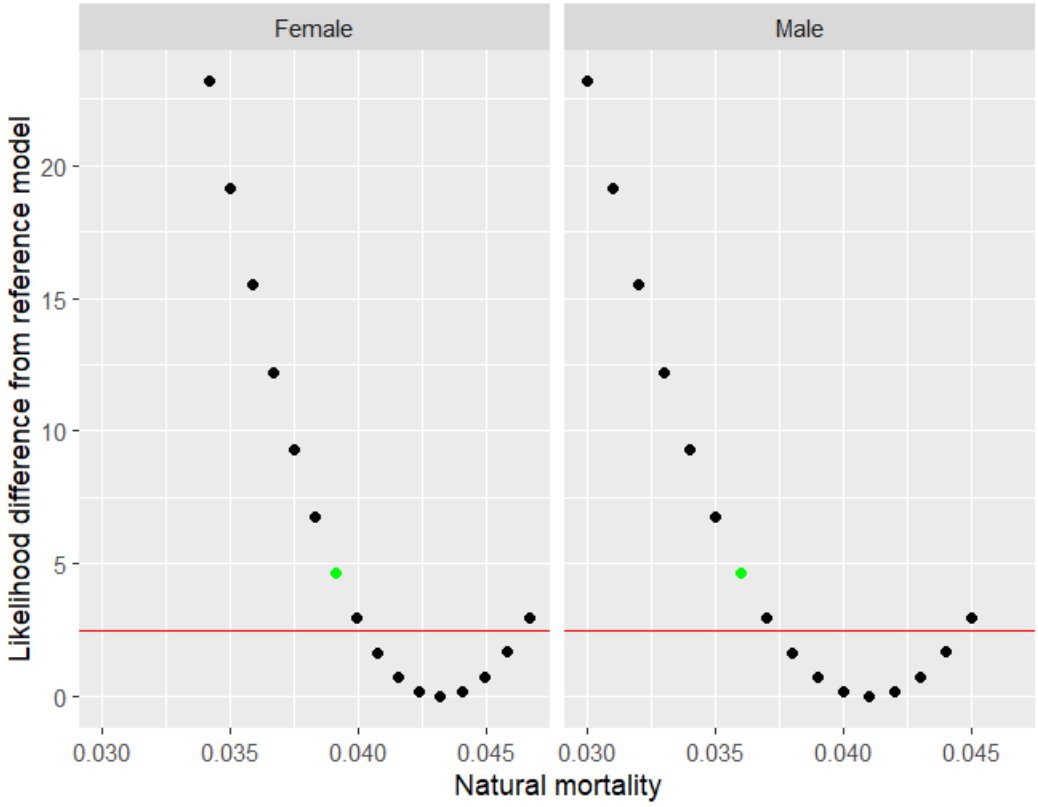


Figure 175: Likelihood differences by natural mortality (M) by sex.

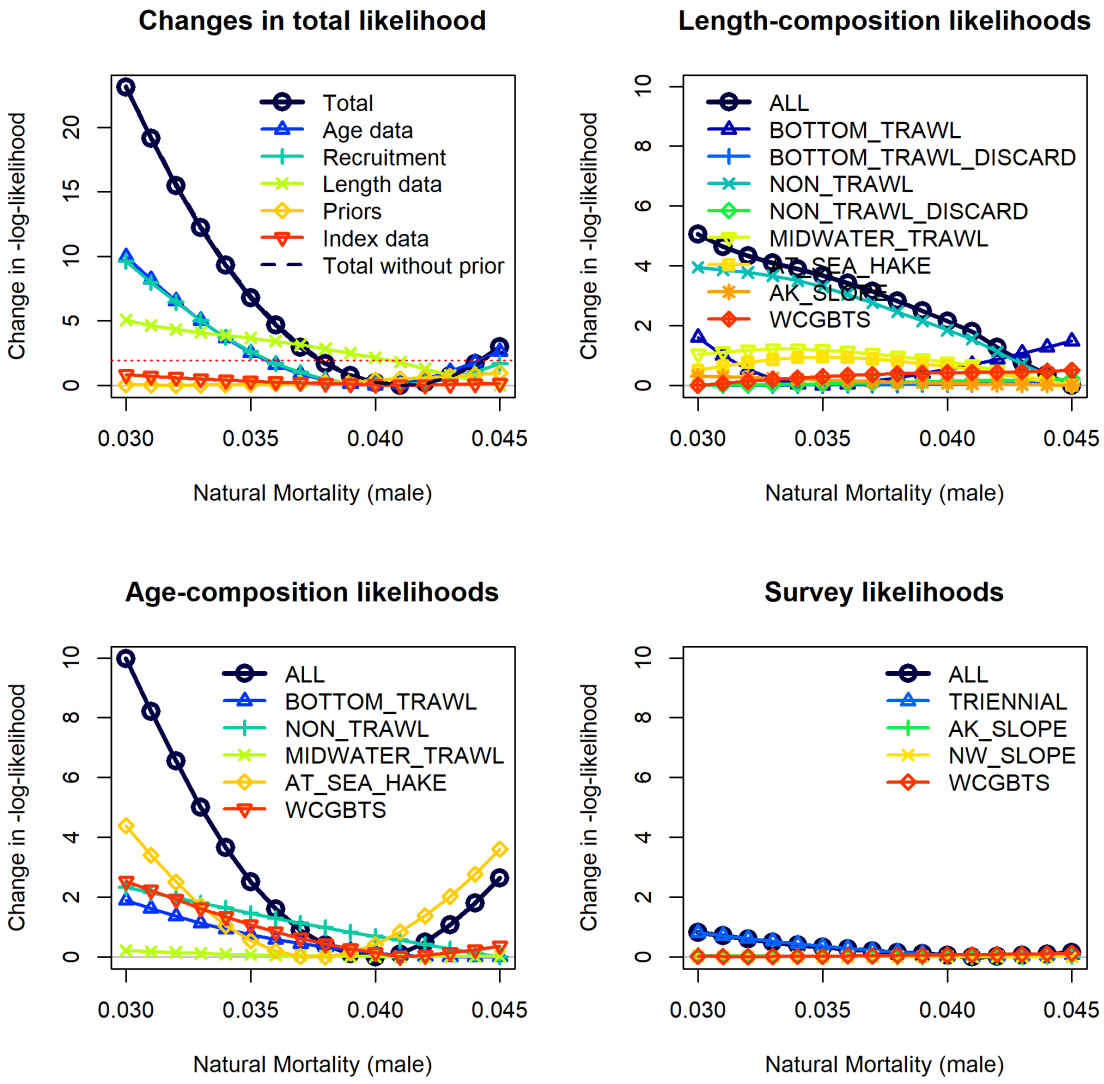


Figure 176: Male natural mortality (M) likelihood profile for each of the likelihood components.

8.12 States of Nature

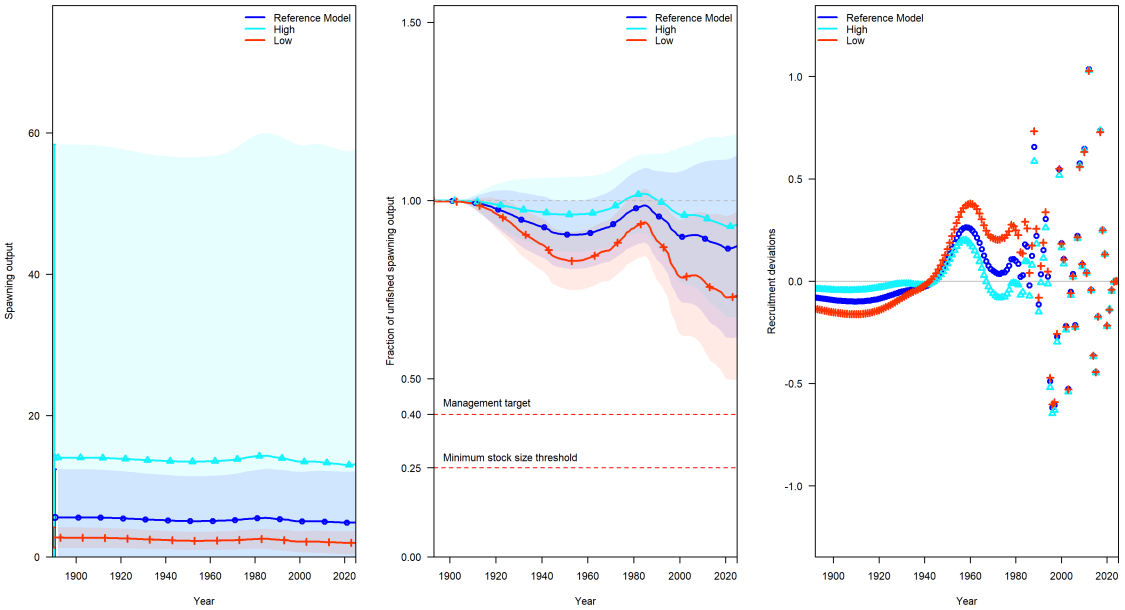


Figure 177: Comparison of spawning output (trillions of eggs; left panel), relative stock status (middle panel) and recruitment estimation (right panel) for the reference model and high and low states of nature.

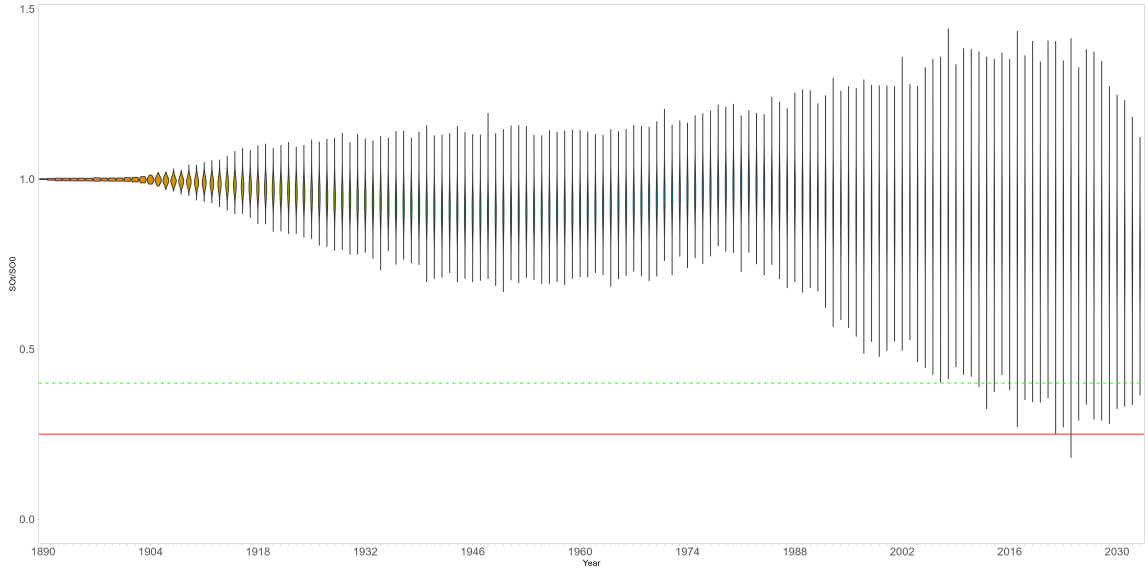


Figure 178: Ensemble relative stock status for the reference model and two states of nature.

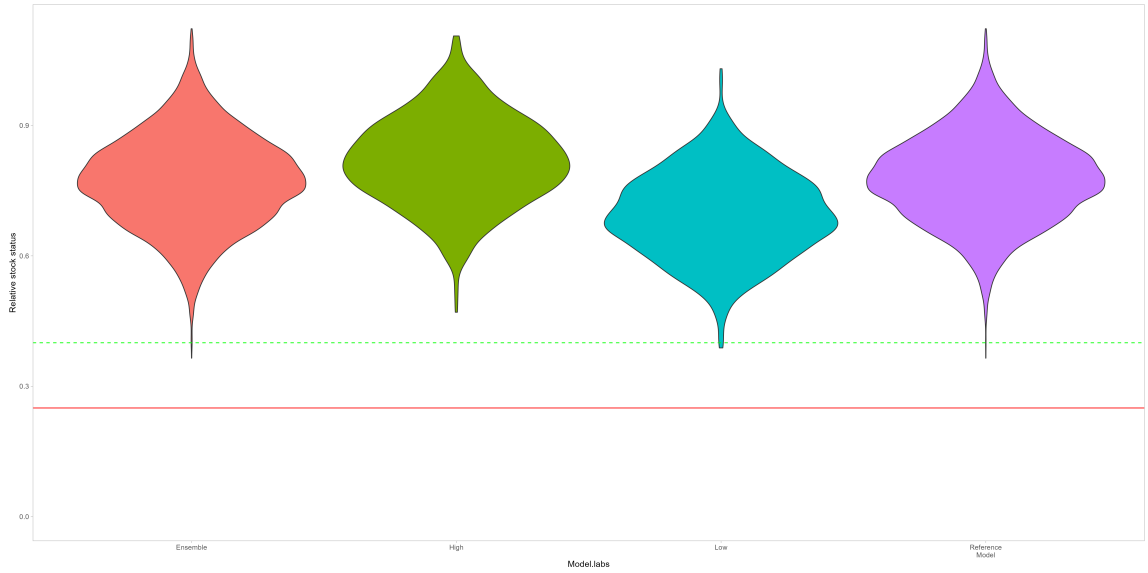


Figure 179: Ensemble terminal year relative stock status for the reference model and two states of nature.

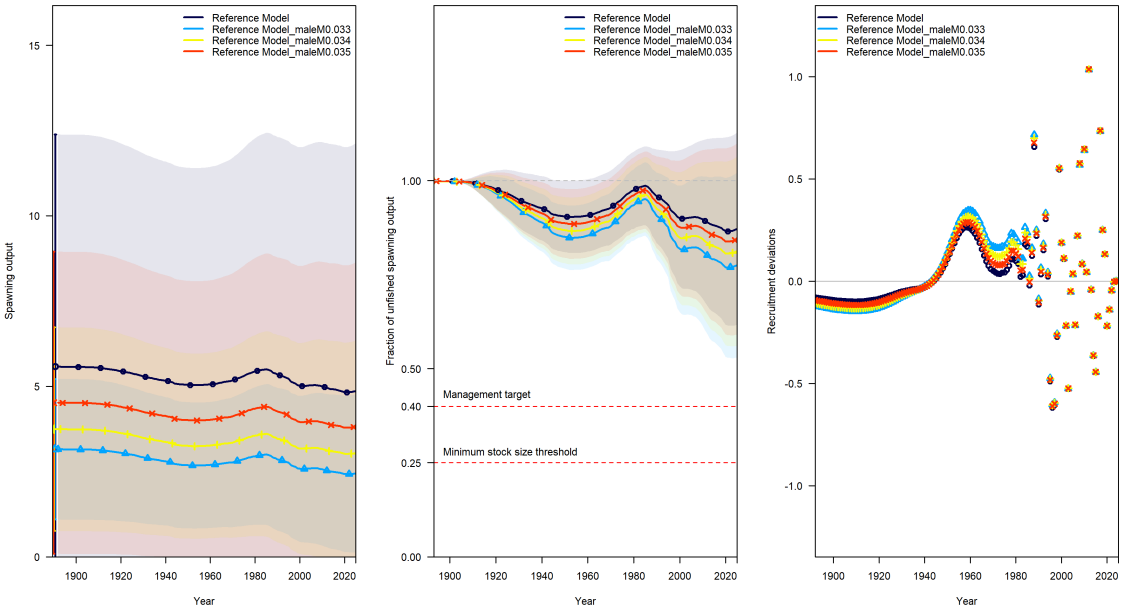


Figure 180: Comparison of spawning output (trillions of eggs; left panel), relative stock status (middle panel) and recruitment estimation (right panel) for the reference model and models that decrease the pre-specified male natural mortality value. Note the decreasing uncertainty in scale as the population reduces the amount of expectation in stock status at or above unfished.

8.13 Management

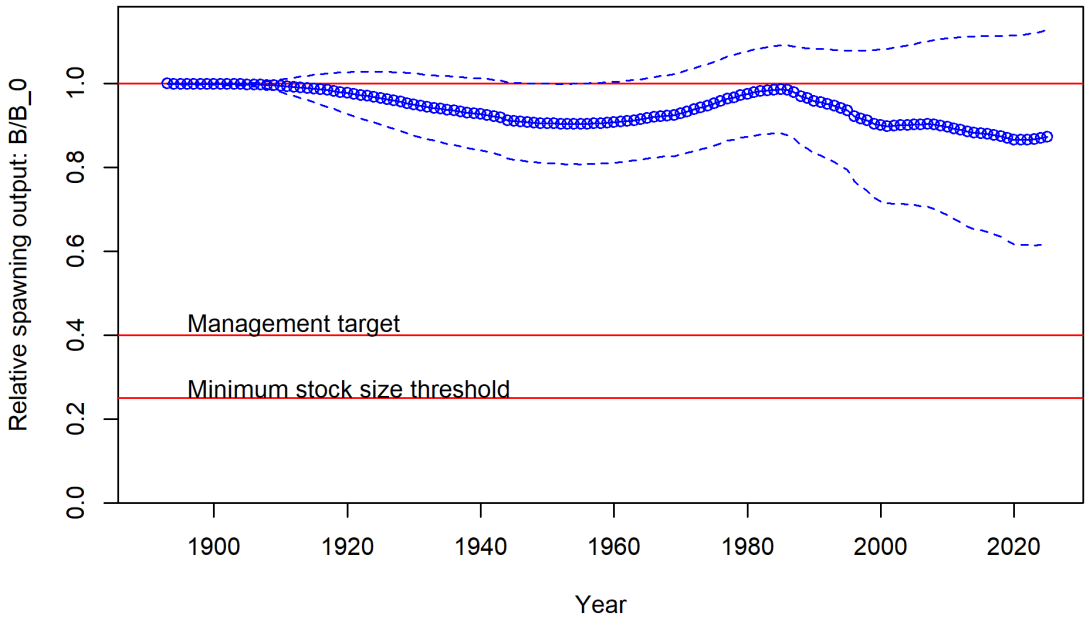


Figure 181: Estimated time series of fraction of unfished spawning output for the reference model.

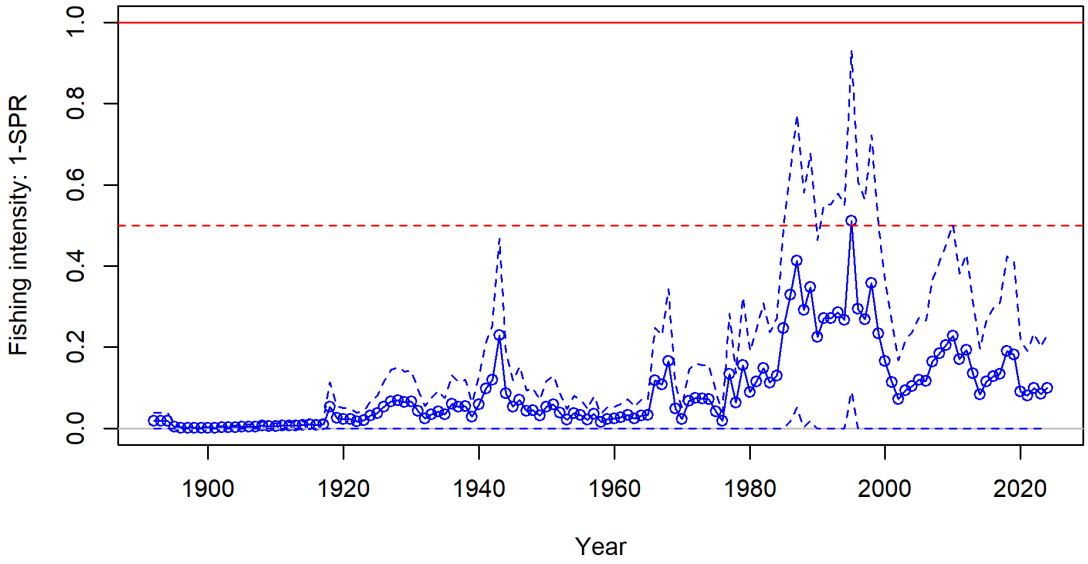


Figure 182: Estimated time series of the fishing intensity (1 - SPR), where SPR is the spawning potential ratio, with approximate 95% asymptotic intervals. The horizontal line at 0.5 corresponds to SPR = 0.5, the management reference point. The horizontal line at 1.0 corresponds to SPR = 0 (all spawning fish removed from the population).

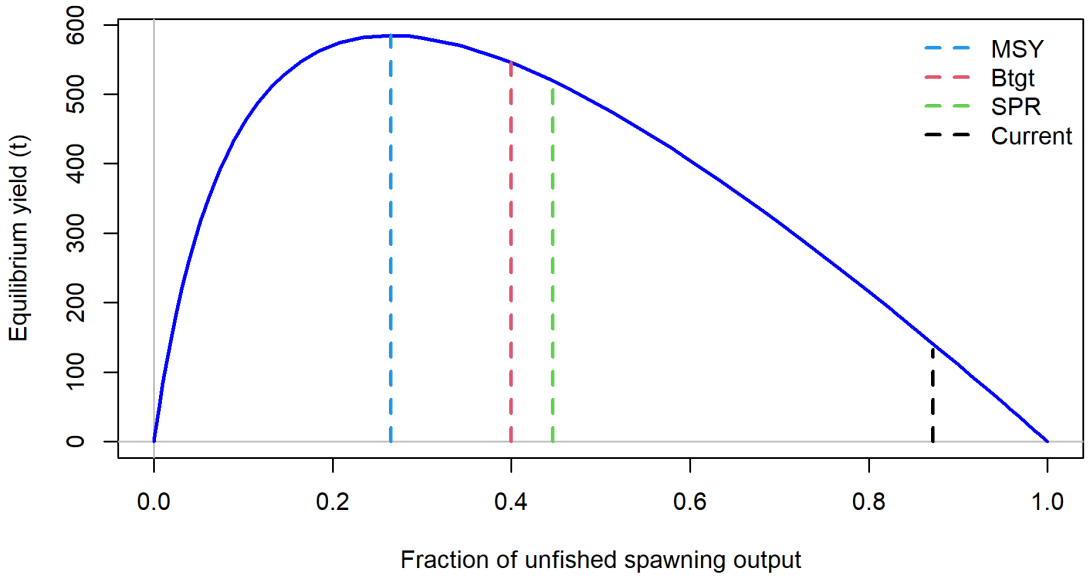


Figure 183: Equilibrium yield curve for the reference model. Values are based on the most recent fishery selectivities and retention curves and with steepness fixed at 0.72.

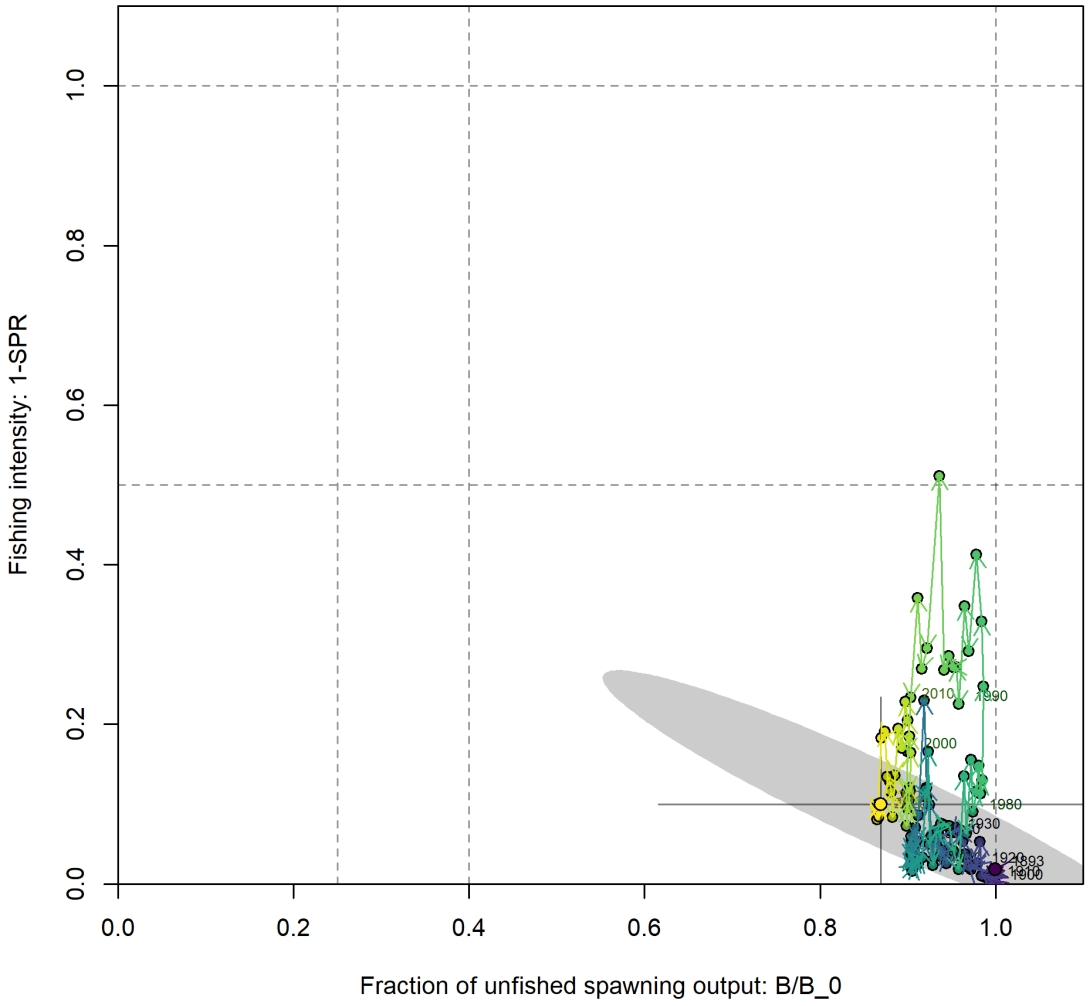


Figure 184: Phase plot of fishing intensity versus fraction unfished. Each point represents the biomass ratio at the start of the year and the relative fishing intensity in that same year. Cooler colors (purple) represent early years and warmer colors (yellow) represent recent years. Lines through the final point show 95% intervals based on the asymptotic uncertainty for each dimension. The shaded ellipse is a 95% region which accounts for the estimated correlation between the two quantities.

9 Appendix

9.1 Risk Table

Below is a risk table for RE/BS to document 1) ecosystem and environmental factors, 2) stock assessment data inputs, and 3) assessment model fits and structural factors that could potentially affect stock productivity and/or uncertainty arising from the stock assessment (see text). Level 1 is favorable/less uncertain, Level 2 neutral, and Level 3 unfavorable/more uncertain. The risk table rubric has currently been developed only for Category 1 species, not for Category 2. The below risk table was constructed as if the Rougheye and Blackspotted Rockfishes stock assessment was a Category 1 assessment. For this reason the risk table is included in this appendix, not in the main document, but retained for its information content and future consideration and development of future risk table rubrics.

Ecosystem and environmental conditions	Assessment data inputs	Assessment model fits and structural uncertainty
• Recruitment: Moderate abundance of fish less than 6.5 years old. Slightly lower abundance in 2024, but slightly more biomass than in 2010. High uncertainty in estimate [Neutral].	• Catch, indices of abundance, lengths and ages are available [Neutral].	• The model expresses a large amount of uncertainty and sensitivity in both scale and status [Unfavorable].
• Habitat: No obvious changes in spatial distribution. Juvenile distributions have been fairly stable through time but with interannual fluctuations [Neutral].	• Catch data are not disaggregated by species. Combined species catch reconstruction is based on reviewed sources and methods, with uncertainty in historical years when rockfish were not always sorted to species. Additional uncertainty in catches may be due to the fact that this complex is a minor portion of the catch. There is also uncertainty in rougheye versus blackspotted contribution to the catch history of the complex [Unfavorable].	• The model captures the appropriate amount of uncertainty [Favorable].
• Prey: Stable or slightly increasing forage (euphausiid and pink shrimp) [Neutral].	• Indices of abundance are generally uninformative [Unfavorable].	• Scale uncertainty is high primarily on the upper end. No evidence the stock is being below or close to the target relative spawning output [Neutral].
• Predators: Predation by skates, fur seals, and California sea lions is unlikely to have changed much in recent years. Potential increase in predation by sablefish, but very uncertain [Neutral].	• Many samples and years of sex-specific length data are available from the surveys and commercial fisheries [Favorable].	• Model scale is sensitive to retrospective peels, indicating a lack of stability and a dependence on recent age data [Unfavorable].

• Competitors: Some potential for hake competition for krill and pandalid shrimp but highly uncertain [Neutral].	• Some age data are available, but more samples are needed to fill out the age structure [Unfavorable]. • Species specific growth and maturity estimates for both species and species combined available. No species-specific information on fecundity, the unobserved genus Sebastes values are used [Neutral].	• The model fits data generally well with realistic selectivity assumptions [Favorable]. • The parameter estimates are robust across a variety of model specifications [Favorable]. • Natural mortality is fixed for males, while being estimated for females [Neutral]. • The assessed area covers the lower end of the species complex distribution range. Stock structure is not well understood. Dispersal patterns and connectivity beyond the assessment area are also not well understood [Unfavorable].
Level 2: Neutral	Level 2: Neutral	Level 2: Neutral

9.1.1 Rating the Ecosystem and Environmental Conditions

To understand the impact of ecosystem and environmental conditions on RE/BS, we evaluated recent trends in drivers of recruitment, predators, and prey, along with context from the climate vulnerability assessment (CVA) of McClure et al. (2023). We did not consider non-fisheries human activities during this evaluation. In considering ecosystem and environmental conditions (column 1), we focus on recent trends over the last 5 years; we assume that long term trends are implicitly represented in the stock assessment and do not represent notable changes that warrant inclusion in the risk table.

Overall we consider ecosystem and environmental conditions to be neutral (Level 2) with medium confidence based on high agreement among indicators and medium evidence, and no apparent concerns. We use this, plus information related to the stock assessment, to fill out the 'risk table' above, based on the framework outlined by the California Current Integrated Ecosystem Assessment (CCIEA) team (Golden et al. 2024).

9.1.2 Environmental Influences on Demographic Rates

9.1.2.1 Recruitment

Recruitment drivers of Rougheye and Blackspotted rockfishes are not well understood. Direct links between oceanographic conditions and RE/BS young-of-the-year (YOY) have not been made, but a

few conditions have been linked to YOY abundance across rockfish species in the California Current. Specifically, winter source water variability was linked to observed spring pelagic YOY abundance for ten species of winter spawning rockfish in the CCE. Cool/fresh conditions (minty) are indicative of subarctic conditions and are consistent with greater pelagic juvenile abundance of some rockfish species (Schroeder et al. 2019; Santora et al. 2021). Further work focused on conditions north of Cape Mendocino would be required to assess the relevance of these studies for RE/BS. In general, there may also be value in considering other more common rockfishes as 'proxies' that signal good recruitment for rarer RE/BS. Gasbarro et al. (2025) found common trends in young-of-the-year rockfish within assemblages of similar species. However, it is unclear what other species might be used as proxies for Rougheye Rockfish, or might exhibit similar recruitment patterns.

Annual variation in the abundance and distribution of RE/BS north of 42 °N was estimated from species distribution models fit to the WCGBTS. Fish 26 cm TL and approximately 6.5 years old were included as juveniles. Juvenile abundance appears to have declined slightly over time from higher levels in the 2003-2008 period, although the uncertainty around the estimates for each year are fairly large. Abundance has increased compared to a low-mark in 2011, but again there is a lot of uncertainty around the estimates. At present, juvenile abundance is moderate and slightly higher than the 2009-2014 period.

9.1.3 Distribution and Habitat Considerations

9.1.3.1 Stock Distribution

The distribution of RE/BS biomass was examined using data from the WCGBTS and species distribution modeling (sdm) using sdmTMB. The sdmTMB model included spatial autocorrelation and a spatiotemporal field modeled as a random walk. The model did not include depth, and was fit as a delta-lognormal model and fit to data north of 42 °N. We did not see obvious changes in spatial distribution in RE/BS biomass. Consistent with this lack of variability in the spatial distribution of Rougheye Rockfish, the center of gravity of RE/BS biomass north of 42 °N showed little variation, increasing by less than 0.5 °N from 2003 to 2024. Juvenile RE/BS distributions (<26 cm and 6.5 years old) have been fairly stable through time but with interannual fluctuations.

9.1.3.2 Predators and Prey

Given the diet importance of euphausiids (krill) and pandalid shrimp (including pink shrimp) for RE/BS, recent trends in abundance of these invertebrate prey groups are relevant. The Rockfish Recruitment and Ecosystem Assessment Survey (RREAS) suggests average to above-average abundance of most forage groups, including krill, for Central California, and typical conditions for krill at the northern sites. Krill abundance at the Newport hydrographic line (J. Fisher and K. Jacobson, pers.comm. 4/25/2025) suggest that krill was at typical levels over the last five years, but with high abundance of juvenile *E. pacifica* in October 2023 and of juvenile *T. spinifera* in July 2023. Additionally, krill length and biomass indices from the Trinidad Head survey line were near average for most of 2024. The coastwide krill abundance index, derived from acoustic data, was not available in 2024, but the 2023 values for this index in the relevant INPFC Vancouver and Columbia

areas was moderate, and for example not as low as 2015. Though shrimp are important prey of RE/BS, survey time series of shrimp abundance in US waters are lacking. However, commercial pink shrimp landings increased by 17% in 2024, though with no clear trend over the last 5 years. Overall, there is evidence for stable or slightly increasing forage (euphausiid and pink shrimp) in the last year.

Predators that impose the largest amounts of predation mortality on RE/BS can be identified from Ecopath food web modeling. The Ecopath models of Field et al. (2006) and Koehn et al. (2016) were recently revised (C. Best-Otubu, P.Y. Hernvann, N. Lezama Ochoa, I. Kaplan, pers. comm.). The Ecopath model includes the functional group Slope Rockfish, which includes RE/BS. The highest sources of predation mortality on Slope Rockfish, from greatest to least, derive from Sablefish, skates, northern fur seals, and California sea lions. Recent population increases (in the last 5 years) of Sablefish may impose some increased predation pressure on RE/BS, but the linkage to RE/BS is uncertain and can can only be inferred from 'unidentified rockfish' found in Sablefish stomachs. Predation by the other three predators (skates, fur seals, and California sea lions) is unlikely to have changed much in recent years, based on stable recent population dynamics (at least through recent assessments in 2019, 2013, and 2014 for these species, respectively).

9.1.3.3 Trophic Overlap with Competitors

Major predators on krill (euphausiids) and pandalid shrimp can be identified via Ecopath modeling, to point to potential competitors for Rougheye and Blackspotted rockfishes. The recently revised Ecopath model suggests that the highest sources of predation mortality (from greatest to less) on euphausiids are Carnivorous zooplankton, Pacific Hake, Large jellyfish, and Mesopelagic fish. Similarly, the highest sources of predation on pandalid shrimp are juvenile rockfish, Pacific Hake, Other cephalopods, Greenstriped Rockish, and Benthic fish. Though we cannot quantitatively determine that forage abundance is limiting for Rougheye and Blackspotted rockfishes, there is some potential for competition by Pacific Hake and RE/BS for prey (euphausiids and pandalid shrimp). Based on the 2025 Pacific Hake stock assessment, Pacific Hake total biomass in 2025 is 72% higher in 2025 than in 2006, which was the base year for the Ecopath calculations. Further research could identify if such trophic overlap with Pacific Hake limits Rougheye and Blackspotted rockfishes and other species.

9.1.4 Climate Vulnerability Assessment Rank

The Rougheye Rockfish climate vulnerability assessment (CVA) of McClure et al. (2023) can provide context for this Risk Table. McClure et al. (2023) found that Rougheye had a climate vulnerability of moderate, based on consideration of both exposure and sensitivity. Climate exposure was high, due largely to potential impacts on these species (and many others) from ocean acidification, mean sea surface temperature, and declines in subsurface oxygen. Biological sensitivity was ranked moderate, due to slow population growth rate and complicated reproductive physiology (live young). We consider effects of climate exposure to be included in other sections of this risk table regarding distribution and prey abundance, and as a result the CVA ranking was not included in our final scoring of the ecosystem and environmental considerations.

9.2 Research and Data Needs

There are many areas of research that could be improved to benefit the understanding and assessment of RE/BS. Below, we identify several of them that we consider particularly important.

- Continued research on distinguishing biology of Rougheye and Blackspotted rockfishes: This assessment reports the status of RE/BS as a pooled complex because it is extremely difficult to separate the catches of each species even in recent data, and attempting to do so would greatly increase the uncertainty in the predictions. Because little is known about the respective biology and catch histories of the two species, it is unclear whether managing them as a complex may place one species at disproportionate risk of overfishing relative to the other. New research presented in this document shows potential differences in maturity between the species. Additional research that will provide insight into the distribution, life history, biological characteristics, and catch and discard profiles of the two species is recommended. Such an endeavor would likely require the efforts of at-sea observers in all fleets, biologists aboard fishery-independent surveys, and port samplers along the entire West Coast, requiring broad, inter-agency collaboration.

- Understanding of coastwide stock structure, connectivity, and distribution: This is a stock assessment for RE/BS off of the west coast of the U.S. and does not consider data from British Columbia or Alaska. Further investigating and comparing the data and predictions from British Columbia and Alaska to determine if there are similarities with the U.S. West Coast observations would help to define the connectivity between Rougheye/Blackspotted Rockfishes north of the U.S.-Canada border.

- Natural mortality: Uncertainty in natural mortality translates into uncertain estimates of status and sustainable fishing levels for RE/BS. The assessment model was able to estimate female natural mortality, consistent with maximum age based meta-analytical prior, but male natural mortality was fixed in the model. Given what seems to be a current population with a deep age structure, the collection of additional age data and further research of the life-history of RE/BS may improve our understanding of RE/BS natural mortality.

- Increasing the number of ageing samples. This assessment increased the number of available aged samples by the thousands, but many more are needed to resolve the age structure, as well as add to our understanding of how the age structure has and is changing over time. This will include the consideration of improving the ageing error of these species, with a consideration towards decreasing the number of ageing error matrices needed, or improving the imprecision of some of the current ageing error matrices. This would necessitate the re-reading of otoliths (in addition to reading new otoliths).

- Developing and applying new age determination techniques, such as Fourier Transform Near-Infrared spectroscopy (FT-NIR): In recent years, progress has been made in using FT-NIR approach for fish age determination. At present, FT-NIR ages for RE/BS have low agreement with traditional age estimates, and further research is needed before they are incorporated into stock assessment. Given the longevity of these species, more age data is needed per year compared to other rockfishes in order to define the age structure. The longevity also

makes ageing these species more difficult. More rapid ageing techniques may help achieve the numbers needed to track age structure changes.

- Historical landings and discards, including investigation of fisheries selectivity: Substantial progress has been made in reconstructing historical landings of rockfishes on the U.S. West Coast, including those for RE/BS. This assessment highlighted the importance of understanding fishery selectivity assumptions associated with removals and how fishery selectivity changes throughout the years. Further understanding and discussion on likely selectivity forms over time would help reduce uncertainty in the estimated scale of the stock.

- Otolith structure may prove to be a distinguishing feature to determine Rougheye from Blackspotted rockfishes (Harris et al. 2019). We encourage more research into this, to assist achieving species-specific identification into the future, and potentially into the past.

- Consider whether the International Pacific Halibut Commission survey may contribute biological samples and possibly an additional index to any future assessments.