

# Status of widow rockfish stock off the U.S. West Coast in 2025



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Northwest Fisheries Science Center

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# AT-A-GLANCE

## U.S. West Coast Widow Rockfish in 2025

**NOAA**  
**FISHERIES**

Northwest Fisheries  
Science Center

### Data and Stock Assessment Model

This assessment reports the status of the widow rockfish (*Sebastes entomelas*) resource off the coast of the United States (U.S.) from southern California to the U.S. - Canadian border using data through 2024.



Landings & Discards



Survey Indices



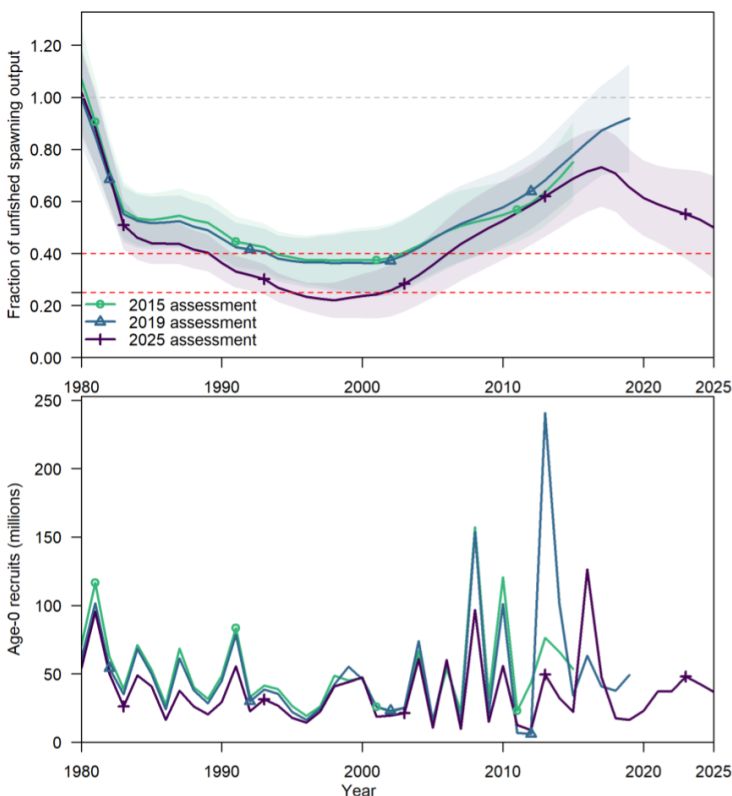
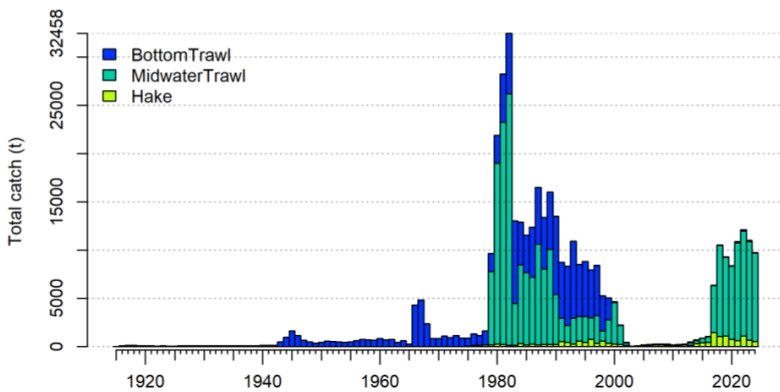
Age Composition



Length Composition



Recruitment Index



### Key Takeaways

- At the start of 2025 the estimated stock status is **50.1%**, which is **above the management target**.
- **Catches increased** since 2017 to a similar level as the 1980s and 1990s, **resulting in a decrease of the spawning output** in recent years.
- Biomass estimates are similar to past results **but catch limits are significantly lower** due to new estimates of natural mortality and recent recruitment, as well as large recent catches.
- Estimated fishing intensity exceeds the new estimated target for recent years, suggesting that in retrospect, catch limits have been too high.

### Base Model Removals & Stock Projections

Year	Removals (mt)	Spawning Output (billions of eggs)	Stock Status (target = 40%)
2024	9,764	11,195	53.1%
2025	10,669 <sup>a</sup>	10,572	50.1%
2026	9,824 <sup>a</sup>	9,630	45.6%
2027	4,596 <sup>b</sup>	8,799	41.7%
2028	4,810 <sup>b</sup>	8,763	41.5%
2029	5,137 <sup>b</sup>	8,870	42.0%
2030	5,409 <sup>b</sup>	9,054	42.9%
2031	5,545 <sup>b</sup>	9,246	43.8%

<sup>a</sup> Based on Groundfish Management Team Recommendations for Forecasting  
<sup>b</sup> Annual Catch Limit (ACL) from the harvest control rule with SPR target = 0.5, P\* of 0.45, and time-varying sigma.

View all groundfish stock assessments

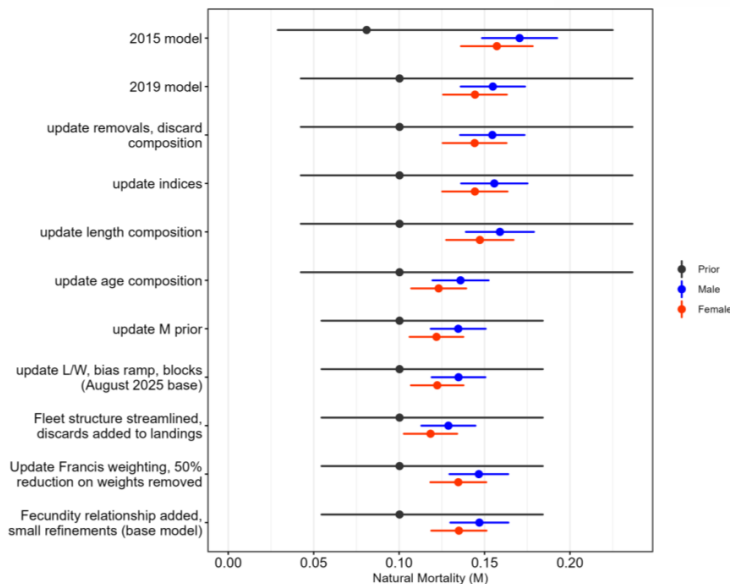


## Major Changes from Recent Assessments

Stock scale and trajectories are generally consistent with previous assessments during overlapping time periods, but projected catch limits from the 2025 assessment are substantially lower. **Why?**

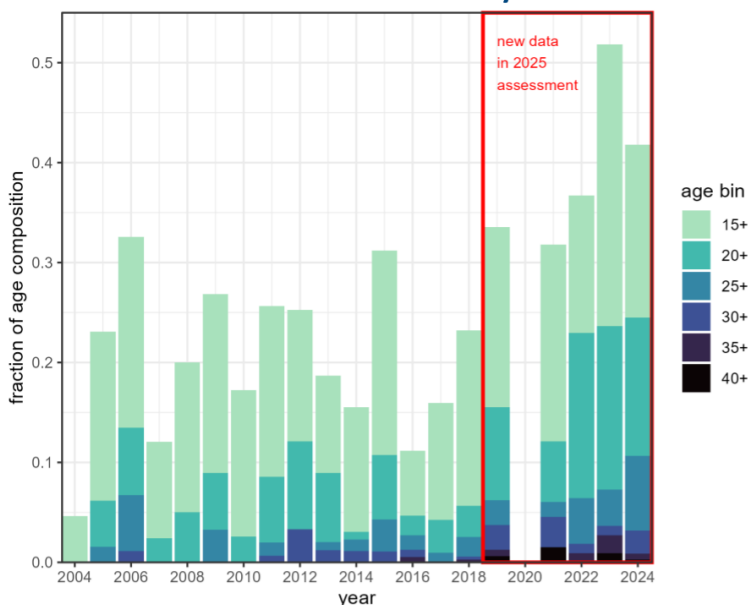
- Recent data do not support the previously estimated very high 2013 recruitment. Data available from multiple sources in 2019 indicated a large cohort that has not been supported by recent observations. The 2019 model was also disproportionately influenced by small amounts of hook-and-line discard data that were not representative of the population.
- The bottom trawl survey has observed more old fish from 2019 to 2024 than previously observed, providing new information about longevity of the species and leading to the lower estimates of natural mortality.
- The combination of lower estimates of natural mortality, lower estimates of recent recruitment, and large recent catches lead to lower estimates of productivity and stock status, which translates to lower projected catch limits.
- Trends in age composition differ between the survey and fisheries. In recent years, the proportion of old fish is declining in the midwater trawl fishery but increasing in the survey, possibly due to selectivity, spatial coverage, and spatial patterns of fishery impacts.

## Evolving Estimates of Natural Mortality



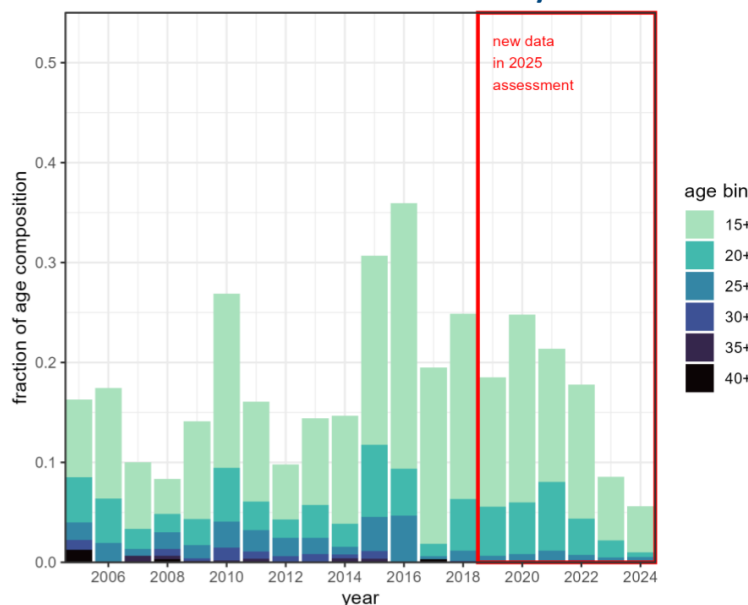
The prior for natural mortality (black) and the estimated  $M$  for females (red) and males (blue) from the 2015 base model, 2019 base model, and selected intermediate models bridging to the 2025 base model. Horizontal lines are 95% intervals.

## Proportion of old widow rockfish in the bottom trawl survey



The fraction of older fish in the sampled ages from the West Coast Groundfish Bottom Trawl Survey (WCGBTS). The data from 2019 to 2024 are new since the previous assessment. No survey was conducted in 2020 due to the COVID-19 pandemic.

## Proportion of old widow rockfish in the midwater trawl fishery



The fraction of older fish in the sampled ages from the commercial midwater trawl fishery. The data from 2019 to 2024 are new since the previous assessment.



## Executive summary

### Stock

This is an assessment of widow rockfish (*Sebastes entomelas*) that reside in the waters off California, Oregon, and Washington, from the U.S.-Canada border in the north to the U.S.-Mexico border in the south. Widow rockfish inhabit water depths of 25–370 m from northern Baja California, Mexico, to Southeastern Alaska. Although catches north of the U.S.-Canada border and south of the U.S.-Mexico border were not included in this assessment, it is not certain if those populations contribute to the biomass of widow rockfish off the U.S. West Coast, possibly through adult migration and/or larval dispersion. Following the 2015 benchmark assessment (Hicks and Wetzel 2015), this assessment is based on a single coastwide area model.

### Catches

Historically, fisheries have caught widow rockfish since the turn of the 20th century. Landings in the trawl fishery are estimated to have increased into the 1940s and remained relatively constant and small (below 1,000 mt per year) throughout the 1950s and into the 1960s, before catches increased from a foreign trawl fleet in the 1970s, with a peak at almost 5,000 mt in 1967. Catches by a midwater trawl fleet increased rapidly in the late 1970s following the discovery that widow rockfish form large aggregations at night.

Total landings of widow rockfish peaked in the early 1980s, increasing from approximately 1,000 metric tons (mt) in 1978 to over 25,000 mt in 1981. The large landings in the early 1980s were curtailed with trip limits beginning in 1982, which resulted in a decline in landings throughout the 1980s and 1990s, following sequential reductions in the trip limits. From 2000 to 2003, landings of widow rockfish dropped from over 4,000 mt to about 40 mt and remained low through 2016. Landings increased rapidly following the quota share reallocation in 2017, and have been near or above 10,000 mt in all years between 2018 and 2024. Midwater trawl gears targeting rockfish and bycatch in the Pacific hake/whiting (*Merluccius productus*, hereafter “hake”) fisheries account for the majority of the recent catch.

Widow rockfish are a desirable market species, and it is believed that discarding was low historically. However, management restrictions (e.g., trip limits) resulted in a substantial amount of discarding beginning in the early 1980s. Trawl rationalization was introduced in 2011. Between 2011 and 2024, very little discarding of widow rockfish has occurred. Catches for the past ten years are in Table i and for the entire time series in Figure i.

Table i: Recent total catch for the bottom trawl, midwater trawl, hake fleets. Catch combines landings and discards. The bottom trawl catch includes catches from fleets that were previously separated as net, and hook-and-line fisheries as described in the model bridging section.

Year	BottomTrawl (mt)	MidwaterTrawl (mt)	Hake (mt)	Total Catch (mt)
2015	15	480	386	881
2016	11	590	441	1,042
2017	39	4,862	1,455	6,356
2018	39	9,412	1,081	10,532
2019	31	8,177	1,102	9,310
2020	77	7,578	747	8,401
2021	108	10,148	617	10,874
2022	136	10,861	1,119	12,116
2023	90	10,234	673	10,997
2024	41	9,172	534	9,747

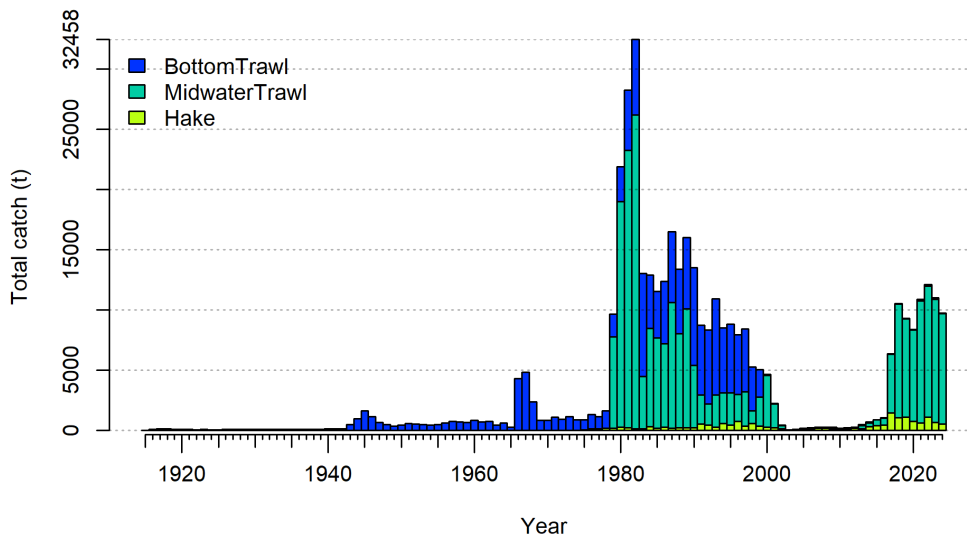


Figure i: Total catches (landings and discards combined) of widow rockfish from 1916 to 2024 for bottom trawl, midwater trawl, and hake fleets.

## Data and Assessment

The most recent benchmark assessment was conducted in 2015 (Hicks and Wetzel 2015), which was then updated in 2019 (Adams et al. 2019). This assessment began as a second update of the 2015 benchmark stock assessment and was initially reviewed by the Pacific Fishery Management Council (PFMC)

Science and Statistical Committee (SSC) Groundfish Subcommittee (GFSC) in August 2025. The GFSC requested additional explorations and changes to be reviewed in October 2025. For the October 2025 supplemental review, the stock assessment team (STAT) provided all the requested materials, but due to the United States federal government shutdown that lasted from October 1, 2025, to November 12, 2025, the STAT and SSC members who are federal employees were unable to participate in the review meeting. At the subsequent November 2025 PFMC meeting, the SSC requested another review of the widow rockfish assessment to allow for full participation of the STAT and SSC members. Many of the changes made after the August 2025 model are outside the scope of the update assessment Terms of Reference, which resulted in a more parsimonious model raised to the current best practices in West Coast groundfish stock assessments.

This assessment uses the length- and age-structured modeling software Stock Synthesis (version 3.30.24.1). The coastwide population was modeled assuming separate growth and mortality parameters for females and males from 1916 to 2024.

The fleet structure in this assessment was streamlined compared to the 2015 benchmark and the 2019 update assessments to focus on major fisheries that remove more than 97% of the catch. These include: 1) a coastwide shore-based bottom trawl fleet (1916–2024), 2) a coastwide shore-based midwater trawl fleet that targets rockfish (1979–2024), and 3) a mostly midwater trawl fleet that targets hake and includes an at-sea fleet (1975–2024) and a domestic shore-based fleet (1991–2024). The bottom trawl fleet includes minimal catches made by net and hook-and-line gears, as well as widow rockfish catches made within the historical foreign fishery targeting Pacific Ocean Perch between 1966–1976. The model includes catch, age, and length data for all three fishing fleets. Catch in each fleet represents total removals. The discard amount for bottom trawl and midwater trawl fleets was reconstructed outside the model and added to the landings within the corresponding fleets.

There are three historical fishery-dependent CPUE indices retained from the 2015 benchmark: 1) Oregon bottom trawl (1984–1999), 2) at-sea foreign hake (1977–1988), and 3) at-sea domestic hake fleets (1983–1998). Data from three fishery-independent surveys were also included in the model: 1) length composition and an index for the Alaska Fisheries Science Center/Northwest Fisheries Science Center West Coast Triennial Shelf Survey (Triennial Survey) were retained from the 2015 benchmark (1977–2004), 2) length and conditional age-at-length compositions and an index for the Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey (WCGBTS) (2003–2024), and 3) a recruitment index from the National Marine Fisheries Service (NMFS) SWFSC and NWFSC/PWCC Midwater Trawl Survey (Juvenile Survey) (2004–2024).

The base model estimated parameters for length-based selectivity for all fleets and surveys, a sex-specific length-at-age relationship, sex-specific natural mortality, and recruitment deviations. A Beverton-Holt stock-recruitment function was used to model productivity, and the steepness parameter was fixed at 0.72 based on a steepness meta-analysis (Thorson et al. 2019) for West Coast rockfishes. The model also uses widow rockfish fecundity-at-length relationships from Dick et al. (2017) instead of assuming spawning output is proportional to body weight as in the 2015 and 2019 models.

Natural mortality is the major source of uncertainty that is proposed as the axis of uncertainty to define states of nature in a decision table.

## Stock biomass and dynamics

The time series of estimated spawning output and the fraction of unfished spawning output are in Figure ii and Figure iii, respectively, and for the most recent year in Table ii. The spawning output declined rapidly with the developing domestic midwater fishery in the late 1970s and early 1980s, and is estimated to have been below the 25% of  $B_0$  overfished reference point from 1996 to 2001 with a minimum of 22% in 1998. A combination of strong recruitment and low catches resulted in a steady increase in spawning output from 2000 through 2016, increasing above the 40% of  $B_0$  target in 2007. A target fishery for widow rockfish was reestablished in 2017. The stock exhibits a decline in the most recent years with the increased catches since 2017.

The 2025 spawning output relative to unfished equilibrium spawning output is 50%, above the target of 40% (95% confidence interval of 30 - 70%).

Spawning output is estimated to be at 10,572 billion eggs in 2025 (95% confidence interval of 5,127 - 16,017 billions of eggs). The uncertainty in the estimated spawning output is high, especially in the early years and at the end of the time series (currently and in projections).

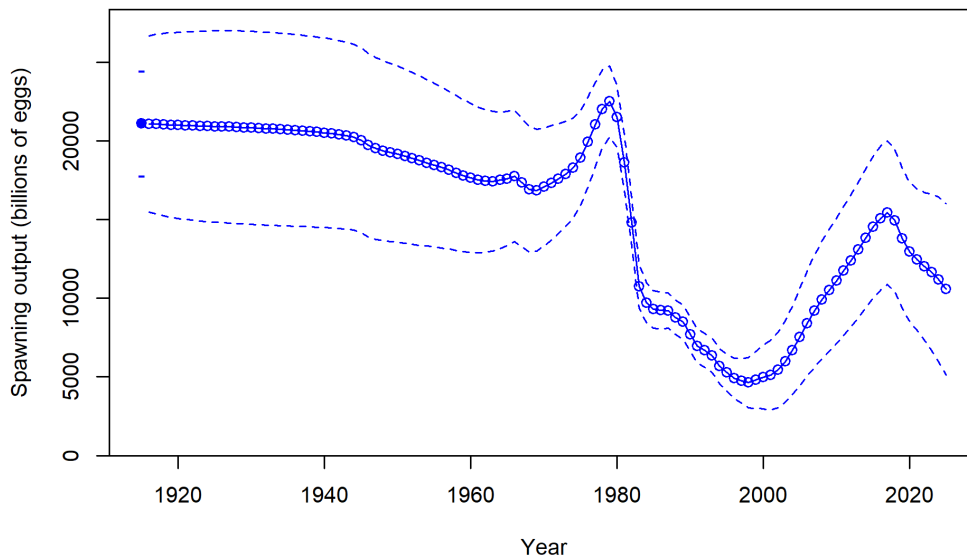


Figure ii: Estimated female spawning output time-series from the base model (solid line) with asymptotic 95% confidence interval (dashed lines).

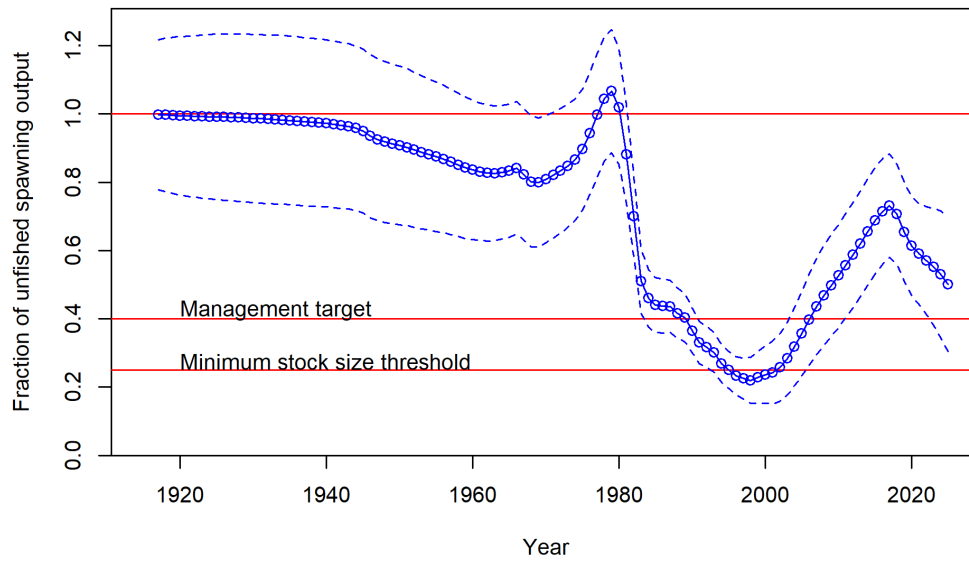


Figure iii: Estimated fraction of unfished spawning output with asymptotic 95% confidence interval (dashed lines) for the base model.

Table ii: Recent trend in estimated female spawning output (billions of eggs) and fraction of unfished spawning output (relative spawning output).

Year	Spawning output	Lower Interval (mt)	Upper Interval (mt)	Fraction Unfished	Lower Interval	Upper Interval
2015	14,522.20	10,010.81	19,033.59	0.688	0.532	0.844
2016	15,088.90	10,522.50	19,655.30	0.715	0.560	0.869
2017	15,435.90	10,875.67	19,996.13	0.731	0.580	0.882
2018	14,925.30	10,426.95	19,423.65	0.707	0.560	0.854
2019	13,816.30	9,386.06	18,246.54	0.654	0.510	0.799
2020	12,947.90	8,536.57	17,359.23	0.613	0.469	0.758
2021	12,457.30	7,967.20	16,947.40	0.590	0.442	0.738
2022	12,032.70	7,339.66	16,725.74	0.570	0.412	0.728
2023	11,644.20	6,667.60	16,620.80	0.552	0.380	0.723
2024	11,194.60	5,945.11	16,444.09	0.530	0.345	0.716
2025	10,571.70	5,126.76	16,016.64	0.501	0.304	0.698

## Recruitment

Recruitment deviations were estimated for the entire time series modeled. There is little information regarding recruitment prior to 1965, and the uncertainty in these estimates is expressed in the model. Estimates of recruitment appear to be episodic and characterized by periods of low recruitment, with several very large, but uncertain, year classes (Figure iv, Figure v).

The 2019 update assessment (Adams et al. 2019) estimated the largest recruitment on record in 2013, and above-average recruitment in 2014. With a more parsimonious fleet structure in this assessment, and the additional years of data, 2013 is now estimated as only the tenth-largest recruitment on record, and 2014 is estimated as below average.

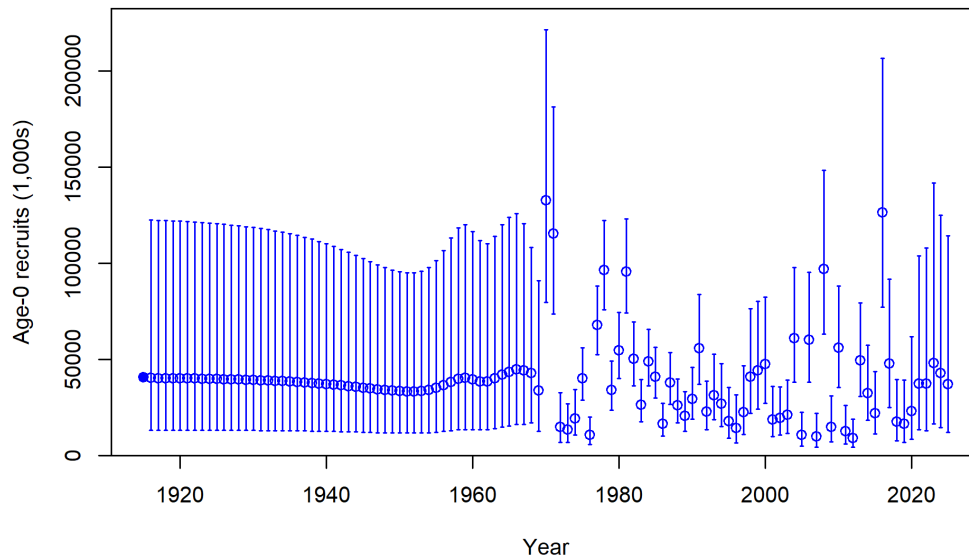


Figure iv: Time-series of estimated recruitments (medians as open circles) for the base model with asymptotic 95% confidence interval (vertical bars). Estimated unfished equilibrium recruitment ( $R_0$ ) is indicated with a filled circle.

Table iii: Recent estimated trend in widow rockfish recruitment with asymptotic 95% confidence intervals determined from the base model.

Year	Recruitment (1,000s)	Lower Interval (1,000s)	Upper Interval (1,000s)	Recruitment Deviations	Lower Interval	Upper Interval
2015	21,973	11,088	43,542	-0.412	-1.010	0.186
2016	126,249	77,149	206,597	1.331	1.014	1.648
2017	47,765	24,880	91,701	0.339	-0.191	0.868
2018	17,416	7,712	39,328	-0.690	-1.426	0.046
2019	16,236	6,719	39,237	-0.774	-1.596	0.048
2020	22,868	8,487	61,615	-0.446	-1.414	0.522
2021	37,217	13,346	103,783	0.023	-1.019	1.064
2022	37,214	12,833	107,917	0.004	-1.091	1.099
2023	48,077	16,299	141,815	0.248	-0.868	1.365
2024	42,674	14,564	125,041	0.136	-0.970	1.241

### Exploitation status

The population declined throughout the 1980s and 1990s when fishing intensity was above the management target. The population then increased between 2002 and 2016 when fishing intensity was well below the management target. Fishing intensity increased substantially in 2017, and is estimated to have been above the management target from 2018 onward, though the relative spawning output remains above the management target of 40%. Recent fishing intensities are in Table [iv](#), and a full time series of relative spawning output and fishing intensity is in Figure [v](#).

Table iv: Estimated recent trend in relative fishing intensity ( $(1-SPR)/(1-SPR_{50\%})$ ) and exploitation rate (as the proportion of age 4+ biomass) with asymptotic 95% confidence intervals for both quantities.

Year	$(1-SPR)/(1-SPR_{50\%})$	Lower Interval (SPR)	Upper Interval (SPR)	Exploitation Rate	Lower Interval (Rate)	Upper Interval (Rate)
2015	0.160	0.104	0.217	0.007	0.005	0.010
2016	0.182	0.120	0.244	0.009	0.006	0.011
2017	0.789	0.600	0.978	0.053	0.038	0.068
2018	1.151	0.930	1.371	0.092	0.064	0.119
2019	1.141	0.907	1.375	0.089	0.061	0.118
2020	1.127	0.878	1.375	0.077	0.050	0.103
2021	1.277	1.016	1.537	0.098	0.062	0.134
2022	1.301	1.023	1.579	0.115	0.069	0.161
2023	1.238	0.928	1.548	0.114	0.063	0.164
2024	1.214	0.870	1.558	0.110	0.057	0.164

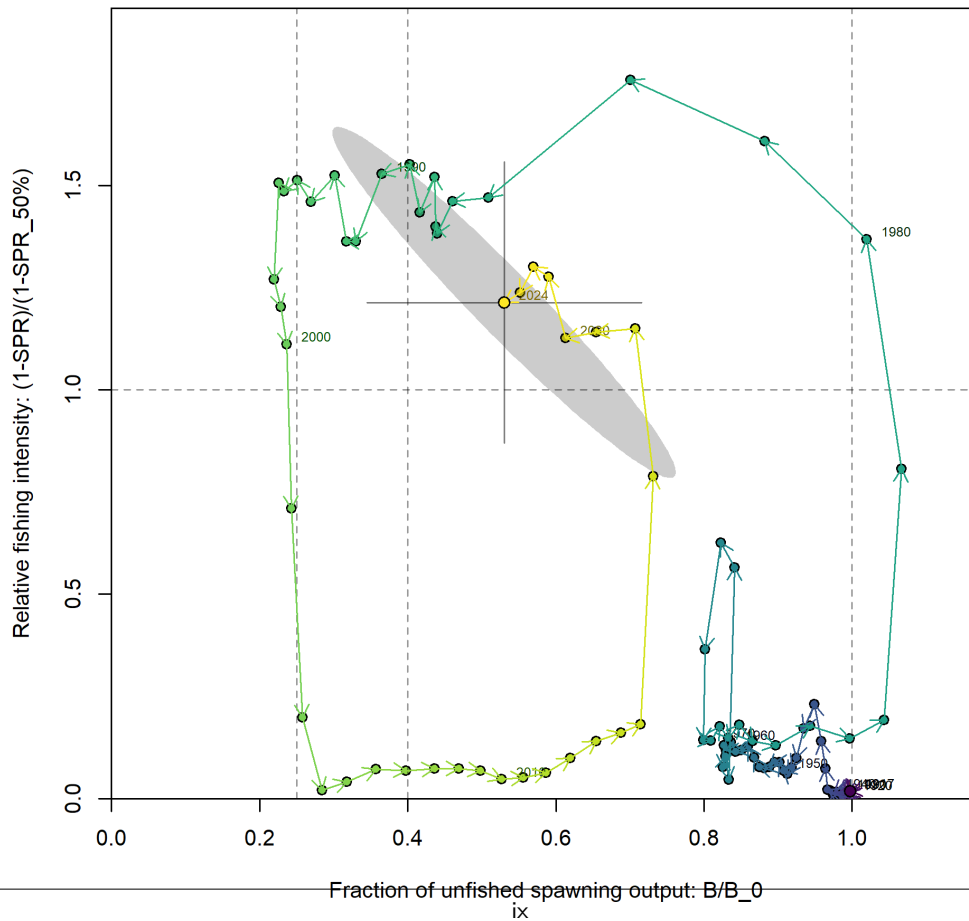


Figure v: Phase plot of relative fishing intensity ( $(1-SPR)/(1-SPR_{50\%})$ ) versus fraction unfished (spawning output,  $B/B_0$ ). Lines through the final point show marginal asymptotic 95% intervals for each dimension. The shaded ellipse is an approximate 95% confidence region which accounts for the estimated covariance between the two quantities.

## Ecosystem considerations

Recruitment is a key mechanism by which the ecosystem may directly impact the population dynamics of widow rockfish; however, the specific pathways through which environmental conditions exert influence on widow rockfish dynamics are unclear. Changes in the environment may result in changes in other population processes as well. Unfortunately, there are few data available for widow rockfish that provide insights into these effects.

Fishing has effects on habitats, in addition to the population itself. Rockfish are often associated with habitats containing living structures such as sponges and corals, which fishing may threaten, although the midwater fishery currently targeting widow rockfish is expected to have fewer impacts on living structures than the historical bottom trawl fishery. Recent studies on essential fish habitat are beginning to characterize important locations for rockfish throughout their life history; however, there is little current information available to evaluate the specific effects of fishing on the ecosystem characteristics pertinent to the management of widow rockfish.

## Reference points

Reference points were calculated using the estimated selectivity parameters and average catch distribution among fleets in the most recent five years of the model (2019–2024). A list of estimates of the current state of the population, as well as reference points based on 1) a target unfished spawning output of 40%, 2) a spawning potential ratio (SPR) of 0.5, and 3) the model estimate of maximum sustainable yield (MSY), are all listed in Table v. The SPR is the expected lifetime reproductive output of a female recruit under a given fishing intensity as a proportion of the unfished expected lifetime reproductive output.

While the estimate of population scale (total spawning output) has remained relatively steady across the 2015, 2019, and 2025 assessments, unfished recruitment ( $R_0$ ) and natural mortality ( $M$ ), which are positively correlated, have declined from 2015 (female  $M$  of  $0.157 \text{ yr}^{-1}$ ) to 2019 ( $0.144 \text{ yr}^{-1}$ ) to 2025 ( $0.135 \text{ yr}^{-1}$ ). Thus, although the population scale is estimated consistently, additional years of data (in particular, age composition data) following the reopening of the fishery have led the model to estimate that the population is less productive, which results in lower yields at all three reference points (proxy based on spawning output, proxy based on fishing intensity, and model estimate of MSY).

Table v: Summary of reference points and management quantities for the base model.

Reference Point	Estimate	Lower Interval	Upper Interval
Unfished Spawning output (billions of eggs)	21,110.8	17,760.2	24,461.4
Unfished Age 4+ Biomass (mt)	156,376	131,787	180,965
Unfished Recruitment (R0)	40,470	28,186	52,755
2025 Spawning output (billions of eggs)	10,572	5,127	16,017
2025 Fraction Unfished	0.501	0.304	0.698
Reference Points Based SO40%	—	—	—
Proxy Spawning output (billions of eggs) SO40%	8,444	7,104	9,785
SPR Resulting in SO40%	0.458	0.458	0.458
Exploitation Rate Resulting in SO40%	0.083	0.076	0.091
Yield with SPR Based On SO40% (mt)	6,239	4,974	7,504
Reference Points Based on SPR Proxy for MSY	—	—	—
Proxy Spawning output (billions of eggs) (SPR50)	9,419	7,924	10,914
SPR50	0.500	—	—
Exploitation Rate Corresponding to SPR50	0.073	0.067	0.079
Yield with SPR50 at SO SPR (mt)	5,931	4,732	7,129
Reference Points Based on Estimated MSY Values	—	—	—
Spawning output (billions of eggs) at MSY (SO MSY)	5,393	4,541	6,246
SPR MSY	0.328	0.324	0.332
Exploitation Rate Corresponding to SPR MSY	0.127	0.116	0.138
MSY (mt)	6,745	5,359	8,132

## Management performance

Since annual catch limits for widow rockfish increased in 2017 and new fishing opportunities for use of midwater trawl gear became available, attainment of the annual catch limit has been high (Table vi). Specifically, attainment of the annual catch limit (ACL) has exceeded 70% every year since 2018, averaged 77% from 2017–2024, and was as high as 88% in 2022.

## Harvest projections and decision table

Projections for overfishing limit (OFL) (mt), ABC (mt), ACL (mt), the buffer between the OFL and ABC, estimated spawning output (billions of eggs), and fraction of unfished spawning output with adopted OFL and ACL and assumed catch for the first two years of the projection period. The predicted OFL is the calculated total catch determined by FSPR=50% which are provided in Table vii.

Table vi: Recent trend in total catch and commercial landings (mt) relative to the management guidelines. Estimated total catch reflects the commercial landings plus the model estimated dead discarded biomass.

Year	OFL (mt)	ABC (mt)	ACL (mt)	Total dead catch (mt)
2015	4137	3929.00	2000	880.84
2016	3990	3790.00	2000	1041.65
2017	14130	13508.28	13508	6356.30
2018	13237	12654.57	12655	10531.98
2019	12375	11830.50	11831	9309.60
2020	11714	11198.58	11199	8400.97
2021	15749	14725.32	14725	10873.65
2022	14826	13788.18	13788	12116.29
2023	13633	12624.16	12624	10996.91
2024	12453	11481.67	11482	9746.77

Table vii: Potential overfishing limit (OFL) (mt), Acceptable Biological Catch (ABC) (mt), ACL (mt), the buffer between the OFL and ABC, estimated spawning output (billions of eggs), and fraction of unfished spawning output with adopted OFL and ACL and assumed catch for the first two years of the projection period. The predicted OFL is the calculated total catch determined by FSPR=50%. Catches in 2025 and 2026 are allocated using the percentage of landings for each fleet in 2019–2024.

Year	Adopted OFL (mt)	Adopted ACL (mt)	Assumed Catch (mt)	OFL (mt)	Buffer	ABC (mt)	ACL (mt)	Spawning output (billions of eggs)	Fraction Unfished
2025	12,254	11,237	10,669	—	1.000	—	—	10,571.70	0.501
2026	11,382	10,392	9,824	—	1.000	—	—	9,630.18	0.456
2027	—	—	—	4,916	0.935	4,596	4,596	8,799.27	0.417
2028	—	—	—	5,172	0.930	4,810	4,810	8,763.01	0.415
2029	—	—	—	5,548	0.926	5,137	5,137	8,869.58	0.420
2030	—	—	—	5,866	0.922	5,409	5,409	9,054.47	0.429
2031	—	—	—	6,047	0.917	5,545	5,545	9,245.68	0.438
2032	—	—	—	6,117	0.913	5,585	5,585	9,403.42	0.445
2033	—	—	—	6,130	0.909	5,572	5,572	9,520.54	0.451
2034	—	—	—	6,123	0.904	5,535	5,535	9,605.99	0.455
2035	—	—	—	6,116	0.900	5,504	5,504	9,671.68	0.458
2036	—	—	—	6,116	0.896	5,480	5,480	9,725.54	0.461

Table viii: Summary table of 12-year projections beginning in 2025 for alternate states of nature based on the axis of uncertainty (a combination of M, h as described in the text). Catches applied to all states of nature are the projections from the base model using  $P^* = 0.45$  and  $\sigma = 0.5$  with the time-varying buffer. Columns range over low, base, and high states of nature. Spawning output is in billions of eggs. OFL values for the years 2027 and beyond for each state of nature are the result of applying the harvest rate to the estimated biomass in that state of nature as discussed in Supplemental NWFSC-SWFSC Report 2 under PFMC Agenda Item G.3.a from September 2025.

Year	Catch	Low Spawn- ing Out- put	Low Frac- tion Un- fished	Low OFL	Base Spawn- ing Out- put	Base Frac- tion Un- fished	Base OFL	High Spawn- ing Out- put	High Frac- tion Un- fished	High OFL
2025	10669	7044	0.292	-	10572	0.501	-	12935	0.632	-
2026	9824	6039	0.251	-	9630	0.456	-	11972	0.585	-
2027	4596	5183	0.215	2818	8799	0.417	4916	11102	0.542	6470
2028	4810	5136	0.213	3079	8763	0.415	5172	11022	0.538	6692
2029	5137	5231	0.217	3412	8870	0.420	5548	11084	0.541	7064
2030	5409	5388	0.223	3666	9054	0.429	5866	11230	0.548	7386
2031	5545	5525	0.229	3771	9246	0.438	6047	11387	0.556	7566
2032	5585	5601	0.232	3753	9403	0.445	6117	11519	0.563	7639
2033	5572	5609	0.233	3665	9521	0.451	6130	11617	0.567	7659
2034	5535	5563	0.231	3557	9606	0.455	6123	11691	0.571	7661
2035	5504	5486	0.228	3460	9672	0.458	6116	11751	0.574	7662
2036	5480	5398	0.224	3386	9726	0.461	6116	11800	0.576	7665

Uncertainty in both natural mortality (estimated for both sexes) and steepness (not estimated in the model) contributed greatly to uncertainty in the results. A combination of these two factors was used as the axis of uncertainty to define low and high states of nature. This differed from the 2019 assessment which included a third factor, 2013 recruitment strength. The 2013 year class is no longer a major source of uncertainty, and there is no recent similarly large estimate of recruitment. The 12.5% and 87.5% quantiles for female and male natural mortality (independently) were chosen as low and high values ( $0.126 \text{ yr}^{-1}$  and  $0.144 \text{ yr}^{-1}$  for females;  $0.137 \text{ yr}^{-1}$  and  $0.157 \text{ yr}^{-1}$  for males). Steepness was fixed in the base model and is not incorporated in the estimation uncertainty. The 12.5% and 87.5% quantiles from the steepness prior (without widow rockfish data) were used to define the low and high values of steepness (0.536 and 0.904). The low combination of these two factors defined the low state of nature and the high combination of these two factors defined the high state of nature. The predictions of spawning output in 2025 from the low and high states of nature are close to the 12.5% and 87.5% quantiles from the base model.

A twelve-year projection of the base model with one catch stream based on  $ACL = ABC$  based on the adjustment of  $P^* = 0.45$  was conducted for each state of nature (Table viii). The projections indicate that the spawning output is likely to initially decrease under all states of nature before partially rebounding (less so under the low state of nature). Predicted ACL catches range from 4,596 mt in 2027 to 5,585 mt in 2032.

## Scientific uncertainty

The model estimate of the log-scale standard deviation of the OFL in 2025 is 0.293. This is less than the default SSC value of 0.5 for a category 1 assessment, so harvest projections assume an initial sigma of 0.5.

## Unresolved problems and major uncertainties

Major sources of uncertainty include natural mortality, stock productivity, and spatial dynamics, which are discussed below. Also see the SSC statement associated with this widow stock assessment in the March 2026 PFMC briefing book for additional discussion of unresolved problems and major uncertainties.

This assessment attempts to capture uncertainty in  $M$  by estimating it inside the model (thereby propagating uncertainty in  $M$  into uncertainty in spawning output and other derived quantities), and by incorporating variation in  $M$  in a decision table. Model sensitivities and profiles over  $M$  showed that current stock status was highly sensitive to the assumption about natural mortality.

Widow rockfish is a relatively long-lived fish, and its natural mortality ( $M$ ) is likely to be lower than many managed fish stocks (e.g., gadoids). Ages above 50 years have been observed, and it is expected that natural mortality could be less than  $0.10 \text{ yr}^{-1}$  (the median of the prior for natural mortality used in this assessment). However, even with length and age data available back to the late 1970s,  $M$  was estimated at 0.135 for females and  $0.147 \text{ yr}^{-1}$  for males, with a small amount of uncertainty (e.g., a 6.1% coefficient of variation for females).

Notably, the estimated  $M$  for both sexes from this assessment is lower than those from the 2015 and 2019 assessments, for which natural mortality was estimated above  $0.15 \text{ yr}^{-1}$  and  $0.14 \text{ yr}^{-1}$ , respectively. The estimates of  $M$  varied slightly depending on the weight given to age and length data, or removing recent years of data, but female  $M$  was always estimated above  $0.12 \text{ yr}^{-1}$ . The likelihood profile over natural mortality provides support for values up to or above  $0.14 \text{ yr}^{-1}$ , but with greater curvature than in the 2019 assessment, suggesting additional data has reduced the support for higher natural mortality values. A contributing factor to this change is the increased mean age and frequency of older fish in the catch observed by the WCGBTS survey in recent years. The successful rebounding of the stock as a result of reduced fishing pressure from 2003–2016 allowed more individuals to reach older ages than observed in the earlier years of the WCGBTS. However, consideration should be given in future assessments to structural changes which may improve the fits to WCGBTS age data.

Steepness was fixed at 0.720 in the base model, but a likelihood profile showed that it would be estimated at a value less than that. Estimates of  $M$  increased with lower steepness, while unfished spawning output increased and current spawning output decreased. Sustainable yields at the  $\text{SPR}_{50\%}$  reference harvest rate ranged from approximately 2641 to 5992 mt depending on the value of steepness.

A greater understanding of the spatial dynamics of widow rockfish would help with interpretation of patterns in the existing data and help improve future assessment models. In particular, there are opposing trends in the age distribution sampled in recent years from the target fishery, which is concentrated in a subset of the range of the stock, and the coastwide age distribution WCGBTS. These differences could be due to some combination of localized depletion, spatial variability in age relative to benthic vs. pelagic habitat, spatial distribution relative to untrawlable habitat, and the rate of mixing among areas.

## Research and Data Needs

There are many areas of research that could be improved to benefit the understanding and assessment of widow rockfish, including the following. Also see the SSC statement associated with this widow stock assessment in the March 2026 PFMC briefing book for additional discussion of research and data needs.

- **Natural mortality:** Uncertainty in natural mortality translates into uncertain estimates of status and sustainable fishing levels for widow rockfish. The collection of additional age data, re-reading of older age samples, reading old age samples that are as of yet unread, and improved understanding of the life history of widow rockfish may reduce that uncertainty. Investigating the ageing error and bias would help to understand the influences that the age data have on this assessment, particularly the influence of age data on natural mortality.
- **Sex-specific selectivity:** The midwater and bottom trawl length-composition data fits showed divergent residual patterns between male and female fish. The underlying mechanism driving this pattern is unclear and could be related to growth, sexing error, or to sex-specific selectivity (e.g., when widow rockfish aggregate, sexes possibly may be aggregating separately). Sex-specific selectivity for these two fleets could be explored or included to address this.
- **Coastwide understanding of stock structure, biology, connectivity, and distribution:** This is a stock assessment for widow rockfish 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 widow rockfish north and south of the U.S.-Canada border. Research into spatial dynamics within the U.S. West Coast (as noted above under Unresolved problems and major uncertainties) is also important.

# 1 Introduction

This is an assessment of widow rockfish that inhabit 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, and does not include Puget Sound.

*Sebastes entomelas* (widow rockfish) is named after its black-lined gut cavity (*ento* meaning within and *melas* meaning black). It has been referred to as buda, beccafico (Italian bird), and viuva (widow) prior to the 1930s. More recently, the widow rockfish is also called brownie, belinda bass, brown bomber, and soft brown.

## 1.1 Distribution and Stock Structure

Widow rockfish inhabit water depths of 25–370 m from northern Baja California, Mexico to Southeastern Alaska, and are most abundant from British Columbia to Northern California. Although catches north of the U.S.-Canada border or south of the U.S.-Mexico border were not included in this assessment, it is possible that these populations contribute to the biomass of widow rockfish off of the U.S. West Coast through adult migration and/or larval dispersion.

This assessment is based on a single coastwide area model. There is little evidence of genetically separate stocks along the U.S. coast, and past assessments have used a single area versus a two-area assessment model with results found to be similar (He et al. 2011). There is some evidence of biological differences between areas. For example, widow rockfish collected off California tend to mature at a smaller length than widow rockfish collected off of Oregon (Barss and Echeverria 1987). This could be due to environmental or anthropogenic effects rather than genetic differences.

## 1.2 Life History

This section is not required for an update assessment; please refer to the most recent benchmark assessment (Hicks and Wetzel 2015) for information.

## 1.3 Ecosystem Considerations

This section is not required for an update assessment; please refer to the most recent benchmark assessment (Hicks and Wetzel 2015) for information.

## 1.4 Fishery description

Widow rockfish were lightly exploited by bottom trawl and hook-and-line gears prior to the 1980s. After many attempts to start trawl fisheries off the west coast of the United States in the late 1800s, the availability of otter trawl nets and the diesel engine in the mid-1920s helped trawl fisheries expand (Douglas et al. 1998). The trawl fisheries really became established during World War II when demand increased for shark livers and bottomfish. A mink food fishery also developed during World War II (Jones and Harry Jr 1960). Foreign fleets began fishing for rockfish in the mid-1960s until the EEZ was implemented in 1977 (Rogers 2003). Longline catches of widow rockfish are present from the turn of the 20th century and continue in recent years, mainly from fisheries targeting sablefish and halibut.

In the late 1960s and early 1970s, it is reported that foreign fishing vessels caught large numbers of widow rockfish (Rogers 2003). In the late 1970s a domestic midwater trawl fishery began developing off of Oregon when it was realized that widow rockfish form dense aggregations at night (Gunderson 1984). The fishery expanded very quickly, with landings from trawl, net, and hook-and-line gears increasing more than 20 times by the early 1980s. As early as 1982, trip limits were imposed to keep catches below recommended annual levels. Trip limits became more restrictive over the years until widow rockfish was declared overfished in 2001. In 2002, harvest guidelines were greatly reduced resulting in decreased catch. Since 2017, catches have steadily increased to levels approximately equal to those in the late 1980's and early 1990's. Widow rockfish catch history by fleet is shown in Figure 6.

The majority of current catches are taken by the midwater trawl fleet, though a significant portion is caught as bycatch by the fishery targeting hake. While historically a major fleet, the catches from the bottom trawl gears have declined due to a combination of regulatory changes, fleet consolidation and reduced ex-vessel value (Jeff Lackey, pers. comm.). The spatial efforts of the midwater trawl fleet has also shifted significantly in recent years. Currently, fishing is concentrated around central Oregon and primarily off the shelf, with the fleet focusing on several well established primary and secondary spots. This change in distribution of efforts is largely due to the fleet attempting to avoid bycatch, reduce catches of undersized fish and minimize distance from processing facilities in central Oregon. If midwater vessels have remaining yellowtail rockfish quota later in the season, they may be more inclined to target some of the Washington grounds where a mix of widow and yellowtail rockfishes is found. The industry has also noted that the fleet is dynamic throughout the season, with fishers responding to changes in oceanographic conditions, feed distribution and target species distribution (Jeff Lackey, pers. comm.).

Historical discarding practices are not well known, but it is believed that little discarding occurred prior to management restrictions. With the introduction of trip limits, limited data from the mid-1980s show occasional very high discard rates of widow rockfish from tows that occurred near the end of a trip. In recent years, discards from all fleets have been low, likely due to a combination of changes in fleet behavior, increased observer coverage and the introduction of the IFQ system in 2011.

## 1.5 Management History

Management history prior to 2015 is detailed in the most recent benchmark assessment (Hicks and Wetzel 2015). In 2017, the NMFS implemented a quota share (QS) reallocation rule, which re-established a target fishery for widow rockfish by allocating quotas among permit holders based on historical allocations, removing daily vessel limits, and allowing the trading of QS (NMFS 2017).

## 1.6 Management performance

Table 9 shows that recent catches have been below recommended catch levels. Total mortality estimates from the West Coast Groundfish Observer Program (WCGOP) and from the stock assessment might differ due to the use of different estimation methods. Investigation into how these methods differ is beyond the scope of an update assessment.

## 1.7 Fisheries off Canada and Alaska

This section is not required for an update assessment; please refer to the most recent benchmark assessment (Hicks and Wetzel 2015) for information.

## 2 Data

Many sources of data were available for this assessment (Figure 7), including indices of abundance, landings, discards, and length and age observations from fishery-dependent and fishery-independent sources. Data used in this assessment are described below. No new data sources were considered in this update assessment.

### 2.1 Fishery-independent data

Data from three fishery-independent surveys were used in this assessment: 1) the SWFSC and NWFSC/PWCC Midwater Trawl Survey (hereafter, “juvenile survey”); 2) the Alaska Fisheries Science Center (AFSC)/NWFSC Triennial Shelf Trawl Survey (hereafter, “triennial survey”); and 3) the NWFSC West Coast Groundfish Bottom Trawl Survey (hereafter, “WCGBTS”). Depth and latitude strata used to analyze the catch-rates, length compositions, and age compositions are the same as in the 2019 update assessment (Adams et al. 2019) and shown in Table 16.

#### 2.1.1 Triennial Survey

The Alaska Fisheries Science Center/Northwest Fisheries Science Center West Coast Triennial Shelf Survey (Triennial Survey) was first conducted by the Alaska Fisheries Science Center (AFSC) in 1977 and was conducted every three years, ending 2004. The survey’s design and sampling methods are most recently described in (Weinberg et al. 2002).

The time series suggests a possible slightly increasing trend in biomass from 1980–1983, although is relatively flat until the end of the period in 2001 and 2004 when the index declines significantly. The index and length compositions for this historical Triennial survey were unchanged from the previous assessment. Please refer to the most recent benchmark assessment (Hicks and Wetzel 2015) and most recent update assessment (Adams et al. 2019) for details on those data inputs.

#### 2.1.2 West Coast Groundfish Bottom Trawl Survey

The Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey (WCGBTS) has been conducted annually, since 2003. It is based on a random-grid design; covering the coastal waters between depths of 55–1,280 m (Keller et al. 2017). No survey occurred in 2020 due to the COVID-19 pandemic. Widow rockfish are not commonly caught in the WCGBTS. Higher catch rates occur north of 40° N latitude and catches are rare south of 36° N latitude. Few large fish are found shallower than 100 m and few small fish are found in the deeper water of the slope. There is no clear trend in length with latitude other than smaller fish tend to occur south of approximately 36° N latitude, and there appears to be some very small fish found near 39° N latitude.

For 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. 2025). This is an updated approach compared to the 2015 benchmark assessment (non-spatial delta-GLMM) and the 2019 update assessment (VAST delta-lognormal model). The `sdmTMB` model used a 200 knot mesh of the survey area (Thorson et al. 2015). The prediction grid was truncated to only include available survey locations in depths between 55–500 m to limit extrapolating beyond the data and edge effects. Tweedie, delta-binomial, delta-gamma, and mixture distributions, which allow for extreme catch events, were investigated. The positive catch weight model includes survey pass ('first' for early season or 'second' for late season) and year. Vessel-year effects, which have traditionally been included in index standardization for this survey, were not included as 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 were included for each unique combination of vessel and year in the data to account for the random selection of commercial vessels used during sampling (Helser et al. 2004; Thorson and Ward 2014).

Results are shown for the delta-gamma and delta-lognormal distributions, which reported the best diagnostics among the explored models (Figure 8). Both models converged (positive definite Hessian matrix) but predicted data from both models showed slightly right-heavy tails compared to the assumed likelihoods, with the gamma model having stronger divergence. Spatiotemporal estimates of biomass from the delta-lognormal model were then converted into annual indices using the `sdmTMB::get_index()` function by integrating across the spatial domain of the survey (Anderson et al. 2025).

Overall, the delta-lognormal index estimates is more comparable to the 2019 spatiotemporal VAST-based index than the delta-gamma index, and less influenced by extreme catch events, particularly in 2013 and 2016; for these reasons, in addition to better model performance observed above, the delta-lognormal `sdmTMB`-based index was used for the base model in this assessment. The delta-lognormal mean value (2262.824) was slightly lower than the means of the index values used in the 2015 benchmark assessment (2701.12) and the 2019 update assessment (3301.765). However, since these are used as relative indices, these differences in mean values have no impact in themselves on the outcome of the assessment. Comparisons of the different error structures, design-based estimate and the VAST index used in 2019 are in Figure 9.

Length, age, and conditional age-at-length compositions were processed using the `nwfscSurvey` package in R publicly available on GitHub (Wetzel et al. 2025). Length compositions were created by expanding to the tow and summing to give a strata specific composition (Table 14). Strata definition was retained from the benchmark assessment. The strata compositions were combined to a coastwide composition using a design-based index of abundance from each stratum. The design based index is constructed by taking the average catch per unit effort (CPUE) defined as catch per area swept across tows in each stratum and year. The sum of strata specific composition data was then calculated, weighting by the average CPUE per stratum multiplied by the area of each stratum. Age distributions were included in the model as conditional-age-at-length (CAAL) observations. The marginal age-compositions were also included, but only for easier viewing of strong cohorts. The CAAL data were not expanded and were binned according to length, age, sex, and year.

The input sample sizes for length and marginal age-composition data were calculated based on Stewart and Hamel (2014). The input sample size of CAAL data was set at the number of fish at each length by sex and by year. Expanded length frequencies from this survey show intermittent years of small fish;

the 2018–2024 period generally suggests most fish are around 40–45cm in length (Figure 10). Strong cohorts are not immediately apparent and it seems that ageing error may result in some variability between years. Conditional age-at-length proportions (Figure 11) show relatively consistent length-at-age with few outliers.

### 2.1.3 Juvenile Survey

An updated coastwide pre-recruit index of abundance for 2001–2024 for widow rockfish was created using data from three midwater trawl surveys targeting young-of-the-year (YOY) rockfish (Juvenile Survey), provided by Tanya Rogers (SWFSC, pers. comm.). All surveys used identical gear, enabling the construction of a consistent coastwide index spanning from 36°N to the U.S./Canada border since 2004. Sampling in 2020 was limited due to the COVID-19 pandemic and excluded from all models. In 2010 and 2012, coverage was incomplete, so these years excluded from the final model to align with the 2019 assessment. Following the 2015 and 2019 assessments, data from 2001–2003 were also excluded due to limited spatial coverage (36°30' to 38°20' N latitude).

The index was built using a spatial GLM with the sdmTMB package (Anderson et al. 2025), modeling 100-day standardized catch-per-tow as a function of year (fixed effect), Julian date (GAM smoother,  $k = 4$ ), spatial random field, and spatiotemporal random effects. Models with Tweedie, delta-lognormal, and delta-gamma error structures were compared; DHARMA residuals and simulation-based diagnostics indicated the Tweedie model performed best. The index shows a moderately strong increasing trend in juvenile abundance from 2017 to 2023, with a slight decline in 2024 (Figure 40). Recent values remain high relative to the previous decade, and uncertainty estimates support the robustness of this trend.

## 2.2 Fishery-dependent data

Widow rockfish is primarily caught by bottom trawl and midwater trawl gears (Table 10). This species also commonly bycaught by fishery targeting Pacific hake/whiting (*Merluccius productus*, hereafter “hake”). Minimal amounts have been historically taken by non-trawl gears such as net and hook-and-line, which represented 1.4% and 1.1% of catches, respectively.

The fleet structure in this assessment was streamlined compared to the 2015 benchmark and the 2019 update assessments. The catches in the model are divided among three fishing fleets:

1. A coastwide shore-based bottom trawl fleet (1916–2024). This fleet also includes minimal catches made by net and hook-and-line gears, as well as widow rockfish catches made within historical foreign fishery targeting Pacific Ocean Perch between 1966–1976.
2. A coastwide shore-based midwater trawl fleet that targets rockfish (1979–2024).
3. A mostly-midwater trawl fleet that targets hake and includes an at-sea fleet (1975–2024) and a domestic shore-based fleet (1991–2024).

Catches by fleet and year are provided in Table 10. As in previous assessments, catches from Puget Sound and those from commercial shrimp trawls, commercial pots, and recreational fisheries were excluded (as these are generally minimal).

### 2.2.1 Landings

Landings from the 1916–2018 period were carried forward into this assessment with two modifications. One was made to the midwater and bottom trawl catches from California. Because PacFIN appears to underestimate midwater trawl catches in California in 1979–1980 when midwater trawl fishery for widow rockfish developed (Edward Dick, SWFSC, pers. comm.) we adjusted midwater and bottom trawl catches from California in these years to reflect the ratio of California midwater to bottom trawl catches in 1981–1982.

The second update was the use of new catch reconstruction for widow rockfish, provided by the Washington Department of Fish and Wildlife (WDFW). New Washington historical landings represent the best scientific information available. 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, since WDFW developed and used an 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.

Recent catches (2019-onward) were extracted from PacFIN for commercial shorebased data and NOR-PAC for at-sea hake fishery bycatch, and were otherwise appended onto the 1916–2018 landings and apportioned among fleets using the same criteria as those documented in the 2015 benchmark assessment Hicks and Wetzel (2015).

### 2.2.2 Fishery catch-per-unit-effort

Three fishery-dependent CPUE indices were included as in the most recent update assessment (Adams et al. 2019). Indices were derived from 1) Oregon bottom trawl (1984–1999), 2) hake at-sea foreign (1977–1988), and 3) hake at-sea domestic fleets (1983–1998). These were not updated; please refer to the most recent benchmark assessment (Hicks and Wetzel 2015) and most recent update assessment (Adams et al. 2019) for information.

### 2.2.3 Fishery length and age data

Biological data from commercial fisheries that caught widow rockfish were extracted from PacFIN on March 25, 2025 and from the NORPAC database on February 3, 2025. Lengths and age samples taken

during port sampling in California, Oregon, and Washington were used to generate length and age compositions. The data were classified into bottom trawl, midwater trawl, and hake trawl. For each fleet, the raw observations were expanded to the trip level, to account for differences in samples sizes relative to 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 widow rockfish landings among states combined into a single fleet (second stage expansion).

Table 11 shows the number of trips sampled and Table 12 shows the number of lengths taken for each year and fleet for non-hake fleets from the three states. Table 13 shows these numbers for the shoreside and at-sea hake fisheries. Expanded length compositions for bottom trawl, midwater trawl and hake fleets are shown in Figure 12 to Figure 14. Table 14 and Table 15 show the number of trips and number ages used in the. Age compositions for the three fleets are shown in Figure 15 and Figure 17. Occasional cohorts appear to move through the population, indicating that widow rockfish population dynamics may be characterized by episodic recruitment events.

#### 2.2.4 Discards

Data on discards of widow rockfish are available from three different sources. Historical sources included Pikitch et al. (1988) and Enhanced Data Collection Project (EDCP, Sampson and Lee (2002)). The West Coast Groundfish Observer Program (WCGOP) provided information on recent discard of widow rockfish between 2002–2023. Since 2011, under trawl rationalization, 100% observer coverage is required for the limited entry trawl sectors, which resulted in a large increase in data and ability to determine discard behavior.

For this assessment, we estimated bottom trawl discards and midwater trawl discards externally, using historical sources as well as WCGOP data, and added calculated discard amounts to landings of the corresponding fleets by year. The methods used to reconstruct discard amounts in different time periods are detailed below.

1. For the years 1982–1989, landings in the bottom trawl and midwater trawl fleets were scaled using fleet-specific discard rates estimated from the Pikitch study.
2. For the years 1990–2001, landings in the bottom trawl and midwater trawl fleets were scaled using fleet-specific discard rates estimated from the EDCP data.
3. For the years 2002–2023, GEMM estimates of fleet-specific discards amounts were added to the landed catch (bottom trawl + other, and midwater trawl).
4. The 2024 values were set to the average from the GEMM estimates for the period 2021–2023.

The treatment of the discard changed from the 2015 benchmark and 2019 update assessments. Then, discards were estimated with retention functions within the model, which was standard practice in 2015, following a long period of large discards due to trip limits. However, discard rates have been low for widow rockfish for more than 10 years so the benefit of using retention functions to extrapolate beyond the range of observed data is reduced and the biological data from the discards are no longer as likely to

be informative about dynamics of the total population. As a part of model bridging, we illustrated that treating discard as catch (rather than estimating them in the model) did not have much impact on model results. Also, this approach avoids hard-to-diagnose issues that come from estimating retention curves (especially with limited amounts of data). For some species, the discard data may provide important information about recent recruitment because the smaller fish are being discarded. However, for this stock, removing the discard amounts and length-compositions from the likelihood had little impact on recruitment estimates.

Widow rockfish bycatch within the hake fishery represents total catch, with discards already accounted for.

## 2.2.5 Biological data

The approach to the estimation of all biological parameters was the same as in the 2019 update assessment, Adams et al. (2019).

### 2.2.5.1 Weight-length relationship

Weight-at-length data were updated for this assessment. Following the approach used in the 2015 benchmark, data used to estimate the length-weight relationship for widow rockfish were gathered from commercial catch sampling schemes (PACFIN, ASHOP) and fishery-independent surveys (Triennial Survey and WCGBTS).

The following relationships between weight and length for females and males were used in the current assessment:

$$\text{Females: } \quad \textit{weight} = 1.5885 \times 10^{-5} \cdot \textit{length}^{2.9873}$$

$$\text{Males: } \quad \textit{weight} = 1.4507 \times 10^{-5} \cdot \textit{length}^{3.0123}$$

where weight is measured in kilograms and length in cm. These parameters were used in the assessment as fixed.

### 2.2.5.2 Maturity schedule

Maturity parameters in this update assessment were carried over from 2015 benchmark and 2019 update assessments; please refer to the most recent benchmark assessment (Hicks and Wetzel 2015) and most recent update assessment (Adams et al. 2019) for information.

### 2.2.5.3 Fecundity

The model uses widow rockfish specific fecundity-at-length relationships from the meta-analysis from Dick et al. (2017) instead of assuming spawning output being proportional to body weight as in 2015 and 2019 models. Accounting for size-dependent fecundity in rockfish stocks using the meta-analysis from Dick et al. (2017) has become standard practice in recent years and reflects the best available science. The fecundity relationship for widow rockfish spawning output (in billions of eggs) as a function of length (in cm) based on the parameters reported in <https://github.com/EJDick-NOAA/Rockfish-Fecundity> is  $SO = 1.10961E-8 * L^{4.545}$ .

### 2.2.5.4 Natural Mortality

In this assessment, natural mortality ( $M$ ) is estimated for females and males, while using the Hamel and Cope (2022) prior. The prior on  $M$  has been updated to reflect the most recent guidance from Hamel and Cope (2022); the log-mean therefore remains unchanged while the log-SD has been set to 0.31. Using a maximum age of 54 the point estimate and median of the prior on  $M$  is 0.10.

### 2.2.5.5 Length-at-age

Growth parameters were fully estimated within the assessment model, for females and males separately following the same formulation in 2015 and 2019 assessment models.

### 2.2.5.6 Ageing bias and imprecision

Ageing error matrices were unchanged from the previous assessment; please refer to the most recent benchmark assessment (Hicks and Wetzel 2015) and most recent update assessment (Adams et al. 2019) for information.

## 2.3 Environmental and Ecosystem Data

This assessment did not use any environmental or ecosystem data related to the stock.

## **3 Assessment model**

### **3.1 History of modeling approaches**

This section is not required for an update assessment; please refer to the most recent benchmark assessment (Hicks and Wetzel 2015) and most recent update assessment (Adams et al. 2019) for information.

### **3.2 Responses to most recent past STAR Panel recommendations**

This section is not applicable to the current assessment.

### **3.3 Responses to SSC Groundfish Subcommittee requests**

Responses to the most recent requests from the Science and Statistical Committee (SSC) and Pacific Fishery Management Council (PFMC) are provided in a separate document.

### **3.4 Model Structure and Assumptions**

#### **3.4.1 Changes from the Last Assessment and Model Bridging**

The last benchmark stock assessment for widow rockfish was conducted in 2015 (Hicks and Wetzel 2015), and it was updated in 2019 (Adams et al. 2019).

In this assessment, the changes made to the 2019 model (Adams et al. 2019) occurred in two stages. The first round of changes was reviewed in August 2025. The model reviewed at the August 2025 Pacific Fishery Management Council (PFMC) Science and Statistical Committee (SSC) Groundfish Subcommittee (GFSC) meeting followed the 2015 benchmark assessment in its structure and assumptions, as required by the Terms of Reference for update assessments (with the exception of removing discard length composition data for the hook-and-line fleet, as discussed and approved at the review meeting).

The second round of changes followed after the August 2025 review meeting, when we explored a larger range of options which go beyond update assessment Terms of Reference and no longer match the 2015 benchmark. The second round of changes resulted in more parsimonious model that was raised to the current best practices in West Coast groundfish stock assessments.

The changes made to the model are listed in two separate groups, according to stages described above.

**Changes made from the 2019 update assessment for August 2025 update:**

The exploration of models began by bridging from the 2019 update assessment to current SS3 version, which produced no discernible difference.

We then focused on data bridging (Figure 24).

- **Adding most recent data from commercial fleets** (as described under “Data”, Section 2). Updating the catch series did not have a substantial effect on the historical biomass; the stock biomass increasing from 2000–2020 before decreasing up to the current period. Note: the catch time series was further updated in the second set of bridging steps to include a catch reconstruction for Washington State.
- **Updating WCGBTS index using current methodology** (as described under “Data”, Section 2).
- **Updating the log-SD of the prior for natural mortality** based on Hamel and Cope (2022). The log-mean remained unchanged while the log-SD has been decreased from 0.44 to 0.31.
- **Updating length-weight parameters estimated** by including most recent data.
- **Extending the main period for estimating recruitment deviations and updating recruitment bias adjustment parameters** based on Methot and Taylor (2011).
- **Adding a block to hake fleet selectivity to account for recent changes in fleet behavior.** Adding a block to hake fleet selectivity accounted for a change in fish mean length (2020–2024) due to shifts in the spatial distribution of the hake fleet and improved the fit to the length compositions (Holland and Martin 2019). This change had a discernible influence on the estimated spawning biomass.
- **Adding hook-and-line discards to landings in the hook-and-line fleet.** WCGOP corrected discard lengths for the hook-and-line fleet to omit nearshore fixed gear samples, which were erroneously included with the hook-and-line fleet in the previous benchmark (Hicks and Wetzel 2015) and update assessments (Adams et al. 2019). This resulted in changes to the discard length distribution and years for which data was available (Figure 18). Because available hook-and-line discard length samples were too scarce, this assessment model was unable to reliably estimate retention parameters. Therefore, in this assessment, we added the hook-and-line discard to hook-and-line landings.

Updates to discards, particularly the removal of hook-and-line length composition data and adding hook-and-line discards to landings, had the most significant impact on the absolute stock biomass: absolute spawning biomass before 1980 was slightly lower than the 2019 update assessment estimates, and noticeably lower from the mid-2010s through the current year.

In the 2015 and 2019 assessments, the hook-and-line discard length data consisted primarily of small fish from nearshore fixed gear (Figure 18), and the model interpreted the presence of those small fish as a recruitment signal, with the 2019 update assessment estimating the 2013 recruitment as the strongest year class over the duration of the fishery. Those discard lengths interacted in the model with discard amounts so that the model exhibited substantial sensitivity to even slight changes in discard data within the hook-and-line fleet. Figure 21, Figure 22 and Figure 23 show intermediate bridging steps in updating

hook-and-line discard data. The slight decrease in 2011–2017 discard amounts (compared to those used in the 2019 assessment) caused a decrease in estimated recruitment (Figure 23) leading to lower spawning biomass (Figure 21). Adding discards for 2018–2023 caused recruitment to be estimated unreasonably high bringing spawning biomass well above the unfished level (Figure 22). Such a disproportionate effect of a small amount of data from the fleet that contributes only 1.1% of catch is most likely related to how discard was modeled in the 2015 assessment. Recent assessments' exploration revealed that there are some hard-to-diagnose issues that come from estimating retention parameters (especially with limited amounts of data). With the discard length data as well as retention parameters removed, and the hook-and-line discards added to landings, the model no longer exhibited large swings in estimated recruitment and no longer estimated extremely high recruitment in the 2010s, which resulted in lower estimates of spawning biomass and stock productivity in recent years.

Updates to survey indices and composition data, following updates to discards, lead to minor changes in spawning biomass estimates (Figure 24). The rest of the changes also had only minor impact on recent relative spawning biomass estimates (Figure 24) and collectively resulted in a very small effect in relative spawning biomass post-1990 (Figure 25).

#### **Changes made from August 2025 model for the January 2026 model:**

After August 2025 review, we explored changes to the model that were outside the Terms of Reference for an update assessment. Those changes included:

- **Streamlining the fleet structure** (as described under “Data”, Section 2). The landings from fleets with minimal and mostly historical catches (hook-and-line and net) were added to the bottom trawl landings with hook-and-line and net composition data removed from the model.
- **Use external estimates of discards rather than estimate within the model.** Methods, used to reconstruct discards in the bottom trawl and midwater trawl fleets, based on the Pikitch, EDCP and WCGOP data are described under “Data” (Section 2). All retention parameters were removed from the model.
- **Updating the data weighting approach.** The data weighting approach was changed to match recent practices, including the use of the Francis rather than McAllister-Ianelli approach, and no longer including a 50% additional reduction in weights. The Francis method performed better in a simulation analysis (Punt 2017) and has been the preferred approach in most recent stock assessments. The 50% multiplier on the data weights used in the previous assessment was an approach more common in 2015 to account for the potential double use of data since length and age are observed from the same fish. However, the sum of the adjusted input sample sizes for length and age data combined are already far lower than the number of sampled fish because they are primarily based on trips or hauls and then further reduced by the data-weighting algorithm. This 50% adjustment is no longer common practice and has not been used any other recent assessments.
- **Use a fecundity relationship rather than assume the number of eggs is proportional to body weight.** Use fecundity-at-length based on the meta-analysis from Dick et al. (2017) has become standard practice in recent years and reflects the best available science.
- **Various additional refinements were made.** These refinements had a minimal impact on the model.

- The landings from Washington were updated to use the new Washington catch reconstruction.
- The historical catch within foreign fishery that targeted Pacific Ocean Perch during 1966–1976 period was moved from the hake fleet to the bottom trawl fleet.
- The bias adjustment ramp was updated after the retuning and also to modify the estimated values to have full bias adjustment starting in 1970.
- The start of the final block on midwater trawl selectivity was moved from 2011 to 2017.

Comparisons of summary biomass, fraction unfished and estimated recruitment for major bridging steps within the second round of changes are shown in Figure 26, Figure 27 and Figure 28. None of the updates resulted in large changes in estimated population trajectories and model outputs, but several important quantities were sensitive to a few of the changes.

Combining discards with landings in bottom trawl and midwater trawl fleets did not reveal unexpected or unreasonable patterns with a disproportionate effect of changes on model results (as it was in case of hook-and-line discard data). Simplifying the fleet structure did not bring about large changes in model results either, but interacted with the Francis weighting approach. Extending the block on midwater trawl selectivity did not cause any noticeable change.

The use of the Francis weighting approach (instead of McAllister-Ianelli) and using  $\lambda = 1$  (and not further down-weighting fishery composition data) resulted in the biggest change from the August 2025 base model, causing the estimates of natural mortality to go up, which translated into increases in the estimated productivity of the stock, including equilibrium catch and estimated overfishing limits (OFLs). Relative to the August 2025 model, the updated data weighting method upweighted length data from the bottom trawl fleet and age data from all three commercial fleets (bottom trawl, midwater trawl, hake); all other composition data sources were downweighted (Table 18). For bottom trawl, in particular, this upweighting is likely in part due to the removal of discard composition data, as Stock Synthesis does not apply separate data weights to discarded and retained composition data from the same fleet. The discard compositions are very noisy and difficult to fit, so their removal allowed for upweighting of the remaining data. The decrease in the weight of WCG BTS conditional age-at-length data by approximately one-third, paired with upweighting of other data, is likely the major driver of the increased estimate of natural mortality.

With the change in fecundity relationship spawning output is now expressed in billions of eggs and no longer directly comparable with spawning biomass expressed in metric tons in previous models. This change did not have much impact on age 4+ biomass (Figure 26), but the spawning output time series was impacted by the changes in relative contributions of larger/older fish which are disproportionately removed from the population, illustrated in Figure 29, which leads to lower estimates of fraction unfished and estimated OFLs. In particular, the stock status (fraction of unfished spawning output) reached a low point of 0.232 in 1998 (below the 0.25 overfished threshold) as compared to a minimum of 0.326 in 2001 in the August 2025 base model. The addition of the fecundity relationship also resulted in slightly lower estimates of OFLs and fraction unfished at the end of the time series compared to the previous step in this bridging, though still higher than the August 2025 estimates. Note that the model reviewed in October 2025 included a fecundity relationship associated with “unobserved rockfish” rather than the parameters specific to widow rockfish. This is the only difference in model configuration

between the October 2025 and current base models, although the difference between the two fecundity relationships is smaller than the difference between either one and the weight-length relationship used to estimate spawning output in previous assessments.

Comparison of the time series estimates from the 2019 update assessment model and this model are shown in Figure 30 to Figure 33.

### 3.4.2 Modeling Platform and Structure

Stock Synthesis statistical catch-at-age modelling framework, version 3.30.24.1, was used for this assessment; and r4ss version 1.52.1 and R version 4.5.0 to investigate and plot the model fits.

### 3.4.3 Model Overview

The model is a two-sex, age-structured model starting in 1916 with an accumulated age group at 40 years. Sex-specific growth and natural mortality were estimated. The length frequency distributions range between 8 and 56 cm, binned into 2 cm intervals. Population 2 cm length bins are defined at a wider range, between 6 and 60 cm. Ageing error was retained from the 2015 benchmark assessment (Hicks and Wetzel 2015). The model uses widow rockfish fecundity-at-length relationships instead of assuming spawning output being proportional to body weight as in the 2015 and 2019 models. With the change in fecundity relationship, spawning output is now expressed in billions of eggs and not in metric tons, as in 2015 and 2019 models.

#### 3.4.3.1 Model Fleets and Areas

The assessment uses a single-area model, consistent with the previous benchmark and update assessments. The fleet structure in this assessment was streamlined compared to the 2015 benchmark and the 2019 update assessments. In this assessment, the catches are divided among three fishing fleets:

1. A coastwide shore-based bottom trawl fleet (1916–2024). This fleet also includes minimal catches made by net and hook-and-line gears, which represented 1.4% and 1.1% of the input catches, respectively. Removals from net and hook-and-line fisheries were previously treated as separate fleets. The bottom trawl fleet also includes widow rockfish catches made within historical foreign fishery targeting Pacific Ocean Perch between 1966–1976.
2. A coastwide shore-based midwater trawl fleet that targets rockfish (1979–2024).
3. A mostly-midwater trawl fleet that targets hake and includes an at-sea fleet (1975–2024) and a domestic shore-based fleet (1991–2024).

The following fishery-independent surveys are also included in the model:

1. Alaska Fisheries Science Center/Northwest Fisheries Science Center West Coast Triennial Shelf Survey (Triennial Survey).
2. Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey (WCGBTS) (2003–2024).
3. recruitment index from the National Marine Fisheries Service (NMFS) SWFSC and NWFSC/PWCC Midwater Trawl Survey (Juvenile Survey) (2004–2024).

### 3.4.4 Model Parameters

#### 3.4.4.1 Estimated and Fixed Parameters

There are 194 estimated parameters in the base model (relative to 214 in the August 2025 base model which included additional parameters for selectivity and retention). These included one parameter for recruitment ( $R_0$ ), 10 sex-specific parameters for sex-specific growth, two sex-specific natural mortality parameters, four parameters for the catchability ( $q$ ) of the hake and the Triennial Survey of abundance (catchability for other indices were calculated analytically using the “float” option in SS3), four parameters each for extra variability for the hake, bottom trawl, juvenile and foreign-at-sea indices of abundance, 36 parameters for selectivity, 125 recruitment deviations (16 of which set up the initial age structure), and 12 forecast recruitment deviations.

Fixed parameters in the model included steepness, standard deviation of recruitment deviates, maturity at age, fecundity-at-length, and length-weight parameters. Consistent with the previous assessment (Adams et al. 2019), steepness was fixed at 0.72, matching the mean of the current west coast rockfish steepness prior (Thorson et al. 2019), described below under “Priors” (Section 3.4.4.2). A likelihood profile was conducted for steepness. The standard deviation of recruitment deviates was fixed at 0.60. Maturity at age was fixed as described in the previous update assessment, Adams et al. (2019). Fecundity-at-length parameters were fixed at values from Dick et al. (2017). Length-weight parameters were fixed at estimates using length-weight observations from the WCGBTS (Figure 19 and Table 19).

All selectivity curves in the base model were length based and had the same shape as the 2015 benchmark and the 2019 update assessments. The base model assumed asymptotic selectivity (using the double-normal formulation in SS3) for each fishery, except for the midwater trawl fishery (Hicks and Wetzel 2015). The WCGBTS and Triennial Survey both used spline curves. The WCGBTS survey fleet selectivity was estimated to be slightly lower at lengths greater than 45 cm, compared to the selectivity estimated in 2019.

Time blocks were used for selectivity parameters in the bottom trawl, midwater trawl, and hake fisheries as indicated in Figure 36.

#### 3.4.4.2 Priors

The prior on natural mortality ( $M$ ) in the previous assessment was defined as a lognormal with mean on the log-scale of  $\ln(5.4/A_{\max})$  and  $SD(\ln(M)) = 0.44$  following Hamel (2015) and Then et al. (2015).

In the current assessment, the prior on  $M$  has been updated to reflect guidance from Hamel and Cope (2022). With this update, the log-mean remains unchanged while the log-SD has been set to 0.31. Using a maximum age of 54 the point estimate and median of the prior on  $M$  is 0.10.

The prior for steepness ( $h$ ) has not changed since the 2019 update assessment (Adams et al. 2019). It assumes a beta distribution with parameters based on Thorson et al. (2019), with mean = 0.72 and SD = 0.16 ( $\alpha = 4.95$ ,  $\beta = 1.93$ ) which was approved for use in all rockfish stock assessments.

#### 3.4.4.3 Recruitment deviations

Recruitment deviations from 1900–2024 were estimated to appropriately quantify uncertainty; inappropriate specifications can have a large effect on model uncertainty. The standard deviation of recruitment variability ( $\sigma_R$ ) was assumed to be 0.6 in the 2015 assessment, based on iteratively tuning to a value slightly less than the observed variability of recruitment deviations in the period 1975–2010 in 2015 (Figure 39). The earliest length-composition data occur in 1976 and the earliest age data were in 1978. The most informed years for estimating recruitment deviations based on available composition data were from about the mid-1970s to about 2019. The period from 1900–1970 was fit using an early series with little or no bias adjustment, the main period of recruitment deviates was 1971–2020 using a bias adjustment ramp, and 2021 onward was fit using forecast recruitment deviates with little bias adjustment. Methot and Taylor (2011) summarize the reasoning behind varying levels of bias adjustment based on the information available to estimate the deviates. The bias adjustment settings were tuned to the estimates produced by `r4ss::SS_fitbiasramp()` with the exception that the first year with full bias adjustment was set to 1970 (instead of the estimate of 1975, which occurs after two large, reasonably well-informed recruitments in 1970 and 1971).

#### 3.4.4.4 Sample weights

The base model uses the Francis (2011) weighting method. This is a departure from the August 2025 base model, which followed the most recent benchmark assessment (Hicks and Wetzel 2015) in using the McAllister and Ianelli (1997) method. The data weighting approach was changed to match recent practices, including the use of the Francis rather than McAllister-Ianelli approach. The Francis method performed better in a simulation analysis (Punt 2017) and has been the preferred approach in most recent stock assessments.

An additional change from the previous assessments was the removal of a 50% additional reduction in weights (via the lambda factors) for all fleets with both marginal length and marginal age compositions, which down-weighted the likelihood contribution by 50% to account for the potential double use of data since length and age are observed from the same fish. This 50% adjustment is no longer common practice and has not been used any other recent assessments. The adjusted input sample sizes are based on trips or hauls rather than the number of sampled fish, and the sum of the adjusted input sample sizes for length and age data combined are already far lower than the number of sampled fish, so no further reduction is necessary to avoid double use.

### 3.4.5 Key Assumptions and Structural Choices

Following recommendation of Pacific Fishery Management Council (PFMC) Science and Statistical Committee (SSC) Groundfish Subcommittee (GFSC) meeting in August 2025, for this update assessment we explored a larger range of options which go beyond update assessment Terms of Reference, which resulted in more parsimonious model that was raised to the current best practices in West Coast groundfish stock assessments.

The major structural choice was related to fleet structure, which was simplified to focus on major fisheries that remove more than 97% of catch. Those included bottom trawl, midwater trawl and hake fleets. The fisheries with minimal and mostly historical catches, such as hook-and line and net, were added to the bottom trawl fleet. In the 2015 benchmark and 2019 update assessments catches were divided among five fleets (bottom trawl, midwater trawl, catches within fleet targeting hake, net and hook-and line).

Also, the 2015 benchmark and 2019 update assessments estimated discards using retention curves for the bottom trawl, midwater trawl, and hook-and-line fleets based on discard biomass and length composition data from the WCGOP. Changes to the underlying discard length composition data for the hook-and-line fleet from WCGOP illustrated that very large recruitment events previously estimated for 2013 and 2014 were mainly driven by very small amounts of composition data for a minor fleet responsible for less than one-tenth of a percent of the catch in the last decade. This led to implausible population dynamics, so the decision was made to consolidate fleets and add the small amount of (primarily historical) catches from net and hook-and-line fisheries to the shore-based bottom trawl fleet. In this assessment, the discards in bottom trawl and midwater trawl fleets were estimated externally, based on historical and the WCGOP data, and added to landings within the corresponding fleets. Therefore, all retention curves and associated parameters were removed from the base model. Discard rates have been low for widow rockfish for more than 10 years so the benefit of using retention functions to extrapolate beyond the range of observed data is reduced and the biological data from the discards are no longer as likely to be informative about dynamics of the total population. This change also helps avoid hard-to-diagnose issues that come from estimating retention curves (especially with limited amounts of data), as we encountered with the hook-and-line fleet, earlier in the assessment process. Removing the discard amounts and length-compositions from the likelihood had little impact on recruitment estimates.

Other structural choices were related to updating the model to the current assessment practices, and included using the Francis weighting approach and fecundity. Details on those changes are provided under “Changes from the Last Assessment and Model Bridging” (Section 3.4.1).

## 3.5 Base 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 (Taylor et al. 2021) is available on the assessment GitHub repository ([github.com/mcgoodman/widow\\_rockfish\\_2025](https://github.com/mcgoodman/widow_rockfish_2025)) along with the Stock Synthesis [input files](#).

### 3.5.1 Parameter Estimates

The base model parameter estimates along with asymptotic standard errors are shown in Table 19. Estimates of key derived parameters and asymptotic 95% confidence intervals are shown in Table 22.

The estimates of natural mortality were  $0.135 \text{ yr}^{-1}$  for females and  $0.147 \text{ yr}^{-1}$  for males. These estimates continue gradual decrease in  $M$  from those of the 2019 update assessment (Female 0.1444, Male: 0.1549; Adams et al. (2019), Figure 34) and the 2015 benchmark assessment (Female: 0.1572, Male: 0.1705; Hicks and Wetzel (2015)). However, they were higher than suggested by the medians of the prior distributions used in this assessment and the previous assessments. Fixing  $M$  at lower values than those estimates resulted in a pattern of below average recruitment in the early part of the time series which is not well informed by age or length composition data (Figure 64). This suggests that the model is attempting to reduce the expected proportion of older fish in the early age compositions to offset the lower  $M$  estimate. The estimates of  $M$  fall within the 95% quantile range of the prior distribution (0.055– 0.184), and are shown in Figure 34.

Updating age composition data resulted in the largest decrease in  $M$  among the various intermediate models bridging from the 2019 assessment. This is broadly consistent with observations of older individuals in updated age composition data. For instance, the maximum age for widow rockfish in the WCGBTS data prior to 2018 was 37 yrs with a 99.9<sup>th</sup> percentile of 37, while data collected since include individuals up to 51 with a 99.9<sup>th</sup> percentile of 45. Updating that natural mortality prior resulted in a comparatively small decrease in  $M$  (Figure 34).

Estimating  $M$  is difficult in stock assessments, and the estimated values may represent model misspecification instead of the actual life-history trait. However, in alternative models to the base, the estimates of female  $M$  were not higher than  $0.13 \text{ yr}^{-1}$  (Table 21), except when forcing asymptotic selectivity on the midwater trawl fleet (Table 21). Uncertainty in the estimated  $M$  was also much less than the range of the prior (Figure 34).

Selectivity curves were estimated for commercial and survey fleets and parameter estimates are provided in Table 19. The estimated selectivity are shown in Figure 35. The selectivity curves showed a strong dome-shaped selectivity for the midwater fleet, while the selectivity for the hake fleet did not support dome-shaped selectivity (Figure 35). The estimated selectivity curves for the Triennial and WCGBTS were similar to each other except that the triennial survey selected larger fish (Figure 36). The WCGBTS exhibited a more pronounced dome-shaped selectivity compared to the 2019 assessment.

In the 2015 benchmark assessment, additional survey variability (observation error added directly to each year's input variability) for the Triennial Survey and WCGBTS was not estimated in the model because initial runs estimated the additional variability parameter at zero (Hicks and Wetzel 2015). To avoid bound issues in estimation of the Hessian, their values were fixed at zero. We retained the same modelling approach for the update assessment. The additional standard deviation added to the fishery-dependent indices was quite large: 0.2 for the bottom trawl index and 0.6 for the foreign at-sea hake fleet. The additional variability on the juvenile survey was the highest, at 1.27, giving the index very little weight in the model.

The estimates of maximum size for both females and males (Table 19) did not differ substantially from Adams et al. (2019). Estimates of  $k$  were slightly different in the model, but that is expected when accounting for selectivity. Estimated growth curves are shown in (Figure 37).

Estimates of recruitment suggest that the widow rockfish population is characterized by variable recruitment with occasional strong recruitment events and periods of low recruitment (Figure 38, Table 22). There is little information regarding recruitment prior to 1965.

### 3.5.2 Fits to the Data

Fits to data are provided for survey abundance indices, length composition data for the fisheries and surveys, marginal age compositions for the fisheries, and conditional age-at-length observations for the WCGBTS.

Survey indices and total discards were fitted assuming a lognormal likelihood. The six indices of abundance (three survey series, and three fishery indices of abundance) are shown in Figure 40. The Triennial Survey treatment was consistent with Adams et al. (2019). Extra standard error was estimated for all of the series except for the two survey series (Table 19). None of the series showed patterns in residuals, and with the large amount of error, none of the series showed serious lack of fit. The recent WCGBTS showed a general increase from 2003–2015 followed by a general decrease from 2016–2024, which was also estimated in the base model (Figure 40). The model did not fit the indices variability well, particularly years with relatively low (2015, 2021, 2022) or high (2016) estimates of abundance, as might be expected for a long-lived rockfish species.

Annual fits to the length-composition data are depicted using Pearson residuals-at-length for all fleets in Figures 41. More detailed plots of fitted and observed proportions at length are shown in Appendix A. The combined WCGBTS length frequencies across years displayed a weakly bimodal distribution with a valley around 37 cm, which the model approximated well (Figure 42). Fits to the Triennial Survey length frequencies (which have not been updated in this assessment) show underestimation of 35–45 cm males and overestimation of similar length females, as in Hicks and Wetzel (2015).

Age data were fitted as marginal age compositions for the fishing fleets and as conditional age-at-length for the WCGBTS, which were expanded by tow and then by strata, following the 2015 benchmark assessment (Hicks and Wetzel (2015)). Pearson residuals for the commercial fleets are shown in Figures 41. Aggregating across years shows that the fit to age comps was good (Figure 44). The observed and expected age-at-length are shown in Figure 45 for the WCGBTS observations. Plots with the residuals for individual observations showed reasonably good fits to the conditional age-at-length data from the WCGBTS (Figure 46).

### 3.5.3 Population Trajectory

The predicted spawning output (billions of eggs) is given in Table 20 and plotted in Figure 47. The predicted spawning output from the base model generally showed a slight decline over the time series

until 1966 when the foreign fleet began. A short, but sharp decline occurred, followed by a steep increase due to strong recruitment. The spawning output declined rapidly with the developing domestic midwater fishery in the late 1970s and early 1980s, and is estimated to have been below the 25% of  $B_0$  overfished reference point from  $\infty$  to  $-\infty$  with a minimum of 2200% in 1998. A combination of strong recruitment and low catches resulted in a steady increase in spawning output from 2000 through 2016, increasing above the 40% of  $B_0$  target in 2001. A target fishery for widow rockfish was reestablished in 2017. The stock exhibits a decline in most recent years with the increased catches since 2017.

The 2025 spawning output relative to unfished spawning output is above the target of 40% of unfished spawning output (50.1%), with a low of 22% in 1998 (Figure 49). Approximate confidence intervals based on the asymptotic variance estimates show that the uncertainty in the estimated spawning output is high, especially in the early years. It should be noted that while the stock is currently above the 40% target, the target does fall within the approximate 95% confidence interval (Figure 49).

Recruitment deviations (Figure 38 and discussed in Section 3.4.4.3) provide a more realistic portrayal of uncertainty. Estimates of recruitment appear to be episodic and characterized by periods of low recruitment, with several very large, but uncertain, estimates. The 2019 update assessment estimated the 2013 recruitment as the strongest year class over the duration of the fishery, however the current assessment does not support this. It may be worthwhile to investigate the periods of strong and weak year classes further to see if it is an artifact of the data, a consistent autocorrelation, or a result of the environment. The input bias adjustment ramp matched the estimated ramp (Figure 39).

The stock-recruit curve resulting from a fixed value of steepness is shown in Figure 39 with estimated annual recruitment also shown. The stock is predicted to have never fallen to low enough levels to make the estimation of steepness well supported by signal in the data. But even then, the estimation of steepness would be complicated by the fact that periods of higher and lower recruitment (often driven by climate and other environmental factors) may cause the estimated steepness value to represent only limited time period rather than a long term average. The lowest levels of predicted spawning output showed some of the smallest recruitment events and very few above average recruitment events. Sensitivities to alternative values of steepness were explored via likelihood profile analysis (discussed below in Section 3.6.5).

## 3.6 Model Diagnostics

### 3.6.1 Convergence

A number of tests were performed to verify convergence of the model. Following conventional AD Model Builder methods (Fournier et al. 2012), we checked that the Hessian matrix for the base model was positive-definite. There were no difficulties in inverting the Hessian to obtain asymptotic variance estimates. The maximum component of the final gradient is very low.

To confirm that the reported estimates were from the global best fit, we evaluated the model's ability to recover similar likelihood estimates when initialized from dispersed starting points (jitter option in

SS3). Starting parameters were jittered using a setting of 0.1 for 100 iterations. This perturbs the initial values used for minimization with the intention of causing the search to traverse a broader region of the likelihood surface. The majority (57 out of 100) returned to the same objective function value as the proposed model. The remaining runs exhibited worse fit than the proposed model. The spread of this search indicates that the jitter was sufficient to search a large portion of the likelihood surface, and that the model is in a global optimum.

We also completed a set of standard model diagnostics that included retrospective analysis and likelihood profiles described below.

### 3.6.2 Parameter Uncertainty

Parameter estimates are shown in Table 19 and Table 20 along with approximate asymptotic standard errors. The only parameters with an absolute value of correlation greater than 0.95 were the female and male natural mortality parameters, which is expected. Estimates of key derived quantities are given in Table 22 along with approximate 95% asymptotic confidence intervals. There is a reasonable amount of uncertainty in the estimates of biomass. The confidence interval of the 2025 estimate of the fraction of unfished spawning output is 30.35%–69.8% and mostly above the management target of 40% of the unfished spawning output.

### 3.6.3 Sensitivity Analyses

Sensitivity analysis was performed to determine the model behavior under different assumptions than those of the base case model. Broad range of sensitivity runs were conducted at multiple stages of the assessment. Here, we present only several of them:

1. Fixed natural mortality at 0.1 for both sexes (the median of the prior used in the assessment).
2. Fixed natural mortality at  $0.144 \text{ yr}^{-1}$  for females and  $0.155 \text{ yr}^{-1}$  for males (2019 assessment estimated values).
3. Fixed natural mortality at  $0.157 \text{ yr}^{-1}$  for females and  $0.17 \text{ yr}^{-1}$  for males (2015 assessment estimated values).
4. Estimating natural mortality using the prior based on the maximum age of 50 years old.
5. Estimating natural mortality using the prior based on the maximum age of 45 years old.
6. Using double-normal selectivity curve for WCGBTS, fixing it asymptotic.
7. Using double-normal selectivity curve for WCGBTS, allowed it to be dome-shaped.
8. Adding small amount of recreational catches as reported by WCGOP.

Differences in likelihood and estimates of key parameters and derived quantities are shown in Table 21. Predicted trajectories of spawning output, fraction unfished, recruitments and recruitment deviations comparisons of model estimates for 2025 are shown in Figure 53, Figure 54, Figure 55, and Figure 56.

Fixing  $M$  at values lower than the base case estimate resulted in decreases in estimated spawning output in recent years. Fixing  $M$  at 0.1, the median of a prior informed by maximum age of 54 years, resulted in largest decrease in spawning output and associated management quantities. The unfished spawning output in sensitivity runs with  $M$  fixed at the estimates from the 2019 and 2015 assessments is very similar among these runs. However, the lower the natural mortality is, the lower the final assessment year spawning output is, since the less productive stock is impacted more by fishery removals. The models with higher natural mortality need to scale up estimated recruitments, in order to provide for a sufficient amount of fish to sustain the catches over time, while having the same recruitment deviations.

The model results were not sensitive to the alternative values of the median of the  $M$  prior, and estimated  $M$  values were similar in all runs. This is an indication that the data provide a stronger signal about  $M$  than the prior.

The last three runs (changing the selectivity pattern for WCGBTS and adding recreational catches) did not have a noticeable impact.

#### 3.6.4 Retrospective Analysis

A 10-year retrospective analysis (Figure 57) was conducted by running the model removing the most recent 1 to 10 years of data (i.e., “Data -1 Years” corresponds to data through 2023 instead of 2024). Population trends from all retrospective runs were very close, and no concerning patterns were observed in the retrospective analysis. There is a general trend of increasing scale and fraction unfished as years are removed. This result is expected because the fraction of older fish in the WCGBTS increased substantially in recent years, providing more information on overall and recent productivity, and sequentially peeling off individual years of WCGBTS age data leads to increasing estimates of natural mortality and unfished recruitment. Additionally, as years are pulled away the estimate of the size of the 2016 year class decreases towards average and the sizes of year classes since 2016 increase towards average. This is also expected as information about those recent year classes is removed.

Retrospective analysis of recruitment deviations over the last 10 years is shown in Figure 58, illustrating which year classes are estimated to be large or small in the current assessment, and also what the recruitment deviations would have been estimated at with years of data sequentially removed. It is worth pointing out that despite substantial changes made to the fleet structure of the model (compared to the 2019 assessment), with seven years of data removed, the model would have still estimated the 2013 year class as very large, which gets smaller with every year of data added. This suggests that multiple sources of earlier data inform the model about the potential of a high 2013 year class, and caution should be taken when large recent year classes are estimated in stock assessments.

Estimated relative spawning output from the base model was also compared with previous assessments (Figure 59). The current assessment follows a similar trend to previous assessments over the overlapping years, and estimated spawning output falls within the mid-range of previous assessments.

### 3.6.5 Likelihood Profiles and key parameters

Likelihood profiles were conducted for unfished virgin recruitment ( $R_0$ ), steepness ( $h$ ) and sex-specific natural mortality ( $M$ ) values simultaneously. These likelihood profiles were conducted by fixing the parameter at specific values and removing the prior on the parameter being profiled. Without the original prior distribution the MLE estimates from the base case will likely be different than the MLE in the likelihood profile, but this displays what information the data have.

For profiles of natural mortality, the negative log-likelihood was minimized at a value of 0.147 for males, and a value of 0.135 for females. Profiles for natural mortality for each sex are illustrated in (Figure 62, Figure 63). Profiles over female natural mortality indicate that the recruitment deviation prior and age data most strongly influence the estimate of natural mortality, with survey indices also being somewhat influential. Length data provides very little information. Profiles over male natural mortality behaved similarly. For steepness, the negative log-likelihood was minimized at a steepness of 0.77, however the 95% confidence interval extends over the entire range of possible steepness values. Profiles for steepness are illustrated in (Figure 61). For  $R_0$ , the negative log-likelihood was minimized at a value of 10.6, which supports the base model estimates of  $R_0$  at 10.608. Profiles for  $R_0$  are illustrated in Figure 60.

## 4 Management

### 4.1 Reference Points

Reference points were calculated using the estimated selectivity parameters and average catch distribution among fleets in the most recent five years of the model (2019–2024). A list of estimates of the current state of the population, as well as reference points based on 1) a target unfished spawning output of 40%, 2) a SPR of 0.5, and 3) the model estimate of maximum sustainable yield (MSY), are all listed in Table 22. The SPR is expected lifetime reproductive output under a given fishing intensity as a proportion of the unfished expected lifetime reproductive output.

The estimated trajectory in spawning output from the base model generally showed a slight decline until the late 1970s, followed by steep increase above unfished equilibrium biomass and reaching a peak in 1979. This was followed by a steep decrease up to the mid-1980s, and then a more gradual decrease through 2000 (Figure 49). Between 2001 and 2016, the spawning output increased continuously due to small catches and several years of high recruitment (though with lower than average recruitment in other recent years). The spawning output relative to unfished equilibrium spawning output climbed above the target of 40% of unfished spawning output in the early 2000s. It is estimated to still be above the target, though the lower bound of the 95% confidence interval lies between the target and minimum stock size threshold (Figure 49). The fishing intensity (relative 1-SPR) exceeded the current estimates of the harvest rate limit ( $SPR_{50\%}$ ) throughout the 1980s and early 1990s, and has again since 2018 (Figure 51). Exploitation rates on widow rockfish between 2001 and 2016 were predicted to be far below target levels. In recent years, the stock has experienced exploitation rates that have been above the target level while the biomass level has remained above the target level (Figure 52).

While the estimate of population scale has remained relatively steady across the 2015, 2019, and 2025 assessments, estimates of natural mortality have declined from 2015 (female  $M$  of  $0.157 \text{ yr}^{-1}$ ) to 2019 ( $0.144 \text{ yr}^{-1}$ ) to 2025 ( $0.135 \text{ yr}^{-1}$ ), reflecting the new information from the realized increase of the number of older fish in the population throughout rebuilding years. Thus, although the population scale is estimated consistently, additional years of data (in particular, age composition data) following the re-opening of the fishery have led the model to estimate that the population is less productive, which results in lower yields at all three reference points (the MSY-proxy based on fishing intensity, which is used for management, as well as the MSY-proxy based on spawning output, and the model estimate of MSY). Also, the model did not support a very large 2013 year class previously estimated in the 2019 assessment, which contributed to decrease in of stock productivity and estimated OFLs.

The equilibrium yield plot is shown in Figure 65, based on a steepness value fixed at 0.720. The predicted maximum sustainable yield under the assumptions of this assessment occurs near 27% of equilibrium unfished spawning output; however, this represents only 12% higher yield with considerably more risk than under the 50% SPR policy, which occurs near 45% of unfished spawning output. The differences among reference points in the fraction of unfished spawning output are typical for rockfish (e.g., the 2025 yellowtail rockfish assessment had MSY estimated at 23% of equilibrium unfished spawning output, which represented an 18% higher yield than under the 50% SPR policy, and both models had the equilibrium spawning output at the SPR target occur at 45% of the unfished equilibrium due to the same fixed steepness value).

## 4.2 Unresolved problems and major uncertainties

Major sources of uncertainty include landings, discards, natural mortality, and recruitment, which are discussed below. Also see the SSC statement associated with this widow stock assessment in the March 2026 PFMC briefing book for additional discussion of unresolved problems and major uncertainties.

Because widow rockfish is a marketable species, historical discard rates were likely lower than less desirable or smaller species. This assessment assumed that discarding was nearly negligible before management restrictions began in 1982. Once trip limits were introduced, discarding tended to be an all or none event; rare, but large, discard events are unlikely to have been detected given low observer coverage. From 2002 onward, the WCGOP has provided data on discards from vessels that were randomly selected for observer coverage, thus some uncertainty is present in the total amount discarded. The implementation of trawl rationalization in 2011 resulted in almost 100% observer coverage for the trawl fleet and very little incentive to discard widow rockfish. Discard mortality is assumed to be 100%, which may overestimate actual mortality (Jarvis & Lowe, 2007).

There may also be uncertainty in the ability of bottom trawl surveys to reliably estimate abundances of widow rockfish, which spend a significant portion of their time in mid-water (Wilkins 1986). Multiple surveys are used in the assessment, but further consideration of additional surveys is reasonable.

This assessment attempts to capture uncertainty in  $M$  by estimating it inside the model (thereby propagating uncertainty in  $M$  into uncertainty in spawning output and other derived quantities), and by incorporating variation in  $M$  in a decision table. Model sensitivities and profiles over  $M$  showed that current stock status was highly sensitive to the assumption about natural mortality.

Widow rockfish is a relatively long-lived fish, and their natural mortality ( $M$ ) is likely to be lower than many managed fish stocks (e.g., gadoids). Ages above 50 years have been observed and it is expected that natural mortality could be less than  $0.10 \text{ yr}^{-1}$  (the median of the prior for natural mortality used in this assessment). However, even with length and age data available back to the late 1970s,  $M$  was estimated at 0.135 for females and  $0.147 \text{ yr}^{-1}$  for males, with a small amount of uncertainty (e.g., a 6.1% coefficient of variation for females).

Notably, the estimated  $M$  for both sexes from this assessment are lower than those from the 2015 and 2019 assessments, for which natural mortality was estimated above  $0.15 \text{ yr}^{-1}$  and  $0.14 \text{ yr}^{-1}$ , respectively. The estimates of  $M$  varied slightly depending on the weight given to age and length data, or removing recent years of data, but female  $M$  was always estimated above  $0.12 \text{ yr}^{-1}$ . The likelihood profile over natural mortality provides support for female  $M$  values up to or above  $0.14 \text{ yr}^{-1}$ , but with greater curvature than in the 2019 assessment, suggesting additional data has reduced the support for higher natural mortality values. A contributing factor to this change may be the increased mean age and frequency of older fish in catch observed by the WCGBTS survey in recent years. The successful rebounding of the stock as a result of reduced fishing pressure from 2003–2016 may have allowed year classes to age and become fully observed by WCGBTS.

Steepness was fixed at 0.720 in the base model, but a likelihood profile showed that it would be estimated at a value less than that. Estimates of  $M$  increased with lower steepness, while unfished spawning output

increased and current spawning output decreased. Sustainable yields at the  $SPR_{50\%}$  reference harvest rate ranged from approximately 2641 to 5992 mt depending on the value of steepness.

### 4.3 Harvest Projections and Decision Tables

Projections for overfishing limit (OFL) (mt), ABC (mt), ACL (mt), the buffer between the OFL and ABC, estimated spawning output (billions of eggs), and fraction of unfished spawning output with adopted OFL and ACL and assumed catch for the first two years of the projection period. The predicted OFL is the calculated total catch determined by  $FSPR=50\%$  are provided in Table 23.

Uncertainty in both natural mortality (estimated for both sexes) and steepness (not estimated in the model) contributed greatly to uncertainty in the results. A combination of these two factors was used as the axis of uncertainty to define low and high states of nature. This differed from the 2019 assessment which included a third factor, 2013 recruitment strength. The 2013 year class is no longer a major source of uncertainty, and there is no recent similarly large estimate of recruitment. The 12.5% and 87.5% quantiles for female and male natural mortality (independently) were chosen as low and high values ( $0.126 \text{ yr}^{-1}$  and  $0.144 \text{ yr}^{-1}$  for females;  $0.137 \text{ yr}^{-1}$  and  $0.157 \text{ yr}^{-1}$  for males). Steepness was fixed in the base model and is not incorporated in the estimation uncertainty. The 12.5% and 87.5% quantiles from the steepness prior (without widow rockfish data) were used to define the low and high values of steepness (0.536 and 0.904). The low combination of these two factors defined the low state of nature and the high combination of these two factors defined the high state of nature. The predictions of spawning output in 2025 from the low and high states of nature are close to the 12.5% and 87.5% quantiles from the base model.

A twelve-year projection of the base model with one catch stream based on  $ACL = ABC$  based on the adjustment of  $P^* = 0.45$  was conducted for each state of nature (Table 24, Figure 66). The projections indicate that the spawning output is likely to initially decrease under all states of nature before partially rebounding (less so under the low state of nature). Predicted ACL catches range from 4,596 mt in 2027 to 5,585 mt in 2032.

Two additional diagnostics were developed during the January 2026 review meeting to better understand the projected catch limits: a time series of vulnerable biomass by fleet, and the age structure of the vulnerable biomass available to the midwater trawl fishery.

The time series of vulnerable biomass by fleet (Figure 67) shows that the vulnerable biomass for the midwater trawl fleet is estimated to be relatively stable from 2019–2024, while the spawning output and Age 4+ biomass both drop considerably during that period, and the survey vulnerable biomass drops even more quickly. The difference between the survey and midwater trawl estimates are primarily due to the interaction of differences in selectivity between these two fleets (as shown in Figure 35) and the large 2016 cohort becoming more fully selected by the steeper but dome-shaped selectivity of the midwater trawl fleet starting in 2020, but not yet as strongly selected by the shallower selectivity estimated for the WCGBT survey. Also note that the decline in the midwater trawl vulnerable biomass from 2016 onward is driven by both population dynamics and the estimated change in fishery selectivity for the midwater fleet associated with the re-opening of the targeted rockfish midwater fishery in 2017.

The comparison between projected selected numbers-at-age for the midwater trawl fishery in 2027 and the equilibrium associated with the SPR target (Figure 68) helps illustrate that the cohorts contributing to the 2027 catch limits are primarily the 2016 cohort (age 11 in 2027) and the 2021 cohort (age 6 in 2027), where the below-average recruitments in 2018–2020 contribute to the 2027 projections having only 46% as many selected fish of ages 7 to 9 as equilibrium projections. This pattern contributes to the projected 2027 catch limits being below the equilibrium catch associated with the SPR target in spite of the stock being estimated above the biomass associated with that equilibrium.

#### 4.4 Evaluation of Scientific Uncertainty

This assessment synthesizes many sources of data and estimates recruitment variability, thus it is classified as a Category 1 stock assessment. Therefore, the sigma to determine the catch reduction to account for scientific uncertainty is 0.50.

Spawning is estimated to be at 10,572 billion eggs in 2025, with a sigma of 0.2628. OFL is estimated to be 6,134 mt in 2025 with a coefficient of variation of 0.2934.

#### 4.5 Regional management considerations

Widow rockfish are managed on a coastwide basis and observed more often in the WCG BTS north of latitude 40° 10' N. Bottom trawl catches in California have historically been as large as in Oregon and larger than in Washington, but recently catches in California have been small. Future assessments and management of widow rockfish may want to monitor where catches are being taken to make sure that specific areas are not being overexploited. In addition, research on the connectivity along the coast as well as regional differences would help to inform the potential for overfishing specific areas.

#### 4.6 Research and Data Needs

There are many areas of research that could be improved to benefit the understanding and assessment of widow rockfish, including the following. Also see the SSC statement associated with this widow stock assessment in the March 2026 PFMC briefing book for additional discussion of research and data needs.

- **Natural mortality:** Uncertainty in natural mortality translates into uncertain estimates of status and sustainable fishing levels for widow rockfish. The collection of additional age data, re-reading of older age samples, reading old age samples that are as of yet unread, and improved understanding of the life-history of widow rockfish may reduce that uncertainty. Investigating the ageing error and bias would help to understand the influences that the age data have on this assessment, particularly the influence of age data on natural mortality.
- **Sex-specific selectivity:** The midwater and bottom trawl length-composition data fits showed divergent residual patterns between male and female fish. The underlying mechanism driving this pattern is unclear, and could be related to growth, sexing error, or to sex-specific selectivity (e.g., when widow rockfish aggregate, sexes possibly may be aggregating separately). Sex-specific selectivity for these two fleets could be explored or included to address this.
- **Coastwide understanding of stock structure, biology, connectivity, and distribution:** This is a stock assessment for widow rockfish 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 widow rockfish north and south of the U.S.-Canada border. Research into spatial dynamics within the U.S. west coast (as noted above under Unresolved problems and major uncertainties), is also important.

## 5 Tables

*Note: table numbering is continuous with executive summary*

### 5.1 Management performance

Table 9: Recent trend in the OFL, ABC, ACL, total landings, total mortality all in metric tons (mt).

Year	OFL (mt)	ABC (mt)	ACL (mt)	Catch (mt)
2015	4,137	3,929	2,000	881
2016	3,990	3,790	2,000	1,042
2017	14,130	13,508	13,508	6,356
2018	13,237	12,655	12,655	10,532
2019	12,375	11,830	11,831	9,310
2020	11,714	11,199	11,199	8,401
2021	15,749	14,725	14,725	10,874
2022	14,826	13,788	13,788	12,116
2023	13,633	12,624	12,624	10,997
2024	12,453	11,482	11,482	9,747

## 5.2 Data

### 5.2.1 Fishery-dependent data

Table 10: Total removals (mt) used in widow rockfish assessment, by year and by fleet. Total removals represent landings and discards combined. Bottom trawl fleet also includes minimal catches made by net and hook-and-line gears, as well as widow rockfish catches made within historical foreign fishery targeting Pacific Ocean Perch between 1966–1976.

Yr	Bottom trawl	Midwater trawl	Hake
1916	78	0	0
1917	122	0	0
1918	140	0	0
1919	97	0	0
1920	99	0	0
1921	82	0	0
1922	71	0	0
1923	78	0	0
1924	50	0	0
1925	62	0	0
1926	95	0	0
1927	79	0	0
1928	90	0	0
1929	87	0	0
1930	113	0	0
1931	100	0	0
1932	100	0	0
1933	86	0	0
1934	91	0	0
1935	98	0	0
1936	110	0	0
1937	103	0	0
1938	83	0	0
1939	76	0	0
1940	121	0	0
1941	129	0	0
1942	145	0	0
1943	494	0	0
1944	965	0	0
1945	1,635	0	0
1946	1,170	0	0
1947	649	0	0
1948	485	0	0

Table 10: Total removals (mt) used in widow rockfish assessment, by year and by fleet. Total removals represent landings and discards combined. Bottom trawl fleet also includes minimal catches made by net and hook-and-line gears, as well as widow rockfish catches made within historical foreign fishery targeting Pacific Ocean Perch between 1966–1976.

<b>Yr</b>	<b>Bottom trawl</b>	<b>Midwater trawl</b>	<b>Hake</b>
1949	379	2	0
1950	432	0	0
1951	562	0	0
1952	554	0	0
1953	476	0	0
1954	454	0	0
1955	470	0	0
1956	610	0	0
1957	771	0	0
1958	713	0	0
1959	683	0	0
1960	823	0	0
1961	688	0	0
1962	771	0	0
1963	446	0	0
1964	611	0	0
1965	269	0	0
1966	4,294	0	0
1967	4,828	0	0
1968	2,398	0	0
1969	849	0	0
1970	853	0	0
1971	1,094	0	0
1972	922	0	0
1973	1,163	0	0
1974	907	0	0
1975	846	0	31
1976	1,198	0	130
1977	1,044	0	123
1978	1,426	0	195
1979	1,880	7,573	200
1980	2,924	18,710	272
1981	4,994	23,022	228
1982	6,278	26,022	158
1983	8,561	4,359	131
1984	4,397	8,198	295
1985	3,852	7,500	183
1986	5,174	6,961	258
1987	5,875	10,426	183

Table 10: Total removals (mt) used in widow rockfish assessment, by year and by fleet. Total removals represent landings and discards combined. Bottom trawl fleet also includes minimal catches made by net and hook-and-line gears, as well as widow rockfish catches made within historical foreign fishery targeting Pacific Ocean Perch between 1966–1976.

<b>Yr</b>	<b>Bottom trawl</b>	<b>Midwater trawl</b>	<b>Hake</b>
1988	5,382	7,791	232
1989	5,914	9,891	212
1990	8,079	5,191	230
1991	5,796	2,406	556
1992	6,159	1,731	448
1993	7,996	2,674	266
1994	5,387	2,540	584
1995	5,685	2,690	429
1996	4,980	2,244	733
1997	5,213	2,871	357
1998	3,616	1,051	587
1999	2,272	2,405	371
2000	106	4,284	284
2001	73	1,983	210
2002	20	253	159
2003	6	14	23
2004	14	37	50
2005	9	46	144
2006	10	47	158
2007	33	24	193
2008	8	79	180
2009	26	96	135
2010	25	72	89
2011	22	60	130
2012	46	62	164
2013	57	268	147
2014	85	331	308
2015	15	480	386
2016	11	590	441
2017	39	4,862	1,455
2018	39	9,412	1,081
2019	31	8,177	1,102
2020	77	7,578	747
2021	108	10,148	617
2022	136	10,861	1,119
2023	90	10,234	673
2024	41	9,172	534

Table 11: Number of trips sampled for length data by gear and state for non-hake fisheries.

Year	Bottom Trawl CA	Bottom Trawl OR	Bottom Trawl WA	Midwater Trawl CA	Midwater Trawl OR	Midwater Trawl WA
1971	0	0	0	0	0	2
1977	0	0	0	25	0	0
1978	50	0	0	0	0	0
1979	32	0	0	0	0	0
1980	101	0	0	6	0	19
1981	72	3	0	59	20	31
1982	88	7	0	89	34	41
1983	158	16	0	46	10	25
1984	146	20	0	29	12	22
1985	149	20	0	25	35	16
1986	108	17	0	25	28	27
1987	88	29	0	49	74	36
1988	79	30	7	37	42	14
1989	81	49	14	30	67	16
1990	80	58	11	39	62	30
1991	74	76	20	17	63	15
1992	55	98	22	5	41	9
1993	60	69	28	5	49	8
1994	54	67	13	2	21	16
1995	53	47	17	11	14	16
1996	49	33	17	11	12	13
1997	54	49	16	10	21	19
1998	41	43	26	3	11	8
1999	38	28	21	5	19	11
2000	14	0	3	16	44	19
2001	12	6	2	10	38	11
2002	22	8	7	1	15	10
2003	7	0	1	0	0	5
2004	5	1	1	0	0	12
2005	4	2	0	0	0	10
2006	7	3	2	0	0	8
2007	7	16	4	0	0	3
2008	5	18	5	0	0	12
2009	19	30	0	0	0	14
2010	18	22	1	0	0	11
2011	6	14	9	0	1	6
2012	14	19	5	0	4	7
2013	20	21	1	0	6	6
2014	18	20	3	0	5	7
2015	37	23	0	0	18	4
2016	27	14	0	0	7	1

Table 11: Number of trips sampled for length data by gear and state for non-hake fisheries.

Year	Bottom Trawl CA	Bottom Trawl OR	Bottom Trawl WA	Midwater Trawl CA	Midwater Trawl OR	Midwater Trawl WA
2017	22	41	0	3	33	3
2018	31	25	7	10	60	4
2019	34	33	1	2	48	12
2020	29	18	0	2	31	5
2021	42	18	2	4	39	7
2022	13	10	0	12	46	4
2023	20	7	0	7	51	7
2024	27	13	0	0	52	9

Table 12: Number of lengths of widow rockfish by gear and state for non-hake fisheries.

Year	Bottom Trawl CA	Bottom Trawl OR	Bottom Trawl WA	Midwater Trawl CA	Midwater Trawl OR	Midwater Trawl WA
1971	0	0	0	0	0	408
1977	0	0	0	96	0	0
1978	303	0	0	0	0	0
1979	436	0	0	0	0	0
1980	727	0	0	13	0	1900
1981	444	250	0	1340	1746	3100
1982	932	792	0	3144	3960	4100
1983	1352	478	0	1411	321	2500
1984	1722	2394	0	1278	1525	2199
1985	1853	2233	0	1176	3971	1600
1986	1740	1425	0	1032	2788	2650
1987	998	865	0	1744	2198	1942
1988	763	916	350	1230	1239	700
1989	1007	1099	700	1325	1843	800
1990	1202	1320	550	1510	1454	1500
1991	1596	1569	997	761	1442	750
1992	1470	1982	1100	222	1760	450
1993	1682	1410	1400	231	1156	400
1994	1359	1464	650	112	557	842
1995	1539	1066	850	519	296	800
1996	1364	845	704	437	316	650
1997	2063	1231	557	382	620	950
1998	1368	1013	865	125	291	400
1999	1420	727	952	240	514	550
2000	263	0	101	641	1147	950
2001	139	98	2	349	960	550
2002	318	185	136	39	319	500

Table 12: Number of lengths of widow rockfish by gear and state for non-hake fisheries.

<b>Year</b>	<b>Bottom Trawl CA</b>	<b>Bottom Trawl OR</b>	<b>Bottom Trawl WA</b>	<b>Midwater Trawl CA</b>	<b>Midwater Trawl OR</b>	<b>Midwater Trawl WA</b>
2003	234	0	46	0	0	208
2004	26	18	3	0	0	508
2005	27	48	0	0	0	399
2006	79	58	7	0	0	461
2007	12	302	104	0	0	250
2008	8	274	76	0	0	1086
2009	170	316	0	0	0	1079
2010	205	233	100	0	0	903
2011	32	246	93	0	30	550
2012	136	353	241	0	95	688
2013	153	365	39	0	215	486
2014	134	324	106	0	150	700
2015	263	295	0	0	530	400
2016	143	254	0	0	210	100
2017	316	864	0	158	949	125
2018	645	161	12	507	1492	350
2019	566	346	50	90	1149	600
2020	593	228	0	83	759	233
2021	850	226	8	183	890	307
2022	272	185	0	502	1025	180
2023	376	135	0	316	1125	571
2024	540	164	0	0	1255	830

Table 13: Number of hauls or trips and number of lengths sampled from the at-sea hake and shoreside hake fisheries.

<b>Year</b>	<b>Landings At-Sea</b>	<b>Landings Shoreside</b>	<b>Lengths At-Sea</b>	<b>Lengths Shoreside</b>
1992	214	0	1474	0
1993	239	0	1468	0
1994	361	3	3458	78
1995	304	19	1789	570
1996	332	18	2620	540
1997	397	30	2841	869
1998	481	32	2431	975
1999	598	52	3070	1551
2000	571	33	2845	1004
2001	522	19	1758	576
2002	369	3	1204	70
2003	291	2	665	26

Table 13: Number of hauls or trips and number of lengths sampled from the at-sea hake and shoreside hake fisheries.

<b>Year</b>	<b>Landings At-Sea</b>	<b>Landings Shoreside</b>	<b>Lengths At-Sea</b>	<b>Lengths Shoreside</b>
2004	512	19	1670	380
2005	1228	1	5538	50
2006	1295	14	6104	594
2007	1491	21	10658	860
2008	1138	36	7324	966
2009	400	24	1976	845
2010	980	43	4734	1214
2011	982	43	3605	1286
2012	914	46	4779	1291
2013	901	40	3808	1160
2014	773	50	3970	1452
2015	522	36	2312	1313
2016	801	49	3934	1465
2017	997	57	5406	1353
2018	461	65	2245	1283
2019	469	73	2642	1536
2020	214	37	902	839
2021	310	61	1776	1279
2022	333	88	1489	1745
2023	469	68	1738	1525
2024	83	60	251	1231

Table 14: Number of trips sampled for ages by gear and state for non-hake fisheries.

<b>Year</b>	<b>Bottom Trawl CA</b>	<b>Bottom Trawl OR</b>	<b>Bottom Trawl WA</b>	<b>Midwater Trawl CA</b>	<b>Midwater Trawl OR</b>	<b>Midwater Trawl WA</b>
1978	7	0	0	0	0	0
1979	11	0	0	0	0	0
1980	27	0	0	0	0	18
1981	14	3	0	30	20	31
1982	87	6	0	71	34	40
1983	151	16	0	45	10	25
1984	144	20	0	29	12	22
1985	137	20	0	25	33	16
1986	106	17	0	22	28	27
1987	84	27	0	49	62	36
1988	67	29	6	34	41	14
1989	75	49	14	30	66	16
1990	70	58	11	32	62	30

Table 14: Number of trips sampled for ages by gear and state for non-hake fisheries.

<b>Year</b>	<b>Bottom Trawl CA</b>	<b>Bottom Trawl OR</b>	<b>Bottom Trawl WA</b>	<b>Midwater Trawl CA</b>	<b>Midwater Trawl OR</b>	<b>Midwater Trawl WA</b>
1991	65	76	20	17	63	15
1992	45	93	22	4	26	9
1993	28	67	28	0	49	8
1994	28	67	13	2	21	15
1995	8	45	17	3	13	16
1996	36	32	14	6	11	13
1997	42	46	11	10	20	19
1998	27	42	14	2	11	8
1999	29	27	19	3	18	10
2000	8	0	2	9	42	19
2001	2	6	0	4	35	10
2002	17	8	2	1	15	10
2003	3	0	0	0	0	5
2004	3	0	1	0	0	12
2005	0	2	0	0	0	10
2006	6	3	1	0	0	8
2007	6	16	4	0	0	3
2008	5	18	5	0	0	12
2009	8	29	0	0	0	14
2010	7	21	1	0	0	11
2011	0	5	7	0	1	5
2012	0	8	5	0	0	7
2013	0	7	1	0	3	5
2014	0	4	2	0	1	7
2015	0	22	0	0	14	4
2016	0	13	0	0	6	1
2017	0	36	0	0	31	3
2018	0	25	7	0	46	4
2019	0	16	1	0	34	12
2020	0	15	0	0	25	5
2021	0	12	2	0	31	6
2022	0	8	0	0	45	4
2023	0	5	0	0	48	7
2024	0	7	0	0	42	7

Table 15: Number of age samples by gear and state for non-hake fisheries.

Year	Bottom Trawl CA	Bottom Trawl OR	Bottom Trawl WA	Midwater Trawl CA	Midwater Trawl OR	Midwater Trawl WA
1978	107	0	0	0	0	0
1979	269	0	0	0	0	0
1980	404	0	0	0	0	1775
1981	205	109	0	598	600	3050
1982	834	174	0	2382	1019	3944
1983	1283	475	0	1365	321	2480
1984	1678	600	0	1278	360	2194
1985	1762	589	0	1176	963	1591
1986	1704	680	0	913	939	2594
1987	968	805	0	1742	1837	1940
1988	692	886	298	1132	1209	695
1989	919	1099	695	1323	1794	799
1990	1051	1310	550	1309	1447	1497
1991	1308	1566	991	761	1413	748
1992	676	1889	1097	82	574	450
1993	472	1361	1398	0	1155	400
1994	516	1463	650	54	556	749
1995	167	1027	850	68	276	800
1996	873	827	699	158	292	649
1997	892	1164	549	187	593	949
1998	1019	987	699	82	291	400
1999	1026	706	950	133	479	500
2000	157	0	100	353	1067	948
2001	43	98	0	132	858	485
2002	294	179	99	21	319	488
2003	87	0	0	0	0	208
2004	7	0	3	0	0	506
2005	0	48	0	0	0	399
2006	74	58	6	0	0	361
2007	11	302	54	0	0	150
2008	8	274	75	0	0	600
2009	81	315	0	0	0	759
2010	54	231	50	0	0	539
2011	0	63	84	0	30	250
2012	0	80	73	0	0	163
2013	0	190	26	0	90	153
2014	0	91	52	0	30	229
2015	0	152	0	0	69	195
2016	0	156	0	0	36	28
2017	0	209	0	0	223	100
2018	0	161	12	0	495	200

Table 15: Number of age samples by gear and state for non-hake fisheries.

Year	Bottom Trawl CA	Bottom Trawl OR	Bottom Trawl WA	Midwater Trawl CA	Midwater Trawl OR	Midwater Trawl WA
2019	0	55	49	0	176	597
2020	0	61	0	0	134	233
2021	0	53	8	0	135	300
2022	0	44	0	0	281	129
2023	0	28	0	0	312	320
2024	0	33	0	0	248	340

### 5.2.2 Fishery-independent data

Table 16: Stratifications used for the WCGBTS.

Strata	Area_km2	Depth1	Depth2	Latitude1	Latitude2
A	10687.86	55	183	34.5	40.5
B	3394.82	183	400	34.5	40.5
C	23042.39	55	183	40.5	49.0
D	7667.81	183	400	40.5	49.0

Table 17: Number of positive tows, lengths, and ages in each year from the Triennial survey and the WCGBTS.

Year	N positive tows, Triennial	N positive tows, WCG-BTS	N tows with lengths, Triennial	N tows with lengths, WCG-BTS	N lengths, Triennial	N lengths, WCG-BTS	N twos with ages, Triennial	N tows with ages, WCG-BTS	N ages, Triennial	N ages, WCG-BTS
1977	80		1		9					
1980	38		3		166		1		22	
1983	70		5		385					
1986	46		8		317					
1989	38		20		713					
1992	50		10		708					
1995	43		43		500					
1998	59		58		738					
2001	28		28		130					
2003		20		18		216				
2004	36	12	33	12	219	84		12		43
2005		20		20		78		18		65
2006		26		26		172		26		89
2007		27		27		92		27		83
2008		17		17		26		15		20
2009		31		31		141		31		123
2010		28		28		240		28		116
2011		31		31		313		31		152
2012		32		32		181		32		91
2013		18		18		364		18		246
2014		29		28		349		28		264
2015		21		21		149		21		93
2016		40		40		888		40		556
2017		30		30		310		30		213
2018		34		34		410		34		353
2019		23		23		219		23		161
2021		18		17		66		17		66
2022		18		18		125		18		109
2023		30		29		159		29		110
2024		35		35		485		35		347

Table 18: Comparison of key data weighting quantities from the August 2025 (Aug.) and the proposed base model (New). ‘Lambda’ is the likelihood multiplier applied in the August 2025 model (Lambda = 1 for all fleets in the new proposed base model). ‘Weight x lambda’ is the product of the estimated data weighting and the lambda. ‘Sum N input’ is the sum of the input sample sizes across all observations (which differs for BottomTrawl because discard data has been removed). ‘Sum N adj.’ is that sum after adjustment by the data weighting and lambda. ‘CAAL’ is conditional age-at-length data. Entries with — indicate that fleet does not exist in the new proposed base model, and the composition data has been removed.

Type	Fleet	Lambda (Aug.)	Weight x lambda (Aug.)	Weight x lambda (New)	Sum N input (Aug.)	Sum N input (New)	Sum N adj. x lambda (Aug.)	Sum N adj. x lambda (New)
Length	BottomTrawl	0.5	0.028	0.055	14976.0	14336.4	422.2	785.0
Length	MidwaterTrawl	0.5	0.104	0.039	14908.6	14908.6	1547.2	587.2
Length	Hake	0.5	0.055	0.022	23864.6	23864.6	1317.5	532.2
Length	Net	0.5	0.248	—	1196.8	—	296.4	—
Length	HnL	0.5	0.186	—	1033.2	—	193.2	—
Length	Triennial	1.0	0.372	0.092	459.0	459.0	171.0	42.1
Length	WCGBTS	1.0	0.635	0.083	989.1	989.1	628.2	82.1
Age	BottomTrawl	0.5	0.083	0.194	8289.2	8289.2	688.3	1610.2
Age	MidwaterTrawl	0.5	0.140	0.151	8358.2	8358.2	1168.2	1258.1
Age	Hake	0.5	0.120	0.262	6051.2	6051.2	730.1	1582.5
Age	Net	0.5	0.250	—	737.8	—	184.7	—
Age	HnL	0.5	0.276	—	125.4	—	34.7	—
CAAL	WCGBTS	1.0	0.296	0.106	3243.6	3243.6	963.5	346.2

### 5.3 Model results

Table 19: Parameter estimates, parameter bounds (low, high), estimation status, estimated standard deviation (SD), prior information [distribution(mean, SD)] used in the base model.

Label	Value	Bounds	Status	SD	Prior
NatM_uniform_Fem_GP_1	0.135	(0.01, 0.3)	ok	0.00824	lognormal(0.100, 0.310)
L_at_Amin_Fem_GP_1	18.9	(10, 40)	ok	0.852	none
L_at_Amax_Fem_GP_1	49.4	(35, 60)	ok	0.365	none
VonBert_K_Fem_GP_1	0.194	(0.01, 0.4)	ok	0.00941	none
CV_young_Fem_GP_1	0.142	(0.01, 0.4)	ok	0.0185	none
CV_old_Fem_GP_1	0.0471	(0.01, 0.4)	ok	0.00397	none
Wtlen_1_Fem_GP_1	1.59e-05	(-3, 3)	fixed		none
Wtlen_2_Fem_GP_1	2.99	(-3, 10)	fixed		none
Mat50%_Fem_GP_1	5.47	(-3, 50)	fixed		none
Mat_slope_Fem_GP_1	-0.775	(-3, 3)	fixed		none
Eggs_scalar_Fem_GP_1	1.11e-08	(-1, 1)	fixed		none
Eggs_exp_len_Fem_GP_1	4.54	(0, 5)	fixed		none
NatM_uniform_Mal_GP_1	0.147	(0.01, 0.3)	ok	0.00867	lognormal(0.100, 0.310)
L_at_Amin_Mal_GP_1	20.3	(10, 40)	ok	0.639	none
L_at_Amax_Mal_GP_1	43.6	(35, 60)	ok	0.313	none
VonBert_K_Mal_GP_1	0.267	(0.01, 0.4)	ok	0.0135	none
CV_young_Mal_GP_1	0.0915	(0.01, 0.4)	ok	0.0113	none
CV_old_Mal_GP_1	0.0548	(0.01, 0.4)	ok	0.00392	none
Wtlen_1_Mal_GP_1	1.45e-05	(-3, 3)	fixed		none
Wtlen_2_Mal_GP_1	3.01	(-3, 10)	fixed		none
CohortGrowDev	1	(0, 2)	fixed		none
FracFemale_GP_1	0.5	(1e-06, 1)	fixed		none
SR_LN(R0)	10.6	(6, 15)	ok	0.155	none
SR_BH_steep	0.72	(0.2, 1)	fixed		beta(0.720, 0.160)
SR_sigmaR	0.6	(0, 2)	fixed		none
SR_regime	0	(-5, 5)	fixed		none
SR_autocorr	0	(0, 0.5)	fixed		none
Early_InitAge_16	-0.00131	(-5, 5)	dev	0.6	normal(0.00, 0.60)
Early_InitAge_15	-0.00149	(-5, 5)	dev	0.6	normal(0.00, 0.60)
Early_InitAge_14	-0.0017	(-5, 5)	dev	0.6	normal(0.00, 0.60)
Early_InitAge_13	-0.00192	(-5, 5)	dev	0.599	normal(0.00, 0.60)

Table 19: Parameter estimates, parameter bounds (low, high), estimation status, estimated standard deviation (SD), prior information [distribution(mean, SD)] used in the base model.

Label	Value	Bounds	Status	SD	Prior
Early_InitAge_12	-0.00217	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_11	-0.00245	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_10	-0.00276	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_9	-0.00309	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_8	-0.00345	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_7	-0.00384	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_6	-0.00427	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_5	-0.00472	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_4	-0.00522	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_3	-0.00577	(-5, 5)	dev	0.598	normal(0.00, 0.60)
Early_InitAge_2	-0.00638	(-5, 5)	dev	0.598	normal(0.00, 0.60)
Early_InitAge_1	-0.00705	(-5, 5)	dev	0.598	normal(0.00, 0.60)
Early_RecrDev_1916	-0.00779	(-5, 5)	dev	0.598	normal(0.00, 0.60)
Early_RecrDev_1917	-0.00861	(-5, 5)	dev	0.598	normal(0.00, 0.60)
Early_RecrDev_1918	-0.00952	(-5, 5)	dev	0.597	normal(0.00, 0.60)
Early_RecrDev_1919	-0.0105	(-5, 5)	dev	0.597	normal(0.00, 0.60)
Early_RecrDev_1920	-0.0116	(-5, 5)	dev	0.597	normal(0.00, 0.60)
Early_RecrDev_1921	-0.0128	(-5, 5)	dev	0.596	normal(0.00, 0.60)
Early_RecrDev_1922	-0.0142	(-5, 5)	dev	0.596	normal(0.00, 0.60)
Early_RecrDev_1923	-0.0157	(-5, 5)	dev	0.596	normal(0.00, 0.60)
Early_RecrDev_1924	-0.0173	(-5, 5)	dev	0.595	normal(0.00, 0.60)
Early_RecrDev_1925	-0.0191	(-5, 5)	dev	0.595	normal(0.00, 0.60)
Early_RecrDev_1926	-0.0211	(-5, 5)	dev	0.594	normal(0.00, 0.60)
Early_RecrDev_1927	-0.0234	(-5, 5)	dev	0.593	normal(0.00, 0.60)
Early_RecrDev_1928	-0.0258	(-5, 5)	dev	0.593	normal(0.00, 0.60)
Early_RecrDev_1929	-0.0285	(-5, 5)	dev	0.592	normal(0.00, 0.60)
Early_RecrDev_1930	-0.0314	(-5, 5)	dev	0.591	normal(0.00, 0.60)
Early_RecrDev_1931	-0.0347	(-5, 5)	dev	0.59	normal(0.00, 0.60)
Early_RecrDev_1932	-0.0383	(-5, 5)	dev	0.589	normal(0.00, 0.60)
Early_RecrDev_1933	-0.0423	(-5, 5)	dev	0.588	normal(0.00, 0.60)
Early_RecrDev_1934	-0.0466	(-5, 5)	dev	0.587	normal(0.00, 0.60)
Early_RecrDev_1935	-0.0515	(-5, 5)	dev	0.586	normal(0.00, 0.60)
Early_RecrDev_1936	-0.0568	(-5, 5)	dev	0.584	normal(0.00, 0.60)
Early_RecrDev_1937	-0.0627	(-5, 5)	dev	0.583	normal(0.00, 0.60)

Table 19: Parameter estimates, parameter bounds (low, high), estimation status, estimated standard deviation (SD), prior information [distribution(mean, SD)] used in the base model.

Label	Value	Bounds	Status	SD	Prior
Early_RecrDev_1938	-0.0693	(-5, 5)	dev	0.581	normal(0.00, 0.60)
Early_RecrDev_1939	-0.0768	(-5, 5)	dev	0.579	normal(0.00, 0.60)
Early_RecrDev_1940	-0.0851	(-5, 5)	dev	0.577	normal(0.00, 0.60)
Early_RecrDev_1941	-0.0942	(-5, 5)	dev	0.574	normal(0.00, 0.60)
Early_RecrDev_1942	-0.104	(-5, 5)	dev	0.572	normal(0.00, 0.60)
Early_RecrDev_1943	-0.115	(-5, 5)	dev	0.569	normal(0.00, 0.60)
Early_RecrDev_1944	-0.126	(-5, 5)	dev	0.566	normal(0.00, 0.60)
Early_RecrDev_1945	-0.137	(-5, 5)	dev	0.563	normal(0.00, 0.60)
Early_RecrDev_1946	-0.148	(-5, 5)	dev	0.561	normal(0.00, 0.60)
Early_RecrDev_1947	-0.159	(-5, 5)	dev	0.558	normal(0.00, 0.60)
Early_RecrDev_1948	-0.169	(-5, 5)	dev	0.555	normal(0.00, 0.60)
Early_RecrDev_1949	-0.178	(-5, 5)	dev	0.553	normal(0.00, 0.60)
Early_RecrDev_1950	-0.185	(-5, 5)	dev	0.551	normal(0.00, 0.60)
Early_RecrDev_1951	-0.189	(-5, 5)	dev	0.55	normal(0.00, 0.60)
Early_RecrDev_1952	-0.188	(-5, 5)	dev	0.55	normal(0.00, 0.60)
Early_RecrDev_1953	-0.179	(-5, 5)	dev	0.551	normal(0.00, 0.60)
Early_RecrDev_1954	-0.161	(-5, 5)	dev	0.554	normal(0.00, 0.60)
Early_RecrDev_1955	-0.131	(-5, 5)	dev	0.558	normal(0.00, 0.60)
Early_RecrDev_1956	-0.0904	(-5, 5)	dev	0.565	normal(0.00, 0.60)
Early_RecrDev_1957	-0.043	(-5, 5)	dev	0.573	normal(0.00, 0.60)
Early_RecrDev_1958	-0.00283	(-5, 5)	dev	0.578	normal(0.00, 0.60)
Early_RecrDev_1959	0.0118	(-5, 5)	dev	0.578	normal(0.00, 0.60)
Early_RecrDev_1960	-0.00448	(-5, 5)	dev	0.571	normal(0.00, 0.60)
Early_RecrDev_1961	-0.0304	(-5, 5)	dev	0.562	normal(0.00, 0.60)
Early_RecrDev_1962	-0.0321	(-5, 5)	dev	0.556	normal(0.00, 0.60)
Early_RecrDev_1963	0.0125	(-5, 5)	dev	0.555	normal(0.00, 0.60)
Early_RecrDev_1964	0.0819	(-5, 5)	dev	0.558	normal(0.00, 0.60)
Early_RecrDev_1965	0.137	(-5, 5)	dev	0.559	normal(0.00, 0.60)
Early_RecrDev_1966	0.191	(-5, 5)	dev	0.549	normal(0.00, 0.60)
Early_RecrDev_1967	0.199	(-5, 5)	dev	0.533	normal(0.00, 0.60)
Early_RecrDev_1968	0.192	(-5, 5)	dev	0.489	normal(0.00, 0.60)
Early_RecrDev_1969	-0.0265	(-5, 5)	dev	0.528	normal(0.00, 0.60)
Main_RecrDev_1970	1.37	(-5, 5)	dev	0.25	normal(0.00, 0.60)
Main_RecrDev_1971	1.22	(-5, 5)	dev	0.228	normal(0.00, 0.60)

Table 19: Parameter estimates, parameter bounds (low, high), estimation status, estimated standard deviation (SD), prior information [distribution(mean, SD)] used in the base model.

Label	Value	Bounds	Status	SD	Prior
Main_RecrDev_1972	-0.833	(-5, 5)	dev	0.402	normal(0.00, 0.60)
Main_RecrDev_1973	-0.929	(-5, 5)	dev	0.351	normal(0.00, 0.60)
Main_RecrDev_1974	-0.584	(-5, 5)	dev	0.301	normal(0.00, 0.60)
Main_RecrDev_1975	0.158	(-5, 5)	dev	0.177	normal(0.00, 0.60)
Main_RecrDev_1976	-1.18	(-5, 5)	dev	0.319	normal(0.00, 0.60)
Main_RecrDev_1977	0.673	(-5, 5)	dev	0.128	normal(0.00, 0.60)
Main_RecrDev_1978	1.02	(-5, 5)	dev	0.112	normal(0.00, 0.60)
Main_RecrDev_1979	-0.0252	(-5, 5)	dev	0.176	normal(0.00, 0.60)
Main_RecrDev_1980	0.451	(-5, 5)	dev	0.147	normal(0.00, 0.60)
Main_RecrDev_1981	1.03	(-5, 5)	dev	0.118	normal(0.00, 0.60)
Main_RecrDev_1982	0.409	(-5, 5)	dev	0.153	normal(0.00, 0.60)
Main_RecrDev_1983	-0.19	(-5, 5)	dev	0.195	normal(0.00, 0.60)
Main_RecrDev_1984	0.45	(-5, 5)	dev	0.125	normal(0.00, 0.60)
Main_RecrDev_1985	0.283	(-5, 5)	dev	0.129	normal(0.00, 0.60)
Main_RecrDev_1986	-0.626	(-5, 5)	dev	0.229	normal(0.00, 0.60)
Main_RecrDev_1987	0.205	(-5, 5)	dev	0.139	normal(0.00, 0.60)
Main_RecrDev_1988	-0.158	(-5, 5)	dev	0.177	normal(0.00, 0.60)
Main_RecrDev_1989	-0.391	(-5, 5)	dev	0.201	normal(0.00, 0.60)
Main_RecrDev_1990	-0.00759	(-5, 5)	dev	0.162	normal(0.00, 0.60)
Main_RecrDev_1991	0.652	(-5, 5)	dev	0.108	normal(0.00, 0.60)
Main_RecrDev_1992	-0.23	(-5, 5)	dev	0.186	normal(0.00, 0.60)
Main_RecrDev_1993	0.101	(-5, 5)	dev	0.165	normal(0.00, 0.60)
Main_RecrDev_1994	-0.0208	(-5, 5)	dev	0.196	normal(0.00, 0.60)
Main_RecrDev_1995	-0.407	(-5, 5)	dev	0.271	normal(0.00, 0.60)
Main_RecrDev_1996	-0.608	(-5, 5)	dev	0.339	normal(0.00, 0.60)
Main_RecrDev_1997	-0.149	(-5, 5)	dev	0.299	normal(0.00, 0.60)
Main_RecrDev_1998	0.462	(-5, 5)	dev	0.216	normal(0.00, 0.60)
Main_RecrDev_1999	0.524	(-5, 5)	dev	0.201	normal(0.00, 0.60)
Main_RecrDev_2000	0.585	(-5, 5)	dev	0.165	normal(0.00, 0.60)
Main_RecrDev_2001	-0.354	(-5, 5)	dev	0.25	normal(0.00, 0.60)
Main_RecrDev_2002	-0.33	(-5, 5)	dev	0.217	normal(0.00, 0.60)
Main_RecrDev_2003	-0.273	(-5, 5)	dev	0.23	normal(0.00, 0.60)
Main_RecrDev_2004	0.754	(-5, 5)	dev	0.117	normal(0.00, 0.60)
Main_RecrDev_2005	-1.03	(-5, 5)	dev	0.341	normal(0.00, 0.60)

Table 19: Parameter estimates, parameter bounds (low, high), estimation status, estimated standard deviation (SD), prior information [distribution(mean, SD)] used in the base model.

Label	Value	Bounds	Status	SD	Prior
Main_RecrDev_2006	0.689	(-5, 5)	dev	0.123	normal(0.00, 0.60)
Main_RecrDev_2007	-1.15	(-5, 5)	dev	0.379	normal(0.00, 0.60)
Main_RecrDev_2008	1.13	(-5, 5)	dev	0.112	normal(0.00, 0.60)
Main_RecrDev_2009	-0.759	(-5, 5)	dev	0.341	normal(0.00, 0.60)
Main_RecrDev_2010	0.561	(-5, 5)	dev	0.159	normal(0.00, 0.60)
Main_RecrDev_2011	-0.941	(-5, 5)	dev	0.341	normal(0.00, 0.60)
Main_RecrDev_2012	-1.29	(-5, 5)	dev	0.352	normal(0.00, 0.60)
Main_RecrDev_2013	0.414	(-5, 5)	dev	0.174	normal(0.00, 0.60)
Main_RecrDev_2014	-0.0184	(-5, 5)	dev	0.237	normal(0.00, 0.60)
Main_RecrDev_2015	-0.412	(-5, 5)	dev	0.305	normal(0.00, 0.60)
Main_RecrDev_2016	1.33	(-5, 5)	dev	0.162	normal(0.00, 0.60)
Main_RecrDev_2017	0.339	(-5, 5)	dev	0.27	normal(0.00, 0.60)
Main_RecrDev_2018	-0.69	(-5, 5)	dev	0.376	normal(0.00, 0.60)
Main_RecrDev_2019	-0.774	(-5, 5)	dev	0.419	normal(0.00, 0.60)
Main_RecrDev_2020	-0.446	(-5, 5)	dev	0.494	normal(0.00, 0.60)
Late_RecrDev_2021	0.0227	(-5, 5)	dev	0.531	normal(0.00, 0.60)
Late_RecrDev_2022	0.00382	(-5, 5)	dev	0.559	normal(0.00, 0.60)
Late_RecrDev_2023	0.248	(-5, 5)	dev	0.57	normal(0.00, 0.60)
Late_RecrDev_2024	0.136	(-5, 5)	dev	0.564	normal(0.00, 0.60)
ForeRecr_2025	0	(-5, 5)	dev	0.6	normal(0.00, 0.60)
ForeRecr_2026	0	(-5, 5)	dev	0.6	normal(0.00, 0.60)
ForeRecr_2027	0	(-5, 5)	dev	0.6	normal(0.00, 0.60)
ForeRecr_2028	0	(-5, 5)	dev	0.6	normal(0.00, 0.60)
ForeRecr_2029	0	(-5, 5)	dev	0.6	normal(0.00, 0.60)
ForeRecr_2030	0	(-5, 5)	dev	0.6	normal(0.00, 0.60)
ForeRecr_2031	0	(-5, 5)	dev	0.6	normal(0.00, 0.60)
ForeRecr_2032	0	(-5, 5)	dev	0.6	normal(0.00, 0.60)
ForeRecr_2033	0	(-5, 5)	dev	0.6	normal(0.00, 0.60)
ForeRecr_2034	0	(-5, 5)	dev	0.6	normal(0.00, 0.60)
ForeRecr_2035	0	(-5, 5)	dev	0.6	normal(0.00, 0.60)
ForeRecr_2036	0	(-5, 5)	dev	0.6	normal(0.00, 0.60)
LnQ_base_BottomTrawl(1)	-6.17	(-25, 25)	fixed		none
Q_extraSD_BottomTrawl(1)	0.204	(0, 2)	ok	0.0662	none
LnQ_base_Hake(3)	-11.1	(-20, 2)	ok	0.183	none

Table 19: Parameter estimates, parameter bounds (low, high), estimation status, estimated standard deviation (SD), prior information [distribution(mean, SD)] used in the base model.

Label	Value	Bounds	Status	SD	Prior
Q_extraSD_Hake(3)	0.386	(0, 2)	ok	0.0891	none
LnQ_base_JuvSurvey(6)	-5.04	(-25, 25)	fixed		none
Q_extraSD_JuvSurvey(6)	1.27	(0, 2)	ok	0.314	none
LnQ_base_Triennial(7)	-1.88	(-4, 4)	ok	0.505	none
Q_extraSD_Triennial(7)	0	(0, 2)	fixed		none
LnQ_base_WCGBTS(8)	-3.34	(-25, 25)	fixed		none
Q_extraSD_WCGBTS(8)	0	(0, 2)	fixed		none
LnQ_base_ForeignAtSea(9)	-11.5	(-25, 25)	fixed		none
Q_extraSD_ForeignAtSea(9)	0.595	(0, 2)	ok	0.155	none
LnQ_base_Hake(3)_BLK10add_1991	0.6	(1e-04, 2)	ok	0.228	normal(0.500, 0.500)
LnQ_base_Triennial(7)_BLK9add_1995	0.249	(1e-04, 2)	ok	0.358	normal(0.500, 0.500)
Size_DbIN_peak_BottomTrawl(1)	42.1	(10, 59)	ok	1.71	none
Size_DbIN_top_logit_BottomTrawl(1)	2.5	(-5, 10)	ok	167	none
Size_DbIN_ascend_se_BottomTrawl(1)	4.06	(-4, 12)	ok	0.326	none
Size_DbIN_descend_se_BottomTrawl(1)	9	(-2, 10)	fixed		none
Size_DbIN_start_logit_BottomTrawl(1)	-9	(-9, 10)	fixed		none
Size_DbIN_end_logit_BottomTrawl(1)	8	(-9, 9)	fixed		none
Size_DbIN_peak_MidwaterTrawl(2)	37.1	(10, 59)	ok	1.2	none
Size_DbIN_top_logit_MidwaterTrawl(2)	-9.25	(-10, 10)	ok	18.1	none
Size_DbIN_ascend_se_MidwaterTrawl(2)	2.8	(-4, 12)	ok	0.495	none
Size_DbIN_descend_se_MidwaterTrawl(2)	3.94	(-2, 10)	ok	1.55	none
Size_DbIN_start_logit_MidwaterTrawl(2)	-9	(-9, 10)	fixed		none
Size_DbIN_end_logit_MidwaterTrawl(2)	-1.17	(-9, 9)	ok	2.02	none
Size_DbIN_peak_Hake(3)	34.5	(10, 59)	ok	2.09	none
Size_DbIN_top_logit_Hake(3)	2.5	(-5, 10)	ok	168	none
Size_DbIN_ascend_se_Hake(3)	2.51	(-4, 12)	ok	1.03	none
Size_DbIN_descend_se_Hake(3)	9	(-2, 10)	fixed		none
Size_DbIN_start_logit_Hake(3)	-9	(-9, 10)	fixed		none
Size_DbIN_end_logit_Hake(3)	8	(-9, 9)	fixed		none
SizeSpline_Code_Triennial(7)	0	(0, 2)	fixed		none
SizeSpline_GradLo_Triennial(7)	0.127	(-0.001, 1)	ok	0.0677	none
SizeSpline_GradHi_Triennial(7)	0.094	(-1, 1)	ok	0.202	none
SizeSpline_Knot_1_Triennial(7)	24	(8, 56)	fixed		none
SizeSpline_Knot_2_Triennial(7)	34	(8, 56)	fixed		none

Table 19: Parameter estimates, parameter bounds (low, high), estimation status, estimated standard deviation (SD), prior information [distribution(mean, SD)] used in the base model.

Label	Value	Bounds	Status	SD	Prior
SizeSpline_Knot_3_Triennial(7)	48	(8, 56)	fixed		none
SizeSpline_Val_1_Triennial(7)	-2.17	(-10, 10)	ok	0.756	none
SizeSpline_Val_2_Triennial(7)	-1	(-10, 10)	fixed		none
SizeSpline_Val_3_Triennial(7)	0.435	(-10, 10)	ok	0.509	none
SizeSpline_Code_WCGBTS(8)	0	(0, 2)	fixed		none
SizeSpline_GradLo_WCGBTS(8)	0.447	(-0.001, 1)	ok	0.299	none
SizeSpline_GradHi_WCGBTS(8)	-0.098	(-1, 1)	ok	0.151	none
SizeSpline_Knot_1_WCGBTS(8)	24	(8, 56)	fixed		none
SizeSpline_Knot_2_WCGBTS(8)	34	(8, 56)	fixed		none
SizeSpline_Knot_3_WCGBTS(8)	48	(8, 56)	fixed		none
SizeSpline_Val_1_WCGBTS(8)	-2.19	(-10, 10)	ok	0.665	none
SizeSpline_Val_2_WCGBTS(8)	-1	(-10, 10)	fixed		none
SizeSpline_Val_3_WCGBTS(8)	0.05	(-10, 10)	ok	0.354	none
minage@sel=1_JuvSurvey(6)	0	(0, 1)	fixed		none
maxage@sel=1_JuvSurvey(6)	0	(0, 1)	fixed		none
minage@sel=1_WCGBTS(8)	0	(0, 1)	fixed		none
maxage@sel=1_WCGBTS(8)	40	(0, 50)	fixed		none
Size_DbIN_peak_BottomTrawl(1)_BLK4repl_1916	39.4	(10, 59)	ok	0.604	none
Size_DbIN_ascend_se_BottomTrawl(1)_BLK4repl_1916	3.47	(-4, 12)	ok	0.161	none
Size_DbIN_peak_MidwaterTrawl(2)_BLK7repl_1916	38.6	(10, 59)	ok	1.32	none
Size_DbIN_peak_MidwaterTrawl(2)_BLK7repl_1983	38.2	(10, 59)	ok	0.593	none
Size_DbIN_peak_MidwaterTrawl(2)_BLK7repl_2002	37.8	(10, 59)	ok	2.19	none
Size_DbIN_ascend_se_MidwaterTrawl(2)_BLK7repl_1916	3.39	(-4, 12)	ok	0.381	none
Size_DbIN_ascend_se_MidwaterTrawl(2)_BLK7repl_1983	2.99	(-4, 12)	ok	0.191	none
Size_DbIN_ascend_se_MidwaterTrawl(2)_BLK7repl_2002	2.96	(-4, 12)	ok	0.715	none
Size_DbIN_descend_se_MidwaterTrawl(2)_BLK7repl_1916	4.11	(-2, 10)	ok	1.35	none
Size_DbIN_descend_se_MidwaterTrawl(2)_BLK7repl_1983	2.57	(-2, 10)	ok	0.82	none
Size_DbIN_descend_se_MidwaterTrawl(2)_BLK7repl_2002	-1.82	(-2, 10)	ok	5.29	none
Size_DbIN_end_logit_MidwaterTrawl(2)_BLK7repl_1916	-1.67	(-9, 9)	ok	3.15	none
Size_DbIN_end_logit_MidwaterTrawl(2)_BLK7repl_1983	-0.609	(-9, 9)	ok	0.307	none
Size_DbIN_end_logit_MidwaterTrawl(2)_BLK7repl_2002	2	(-9, 9)	ok	2.97	none
Size_DbIN_peak_Hake(3)_BLK11repl_1916	41.4	(10, 59)	ok	0.67	none
Size_DbIN_top_logit_Hake(3)_BLK11repl_1916	2.5	(-5, 10)	ok	168	none
Size_DbIN_ascend_se_Hake(3)_BLK11repl_1916	3.35	(-4, 12)	ok	0.18	none

Table 20: Time series of population estimates from the base case model.

Year	Total Biomass (mt)	Spawning output (billions of eggs)	Total Biomass 4+ (mt)	Fraction Un-fished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR <sub>-50%</sub> )	Exploitation Rate
1916	161,653	21,079	156,039	0.999	40,150	78	0.011	0.001
1917	161,529	21,062	155,919	0.998	40,114	122	0.018	0.001
1918	161,366	21,040	155,761	0.997	40,074	140	0.021	0.001
1919	161,191	21,015	155,590	0.995	40,029	97	0.014	0.001
1920	161,061	20,997	155,466	0.995	39,982	99	0.015	0.001
1921	160,930	20,979	155,341	0.994	39,930	82	0.012	0.001
1922	160,814	20,964	155,232	0.993	39,873	71	0.011	0.000
1923	160,705	20,951	155,130	0.992	39,811	78	0.012	0.001
1924	160,584	20,936	155,016	0.992	39,743	50	0.007	0.000
1925	160,483	20,926	154,923	0.991	39,669	62	0.009	0.000
1926	160,360	20,913	154,810	0.991	39,587	95	0.014	0.001
1927	160,196	20,894	154,656	0.990	39,496	79	0.012	0.001
1928	160,039	20,877	154,510	0.989	39,397	90	0.013	0.001
1929	159,859	20,857	154,342	0.988	39,288	87	0.013	0.001
1930	159,669	20,837	154,166	0.987	39,168	113	0.017	0.001
1931	159,441	20,811	153,952	0.986	39,035	100	0.015	0.001
1932	159,210	20,787	153,738	0.985	38,890	100	0.015	0.001
1933	158,963	20,760	153,508	0.983	38,732	86	0.013	0.001
1934	158,708	20,734	153,273	0.982	38,558	91	0.014	0.001
1935	158,426	20,705	153,013	0.981	38,368	98	0.015	0.001
1936	158,113	20,673	152,723	0.979	38,158	110	0.016	0.001
1937	157,761	20,637	152,396	0.978	37,926	103	0.015	0.001
1938	157,385	20,598	152,049	0.976	37,668	83	0.012	0.001
1939	156,995	20,560	151,690	0.974	37,381	76	0.011	0.001
1940	156,573	20,519	151,303	0.972	37,066	121	0.018	0.001
1941	156,065	20,467	150,833	0.970	36,720	129	0.020	0.001
1942	155,503	20,410	150,314	0.967	36,342	145	0.022	0.001
1943	154,877	20,345	149,735	0.964	35,942	494	0.073	0.003
1944	153,870	20,224	148,778	0.958	35,536	965	0.140	0.006
1945	152,386	20,030	147,349	0.949	35,111	1,635	0.231	0.011
1946	150,273	19,738	145,293	0.935	34,674	1,170	0.172	0.008
1947	148,649	19,520	143,727	0.925	34,265	649	0.099	0.005
1948	147,527	19,381	142,663	0.918	33,889	485	0.076	0.003
1949	146,524	19,266	141,719	0.913	33,556	381	0.060	0.003
1950	145,570	19,161	140,819	0.908	33,295	432	0.068	0.003
1951	144,510	19,044	139,807	0.902	33,146	562	0.089	0.004
1952	143,285	18,900	138,621	0.895	33,165	554	0.088	0.004
1953	142,049	18,751	137,410	0.888	33,427	476	0.077	0.003
1954	140,893	18,608	136,258	0.881	34,011	454	0.074	0.003
1955	139,793	18,464	135,132	0.875	35,000	470	0.077	0.003
1956	138,759	18,314	134,031	0.868	36,431	610	0.100	0.005
1957	137,738	18,144	132,894	0.859	38,160	771	0.126	0.006

Table 20: Time series of population estimates from the base case model.

Year	Total Biomass (mt)	Spawning output (billions of eggs)	Total Biomass 4+ (mt)	Fraction Un-fished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR <sub>50%</sub> )	Exploitation Rate
1958	136,799	17,956	131,784	0.851	39,678	713	0.118	0.005
1959	136,235	17,790	131,011	0.843	40,221	683	0.115	0.005
1960	136,076	17,651	130,649	0.836	39,536	823	0.137	0.006
1961	136,179	17,523	130,627	0.830	38,492	688	0.117	0.005
1962	136,775	17,459	131,225	0.827	38,409	771	0.130	0.006
1963	137,557	17,433	132,099	0.826	39,883	446	0.077	0.003
1964	138,806	17,506	133,400	0.829	41,870	611	0.103	0.005
1965	139,961	17,598	134,463	0.834	43,338	269	0.046	0.002
1966	141,515	17,767	135,790	0.842	44,813	4,294	0.565	0.032
1967	139,388	17,366	133,427	0.823	44,144	4,828	0.626	0.036
1968	137,219	16,920	131,100	0.801	42,755	2,398	0.365	0.018
1969	137,810	16,867	131,665	0.799	33,638	849	0.143	0.006
1970	140,465	17,081	134,144	0.809	132,665	853	0.142	0.006
1971	144,015	17,333	136,657	0.821	115,417	1,094	0.176	0.008
1972	148,722	17,582	138,742	0.833	14,778	922	0.147	0.007
1973	154,967	17,897	139,575	0.848	13,445	1,163	0.180	0.008
1974	163,294	18,278	153,365	0.866	19,026	907	0.140	0.006
1975	172,030	18,930	169,843	0.897	40,135	877	0.130	0.005
1976	177,385	19,921	174,863	0.944	10,545	1,328	0.178	0.008
1977	178,784	21,043	175,189	0.997	67,871	1,167	0.146	0.007
1978	177,862	22,027	172,780	1.043	96,292	1,621	0.191	0.009
1979	175,689	22,514	170,390	1.066	33,987	9,653	0.806	0.057
1980	165,542	21,529	155,511	1.020	54,487	21,906	1.369	0.141
1981	145,738	18,616	135,524	0.882	95,410	28,244	1.609	0.208
1982	123,718	14,792	117,077	0.701	50,092	32,458	1.758	0.277
1983	100,648	10,753	91,564	0.509	26,190	13,051	1.471	0.143
1984	99,416	9,717	89,273	0.460	48,775	12,890	1.461	0.144
1985	99,603	9,292	93,651	0.440	40,931	11,535	1.383	0.123
1986	100,260	9,234	95,486	0.437	16,462	12,393	1.400	0.130
1987	98,450	9,212	92,532	0.436	37,769	16,484	1.520	0.178
1988	91,405	8,784	86,810	0.416	26,017	13,404	1.435	0.154
1989	85,979	8,498	82,638	0.403	20,481	16,017	1.552	0.194
1990	76,555	7,698	72,080	0.365	29,400	13,501	1.528	0.187
1991	69,298	6,971	65,711	0.330	55,560	8,759	1.363	0.133
1992	66,407	6,690	62,609	0.317	22,763	8,338	1.364	0.133
1993	63,909	6,371	58,834	0.302	31,286	10,935	1.524	0.186
1994	59,272	5,685	53,376	0.269	26,847	8,511	1.460	0.159
1995	57,816	5,292	54,246	0.251	17,867	8,803	1.513	0.162
1996	55,913	4,920	52,019	0.233	14,290	7,957	1.486	0.153
1997	54,579	4,762	51,421	0.226	22,377	8,441	1.507	0.164
1998	52,260	4,638	49,740	0.220	40,872	5,255	1.270	0.106
1999	52,422	4,826	49,539	0.229	44,046	5,048	1.203	0.102
2000	52,554	4,992	48,217	0.236	47,344	4,674	1.111	0.097

Table 20: Time series of population estimates from the base case model.

Year	Total Biomass (mt)	Spawning output (billions of eggs)	Total Biomass 4+ (mt)	Fraction Un-fished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR_50%)	Exploitation Rate
2001	53,361	5,124	47,520	0.243	18,657	2,265	0.710	0.048
2002	57,404	5,445	51,638	0.258	19,454	432	0.199	0.008
2003	63,793	5,997	58,922	0.284	21,170	43	0.020	0.001
2004	70,648	6,708	67,787	0.318	60,944	101	0.041	0.001
2005	76,532	7,532	73,117	0.357	10,504	199	0.072	0.003
2006	81,633	8,395	77,054	0.398	60,168	215	0.068	0.003
2007	86,164	9,204	79,957	0.436	9,736	250	0.073	0.003
2008	91,308	9,899	87,447	0.469	96,802	268	0.073	0.003
2009	96,025	10,518	89,298	0.498	14,774	257	0.067	0.003
2010	101,612	11,117	96,410	0.527	55,845	186	0.047	0.002
2011	106,926	11,740	97,798	0.556	12,540	212	0.051	0.002
2012	113,179	12,384	109,498	0.587	8,954	273	0.062	0.002
2013	118,105	13,082	112,865	0.620	49,443	472	0.099	0.004
2014	121,949	13,820	119,665	0.655	32,350	723	0.141	0.006
2015	123,844	14,522	120,504	0.688	21,973	881	0.160	0.007
2016	124,597	15,089	118,504	0.715	126,249	1,042	0.182	0.009
2017	125,747	15,436	120,077	0.731	47,765	6,356	0.789	0.053
2018	122,629	14,925	114,902	0.707	17,416	10,532	1.151	0.092
2019	116,555	13,816	104,377	0.654	16,236	9,310	1.141	0.089
2020	114,538	12,948	109,729	0.613	22,868	8,401	1.127	0.077
2021	113,380	12,457	110,824	0.590	37,217	10,874	1.277	0.098
2022	108,443	12,033	105,476	0.570	37,214	12,116	1.301	0.115
2023	100,976	11,644	96,857	0.552	48,077	10,997	1.238	0.114
2024	93,859	11,195	88,467	0.530	42,674	9,747	1.214	0.110
2025	88,274	10,572	82,550	0.501	36,894	10,669	1.351	0.129
2026	82,615	9,630	76,358	0.456	36,267	9,824	1.385	0.129
2027	79,012	8,799	73,427	0.417	35,624	4,596	0.958	0.063
2028	81,326	8,763	76,229	0.415	35,594	4,810	0.955	0.063
2029	83,523	8,870	78,501	0.420	35,682	5,137	0.952	0.065
2030	85,224	9,054	80,251	0.429	35,832	5,409	0.949	0.067
2031	86,366	9,246	81,389	0.438	35,981	5,545	0.946	0.068
2032	87,094	9,403	82,102	0.445	36,101	5,585	0.943	0.068
2033	87,573	9,521	82,560	0.451	36,187	5,572	0.941	0.067
2034	87,928	9,606	82,897	0.455	36,250	5,535	0.937	0.067
2035	88,237	9,672	83,192	0.458	36,297	5,504	0.935	0.066
2036	88,530	9,726	83,475	0.461	36,335	5,480	0.932	0.066

## 5.4 Model diagnostics

Table 21: Sensitivity analysis results: differences in negative log-likelihood, estimates of key parameters, and estimates of derived quantities between the base model and several alternative models (columns). See main text for details on each sensitivity analysis. Red values indicate negative log-likelihoods that were lower (fit better) than the base model. Note that the 'Parm priors' and 'Total' likelihoods are not comparable for the two 'M prior...' sensitivities due to both the prior differing from the base model.

Label	January 2026 base model	M=0.1 (the median of a prior)	M fixed at 2019 model estimates	M fixed at 2015 model estimates	M prior based on max age 50	M prior based on max age 45	WCG-BTS selectivity double-normal, asymptotic	WCG-BTS selectivity double-normal, allowed to be dome	Recreational catches added
<b>Diff. in likelihood from base model</b>									
Total	0	23.01	0.85	3.49	-0.48	-0.97	1.65	1.65	0.01
Index	0	2.563	0.167	0.952	0.005	0.016	0.06	0.06	0.002
Length comp	0	-0.588	-0.471	-0.222	-0.004	-0.011	1.781	1.781	-0.004
Age comp	0	11.582	1.405	2.533	0.043	0.109	-0.101	-0.101	0.015
Parm priors	0	-1.255	0.491	1.425	-0.435	-0.884	-0.006	-0.006	-0.001
<b>Estimates of key parameters</b>									
M Female	0.135	0.1	0.144	0.157	0.136	0.137	0.135	0.135	0.135
M Male	0.147	0.1	0.155	0.17	0.148	0.149	0.147	0.147	0.147
<b>Estimates of derived quantities</b>									
Unfished age 4+ bio 1000 mt	156.4	153.1	159.2	168.3	156.7	157.1	155.9	155.9	156.5
B0 trillions of eggs	21.11	21.1	20.83	21.56	21.11	21.11	21.04	21.04	21.12
B2025 trillions of eggs	10.57	4.61	11.47	13.39	10.67	10.81	10.39	10.39	10.57
Fraction unfished 2025	0.501	0.218	0.55	0.621	0.506	0.512	0.494	0.494	0.5
Relative fishing intensity 2024	1.214	1.719	1.122	0.989	1.205	1.193	1.226	1.226	1.214
2027 OFL mt	4916	1307	5809	7400	4995	5108	4831	4831	4914
2027 ACL mt	4596	351	5431	6919	4671	4776	4517	4517	4595
Equil. catch at MSY mt	6746	5073	7249	8244	6789	6851	6720	6720	6748
Equil. catch at SPR targ. mt	5931	4548	6360	7193	5967	6020	5909	5909	5933

## 5.5 Management

Table 22: Estimates of key derived parameters and reference points with approximate 95% asymptotic confidence intervals.

Reference Point	Estimate	Lower Interval	Upper Interval
Unfished Spawning output (billions of eggs)	21,110.8	17,760.2	24,461.4
Unfished Age 4+ Biomass (mt)	156,376	131,787	180,965
Unfished Recruitment (R0)	40,470	28,186	52,755
2025 Spawning output (billions of eggs)	10,572	5,127	16,017
2025 Fraction Unfished	0.501	0.304	0.698
Reference Points Based SO40%	—	—	—
Proxy Spawning output (billions of eggs) SO40%	8,444	7,104	9,785
SPR Resulting in SO40%	0.458	0.458	0.458
Exploitation Rate Resulting in SO40%	0.083	0.076	0.091
Yield with SPR Based On SO40% (mt)	6,239	4,974	7,504
Reference Points Based on SPR Proxy for MSY	—	—	—
Proxy Spawning output (billions of eggs) (SPR50)	9,419	7,924	10,914
SPR50	0.500	—	—
Exploitation Rate Corresponding to SPR50	0.073	0.067	0.079
Yield with SPR50 at SO SPR (mt)	5,931	4,732	7,129
Reference Points Based on Estimated MSY Values	—	—	—
Spawning output (billions of eggs) at MSY (SO MSY)	5,393	4,541	6,246
SPR MSY	0.328	0.324	0.332
Exploitation Rate Corresponding to SPR MSY	0.127	0.116	0.138
MSY (mt)	6,745	5,359	8,132

Table 23: Potential OFL (mt), ABC (mt), ACL (mt), the buffer between the OFL and ABC, estimated spawning output (billions of eggs), and fraction of unfished spawning output with adopted OFL and ACL and assumed catch for the first two years of the projection period. The predicted OFL is the calculated total catch determined by FSPR=50%. Catches in 2025 and 2026 are allocated using the percentage of landings for each fleet in 2019–2024.

Year	Adopted OFL (mt)	Adopted ACL (mt)	Assumed Catch (mt)	OFL (mt)	Buffer	ABC (mt)	ACL (mt)	Spawning output (billions of eggs)	Fraction Unfished
2025	12,254	11,237	10,669	—	1.000	—	—	10,571.70	0.501
2026	11,382	10,392	9,824	—	1.000	—	—	9,630.18	0.456
2027	—	—	—	4,916	0.935	4,596	4,596	8,799.27	0.417
2028	—	—	—	5,172	0.930	4,810	4,810	8,763.01	0.415
2029	—	—	—	5,548	0.926	5,137	5,137	8,869.58	0.420
2030	—	—	—	5,866	0.922	5,409	5,409	9,054.47	0.429
2031	—	—	—	6,047	0.917	5,545	5,545	9,245.68	0.438
2032	—	—	—	6,117	0.913	5,585	5,585	9,403.42	0.445
2033	—	—	—	6,130	0.909	5,572	5,572	9,520.54	0.451
2034	—	—	—	6,123	0.904	5,535	5,535	9,605.99	0.455
2035	—	—	—	6,116	0.900	5,504	5,504	9,671.68	0.458
2036	—	—	—	6,116	0.896	5,480	5,480	9,725.54	0.461

Table 24: Summary table of 12-year projections beginning in 2025 for alternate states of nature based on the axis of uncertainty (a combination of M, h as described in the text). Catches applied to all states of nature are the projections from the base model using  $P^* = 0.45$  and  $\sigma = 0.5$  with the time-varying buffer. Columns range over low, base, and high states of nature. Spawning output is in billions of eggs. OFL values for the years 2027 and beyond for each state of nature are the result of applying the harvest rate to the estimated biomass in that state of nature as discussed in Supplemental NWFSC-SWFSC Report 2 under PFMC Agenda Item G.3.a from September 2025.

Year	Catch	Low Spawn- ing Out- put	Low Frac- tion Un- fished	Low OFL	Base Spawn- ing Out- put	Base Frac- tion Un- fished	Base OFL	High Spawn- ing Out- put	High Frac- tion Un- fished	High OFL
2025	10669	7044	0.292	-	10572	0.501	-	12935	0.632	-
2026	9824	6039	0.251	-	9630	0.456	-	11972	0.585	-
2027	4596	5183	0.215	2818	8799	0.417	4916	11102	0.542	6470
2028	4810	5136	0.213	3079	8763	0.415	5172	11022	0.538	6692
2029	5137	5231	0.217	3412	8870	0.420	5548	11084	0.541	7064
2030	5409	5388	0.223	3666	9054	0.429	5866	11230	0.548	7386
2031	5545	5525	0.229	3771	9246	0.438	6047	11387	0.556	7566
2032	5585	5601	0.232	3753	9403	0.445	6117	11519	0.563	7639
2033	5572	5609	0.233	3665	9521	0.451	6130	11617	0.567	7659
2034	5535	5563	0.231	3557	9606	0.455	6123	11691	0.571	7661
2035	5504	5486	0.228	3460	9672	0.458	6116	11751	0.574	7662
2036	5480	5398	0.224	3386	9726	0.461	6116	11800	0.576	7665

## 6 Figures

Note: figure numbering is continuous with executive summary

### 6.1 Data

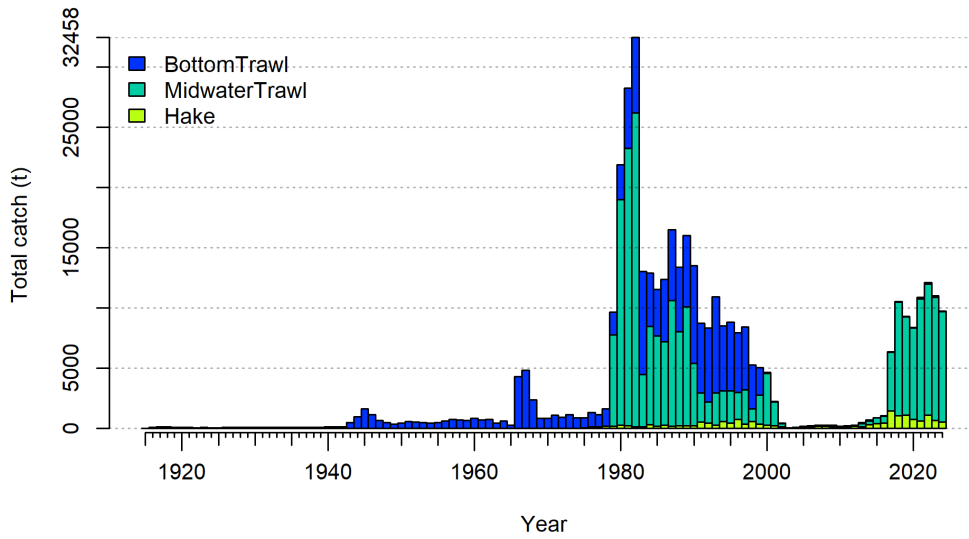


Figure 6: Total catches (landings and discards combined) of widow rockfish from 1916 to 2024 for bottom trawl, midwater trawl, and hake fleets.

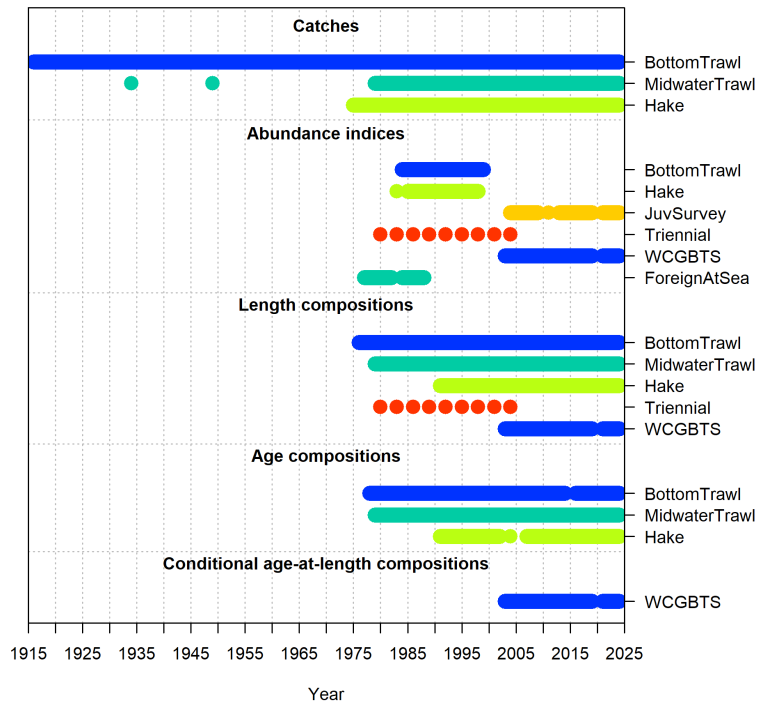


Figure 7: Data sources by type and year that were used in the base model.

### 6.1.1 Indices

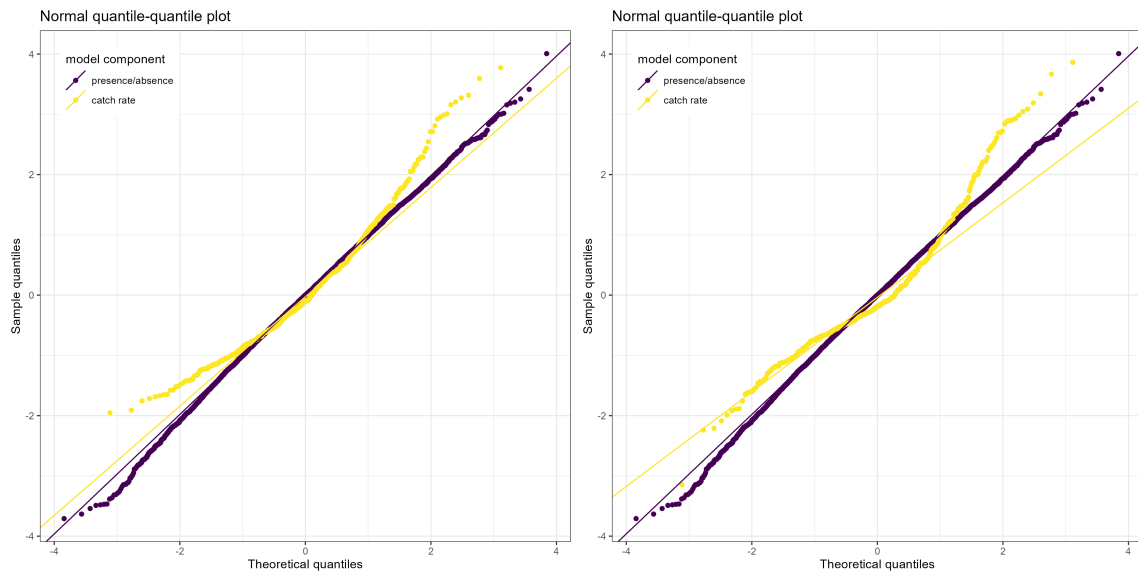


Figure 8: QQ plots for delta-gamma (panel 1) and delta-lognormal (panel 2, used in base model) sdmTMB index.

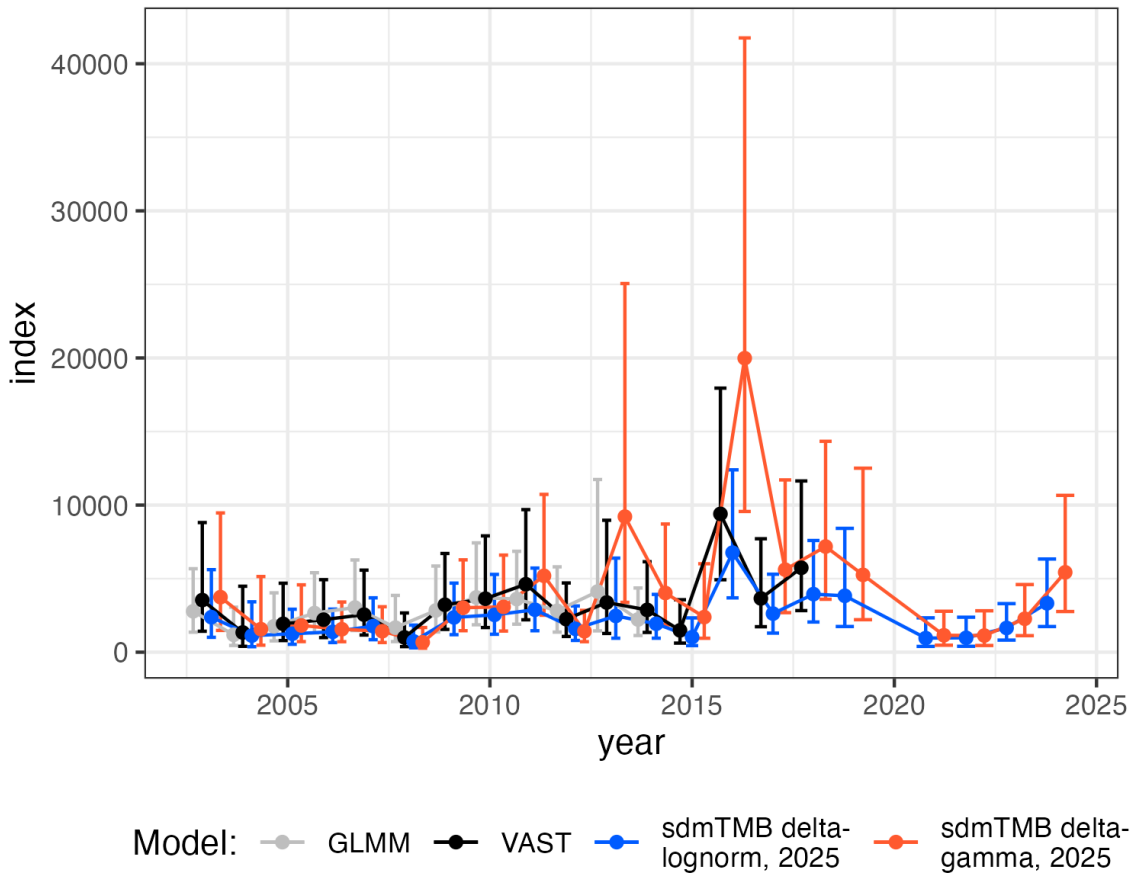


Figure 9: Comparison of the estimated index of relative abundance for the West Coast Groundfish Bottom Trawl Survey using a GLMM (gray line, 2015 stock assessment), VAST (black line, 2019 stock assessment), a delta-gamma sdmTMB index (blue line) and a delta-lognormal sdmTMB index (red line, used in base model). The error bars give 5 and 95% intervals for each survey.

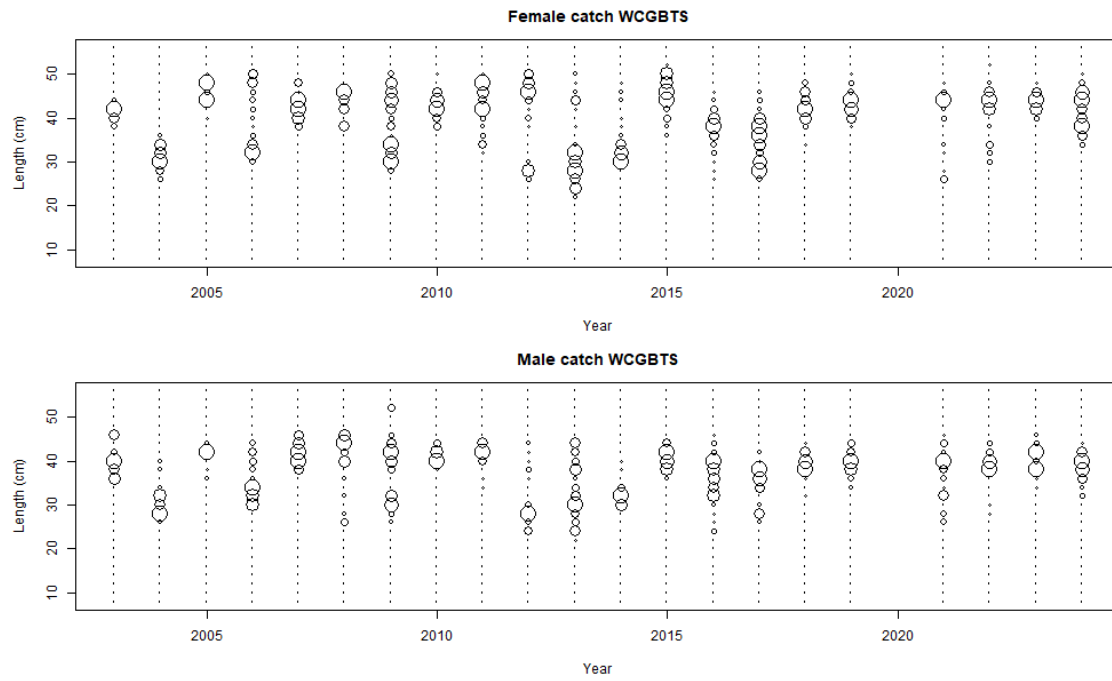


Figure 10: Expanded length compositions for the WCGBTs

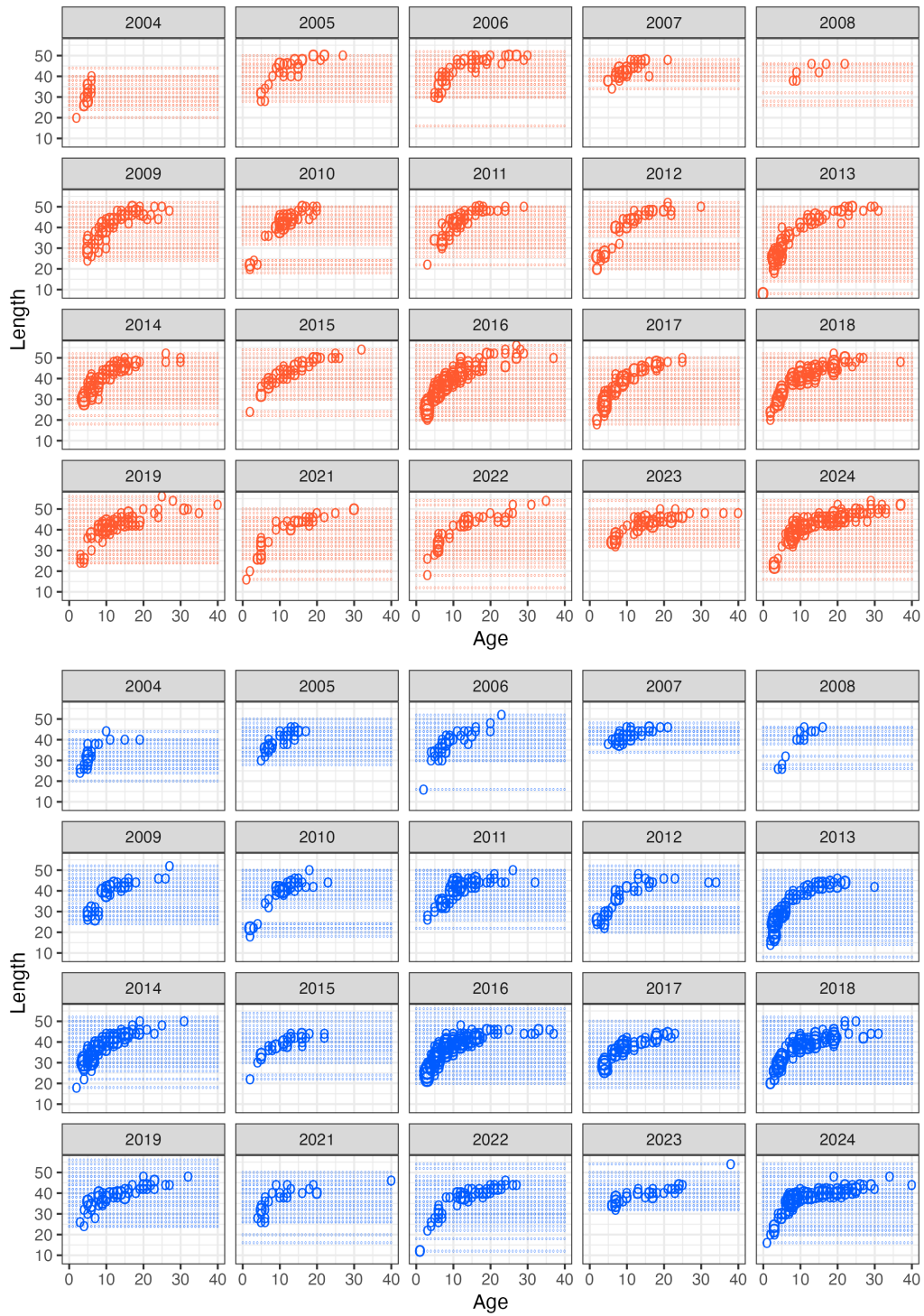


Figure 11: Conditional age-at-length from WCGBTs observations for females (red) and males (blue).

### 6.1.2 Composition data

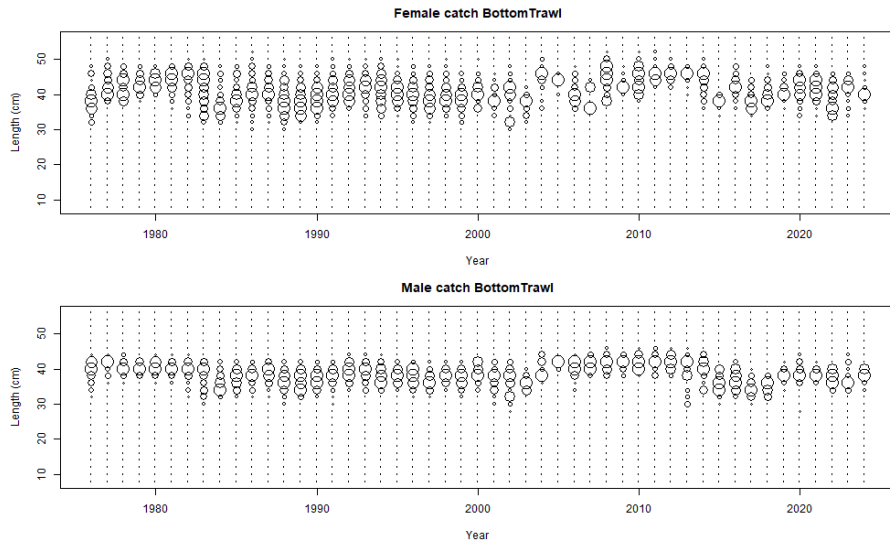


Figure 12: Expanded length compositions for the bottom trawl fishery. The area of the circle is proportional to the proportion-at-length.

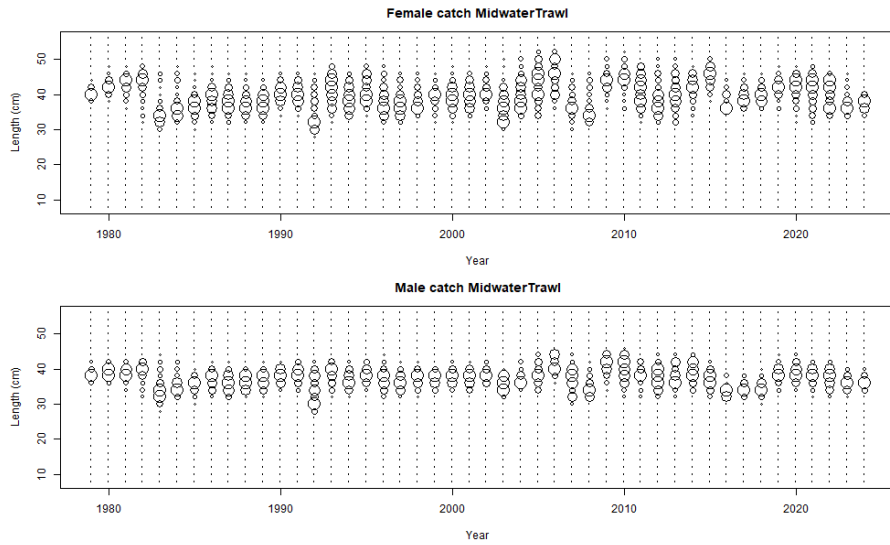


Figure 13: Expanded length compositions for the midwater trawl fishery. The area of the circle is proportional to the proportion-at-length.

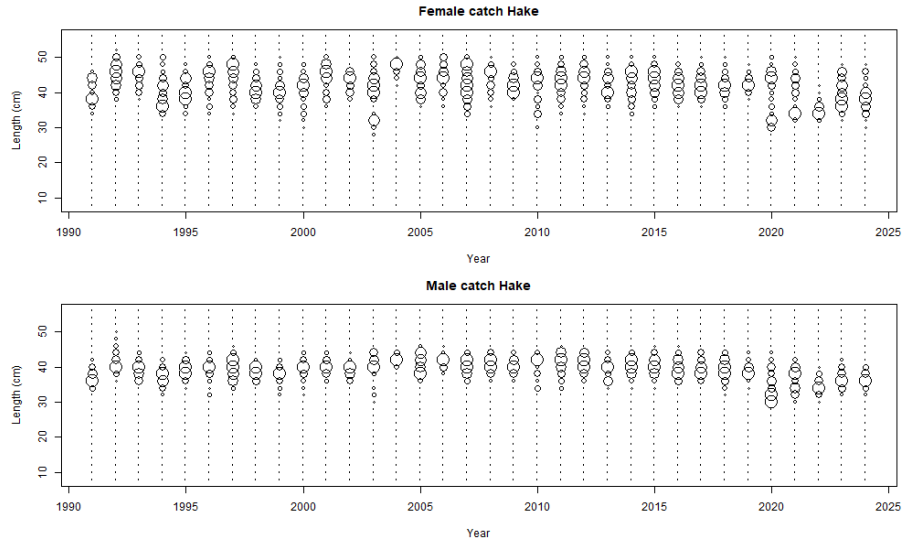


Figure 14: Expanded length compositions for the hake fishery. The area of the circle is proportional to the proportion-at-length.

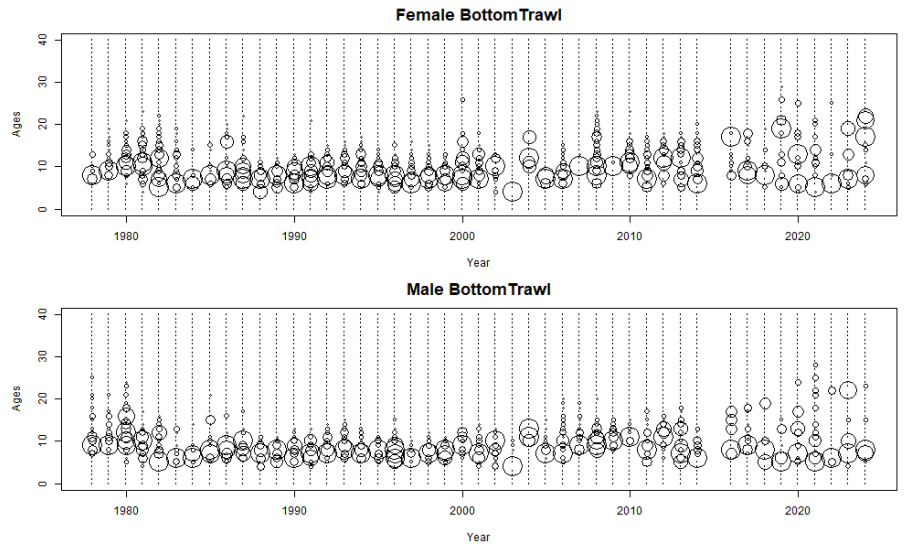


Figure 15: Expanded age compositions for the bottom trawl fishery. The area of the circle is proportional to the proportion-at-age.

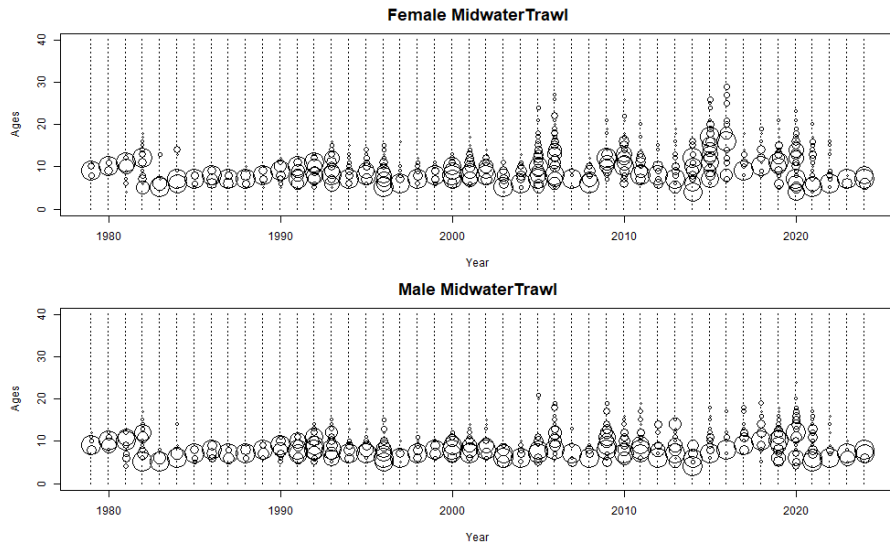


Figure 16: Expanded age compositions for the midwater trawl fishery. The area of the circles is proportional to the proportion-at-age.

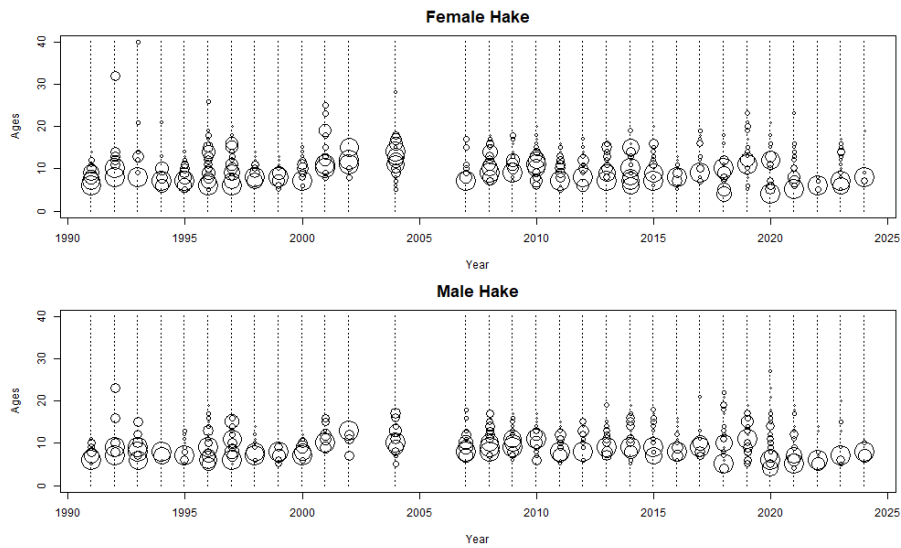


Figure 17: Expanded age compositions for the hake fishery. The area of the circles is proportional to the proportion-at-age.

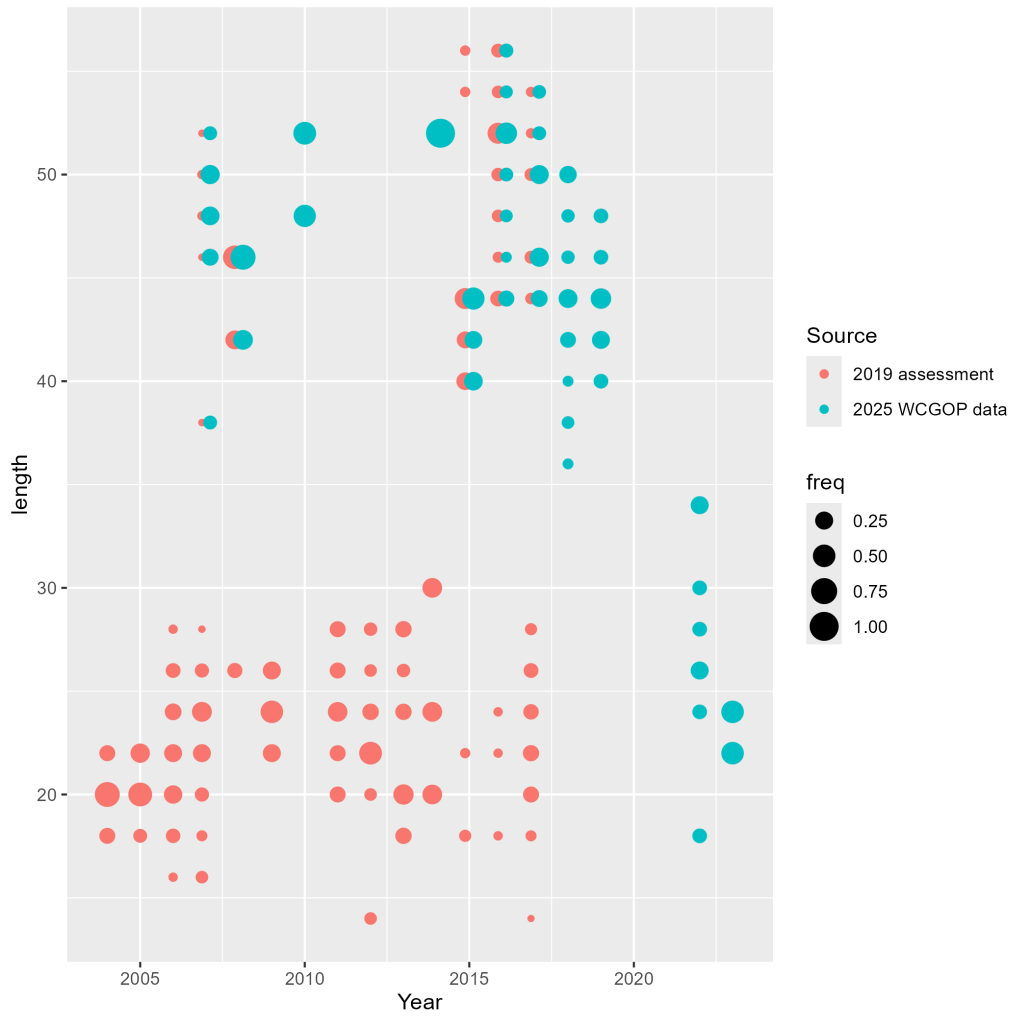


Figure 18: Comparison between discard data for the hook-and-line fleet from the 2019 assessment, which included nearshore fixed gear fleets, and discards queried from WCGOP for this assessment.

### 6.1.3 Biological data

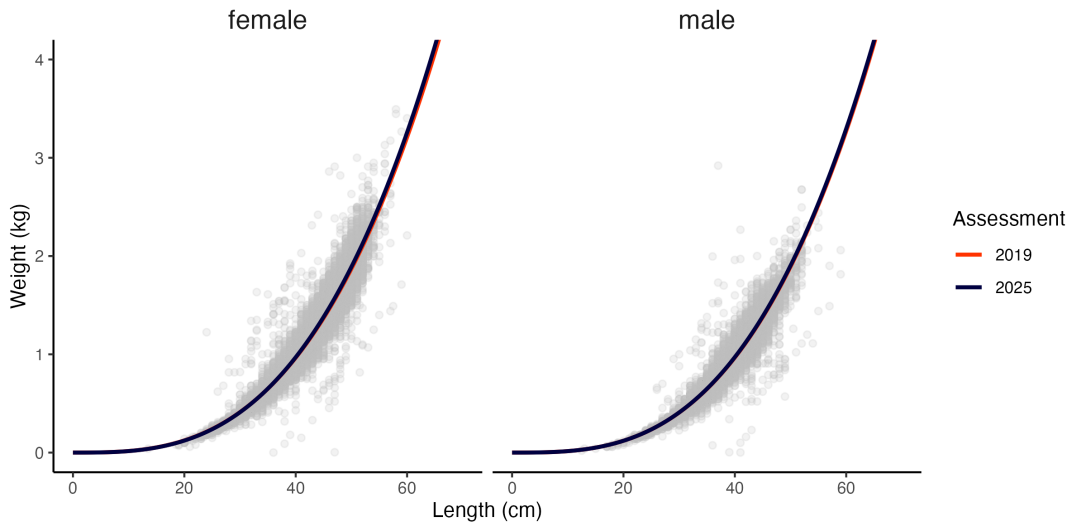


Figure 19: Fits to weight-at-length observations (dashed line) for females (left) and males (right) from the previous and current assessments. Fits to the current assessment use observations from all data sources (points)

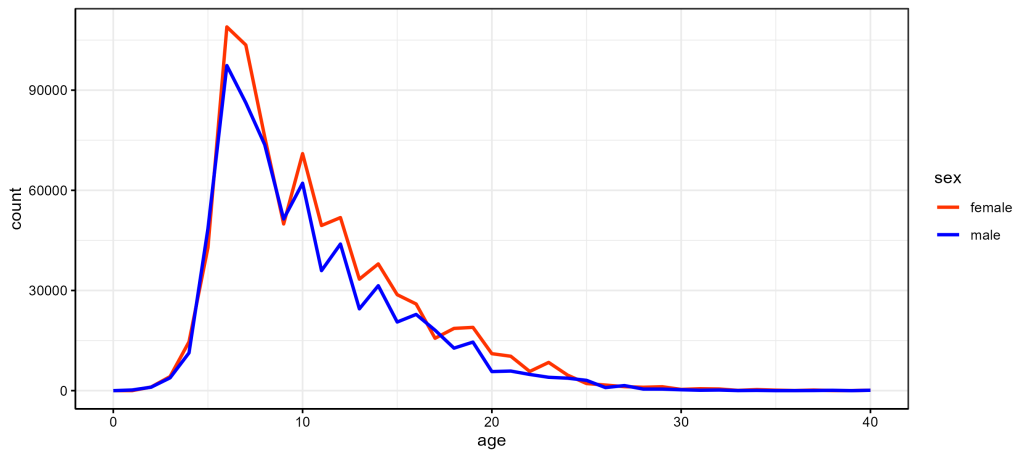


Figure 20: Number at age observed from all data for female and male widow rockfish.

## 6.2 Model

### 6.2.1 Bridging

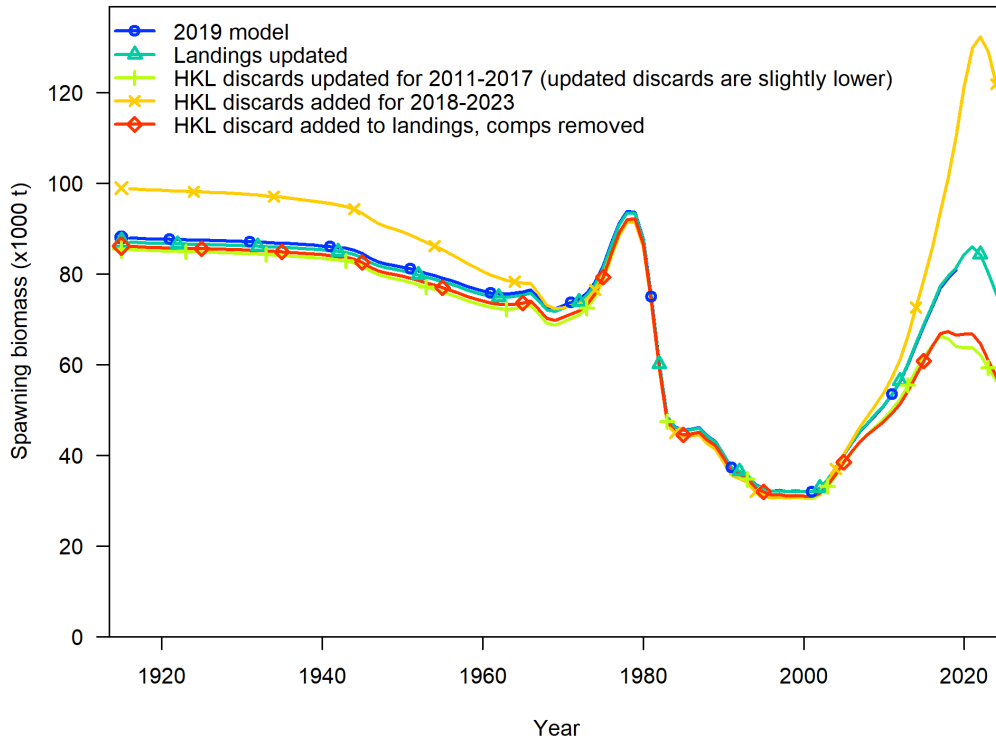


Figure 21: Spawning biomass with intermediate steps in hook-and-line discard data updates.

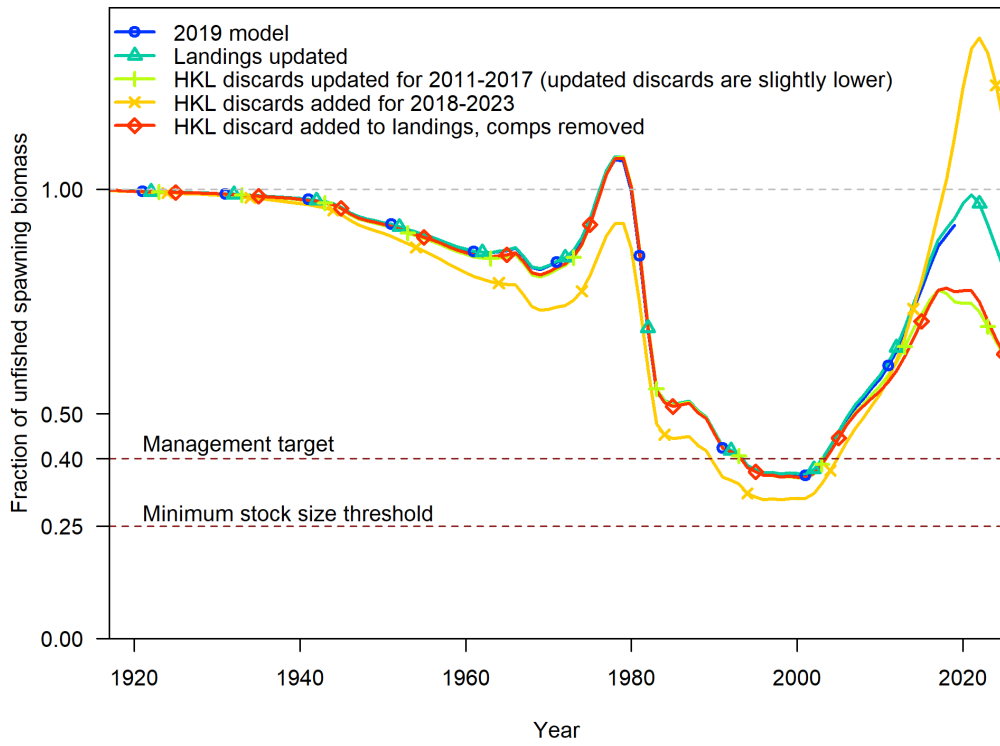


Figure 22: Fraction unfished with intermediate steps in hook-and-line discard data updates.

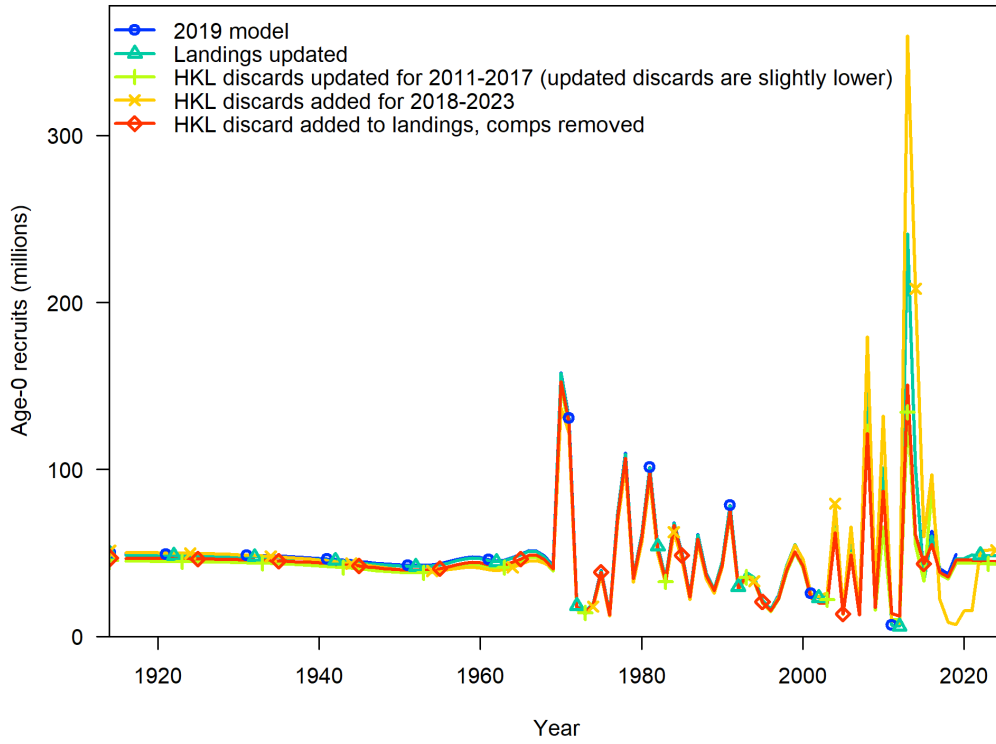


Figure 23: Fraction unfished with intermediate steps in hook-and-line discard data updates.

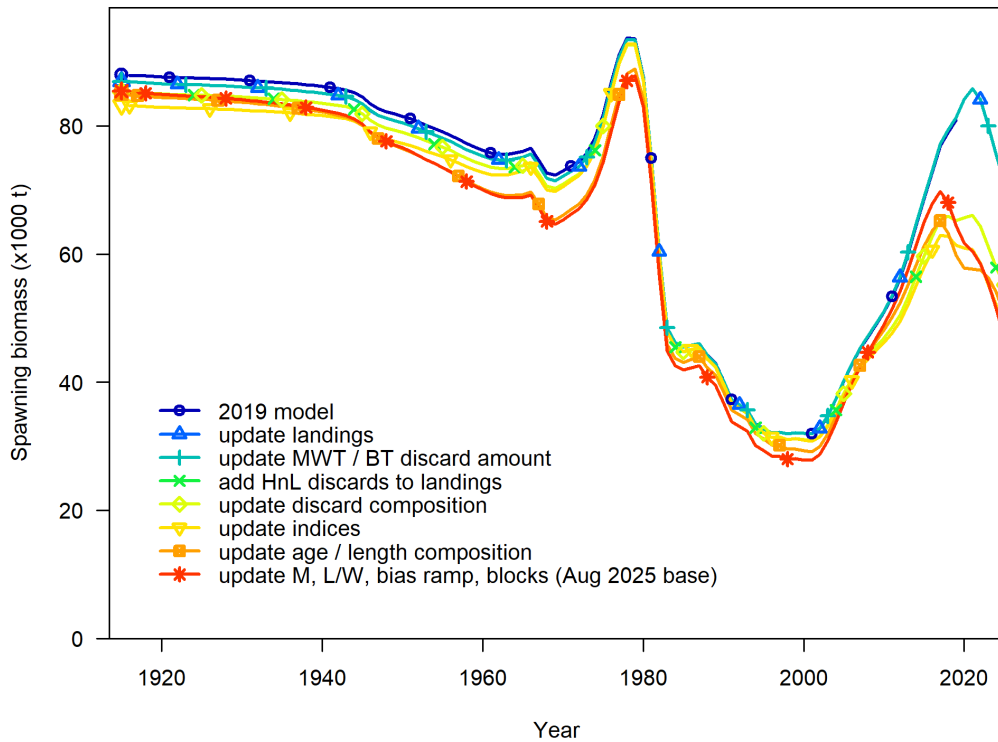


Figure 24: Time series of spawning biomass (SB) estimates from model runs bridging from the 2019 assessment (dark blue) to the August 2025 base model (red). For illustration purposes, the addition of midwater and bottom trawl discards (without updating hook-and-line discards) precedes the addition of hook-and-line discards to hook-and-line landings. Some bridging steps with minimal impact on SB are grouped (including updating mortality priors, length/weight regression estimates, stock-recruitment bias ramp estimation, and the addition of blocks on midwater and hake retention).

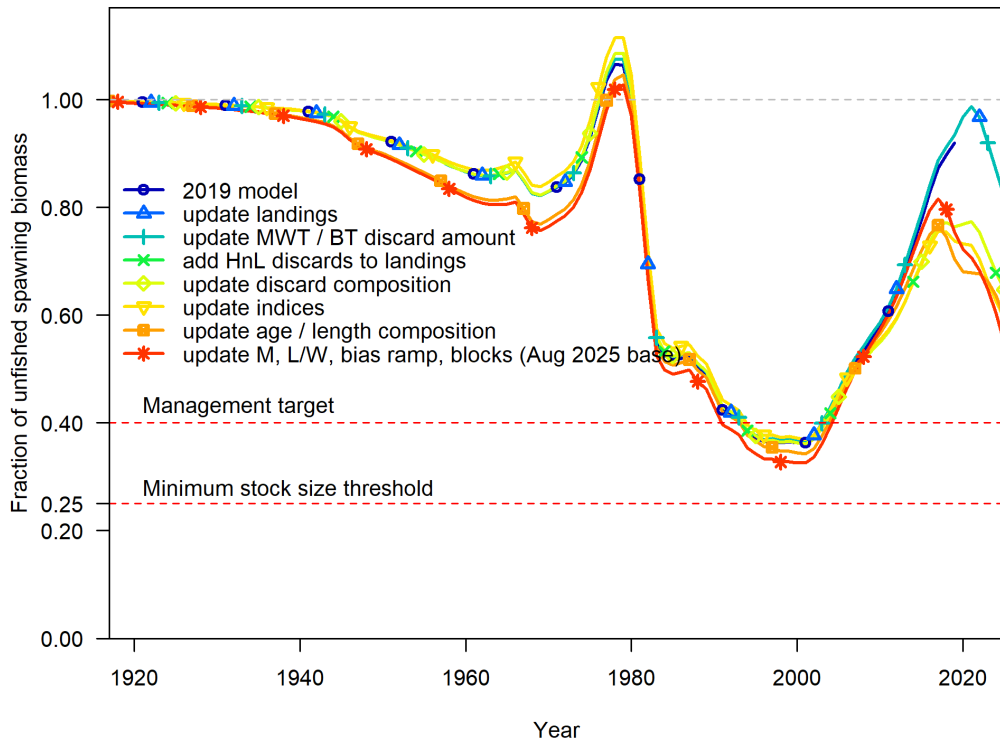


Figure 25: Time series of relative spawning biomass (fraction unfished) estimates from model runs bridging from the 2019 assessment (dark blue) to the August 2025 base model (red).

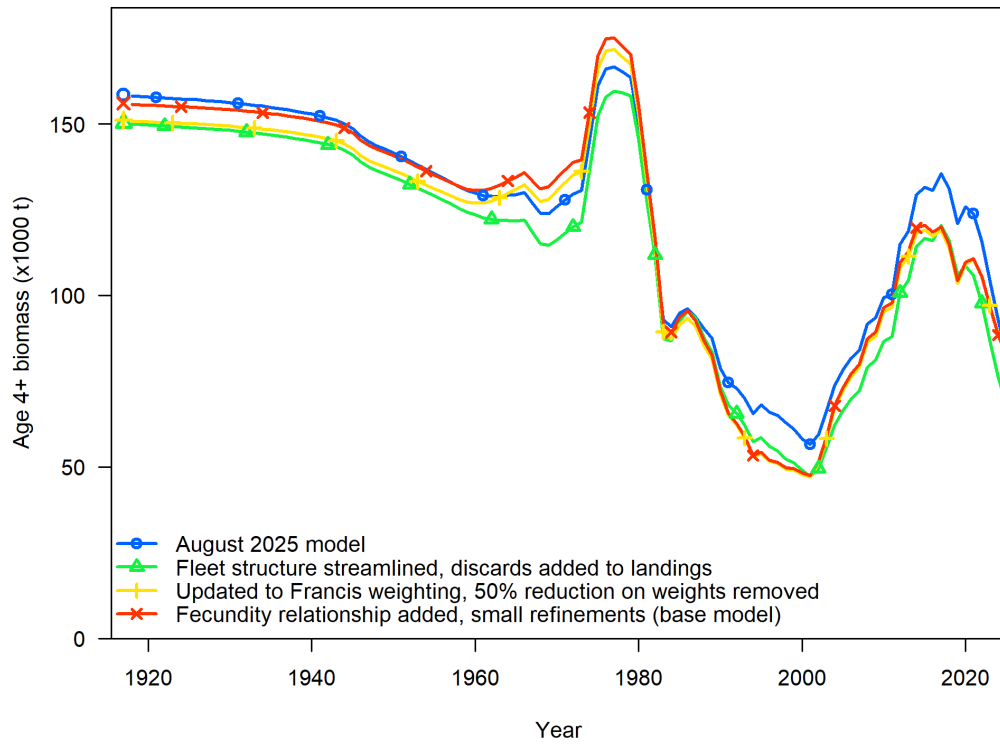


Figure 26: Time series of age 4+ biomass estimates from model runs bridging from the August 2025 model (blue) to the base model (red). Age 4+ biomass is used for this comparison because the units of spawning output differ among models due to the inclusion of the fecundity relationship in the base model.

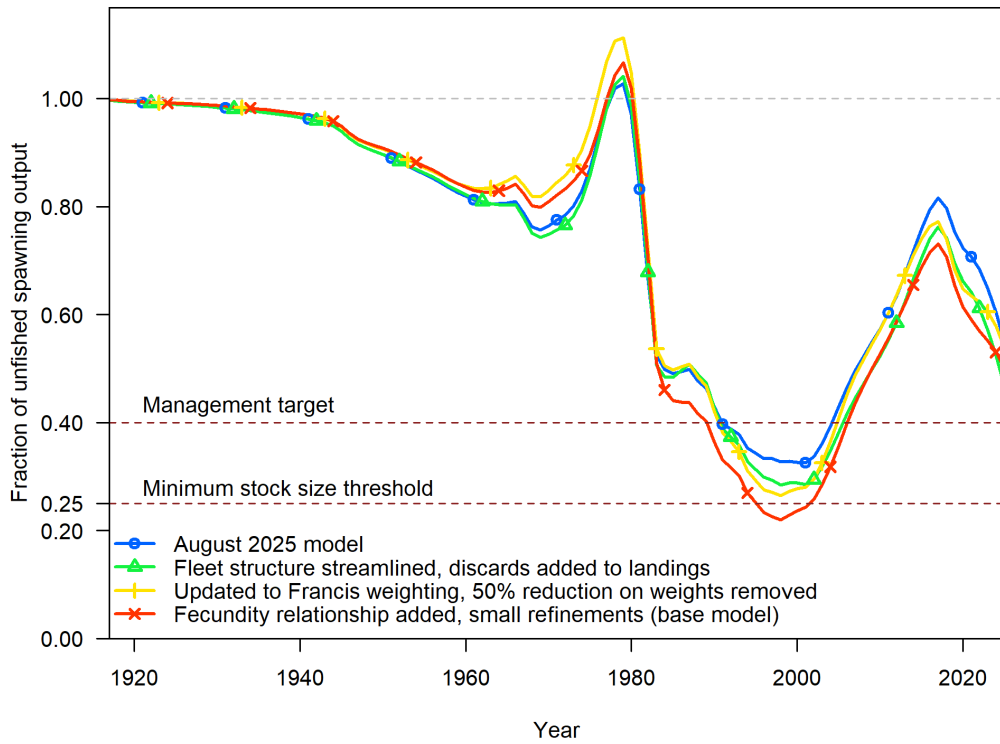


Figure 27: Time series of relative spawning biomass (fraction unfished) estimates from model runs bridging from the August 2025 model (blue) to the base model (red).

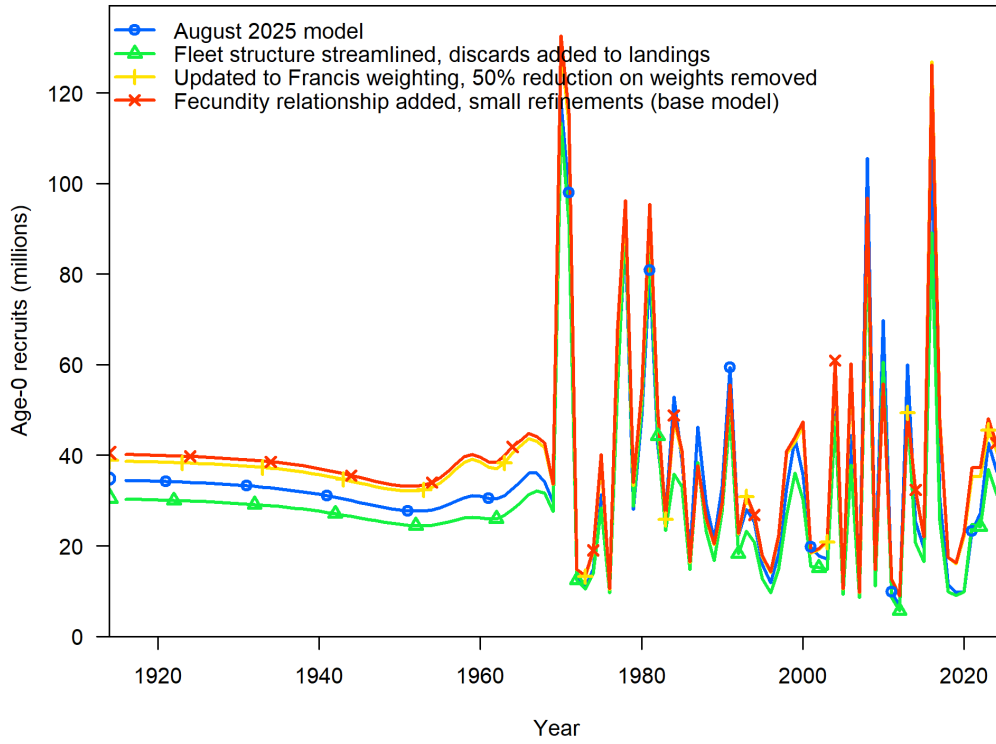


Figure 28: Time series of estimated recruitment from model runs bridging from the August 2025 model (blue) to the base model (red).

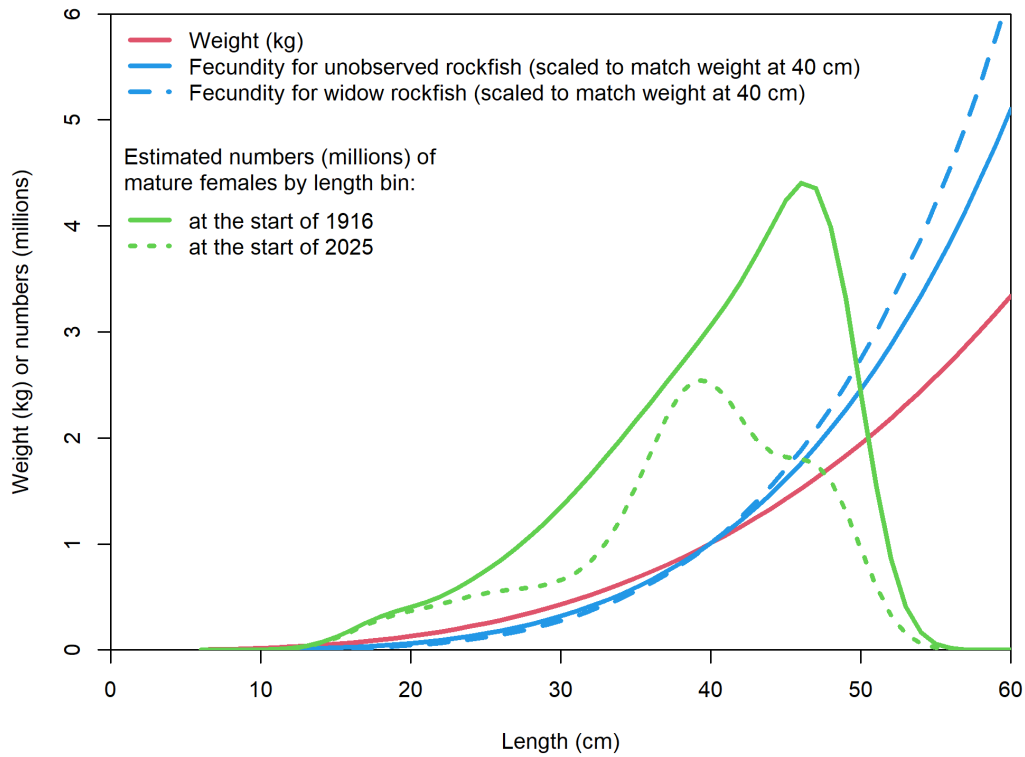


Figure 29: Two fecundity-at-length relationships (blue) are contrasted with weight-at-length for females (red), along with the mature numbers at length at the start and end of the base model (green). The exponent of the weight-at-length curve is 2.987 compared to 4.043 for the unobserved rockfish fecundity (used in the October 2025 model) and 4.545 for the Widow rockfish-specific fecundity (used in the January 2026 base model). Comparing these relationships to the number of mature fish in each length bin in 1916 and 2025 shows that when the fecundity relationships are used, the spawning output is more dependent on the larger fish (over 40 cm) which are disproportionately removed from the population due to selective fishing on larger sizes. This combination of factors leads to lower estimates of fraction of unfished when one of the fecundity relationships is used.

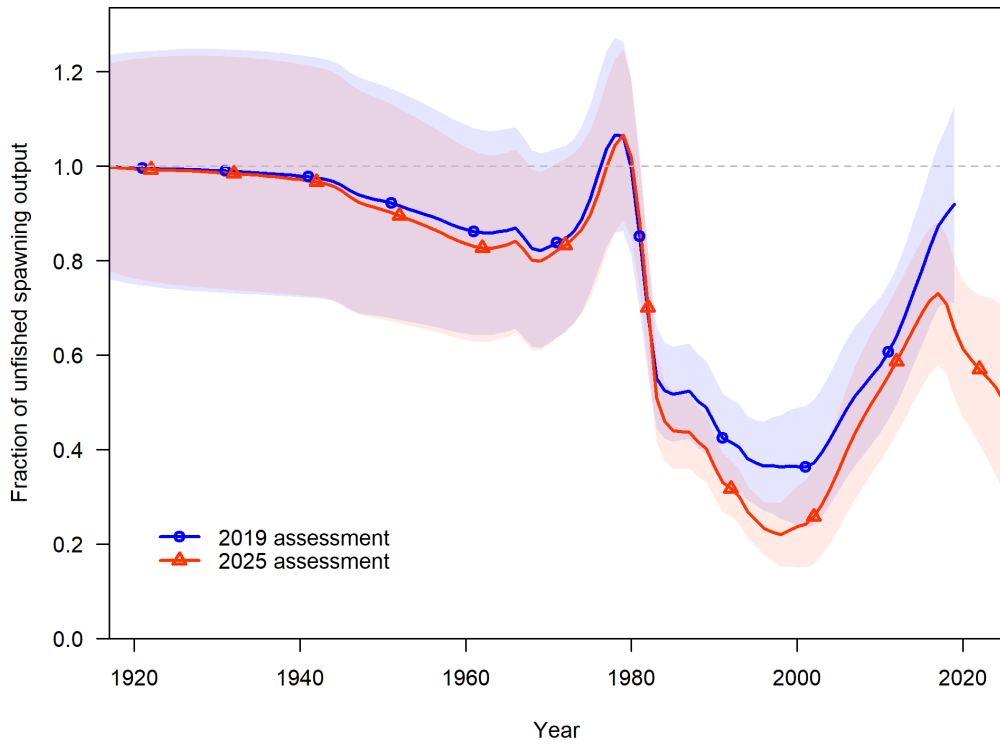


Figure 30: Time series of fraction of unfished spawning output estimates and asymptotic 95% confidence intervals estimates from 2019 and 2025 base models.

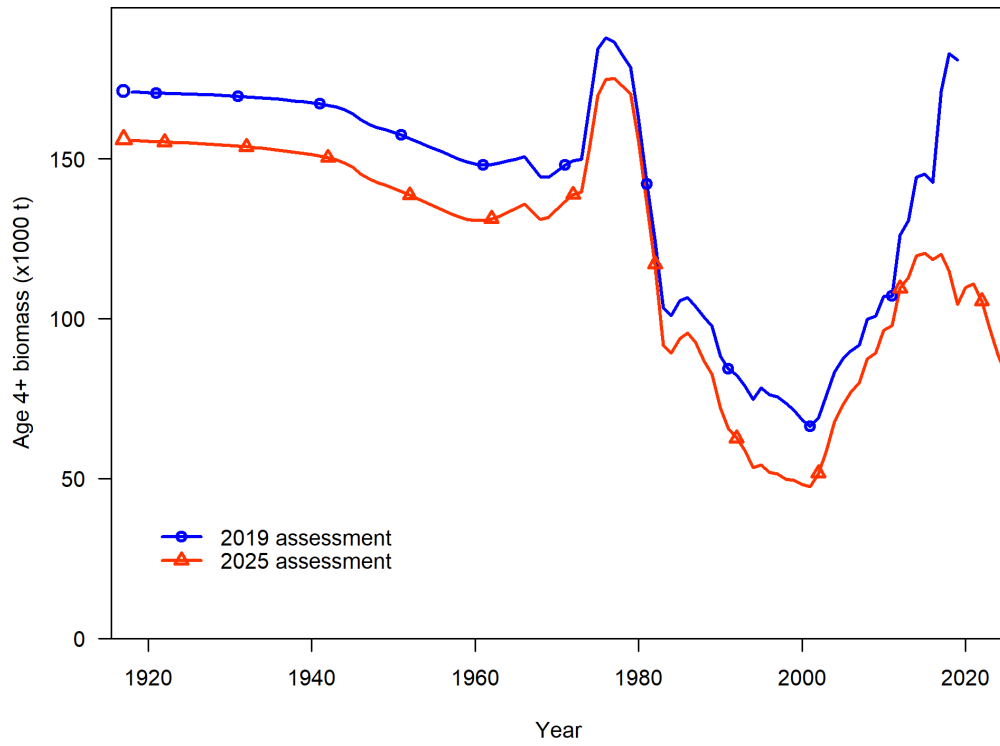


Figure 31: Time series of age 4+ biomass from the 2019 and 2025 base models.

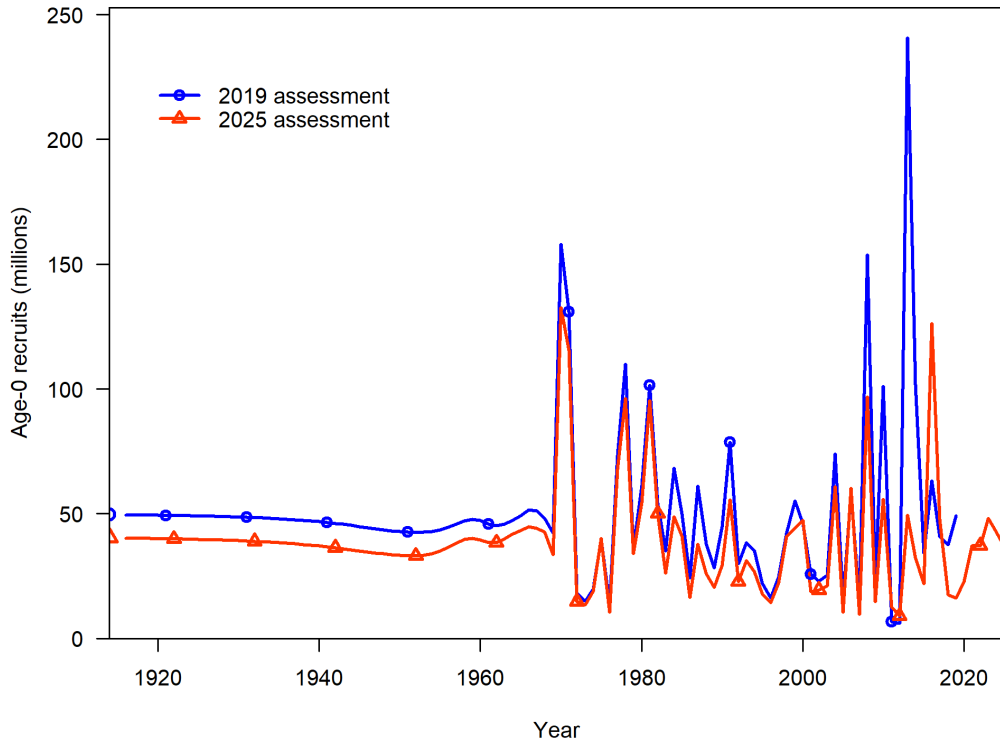


Figure 32: Estimates of age-0 recruits (in millions of individuals) from 2019 and 2025 base models.

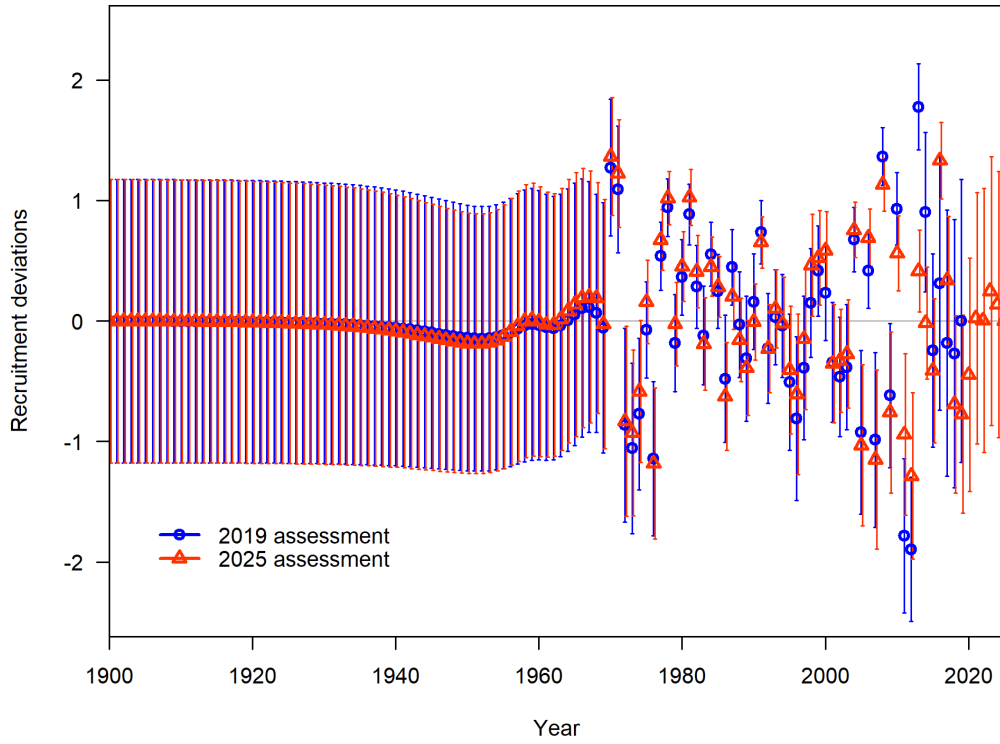


Figure 33: Estimates of age-0 (log-)recruitment deviations from 2019 and 2025 base models, with asymptotic 95% confidence intervals.

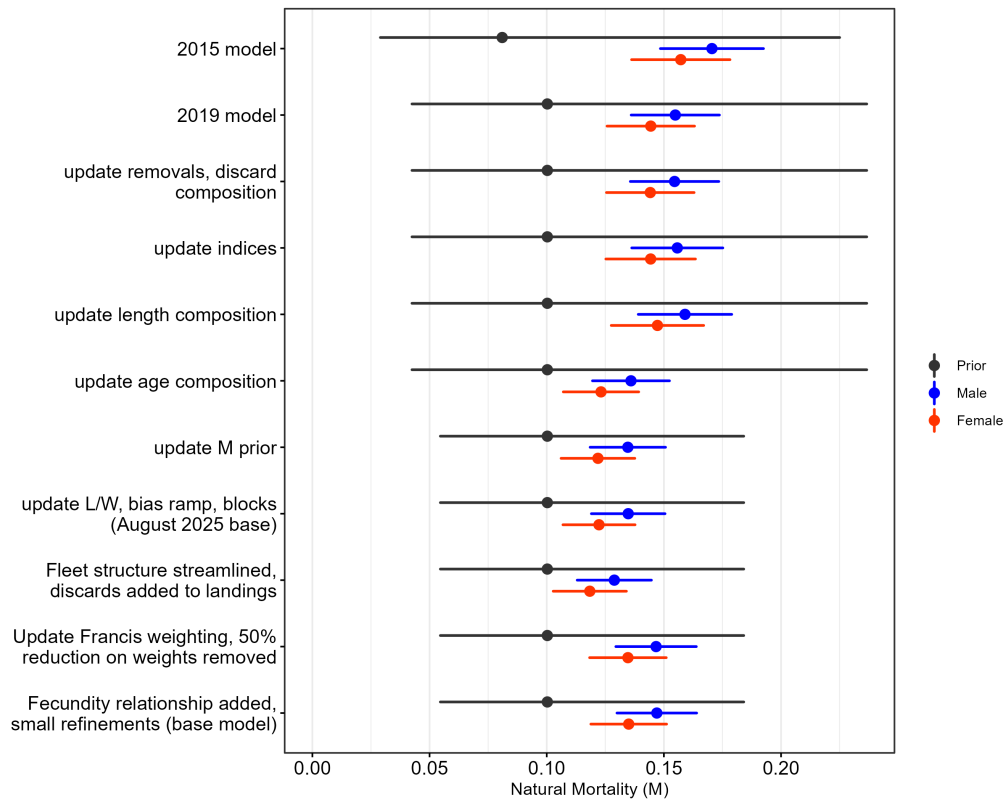


Figure 34: The prior for natural mortality (grey) and the estimated M for females (red) and males (blue) from the 2015 base model, 2019 base model, and selected intermediate models bridging to the base model. Prior 95% quantiles are based on the assumed lognormal distribution. Depicted bridging models are selected to highlight changes with a notable impact on M.

### 6.2.2 Selectivity

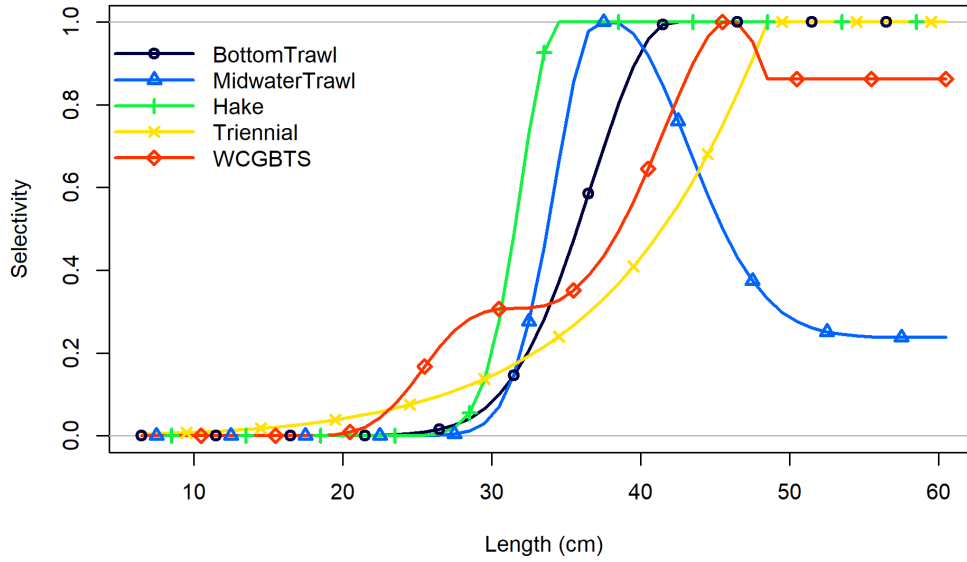


Figure 35: Estimated selectivity for different fleets and surveys.

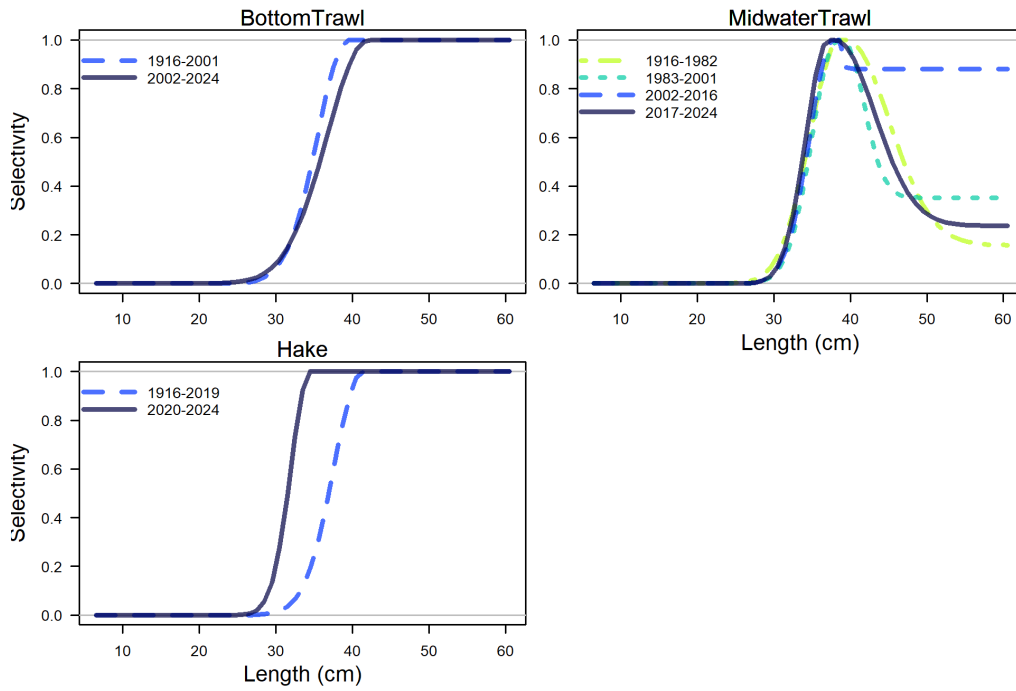


Figure 36: Estimated selectivity curves by time block for bottom trawl, midwater trawl, and hake fleets.

6.2.3 Biology

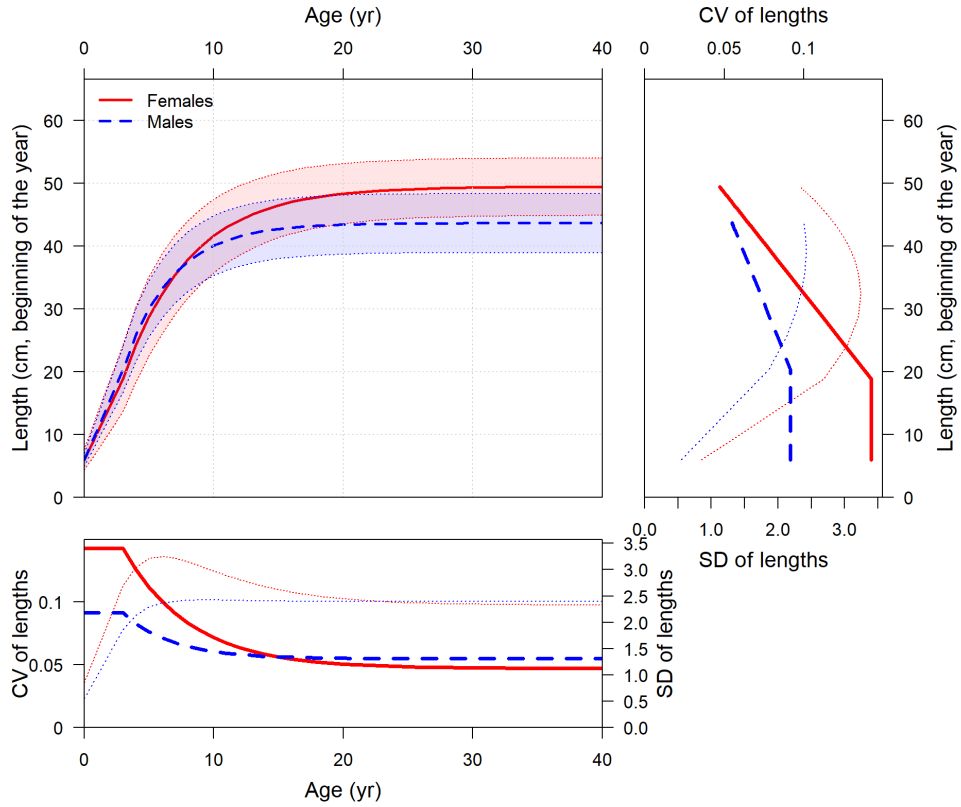


Figure 37: Length at age (top-left panel) with estimated coefficient of variation (CV, thick line) and calculated standard deviation (SD, thin line) versus length at age in the top-right panel and versus age in the lower-left panel.

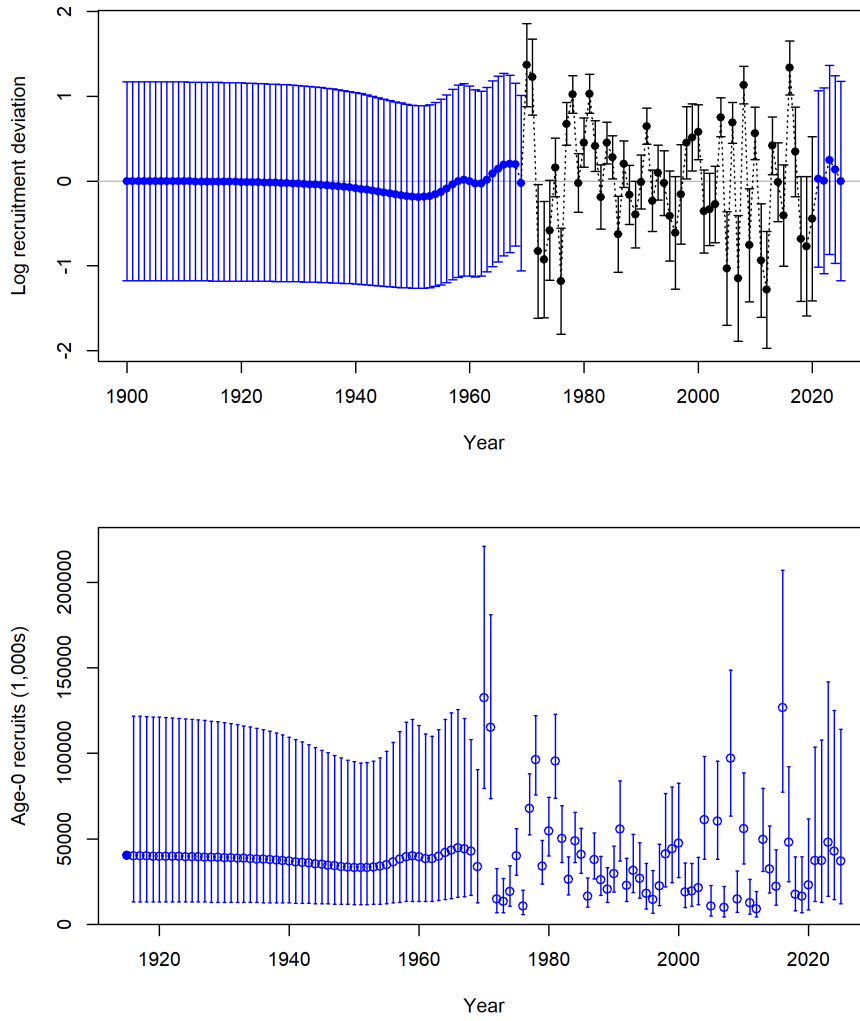


Figure 38: Estimates of recruitment (upper) and recruitment deviates (lower) with approximate asymptotic 95% confidence intervals (vertical lines) from the MLE estimates.

### 6.2.4 Fits to data

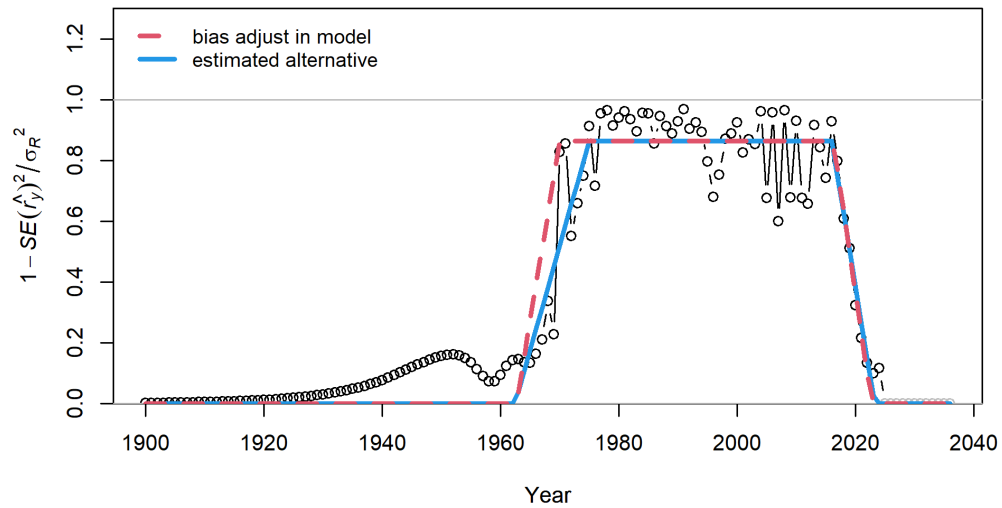


Figure 39: Estimated and input recruitment bias adjustment ramp. Red line shows current settings for bias adjustment specified in the model. Blue line shows least squares estimate of alternative bias adjustment relationship for recruitment deviations.

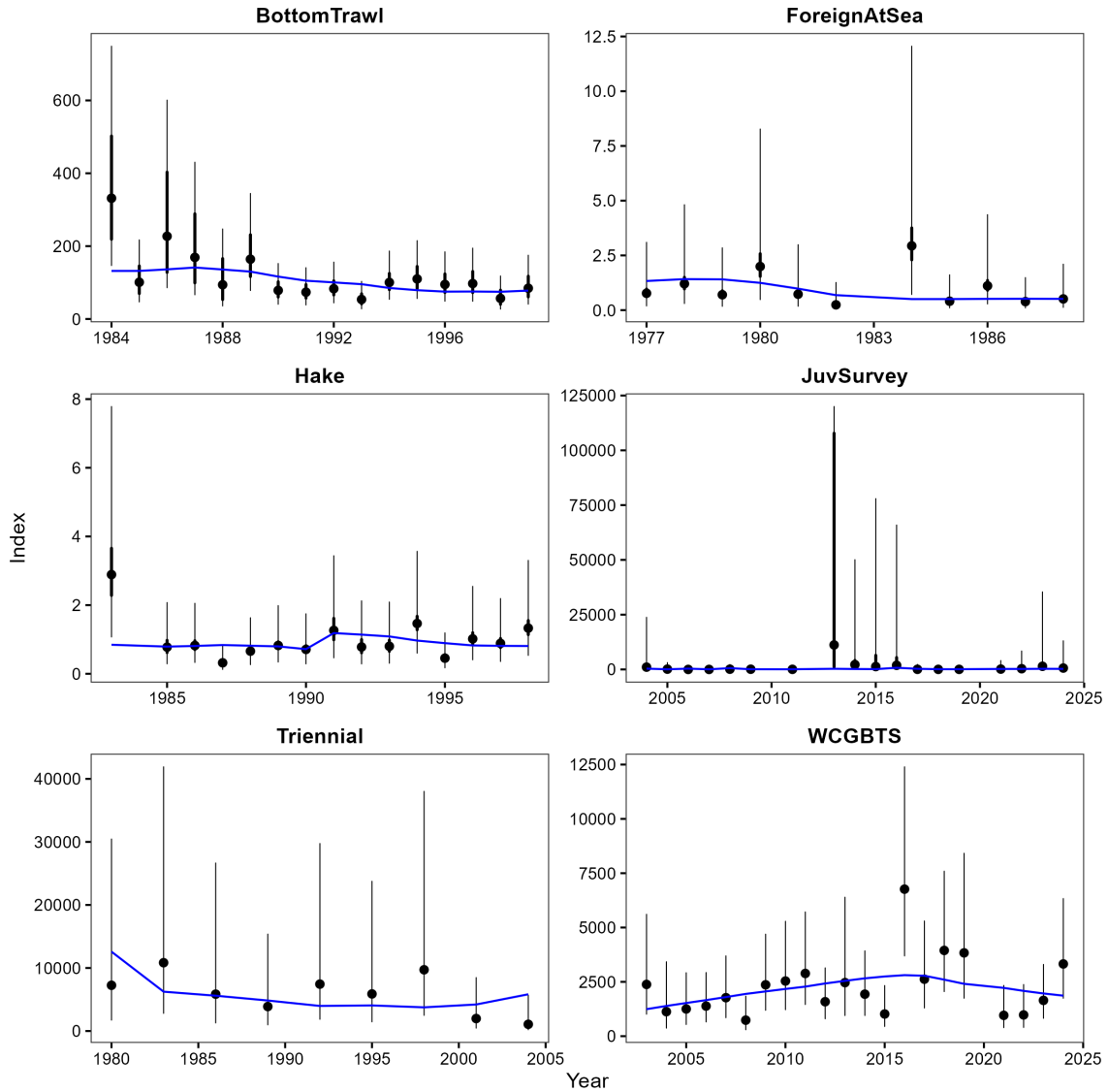


Figure 40: Fits (blue lines) to the abundance estimates (black points) for the base model. A separate  $q$  is estimated for the Hake series starting in 1991. Except the juvenile survey (counts) all indices are biomass-based. 95% confidence intervals are shown assuming a normal distribution of the log-estimates. Thicker lines (if present) indicate input uncertainty before addition of the estimated additional uncertainty parameter. The y-axis of the juvenile survey is truncated to highlight interannual variability in counts.

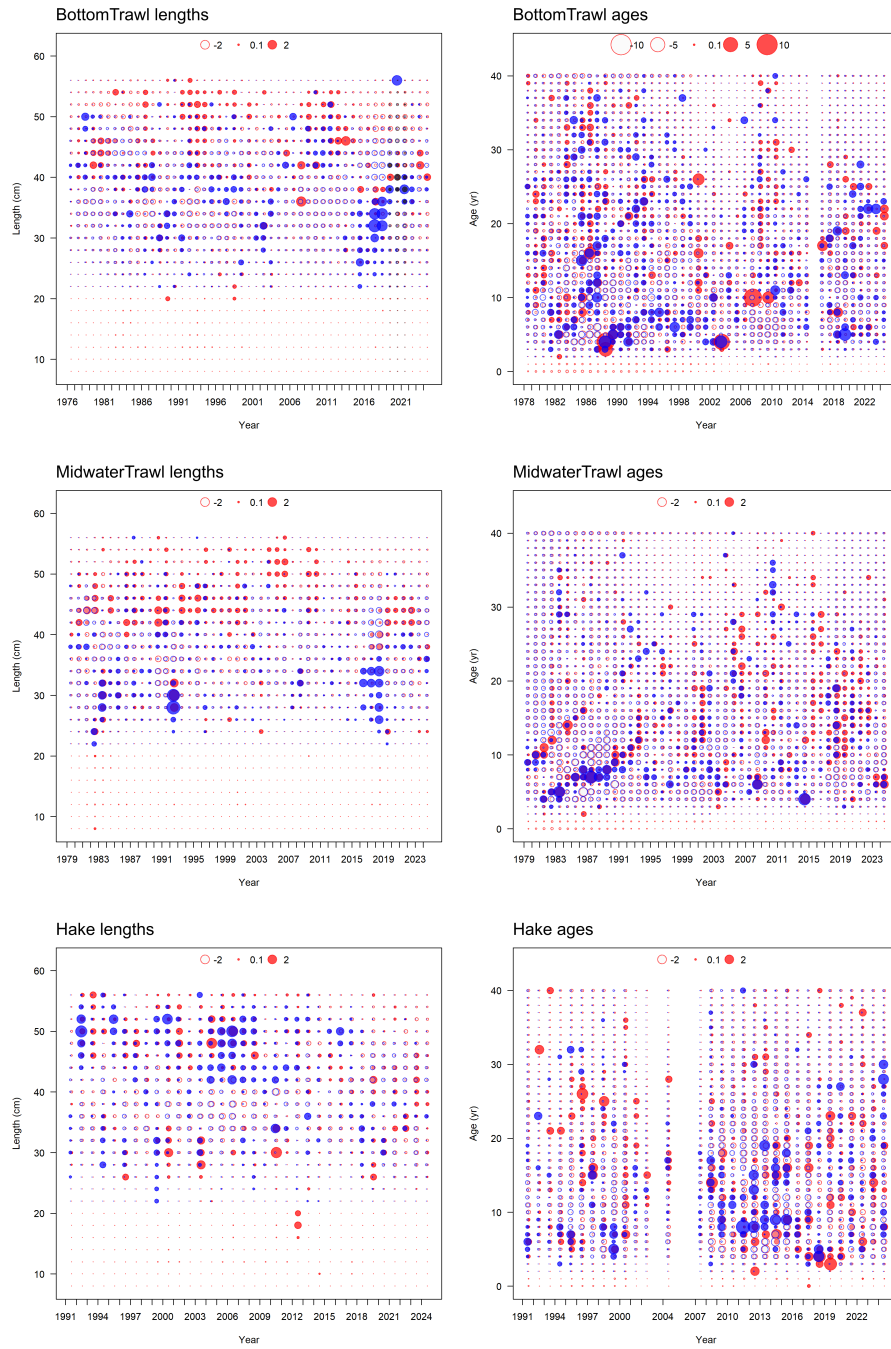


Figure 41: Pearson residuals for fits to length frequency data (left) and age frequency data (right) for landings from the commercial fleets (rows). Filled circles indicate that the fitted proportion was less than the observed proportion. Red indicates females, blue males, and grey unsexed.

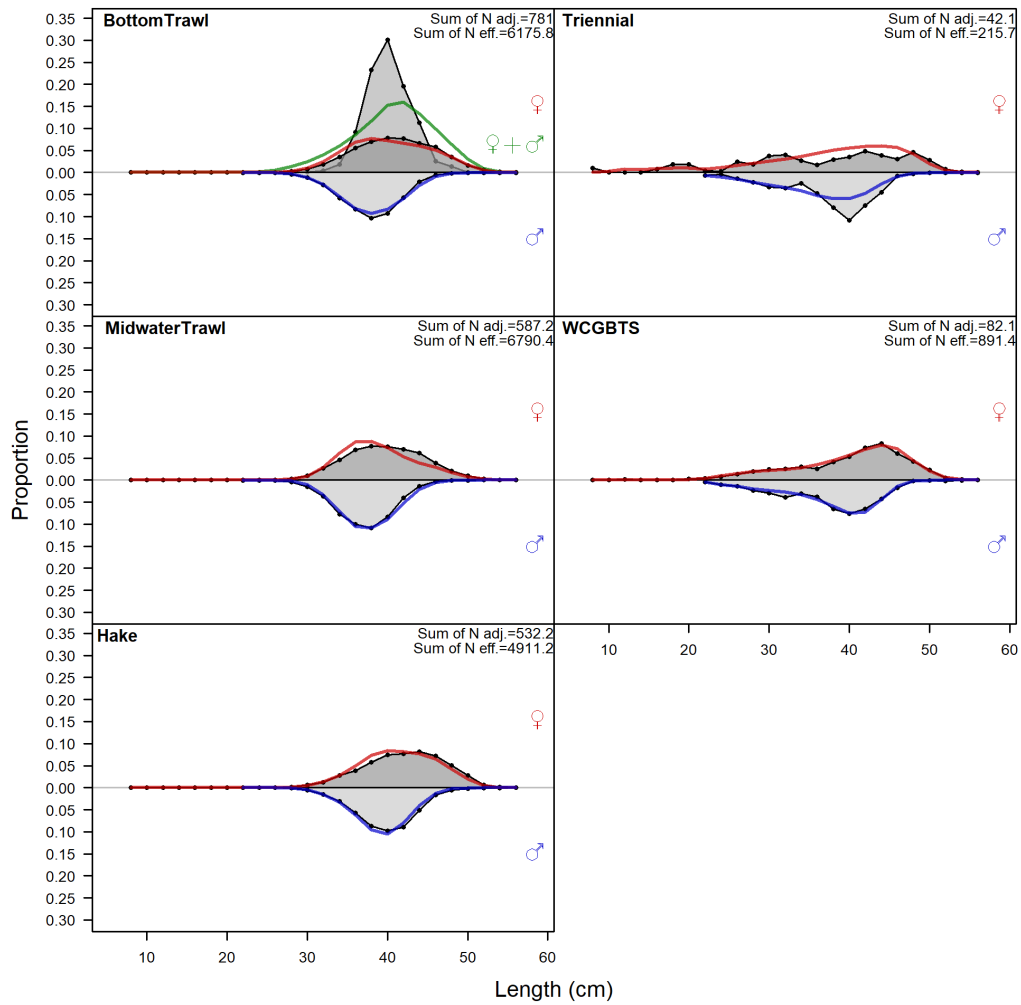


Figure 42: Combined length frequencies for all years from fishery (retained catch) and survey length frequency data (points). Fits are shown by the red line (females) and blue line (males).

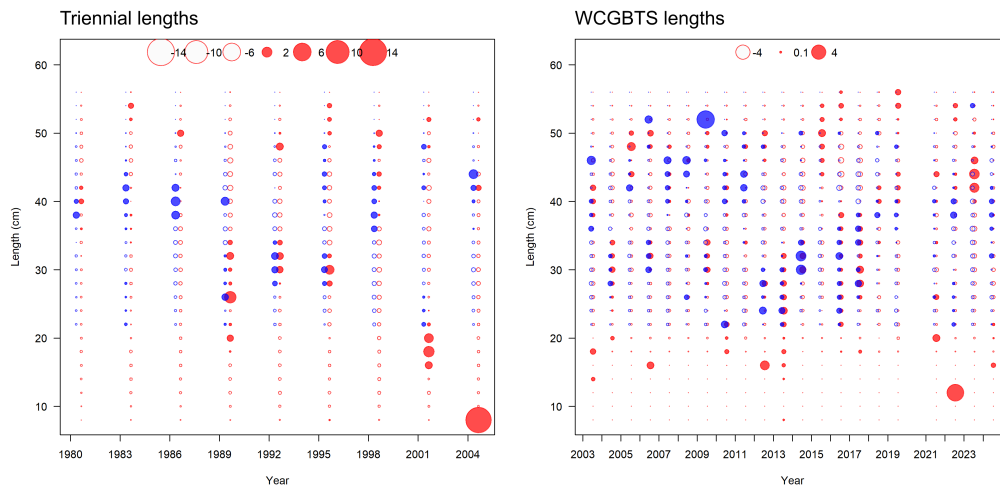


Figure 43: Pearson residuals for fits to the triennial survey length frequency data (left) and WCGBTS length frequency data (right). Filled circles indicate that the fitted proportion was less than the observed proportion. Red indicates females, blue males, and gray unsexed.

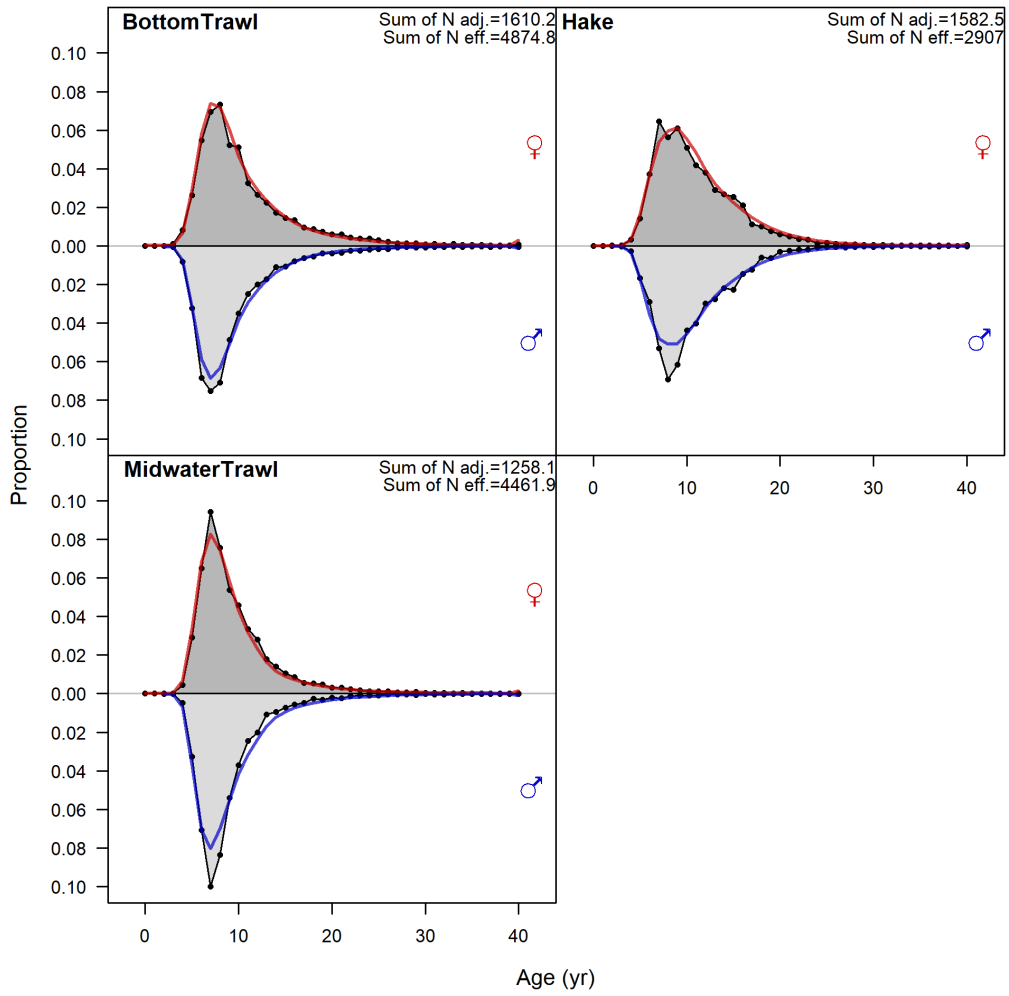


Figure 44: Combined age frequencies for all years from fishery (retained catch) and survey length frequency data (points). Fits are shown by the red line (females) and blue line (males).

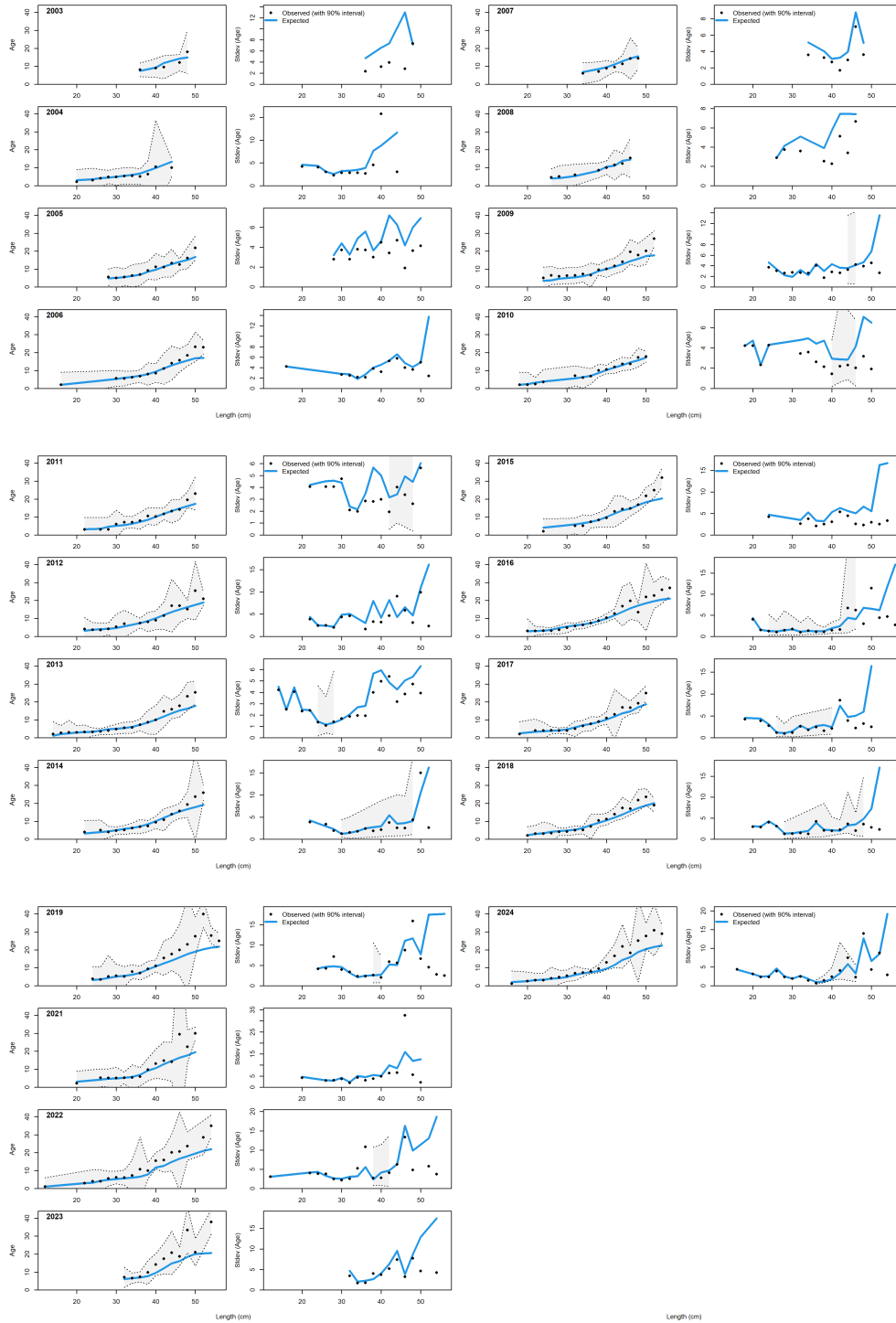


Figure 45: Observed and expected age-at-length with 95% confidence intervals (left) and observed and expected standard deviation of age-at-length with 95% confidence intervals (right) for the WCGBTs.

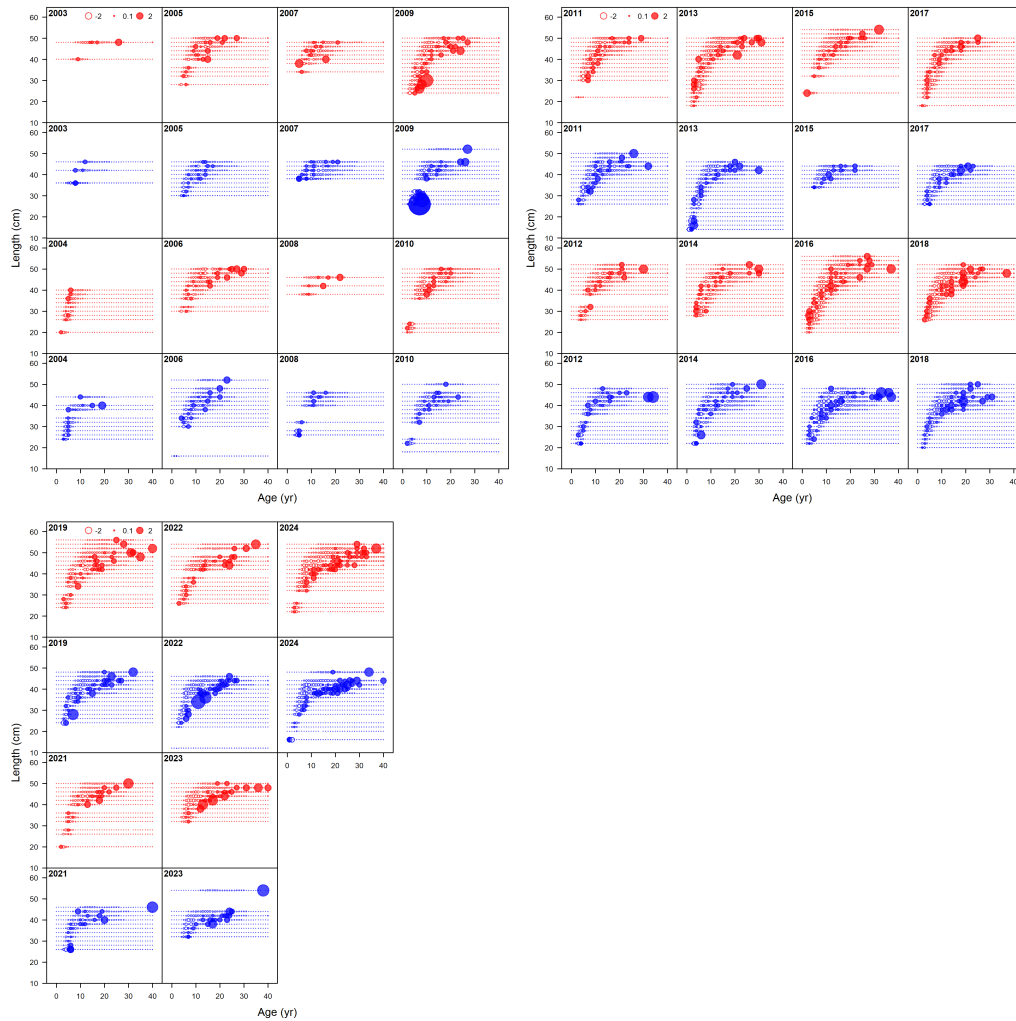


Figure 46: Combined age and length frequency data for all years from fishery (retained catch) and survey length frequency data (points) for females (red) and males (blue).

### 6.2.5 Time series

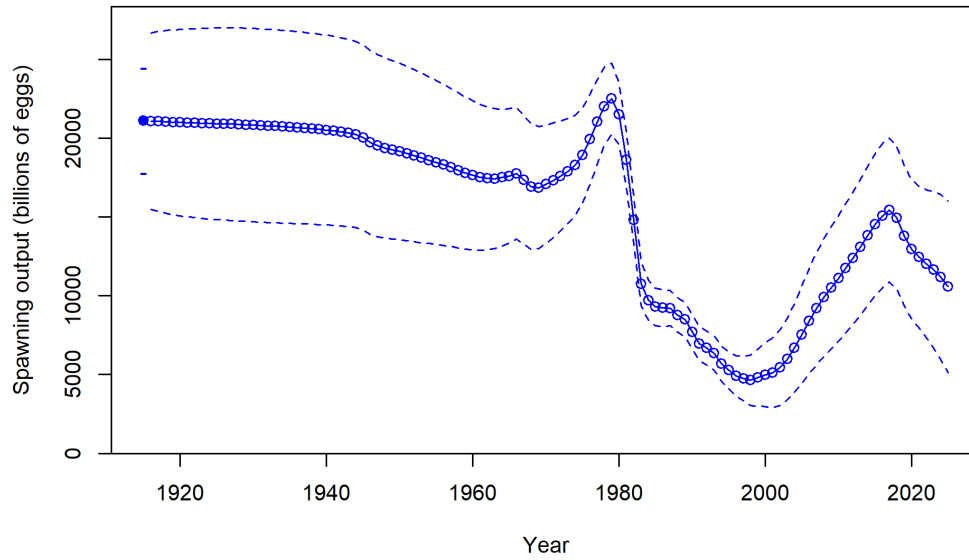


Figure 47: Predicted spawning output (billions of eggs) for widow rockfish using the base model. The solid line is the MLE estimate, and the dashed lines depict the approximate asymptotic 95% confidence intervals.

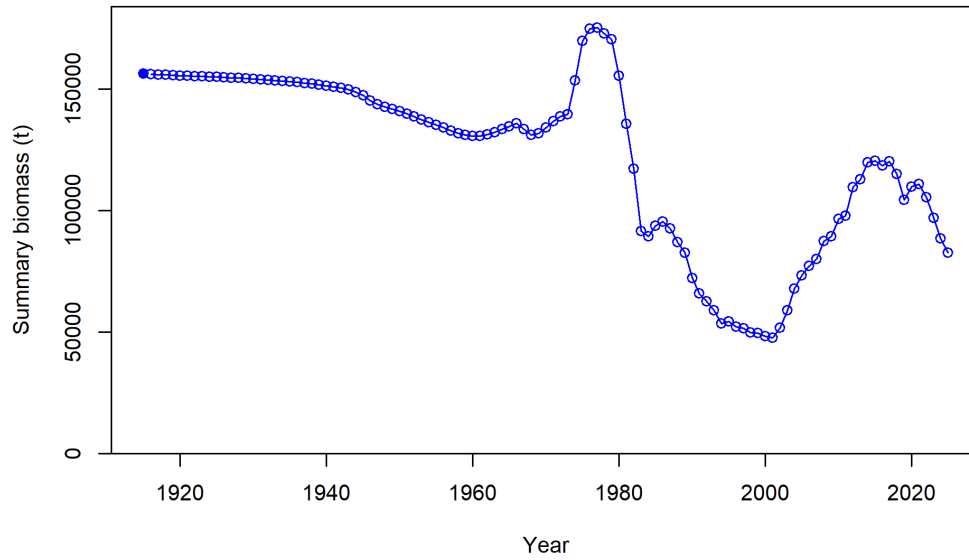


Figure 48: Predicted summary biomass (age 4+) from the base model.

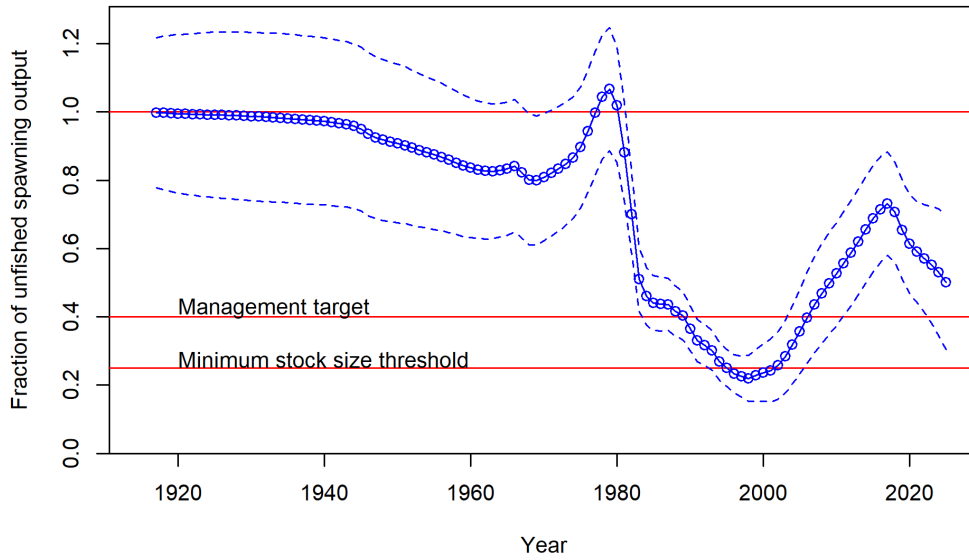


Figure 49: Predicted relative spawning output from the widow rockfish base model. The solid blue line is the MLE estimate, and the dashed lines depict the approximate asymptotic 95% confidence intervals. The red lines show the equilibrium level (100%), the management target of 40% of unfished biomass, and the minimum stock size threshold of 25% of unfished biomass.

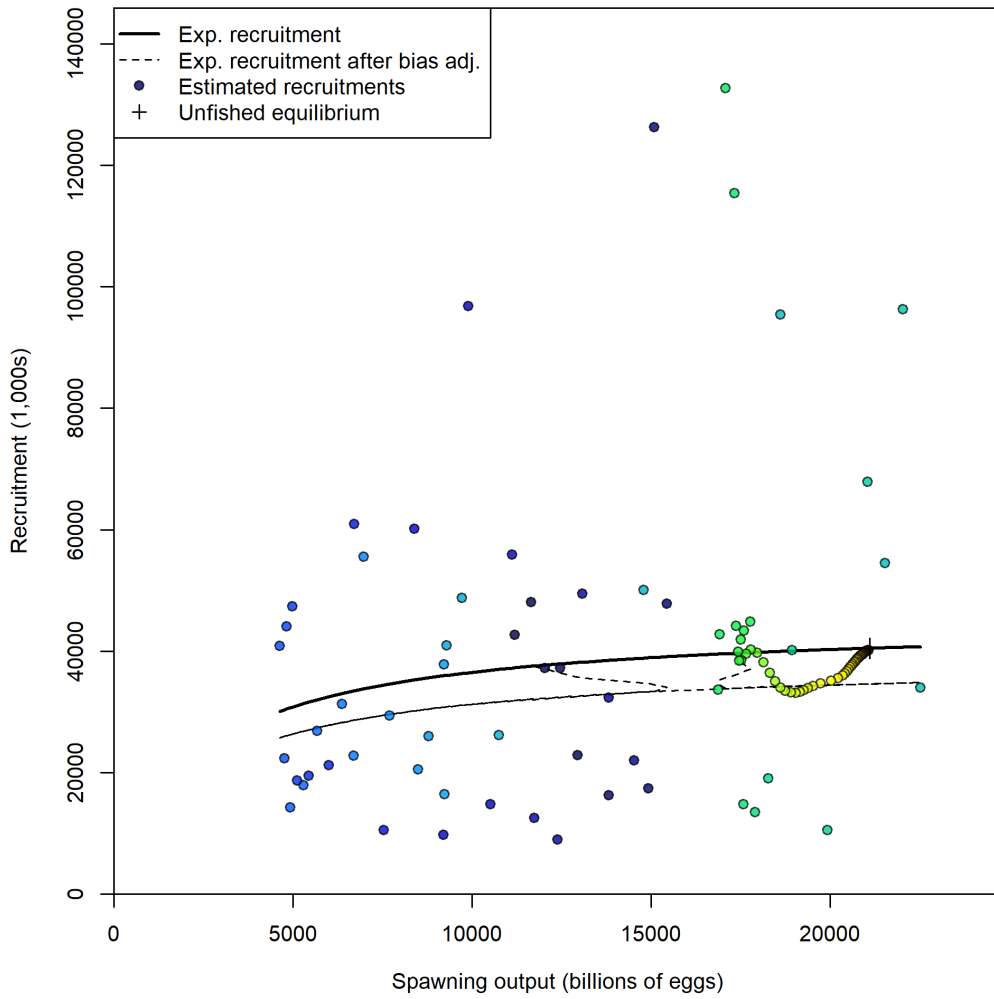


Figure 50: Estimated recruitment and the assumed stock-recruit relationship (black line). The dashed line shows the effect of the bias correction for the lognormal distribution.

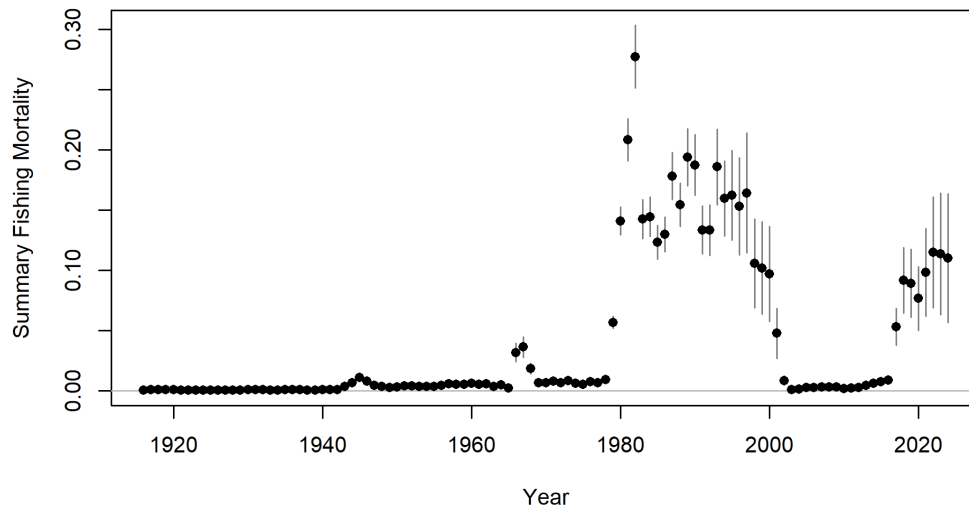


Figure 51: Plot of the summary fishing mortality for each year of the model with 95% confidence intervals.

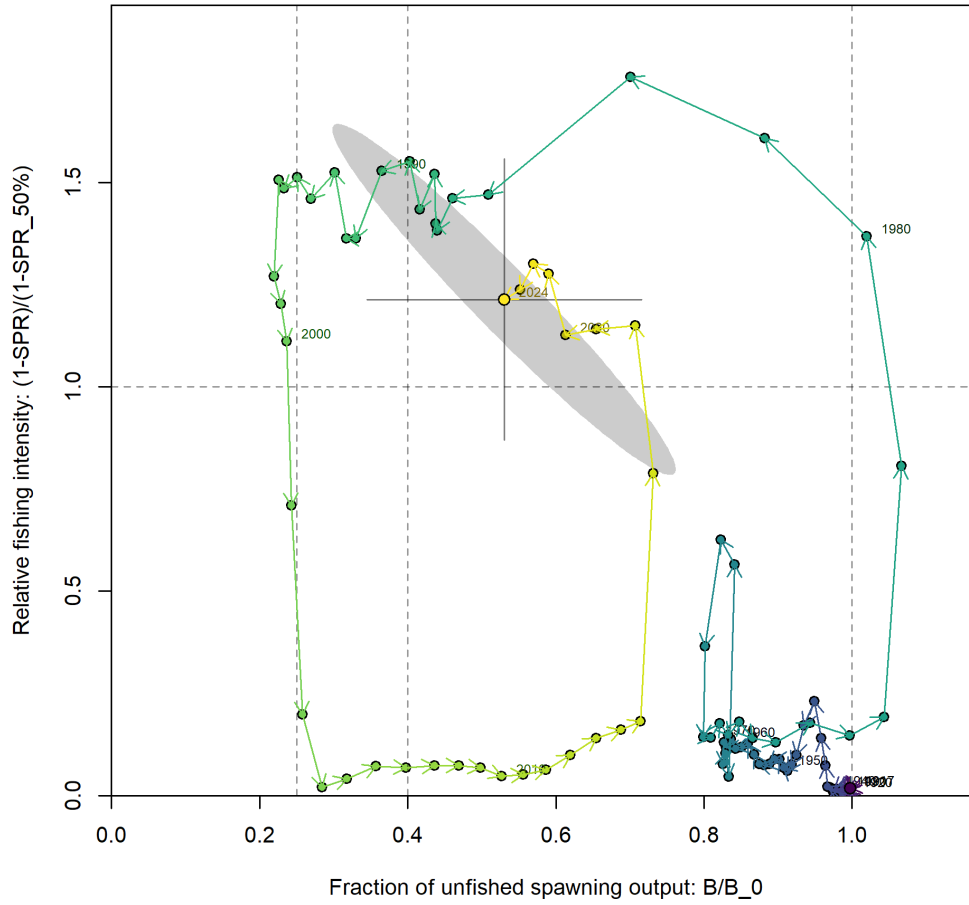


Figure 52: Phase plot of biomass ratio vs. SPR ratio. Each point represents the biomass ratio at the start of the year and the relative fishing intensity in that same year. Warmer colors (red) represent early years and colder colors (blue) represent recent years. Lines through the final point show 95% 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: -0.968.

### 6.3 Model Diagnostics

#### 6.3.1 Sensitivity analyses

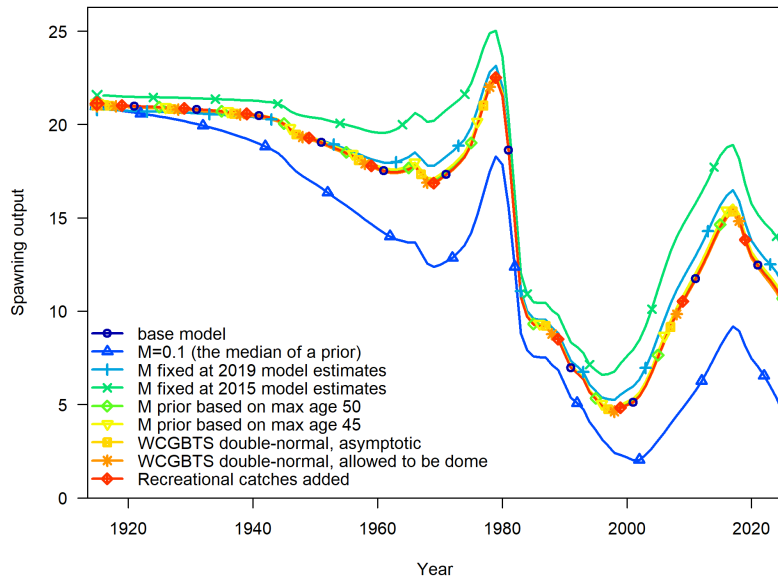


Figure 53: Spawning output for the base model and sensitivity runs.

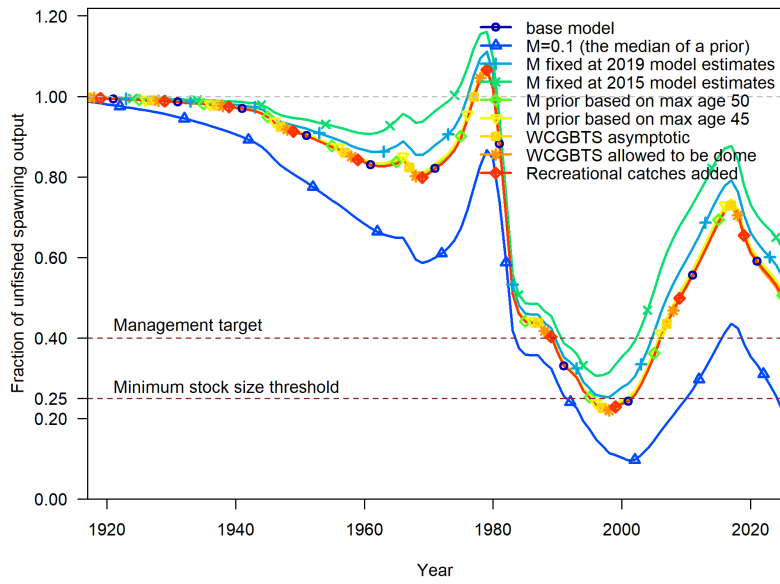


Figure 54: Comparison of fraction unfished for the base model and sensitivity runs.

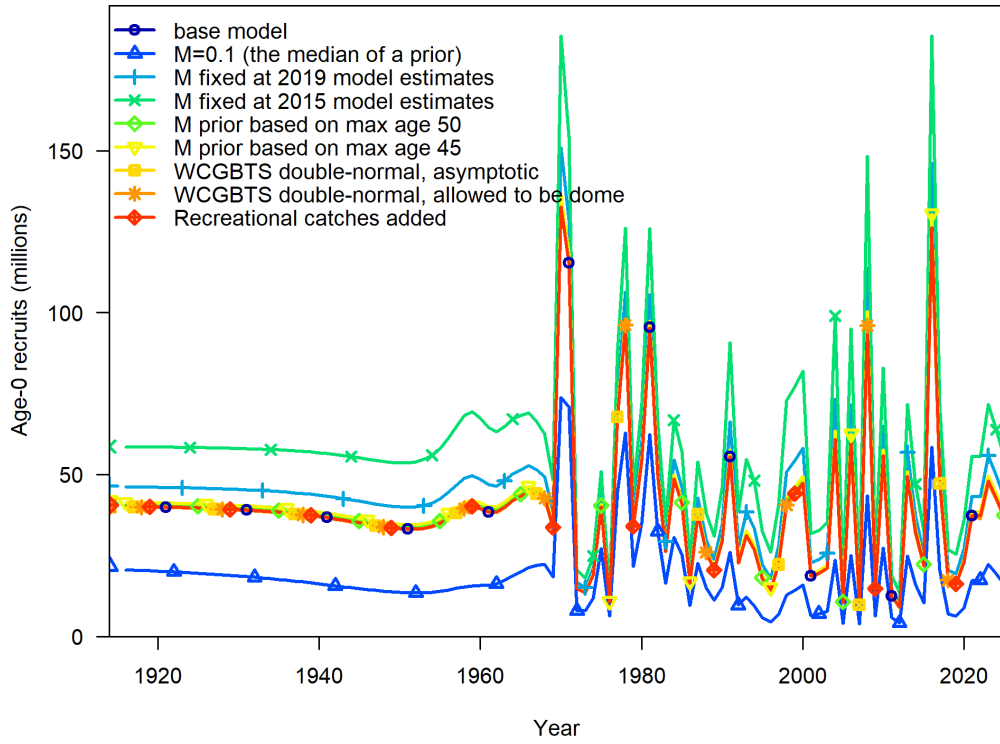


Figure 55: Estimates of recruitment for base model and sensitivity models.

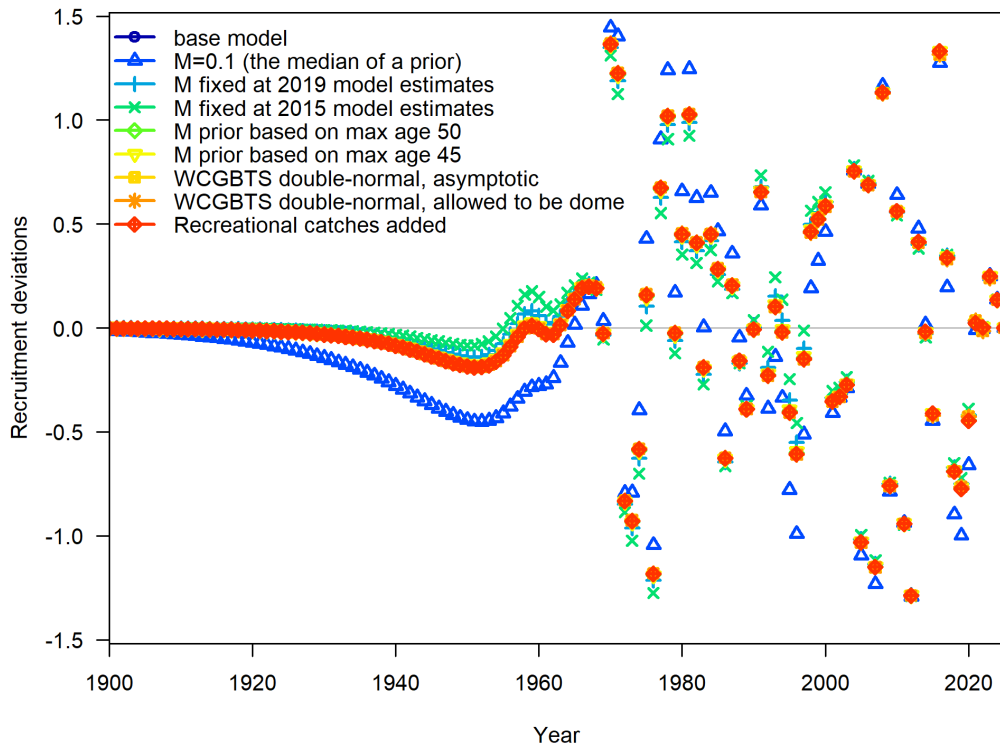


Figure 56: Estimates of recruitment deviations for base model and sensitivity models.



### 6.3.2 Retrospective analysis

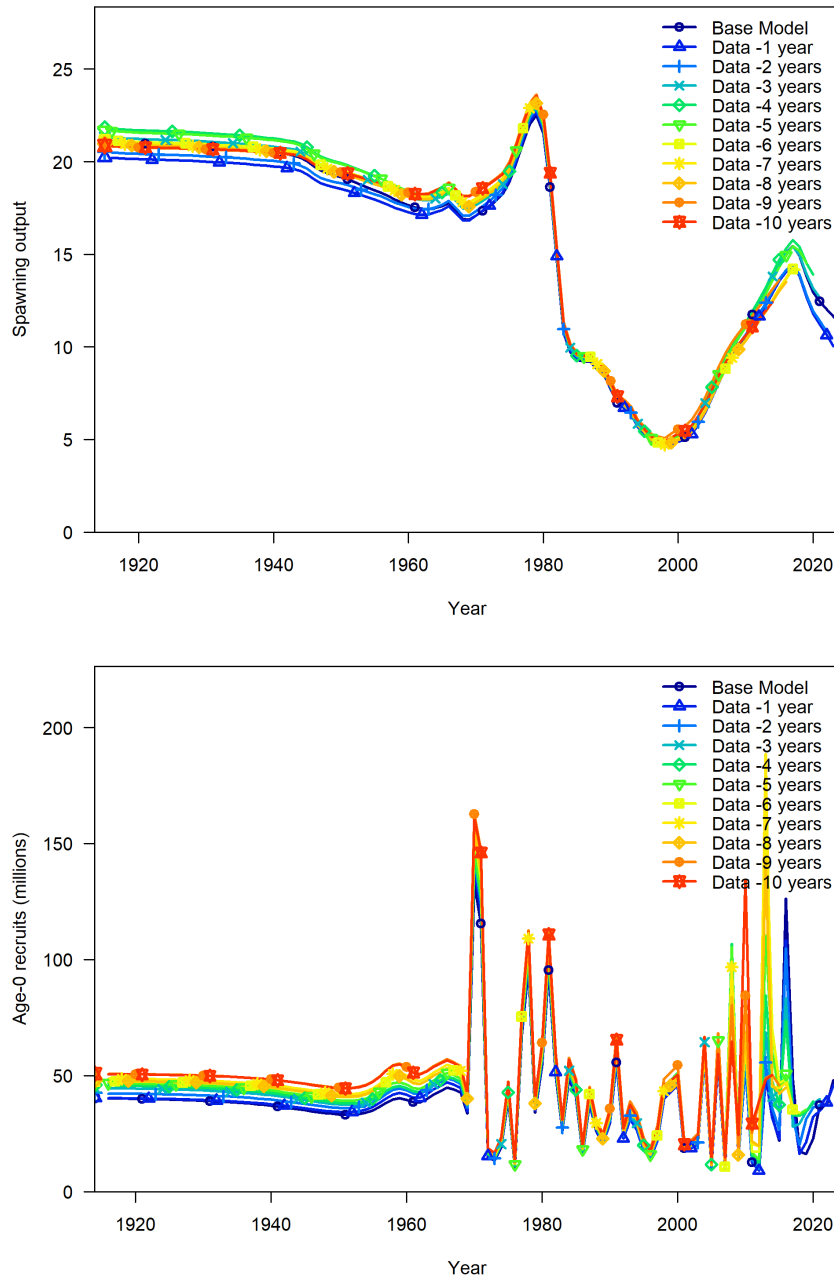


Figure 57: Ten-year retrospective estimates of spawning output (top) and recruitment deviations (bottom).

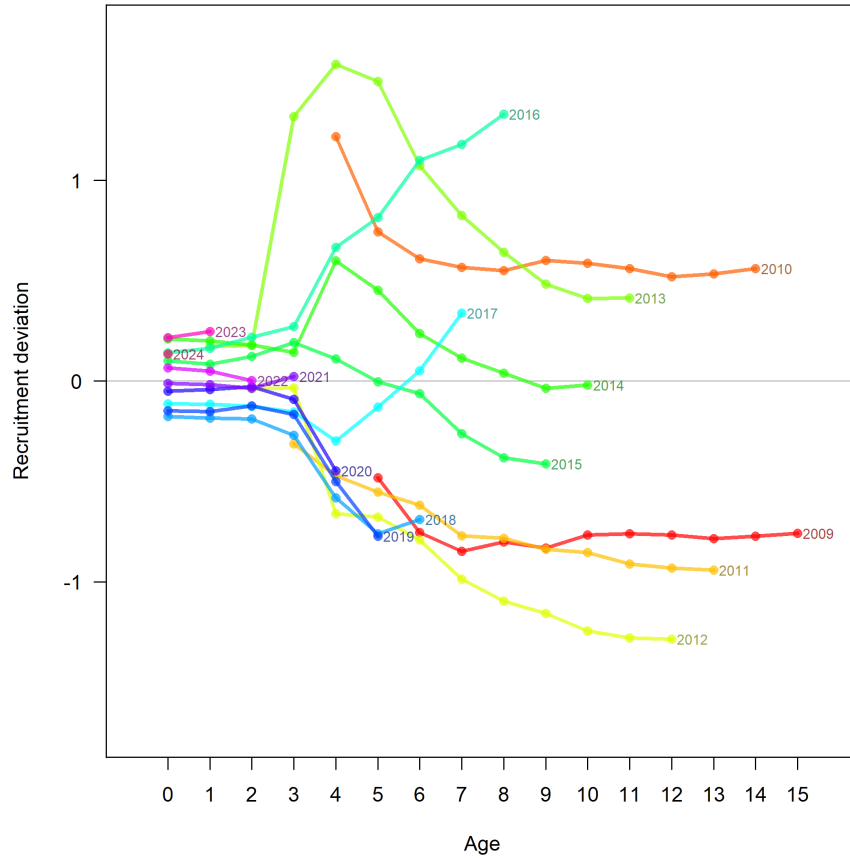


Figure 58: Retrospective analysis of recruitment deviations over the last 10 years. Lines represent estimated recruitment deviations for cohorts born from 2009 to 2024, with cohort birth year marked at the right of each color-coded line. For example, the right-most point for the 2016 cohort shows the cohort at age-8 (i.e., as estimated by the base model and includes data through 2024). The next point to the left is the 2016 cohort at age-7, calculated by removing one year of data (so includes data up to 2023). Because the retrospective analysis only peeled 10 years of data, the lines for the oldest cohorts are incomplete.

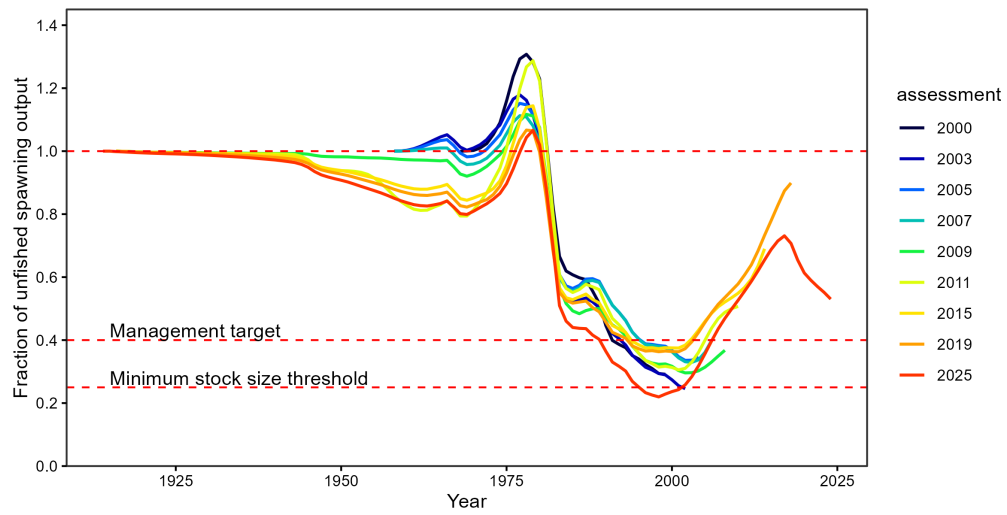


Figure 59: Estimated fraction of unfished spawning output from past assessments in comparison with the current assessment. The units of spawning output differ among assessments but the ratio remains comparable.

### 6.3.3 Likelihood profiles

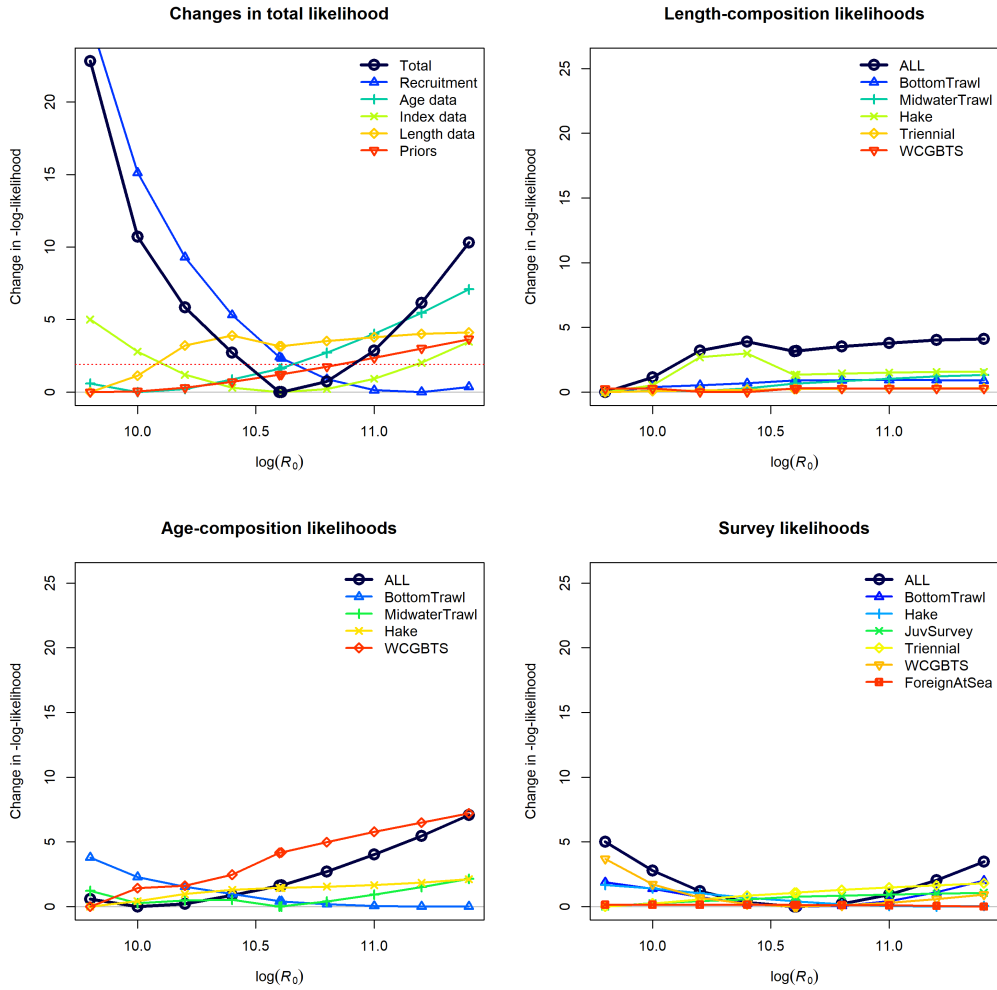


Figure 60: Likelihood components in the likelihood profile for unfished equilibrium recruitment ( $R_0$ )

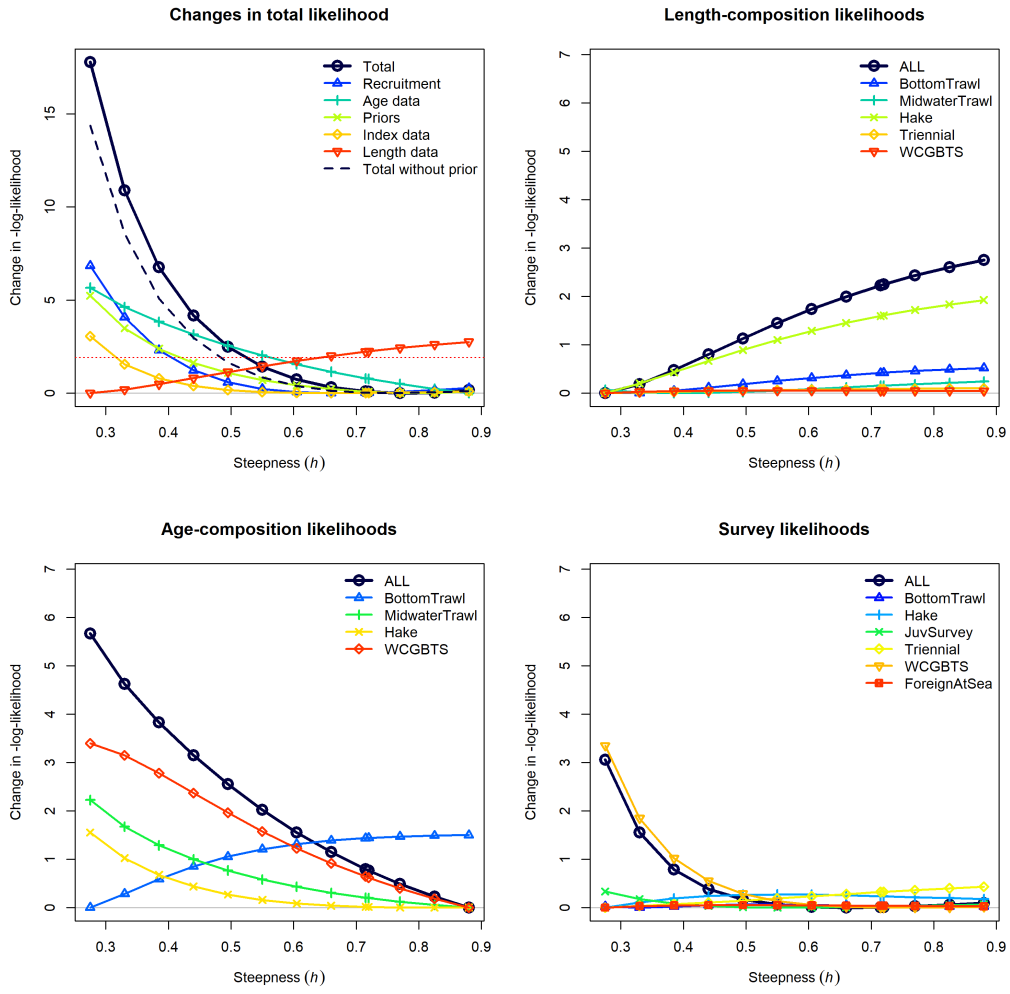


Figure 61: Likelihood components in the likelihood profile for steepness ( $h$ ).

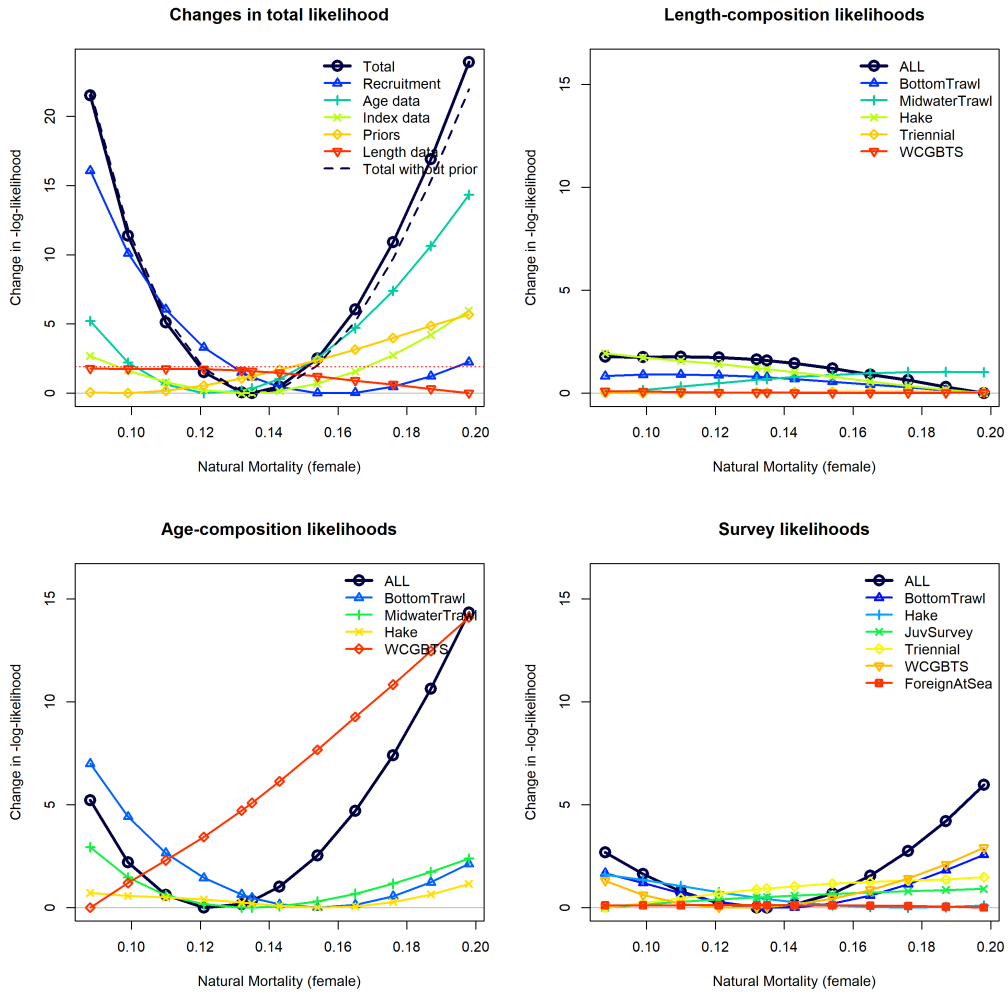


Figure 62: Likelihood components in the likelihood profile for female natural mortality ( $M$ ). Male natural mortality are set to the same value.

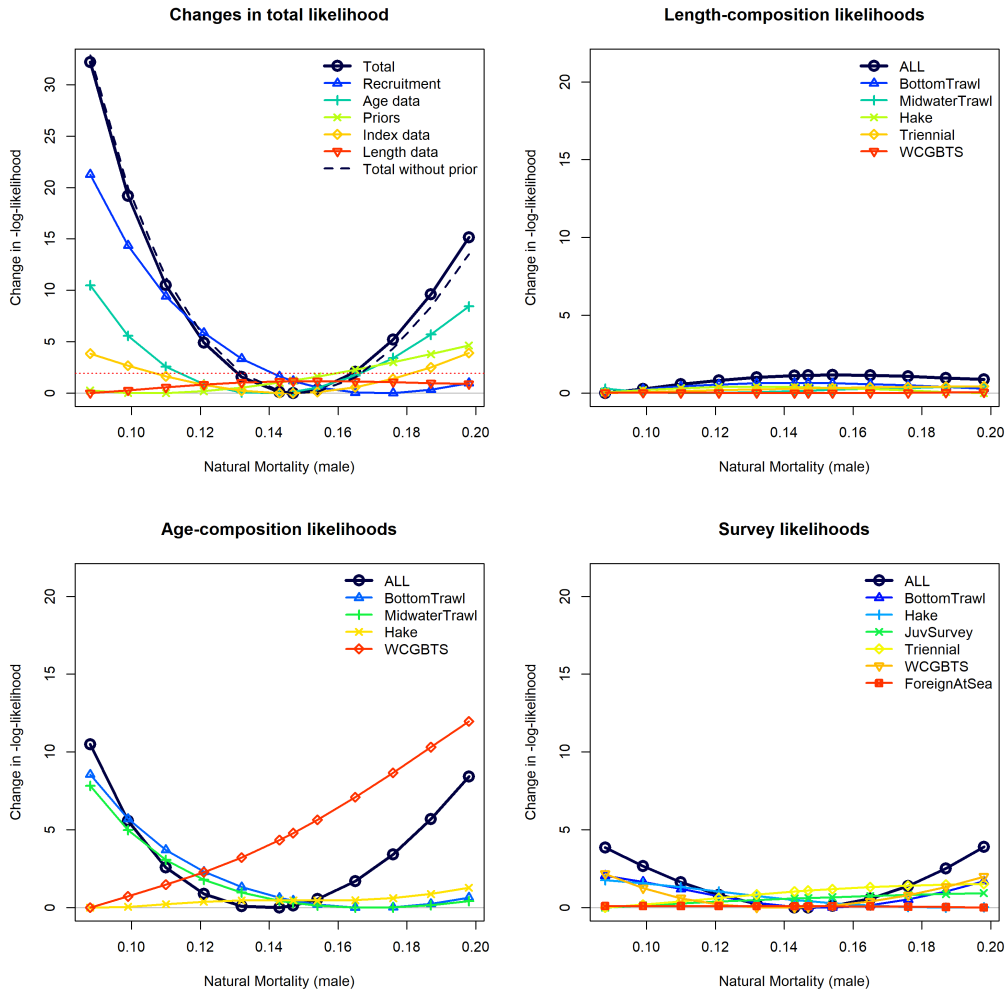


Figure 63: Likelihood components in the likelihood profile for male natural mortality ( $M$ ). Female natural mortality is set to the same value.

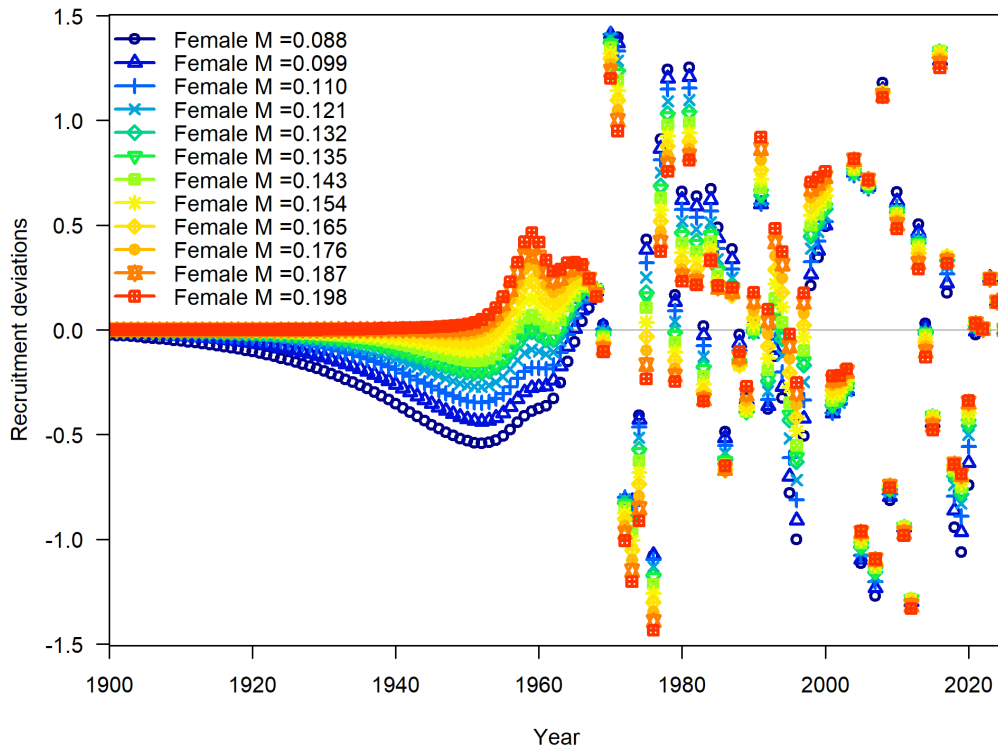


Figure 64: Time series of recruitment deviations for models with different fixed values of natural mortality ( $M$ ). The base model has  $M = 0.135$ .

## 6.4 Management

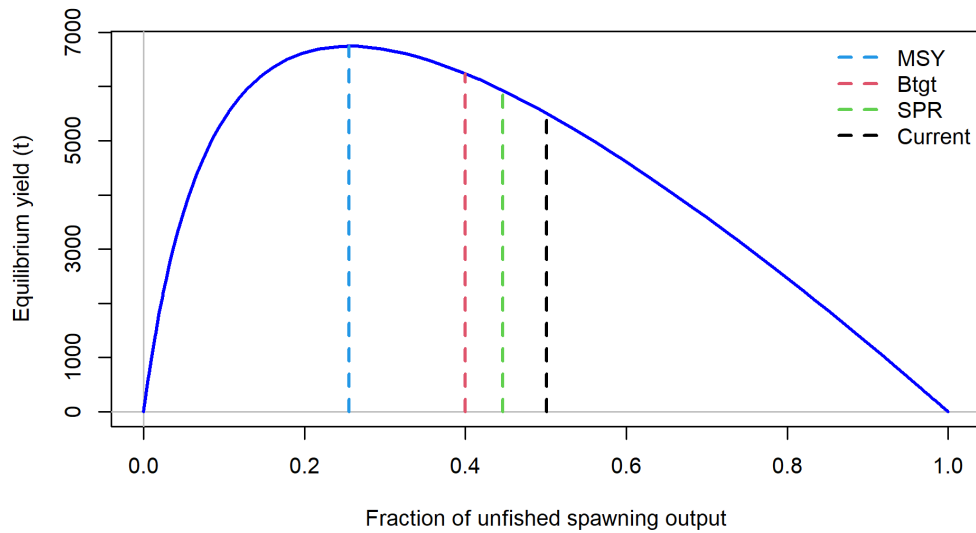


Figure 65: Estimated plot of equilibrium yield vs the fraction of unfished biomass.

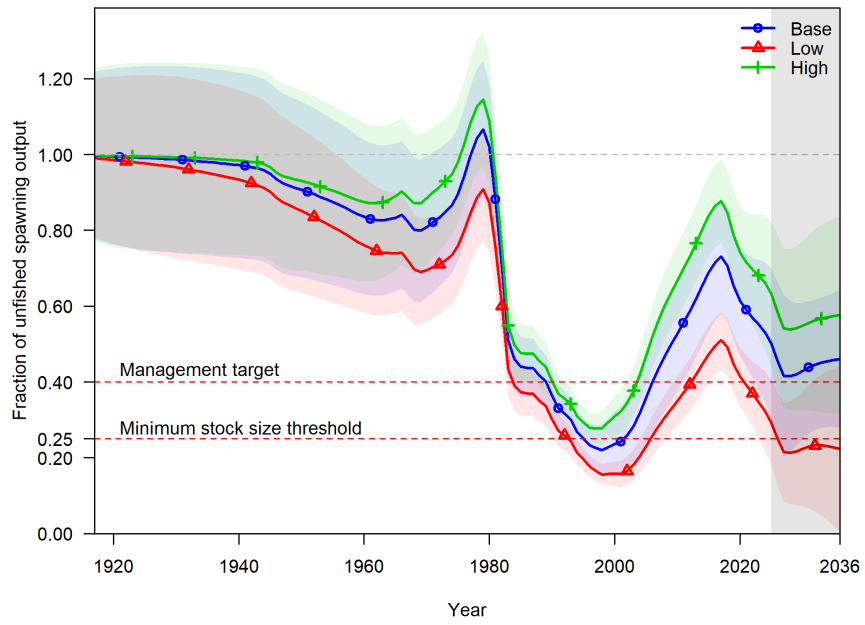


Figure 66: Base model, low state of nature, and high state of nature spawning output trajectories under the default catch scenarios:  $ACL = p*0.45$  for 2027 to 2036. The shaded areas indicate the 12.5% and 87.5% lognormal quantiles of spawning biomass.

### Vulnerable biomass by fleet

(points indicate selectivity blocks for fishing fleets)

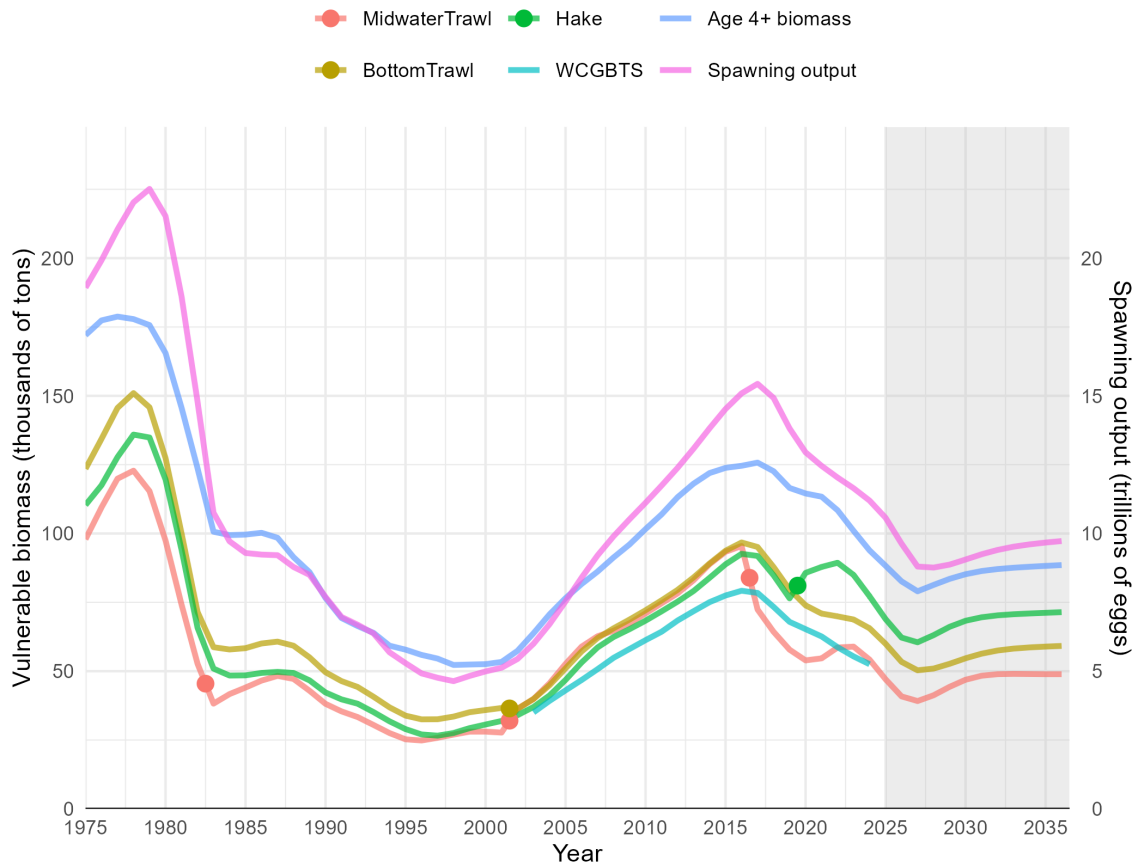


Figure 67: Estimated vulnerable biomass for each of the three fishing fleets along with the model expected values of WCGBTS vulnerable biomass (for the range of years of the survey), age 4+ biomass, and spawning output.

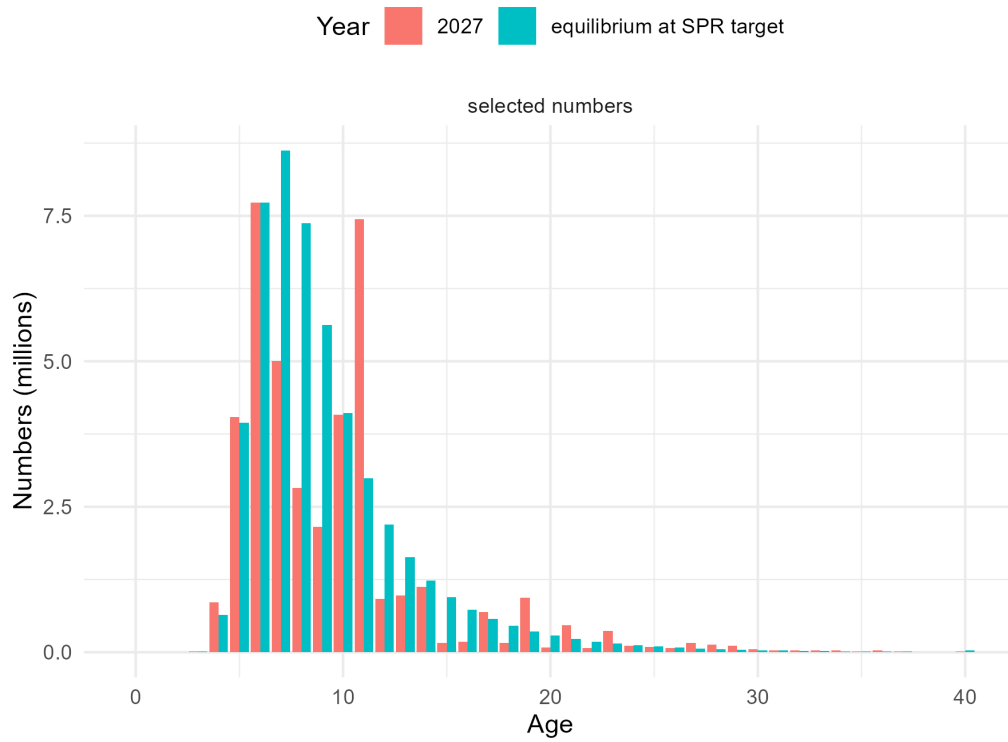


Figure 68: Projected selected numbers-at-age for the midwater trawl fishery in 2027 (red) and at the equilibrium associated with the SPR target (blue).

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