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




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Please cite this publication as:

Kinneen, M., Goodman, M. C., Sulc, A., Balstad, L., Diaz, R., Randrup, K., Patrone, W., Spencer, L., Morell, A., Rovellini, A., Dedrick, A., Grunloh, N., Bargas, M., Hopkins, S., Gersteva, V., Oken, K., Taylor, I., Haltuch, M., & Hamel, O. (2025) Status of widow rockfish stock off the U.S. West Coast in 2025. Pacific Fishery Management Council, Portland, Oregon.

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# 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 | 14.6 | 480.1 | 386.2 | 880.8 |
| 2016 | 11.3 | 589.6 | 440.8 | 1,041.7 |
| 2017 | 39.3 | 4,861.9 | 1,455.2 | 6,356.3 |
| 2018 | 39.2 | 9,411.5 | 1,081.3 | 10,532.0 |
| 2019 | 30.6 | 8,177.4 | 1,101.6 | 9,309.6 |
| 2020 | 76.6 | 7,577.7 | 746.7 | 8,401.0 |
| 2021 | 108.4 | 10,147.9 | 617.3 | 10,873.6 |
| 2022 | 136.4 | 10,860.9 | 1,119.0 | 12,116.3 |
| 2023 | 89.7 | 10,234.1 | 673.2 | 10,996.9 |
| 2024 | 40.9 | 9,172.1 | 533.8 | 9,746.8 |

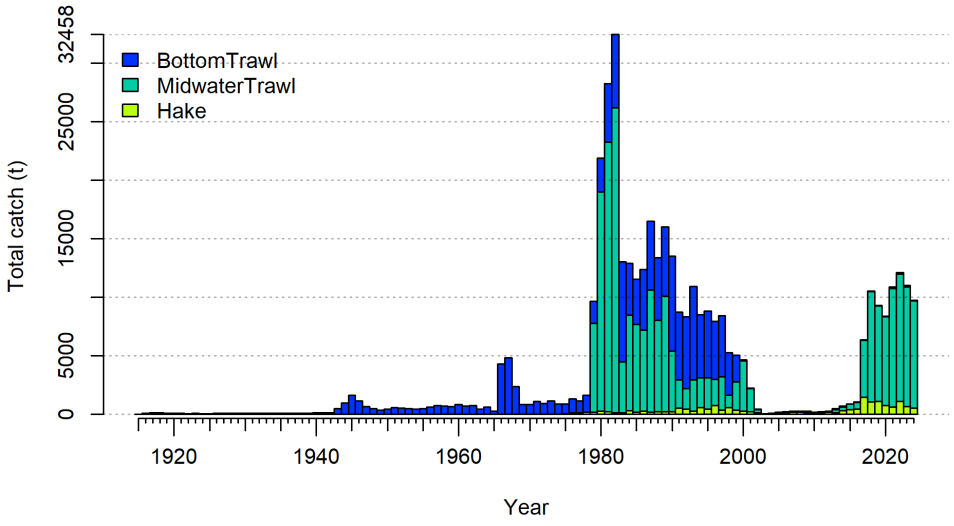



Figure i: Total catches (landings and discards combined) of widow rockfish from 1916 to 2024 for bottom trawl, midwater trawl, and hake fleets.

### 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).

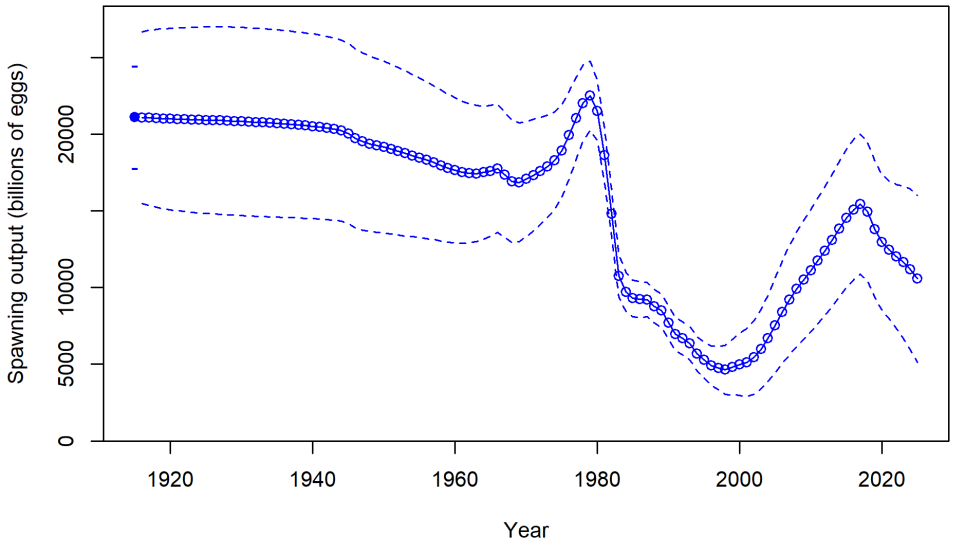



Figure ii: Estimated female spawning output time-series from the base model (solid line) with asymptotic 95% confidence interval (dashed lines).

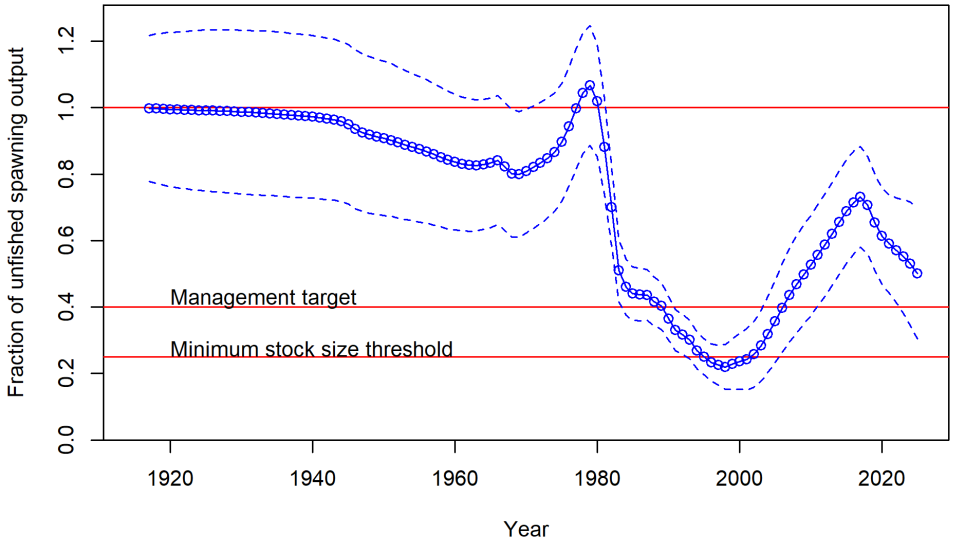



Figure iii: Estimated fraction of unfished spawning output with asymptotic 95% confidence interval (dashed lines) for the base model.

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 | 10,011 | 19,034 | 0.688 | 0.532 | 0.844 |
| 2016 | 15,089 | 10,522 | 19,655 | 0.715 | 0.560 | 0.869 |
| 2017 | 15,436 | 10,876 | 19,996 | 0.731 | 0.580 | 0.882 |
| 2018 | 14,925 | 10,427 | 19,424 | 0.707 | 0.560 | 0.854 |
| 2019 | 13,816 | 9,386 | 18,247 | 0.654 | 0.510 | 0.799 |
| 2020 | 12,948 | 8,537 | 17,359 | 0.613 | 0.469 | 0.758 |
| 2021 | 12,457 | 7,967 | 16,947 | 0.590 | 0.442 | 0.738 |
| 2022 | 12,033 | 7,340 | 16,726 | 0.570 | 0.412 | 0.728 |
| 2023 | 11,644 | 6,668 | 16,621 | 0.552 | 0.380 | 0.723 |
| 2024 | 11,195 | 5,945 | 16,444 | 0.530 | 0.345 | 0.716 |
| 2025 | 10,572 | 5,127 | 16,017 | 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.

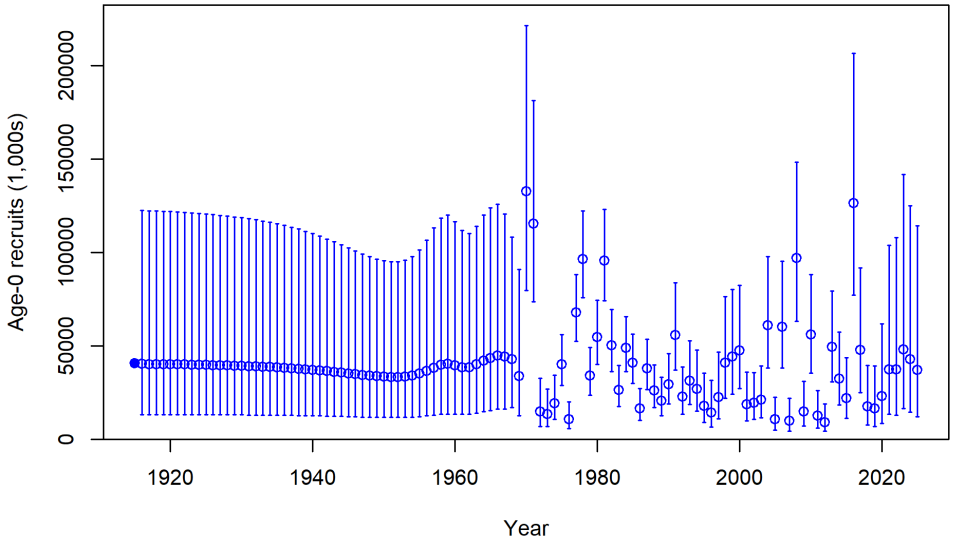



Figure iv: Time-series of estimated recruitments (medians as open circles) for the base model with asymptotic 95% confidence interval (vertical bars). Estimated unfished equilibrium recruitment ($R_0$) is indicated with a filled circle.

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-SPR50%) | 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 |

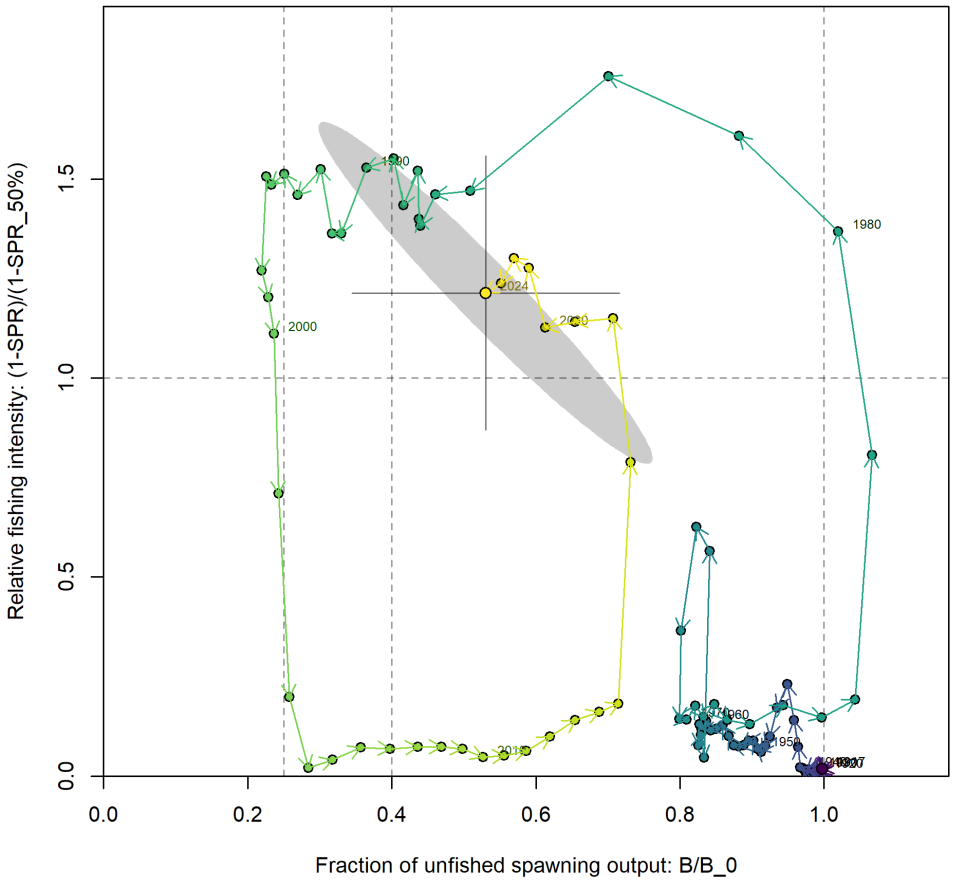



Figure v: Phase plot of relative fishing intensity ((1-SPR)/(1-$SPR_{50\%}$)) versus fraction unfished (spawning output, ($B/B_0$). Lines through the final point show marginal asymptotic 95% intervals for each dimension. The shaded ellipse is an approximate 95% confidence region which accounts for the 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 $yr^{-1}$) to 2019 (0.144 $yr^{-1}$) to 2025 (0.135 $yr^{-1}$). 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) | 21,111 | 17,760 | 24,461 |
| 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 | 0.5 | | |
| 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.

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) | 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 |

### 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 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 | - | - | - | - | 10,571.70 | 0.501 |
| 2026 | 11,382 | 10,392 | 9,824 | - | - | - | - | 9,630.18 | 0.456 |
| 2027 | - | - | - | 4,916 | 0.935 | 4,596 | 4,596 | 8,799.27 | 0.417 |
| 2028 | - | - | - | 5,172 | 0.93 | 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 | 0.9 | 5,504 | 5,504 | 9,671.68 | 0.458 |
| 2036 | - | - | - | 6,116 | 0.896 | 5,480 | 5,480 | 9,725.54 | 0.461 |

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 $yr^{-1}$ and 0.144 $yr^{-1}$ for females; 0.137 $yr^{-1}$ and 0.157 $yr^{-1}$ 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.

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 Spawning Output | Low Fraction Unfished | Low OFL | Base Spawning Output | Base Fraction Unfished | Base OFL | High Spawning Output | High Fraction Unfished | 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 |

### 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 $yr^{-1}$ (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 $yr^{-1}$ 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 $yr^{-1}$ and 0.14 $yr^{-1}$, 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 $yr^{-1}$. The likelihood profile over natural mortality provides support for values up to or above 0.14 $yr^{-1}$, 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 $SPR_{50\%}$ 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. 2022). 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. 2022).

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. 2022), 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 NORPAC 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:

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

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

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 $SO = 1.10961\text{E}{-8} * L^{4.545}$.

#### 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 WCGBTS 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 of 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/Amax) 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 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 that 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) 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 $yr^{-1}$ for females and 0.147 $yr^{-1}$ 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$^{th}$ percentile of 37, while data collected since include individuals up to 51 with a 99.9$^{th}$ 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 $yr^{-1}$ (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 unfinished 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 $yr^{-1}$ for females and 0.155 $yr^{-1}$ for males (2019 assessment estimated values).
3. Fixed natural mortality at 0.157 $yr^{-1}$ for females and 0.17 $yr^{-1}$ 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-liklihood 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 $yr^{-1}$) to 2019 (0.144 $yr^{-1}$) to 2025 (0.135 $yr^{-1}$), 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 teh 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 $yr^{-1}$ (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 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 yr$^{-1}$ and 0.14 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 yr$^{-1}$. The likelihood profile over natural mortality provides support for female $M$ values up to or above 0.14 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 yr$^{-1}$ and 0.144 yr$^{-1}$ for females; 0.137 yr$^{-1}$ and 0.157 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 WCGBTS 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 | 3,929.00 | 2,000 | 880.84 |
| 2016 | 3,990 | 3,790.00 | 2,000 | 1,041.65 |
| 2017 | 14,130 | 13,508.28 | 13,508 | 6,356.30 |
| 2018 | 13,237 | 12,654.57 | 12,655 | 10,531.98 |
| 2019 | 12,375 | 11,830.50 | 11,831 | 9,309.60 |
| 2020 | 11,714 | 11,198.58 | 11,199 | 8,400.97 |
| 2021 | 15,749 | 14,725.32 | 14,725 | 10,873.65 |
| 2022 | 14,826 | 13,788.18 | 13,788 | 12,116.29 |
| 2023 | 13,633 | 12,624.16 | 12,624 | 10,996.91 |
| 2024 | 12,453 | 11,481.67 | 11,482 | 9,746.77 |

## 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 |

| Yr | Bottom trawl | Midwater trawl | Hake |
|---|---|---|---|
| 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 |
| 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 |

| Yr | Bottom trawl | Midwater trawl | Hake |
|---|---|---|---|
| 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 |
| 1988 | 5,382 | 7,791 | 232 |
| 1989 | 5,914 | 9,891 | 212 |

| Yr | Bottom trawl | Midwater trawl | Hake |
|---|---|---|---|
| 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 |

| Yr | Bottom trawl | Midwater trawl | Hake |
|---|---|---|---|
| 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 | | | Midwater Trawl | | |
|---|---|---|---|---|---|---|
| | CA | OR | WA | CA | OR | 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 |

| Year | Bottom Trawl | | | Midwater Trawl | | |
|---|---|---|---|---|---|---|
| | CA | OR | WA | CA | OR | WA |
| 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 |
| 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 | | | Midwater Trawl | | |
|---|---|---|---|---|---|---|
| | CA | OR | WA | CA | OR | 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 | 1,900 |
| 1981 | 444 | 250 | 0 | 1,340 | 1,746 | 3,100 |
| 1982 | 932 | 792 | 0 | 3,144 | 3,960 | 4,100 |
| 1983 | 1,352 | 478 | 0 | 1,411 | 321 | 2,500 |
| 1984 | 1,722 | 2,394 | 0 | 1,278 | 1,525 | 2,199 |
| 1985 | 1,853 | 2,233 | 0 | 1,176 | 3,971 | 1,600 |
| 1986 | 1,740 | 1,425 | 0 | 1,032 | 2,788 | 2,650 |
| 1987 | 998 | 865 | 0 | 1,744 | 2,198 | 1,942 |
| 1988 | 763 | 916 | 350 | 1,230 | 1,239 | 700 |
| 1989 | 1,007 | 1,099 | 700 | 1,325 | 1,843 | 800 |
| 1990 | 1,202 | 1,320 | 550 | 1,510 | 1,454 | 1,500 |
| 1991 | 1,596 | 1,569 | 997 | 761 | 1,442 | 750 |
| 1992 | 1,470 | 1,982 | 1,100 | 222 | 1,760 | 450 |
| 1993 | 1,682 | 1,410 | 1,400 | 231 | 1,156 | 400 |
| 1994 | 1,359 | 1,464 | 650 | 112 | 557 | 842 |
| 1995 | 1,539 | 1,066 | 850 | 519 | 296 | 800 |
| 1996 | 1,364 | 845 | 704 | 437 | 316 | 650 |
| 1997 | 2,063 | 1,231 | 557 | 382 | 620 | 950 |
| 1998 | 1,368 | 1,013 | 865 | 125 | 291 | 400 |
| 1999 | 1,420 | 727 | 952 | 240 | 514 | 550 |
| 2000 | 263 | 0 | 101 | 641 | 1,147 | 950 |

| Year | Bottom Trawl | | | Midwater Trawl | | |
|---|---|---|---|---|---|---|
| | CA | OR | WA | CA | OR | WA |
| 2001 | 139 | 98 | 2 | 349 | 960 | 550 |
| 2002 | 318 | 185 | 136 | 39 | 319 | 500 |
| 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 | 1,086 |
| 2009 | 170 | 316 | 0 | 0 | 0 | 1,079 |
| 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 | 1,492 | 350 |
| 2019 | 566 | 346 | 50 | 90 | 1,149 | 600 |
| 2020 | 593 | 228 | 0 | 83 | 759 | 233 |
| 2021 | 850 | 226 | 8 | 183 | 890 | 307 |
| 2022 | 272 | 185 | 0 | 502 | 1,025 | 180 |
| 2023 | 376 | 135 | 0 | 316 | 1,125 | 571 |
| 2024 | 540 | 164 | 0 | 0 | 1,255 | 830 |

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

| Year | Number of hauls (at-sea) or trips (shoreside) | | Number of lengths | |
|---|---|---|---|---|
| | Domestic at-sea | Shoreside | Domestic at-sea | Shoreside |
| 1992 | 214 | 0 | 1,474 | 0 |
| 1993 | 239 | 0 | 1,468 | 0 |
| 1994 | 361 | 3 | 3,458 | 78 |
| 1995 | 304 | 19 | 1,789 | 570 |
| 1996 | 332 | 18 | 2,620 | 540 |
| 1997 | 397 | 30 | 2,841 | 869 |
| 1998 | 481 | 32 | 2,431 | 975 |
| 1999 | 598 | 52 | 3,070 | 1,551 |
| 2000 | 571 | 33 | 2,845 | 1,004 |
| 2001 | 522 | 19 | 1,758 | 576 |
| 2002 | 369 | 3 | 1,204 | 70 |
| 2003 | 291 | 2 | 665 | 26 |
| 2004 | 512 | 19 | 1,670 | 380 |
| 2005 | 1,228 | 1 | 5,538 | 50 |
| 2006 | 1,295 | 14 | 6,104 | 594 |
| 2007 | 1,491 | 21 | 10,658 | 860 |
| 2008 | 1,138 | 36 | 7,324 | 966 |
| 2009 | 400 | 24 | 1,976 | 845 |
| 2010 | 980 | 43 | 4,734 | 1,214 |
| 2011 | 982 | 43 | 3,605 | 1,286 |
| 2012 | 914 | 46 | 4,779 | 1,291 |
| 2013 | 901 | 40 | 3,808 | 1,160 |
| 2014 | 773 | 50 | 3,970 | 1,452 |

| Year | Number of hauls (at-sea) or trips (shoreside) | | Number of lengths | |
|---|---|---|---|---|
| | Domestic at-sea | Shoreside | Domestic at-sea | Shoreside |
| 2015 | 522 | 36 | 2,312 | 1,313 |
| 2016 | 801 | 49 | 3,934 | 1,465 |
| 2017 | 997 | 57 | 5,406 | 1,353 |
| 2018 | 461 | 65 | 2,245 | 1,283 |
| 2019 | 469 | 73 | 2,642 | 1,536 |
| 2020 | 214 | 37 | 902 | 839 |
| 2021 | 310 | 61 | 1,776 | 1,279 |
| 2022 | 333 | 88 | 1,489 | 1,745 |
| 2023 | 469 | 68 | 1,738 | 1,525 |
| 2024 | 83 | 60 | 251 | 1,231 |

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

| Year | Bottom Trawl | | | Midwater Trawl | | |
|---|---|---|---|---|---|---|
| | CA | OR | WA | CA | OR | WA |
| 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 |
| 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 |

| Year | Bottom Trawl | | | Midwater Trawl | | |
|---|---|---|---|---|---|---|
| | CA | OR | WA | CA | OR | WA |
| 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 | | | Midwater Trawl | | |
|---|---|---|---|---|---|---|
| | CA | OR | WA | CA | OR | WA |
| 1978 | 107 | 0 | 0 | 0 | 0 | 0 |
| 1979 | 269 | 0 | 0 | 0 | 0 | 0 |
| 1980 | 404 | 0 | 0 | 0 | 0 | 1,775 |
| 1981 | 205 | 109 | 0 | 598 | 600 | 3,050 |
| 1982 | 834 | 174 | 0 | 2,382 | 1,019 | 3,944 |
| 1983 | 1,283 | 475 | 0 | 1,365 | 321 | 2,480 |
| 1984 | 1,678 | 600 | 0 | 1,278 | 360 | 2,194 |
| 1985 | 1,762 | 589 | 0 | 1,176 | 963 | 1,591 |
| 1986 | 1,704 | 680 | 0 | 913 | 939 | 2,594 |
| 1987 | 968 | 805 | 0 | 1,742 | 1,837 | 1,940 |
| 1988 | 692 | 886 | 298 | 1,132 | 1,209 | 695 |
| 1989 | 919 | 1,099 | 695 | 1,323 | 1,794 | 799 |
| 1990 | 1,051 | 1,310 | 550 | 1,309 | 1,447 | 1,497 |
| 1991 | 1,308 | 1,566 | 991 | 761 | 1,413 | 748 |
| 1992 | 676 | 1,889 | 1,097 | 82 | 574 | 450 |
| 1993 | 472 | 1,361 | 1,398 | 0 | 1,155 | 400 |
| 1994 | 516 | 1,463 | 650 | 54 | 556 | 749 |
| 1995 | 167 | 1,027 | 850 | 68 | 276 | 800 |
| 1996 | 873 | 827 | 699 | 158 | 292 | 649 |
| 1997 | 892 | 1,164 | 549 | 187 | 593 | 949 |
| 1998 | 1,019 | 987 | 699 | 82 | 291 | 400 |
| 1999 | 1,026 | 706 | 950 | 133 | 479 | 500 |
| 2000 | 157 | 0 | 100 | 353 | 1,067 | 948 |
| 2001 | 43 | 98 | 0 | 132 | 858 | 485 |
| 2002 | 294 | 179 | 99 | 21 | 319 | 488 |

| Year | Bottom Trawl | | | Midwater Trawl | | |
|---|---|---|---|---|---|---|
| | CA | OR | WA | CA | OR | WA |
| 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 |
| 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 | 10,687.86 | 55 | 183 | 34.5 | 40.5 |
| B | 3,394.82 | 183 | 400 | 34.5 | 40.5 |
| C | 23,042.39 | 55 | 183 | 40.5 | 49.0 |
| D | 7,667.81 | 183 | 400 | 40.5 | 49.0 |

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

| Year | Number of positive tows | | Number of tows with lengths | | Number of lengths | | Number of tows with ages | | Number of ages | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tri | NW | Tri | NW | Tri | NW | Tri | NW | Tri | NW |
| 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 |

| Year | Number of positive tows | | Number of tows with lengths | | Number of lengths | | Number of tows with ages | | Number of ages | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tri | NW | Tri | NW | Tri | NW | Tri | NW | Tri | NW |
| 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 | 0 | none |
| Wtlen_2_Fem_GP_1 | 2.99 | (-3, 10) | fixed | 0 | none |
| Mat50%_Fem_GP_1 | 5.47 | (-3, 50) | fixed | 0 | none |
| Mat_slope_Fem_GP_1 | -0.775 | (-3, 3) | fixed | 0 | none |
| Eggs_scalar_Fem_GP_1 | 1.11e-08 | (-1, 1) | fixed | 0 | none |
| Eggs_exp_len_Fem_GP_1 | 4.54 | (0, 5) | fixed | 0 | 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 |

| Label | Value | Bounds | Status | SD | Prior |
|---|---|---|---|---|---|
| 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 | 0 | none |
| Wtlen_2_Mal_GP_1 | 3.01 | (-3, 10) | fixed | 0 | none |
| CohortGrowDev | 1 | (0, 2) | fixed | 0 | none |
| FracFemale_GP_1 | 0.5 | (1e-06, 1) | fixed | 0 | none |
| SR_LN(R0) | 10.6 | (6, 15) | ok | 0.155 | none |
| SR_BH_steep | 0.72 | (0.2, 1) | fixed | 0 | beta(0.720, 0.160) |
| SR_sigmaR | 0.6 | (0, 2) | fixed | 0 | none |
| SR_regime | 0 | (-5, 5) | fixed | 0 | none |
| SR_autocorr | 0 | (0, 0.5) | fixed | 0 | 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) |
| 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) |

| Label | Value | Bounds | Status | SD | Prior |
|---|---|---|---|---|---|
| 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) |

| Label | Value | Bounds | Status | SD | Prior |
|---|---|---|---|---|---|
| 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) |
| 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) |

| Label | Value | Bounds | Status | SD | Prior |
|---|---|---|---|---|---|
| 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) |

| Label | Value | Bounds | Status | SD | Prior |
|---|---|---|---|---|---|
| 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) |
| 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) |

| Label | Value | Bounds | Status | SD | Prior |
|---|---|---|---|---|---|
| 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) |

| Label | Value | Bounds | Status | SD | Prior |
|---|---|---|---|---|---|
| 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) |
| 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) |

| Label | Value | Bounds | Status | SD | Prior |
|---|---|---|---|---|---|
| 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 | 0 | 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 |
| Q_extraSD_Hake(3) | 0.386 | (0, 2) | ok | 0.0891 | none |
| LnQ_base_JuvSurvey(6) | -5.04 | (-25, 25) | fixed | 0 | none |

| Label | Value | Bounds | Status | SD | Prior |
|---|---|---|---|---|---|
| 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 | 0 | none |
| LnQ_base_WCGBTS(8) | -3.34 | (-25, 25) | fixed | 0 | none |
| Q_extraSD_WCGBTS(8) | 0 | (0, 2) | fixed | 0 | none |
| LnQ_base_ForeignAtSea(9) | -11.5 | (-25, 25) | fixed | 0 | 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_DblN_peak_BottomTrawl(1) | 42.1 | (10, 59) | ok | 1.71 | none |
| Size_DblN_top_logit_BottomTrawl(1) | 2.5 | (-5, 10) | ok | 167 | none |
| Size_DblN_ascend_se_BottomTrawl(1) | 4.06 | (-4, 12) | ok | 0.326 | none |
| Size_DblN_descend_se_BottomTrawl(1) | 9 | (-2, 10) | fixed | 0 | none |
| Size_DblN_start_logit_BottomTrawl(1) | -9 | (-9, 10) | fixed | 0 | none |
| Size_DblN_end_logit_BottomTrawl(1) | 8 | (-9, 9) | fixed | 0 | none |
| Size_DblN_peak_MidwaterTrawl(2) | 37.1 | (10, 59) | ok | 1.2 | none |
| Size_DblN_top_logit_MidwaterTrawl(2) | -9.25 | (-10, 10) | ok | 18.1 | none |
| Size_DblN_ascend_se_MidwaterTrawl(2) | 2.8 | (-4, 12) | ok | 0.495 | none |
| Size_DblN_descend_se_MidwaterTrawl(2) | 3.94 | (-2, 10) | ok | 1.55 | none |

| Label | Value | Bounds | Status | SD | Prior |
|---|---|---|---|---|---|
| Size_DblN_start_logit_MidwaterTrawl(2) | -9 | (-9, 10) | fixed | 0 | none |
| Size_DblN_end_logit_MidwaterTrawl(2) | -1.17 | (-9, 9) | ok | 2.02 | none |
| Size_DblN_peak_Hake(3) | 34.5 | (10, 59) | ok | 2.09 | none |
| Size_DblN_top_logit_Hake(3) | 2.5 | (-5, 10) | ok | 168 | none |
| Size_DblN_ascend_se_Hake(3) | 2.51 | (-4, 12) | ok | 1.03 | none |
| Size_DblN_descend_se_Hake(3) | 9 | (-2, 10) | fixed | 0 | none |
| Size_DblN_start_logit_Hake(3) | -9 | (-9, 10) | fixed | 0 | none |
| Size_DblN_end_logit_Hake(3) | 8 | (-9, 9) | fixed | 0 | none |
| SizeSpline_Code_Triennial(7) | 0 | (0, 2) | fixed | 0 | 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 | 0 | none |
| SizeSpline_Knot_2_Triennial(7) | 34 | (8, 56) | fixed | 0 | none |
| SizeSpline_Knot_3_Triennial(7) | 48 | (8, 56) | fixed | 0 | none |
| SizeSpline_Val_1_Triennial(7) | -2.17 | (-10, 10) | ok | 0.756 | none |
| SizeSpline_Val_2_Triennial(7) | -1 | (-10, 10) | fixed | 0 | none |
| SizeSpline_Val_3_Triennial(7) | 0.435 | (-10, 10) | ok | 0.509 | none |
| SizeSpline_Code_WCGBTS(8) | 0 | (0, 2) | fixed | 0 | none |
| SizeSpline_GradLo_WCGBTS(8) | 0.447 | (-0.001, 1) | ok | 0.299 | none |

| Label | Value | Bounds | Status | SD | Prior |
|---|---|---|---|---|---|
| SizeSpline_GradHi_WCGBTS(8) | -0.098 | (-1, 1) | ok | 0.151 | none |
| SizeSpline_Knot_1_WCGBTS(8) | 24 | (8, 56) | fixed | 0 | none |
| SizeSpline_Knot_2_WCGBTS(8) | 34 | (8, 56) | fixed | 0 | none |
| SizeSpline_Knot_3_WCGBTS(8) | 48 | (8, 56) | fixed | 0 | none |
| SizeSpline_Val_1_WCGBTS(8) | -2.19 | (-10, 10) | ok | 0.665 | none |
| SizeSpline_Val_2_WCGBTS(8) | -1 | (-10, 10) | fixed | 0 | none |
| SizeSpline_Val_3_WCGBTS(8) | 0.05 | (-10, 10) | ok | 0.354 | none |
| minage@sel=1_JuvSurvey(6) | 0 | (0, 1) | fixed | 0 | none |
| maxage@sel=1_JuvSurvey(6) | 0 | (0, 1) | fixed | 0 | none |
| minage@sel=1_WCGBTS(8) | 0 | (0, 1) | fixed | 0 | none |
| maxage@sel=1_WCGBTS(8) | 40 | (0, 50) | fixed | 0 | none |
| Size_DblN_peak_BottomTrawl(1)_BLK4repl_1916 | 39.4 | (10, 59) | ok | 0.604 | none |
| Size_DblN_ascend_se_BottomTrawl(1)_BLK4repl_-1916 | 3.47 | (-4, 12) | ok | 0.161 | none |
| Size_DblN_peak_MidwaterTrawl(2)_BLK7repl_1916 | 38.6 | (10, 59) | ok | 1.32 | none |
| Size_DblN_peak_MidwaterTrawl(2)_BLK7repl_1983 | 38.2 | (10, 59) | ok | 0.593 | none |
| Size_DblN_peak_MidwaterTrawl(2)_BLK7repl_2002 | 37.8 | (10, 59) | ok | 2.19 | none |
| Size_DblN_ascend_se_MidwaterTrawl(2)_BLK7repl_-1916 | 3.39 | (-4, 12) | ok | 0.381 | none |

| Label | Value | Bounds | Status | SD | Prior |
|---|---|---|---|---|---|
| Size_DblN_ascend_se_MidwaterTrawl(2)_BLK7repl_-1983 | 2.99 | (-4, 12) | ok | 0.191 | none |
| Size_DblN_ascend_se_MidwaterTrawl(2)_BLK7repl_-2002 | 2.96 | (-4, 12) | ok | 0.715 | none |
| Size_DblN_descend_se_MidwaterTrawl(2)_-BLK7repl_1916 | 4.11 | (-2, 10) | ok | 1.35 | none |
| Size_DblN_descend_se_MidwaterTrawl(2)_-BLK7repl_1983 | 2.57 | (-2, 10) | ok | 0.82 | none |
| Size_DblN_descend_se_MidwaterTrawl(2)_-BLK7repl_2002 | -1.82 | (-2, 10) | ok | 5.29 | none |
| Size_DblN_end_logit_MidwaterTrawl(2)_BLK7repl_-1916 | -1.67 | (-9, 9) | ok | 3.15 | none |
| Size_DblN_end_logit_MidwaterTrawl(2)_BLK7repl_-1983 | -0.609 | (-9, 9) | ok | 0.307 | none |
| Size_DblN_end_logit_MidwaterTrawl(2)_BLK7repl_-2002 | 2 | (-9, 9) | ok | 2.97 | none |
| Size_DblN_peak_Hake(3)_BLK11repl_1916 | 41.4 | (10, 59) | ok | 0.67 | none |
| Size_DblN_top_logit_Hake(3)_BLK11repl_1916 | 2.5 | (-5, 10) | ok | 168 | none |
| Size_DblN_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 Unfished | Age-0 Recruits (1,000s) | Total Mortality (mt) | (1-SPR)/(1-SPR_50%) | 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 |

| Year | Total Biomass (mt) | Spawning output (billions of eggs) | Total Biomass 4+ (mt) | Fraction Unfished | Age-0 Recruits (1,000s) | Total Mortality (mt) | (1-SPR)/(1-SPR_50%) | Exploitation Rate |
|---|---|---|---|---|---|---|---|---|
| 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 |
| 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 |

| Year | Total Biomass (mt) | Spawning output (billions of eggs) | Total Biomass 4+ (mt) | Fraction Unfished | Age-0 Recruits (1,000s) | Total Mortality (mt) | (1-SPR)/(1-SPR_50%) | Exploitation Rate |
|---|---|---|---|---|---|---|---|---|
| 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 |

| Year | Total Biomass (mt) | Spawning output (billions of eggs) | Total Biomass 4+ (mt) | Fraction Unfished | Age-0 Recruits (1,000s) | Total Mortality (mt) | (1-SPR)/(1-SPR_50%) | Exploitation Rate |
|---|---|---|---|---|---|---|---|---|
| 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 |
| 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 |

| Year | Total Biomass (mt) | Spawning output (billions of eggs) | Total Biomass 4+ (mt) | Fraction Unfished | Age-0 Recruits (1,000s) | Total Mortality (mt) | (1-SPR)/(1-SPR_50%) | Exploitation Rate |
|---|---|---|---|---|---|---|---|---|
| 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 |

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 to that component) 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 |
|---|---|---|---|---|---|---|---|---|---|
| **Diff. in likelihood from base model** | | | | | | | | | |
| 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 |
| **Estimates of key parameters** | | | | | | | | | |
| 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 |
| **Estimates of derived quantities** | | | | | | | | | |
| 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) | 21,111 | 17,760 | 24,461 |
| 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 | 0.5 | | |
| 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 | - | - | - | - | 10,571.70 | 0.501 |
| 2026 | 11,382 | 10,392 | 9,824 | - | - | - | - | 9,630.18 | 0.456 |
| 2027 | - | - | - | 4,916 | 0.935 | 4,596 | 4,596 | 8,799.27 | 0.417 |
| 2028 | - | - | - | 5,172 | 0.93 | 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 | 0.9 | 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 Spawning Output | Low Fraction Unfished | Low OFL | Base Spawning Output | Base Fraction Unfished | Base OFL | High Spawning Output | High Fraction Unfished | 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

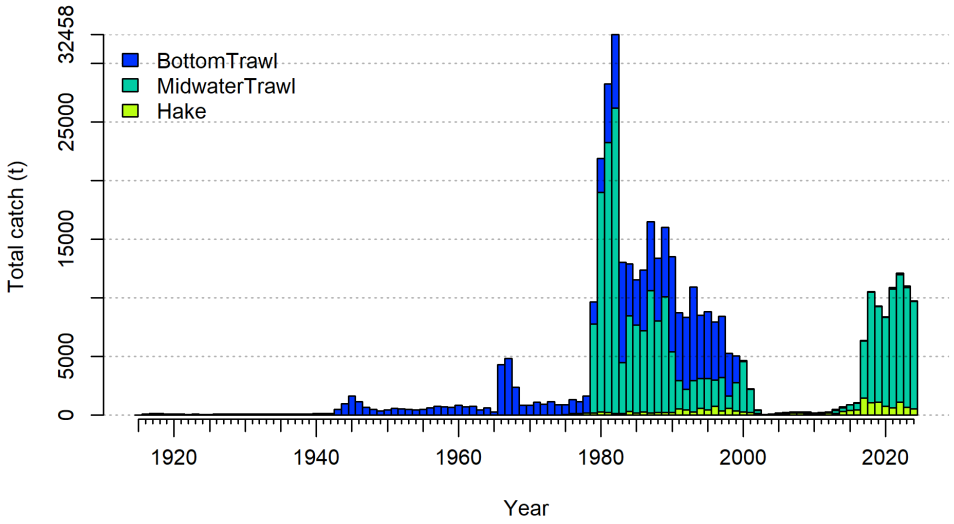



Figure 6: Total catches (landings and discards combined) of widow rockfish from 1916 to 2024 for bottom trawl, midwater trawl, and hake fleets.

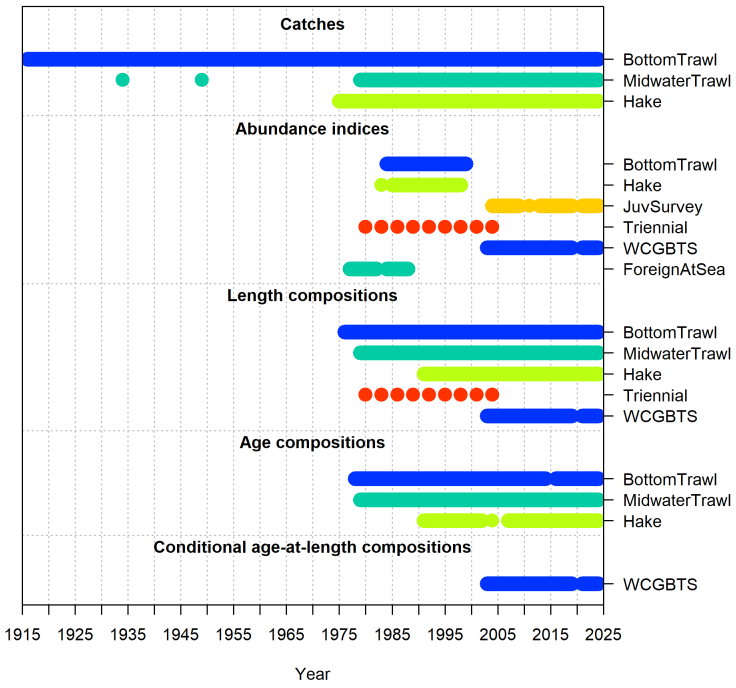



Figure 7: Data sources by type and year that were used in the base model.

### 6.1.1 Indices

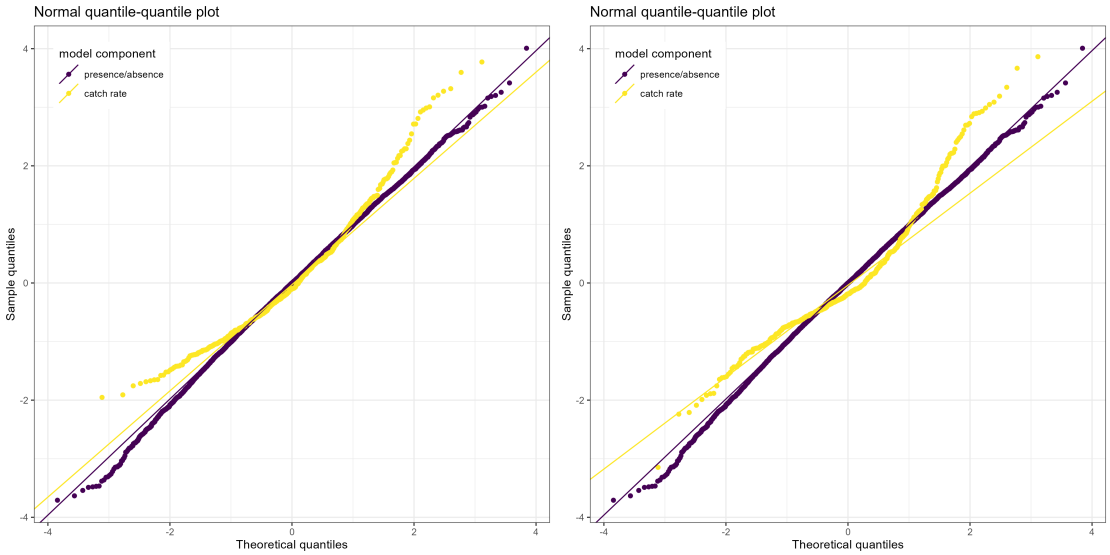



Figure 8: QQ plots for delta-gamma (panel 1) and delta-lognormal (panel 2, used in base model) sdmTMB index.

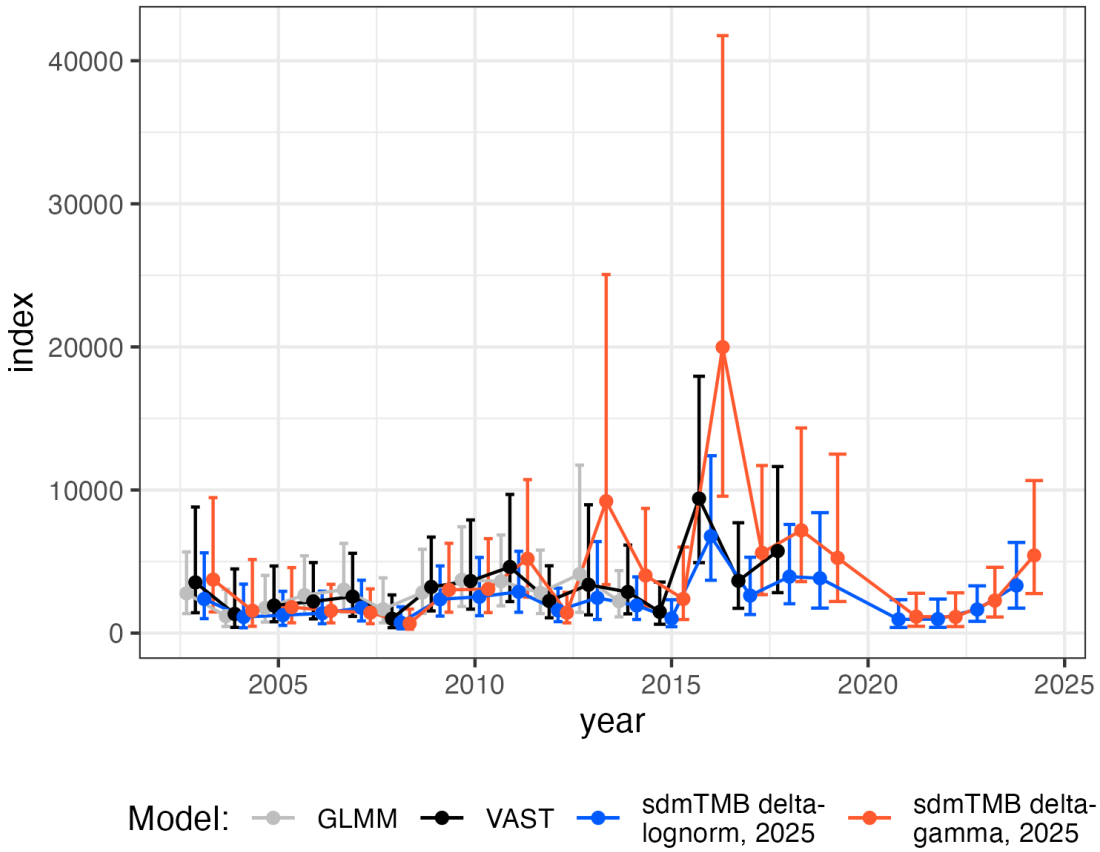



Figure 9: Comparison of the estimated index of relative abundance for the West Coast Groundfish Bottom Trawl Survey using a GLMM (gray line, 2015 stock assessment), VAST (black line, 2019 stock assessment), a delta-gamma sdmTMB index (blue line) and a delta-lognormal sdmTMB index (red line, used in base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

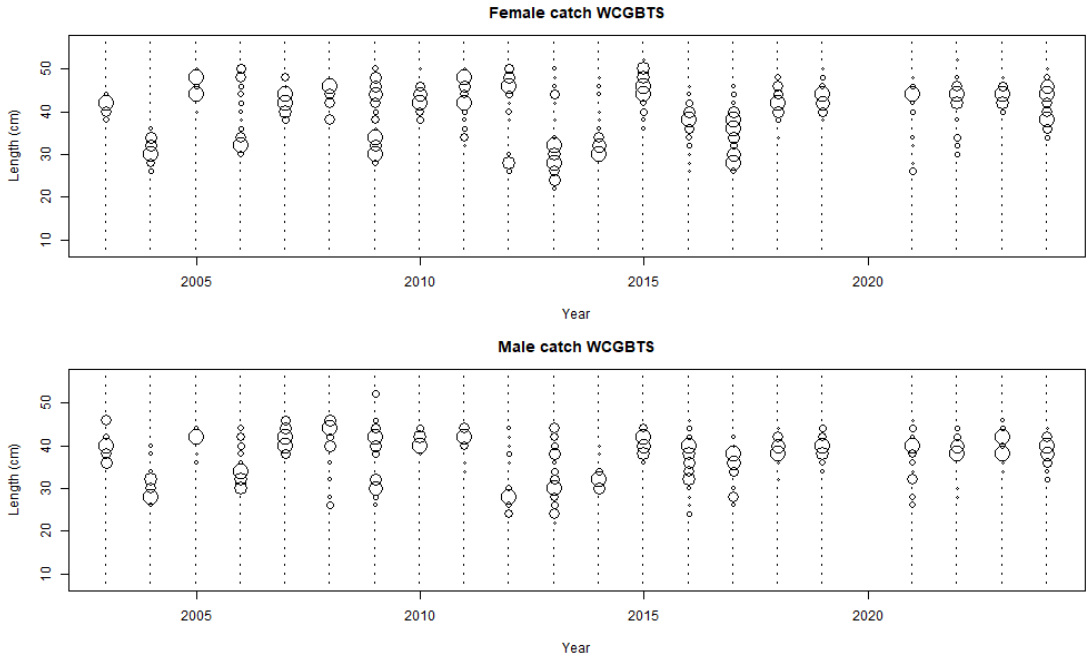



Figure 10: Expanded length compositions for the WCGBTS

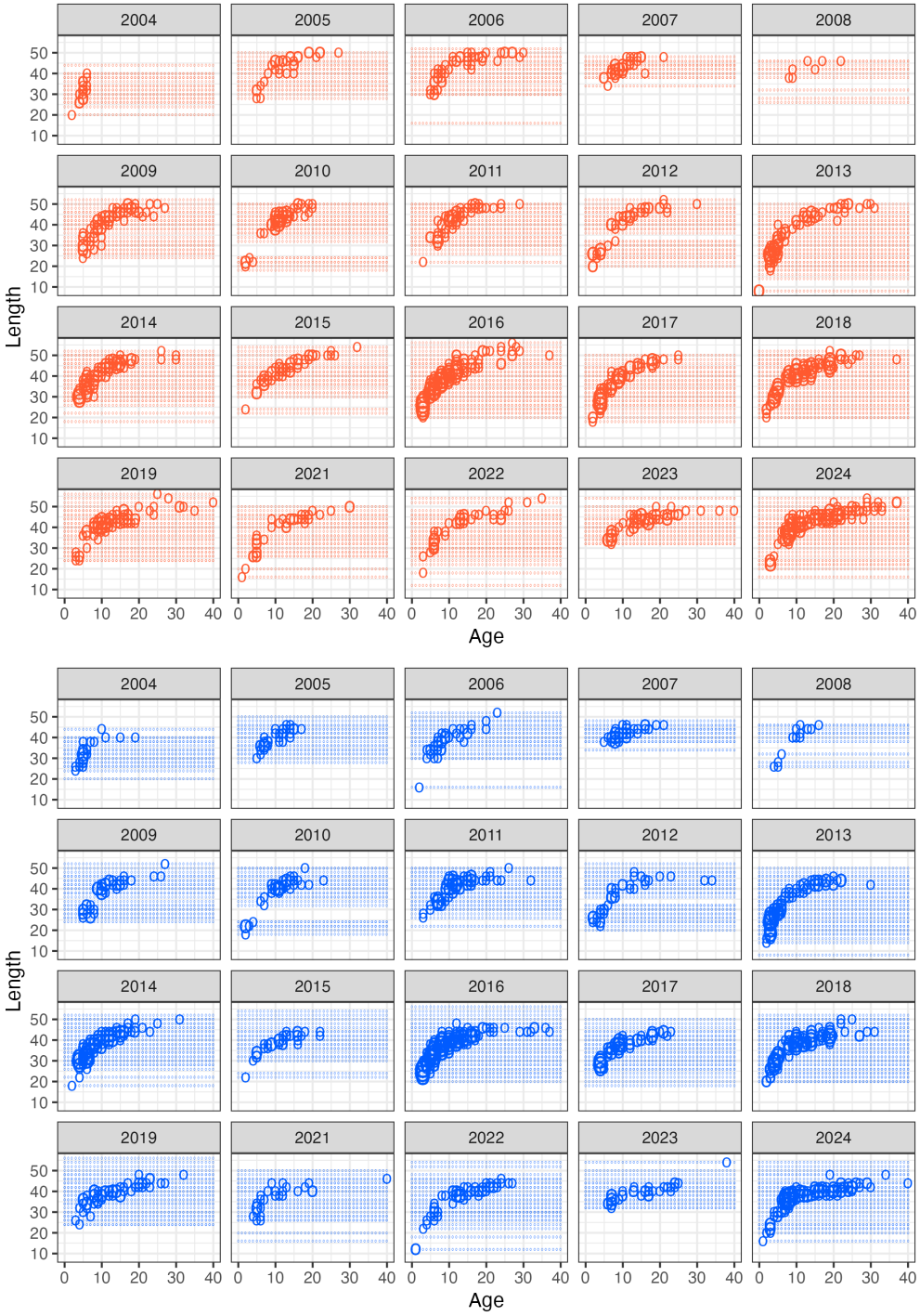



Figure 11: Conditional age-at-length from WCGBTS observations for females (red) and males (blue).

### 6.1.2 Composition data

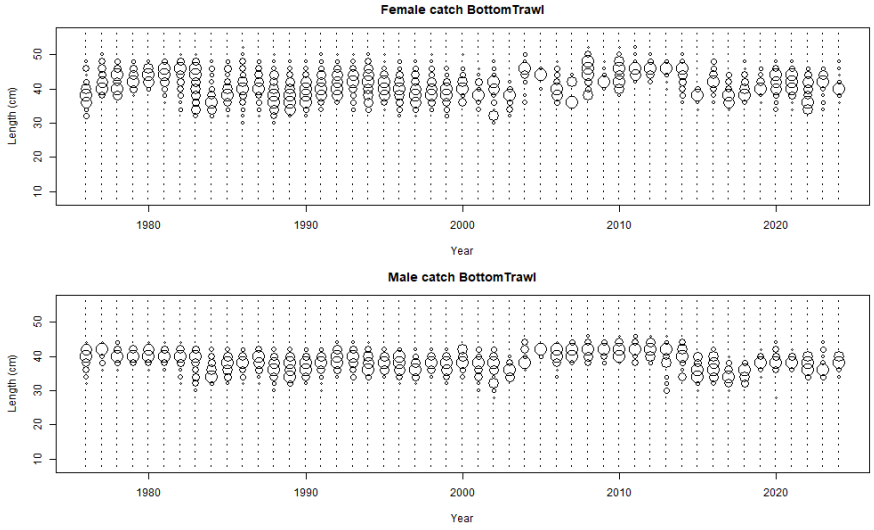



Figure 12: Expanded length compositions for the bottom trawl fishery. The area of the circle is proportional to the proportion-at-length.

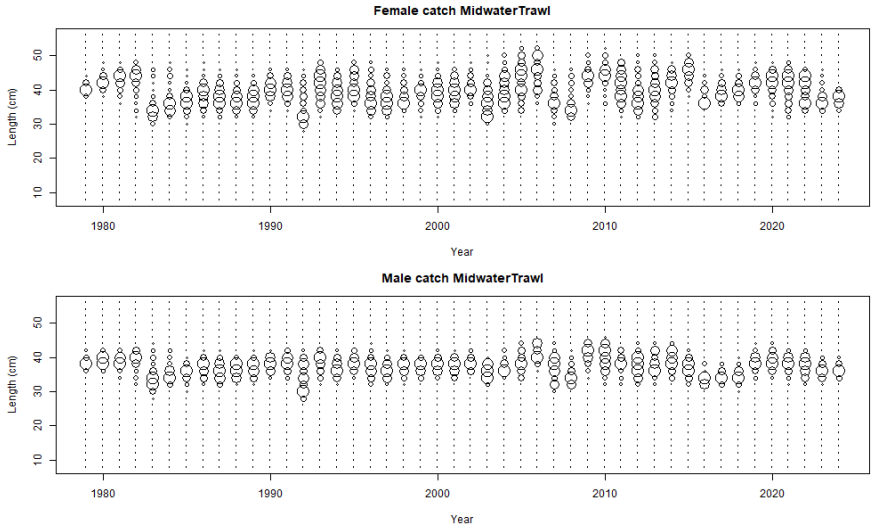



Figure 13: Expanded length compositions for the midwater trawl fishery. The area of the circle is proportional to the proportion-at-length.

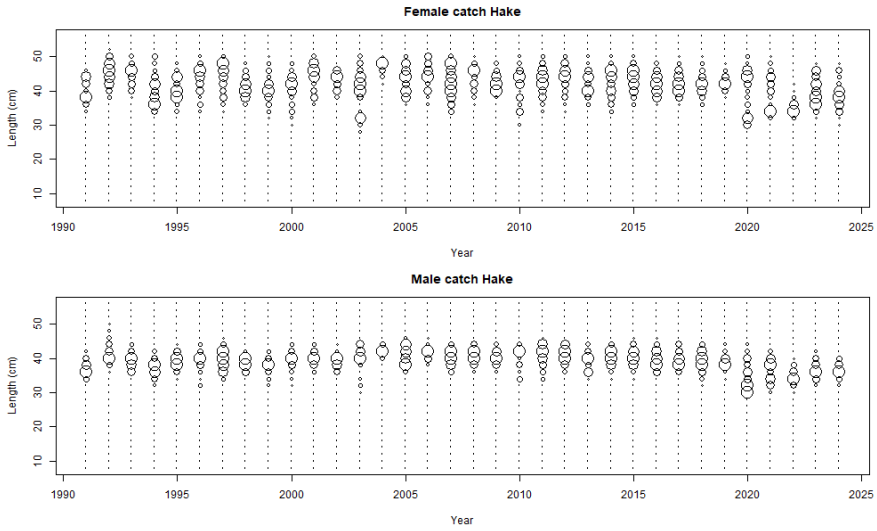



Figure 14: Expanded length compositions for the hake fishery. The area of the circle is proportional to the proportion-at-length.

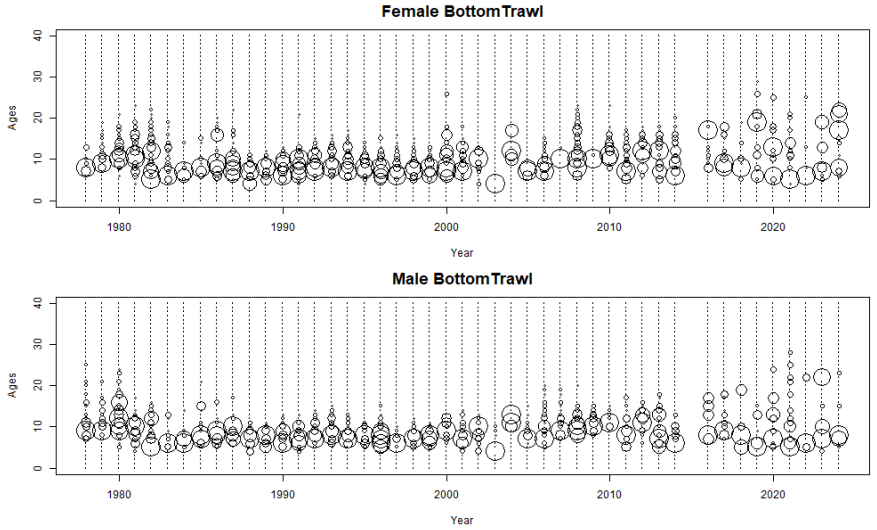



Figure 15: Expanded age compositions for the bottom trawl fishery. The area of the circle is proportional to the proportion-at-age.

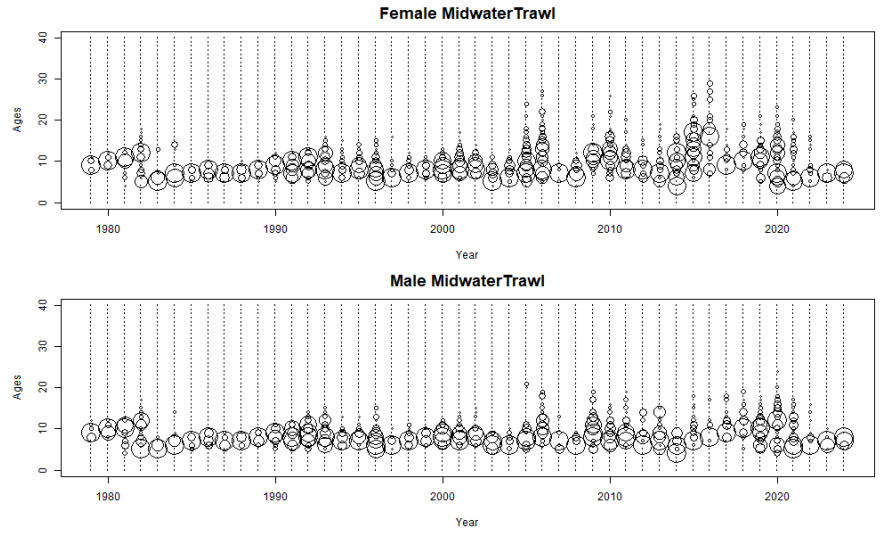



Figure 16: Expanded age compositions for the midwater trawl fishery. The area of the circles is proportional to the proportion-at-age.

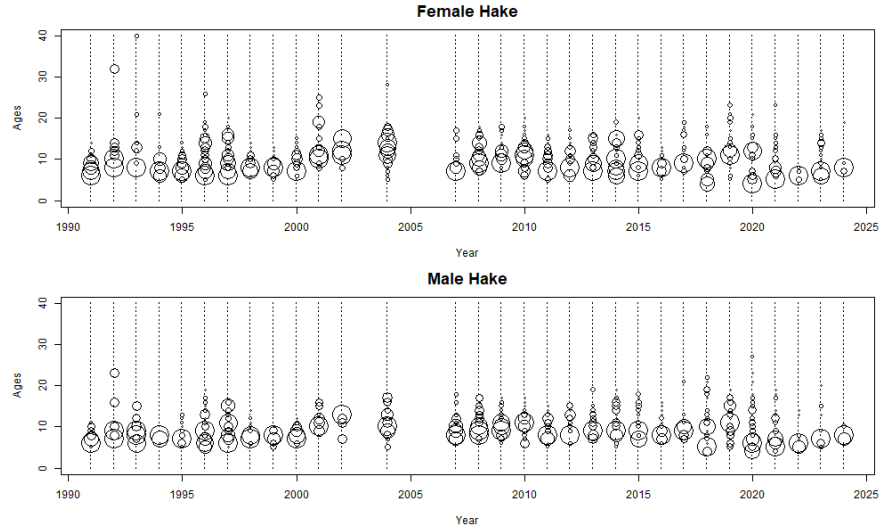



Figure 17: Expanded age compositions for the hake fishery. The area of the circles is proportional to the proportion-at-age.

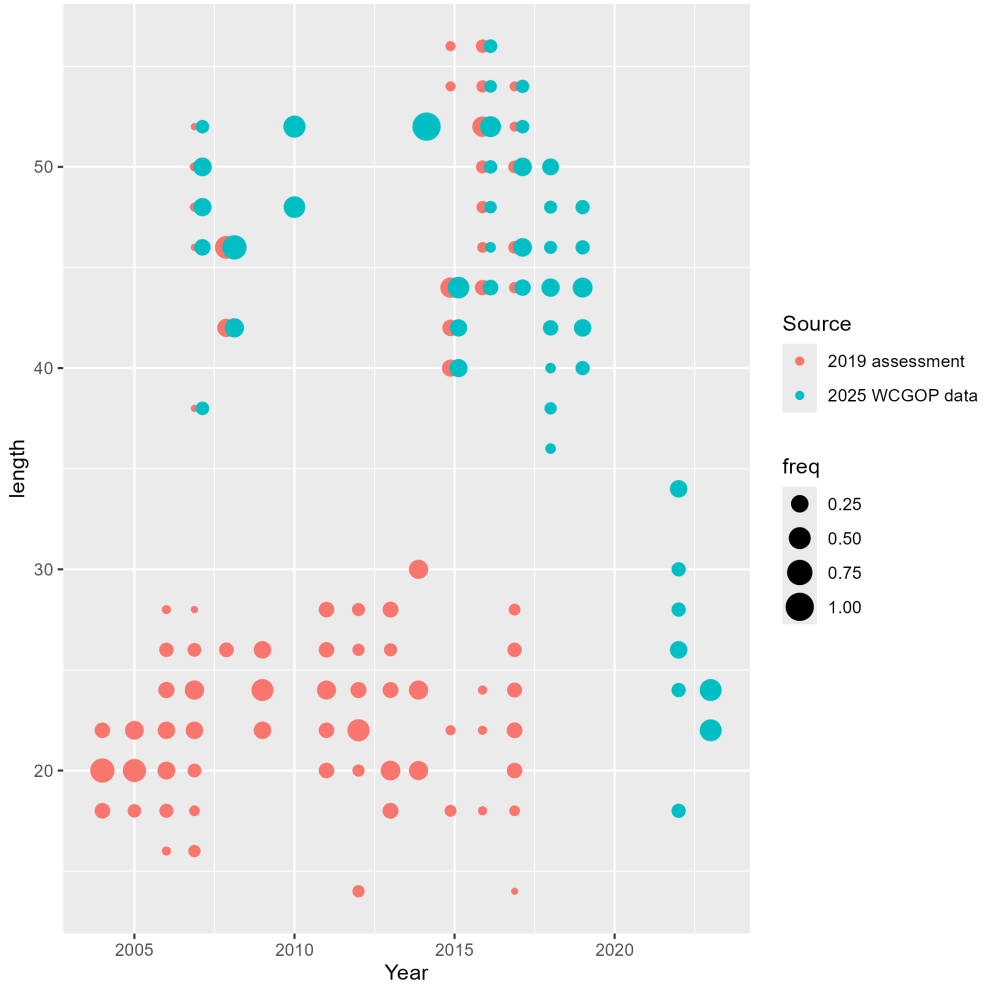



Figure 18: Comparison between discard data for the hook-and-line fleet from the 2019 assessment, which included nearshore fixed gear fleets, and discards queried from WCGOP for this assessment.

### 6.1.3 Biological data

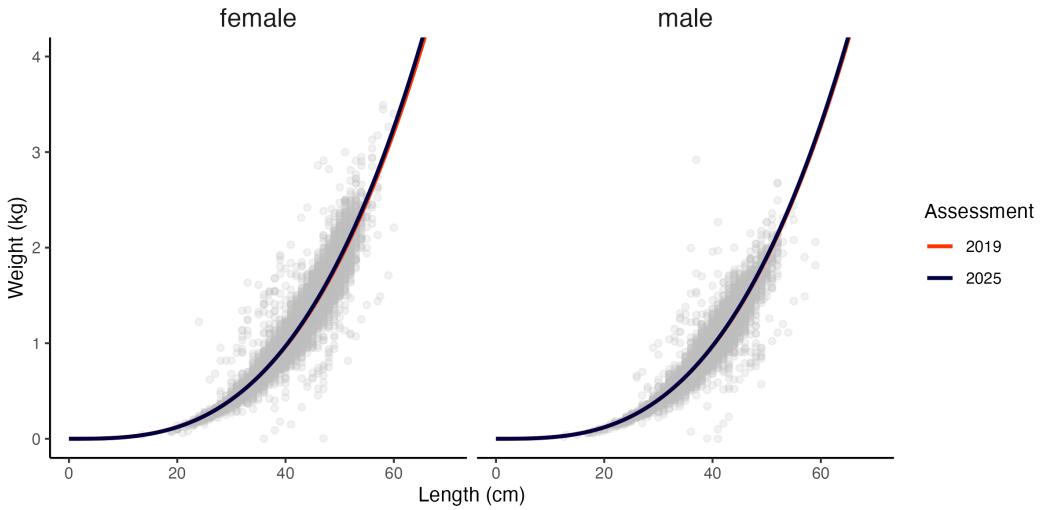



Figure 19: Fits to weight-at-length observations (dashed line) for females (left) and males (right) from the previous and current assessments. Fits to the current assessment use observations from all data sources (points)

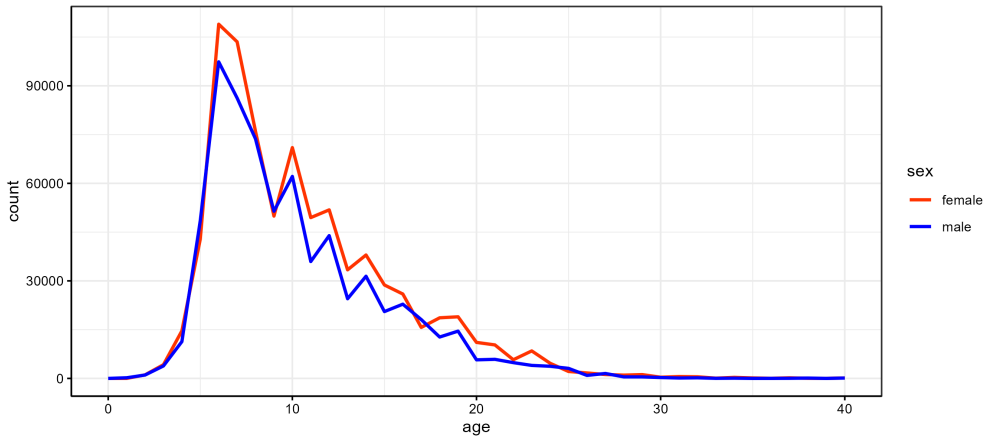



Figure 20: Number at age observed from all data for female and male widow rockfish.

## 6.2 Model

### 6.2.1 Bridging

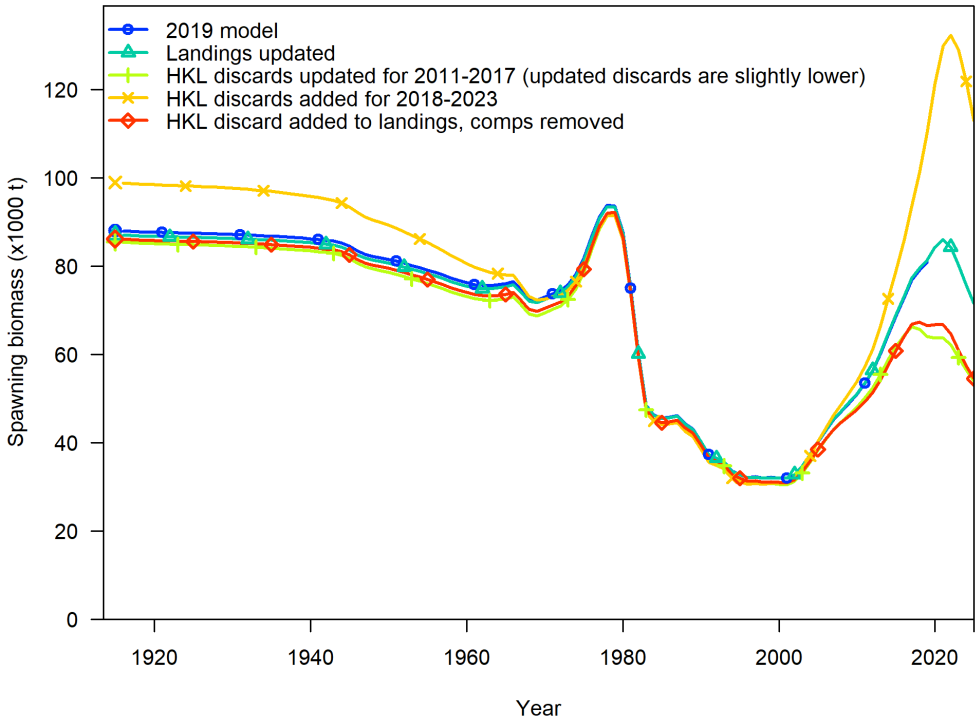



Figure 21: Spawning biomass with intermediate steps in hook-and-like discard data updates.

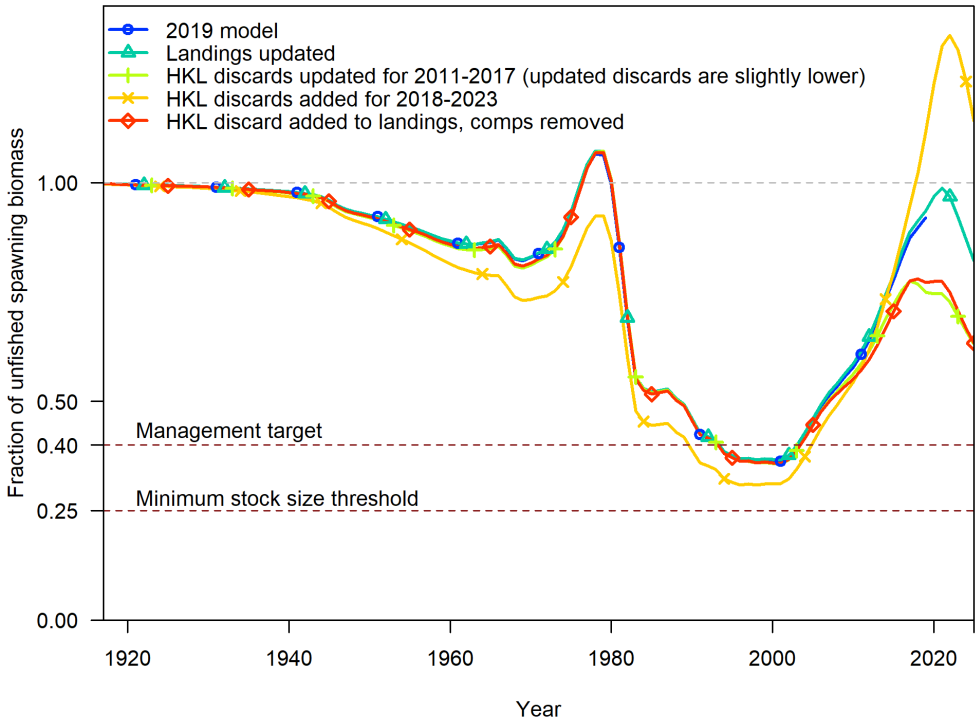



Figure 22: Fraction unfished with intermediate steps in hook-and-like discard data updates.

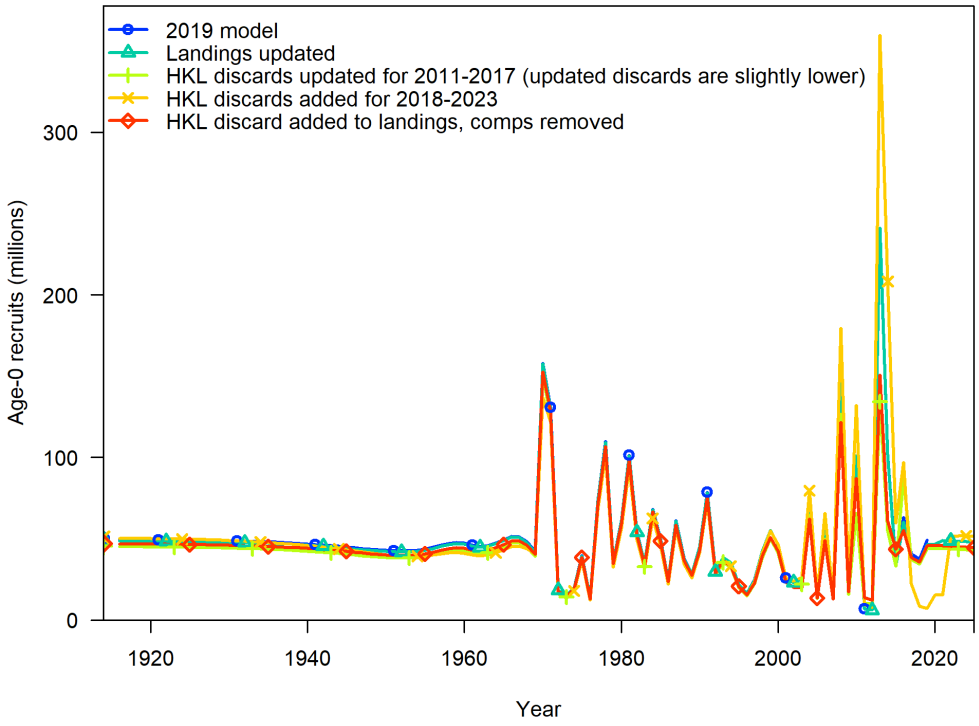



Figure 23: Fraction unfished with intermediate steps in hook-and-like discard data updates.

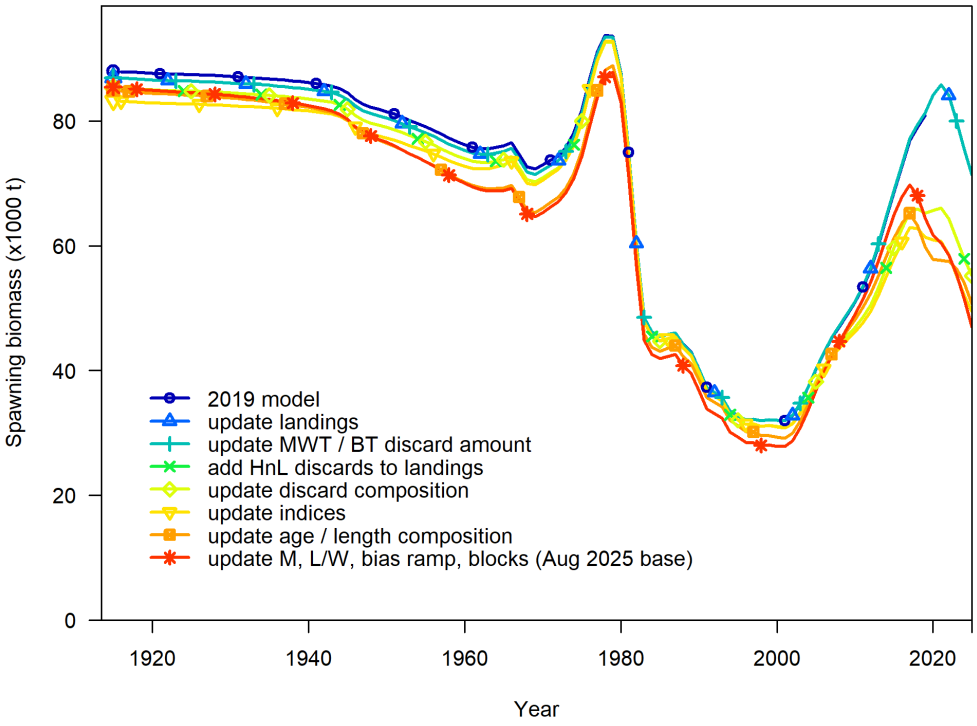



Figure 24: Time series of spawning biomass (SB) estimates from model runs bridging from the 2019 assessment (dark blue) to the August 2025 base model (red). For illustration purposes, the addition of midwater and bottom trawl discards (without updating hook-and-line discards) precedes the addition of 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).

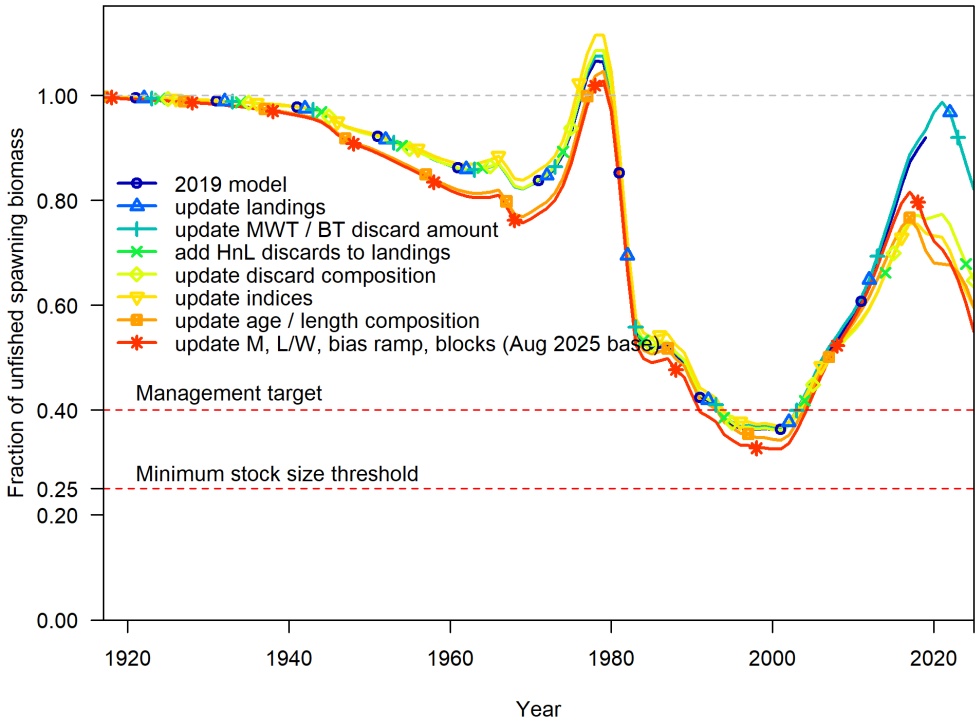



Figure 25: Time series of relative spawning biomass (fraction unfished) estimates from model runs bridging from the 2019 assessment (dark blue) to the August 2025 base model (red).

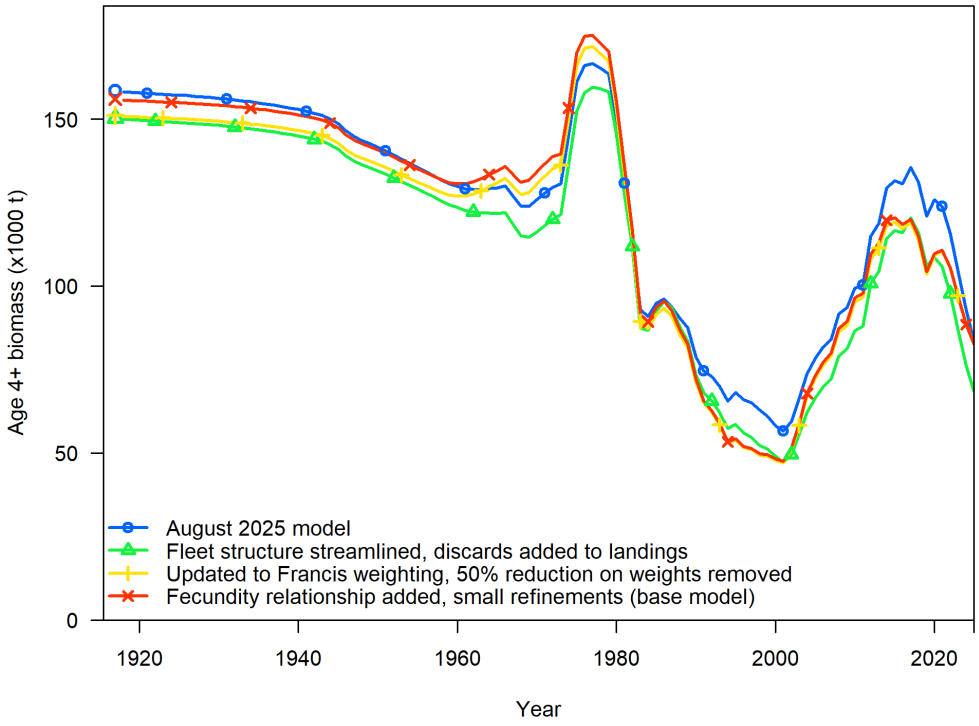



Figure 26: Time series of relative spawning biomass (fraction unfished) estimates from model runs bridging from the August 2025 model (blue) to the base model (red).

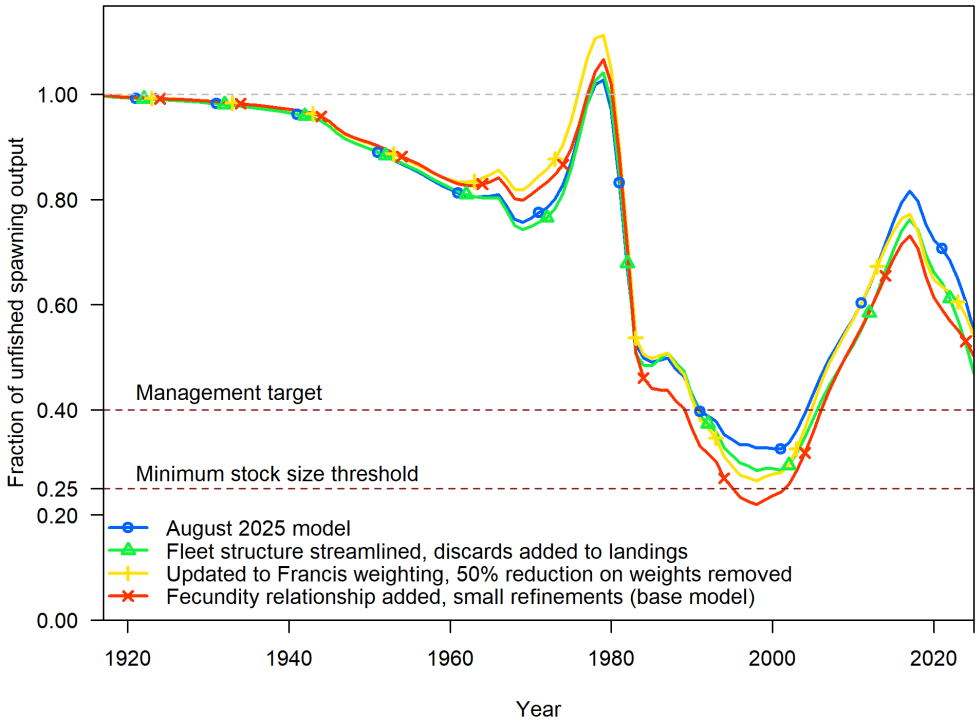



Figure 27: Time series of relative spawning biomass (fraction unfished) estimates from model runs bridging from the August 2025 model (blue) to the base model (red).

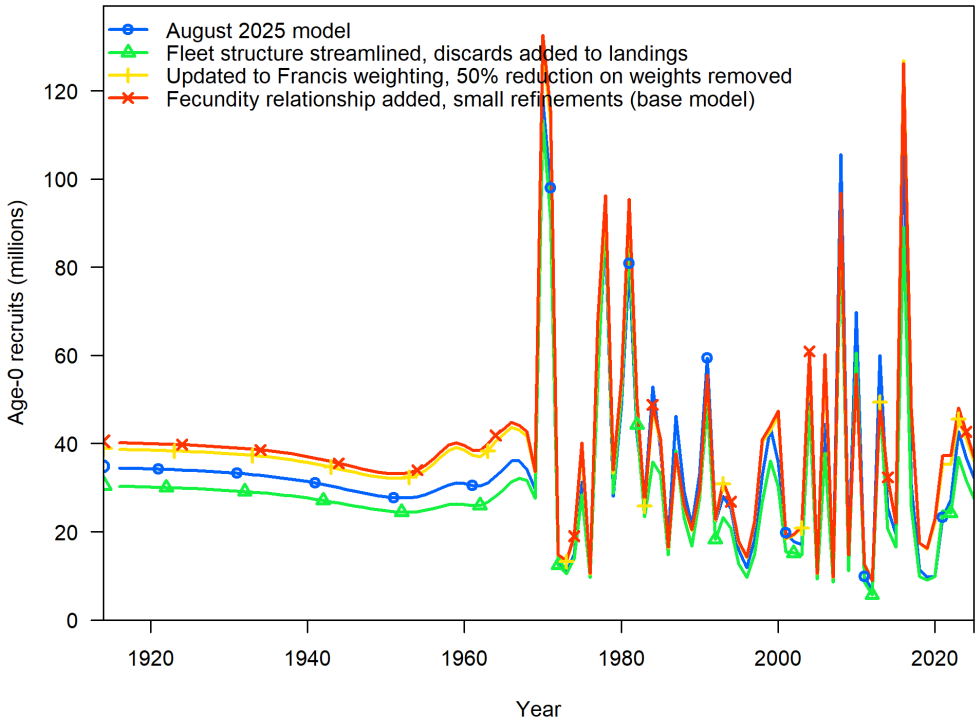



Figure 28: Time series of estimated recruitment from model runs bridging from the August 2025 model (blue) to the base model (red).

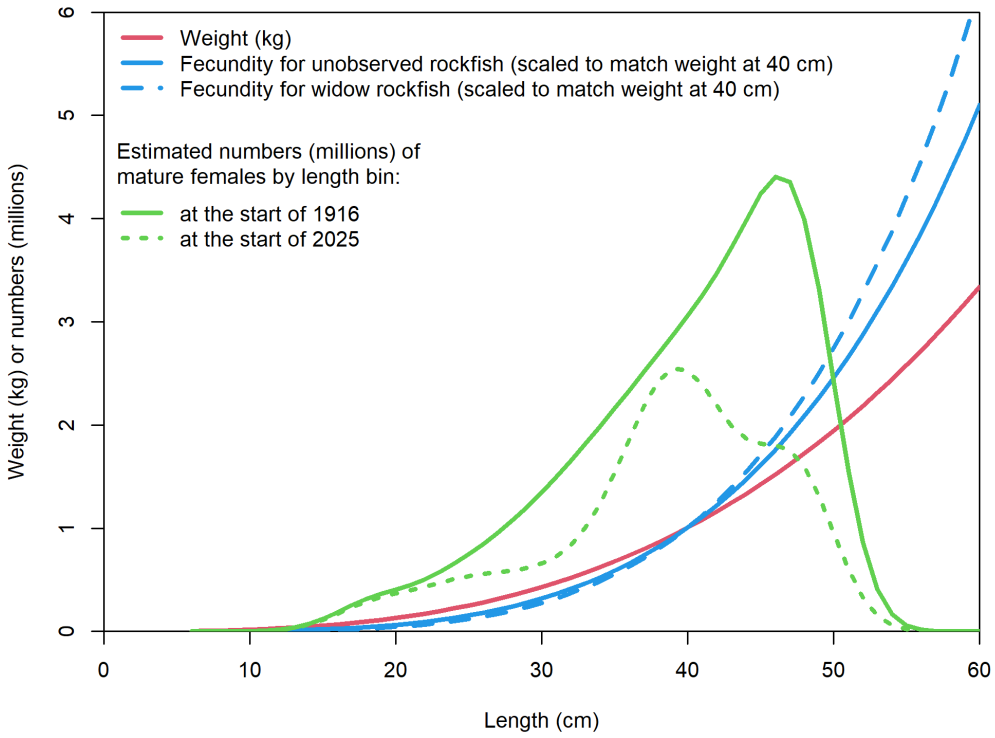



Figure 29: Two fecundity-at-length relationships (blue) are contrasted with weight-at-length for females (red), along with the mature numbers at length at the start and end of the base model (green). The exponent of the weight-at-length curve is 2.987 compared to 4.043 for the unobserved rockfish fecundity (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.

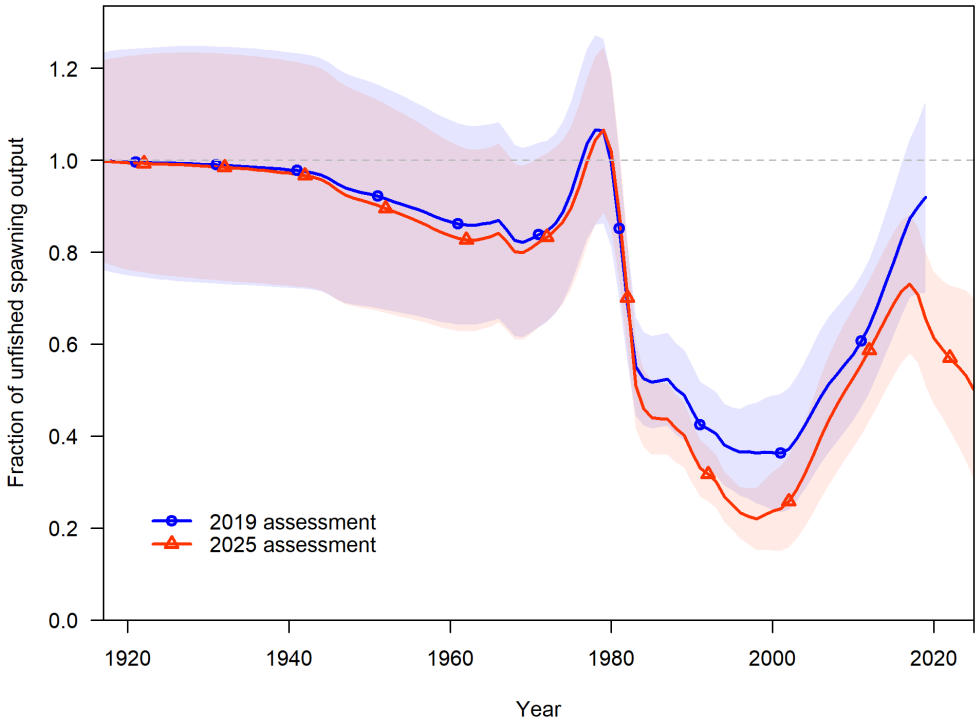



Figure 30: Time series of fraction of unfished spawning output estimates and asymptotic 95% confidence intervals estimates from 2019 and 2025 base models.

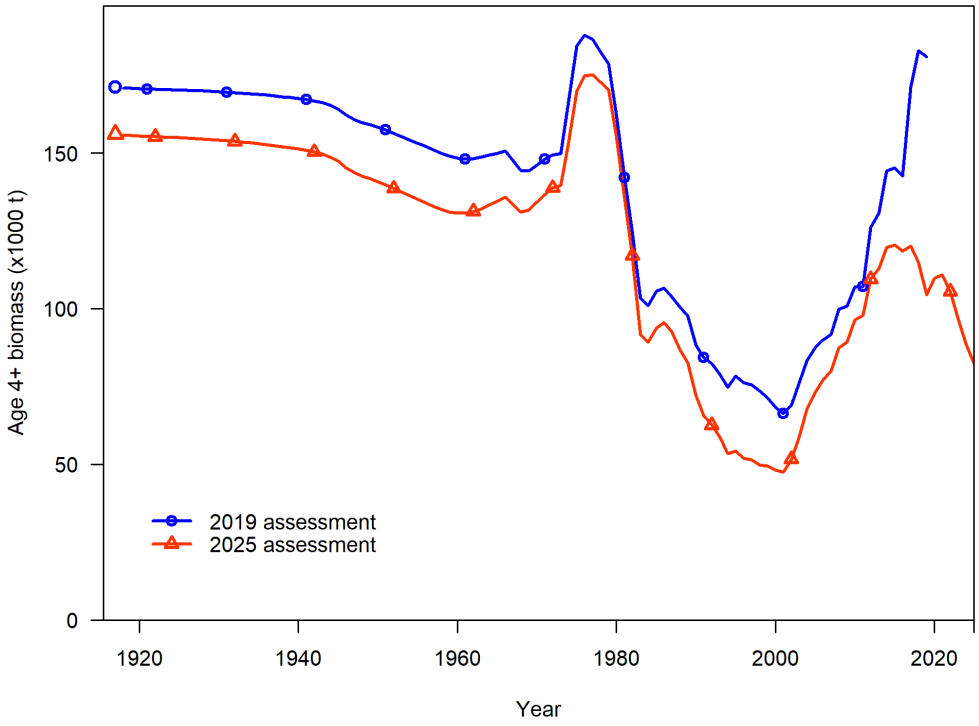



Figure 31: Time series of age 4+ biomass from the 2019 and 2025 base models.

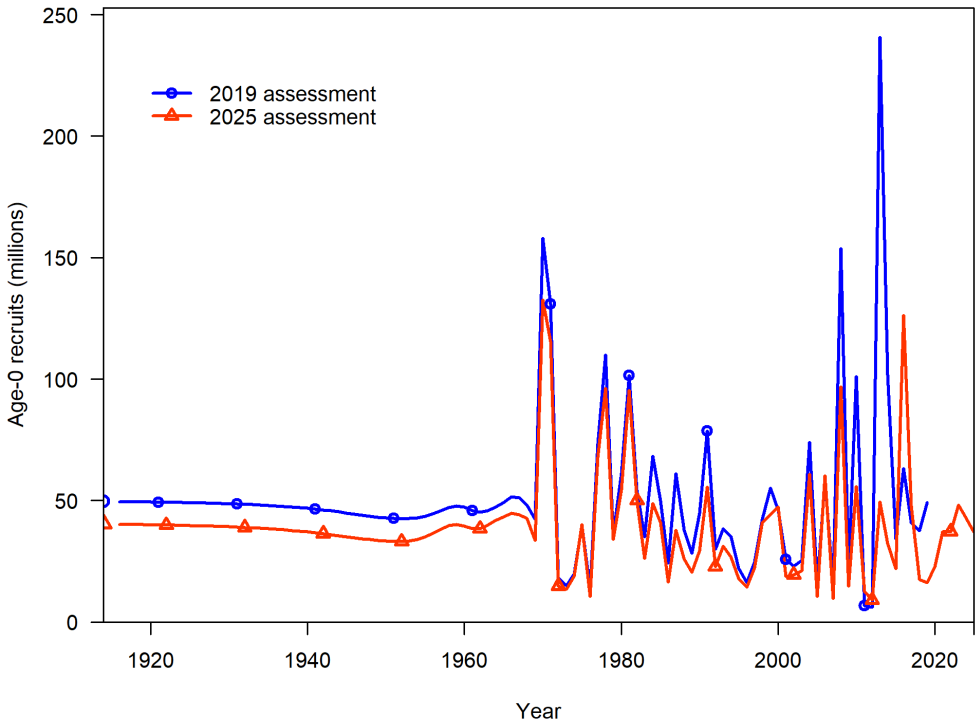



Figure 32: Estimates of age-0 recruits (in millions of individuals) from 2019 and 2025 base models.

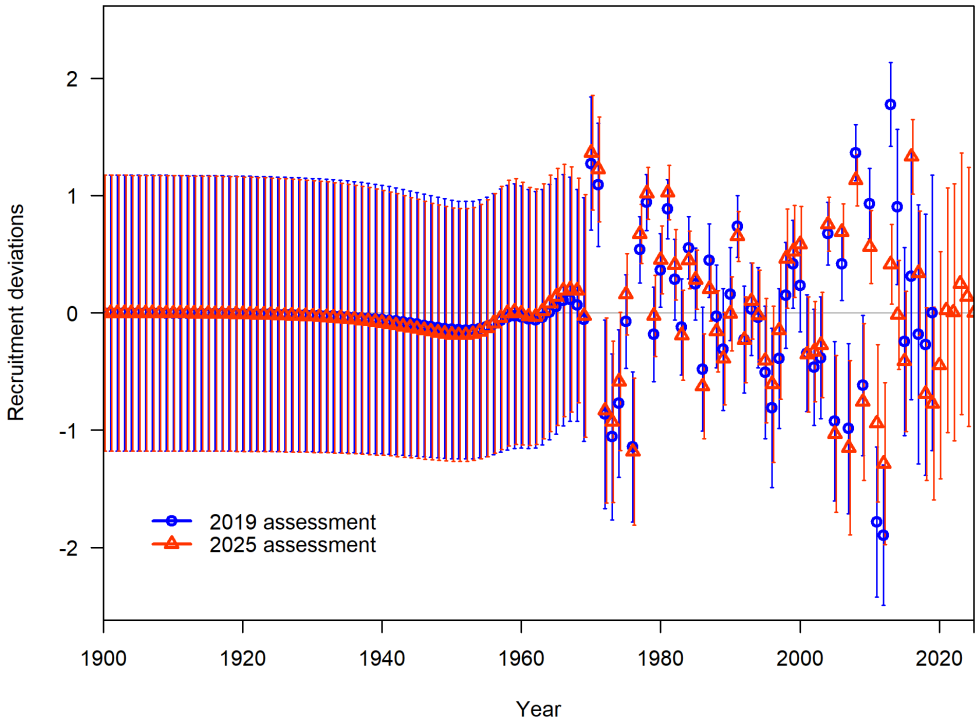



Figure 33: Estimates of age-0 (log-)recruitment deviations from 2019 and 2025 base models, with asymptotic 95% confidence intervals.

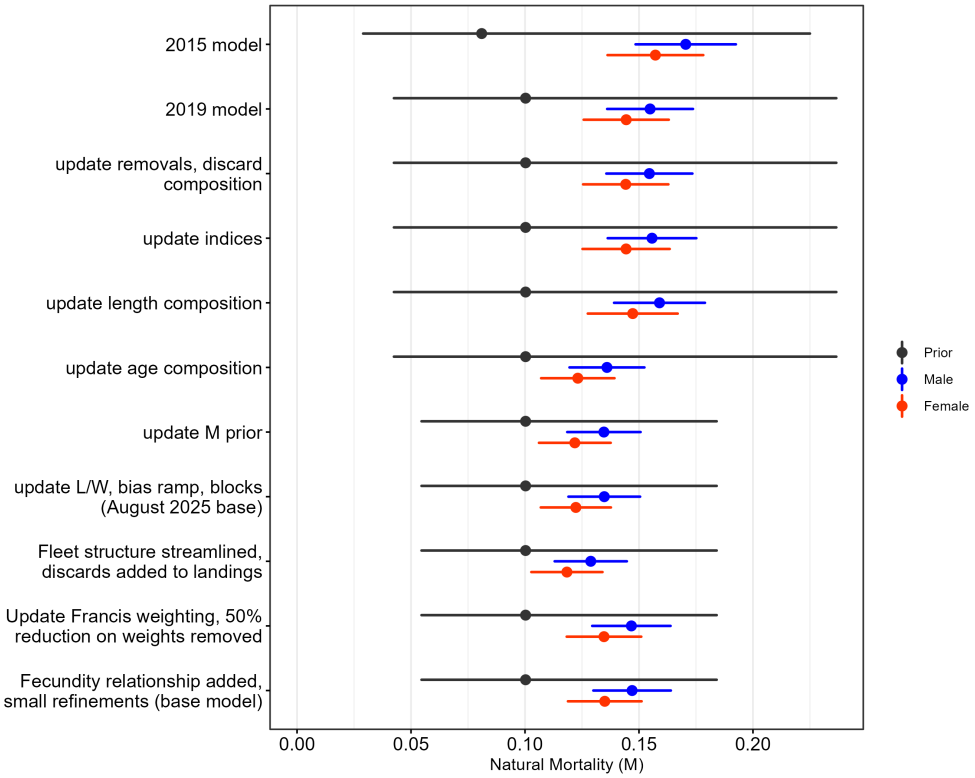



Figure 34: The prior for natural mortality (grey) and the estimated M for females (red) and males (blue) from the 2015 base model, 2019 base model, and selected intermediate models bridging to the base model. Prior 95% quantiles are based on the assumed lognormal distribution. Depicted bridging models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

### 6.2.2 Selectivity

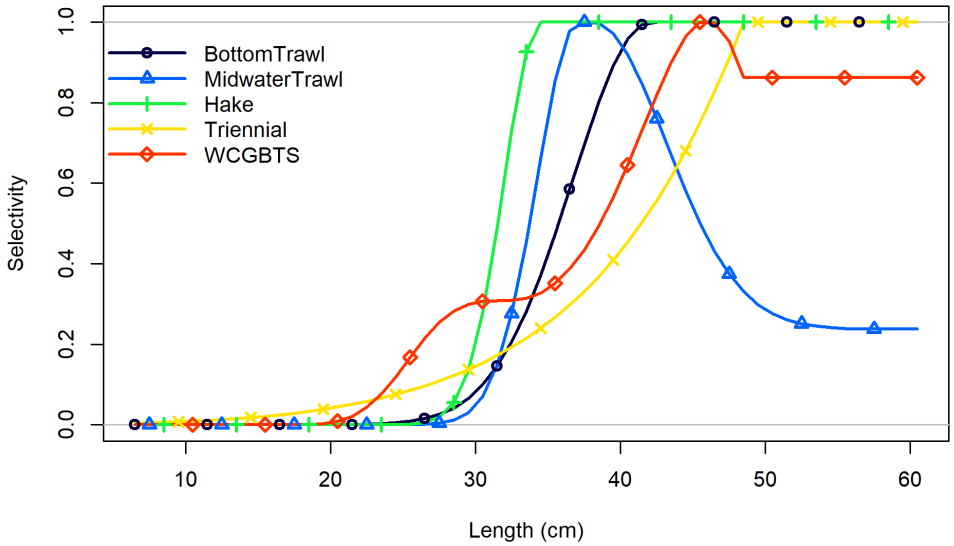



Figure 35: Estimated selectivity for different fleets and surveys.

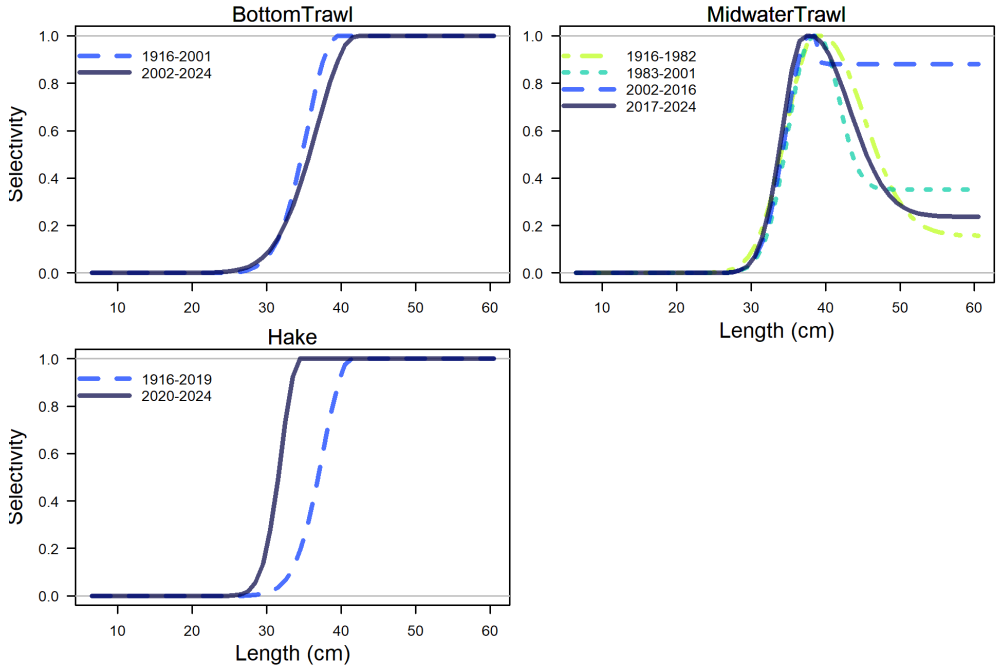



Figure 36: Estimated selectivity curves by time block for bottom trawl, midwater trawl, and hake fleets.

### 6.2.3 Biology

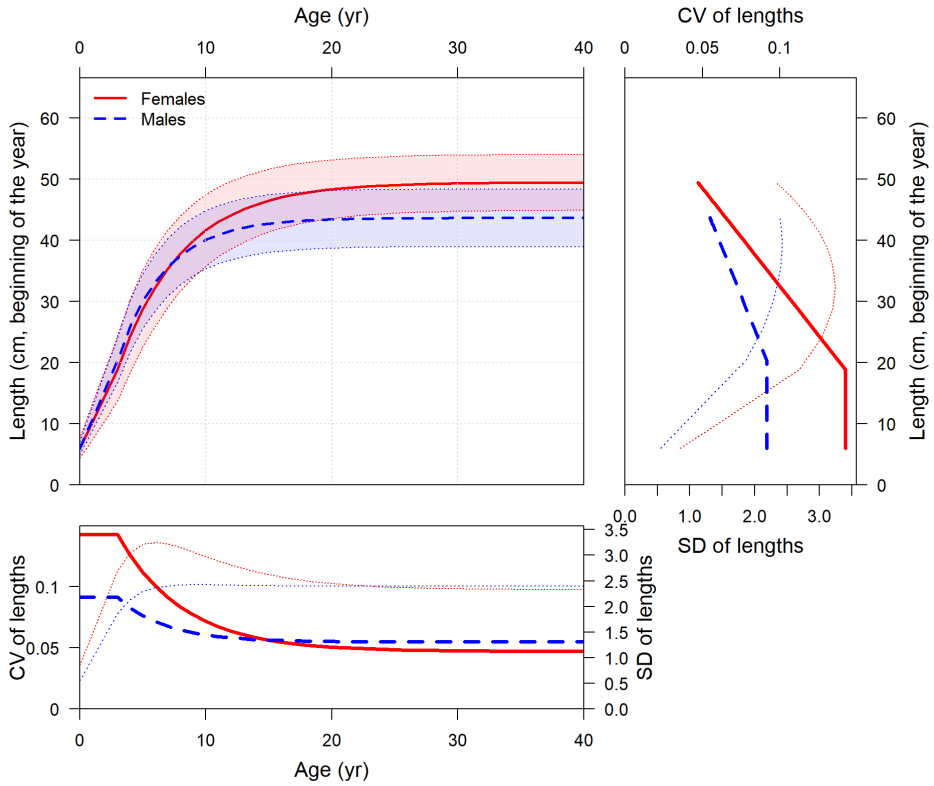



Figure 37: Length at age (top-left panel) with estimated coefficient of variation (CV, thick line) and calculated standard deviation (SD, thin line) versus length at age in the top-right panel and versus age in the lower-left panel.

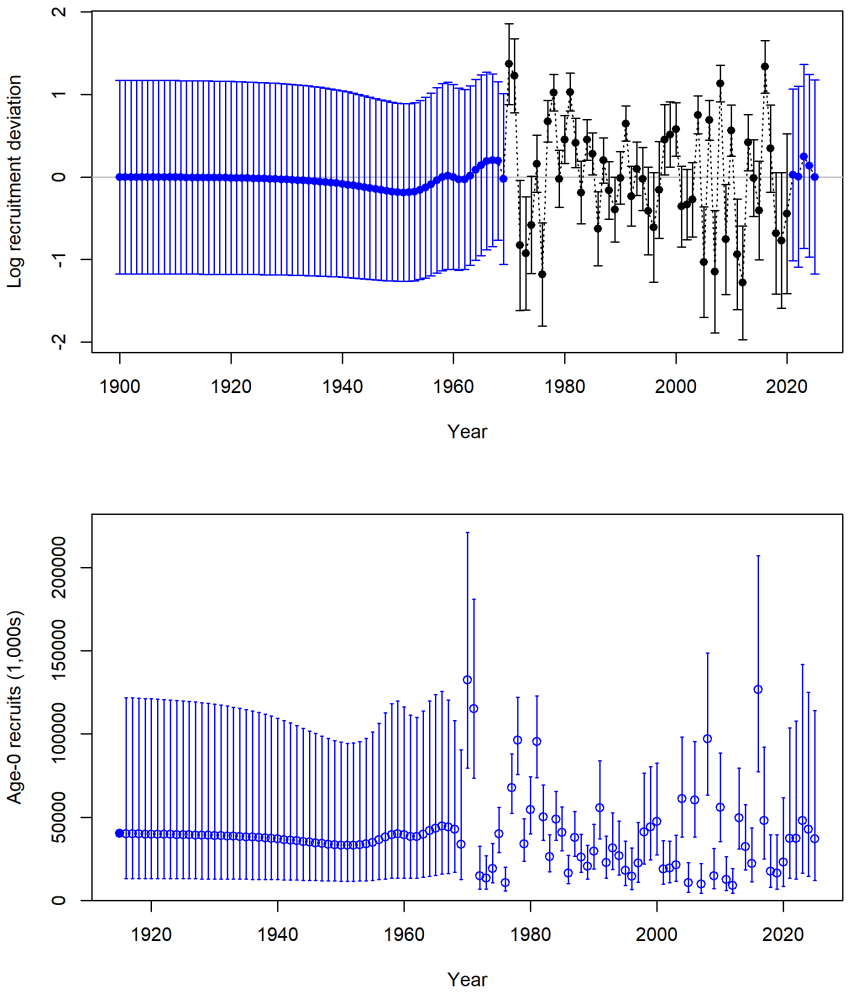



Figure 38: Estimates of recruitment (upper) and recruitment deviates (lower) with approximate asymptotic 95% confidence intervals (vertical lines) from the MLE estimates.

### 6.2.4 Fits to data

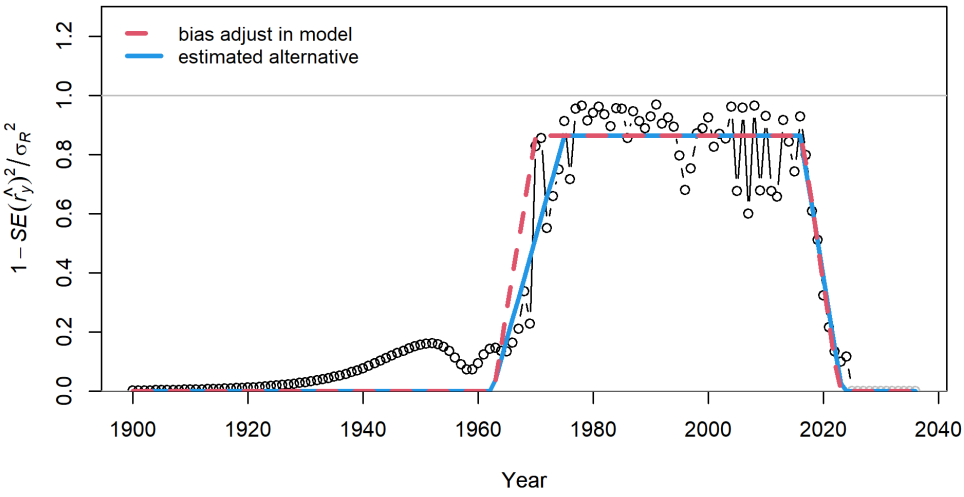



Figure 39: Estimated and input recruitment bias adjustment ramp. Red line shows current settings for bias adjustment ramp. Red line shows current settings for bias adjustment specified in the model. Blue line shows least squares estimate of alternative bias adjustment relationship for recruitment deviations.

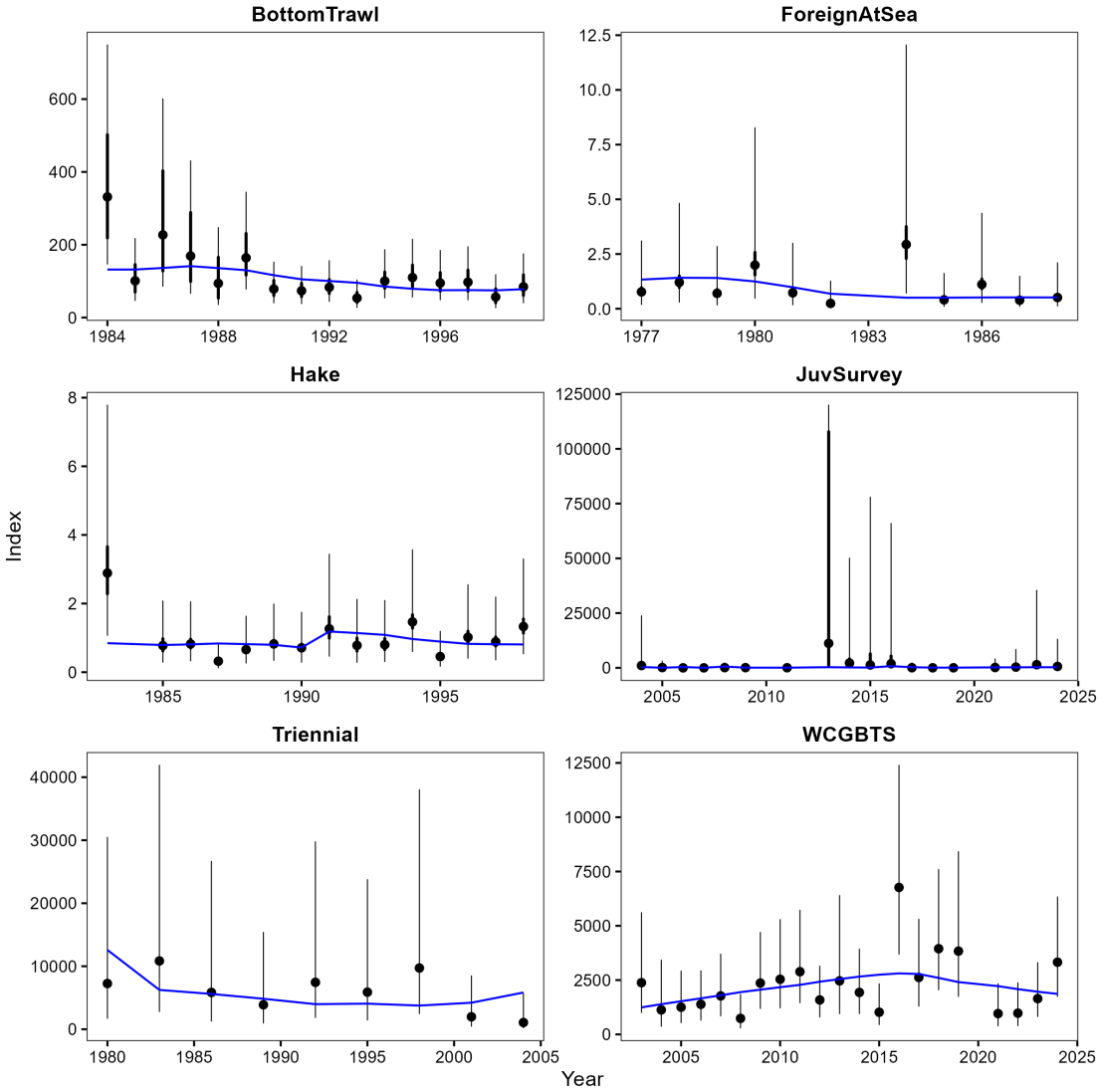



Figure 40: Fits (blue lines) to the abundance estimates (black points) for the base model. A separate q is estimated for the Hake series starting in 1991. Except the juvenile survey (counts) all indices are biomass-based. 95% confidence intervals are shown assuming a normal distribution of the log-estimates. 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.

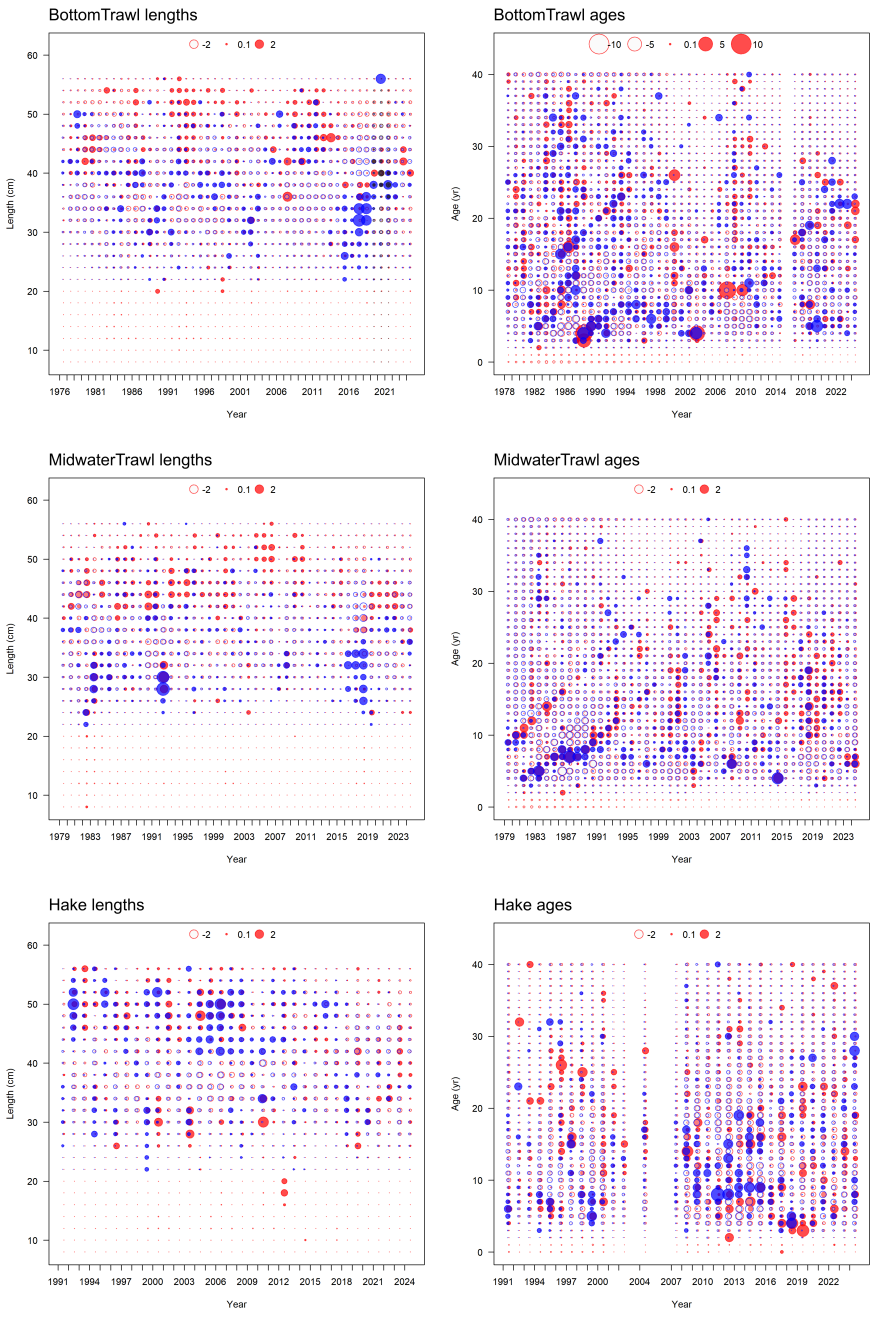



Figure 41: Pearson residuals for fits to length frequency data (left) and age frequency data (right) for landings from the trawl commercial fleets (rows). Filled circles indicate that the fitted proportion was less than the observed proportion. Red indicates females, blue males, and gray unsexed.

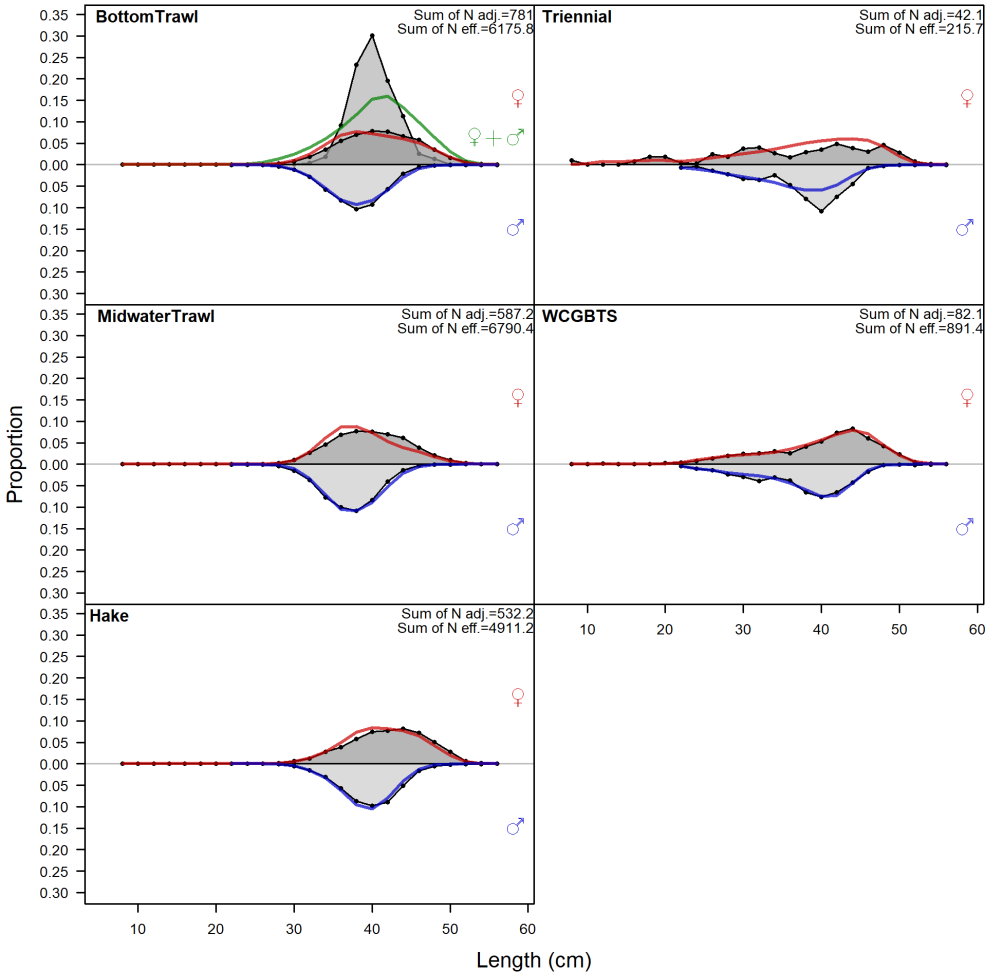



Figure 42: Combined length frequencies for all years from fishery (retained catch) and survey length frequency data (points). Fits are shown by the red line (females) and blue line (males).

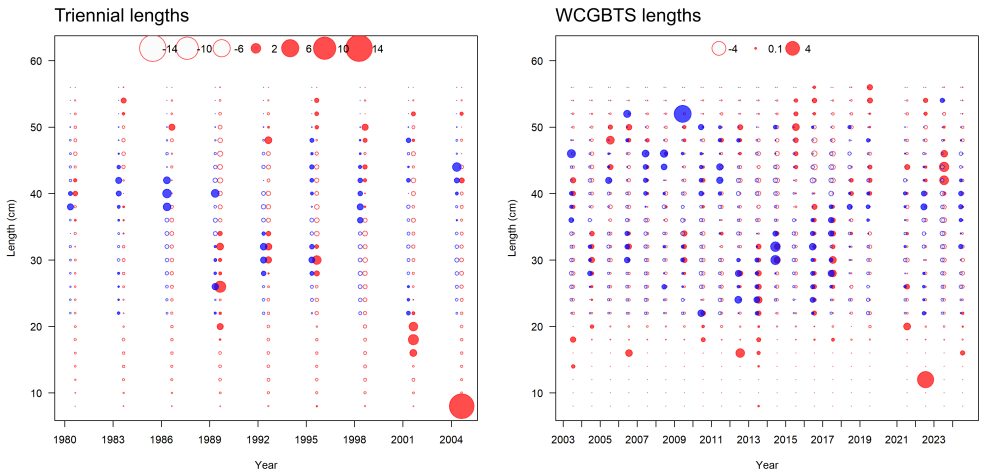



Figure 43: Pearson residuals for fits to the triennial survey length frequency data (left) and WCGBTS length frequency data (right). Filled circles indicate that the fitted proportion was less than the observed proportion. Red indicates females, blue males, and gray unsexed.

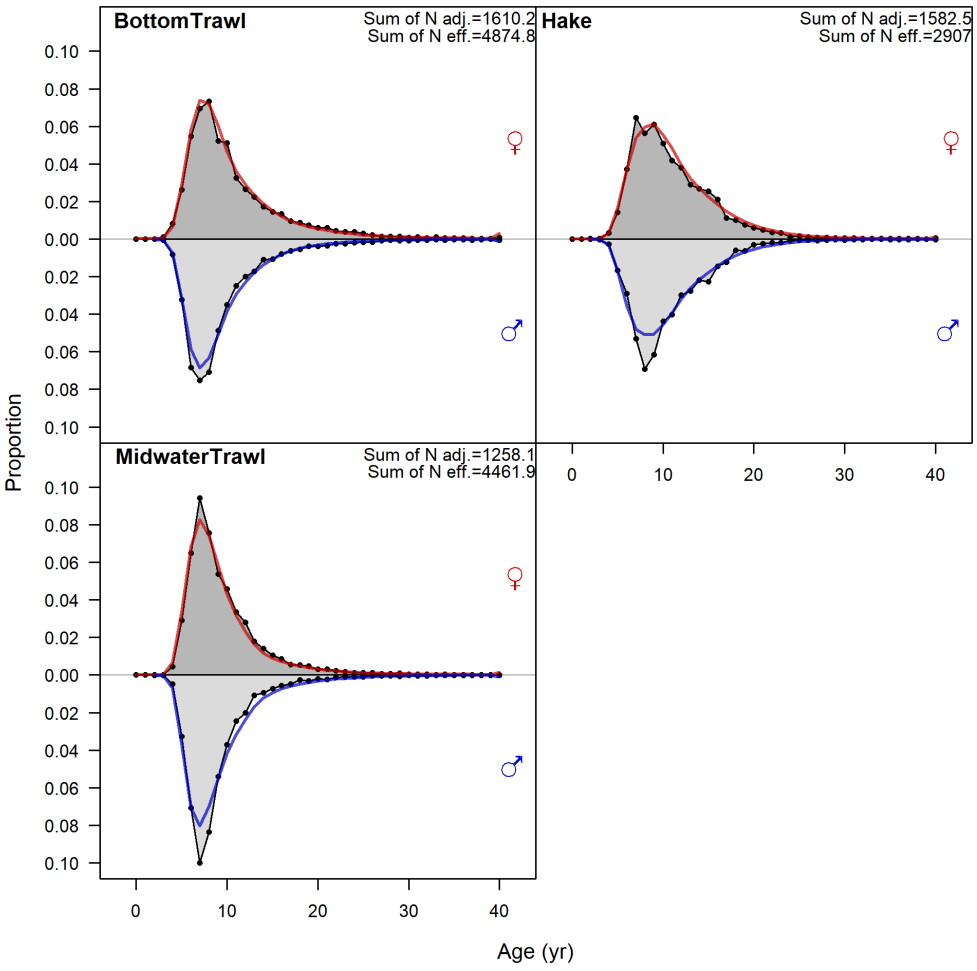



Figure 44: Combined age frequencies for all years from fishery (retained catch) and survey length frequency data (points). Fits are shown by the red line (females) and blue line (males).

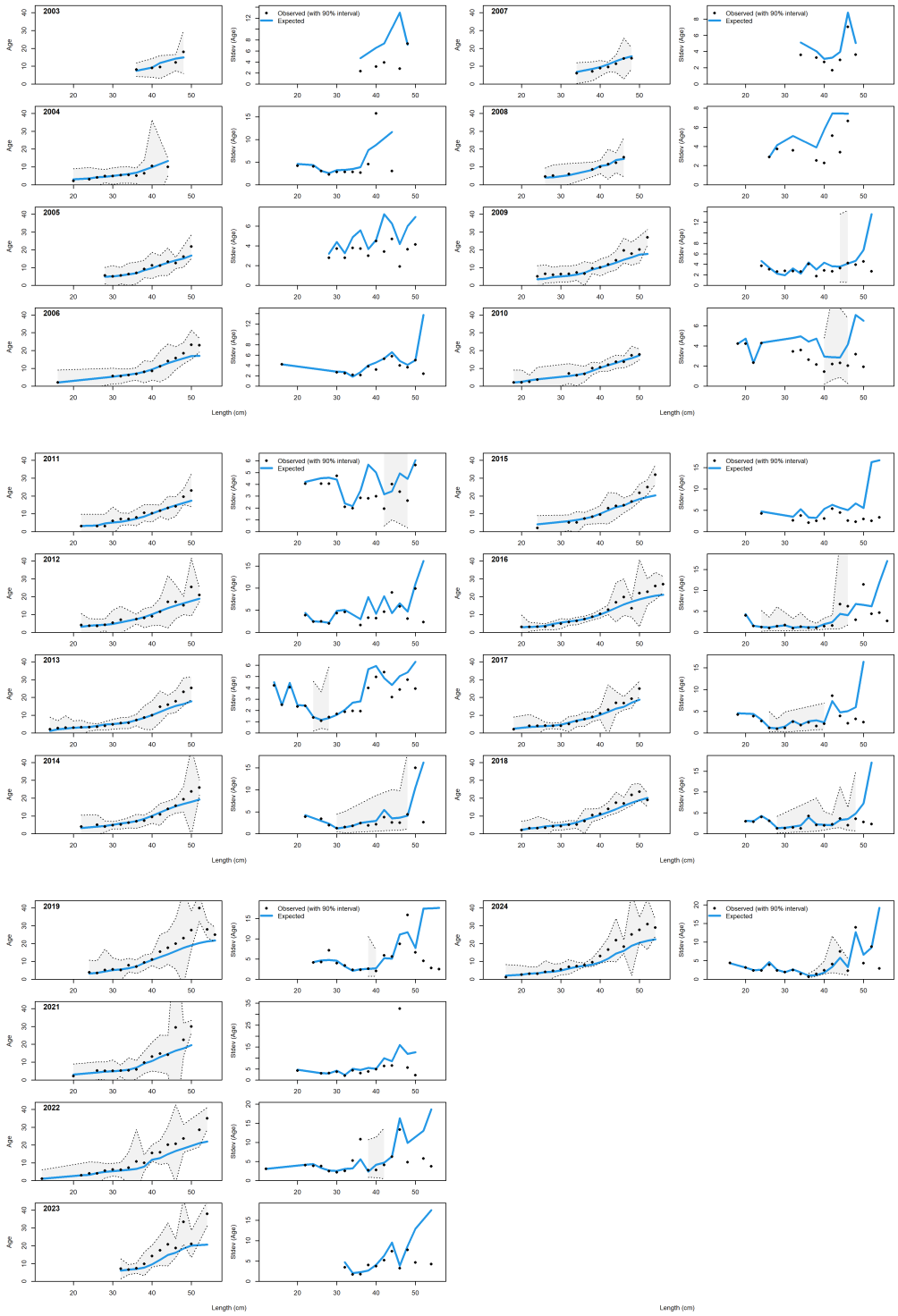



Figure 45: Observed and expected age-at-length with 95% confidence intervals (left) and observed and expected standard deviation of age-at-length with 95% confidence intervals (right) for the WCGBTS.

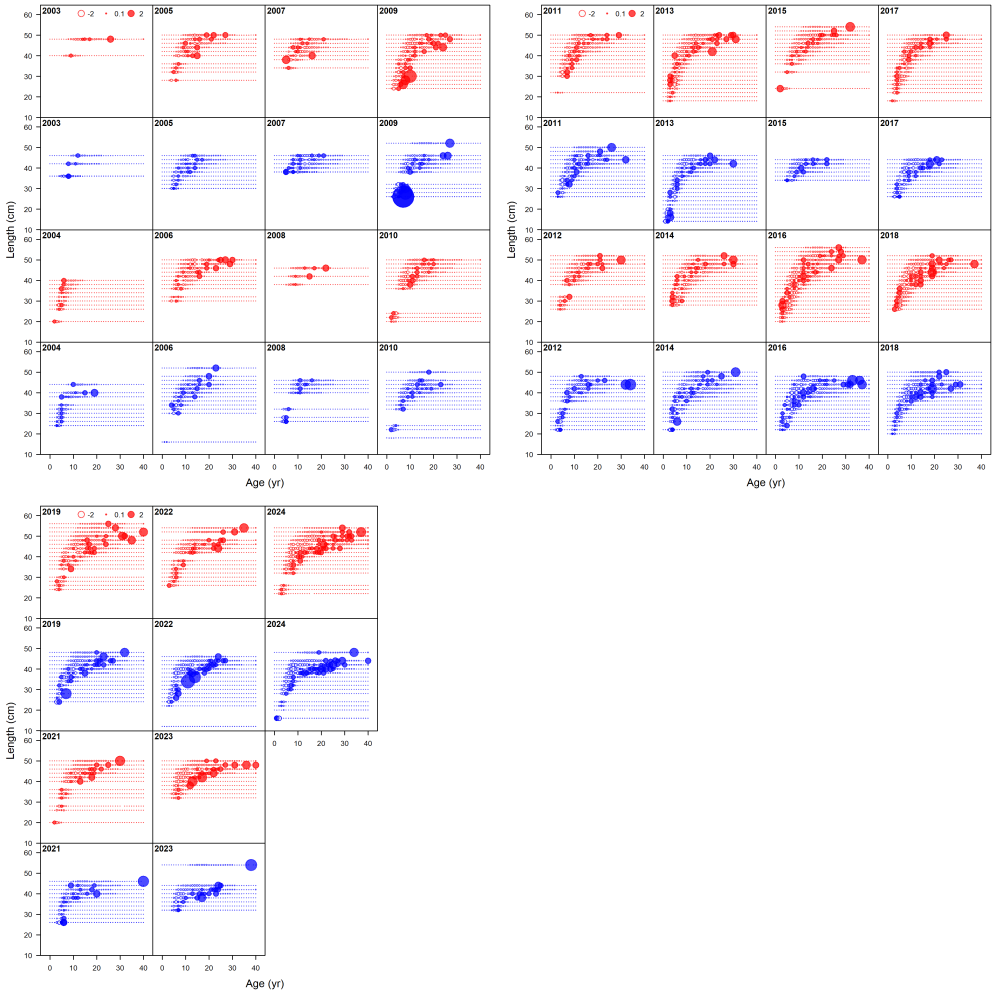



Figure 46: Combined age and length frequency data for all years from fishery (retained catch) and survey length frequency data (points) for females (red) and males (blue).

### 6.2.5 Time series

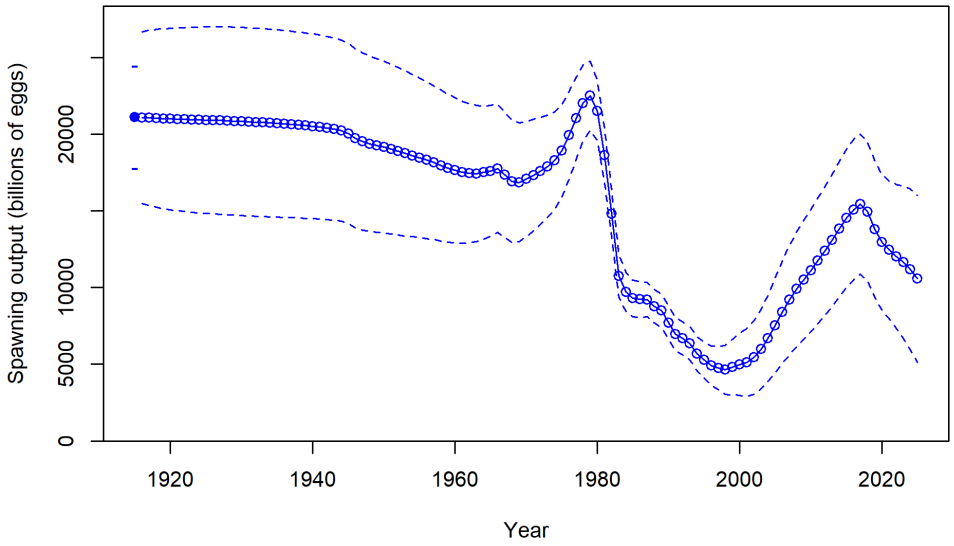



Figure 47: Predicted spawning output (billions of eggs) for widow rockfish using the base model. The solid line is the MLE estimate, and the dashed lines depict the approximate asymptotic 95% confidence intervals.

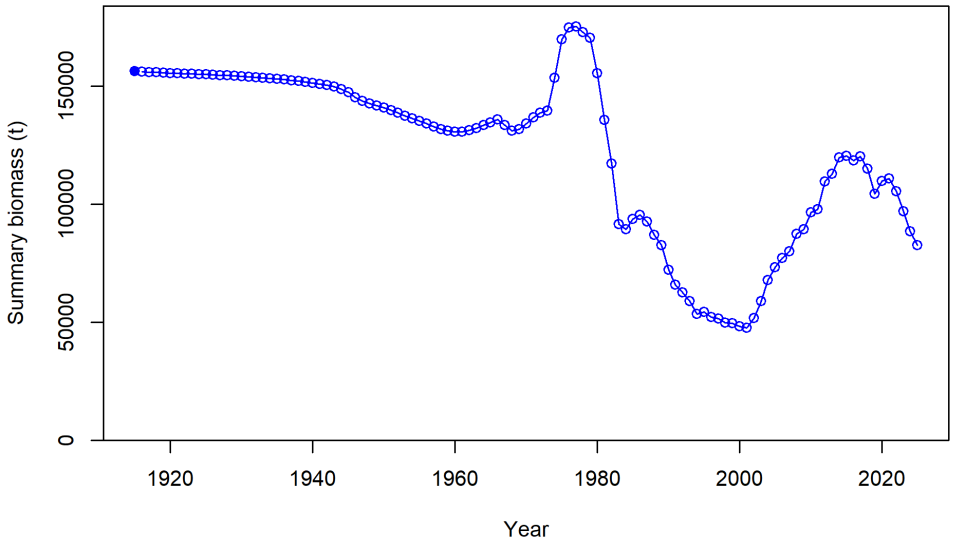



Figure 48: Predicted summary biomass (age 4+) from the base model.

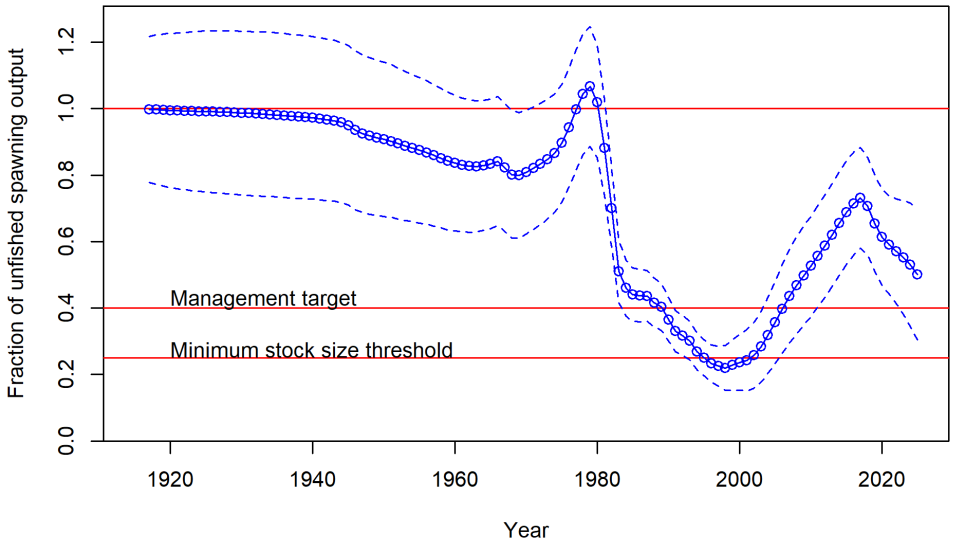



Figure 49: Predicted relative spawning output from the widow rockfish base model. The solid blue line is the MLE estimate, and the dashed lines depict the approximate asymptotic 95% confidence intervals. The red lines show the equilibrium level (100%), the management target of 40% of unfished biomass,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

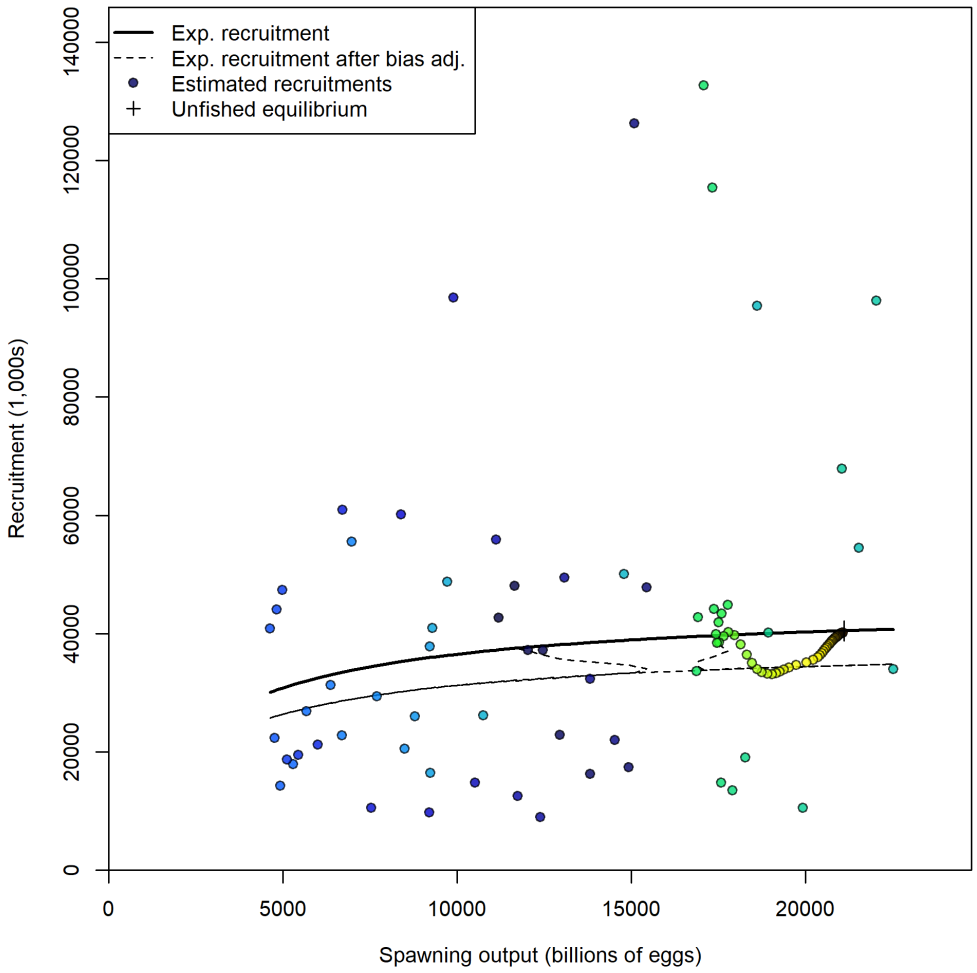



Figure 50: Estimated recruitment and the assumed stock-recruit relationship (black line). The dashed line shows the effect of the bias correction for the lognormal distribution.

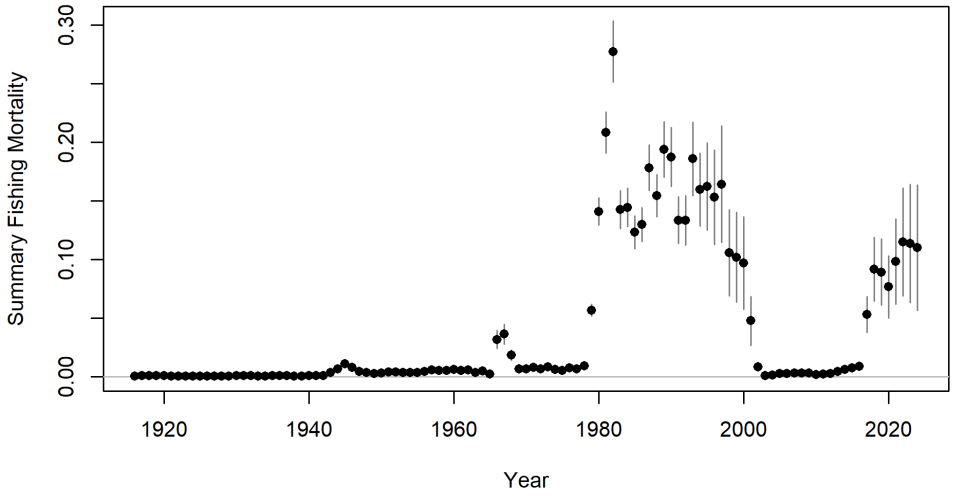



Figure 51: Plot of the summary fishing mortality for each year of the model with 95% confidence intervals.

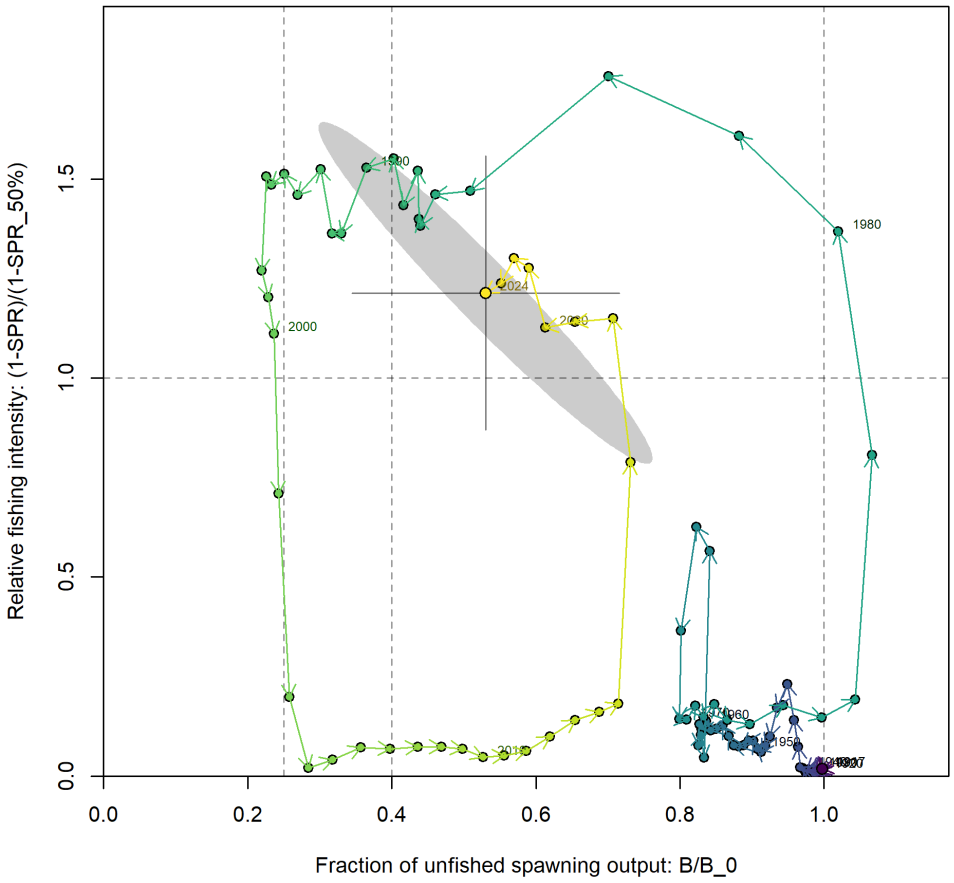



Figure 52: Phase plot of relative fishing intensity (1-SPR)/(1-SPR_50%) (y-axis) and fraction unfished spawning output (x-axis) for widow rockfish.

## 6.3 Model Diagnostics

### 6.3.1 Sensitivity analyses

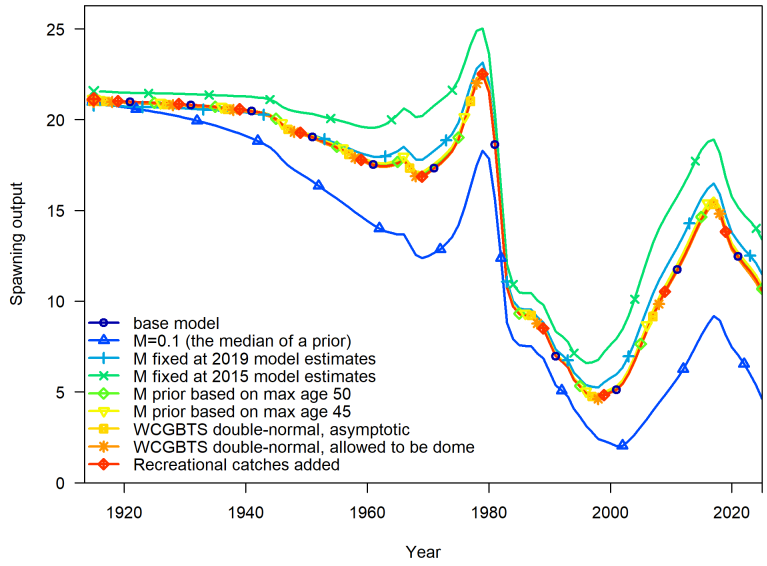



Figure 53: Spawning output (with 95% confidence interval around the base model) for the base model and sensitivity runs.

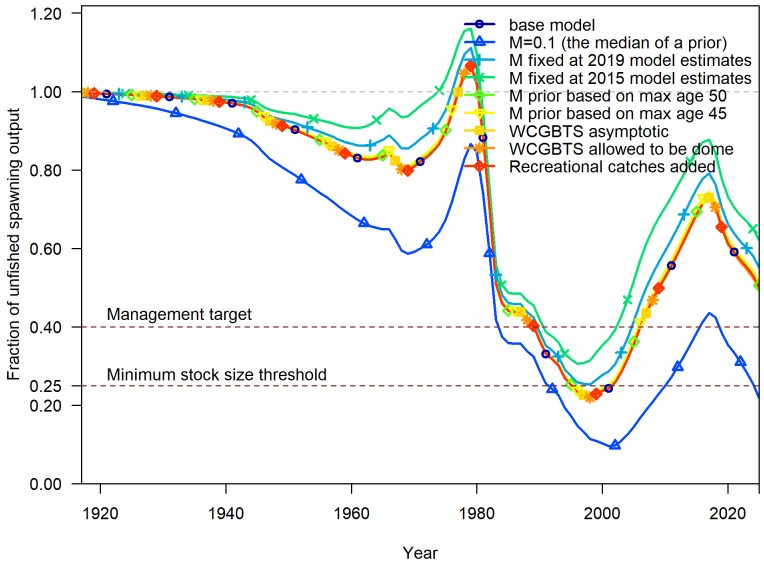



Figure 54: Comparison of fraction unfished for the base model and sensitivity runs.

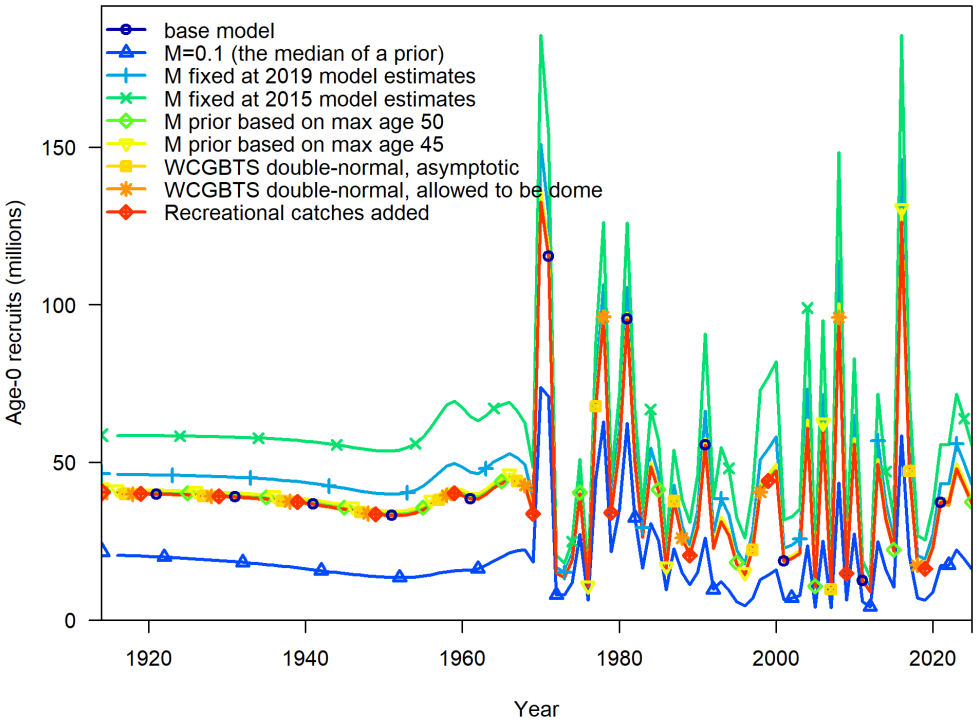



Figure 55: Estimates of recruitment for base model and sensitivity models.

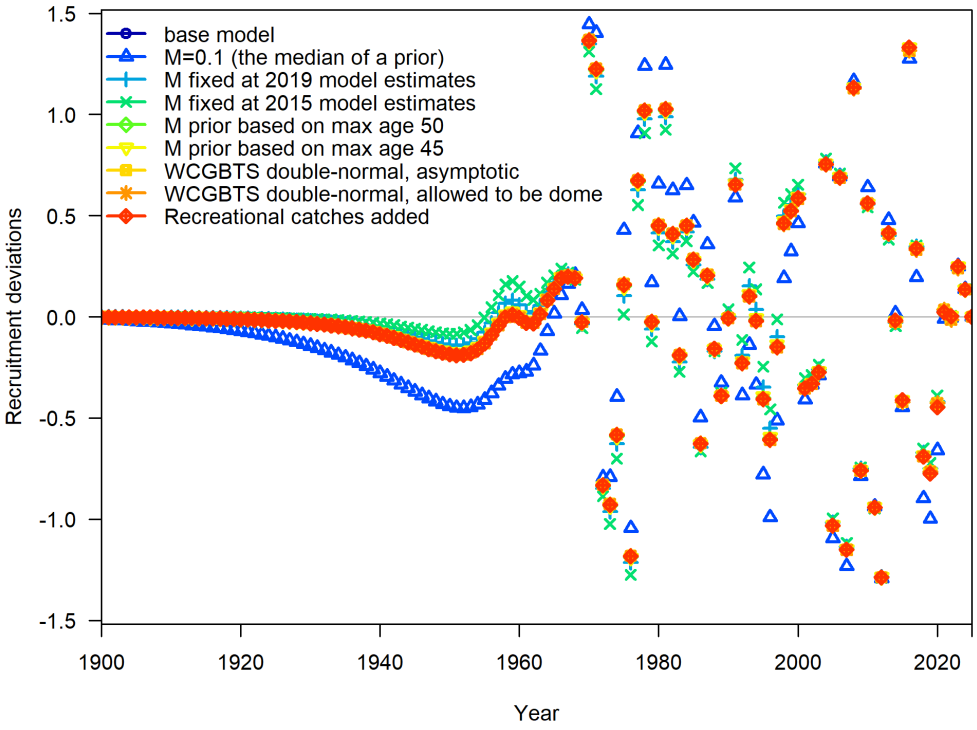



Figure 56: Estimates of recruitment deviations for base model and sensitivity models.

### 6.3.2 Retrospective analysis

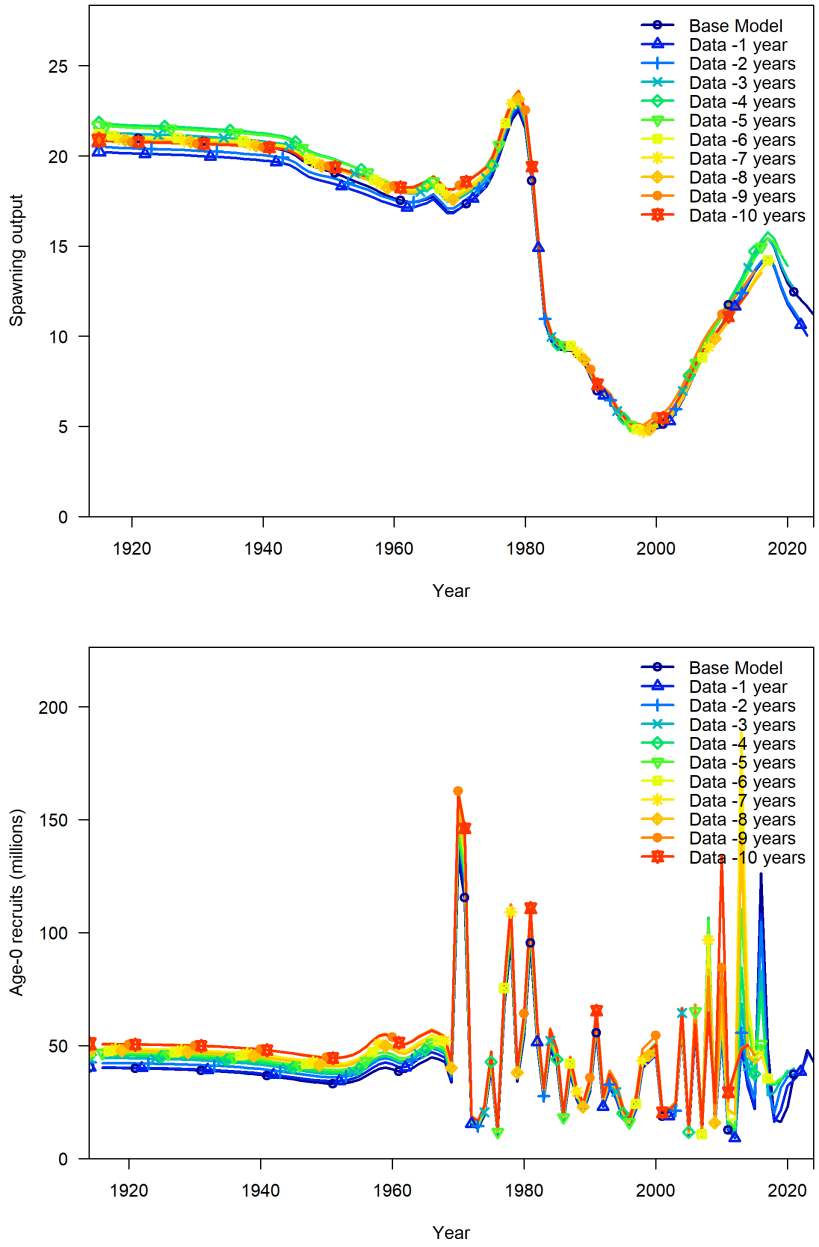



Figure 57: Ten-year retrospective estimates of spawning output (top) and recruitment deviations (bottom).

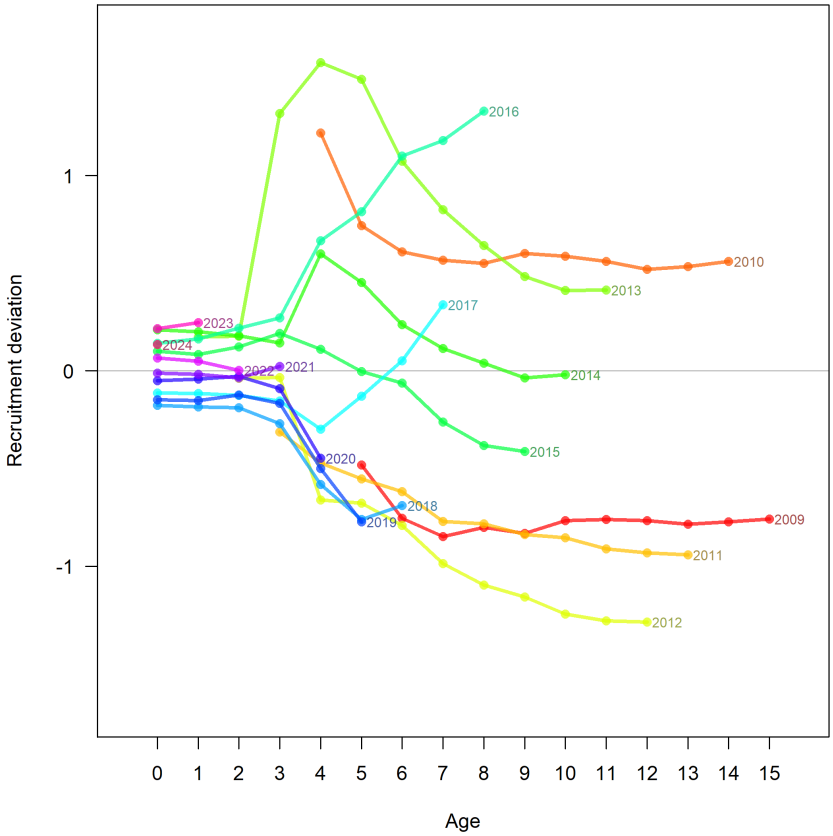



Figure 58: Retrospective analysis of recruitment deviations over the last 10 years. Lines represent estimated recruitment deviations for cohorts born from 2009 to 2024, with cohort birth year marked at the right of each color-coded line. For example, the right-most point for the 2016 cohort shows the 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.

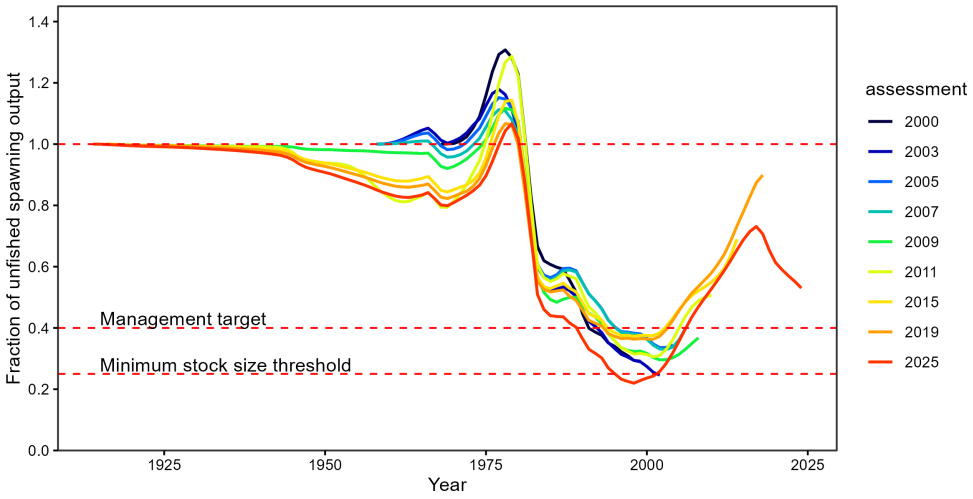



Figure 59: Estimated fraction of unfished spawning output from past assessments in comparison with the current assessment. The units of spawning output differ among assessments but the ratio remains comparable.

### 6.3.3 Likelihood profiles

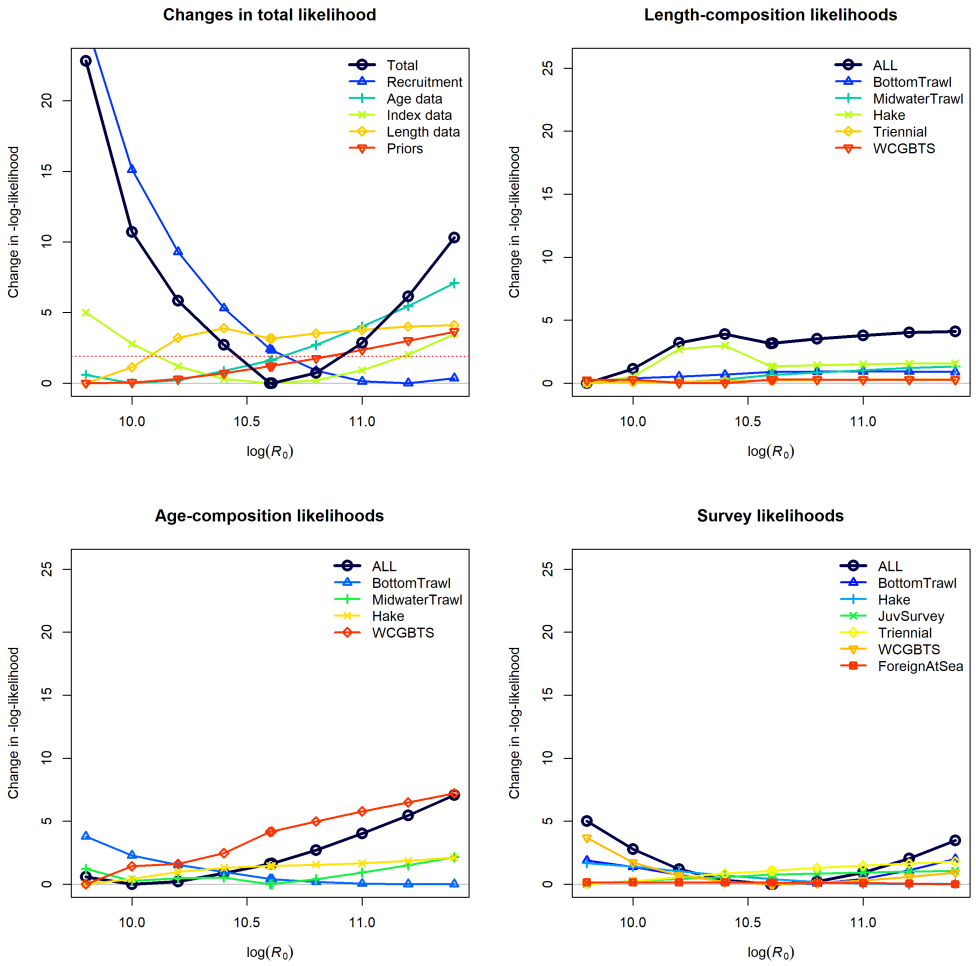



Figure 60: Likelihood components in the likelihood profile for unfished equilibrium recruitment ($R_0$)

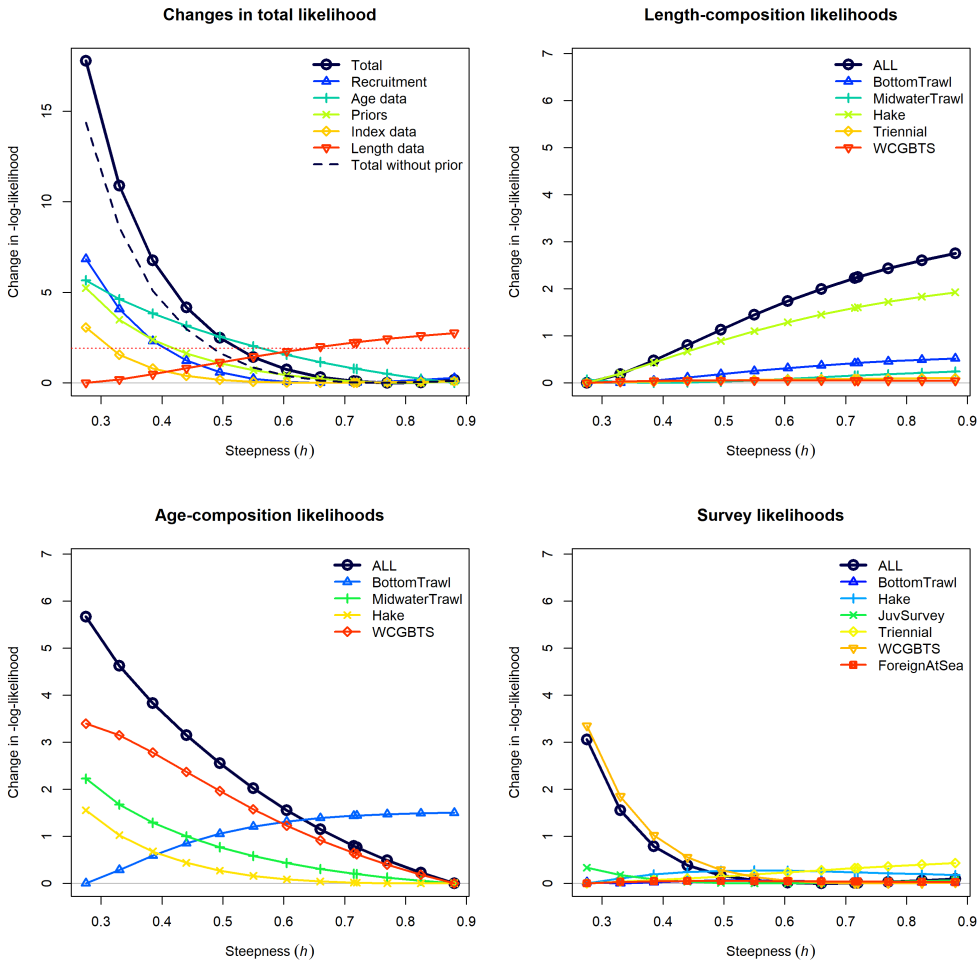



Figure 61: Likelihood components in the likelihood profile for steepness ($h$).

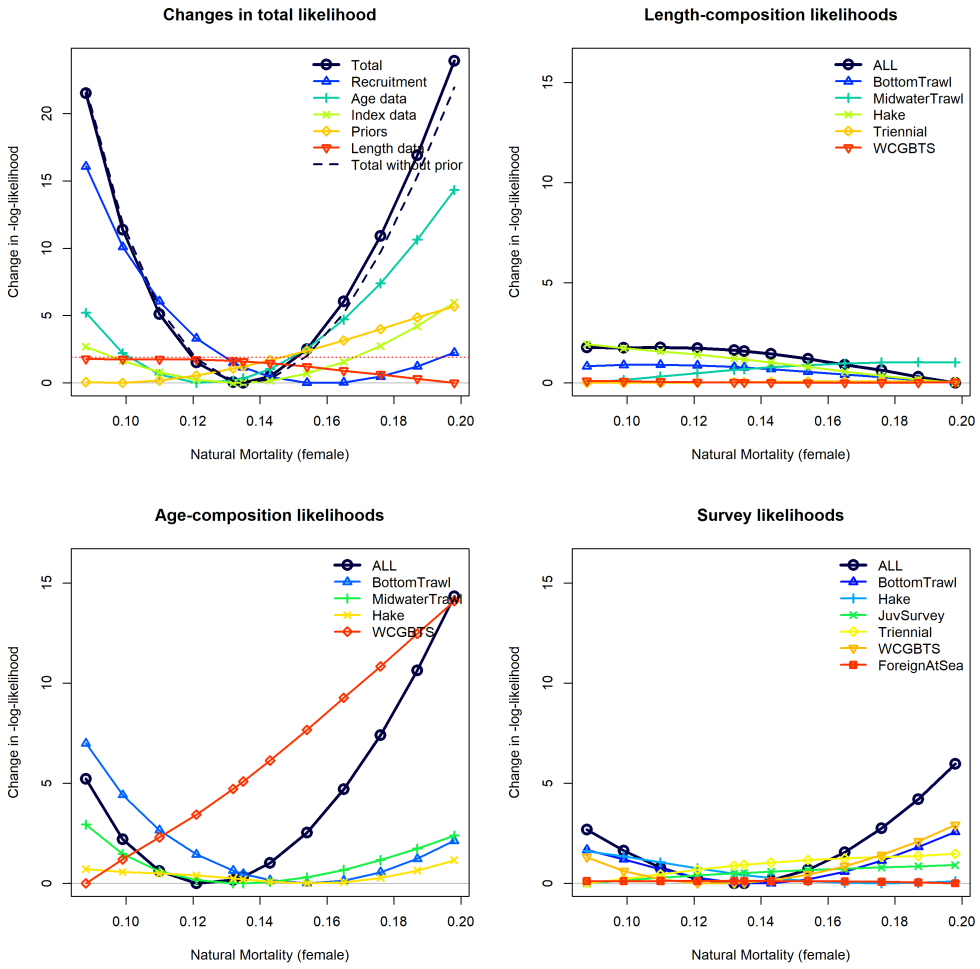



Figure 62: Likelihood components in the likelihood profile for female natural mortality ($M$). Male natural mortality are set to the same value.

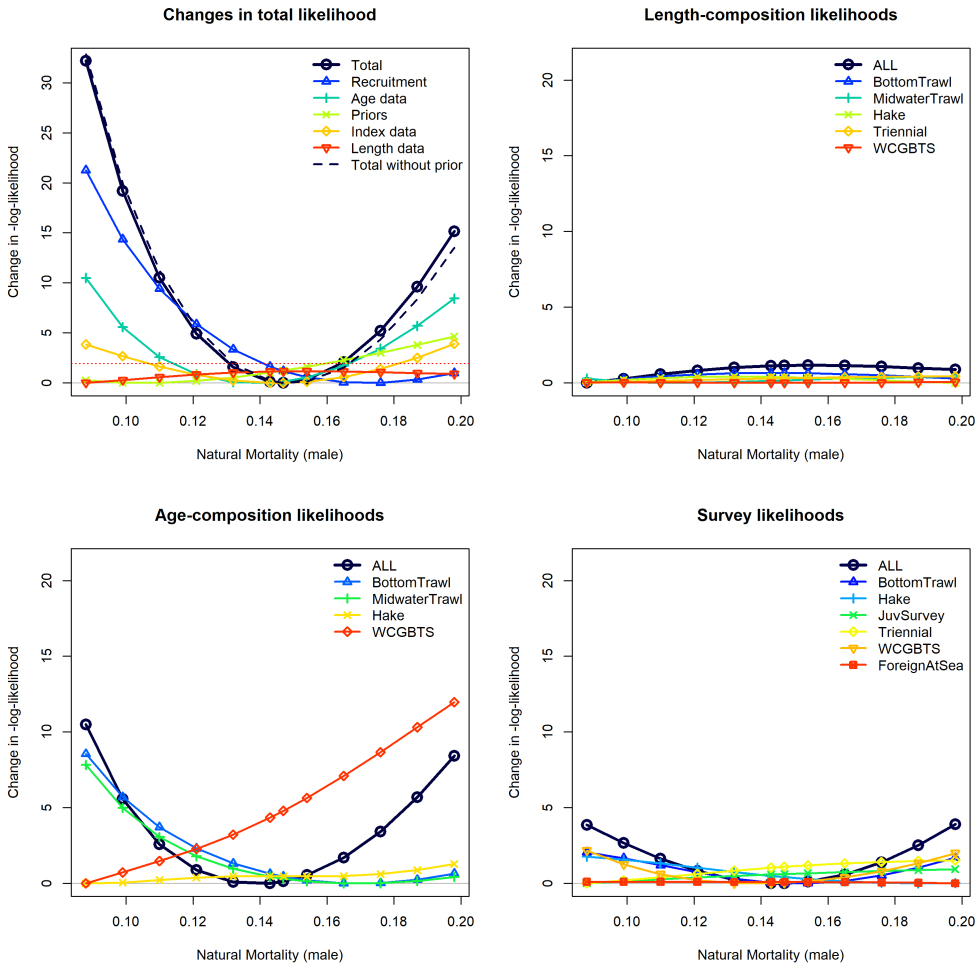



Figure 63: Likelihood components in the likelihood profile for male natural mortality ($M$). Female natural mortality is set to the same value.

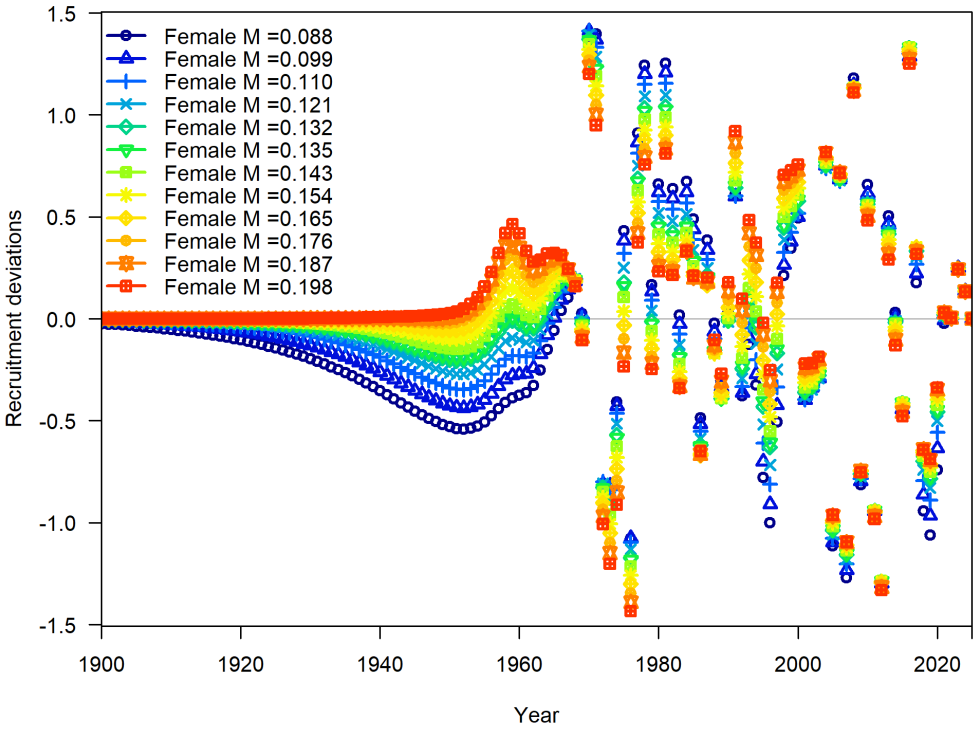



Figure 64: Time series of recruitment deviations for models with different fixed values of natural mortality ($M$). The base model has $M = 0.135$.

### 6.4 Management

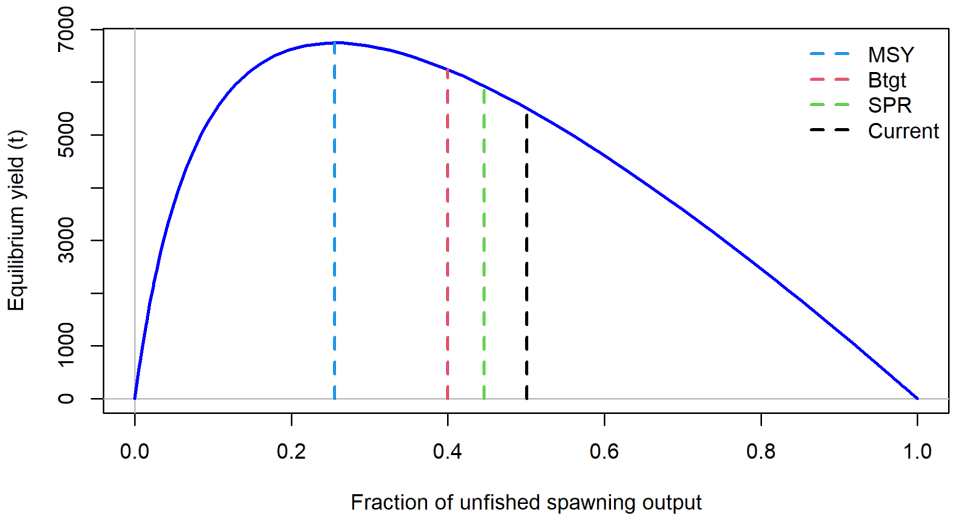



Figure 65: Estimated plot of equilibrium yield vs the fraction of unfished biomass.

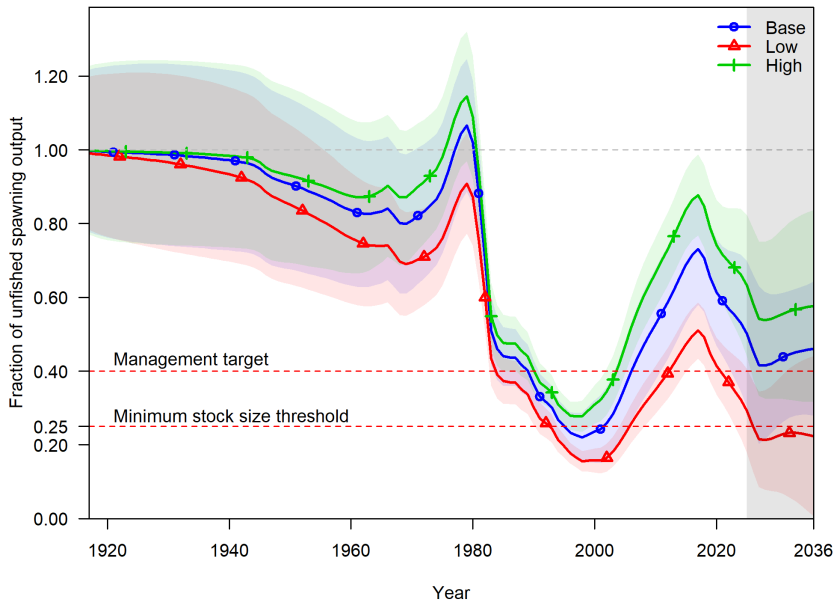



Figure 66: Base model, low state of nature, and high state of nature spawning output trajectories under the default catch scenarios: ACL = p*0.45 for 2027 to 2036. The shaded areas indicate the 12.5% and 87.5% lognormal quantiles of spawning biomass.

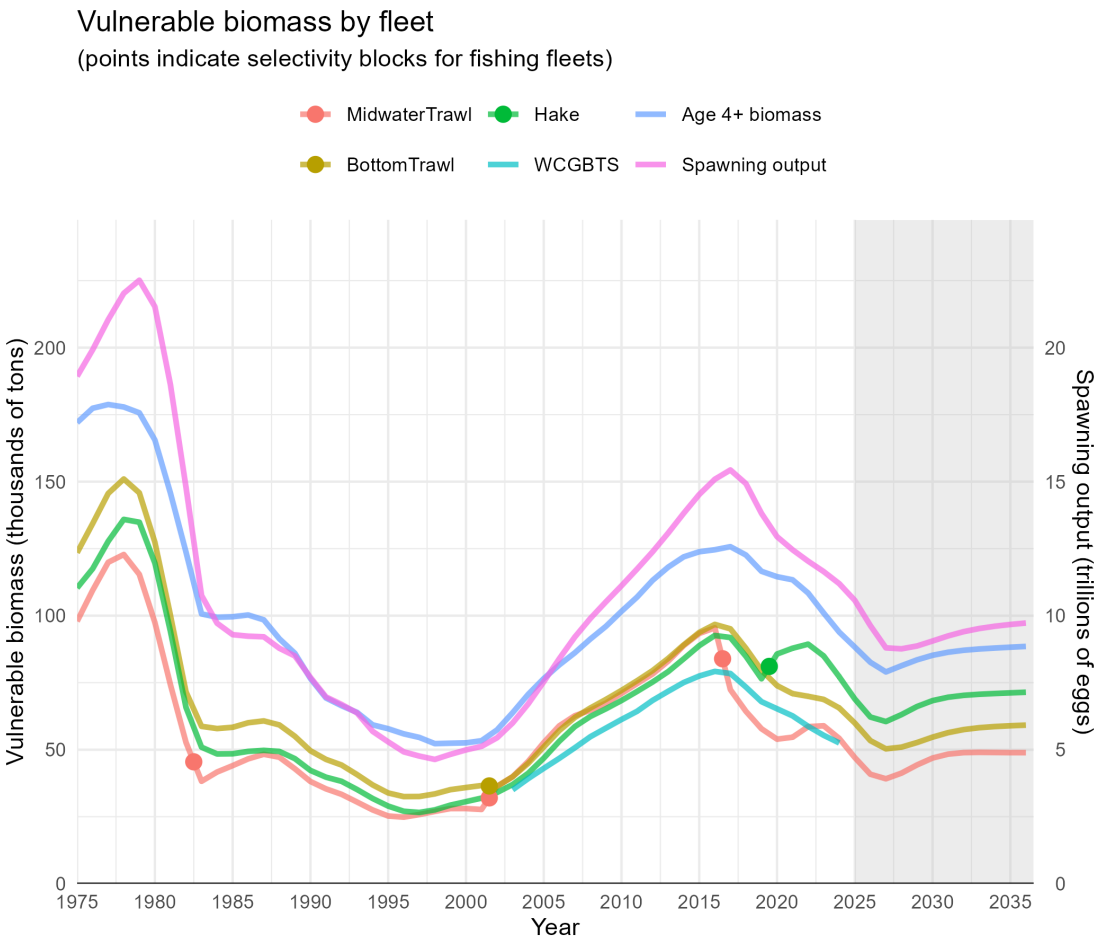



Figure 67: Estimated vulnerable biomass for each of the three fishing fleets along with the model expected values of WCGBTS vulnerable biomass (for the range of years of the survey), age 4+ biomass, and spawning output.

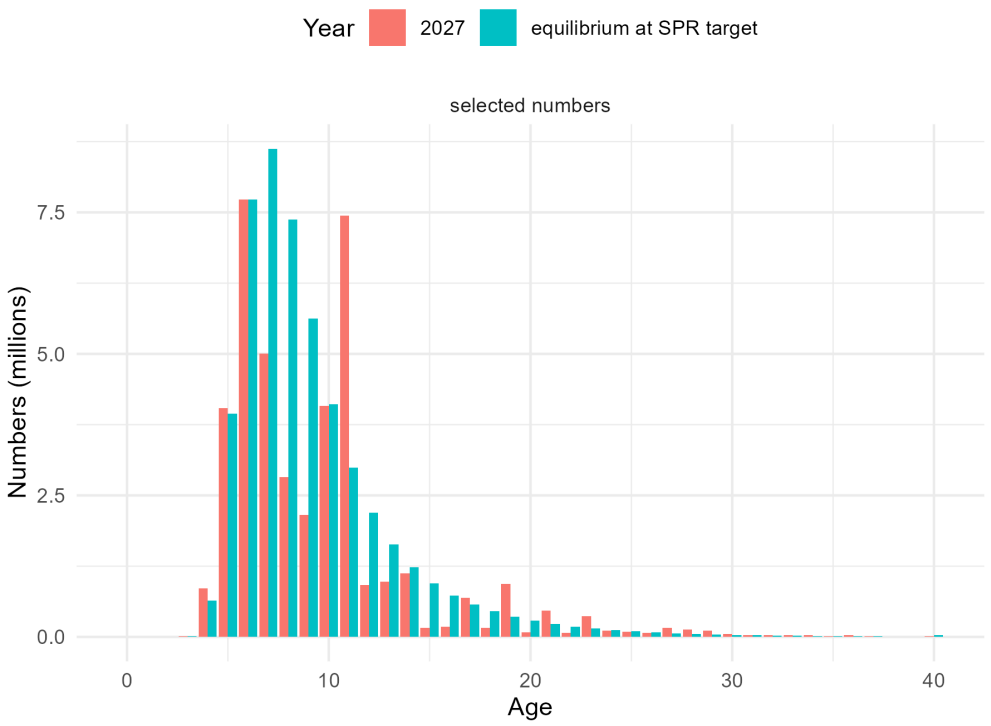



Figure 68: Projected selected numbers-at-age for the midwater trawl fishery in 2027 (red) and at the equilibrium associated with the SPR target (blue).

# 7 References

Adams, G., Kapur, M., McQuaw, K., Hamel, O., Stephens, A., and Wetzel, C. 2019. Status of Widow Rockfish (Sebastes entomelas) Along the U.S. West Coast in 2019. Pacific Fishery Management Council, Portland, Oregon.

Anderson, S.C., Ward, E.J., English, P.A., and Barnett, L.A. 2022. sdmTMB: An R package for fast, flexible, and user-friendly generalized linear mixed effects models with spatial and spatiotemporal random fields. BioRxiv: 2022–03.

Barss, W., and Echeverria, T.W. 1987. Maturity of widow rockfish Sebastes entomelas from the northeastern Pacific, 1977-82. pp. 13–18.

Dick, E., Beyer, S., Mangel, M., and Ralston, S. 2017. A meta-analysis of fecundity in rockfishes (genus sebastes). Fisheries Research **187**: 73–85. Elsevier.

Douglas, D.A., and others. 1998. Species composition of rockfish in catches by oregon trawlers, 1963-93.

Fournier, D.A., Skaug, H.J., Ancheta, J., Ianelli, J., Magnusson, A., Maunder, M.N., Nielsen, A., and Sibert, J. 2012. AD Model Builder: Using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software **27**(2): 233–249.

Francis, R.C. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences **68**(6): 1124–1138.

Gunderson, D.R. 1984. The great widow rockfish hunt of 1980-1982. North American Journal of Fisheries Management **4**(4B): 465–468. Taylor & Francis.

Hamel, O.S. 2015. A method for calculating a meta-analytical prior for the natural mortality rate using multiple life history correlates. ICES Journal of Marine Science **72**(1): 62–69.

Hamel, O.S., and Cope, J.M. 2022. Development and considerations for application of a longevity-based prior for the natural mortality rate. Fisheries Research **256**: 106477.

He, X., Pearson, D., Dick, E.J., Field, J., Ralston, S., and MacCall, A. 2011. Status of the widow rockfish resource in 2011. Pacific Fishery Management Council, Portland, OR.

Helser, T.E., Punt, A.E., and Methot, R.D. 2004. A generalized linear mixed model analysis of a multi-vessel fishery resource survey. Fisheries Research **70**(2-3): 251–264.

Hicks, A., and Wetzel, C. 2015. The Status of Widow Rockfish (Sebastes entomelas) Along the U.S. West Coast in 2015. Pacific Fishery Management Council, Portland, OR.

Holland, D.S., and Martin, C. 2019. Bycatch quotas, risk pools, and cooperation in the Pacific whiting fishery. Frontiers in Marine Science **6**: 600.

Jones, W.G., and Harry Jr, G.Y. 1960. The oregon trawl fishery for mink food 1948-1957. Fish Commission of Oregon Research Briefs **8**: 14–30.

Keller, A.A., Wallace, J.R., and Methot, R.D. 2017. The northwest fisheries science center's west coast groundfish bottom trawl survey: History, design, and description. NOAA Technical Memorandum NMFS NOAA-TM-NMFS-NWFSC-136: 38 pp.

McAllister, M.K., and Ianelli, J.N. 1997. Bayesian stock assessment using catch-age data and the sampling-importance resampling algorithm. Canadian Journal of Fisheries and Aquatic Sciences **54**(2): 284–300.

Methot, R.D., and Taylor, I.G. 2011. Adjusting for bias due to variability of estimated

recruitments in fishery assessment models. Canadian Journal of Fisheries and Aquatic Sciences **68**(10): 1744–1760.

NMFS. 2017. Magnuson-Stevens Act Provisions; Fisheries Off West Coast States; Pacific Coast Groundfish Fishery; Widow Rockfish Reallocation in the Individual Fishing Quota Fishery.

Pikitch, E.K., Erickson, D.L., and Wallace, J.R. 1988. An evaluation of the effectiveness of trip limits as a management tool.

Punt, A.E. 2017. Some insights into data weighting in integrated stock assessments. Fisheries Research **192**: 52–65.

Rogers, J.B. 2003. Species allocation of sebastes and sebastolobus sp. Caught by foreign countries from 1965 through 1976 off washington, oregon, and california, USA.

Sampson, D.B., and Lee, Y.-W. 2002. Evaluating the accuracy of trawl logbook estimates of groundfish discards. *In* International institute of fisheries economics and trade.

Stewart, I.J., and Hamel, O.S. 2014. Bootstrapping of sample sizes for length-or age-composition data used in stock assessments. Canadian journal of fisheries and aquatic sciences **71**(4): 581–588.

Taylor, I.G., Doering, K.L., Johnson, K.F., Wetzel, C.R., and Stewart, I.J. 2021. Beyond visualizing catch-at-age models: Lessons learned from the r4ss package about software to support stock assessments. Fisheries Research **239**: 105924. Available from https://doi.org/10.1016/j.fishres.2021.105924.

Then, A.Y., Hoenig, J.M., Hall, N.G., Hewitt, D.A., and Handling editor: Ernesto Jardim. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science **72**(1): 82–92.

Thorson, J.T., Dorn, M.W., and Hamel, O.S. 2019. Steepness for west coast rockfishes: Results from a twelve-year experiment in iterative regional meta-analysis. Fisheries Research **217**: 11–20. Elsevier.

Thorson, J.T., Shelton, A.O., Ward, E.J., and Skaug, H.J. 2015. Geostatistical delta-generalized linear mixed models improve precision for estimated abundance indices for West Coast groundfishes. ICES Journal of Marine Science **72**(5): 1297–1310.

Thorson, J.T., and Ward, E.J. 2014. Accounting for vessel effects when standardizing catch rates from cooperative surveys. Fisheries Research **155**: 168–176.

Weinberg, J.R., Rago, P.J., Wakefield, W.W., and Keith, C. 2002. Estimation of tow distance and spatial heterogeneity using data from inclinometer sensors: An example using a clam survey dredge. Fisheries Research **55**(1-3): 49–61.

Wetzel, C.R., Johnson, K.F., and Hicks, A.C. 2025. nwfscSurvey: Northwest Fisheries Science Center Survey. Available from https://github.com/pfmc-assessments/nwfscSurvey.

Wilkins, M.E. 1986. Development and evaluation of methodologies for assessing and monitoring the abundance of widow rockfish, sebastes entomelas. Fishery Bulletin **84**(2).

## Acronyms

ABC Acceptable Biological Catch. xv, xvi, 31, 34, 75

ACL annual catch limit. xiv, xv, xvi, 31, 34, 75, 132

Juvenile Survey SWFSC and NWFSC/PWCC Midwater Trawl Survey. iv, 6

NMFS National Marine Fisheries Service. iv, 3

OFL overfishing limit. xv, xvi, 32, 34, 75

**sdmTMB** Species Distribution Models with Template Model Builder. 5

SPR spawning potential ratio. xii, 28

Triennial Survey Alaska Fisheries Science Center/Northwest Fisheries Science Center West Coast Triennial Shelf Survey. iv, 10, 18, 21, 22

WCGBTS Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey. iv, xvii, 4, 10, 13, 16, 18, 21, 22, 23, 25, 26, 30, 32

WCGOP West Coast Groundfish Observer Program. 3, 20, 29