Stock Assessment Update: Status of Widow Rockfish Stock (Sebastes entomelas) off the U.S. West Coast in 2025

Michael Kinneen[1], Maurice Goodman[1], Anna Sulc[1], Laurinne Balstad[2], Raquel Ruiz Diaz[1], Kristina Randrup[1], Will Patrone[1], Laura Spencer[1], Alaia Morell[3], Alberto Rovellini[1], Allison Dedrick[4], Nick Grunloh[5], Madison Bargas[6], Stephanie Hopkins[7], Vladlena Gertseva[8], Kiva L. Oken[9], Ian G. Taylor[8], Melissa A. Haltuch[10] and Owen Hamel[8]

1. School of Aquatic & Fishery Sciences (SAFS), University of Washington, 1122 NE Boat St
2. Department of Environmental Science and Policy, University of California Davis, Wickson Hall, 350 N Quad
3. UW Puget Sound Institute, Center for Urban Waters, 326 East D Street
4. California Department of Fish and Wildlife, 1740 North Market Boulevard
5. Southwest Fisheries Science Center, 8901 La Jolla Shores Drive
6. Coastal Oregon Marine Experiment Station, Oregon State University, 430 Strand Agriculture Hall
7. University of California, Santa Cruz, Institute of Marine Sciences' Fisheries Collaborative Program, 1156 High Street
8. NOAA Fisheries Northwest Fisheries Science Center, 2725 Montlake Boulevard East
9. NOAA Fisheries Northwest Fisheries Science Center, 2725 Montlake Boulevard East
10. NOAA Alaska Fisheries Science Center, 7600 Sand Point Way N.E., Building 4

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Executive Summary

Stock

This is an update assessment of widow rockfish (*Sebastes entomelas*) that reside in the waters off California, Oregon, and Washington from the U.S.-Canadian border in the north to the U.S.-Mexico border in the south. This is an update of the 2015 benchmark assessment (Hicks and Wetzel 2015). 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 of the U.S. West Coast, possibly through adult migration and/or larval dispersion.

There is little evidence of genetically separate stocks along the U.S. coast and the previous benchmark assessment used a single area, coastwide model with multiple fisheries (Hicks and Wetzel 2015). There is some evidence of biological differences between areas. For example, widow rockfish collected off California tend to mature at a smaller length than do widow rockfish collected off of Oregon (Barss and Echeverria 1987). This may be due to environmental or anthropogenic effects rather than genetic differences. The 2015 benchmark assessment decided to continue with a single area model for this assessment rather than lose prediction power by splitting the model and data into two separate areas. An update assessment was carried out in 2019 and maintained the same general model structure as the 2015 benchmark assessment.

Catches

The historical reconstruction of landings for widow rockfish suggests that hook-and-line and bottom trawl 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 the foreign trawl fleet increased catches into the 1970s, with a peak at almost 5,000 mt in 1967. In the late 1970s a midwater trawl fishery developed for widow rockfish and catches increased rapidly with the discovery of large aggregations that form 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. After this sudden increase in catch, widow rockfish were given their own market category and often identified to species in the landings. However, species composition sampling of market categories occurred before the mid-1980s when widow rockfish was not specifically identified. The uncertainty in species composition is greater in past years, thus landings of widow rockfish are not well known further back in history.

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. Catches increased rapidly following the quota share reallocation in 2017, and have been near or above 10,000 mt in all years between 2018-2024. Midwater trawl gears in groundfish and Pacific Whiting (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 1982. Trawl rationalization was introduced in 2011. Between 2011 and 2016 very little discarding of widow rockfish is estimated to have occurred, though discards have increased in recent years. Discards were estimated in the model with the assistance of data from the West Coast Observer Program (WCGOP), and total catches (discards plus landings) are reported in addition to landings.

Table i: Recent landings for the bottom trawl, midwater trawl, at-sea hake, net, and hook-and-line fisheries and the total landings across fisheries and the total mortality (discards + landings) (mt). 100% mortality is assumed for discards and catch sources are described below.

Year	Bottom Trawl	Midwater Trawl	At-Sea Hake	Net	Hook-and-line	Total Landings	Total Mortality
2015	12.1800	479.20	386.200	0.00000000	2.09482	879.6748	879.8598
2016	9.6200	588.00	440.800	0.00000000	1.00793	1039.4279	1039.6021

Year	Bottom Trawl	Midwater Trawl	At-Sea Hake	Net	Hook-and-line	Total Landings	Total Mortality
2017	35.9300	4852.10	1455.200	0.00000000	2.69737	6345.9274	6361.5003
2018	35.9300	9374.30	1081.300	0.00000000	1.63811	10493.1681	10522.9210
2019	27.8571	8157.92	1101.550	0.00000000	2.11612	9289.4432	9315.2946
2020	73.6268	7532.17	746.694	0.00181437	2.74634	8355.2390	8379.5927
2021	103.7410	10141.30	617.298	0.00000000	4.54716	10866.8862	10899.7342
2022	126.7760	10839.80	1119.030	0.05488470	8.77075	12094.4316	12129.7126
2023	82.3310	10228.00	673.161	0.00000000	7.07973	10990.5717	11023.5033
2024	27.5870	9160.79	533.840	0.00000000	12.90020	9735.1172	9764.1159

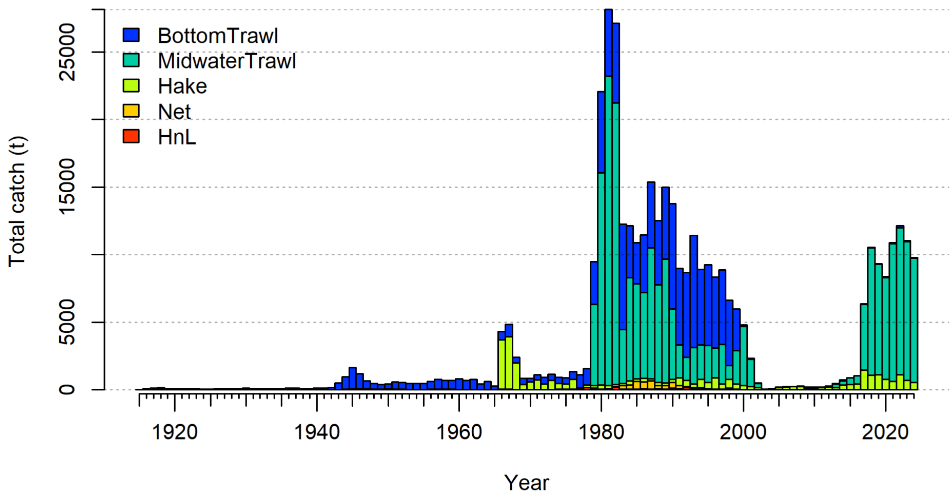

Figure i: Landings of Widow Rockfish from 1916 to 2018 for bottom trawl, midwater trawl, net, and hook- and-line fisheries, and catches of Widow Rockfish for the foreign (1966–1976) and Pacific Whiting (hake) fisheries (green).

Data and Assessment

This is an update assessment of the 2015 full assessment of widow rockfish (Hicks and Wetzel 2015), following a previous update assessment in 2019. In this assessment, aspects of the model including catches, data, and modelling assumptions were generally consistent with the 2015 and 2019 assessments. However, the assessment used the updated version of the length- and age-structured modeling software Stock Synthesis (version 3.30.2), while the benchmark assessment used version 3.24U. The coastwide population was modeled assuming separate growth and mortality parameters for each sex (a two-sex model) from 1916 to 2024, and forecasted beyond 2024.

The definitions of fishing fleets have not been changed from those in the 2015 assessment. Five fishing fleets were specified within the model: 1) a shorebased bottom trawl fleet with coastwide catches from 1916–2024, 2) a shorebased midwater trawl fleet with coastwide catches from 1979–2024, 3) a mostly midwater trawl fleet that targets Pacific Hake/Whiting (Merluccius productus) and includes a foreign and at-sea fleet with catches from 1975–2024, a domestic shorebased fleet that targeted Pacific Hake with catches from 1991–2024, and foreign vessels that targeted Pacific Hake and rockfish between 1966–1976, 4) a net fishery consisting of catches mostly from California from 1981–2024, and 5) a hook-and-line fishery (predominantly longline) with coastwide catches from 1916–2024. Landings are summarized in Figure i.

Data from three fishery-independent surveys were also included in the model: 1) the National Marine Fisheries Service (NMFS) Southwest Fisheries Science Center (SWFSC) and Northwest Fisheries Science Center (NWFSC)/Pacific Whiting Conservation Cooperative (PWCC) Midwater Trawl Survey that provides pre-recruit indices of abundance, 2) the NMFS Triennial Shelf Survey which was conducted from 1977–2004 in depths less than 500 meters, and 3) the NWFSC West Coast Groundfish Bottom Trawl Survey (WCGBTS) which has been surveying the entire U.S. West Coast in depths between 55 and 1,280 meters since 2003.

The data used in the assessment model consisted of survey abundance indices, length compositions, discard data, and age compositions. Model-based biomass indices and length compositions were determined for the NMFS Triennial Shelf and NWFSC West Coast Groundfish Bottom Trawl Surveys. Length and age compositions were also available from the five fisheries. Age data for all years of the WCGBTS were input as age-at-length compositions. Discard data for the bottom trawl, midwater trawl, and hook-and-line fisheries were available in various years in the form of discarded biomass and length compositions. A small amount of data was available to inform discarding practices of widow rockfish prior to 2002. The variances and sample sizes on all of the data were tuned to the expected variability in the model predictions.

The base model estimated parameters for length-based selectivity for all fleets and surveys, retention curves based on length for the bottom trawl, midwater trawl, and hook-and-line fishing fleets, a length-at- age relationship, natural mortality for males and females assuming lognormal priors, and recruitment deviations starting in 1900. 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 for west coast rockfishes.

Uncertainty for the parameter estimates and derived quantities was determined in three ways. First, estimation uncertainty in the base model was determined using approximate asymptotic 95% confidence intervals based on maximum likelihood theory. Second, model uncertainty was investigated with various sensitivity runs where alternative model structures were implemented. Finally, the major axis of uncertainty was determined to define a range of states of nature and results are presented in a decision table.

Although there are many types of data available for widow rockfish since the late 1970s, which were used in this assessment, there is little information about steepness and natural mortality, and recent recruitment (although likelihood profiles in this update assessment suggest additional data has contributed higher certainty in natural mortality estimates). Estimates of steepness are uncertain partly because of variable recruitment. Uncertainty in natural mortality is common in many fish stock assessments even when length and age data are available. Finally, there is little information about the strength of recent recruitment because the young fish are seen with a lower probability in the fisheries and surveys. These uncertainties were characterized as best as possible in the predictions and projections from this assessment.

Stock biomass and dynamics

The predicted spawning biomass 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 (peaking in 1979) due to strong recruitment. The spawning biomass declined rapidly with the developing domestic midwater fishery in the late 1970s and early 1980s. The stock continued to decline until 2000. A combination of strong recruitment and low catches resulted in a steady increase in spawning biomass through 2016, though the reestablishment of a target fishery for widow rockfish in 2017 has since resulted in a steep decline in biomass.

The 2024 spawning stock biomass (SSB) relative to unfished equilibrium spawning biomass is 56. This is above the target of 40% of unfished spawning biomass, and above the minimum estimated value of of 34 which the population approached in 1998-2001.

Approximate confidence intervals based on the asymptotic variance estimates show that the uncertainty in the estimated spawning biomass is high, especially in the early years. Spawning biomass is estimated to be at `r`format(SSB$Value[SSB$Year == 2024], big.mark = “,”, digits = 1)‘ mt in 2019, with an asymptotic 95% confidence interval of 23,459 - 67,427. The corresponding confidence interval for the relative SSB is 36.8% - 74.4%, for which the lower bound is below the management target of 40%.

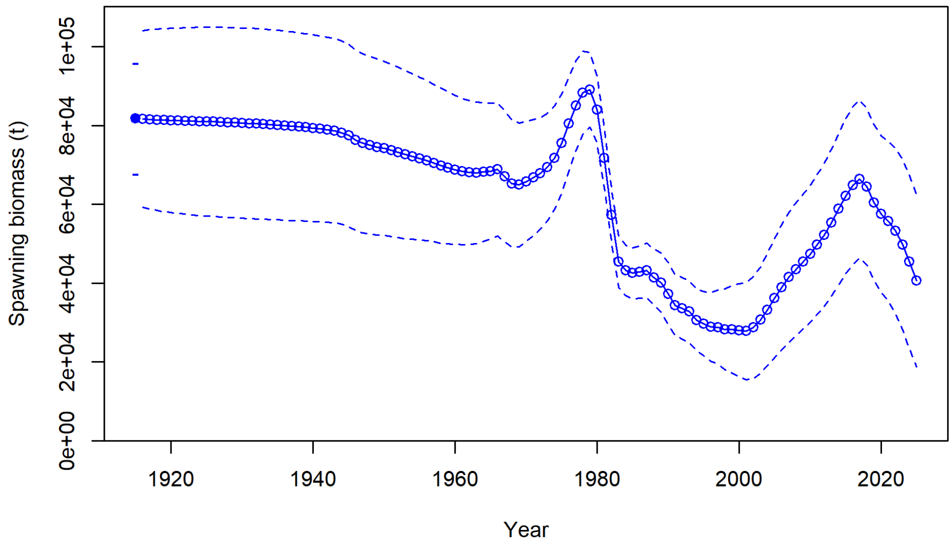

Figure ii: Estimated female spawning biomass time-series from the base model (solid line) with an approximate asymptotic 95% confidence interval (dashed lines).

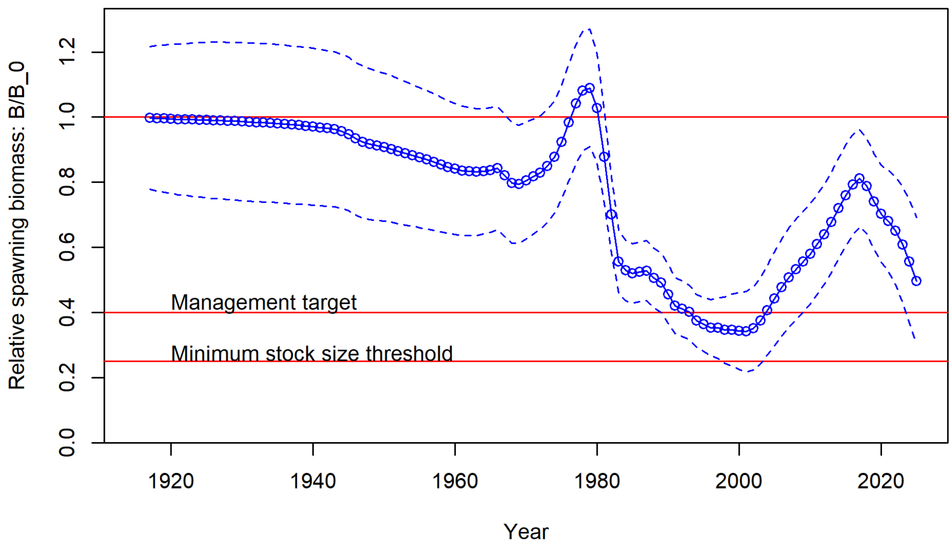

Figure iii: Estimated relative spawning biomass (depletion) with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model.

Table ii: Recent landings for the bottom trawl, midwater trawl, at-sea hake, net, and hook-and-line fisheries and the total landings across fisheries and the total mortality (discards + landings) (mt). 100% mortality is assumed for discards and catch sources are described below.

Year	Spawning Biomass	~95% Confidence Interval	Estimated Depletion (%)	~95% Confidence Interval
2015	62,102	42367 - 81836	0.760	0.604 - 0.915
2016	64,772	44724 - 84820	0.792	0.639 - 0.946
2017	66,368	46318 - 86418	0.812	0.663 - 0.962
2018	64,402	44578 - 84226	0.788	0.642 - 0.934
2019	60,465	40745 - 80185	0.740	0.593 - 0.886
2020	57,485	37654 - 77316	0.703	0.554 - 0.853
2021	55,682	35407 - 75956	0.681	0.526 - 0.836
2022	53,222	32240 - 74203	0.651	0.486 - 0.817
2023	49,724	28075 - 71372	0.608	0.43 - 0.786
2024	45,443	23459 - 67427	0.556	0.368 - 0.744
2025	40,603	18692 - 62514	0.497	0.302 - 0.692

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.

There are very large, but uncertain, estimates of recruitment (in descending order of magnitude) in 1970, 2008, 2016, and 1971. Other large recruitment events (in descending order of magnitude) occurred in 1978, 1981, 2010, and 1991. Previous estimates of high recruitments in 2013 and 2014 are lower than previously estimated (see 2019 update assessment) following the addition of new data.

The five lowest recruitments (in ascending order) occurred in 2012, 2019, 2020, 2011, and 1976. Estimates of recruitment appear to be episodic and characterized by periods of low recruitment.

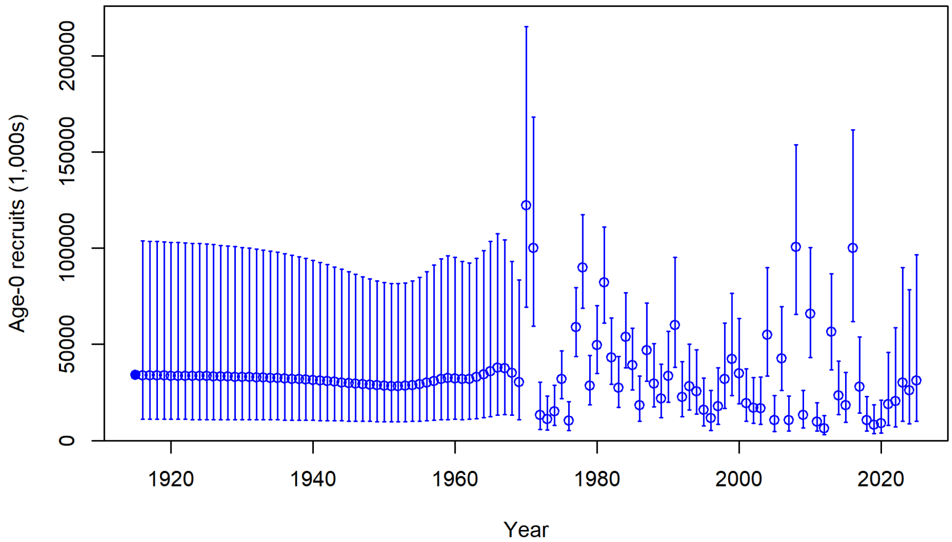

Figure iv: Time-series of estimated recruitments (medians as open circles) for the base case model with approximate asymptotic 95% confidence interval (vertical bars). Estimated mean unfished equilibrium recruitment (R0) is shown as the closed circle with a 95% confidence interval at the beginning of the time series.

Table iii: Recent estimated trend in Widow Rockfish recruitment with approximate 95% confidence intervals determined from the base model. Recruitment deviations were fixed at zero in 2019 in the base model.

Year	Estimated Recruitment (number in thousands)	~95% Confidence Interval	Estimated Recruitment Deviation	~95% Confidence Interval
2015	18,395	9562 - 35389	-0.434	-0.99 - 0.122
2016	100,038	61910 - 161646	1.255	0.969 - 1.54
2017	27,892	14432 - 53906	-0.026	-0.554 - 0.503
2018	10,615	4923 - 22886	-1.007	-1.671 - -0.342
2019	8,289	3676 - 18688	-1.268	-1.985 - -0.55
2020	8,907	3771 - 21042	-1.210	-1.991 - -0.43
2021	18,889	7804 - 45720	-0.476	-1.308 - 0.356
2022	20,464	7124 - 58784	-0.411	-1.484 - 0.662
2023	30,114	10086 - 89911	-0.036	-1.161 - 1.089
2024	26,046	8634 - 78567	-0.189	-1.325 - 0.947
2025	31,045	9969 - 96683	0.000	-1.176 - 1.176

Exploitation status

The spawning biomass of widow rockfish reached a low in 2001 before increasing due to low catch levels.

The lower bound of the 95% confidence interval of the estimated depletion dipped below the overfished threshold (25% minimum stock size threshold) in the very late 1990s and early 2000s. After recovering after 2016, the lower bound of the 95% confidence interval dipped below the 40% management target in 2024 but remains above the overfished threshold. The current depletion estimate is greater than the spawning biomass target.

Throughout the 1980s and 1990s the exploitation rate and (1-SPR) were mostly above target levels. Recent exploitation rates on widow rockfish are estimated to have exceeded target levels in all years since 2018.

Table iv: Recent trend in spawning potential ratio and summary exploitation rate. Harvest rate is defined as catch divided by age 4+ biomass.

Year	Estimated (1-SPR)/(1-SPR50%)	~95% Confidence Interval	Harvest rate (proportion)	~95% Confidence Interval
2015	0.144	0.092 - 0.197	0.007	0.005 - 0.009
2016	0.161	0.104 - 0.218	0.008	0.006 - 0.011
2017	0.736	0.546 - 0.926	0.050	0.035 - 0.065
2018	1.070	0.844 - 1.296	0.086	0.059 - 0.112
2019	1.054	0.816 - 1.291	0.083	0.056 - 0.11
2020	1.041	0.79 - 1.291	0.072	0.047 - 0.098
2021	1.210	0.944 - 1.476	0.097	0.06 - 0.133
2022	1.270	0.989 - 1.551	0.116	0.069 - 0.164
2023	1.248	0.936 - 1.56	0.119	0.065 - 0.173
2024	1.257	0.909 - 1.605	0.121	0.06 - 0.181

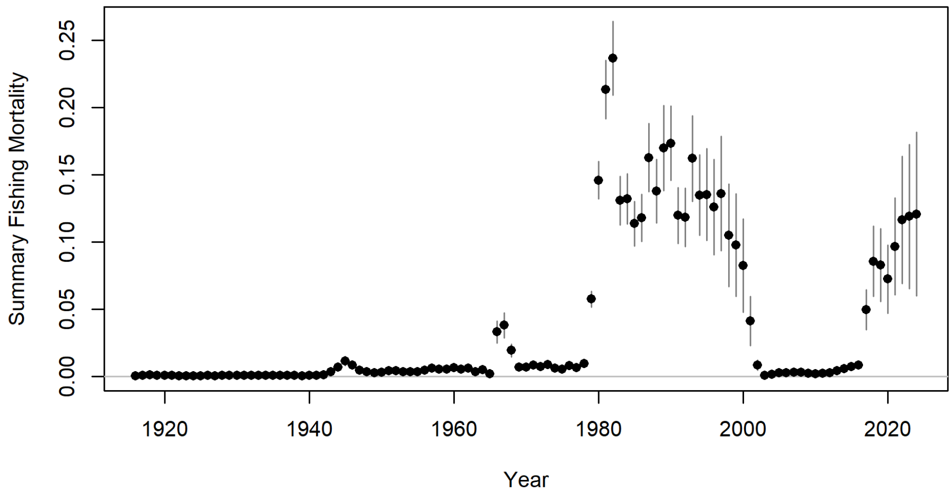

Figure v: Time-series of estimated summary harvest rate (catch divided by age 4+ biomass) for the base case model (round points) with approximate 95% asymptotic confidence intervals (gray lines).

Ecosystem considerations

Rockfish (Sebastes spp.) are an important component of the California Current ecosystem along the U.S. West Coast, comprising more than sixty-five species filling various niches in both soft and hard bottom habitats from the nearshore to the continental slope, as well as near bottom and pelagic zones. Widow rockfish frequently aggregate in the pelagic zone.

Recruitment is one mechanism by which the ecosystem may directly impact the population dynamics of widow rockfish. The specific pathways through which environmental conditions exert influence on widow rockfish dynamics are unclear; however, changes in water temperature and currents, distribution of prey and predators, and the amount and timing of upwelling are all possible linkages. Changes in the environment may also result in changes in age-at-maturity, fecundity, growth, and survival which can affect how the status of the stock and its susceptibility to fishing are determined. Unfortunately, there are few data available for widow rockfish that provide insights into these effects.

Fishing has effects on both the age structure of a population as well as the target species habitat. Fishing often targets larger, older fish, and years of fishing mortality results in a truncated age-structure when compared to unfished conditions. Rockfish are often associated with habitats containing living structures such as sponges and corals, and fishing may alter that habitat to a less desirable state. This assessment provides insight

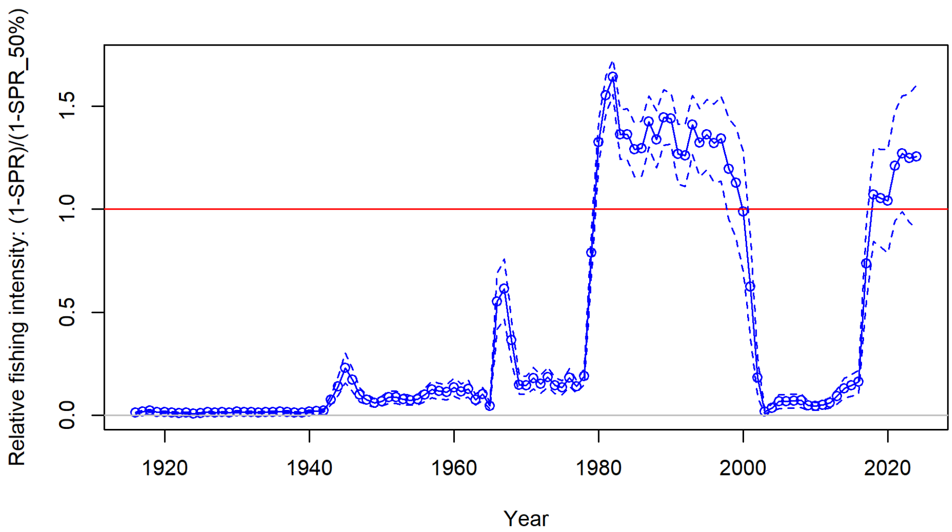

Figure vi: Trend in estimated fishing intensity (relative to the SPR management target) through 2018 with 95% asymptotic confidence intervals. One minus SPR is used so that higher exploitation rates occur on the upper portion of the y-axis. The relative management target is plotted as a horizontal line and values above this reflect harvests in excess of the overfishing proxy based on SPR50%.

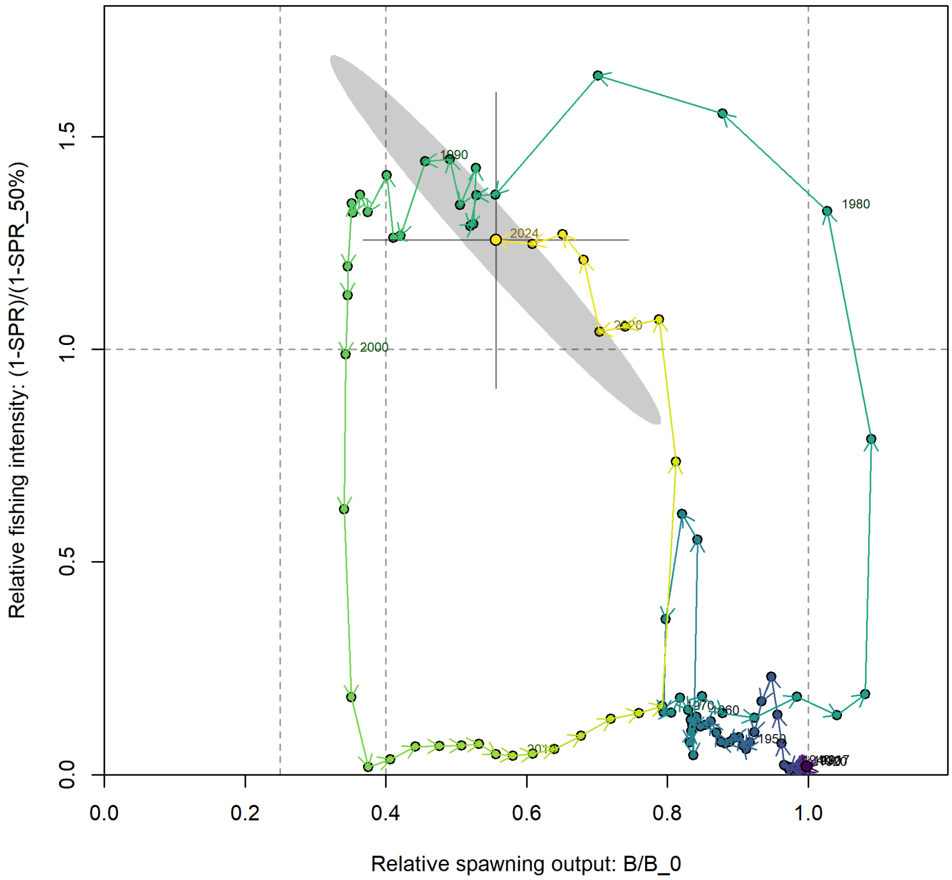

Figure vii: Phase plot of estimated relative (1-SPR) vs. relative biomass for the base case model. The relative (1- SPR) is (1-SPR) divided by 0.5 (one minus the SPR target). 2018 is noted a red circle.

on the effects of fishing on age structure, and 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 issues specific to widow rockfish.s

Reference points

Reference points were calculated using the estimated selectivities and catch distribution among fleets in the most recent year of the model (2024). Sustainable total yields (landings plus discards) were 5,625 mt when using an SPR50% reference harvest rate and with a 95% confidence interval of 4,326 to 6,925 mt. The spawning biomass equivalent to 40% of the unfished spawning output (SB40%) was 32,766 mt. Catches between the late 1990's and 2016 were well below the point estimate of potential long-term yields calculated using an SPR50% reference point, and the population is estimated to have increased continuously throughout that time period. However, catches from 2017 through 2024 were above the point estimate of potential long-term yields using an SPR50% reference point, exceeding the upper bound of the confidence interval in all years since 2018, and exceeding the point estimate by on average 82%.

The predicted spawning biomass 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 decease through 2000 (Figure 61). Between 2001 and 2016, the spawning biomass increased continuously due to small catches, and several years of high recruitment (though with lower than average recruitment in other recent years). The spawning biomass relative to unfished equilibrium spawning biomass climbed above the target of 40% of unfished spawning biomass in the early 2000's. 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 51). The fishing intensity (relative 1-SPR) exceeded the current estimates of the harvest rate limit (SPR50%) throughout the 1980s and early 1990s, and has again since 2018 (**?@fig-pred-one-SPR**). 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 (**?@fig-relative-one-SPR**).

The equilibrium yield plot is shown in Figure 61, based on a steepness value fixed at 0.720. The predicted maximum sustainable yield under the assumptions of this assessment occurs near 25% of equilibrium unfished spawning biomass.

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Quantity	Estimate	Lower Interval	Upper Interval
Unfished Spawning Biomass (mt)	81,733.60	67,571.06	95,896.14
Unfished Age 4+ Biomass (mt)	151,584.00	125,227.97	177,940.03
Unfished Recruitment (R0)	34,102.80	22,838.30	45,367.30
2025 Spawning Biomass (mt)	40,603.10	18,692.07	62,514.13
2025 Fraction Unfished	0.50	0.30	0.69
Reference Points Based SB40%			
Proxy Spawning Biomass (mt) SB40\%	32,693.40	27,028.38	38,358.42
SPR Resulting in SB40\%	0.46	0.46	0.46
Exploitation Rate Resulting in SB40\%	0.09	0.08	0.10
Yield with SPR Based On SB40\% (mt)	5,902.11	4,529.61	7,274.61
Reference Points Based on SPR Proxy for MSY			
Proxy Spawning Biomass (mt) (SPR50)	36,465.80	30,147.13	42,784.47
SPR50	0.50		
Exploitation Rate Corresponding to SPR50	0.08	0.07	0.08
Yield with SPR50 at SB SPR (mt)	5,628.26	4,323.47	6,933.05
Reference Points Based on Estimated MSY Values			
Spawning Biomass (mt) at MSY (SB MSY)	21,666.80	17,966.35	25,367.25
SPR MSY	0.34	0.33	0.34
Exploitation Rate Corresponding to SPR MSY	0.13	0.12	0.14
MSY (mt)	6,310.24	4,827.96	7,792.52

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Management performance

Exploitation rates on widow rockfish exceeded MSY proxy target harvest rates during the 1980s and 1990s and spawning biomass is predicted to have fallen below the proxy management target of 40%. Exploitation rates decreased in the late 1990s due to management restrictions, and have increased in recent years. Predicted catches in the last decade have not exceeded the annual catch limit (ACL) set by management.

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.

X	Year	OFL mt	ABC mt	ACL mt	Landings mt	Total Mortality mt
1	2,015	4,137	3,929.00	2,000	879.67	879.86
2	2,016	3,990	3,790.00	2,000	1,039.43	1,039.60
3	2,017	14,130	13,508.28	13,508	6,345.93	6,361.50
4	2,018	13,237	12,654.57	12,655	10,493.17	10,522.92
5	2,019	12,375	11,830.50	11,831	9,289.44	9,315.29
6	2,020	11,714	11,198.58	11,199	8,355.24	8,379.59
7	2,021	15,749	14,725.32	14,725	10,866.89	10,899.73
8	2,022	14,826	13,788.18	13,788	12,094.43	12,129.71
9	2,023	13,633	12,624.16	12,624	10,990.57	11,023.50
10	2,024	12,453	11,481.67	11,482	9,735.12	9,764.12

Harvest projections and decision table

Two categories of parameters that greatly contributed to uncertainty in the results were natural mortality (an important estimated parameter) and steepness (not estimated in the model). 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 12.5% and 87.5% quantiles for female and male natural mortality (independently) were chosen as low and high values (0.115 yr-1 and 0.134 yr-1 for females; 0.127 yr-1 and 0.146 yr-1 for males). Steepness is probably the most important factor since it 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 three factors defined the low state of nature and the high combination of these three factors defined the high state of nature. The predictions of spawning biomass in 2025 from the low and high states of nature are close to the 12.5% and 87.5% lognormal quantiles from the base model.

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

A twelve year projection of the base model with catches equal to the current ACL in 2025 and 2026 (10,669 mt and 9824 mt, respectively) and catches of 9,000 mt for all later years and a catch allocation equal to the percentages for each fleet in 2024 predicts spawning biomass will decrease over the projection period for all states of nature (Table 36).

Projections with catches based on the predicted annual catch limit (ACL) using the SPR rate of 50%, the 40:10 control rule, and a 0.45 P* adjustment using a sigma of 0.50 from 2027 onward suggest that the spawning biomass will decrease over the projection period for all states of nature (Table 36).Predicted ACL catches range from 3,321 mt in 2027 to 4,392 mt in 2036.

Projections with catches based on the predicted annual catch limit (ACL) using the SPR rate of 50%, the 40:10 control rule, and a 0.25 P* adjustment using a sigma of 0.50 from 2021 onward suggest that the spawning biomass will decrease over the projection period for all states of nature. Predicted ACL catches range from 1,790 mt in 2027 to 1,886 mt in 2036.

Table vii: Projection of potential OFL, landings, and catch, summary biomass (age-4 and older), spawning biomass, and depletion for the base case model projected with total catch equal to the predicted ABC. The predicted OFL is the calculated total catch determined by FSPR=50%.

Year	Predicted OFL mt	ABC Catch mt	Age 4 Biomass mt	Spawning Biomass mt	Fraction Unfished
2025	5,667.08	10,668.60	71,230.3	40,603.1	0.496774
2026	4,568.58	9,823.60	61,354.3	34,836.7	0.426222
2027	3,818.51	3,455.72	54,693.2	29,822.0	0.364868
2028	3,874.75	3,444.96	55,075.5	28,880.8	0.353352
2029	4,097.94	3,618.37	56,834.7	28,693.4	0.351059
2030	4,388.78	3,876.11	58,903.9	29,027.1	0.355143
2031	4,688.19	4,152.26	60,901.5	29,655.1	0.362826
2032	4,947.78	4,403.51	62,707.4	30,395.7	0.371887
2033	5,145.09	4,598.00	64,258.2	31,118.6	0.380732

Year	Predicted OFL mt	ABC Catch mt	Age 4 Biomass mt	Spawning Biomass mt	Fraction Unfished
2034	5,286.93	4,732.88	65,574.6	31,766.1	0.388654
2035	5,390.60	4,833.57	66,710.1	32,334.1	0.395603
2036	5,470.43	4,901.50	67,704.2	32,834.0	0.401720

Table viii: Summary table of 12-year projections beginning in 2021 for of nature based on the axis of uncertainty (a combination of recruitment strength). Columns range over low, mid, and hig and rows range over different assumptions of total catch le retained). Catches in 20XX and 20XX are allocated using t landings for each fleet in 20XX.

				State of nat		
				Low		Base
Management decision	Year	OFL	catch (mt)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)
9,000 K	2027	0	9,000	17,024	0.195	
	2028	0	9,007	13,360	0.153	
	2029	0	9,068	10,428	0.120	
	2030	0	9,067	7,962	0.091	
	2031	0	7,419	5,757	0.066	
	2032	0	6,404	4,389	0.050	
	2033	0	5,494	3,396	0.039	
	2034	0	4,662	2,631	0.030	
	2035	0	3,901	2,019	0.023	
	2036	0	3,187	1,509	0.017	
9,000 K	2027	0	9,001			34,918
	2028	0	9,000			30,977
	2029	0	9,000			27,812
	2030	0	9,000			25,315
	2031	0	9,000			23,321
	2032	0	9,000			21,690
	2033	0	9,000			20,279
	2034	0	9,000			18,981
	2035	0	9,000			17,736
	2036	0	9,000			16,511
	2027	0	3,231	24,754	0.284	34,918

				State of nat		
				Low		Base
Management decision	Year	OFL	catch (mt)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)
ACLp*=0.45, sigma=0.50	2028	0	3,204	23,939	0.275	33,924
	2029	0	3,351	23,652	0.271	33,609
	2030	0	3,574	23,687	0.272	33,792
	2031	0	3,808	23,860	0.274	34,288
	2032	0	4,020	24,056	0.276	34,944
	2033	0	4,180	24,202	0.278	35,642
	2034	0	4,279	24,280	0.279	36,319
	2035	0	4,350	24,303	0.279	36,957
	2036	0	4,392	24,286	0.279	37,550
ACLp*=0.25, sigma=0.50	2027	0	1,790	24,754	0.284	
ACLp*=0.25, sigma=0.50	2028	0	1,750	24,698	0.283	
ACLp*=0.25, sigma=0.50	2029	0	1,791	25,148	0.289	
ACLp*=0.25, sigma=0.50	2030	0	1,863	25,952	0.298	
ACLp*=0.25, sigma=0.50	2031	0	1,939	26,957	0.309	
ACLp*=0.25, sigma=0.50	2032	0	1,991	28,047	0.322	
ACLp*=0.25, sigma=0.50	2033	0	1,993	29,155	0.335	
ACLp*=0.25, sigma=0.50	2034	0	1,969	30,261	0.347	
ACLp*=0.25, sigma=0.50	2035	0	1,929	31,364	0.360	
ACLp*=0.25, sigma=0.50	2036	0	1,886	32,473	0.373	
ACLp*=0.25, sigma=0.50	2027	0	2,572			29,822
ACLp*=0.25, sigma=0.50	2028	0	2,577			29,349
ACLp*=0.25, sigma=0.50	2029	0	2,706			29,596
ACLp*=0.25, sigma=0.50	2030	0	2,888			30,369
ACLp*=0.25, sigma=0.50	2031	0	3,082			31,461
ACLp*=0.25, sigma=0.50	2032	0	3,248			32,692
ACLp*=0.25, sigma=0.50	2033	0	3,332			33,935

				State of nat		
				Low		Base
Management decision	Year	OFL	catch (mt)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)
ACLp*=0.25, sigma=0.50	2034	0	3,378			35,143
ACLp*=0.25, sigma=0.50	2035	0	3,397			36,298
ACLp*=0.25, sigma=0.50	2036	0	3,404			37,406

Scientific uncertainty

Spawning biomass is estimated to be at 40,603 mt in 2025, with a sigma of 0.2753. OFL is estimated to be 5,667.1 mt in 2019 with a coefficient of variation of 0.3187.

Research and data needs

There are many areas of research that could be improved to benefit the understanding and assessment of widow rockfish. Below, we specifically identify five topics that we believe are most important (order does not indicate importance).

- **Historical landings and discards:** The historical landings and discards are uncertain for widow rockfish and improvements would increase the certainty that fishing removals are applied appropriately. Because landings are assumed to be known exactly in the assessment model, uncertainty in the predictions does not include uncertainty in the landings. A thorough look at historical landings, species compositions, and discarding practices would reduce the potential uncertainty that is not entirely accounted for.
- **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 unread, and improved understanding of the life-history of widow rockfish may reduce that uncertainty.
- **Maturity and fecundity::** There are few studies on the maturity of widow rockfish and even less recent information. There have been no studies that reported results of a histological analysis. Further research on the maturity and fecundity of widow rockfish, the potential differences between areas, the possibility of changes over time would greatly improve the assessment of these species.

- **Age data and error:** There is a considerable amount of error in the age data and potential for bias. Investigating the ageing error and bias would help to understand the influences that the age data have on this assessment. Disagreement between surface reads of age versus break-and-burn reads is worth more investigation.
- **Basin-wide 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.

Table ix: Summary table of results for the as

Quantity	2015	2016	2017	2018	2019	
OFL	fill in	fill in	fill in	fill in	fill in	
ACL	fill in	fill in	fill in	fill in	fill in	
Total Catch	879.67482	1039.42793	6345.92737	10493.16811	9289.44322	835
Total Dead	879.85982	1039.6021	6361.50027	10522.92101	9315.29462	837
(1-SPR)/(1-SPR_50%)	0.144426	0.161199	0.736208	1.07014	1.05354	
Exploitation Rate	0.00704019	0.00840339	0.0496841	0.0855249	0.0827456	0.
Age 4+ Biomass (mt)	124977	123712	128039	123039	112578	
Spawning Biomass (mt)	62101.9	64772.2	66368.3	64402.2	60464.7	
Lower Interval	42367.4146324631	44724.1203949367	46318.4564273506	44577.9482819712	40744.5223695503	37653
Upper Interval	81836.3853675369	84820.2796050633	86418.1435726494	84226.4517180288	80184.8776304497	77316
Recruits	18395.3	100038	27891.7	10614.7	8288.55	
Lower Interval	9562.02585793987	61910.4779255311	14431.5752888199	4923.27834451949	3676.17797624987	3770.
Upper Interval	35388.6370019611	161646.32836525	53905.8913057588	22885.5344356926	18687.9039987564	21042
Fraction Unfished	0.759809	0.792479	0.812008	0.787953	0.739778	0
Lower Interval	0.604216083108897	0.638578708005946	0.662501163273691	0.641929215270617	0.593202877401766	0.5540
Upper Interval	0.915401916891103	0.946379291994054	0.961514836726309	0.933976784729383	0.886353122598234	0.8526

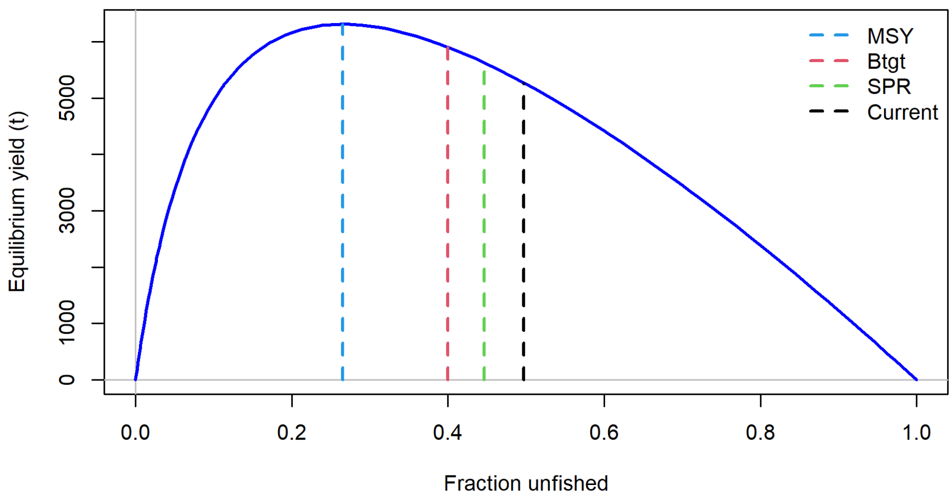


Figure viii: Equilibrium yield curve for the base case model and associated target and limit reference points. Values are based on 2019 fishery selectivity and distribution with steepness fixed at 0.720. The %unfished is relative to unfished spawning biomass.

1 Introduction

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.

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 waters (Table 1, Figure 1). This assessment represents a thorough reconsideration of the data, data preparation, and model structure for assessing Widow Rockfish, including reinvestigations of recent and historical catches (including discards), length and age data, and fleet structure.

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.

There is little evidence of genetically separate stocks along the U.S. coast and past assessments have used a single area, coastwide model with multiple fisheries (He et al. 2011). In 2011, a two-area assessment model was brought forward for review, and was found to be similar to a coastwide model (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 may be due to environmental or anthropogenic effects rather than genetic differences. The connectivity of Widow Rockfish populations throughout its range is unknown and it was decided to continue with a single area model for this assessment instead of potentially lose prediction power by splitting the data into two separate areas.

1.2 Life History and Ecosystem Interactions

Widow Rockfish are atypical for West Coast rockfish species because they form dense midwater aggregations at night, which were largely undetected until the late 1970s. They are typically found over high relief strata and near cobblestone. The diet of Widow Rockfish is dominated by species that comprise the deep scattering layers, including salps, myctophids, *Sergestes similis* (a caridean shrimp), and euphausiids (P. Adams 1987).

Widow Rockfish are ovoviviparous with gestation lasting from 1 to 3 months. Parturition occurs earlier in southern latitudes (December-March off California) than in northern latitudes (April in British Columbia) and occur once a year (Barss and Echeverria 1987). Estimates of fecundity of Widow Rockfish range from 95,375 oocytes at 33 cm to 1,113,000 oocytes at 52 cm (Boehlert, Barss, and Lamberson 1982).

There is little information regarding the movement of Widow Rockfish. Past assessments have assumed a two-area model because of differences in growth and maturity (see (He et al. 2011)). However, using recent observations from the NWFSC shelf/slope survey to follow two separate cohorts through time and space suggests that Widow Rockfish may recruit in the south and disperse northward as they age (Figure 2). Spatial recruitment and movement patterns of Widow Rockfish are uncertain and much more investigation and sampling is needed to fully understand them.

1.3 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 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 1960). Foreign fleets began fishing for rockfish in the mid-1960s until the EEZ was implemented in 1977 (J. B. Rogers 2003). Longline catches of Widow Rockfish are present from the turn of the 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 (J. B. 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 (Table 1). As early as 1982, trip limits were imposed to keep catches below recommended annual levels (Table 3). Trip limits became more restrictive over the years until Widow Rockfish was declared overfished in 2001. In 2002, harvest guidelines were greatly reduced and over the last decade have been small, although increasing since 2004 (Table 4).

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.

More detailed information of the fisheries in each state is given in Section 2.2.1 where the reconstructed landings are discussed.

1.4 Management History and Performance

Widow Rockfish has been a small large component of groundfish fisheries since the late 1970s. The landings of Widow Rockfish have been historically governed by harvest guidelines and trip limits, while recently management is imposed with total catch harvest limits in the form of overfishing limits (OFLs), acceptable biological catches (ABCs), and annual catch limits (ACLs). A trawl rationalization program, consisting of an individual fishing quota (IFQ) or catch shares system was implemented in 2011 for the limited entry trawl fleet targeting non-whiting groundfish, including Widow Rockfish, and the trawl fleet targeting and delivering whiting to shore-based processors. The limited entry at-sea trawl sectors (motherships and catch-processors) that target whiting and process at sea are managed in a system of harvest cooperatives.

Limits on Widow Rockfish were first established in 1982 (Table 3). These were implemented as trip limits and cumulative landing limits that were first imposed by trip, then week, then every 2 weeks, month, 2 months, and eventually into periods. In many years, the trip limits on Widow Rockfish were significantly reduced at the end of the year to avoid exceeding the harvest recommendations. Some important years were 1985 when trip limits were reduced to 30,000 pounds once per week or 60,000 pounds once every 2 weeks, 1990 when trip limits were reduced to 15,000 or 25,000 pounds every one or two weeks, respectively, 1998 when a 25,000 pound cumulative limit per two-month period was implemented, and 2011 when catch shares was implemented.

A sorting requirement was implemented for Widow Rockfish in the early 1980s with California beginning in 1982, Oregon in 1984, and Washington in 1988. Some important events that could affect fishery selectivity are the gear restrictions implemented in 2000, implementation of Rockfish Conservation Areas (RCA's) in 2002, seasonal changes to the RCA's in 2007, and the beginning of catch shares in 2011.

Table 4 shows that recent landings have been below recommended catch levels. Landings are a considerable amount below the ACL, and it is unlikely that total mortality has exceeded the ACL in the last 10 years.

1.5 Fisheries off Canada and Alaska

Widow Rockfish are distributed throughout Canada and Southeast Alaska and are commonly caught in trawl and hook-and-line fisheries. However, the landings from the fisheries in these areas are estimated to harvest Widow Rockfish at much smaller rate than has been observed off California, Oregon, and Washington mostly due to lower abundance of Widow Rockfish, but also partly due to precautionary behavior of Canadian managers after the large catches followed by management restrictions and concerns of the U.S. fishery in the early 1980s.

Alaska formed the "Other Rockfish" complex in 2012 from the combination of Other Slope Rockfish and the Widow and Yellowtail Rockfishes from the Pelagic Shelf Rockfish category. This new complex includes 18 species and Widow Rockfish are a small proportion of the catch (less than 5%). Total biomass estimates are provided by the Gulf of Alaska (GOA) triennial/biennial trawl survey. ABC's and OFL's were set for the Other Rockfish Complex and component species in 2013 with a recommended OFL in 2014 of 5,347 mt for the complex. Widow Rockfish comprise a small part of this complex in Alaska.

The fishery for Widow Rockfish in British Columbia, Canada started in 1986 although some very small landings occurred in the mid-1970s. Landings peaked at about 4,500 mt in 1990 and were around 2,000 mt throughout the 1990s [dfo_widow_1999]. Most landings occurred in a midwater trawl fishery, but there have also been reports of "nuisance catches in the salmon troll fishery". An assessment of Widow Rockfish in Canada was completed in 1998 (R. Stanley 1999) as part of a shelf rockfish complex. Additional research has since been done on the estimation of biomass of particular aggregations of Widow Rockfish (RD Stanley et al. 2000), but no formal assessment has been done since.

2 Data

Many sources of data were available for this assessment, including indices of abundance (Table 5), length observations, and age observations from fishery-dependent and fishery-independent sources.

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"). These surveys employed different designs and sampling methodologies, were conducted during different years and time periods within years, and included coverage over different areas of the coast. In some instances, the survey frequency, depths, and geographic areas covered were not internally consistent within surveys. A brief description of each survey is provided below.

Strata were defined by latitude and depth to analyze the catch-rates, length compositions, and age compositions using stratified random sampling theory (Table 6 & Table 7). The latitude and depth breaks were chosen based on the design of the survey as well as by looking at biological patterns in relation to latitude and depth. Indices of abundance for all of the surveys were derived using model based approaches described below.

2.1.1 SWFSC and NWFSC/PWCC Midwater Trawl Survey

We updated the coastwide pre-recruit index of abundance for widow rockfish using data from three midwater trawl surveys targeting young-of-the-year (YOY) rockfish (SWFSC and NWFSC/PWCC Midwater Trawl Survey (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. For building the widow rockfish pre-recruit index, we used data from 2001 to 2024 without spatial subsetting (including CA, OR, and WA). 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 were used to construct the index but excluded from the final model to align with the 2019 assessment. Data from 2001–2003 were also excluded following the 2015 assessment due to limited spatial coverage (36°30 to 38°20 N latitude). However, a sensitivity analysis was conducted to examine the impact of including those early years (see Figure: Sensitivity Analysis).

The index was built using a spatial GLM with the sdmTMB package [anderson_sdmtmb_-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 strong increasing trend in juvenile abundance from 2017 to 2023, with a slight decline in 2024. Despite the dip, recent values remain high relative to the previous decade, and uncertainty estimates support the robustness of this trend.

2.1.2 Alaska Fisheries Science Center/Northwest Fisheries Science Center West Coast Triennial Shelf 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 until 2004 (**weinberg_-2001_2002?**). Its basic design was a series of equally-spaced east-to-west transects across the continental shelf from which searches for tows in a specific depth range were initiated. The survey design changed slightly over time. In general, all of the surveys were conducted in the mid summer through early fall. The 1977 survey was conducted from early July through late September. The surveys from 1980 through 1989 were conducted from the middle of July to late September. The 1992 survey was conducted from the middle of July through early October. The 1995 survey was conducted from early June through late August. The 1998 survey was conducted from early June through early August. Finally, the 2001 and 2004 surveys were conducted from May to July.

Haul depths ranged from 91–457 m during the 1977 survey. Due to haul performance issues and truncated sampling with respect to depth, the data from 1977 were omitted from this analysis. The surveys in 1980, 1983, and 1986 covered the U.S. West Coast south to 36.8°N latitude and a depth range of 55–366 m. The surveys in 1989 and 1992 covered the same depth range but extended the southern range to 34.5°N (near Point Conception). From 1995 through 2004, the surveys covered the depth range 55–500 m and surveyed south to 34.5°N. In 2004, the final year of the Triennial Survey series, Northwest Fisheries Science Center (NWFSC) Fishery Resource and Monitoring Division (FRAM) conducted the survey following similar protocols to earlier years.

Following the 2015 assessment, the triennial index was estimated using a delta-generalized linear mixed model (GLMM) following the methods of (Thorson and Ward 2013). The survey were stratified by latitude and depth, with the stratifications shown in Table XX. The Delta-GLMM approach explicitly models both the zero and non-zero catches and allows for skewness in the distribution of catch rates and vessel-specific differences in catchability (via inclusion of random effects). Multiple error structures were considered in 2015, including lognormal and gamma error structures with and without extreme catch events. The gamma distribution with random strata-year effects accounting for extreme catch events fit the data the best using median deviance values and Deviance Information Criterion (DIC) values and thus was used in 2015, 2019 and here, in the 2025 assessment (though see sensitivity run for model without the triennial survey index). 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.

2.1.3 Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey

The Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey (WCGBTS) is based on a random-grid design; covering the coastal waters between depths of 55–1,280 m (Bradburn, Keller, and Horness 2011). This design generally uses four industry-chartered vessels per year assigned to a roughly equal number of randomly selected grid cells and divided into two 'passes' of the coast. Two vessels fish from north to south during each pass between late May to early October. There were only two vessels used in 2019 and three in 2013, with one of the three that year unable to complete its survey pass due to a government shutdown. No survey occurred in 2020 due to Coronavirus disease (COVID-19). This design therefore incorporates both vessel-to-vessel differences in catchability, as well as variance associated with selecting a relatively small number (approximately 700) of possible cells from a very large set of possible cells spread from the Mexican to the Canadian borders. Note that the Survey is not permitted to access the Cowcod Conservation Areas (CCAs) in Southern California.

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 (Figure 11). 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.

Geostatistical models of biomass density were fit to survey data using the R package Species Distribution Models with Template Model Builder (`sdmTMB`) (**Anderson_-2022_SRP?**). This approach reflects an updated approach compared to the 2015 assessment (non-spatial delta-GLMM) and the 2019 update assessment (VAST delta-lognormal model). These models can account for latent spatial factors with a constant spatial Gaussian random field and spatiotemporal deviations to evolve as a random walk Guassian random field using a 200 knot grid of the survey area (Thorson et al. 2015). The prediction grid was also truncated to only include available survey locations in depths between 55–500 m to limit extrapolating beyond the data and edge effects. 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, Punt, and Methot 2004; Thorson and Ward 2014).

Results are only shown for the delta-gamma and delta-lognormal distributions, which reported the best diagnostics among the explored models. Both models converged (positive, definite Hessian matrix) but predicted data from both models showed slightly right-heavy tails compared to null expectations, with the gamma model having stronger divergence. The delta-lognormal distribution ultimately had the best model diagnostics, e.g., similar distributions of theoretical normal quantiles and model quantiles, high precision, lack of extreme predictions that are incompatible with the life history, and low Akaike information criterion (AIC). Spatiotemporal estimates of positive catch for the delta-lognormal distribution were then converted into annual indices using sdmtmb::get_-index() function informed by the spatial bounds of the survey (**Anderson_2022_-SRP?**).

The index estimate is relatively stable, with a slightly increasing trend in recent years and a moderate peak in 2016. Overall, the delta-lognormal index estimates were more comparable to the 2019 spatiotemporal VAST-based index than the delta-gamma index, and seemed less influenced by potential extreme catch events, particularly in 2013 and 2016; for these reasons, in addition to better model performance described 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 assessment (2701.12) and the 2019 update assessment (3301.765). Comparisons of the different error structures, design-based estimate and the VAST index used in 2019 are in Figure XX.

Length, age, and conditional age-at-length compositions were created by expanding to the tow and summing to give a strata specific composition (Table 9). The strata compositions were combined to a coastwide composition using a design-based index of abundance from each strata. 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. The 2015 assessment weighted composition data by a Delta-GLMM. Unsexed fish were apportioned to males and females according to the estimated sex ratio for lengths greater than 28 cm. The sex ratio of lengths less than 28 cm was assumed to be 0.5. The design based weighting was selected because a Delta-GLMM based index was not constructed for this assessment and sdmTMB based weighting providing results inconsistent with the previous assessment.

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 13). Age compositions (Figure 14) show a high proportion of a single age in 2004 and 2014, with a more even distribution of ages in the 2018–2024 period. 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 15) show relatively consistent length-at-age with few outliers.

2.2 Fishery-dependent data

2.2.1 Landings

Widow rockfish have been caught in trawl and hook-and-line fisheries since the early part of the 20th century. Widow rockfish are a desirable rockfish and are not likely to be discarded for market reasons. However, smaller widow rockfish are found at shallower depths and discarding practices in the early 1900s are uncertain. In data from the early 1980s, widow rockfish have had their own landing category, beginning in California in 1982, Oregon in 1984, and Washington in 1988. Estimates of historical landings of widow rockfish rely upon species-composition sampling data from each period. The uncertainty in species composition is greater in past years, with less systematic and extensive sampling occurring prior to 1980. Consequently, the precision with which landings of widow rockfish can be estimated likely decreases for earlier years.

The definitions of fishing fleets have not been changed from those in the 2015 and 2019 assessments. Five fishing fleets were specified within the model: 1) a shorebased bottom trawl fleet with coastwide catches from 1916–2024, 2) a shorebased midwater trawl fleet with coastwide catches from 1979–2024, 3) a mostly midwater trawl fleet that targets Pacific Hake/Whiting (Merluccius productus) and includes a foreign and at-sea fleet with catches from 1975–2024, a domestic shorebased fleet that targeted Pacific Hake with catches from 1991–2024, and foreign vessels that targeted Pacific Hake and rockfish between 1966–1976, 4) a net fishery consisting of catches mostly from California from 1981–2024, and 5) a hook-and-line fishery (predominantly longline) with coastwide catches from 1916–2024. 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).

Catches from all years (1916-2018) were carried forward into this assessment, with two exceptions. First, discards from the hook-and-line fleet were added to the removals for this fleet . The hook-and-line removals of widow rockfish are extremely minimal (Figure 1) and comprised only approximately 0.2% of the total removals over the last twenty years, with discard being a small fraction of that. The biological samples of the discard amount are also scarce, with input sample sizes not exceeding 6 and averaging around 3 per year (Table X). With this limited data, the model was unable to reliably estimate retention parameters and exhibited substantial sensitivity to even slight changes in discard amounts within the hook-and-line fleet. Therefore, in this assessment, we added hook-and-line discards to hook-and-line landings. Second, because PacFIN appear to underestimate midwater trawl catches in California in 1979-1980 (Edward Dick, Pers. Comms.) 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. New catches (2019-onward) from PacFIN and ASHOP were otherwise appended onto the 1916-2018 landings and apportioned among fleets using the same criteria as those documented in the 2015 assessment.

2.2.2 Fishery length and age data

Biological data from commercial fisheries that caught widow rockfish were extracted from PacFIN (PSMFC) on July 3, 2019, from CALCOM on July 3, 2019 and from the NORPAC database on July 3, 2019. Lengths taken during port sampling in California, Oregon, and Washington were used to calculate length and age compositions. The data were classified into bottom trawl, midwater trawl, hake trawl, net, and hook-and-line fleets

Table 10 shows the number of landings sampled and Table 11 shows the number of lengths taken for each year, gear, and fleet from the three states. Table 12 shows these numbers for the at-sea fleet.

Consistent with the 2015 assessment, length and age samples from PacFIN and CALCOM were expanded up to the total landing then combined into state-specific frequencies (Table 13). Expansion factors were calculated in a way such that large expansions would not occur and based on ideas first presented by Owen Hamel (pers. comm., NWFSC). First the expansion factor (Ek) was the total catch weight (Wk) divided by the sample weight (wk), and raised to 0.9 to account for non-homogeneity within a trip. Then, expansion factors greater than 300 were capped (100 for net fisheries) to reduce the influence of small samples (i.e., a few fish representing a large catch). The predicted total numbers at length or age weighted by landings for each state were added to create a coast-wide length frequency. The effective sample sizes of the state combined length frequencies were determined from the following formula, which has been used in previous widow rockfish assessments as well as other west coast groundfish assessments.

Fishery Samples	Survey Samples
$N_{eff} = N_{sample} + 0.138N_{fish}, \frac{N_{fish}}{N_{sample}} < 44$	$N_{eff} = N_{sample} + 0.0707N_{fish}, \frac{N_{fish}}{N_{sample}} < 55$
$N_{eff} = 7.06N_{sample}, \frac{N_{fish}}{N_{sample}} \geq 44$	$N_{eff} = 4.89N_{sample}, \frac{N_{fish}}{N_{sample}} \geq 55$

This is slightly different than the sample size of 2.43 per haul for rockfish that (Stewart and Hamel 2014) report. Observed lengths were expanded to the tow from At-Sea Hake Observer Program samples (NORPAC). Tows are typically well sampled, thus expansion factors were not modified from what was calculated. Hake fishery length compositions were created by combining shoreside and at-sea length compositions, weighting by the catch from each sector. The effective sample sizes for hake fishery length and age comps were calculated using the above equations for the shoreside fleet and added to the number of tows sampled from the at-sea fleet.

Expanded length compositions for bottom trawl, midwater trawl, hake fisheries, net, and hook-and-line are shown in Figure 17 to Figure 21. It is quickly apparent that all of these fisheries rarely land fish less than 26 cm. All of the non-hake fleets show a strong cohort coming though in the late 1970s and early 1980s, and then another cohort coming through in the late 1980s. Sample sizes typically dropped off after 2000, except in the hake fishery where nearly every tow is sampled. Age compositions for the five fleets are shown in Figure 22 and Figure 26. Occasional cohorts appear to move through the population, indicating that widow rockfish population dynamics may be characterized by episodic recruitment events.

2.2.3 Discards

Treatment and source of discard data was consistent with the 2015 assessment. Data on discards on Widow Rockfish are available from three different sources. The earliest source is called the Pikitch data and comes from a study organized by Ellen Pikitch that collected data on trawl discards from 1985–1987 (John Wallace, pers. comm and a manuscript in prep). The second source is called EDCP data, which stands for Enhanced groundfish Data Collection Project. These data were collected from late 1995 to early 1999 by at-sea observers on vessels that voluntarily participated in the project. These data were obtained from John Wallace (NWFSC, pers. comm.) and a report to the Oregon Trawl Commission written by David Sampson describes the data. The third data source is from the WCGOP. This program is part of the NWFSC and has been recording discard observations since 2003.

Results of the Pikitch data were obtained from John Wallace (NWFSC, pers. comm.) in the form of ratios of discard weight to retained weight of Widow Rockfish and sex-specific length frequencies. Although results were extended to additional years using data from a mesh study, it was decided to use only the results from the specific years of the study since there were many observations from those years (1985– 1987). Discard estimates are shown in Table 16 and range from 463 to 1,847 mt. Length compositions for discards show a wide range of sizes being discarded, with a peak around 40 cm (Figure 27).

Observations of discards from the EDCP dataset were provided as total discards and total landings per trip (i.e., fish ticket). For each year, the discards were summed and divided by the total observed landings to provide a ratio of discarded to retained catch. This was then applied to the total landings of that fleet to estimate total discards in that year (Table 16). Variability was estimated from individual trip discard ratios. Length data were not available.

The WCGOP has been collecting on-vessel data since 2002 to mainly record discard information, and are current through 2023. A proportion of the fleet for various gear types has been observed in each year and the data collected are used to estimate the total mortality for various species. 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. However, given the change in management, it is likely that there has been a change in discarding behavior.

Widow discard lengths composition data are available for the bottom trawl, , and midwater fleets. The bottom trawl data for 1985-87 is from the Pickitch study, and is unchanged from the 2019 assessment. Discard length data for 2004-2023 was provided by the West Coast Groundfish Observer Program (WCGOP). Historic WCGOP discard lengths from 2004 – 2017 are unchanged for the bottom trawl fleet, and new data are available for all consecutive years through 2023. Major changes occurred only in the treatment of the hook-and-line discard data. Historic discard lengths for the hook & line fleet provided by WCGOP this year were corrected to omit nearshore fixed gear fleets, which were included with the hook-and-line fleet in the previous benchmark and update assessments. This change resulted in changes to the discard length distribution and years for which data was available. The hook-and-line removals of widow rockfish are extremely minimal (Figure XX) and comprised only approximately 0.2% of the total removals over the last twenty years, with discard being a small fraction of that. The biological samples of the discard amount are also scarce, with input sample sizes not exceeding 6 and averaging around 3 per year. With this limited data, the model was unable to reliably estimate retention parameters and exhibited substantial sensitivity to even slight changes in discard amounts within the hook-and-line fleet. Therefore, in this assessment, we added the hook-and-line discard to hook-and-line landings. Discard length composition data, which are newly available from WCGOP for midwater fleets (hake, rockfish) for several years beginning in 2016, were not included in this updated assessment as this would require major changes to the model structure which are beyond the scope of this update assessment but will need to be considered in the next full assessment.

Table 18 shows the number of vessels, trips, hauls with Widow Rockfish and the number of Widow Rockfish observed by the WCGOP in the years 2002–2013 for each fleet. One year of data from midwater trawl had to be removed due to confidentiality (at least three vessels need to be observed within a year, regardless of species caught, for the strata defined). Sample sizes are largest for bottom trawl and least for hook-and-line. Midwater trawl and shoreside hake were sampled in few years, mostly since 2011. Since 2011, when the trawl rationalization program was implemented, observer coverage rates increased to nearly 100% for all the limited entry trawl vessels in the program. Open access and non- sablefish fixed gear fisheries have continued with observer rates less than 13% of all groundfish landings 9 (WCGOP report,http://www.nwfsc.noaa.gov/research/divisions/fram/observation/data_products/sector_products.cfm).

Table 16 shows discard totals in metric tons for each year, the source of the discard data, and whether it was included in the assessment. Coefficients of variation (CV) are set to 5% for years/fleets with 100% observer coverage. For the non-catch shares sectors the WCGOP errors were calculated by bootstrapping vessels within ports because the observer program randomly chooses vessels within ports to be observed.

Total discards were estimated in many years for some fleets and few for others (Table 16). Discards in the bottom trawl fleet were estimated for all available years (2002–2023), and discard rates (d/[d+r]) were typically greater than 50% prior to implementation of the trawl rationalization program in 2011, but less than 5% thereafter. The hook-and-line fleet discard rates ranged from 0% to 100% while quantities were low for all years (<0.2 mt). Observations of the midwater trawl fleet were available in only one year prior to catch-shares (2002), and every year post-catch shares (2011-2023). The discard ratio was 42.5% in 2002. The discard quantities were virtually 0 in 2012 and 2013 and then have continuously increased in the 2014-2018 period (from 0.01 mt in 2014 to 37.2 mt in 2018, Table 16). The discard quantities remain at an average level of 33.8mt for the period 2018-2023. However, the discard rates remain low (<0.5%) for the entire period (2011-2023). The shoreside hake fleet was only observed post- trawl rationalization, and even though they do not typically sort the catch at-sea, 2011 showed a discard rate of 9.6%. This was mainly the result of a single very large discard event recorded in the observer database, and because it was not indicative of more recent years and the shoreside hake fishery is managed under a maximum retention regulation, discard estimates were simply added into landings and not modeled separately for this fleet. No observations of the net fleet were available even though a very small amount of Widow Rockfish was landed by this gear between 2002 and 2023. Overall, this period of time (2002–2023) is a period with highly regulated fisheries, and discarding could have been a result of trip limits being reached. Therefore, these numbers may not be indicative of previous years when the fishery was not as tightly regulated. Variability from bootstrapping the discard data often had a long tail or was characterized by small discards or large discards, indicating that tow-specific discard rates were sometimes zero and sometimes near 100%.

Length compositions of the discards for the bottom trawl are in Figure 29. These discards were fitted to in the model. Estimated total catches, the sum of estimated discards and fixed landings, are reported where necessary.

$$D_{y,f} = \frac{d_{y,f}}{r_{y,f}} R_{y,f}$$

2.2.4 Biological data

2.2.4.1 Weight-length relationship

Weight-at-length data, which are the same used in the 2015 assessment, were collected from fisheries sampling and by the Triennial and NWFSC WCGBT Surveys, and were used to estimate a weight-length relationship for widow rockfish (Figure 30). Weight-at-length was similar between sources with the fishery samples showing a slightly smaller weight at large sizes when compared to the survey data (Figure 31). WCGOP data were not used because only small fish were sampled, the weight of these small fish were typically less than from other sources (Figure 30), and the curves fitted to only WCGOP data were unable to estimate the slope. There were only 81 observations from the WCGOP data, which is a small amount of data compared to everything available. However, these observations may be useful to understand discards.

The weight-length relationship used in the 2011 assessment was similar for males but predicted slightly heavier females at larger sizes than the 2015 assessment (Figure 31). The following relationships between weight and length for females and males were estimated for the 2015 assessment from all of the data combined and were used in the current assessment:

$$\text{Females:} \qquad weight = 1.7355 \times 10^{-5} \cdot Length^{2.9617}$$

$$\text{Males:} \qquad weight = 1.4824 \times 10^{-5} \cdot Length^{3.0047}$$

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

2.2.4.2 Maturity schedule

Estimates of maturity used in this update were the same as the 2015 assessment. Estimates of maturity at length have been presented by (Barss and Echeverria 1987), (Echeverria

1987), and (Love 1990). (Barss and Echeverria 1987) supplied data collected from Oregon and California commercial and recreational samples, which allowed us to estimate the proportion mature-at-length and proportion mature-at-age for samples from each state (Figure 32). As noted by (Barss and Echeverria 1987), the samples from Oregon matured at older age and larger length. Estimates of maturity-at-length from California reported by (Barss and Echeverria 1987) are similar to estimates of length-at-50%-mature from samples collected in California reported by (Echeverria 1987) and (Love 1990), although (Barss and Echeverria 1987) show the smallest length-at-50%-mature. To maintain some consistency with the 2011 assessment and to avoid any potential growth issues by area, the 2015 assessment used maturity-at-age data from the 2011 assessment, but used the data provided by (Barss and Echeverria 1987) to estimate a new maturity curve following a logistic function with the data from California and Oregon equally weighted to avoid California dominating the estimated relationship. This maturity-at-age curve falls between the estimated California and Oregon maturity-at-age curves (Figure 32, right), with the age-at-50%-mature estimated at 5.47 and with a slope of -0.7747 (as specified in SS). This logistic maturity-at-age curve was used in the 2015 and 2019 update assessment except that maturity-at-age for ages 2 and lower were set equal to zero (Table 19).

2.2.4.3 Fecundity

Fecundity in rockfish is often not a linear function of weight, but increases faster at larger weights (Dick 2009). Therefore, this relationship is often accounted for in rockfish assessments by using spawning output (numbers of eggs) to determine current status. (Dick 2009) did not find a significant relationship between the number of eggs per gram of body weight and body weight for widow rockfish. Therefore, spawning output was assumed to be proportional to weight, which is the same as spawning biomass, and is reported here.

2.2.4.4 Natural Mortality

Natural mortality used in this update differed from the 2015 assessment. Natural mortality (M) is a parameter that is often highly uncertain in fish stocks. Past assessments of widow rockfish assumed constant natural mortality of 0.125 yr-1 or 0.15 yr-1. The 2011 assessment estimated M with a prior developed by Owen Hamel (NWFSC, pers. comm.) using methods described in (Hamel 2014). This prior was based on a maximum age of 44 and 40 for females and males, respectively, a mean temperature of 8 degrees Celsius (about 150m deep off of Oregon), and a gonadosomatic index of 9.99% and 1.86% for females and males, respectively (Love 1990). The sex-specific lognormal priors for M have medians of 0.124 yr-1 and 0.129 yr-1 for females and males, respectively, and a coefficient of variation (CV) of 30.7% for each sex. In 2015, discussions with Owen

Hamel (NWFSC) led to the development of a new prior based solely on maximum age to use when estimating M. Using all of the available age data, a maximum age of 54 was determined for both females and males, although it has been rare to observe widow rockfish older than about 45 years old (Figure 33). This resulted in a prior with a much smaller median (0.0810 or -2.513284 in log space) and a larger standard deviation in log space (0.523694). For the update assessment, an updated meta-anaysis resulted in a prior with a slightly smaller median than the 2015 assessment (0.10 or -2.30 in log space) and a smaller standard deviation in log space (0.438). Figure 34 shows that these prior distributions are wide and not highly informative.

2.2.4.5 Length-at-age

Estimates of length-at-age used in this update were the same as the 2015 assessment. Two different labs have aged the majority of processed otoliths for widow rockfish. The SWFSC has been aging widow rockfish otoliths for many years, including all of the fishery data prior to 2011 and otoliths collected from the NWFSC WCGBT survey in 2009 and 2010. The Cooperative Ageing Project (CAP) in Newport, Oregon aged 1,100 otoliths from the NWFSC WCGBT survey, 2,026 otoliths provided by ASHOP, and 3,467 otoliths collected by port samplers. All of the commercial fishery samples were collected in the years 2011–2014. In total, there are 105,814 paired age and length observations ranging from 1978 to 2014. Figure 35 shows the lengths and ages for all years and all data as well as predicted von Bertalanffy fits to the data. Females grow larger than males and sex specific growth parameters were estimated at the following values:

$$\text{Females:} \qquad L_\infty = 50.34, \quad k = 0.15, \quad t_0 = -2.22$$

$$\text{Males:} \qquad L_\infty = 44.19, \quad k = 0.21, \quad t_0 = -1.78$$

The data from each source (ASHOP, port sampling/BDS, Triennial survey, and NWFSC survey) are shown in Figure 36 with fitted von Bertalanffy lines. All of these sources are quite similar, especially observations from ASHOP and the NWFSC survey. The standard deviation (SD) and coefficient of variation (CV) of length-at-age are shown in Figure 37. Modelling the CV as a function of predicted length-at-age appears to be somewhat linear from a value just over 0.1 at small lengths and slightly less than 0.045 at larger lengths. However, variance in length- at-age was estimated separately in stock-synthesis.

2.2.4.6 Sex ratios

Females tend to grow larger than males and it is expected that the proportion of females approaches one at large lengths and is less than 0.5 at intermediate lengths. Figure 38 shows that the proportion of females at length from survey data is approximately 50% until approximately 34 cm, when the proportion of females drops below 50%. At lengths larger than 46 cm, the proportion of females increases rapidly to one, suggesting that few males grow larger than 50 cm.

2.2.4.7 Ageing bias and imprecision

Uncertainty surrounding the ageing-error process for widow rockfish used in the 2015 assessment was incorporated by estimating ageing error by age. No changes were made from the 2015 assessment for the update. Age-composition data used in the model were from break-and-burn and surface reads and were aged by the Cooperative Ageing Project (CAP) in Newport, Oregon and the SWFSC in Santa Cruz, California. 12 Break-and-burn double reads of 1788 otoliths were performed by both the CAP and the SWFSC lab combined. Additionally, 100 otoliths were read both by surface and break-and-burn methods. An ageing error estimate was made based on these double reads using a computational tool specifically developed for estimating ageing error (Punt et al. 2008), and using release 1.0.0 of the R package nwfscAgeingError (Thorson, Stewart, and Punt 2012) for input and output diagnostics, publicly available at: https://github.com/nwfsc-assess/nwfscAgeingError. The maximum aged fish read by the surface reading method was 10 years and the cross otolith reads between the surface and break-and-burn ageing methods showed limited variation. Therefore, a unique ageing error was not created for surface read otoliths. A non-linear standard error was estimated by age where there is more variability in the estimated age of older fish was estimated for each reading lab (Table 20 and Figure 39).

3 Assessment model

An age-structured stock assessment model was used to predict the biomass trajectory of Widow Rockfish with an approach of balancing parsimony with complexity. This allowed for the determination of general trends in the biomass over time without introducing extraneous data partitions that explain little additional variation. The assessment followed the same model structure as the 2015 base assessment (Hicks & Wetzel, 2015).

3.1 History of modeling approaches

Interest in assessing Widow Rockfish began with a workshop on Widow Rockfish that was held at the NMFS SWFSC lab on December 11–12, 1980 (Lenarz & Gunderson 1987). This workshop was in response to the increase in catches that began in 1979. Descriptions of the fisheries in different states were given along with the biological research that was being done.

A 1984 assessment of Widow Rockfish ((Lenarz 1984)) summarizes a 1983 report provided to the groundfish management team, and then reports the results of a full assessment. Changes included reducing M from 0.25 yr-1 to 0.15 yr-1, modeling sexes combined, and making improvements to the cohort analysis. The assessment reported that the population had declined considerably since 1980 (more than 50%) and that 1977 and 1978 were potentially strong cohorts. Assessments through 1988 suggested an equilibrium yield around 10,000 mt and strong cohorts in the late 1970s or early 1980s.

In 1990 ((Hightower and Lenarz 1990)), stock synthesis was introduced as an assessment tool and F0.1 was used to determine sustainable yield for M values of 0.15 yr-1 and 0.2 yr-1. Equilibrium yield estimates were slightly less than 10,000 mt. In 1988 ((Hightower and Lenarz 1990)) FSPR=35% was used to determine ABC, which was 11% less than the ABC from the previous assessment. This assessment also reported results of an area-stratified model where northern and southern areas were treated as separate fisheries, with different selectivities. An assessment in 1993 ((J. Rogers and Lenarz 1993)) produced similar results as the 1990 assessment, but made some notable observations. They found that the 1980 and 1981 year classes were stronger than the 1978, 1979, and 1984 year classes. They also reported different selectivities between bottom trawl and midwater trawl gears and suggested separating the landings by gear type.

The 1997 assessment ((Ralston and Pearson 1997)) defined the fleet structure that would pretty much remain until 2011. They define a mixed gear fishery in Eureka and Conception INPFC areas, an Oregon bottom trawl fishery, an Oregon midwater trawl fishery, and a Vancouver-Columbia trawl fishery. They reported that the fishery had been supported by a small number of strong cohorts: 1977, 1978, 1980, 1981, and especially

1970. They cautioned against using a constant harvest rate policy of F35% or F40% because of the low stock size.

An age-based model similar to Stock Synthesis was coded in ADMB ((Fournier et al. 2012)) for the 2000 assessment ((Williams et al. 2000)). The differences between SS and the new ADMB model were minor. This assessment predicted that the Widow Rockfish stock was below the B25% minimum stock size threshold and the NMFS formally declared the stock to be overfished, but that the population was likely to increase with reasonable catches. Natural mortality was fixed at 0.15 yr-1 in this model and a starting year of 1968 was chosen based on the assumption that the 1965 year class was the earliest recruitment that could be estimated given the available data. The assessment model remained the same through 2007 with the exception of starting in 1958 and reducing the fixed value of M to 0.125 yr-1. In 2009, a full 13 assessment was completed with a two-area model for a coastwide stock that estimated the proportion of recruitment in each area and started with reconstructed landings back to 1916 ((He et al. 2009)).

The stock was not declared rebuilt until the 2011 assessment (He et al. (2011)]) This assessment was a one-area model with fisheries stratified by areas as in previous assessments. This was the result of an investigation that found little difference between a one-area model and a two-area model. The model used Stock Synthesis, started in 1916, estimated recruitment, estimated M with a prior distribution, used length-based selectivity, and assumed a time-varying, but flat discard rate for all fisheries before 2007.

The last full assessment was conducted in 2015 (Hicks & Wetzel, 2015). This was an age-structured benchmark assessment reconfiguring the fleet structure based on fishing and discarding strategy rather than space. For example, states were combined, but gears were kept separate. Several sources of data were re-evaluated, and additional length and age data were used.

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 ((National Marine Fisheries Service (NMFS) National Oceanic and Atmospheric Administration (NOAA) Commerce 2017)). The most recent update assessment was conducted in 2019 ((G. Adams et al. 2019)). The 2019 assessment included updated data (landings, survey indices, length / age composition, and discards), an updated prior on natural mortality (M), updated fixed steepness, and routine model bridging steps, but the model was otherwise unchanged from the 2015 assessment. The assessment estimated spawning stock biomass (SSB) in 2018 to be near the unfished SSB.

3.2 Responses to SSC Groundfish Subcommittee requests

To be completed after review.

3.3 Model Structure and Assumptions

3.3.1 Model Changes from the Last Assessment

The specifications of the assessment are listed in Table 21 and are not changed from the 2019 assessment, except by updating data, the prior on natural mortality, time blocks on selectivity and retention parameters, and other routine model bridging steps.

Data updated from the 2019 assessment include landings, survey indices, age / length composition data, and discard data. The only major change to the treatment of data and fleets was the addition of hook-and-line discards to hook-and-line landings, and the accompanying removal of the likelihood for hook-and-line discards. Removals from the hook-and-line fleet are generally minimal, approximately 0.2% of the total removals in the last two decades, of which discards are a small fraction. Owing to the very limited discard sample size for this fleet, the model was unable to reliably estimate discards and these data displayed substantial leverage on the model. Updates to the data had the largest impact on SSB among the various model bridging steps undertaken; in particular, the addition of (non-hook-and-line) discard data resulted in a small decrease in absolute SSB prior to 1980 and a large decrease in absolute SSB from the mid 2010s through the current year (Figure 31). Changes from other data sources were smaller. See “Data” and “Model Bridging” sections for detail.

The structural changes to the model were minimal, and were limited to the addition of an additional block on midwater trawl retention (from 2011–2016) and hake selectivity (from 2020 onward). In addition, the model estimates retention in the midwater trawl in late years (2017 onward), whereas it was fixed at 0.99 in the previous assessment. These changes were undertaken to address poor fit to midwater trawl discards and hake fleet length compositions, assumed to be due to management changes in 2017 and shifts in the spatial distribution of the hake fleet, respectively. Neither change had a discernible influence on the estimated SSB. See “Model Bridging” section for detail.

Other model bridging steps undertaken include updating the prior on natural mortality, updating fixed length-weight regression parameters, updating recruitment bias adjustment parameters, and amending initial values after jittering analyses suggested the model had converged to a local (but highly similar) minimum. None of these changes had a discernible effect on the model estimates; see “Parameters” and “Model Bridging” sections for detail.

3.3.2 Modeling Platform and Structure

For this update assessment, new versions of the previously used software were used. Stock Synthesis v3.30.13 was used to estimate the parameters in the 2019 model. R4SS, version

1.35.3, along with R version 3.5.3 were used to investigate and plot the 2019 model fits. For the update, Stock Synthesis v3.30.2 and R4SS, version 1.51.0, along with R version 4.5.0 were used. A summary of the data sources used in the model (details discussed above) is shown in Figure 40. Stock Synthesis has many options when setting up a model and the assessment model for Widow Rockfish was set up in the following manner.

3.3.3 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 lengths in the population were tracked by 1 cm intervals and the length data were binned into 2 cm intervals. A curvilinear ageing imprecision relationship was estimated and used to model ageing error. Fecundity was assumed to be proportional to body weight, thus spawning biomass was used as the measure of spawning output.

3.3.3.1 Model Fleets and Areas

Widow Rockfish are observed along the entire U.S. West Coast in survey and fishery observations. Past assessments have attempted modelling Widow Rockfish in two separate areas split by latitude 43° Investigations in 2011 found that a single area model produced similar results, and the 2015 assessment authors additionally concluded that NWFSC bottom trawl survey data suggest adult ontogenetic movement among areas and found data to inform differences in life-history assumptions among areas were insufficient. Therefore the current assessment uses a single-area model.

Multiple fisheries encounter Widow Rockfish. The definitions of fishing fleets have not been changed from those in the 2015 and 2019 assessments. Five fishing fleets were specified within the model: 1) a shorebased bottom trawl fleet with coastwide catches from 1916–2024, 2) a shorebased midwater trawl fleet with coastwide catches from 1979–2024, 3) a mostly midwater trawl fleet that targets Pacific Hake/Whiting (Merluccius productus) and includes a foreign and at-sea fleet with catches from 1975–2024, a domestic shorebased fleet that targeted Pacific Hake with catches from 1991–2024, and foreign vessels that targeted Pacific Hake and rockfish between 1966–1976, 4) a net fishery consisting of catches mostly from California from 1981–2024, and 5) a hook-and-line fishery (predominantly longline) with coastwide catches from 1916–2024. 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).

The Triennial Shelf Survey was kept as a single series, as in the 2015 and 2019 assessment. Assessment of other groundfish have split this survey into an early and a late series, based mostly on the shift to deeper depths and the timing of the survey (see section 2.1.2), by estimating different catchability parameters and selectivity parameters for each period. Age data were not available for the Triennial survey, but were available for the NWFSC WCGBT survey and were entered into the model as conditional age-at-length. Length-frequencies were calculated for the Triennial and the NWFSC WCGBT surveys within each stratum, and then combined across strata using the biomass in each stratum, and then combined across strata using the biomass in each stratum as the weighting factor. This reduced the influence of a few fish observed in a large area.

3.3.4 Model Parameters

3.3.4.1 Estimated and Fixed Parameters

There were 214 estimated parameters in the base model. These included one parameter for recruitment (R0), 10 sex-specific parameters for growth, two sex-specific natural mortality parameters, four parameters for extra variability on the survey indices (survey indices were fixed at zero), four parameters for the catchability of the hake series and the Triennial Shelf survey (the catchabilities for other surveys were calculated analytically), 49 parameters for selectivity, retention, and time blocking of the fleets, eight parameters for survey selectivity, 125 recruitment deviations, and 12 forecast recruitment deviations.

Fixed parameters in the model were as follows. Steepness was fixed at 0.72, which is the same as the 2019 assessment as is the mean of the current west coast rockfish steepness prior as described above. A sensitivity analysis and a likelihood profile were done for steepness. The standard deviation of recruitment deviates was fixed at 0.60. Maturity at age was fixed as described in Section 2.3.2. Length-weight parameters were fixed at estimates using length-weight observations from the NWFSC WCGBT survey (Figure fig-wl-fits and Table 22).

Dome-shaped selectivity was explored for both the fishery and the surveys in the 2015 assessment. Older Widow Rockfish are often found in deeper waters and may move into areas that limit their availability to fishing gear, especially trawl gear. Little evidence was found in 2015 for domed shape selectivity in all but the midwater trawl fleet. The final base model assumed asymptotic selectivity (using the double-normal formulation in SS3) for each fishery, except for the midwater trawl fishery. The NWFSC and Triennial surveys both used spline curves. All selectivity curves were length based and the same shape as the 2019 update, with the exception of the NWFSC survey fleet. The NWFSC 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 and retention parameters in the bottom trawl, midwater trawl, hake and hook-and-line fisheries as indicated in Table 21.

3.3.4.2 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)) = 0.4384343 following analysis of the data in (Then et al. 2015) by Owen Hamel and the authors. In the current assessment the prior on M has been updated to reflect 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.

The prior for steepness (h) assumes a beta distribution with parameters based on an update of the Dorn rockfish prior (commonly used in past West Coast rockfish assessments) conducted by Jim Thorson (pers. comm, NWFSC, NOAA) which was reviewed and endorsed by the SSC in 2015. During the stock assessment review, it was decided that the steepness prior should be developed without the past Widow Rockfish data to avoid using the same data to inform both the model prior and likelihood. Without Widow Rockfish, the prior used for the 2015 assessment was a beta distribution with mean = 0.798 and SD = 0.132 (corresponding beta parameters $\alpha = 6.59$ and $\beta = 1.667$). The 2019 update assessments used the current West Coast rockfish steepness prior with mean = 0.72 and SD = 0.16 ($\alpha = 4.95$, $\beta = 1.93$) which was approved for use in all rockfish stock assessments for 2019. This update assessment uses the same prior.

3.3.4.3 Recruitment deviations

The specification of when to estimate recruitment deviations is an assumption that likely affects model uncertainty. It was decided to estimate recruitment deviations from 1900–2024 to appropriately quantify uncertainty. 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 2014. 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 with an upward and downward ramping of bias adjustment, 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 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 37).

Survey indices and total discards were fitted assuming a lognormal likelihood.

3.3.4.4 Sample weights

Following the 2015 assessment, the base model was iteratively reweighted using the approach described in (McAllister and Ianelli 1997) such that the various data sources were mostly consistent with each other in terms of the relationship between input and effective sample sizes. Length and age-at-length compositions from the NWFSC WCGBT survey were fit along with length and marginal age compositions from the fishery fleets. Length data started with a sample size determined from the equation listed in Section 2.2.3. Conditional age-at-length data assumed that each age was a random sample within the length bin and started with a sample size equal to the number of fish in that length bin. One extra variability parameter that was added to the input variance was estimated for each survey index series. Vessels present in the WCGOP data were bootstrapped to provide uncertainty of the total discard.

An alternative method to determine weightings for the different data sources is called the Francis method, which was based on equation TA1.8 in (Francis 2011). This formulation looks at the mean length or age and the variance of the mean to determine if across years, the variability is explained by the model. If the variability around the mean does not encompass the model predictions, then that data source should be down-weighted. This method does account for correlation in the data (i.e., the multinomial distribution) as opposed to the (McAllister and Ianelli 1997) method of looking at the difference between individual observations and predictions. As the 2015 full assessment used the McAllister & Ianelli method and changing the weighting method is outside the TORs for an update, Francis weighting method is presented as a sensitivity.

The 2015 and 2019 assessments weighted composition data via the lambdas. In the current assessment, the method to weight the composition datasets in SS3 was to use variance adjustment factors as the weighting factors. The fleet and data-type (length or age) factor was entered as variance adjustments factors until the harmonic mean of the effective sample sizes matched the mean of the adjusted input sample sizes (McAllister and Ianelli 1997). Once the weighting was determined, lambda factors for all fleets with both marginal length and marginal age compositions were down-weighted by 0.5 to account for the potential double use of data since length and age are observed from the same fish.

3.3.5 Key Assumptions and Structural Choices

The key assumptions in the model were that the assessed population is a single stock with biological parameters characterizing the entire coast, maturity at age has remained constant over the period modeled, weight-at-length has remained constant over the period modeled, the standard deviation in recruitment deviation is 0.60, and steepness is 0.72. These are simplifying assumptions that unfortunately cannot be verified or disproven. Sensitivity analyses were conducted for most of these assumptions to determine their effect on the results. Structurally, the model assumed that the catches from each fleet were representative of the coastwide population, instead of specific areas, and fishing mortality prior to 1916 was negligible. It also assumed that discards were low prior to 1982 and after 2010, though have been increasing after 2018.

3.3.5.1 Model Bridging

The exploration of models began by bridging from the 2019 update assessment to SS3 version 3.30.2, which produced no discernible difference. We then focused on data bridging. Updating the catch series did not have a substantial effect on the historical biomass, and estimated the stock biomass increasing from 2000 to 2020 before decreasing up to the current period. Updating the model discards had the most significant impact on the absolute stock biomass (SSB), with a small decrease in absolute SSB prior to 1980 and a large decrease in absolute SSB from the mid 2010s through the current year (Figure 31). Updating model indices had a similar effect, while updating the age and length composition data increased the absolute stock biomass in the current period. Updates to discards likewise had the largest effect on relative SSB (fraction of unfished biomass); changes in relative SSB owing to all other datasets were in general small.

None of the model bridging steps had a substantial effect on the estimates of stock biomass (Figure 31). The model bridging changes included (1) updating the prior for natural mortality (M) to follow that recommended by (Hamel and Cope 2022), (2) updating fixed parameters of the male and female length-weight curve by fitting to data from the NWFSC WCGBT, ASHOP, and the triennial survey outside the model, (3) re-fitting the bias adjustment ramp for recruitment deviates, (4) adding a block on retention in the midwater trawl fishery from 2011-2016 and allowing estimation of retention in the final years of the model, which was previously fixed at 0.99, (5) adding a block to hake fleet selectivity from 2020-2024 (5) re-fitting the model using the MLE as initial values following a jittering analysis which revealed the previous MLE was a local minima. These changes collectively resulted in a very small decrease in relative SSB post-1990, and pairwise correlations among all shared parameters in these models were high (>0.999). Bridging from the previous prior on M to the (Hamel and Cope 2022) prior is detailed in the “priors” section.

The 2015 assessment attempted to estimate discards in the model, wherein the authors investigated time blocks for changes in selectivity and retention to match the limited discard data as best as possible. Using major changes in management (mainly in trip limits, Table 3) and observed changes in landings, a set of blocks was found for the bottom trawl, midwater trawl, and hook-and-line fleets. In the spirit of parsimony, they used as few blocks as possible, allowed blocks only for time periods with data, and added new blocks when they felt they were justified by changes in management and they improved the fit to the data. The same structure was followed for the update, except for the aforementioned addition of blocks to the midwater trawl and hake fleets.

The addition of midwater trawl and hake fleets block was necessitated by poor fits to midwater trawl discards and the length composition data from the hake fleet in from 2020 - 2024, respectively. The poor fit to hake fleet length composition data may be due to the high variability in the distribution of the hake / pacific whiting fleet between years, as the fleet moves to avoid bycatch (Holland and Martin 2019). Poor fit to midwater trawl discards is thought to be due to (1) the previous decision to fix late-year retention to 0.99 which represented an overestimate of the (very low) discards in 2011-2016, and (2) the reallocation of quota shares and subsequent increase in midwater trawl discards in 2017. These choices are described in more detail in the "fits to data" section.

3.4 Base Model Results

The base model parameter estimates along with approximate asymptotic standard errors are shown in Table 23 and the likelihood components are shown in Table 25. Estimates of key derived parameters and approximate 95% asymptotic confidence intervals are shown in Table 26.

3.4.1 Parameter Estimates

The estimates of natural mortality (0.124599 yr-1 and NA yr-1 for females and males, respectively) were higher than suggested by the medians of the prior distributions used in this assessment and the 2015 assessment. Fixing M at lower values than those estimates resulted in a pattern of reduced recruitment immediately before the fishery started. This suggests that the model is attempting to reduce the number of observations of older fish in the data. The estimates of M fall within the 95% confidence interval of the prior distribution (0.0425–0.237), and are shown in Figure 32.

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 M were rarely less than 0.14 yr-1 (Table 29). Uncertainty in the estimated M was also much less than the range of the prior (Figure 32). The assumption that appeared to have the largest effect on M was introducing dome-shaped selectivity in the midwater trawl fleet, which made M smaller (Table 29).

Selectivity curves were estimated for commercial and survey fleets and parameter estimates are provided in Table 24. The estimated selectivity, retention, and keep (the product of selectivity and retention) curves for the trawl and hook-and-line fleets are shown in Figure 33. The selectivity curves showed a shift to larger fish in 2002 for the bottom trawl fishery and a shift to smaller fish in 2003 for the hook-and-line fishery. The bottom trawl shift is consistent with the introduction of the RCA and gear restrictions (shoreward of the 18 RCA) that virtually eliminated fishing in shelf habitats where smaller Widow Rockfish would more likely be encountered. Around this same time, the fixed-gear RCA specifications began preventing fishing between 30 and 100 m.

The retention curves (Figure XYZ) showed a shift to retaining a lower percentage of fish since trip limits were introduced. The asymptote of the retention curve for the bottom trawl fishery sequentially decreased as more management restrictions were introduced to about 50% retention of larger fish in the 1998-2010 period. In recent years, bottom trawl retention is estimated at approximately 99%.

Midwater trawl and hook-and-line fisheries estimated an asymptote to retention just above 80% for the period 1983-2010. Both the selectivity for the hake fleet and the selectivity of the net fleet did not support dome-shaped selectivity (Figure 46). The estimated selectivity curves for the Triennial and NWFSC WCGBT surveys were similar to each other except that the triennial survey selected larger fish (Figure 46). The NWFSC WCGBT survey exhibited a more pronounced dome-shaped selectivity compared to the 2015 assessment.

In 2015, additional survey variability (process error added directly to each year's input variability) for the triennial and NWFSC WCGBT surveys was not estimated in the model because the estimate was zero. To avoid bound issues in estimation of the Hessian, the authors fixed these at zero because the model results included reasonable estimates of variance. We retained the same modelling approach for the update assessment. The additional standard deviation added to the fishery-dependent indices was quite large, ranging from 0.16 for the bottom trawl index and 0.58 for the foreign at-sea hake fleet. The additional variability on the juvenile survey was the highest, at 0.83, giving the index very little weight in the model.

The estimates of maximum size for both females and males (Table 23) were not unexpected given the data in Figure 35. Estimates of k were slightly different in the model, but that is expected when accounting for selectivity. Estimated growth curves are shown in (Figure 47).

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 48, Table 27). There is little information regarding recruitment prior to 1965, and the uncertainty in these estimates is expressed in the model. There are very large, but uncertain, estimates of recruitment in 2013, 1970, 2008, and 1971. Other large recruitment events (in descending order of magnitude) occurred in 1978, 2014, 1981, 2010, and 1991. The five lowest recruitments (in ascending order) occurred in 2012, 2011, 1976, 2007, and 1973. Two of the four largest estimated recruitments occurred in the last 11 years.

3.4.2 Fits to the Data

There are numerous types of data for which the fits are discussed: survey abundance indices, discard data (biomass and length compositions), length composition data for the fisheries and surveys, marginal age compositions for the fisheries, and conditional age-at-length observations for the NWFSC WCGBT survey.

Survey indices and total discards were fitted assuming a lognormal likelihood.The five indices of abundance (three survey series, and two fishery indices of abundance) shown in Figure 36. The Triennial Shelf Survey was kept as a single series, as in the 2015 and 2019 assessments. Extra standard error was estimated for all of the series except for the two survey series (Table 23). 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 NWFSC WCGBT survey showed a general increase from 2003 - 2015 followed by a general decrease from 2016 - 2024, which was also estimated in the base model (Figure 51, lower left). Low (2015, 2021, 2022) and high (2016) estimates of abundance did not fit well in the model.

Fitting the total observed discard amounts required time blocks (Figure 52). Fits to the trawl discards from the Pikitch data in 1985–1987 in the time block 1982–1989 were quite good. The EDCP data (1995–1999) were not fit as well. In the time block 1990–1997, the EDCP discard observations showed a high error, and the fits were within the confidence limits, but below the point estimate in two of the three years. The 2015 assessment introduced a time block in 1998 because a serious reduction in trip limits occurred in that year (Table 3) and continued to 2010. The EDCP data showed a very small amount of discarding, which was consistent with the WCGOP data from that time period, but in 1998 and 1999, landings from the bottom trawl fleet were very large compared to 2000–2010. Therefore, a large amount of discards were predicted for 1998 and 1999, which do not match the observations. It is believed that the EDCP observations in 1998 and 1999 are not indicative of the actual discards because the sample sizes from the EDCP data were small in those years, and 1999 had a few samples from early in the year and at the beginning of the two-month trip limit period. The predicted discards for the years 2002–2010 were small (ranging from 1.97 to 15.8 mt). Observed discards from WCGOP were low (mean 0.5 mt, SD 0.7 mt) following the implementation of catch shares in 2011. Following the reallocation of quota shares and re-establishment of a target fishery for widow rockfish in 2017, however, observed discards increased markedly (mean 30.4 mt), though with high interannual variability (SD 14.9 mt).

The 2019 model applied four time blocks to midwater trawl retention, with constant fixed discard rates of 1% in both early years (1916-1981) and late years (2011 onward). With the addition of new discard data since the 2017 reallocation, however, the use of a fixed discard rate from 2011 onward resulted in poor fits to the discard data. Therefore the current assessment utilizes an additional block on retention from 2011-2016, with the final block beginning in 2017; retention is estimated in both the 2011-2016 and 2017-2024 time blocks, though it remains fixed for the earliest time block (1916-1981) at the value used in the previous assessment. The first time block with discard data was 1983 to 2001. Predicted discards for all three years of the Pikitch data (1985–1987) were underfit, but within the confidence limits (Figure 52). EDCP data in 1997 and 1998 were underfit. The second time block was 2002 to 2010, which contained only one observation in 2002 (and was fit exactly, as expected). Discard rates were overestimated in 2012-2013 and underestimated in 2015-2016, though they were generally well fit in in the 2017-2024 time blocks.

Hook-and-line discard biological data was recently revised by WCGOP. Samples from nearshore pot and net gears that were for previous assessments added to hook-and-line samples are now removed, according to current best practices. This update to the data resulted in two issues: i) reduced sample sizes and ii) length compositions which differed significantly from the 2019 assessment. As a result, retention parameters for the hook-and-line fleet were poorly informed, and the decision was made to combine hook-and-line discard and retained catch. Biological samples for hook-and-line discards were then removed from the model, and discards were not estimated for the hook-and-line fleet. Hook-and-line removals were approximately 0.2% of the total Widow Rockfish removals in the last two decades.

Fits to the length-composition data are displayed in two different ways: the Pearson residuals-at-length are shown for each year for all types of length compositions, and also compared across fleets. More detailed plots of fitted lines drawn over the plotted proportions at length are shown in Appendix A. Pearson residuals for the fisheries (Figure 53 to Figure 54) do not show consistent patterns, but they do show that some fleets are not fitting some cohorts. Each fleet also shows that there are periods where older fish are underfit, and periods when older fish are overfit. With a peaked length frequency distribution, it is common for these patterns to appear given shifts in the expected distribution due to sampling error, and time-varying parameters that are assumed time-invariant. The net fishery observed some very large fish in the first two years of data, but did not observe those fish in later years. This pattern was not seen in any other fishery. There were also years where females showed positive residuals (filled circle, observed > expected) and males showed negative residuals (e.g., Figure 53, early years of bottom trawl and midwater trawl). It is uncertain if this pattern is related to growth, sexing error, or to sex-specific selectivity (e.g., when Widow Rockfish aggregate, sexes possibly may be aggregating separately). Overall, the fits to commercial fishery length compositions showed some patterns that the 2015 assessment deemed to require complicated modelling assumptions to alleviate. However, the residuals were mostly less than 2 in absolute value, especially for fleets that were well informed by data.

Looking at the fits to length compositions aggregated for all years shows that the general shape of the length distributions are captured (Figure 55).

The fits to bottom trawl discard length frequencies were generally good except in the years since trawl rationalisation began (2011). These recent years observed small fish, which the estimated selectivity of the trawl fleet did not allow for. There were no other years that showed small fish being caught by the trawl fleet. Attempting to explain these small fish with additional time blocks on selectivity and retention did not help because explaining the small fish in the discards worsened the fits to the landed and larger fish. Discards are extremely small in this time period, so it is unlikely that a misfit here will have a lot of effect on the model. Combining the discard length frequencies over years may not be appropriate for the bottom trawl fishery due to the likely changes in discarding practices, but Figure 56 shows the prediction of discarding smaller females than observed and a more peaked observed distribution of discarded males than predicted.

The Triennial Shelf and NWFSC WCGBT surveys length frequencies showed underfitting of older fish in some years and underfitting of younger fish in others (Figure 57). The combined length frequencies across years were bimodal with a valley around 37 cm, and the model showed an indication of a bimodal distribution but was unable to adequately capture both peaks (Figure 55). The nonparametric selectivity pattern helped to reduce this pattern, but selectivity may be even more complicated for the surveys.

Age data were fitted as marginal age compositions for the fishing fleets and as conditional age-at-length for the NWFSC WCGBT survey, which were expanded by tow and then by strata. Raw observations of age-at-length, which assumes that within each length bin the observed ages are a random sample of fish, were not used because they are inconsistent with the length compositions which are expanded. Using expanded age-at-length ensures that as the length bin size is increased, it approaches the expanded marginal age composition. Pearson residuals for the commercial fleets are shown in Figure 53 and Figure 54. For the trawl fisheries in Figure 53, there are diagonal patterns that mostly correspond to cohorts ageing through the years. However, there are instances where the diagonal seems to shift, such as the filled circles of the midwater trawl fishery on the lower left of the plot (years 1981–1991). The patterns match the length compositions residuals in some cases. The bottom trawl fishery shows the largest residuals in the most recent years, which could indicate a change in selectivity. The net and hook-and- line fits to age compositions (Figure 54) showed larger residuals than the trawl fisheries. As with the fits to the length compositions, the net fishery showed the inability to match the large number of older fish observed in the early years. There appears to be a strong shift in residuals in 1988 when a lack of fit to potentially a cohort appears. The residuals were typically less than 2 for fits to the age data. However, the female age compositions occasionally produced some large residuals that were not consistently seen in the male age compositions. Aggregating across years shows that the fit to age comps was good for the trawl fleets and less so for the net and hook-and-line fleets, which had smaller sample sizes (Figure 58). The aggregated data also showed that the predictions were often unable to fit the peak in the data.

The observed and expected age-at-length are shown in Figure 59 for the twelve years of the NWFSC WCGBT survey observations. The fits generally match the observations with some misfit at larger lengths. The standard deviation of age-at-length was variable and often the expectation was higher than the observations at larger lengths. Plots with the residuals for individual observations showed reasonably good fits to the conditional age-at-length data from the NWFSC shelf/combo survey (Figure 60). Some outliers are apparent, with large residuals mostly at smaller lengths for a given age.

3.4.3 Population Trajectory

The predicted spawning biomass (in metric tons) is given in Table 27 and plotted in Figure 61. The predicted spawning biomass 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 biomass declined rapidly with the developing domestic midwater fishery in the late 1970s and early 1980s. The stock continued to decline until 2000 when a combination of strong recruitment and low catches resulted in a quick increase from 2000 - 2018. The stock declined rapidly from 2019 until the end of the time series, due to a combination of increased catches and low recruitment.

The 2025 spawning biomass relative to unfished equilibrium spawning biomass is above the target of 40% of unfinished spawning biomass (49.7%), with a low of 34.1% in 2001 (Figure 63). This suggests that Widow Rockfish was not overfished, as was inferred from previous assessments (Williams et al. 2000). Approximate confidence intervals based on the asymptotic variance estimates show that the uncertainty in the estimated spawning biomass 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 61).

Recruitment deviations were estimated for the entire time series that was modeled (Figure 48 and discussed in Section 3.3.1) and provide a more realistic portrayal of uncertainty. There are very large, but uncertain, estimates of recruitment in 1970, 2008, 2016, and 1971 (in descending order of magnitude). Other large recruitment events (in descending order of magnitude) occurred in 1978, 1981, 2010, 1991, and 1997. The five lowest recruitments (in ascending order) occurred in 2012, 2019, 2020, 2011, and 1976. The 2008 and 2016 year classes were estimated as 2 of the 4 strongest year classes. 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 (Figure 49).

The stock-recruit curve resulting from a fixed value of steepness is shown in Figure 64 with estimated recruitments also shown. The stock is predicted to have never fallen to low enough levels that the steepness is obvious. However, the lowest levels of predicted spawning biomass showed some of the smallest recruitments and very few above average recruitments. Steepness was not estimated in this model, but sensitivities to alternative values of steepness are discussed below.

The population numbers-at-age for each year are shown in Appendix B.

3.5 Model Diagnostics

Three types of uncertainty are presented for the assessment of Widow Rockfish. First, uncertainty in the parameter estimates was determined using approximate asymptotic estimates of the standard error. These estimates were based on the maximum likelihood theory that the inverse of the Hessian matrix (the second derivative of the log-likelihood function with respect to the parameter vector) approaches the true uncertainty of the parameter estimates as the sample size approaches infinity. This approach takes into account the uncertainty in the data and supplies correlation estimates between parameters, but does not capture possible skewness in the error distribution of the parameters and may not accurately estimate the standard error in some cases (see (Stewart et al. 2013)).

The second type of uncertainty that is presented is related to modeling and structural error. This uncertainty cannot be captured in the base model as it is related to errors in the assumptions used in specifying the base model. Therefore, sensitivity analyses were conducted where assumptions were modified to reveal the effect they have on the model results.

Lastly, a major axis of uncertainty was determined from a parameter or structural assumption that results in the greatest change in stock status and advice, and projections were made for different states of nature based upon that parameter or structural assumption.

3.5.1 Convergence

Due to it consistently hitting the lower bound when estimated, the decision was made to fix the log-ascending width of the hook-and-line fleet selectivity curve at -5. Model convergence was determined by examining the final gradient, checking that the Hessian was positive (semi-)definite, and initializing the minimizer from perturbed values around the maximum likelihood estimates (MLE) to determine if the model found a better minimum ("jittering"). Initial jittering analyses indicated that the model had converged to a false (local) minimum, though the difference in log-likelihoods at the previous estimates and the new MLE was small (<0.5). After accepting the new MLE as the base model, jittering was repeated 100 times with a jitter coefficient of 0.10 and a better minimum was not found. 4% of the jittered models achieved the minimum negative log-likelihood and 23% were within two likelihood units. The model did not experience convergence issues when provided reasonable starting values. Through the jittering done as explained above and likelihood profiles, we are confident that the base case as presented represents the best fit to the data given the assumptions made. There were no difficulties in inverting the Hessian to obtain the parameter variance-covariance matrix. Likelihood profile runs which fixed M, R0 and h at more extreme values did not initially converge. This was addressed by using the parameter estimates from models with less extreme values as starting values in subsequent models. Convergence was defined as the lowest negative log-likelihood achieved with jittering where the Hessian matrix was invertible.

3.5.2 Parameter Uncertainty

Parameter estimates are shown in Table 22, Table 23, and Table 28 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 26 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 depletion is 30.12%–69.17% and above the management target of 40% of the unfished spawning biomass.

3.5.3 Sensitivity Analyses

Sensitivity analysis was performed to determine the model behavior under different assumptions than those of the base case model. 11 sensitivity analyses were conducted to explore the potential differences in model structure and assumptions, including:

1. Fixed natural mortality at 0.1 for both sexes (2015 assessment prior)
2. Fixed natural mortality at 0.124 yr-1 for females and 0.129 yr-1 for males (2011 assessment prior)
3. Fixed steepness at 0.4
4. Fixed steepness at 0.6
5. Fixed steepness at 0.798 (2015 assessment value)
6. Forcing asymptotic selectivity on the midwater trawl fleet
7. Fitting logistic curves for NWFSC WCGBT survey selectivities
8. Weighting the composition data using the Francis method
9. Updated Washington catch reconstruction
10. Inclusion of previously excluded shrimp trawl data

11. Exclusion of triennial survey data

Likelihood values and estimates of key parameters are shown in Table 29. Predicted spawning biomass trajectories, estimated recruitment deviations and comparisons of model estimates for 2025 are shown in in Figure 65 (sens_compare2_spawningbio_-uncertainty.png), Figure XX (sens_compare11_recdevs.png) and Figure XX (sens_-summary.png). The estimates of current stock depletion ranged from 49.14%-153.59% across the sensitivity runs, with fixing natural mortality to 0.1 (2015 assessment prior) resulting in the lowest estimate and forcing asymptotic selectivity on the midwater trawl fleet resulting in the highest estimate. Generally, the trajectory of the spawning biomass was qualitatively similar across all tested models, e.g., peak around late 1970s and late 2010s, projected decrease in biomass in 2025 followed by some recovery into the 2030s; the quantitative magnitude of these trends did vary across cases.

Fixing M at values lower than the base case estimate resulted in decreases in estimated spawning biomass, while fixing steepness across the values tested resulted in similar or increased estimated spawning biomass. The relative spawning biomass in 2025 changed to 86.73% with an M of 0.124 yr-1 and 0.129 yr-1 for females and males, respectively (2011 assessment prior), and to 49.14% with an M of 0.1 yr-1 (2015 assessment prior).

Fixing steepness at a value of 0.6 resulted in an increase of the spawning biomass to 138.4% and a decrease in equilibrium yield at a SPR50% reference harvest rate, while other tested values for fixed steepness increased spawning biomass slightly (108.58% and 108.58% for steepness at 0.4 and 0.798, respectively) and increasing equilibrium yield at a SPR50% reference harvest rate slightly. Fixing steepness at a value of 0.4 resulted in low recruitment deviations in the 2019-2024 period relative to other tested models and the base model.

Forcing asymptotic selectivity on the midwater fleet increased estimated biomass in 2025 by 153.59% compared to base model, while forcing logistic selectivity on the NWFSC WCGBT resulted in similar estimated spawning biomass to the base model. Including shrimp trawl data and updating WA catch reconstruction had almost no impact on the estimated spawning biomass. Excluding the triennial survey data lead to slight increases in estimated spawning biomass.

The alternative weighting using the Francis method generally increased the estimate of spawning biomass across the timeseries, but the estimated biomass for 2025 was similar between the Francis weighted model and the base model (117.66% compared to base model).

3.5.4 Retrospective Analysis

A 5-year retrospective analysis was conducted by running the model using data only through 2020, 2021, 2022, 2023, and 2024 progressively (Table 30 and Figure 66). The initial scale of the spawning population was basically unchanged for all of these retrospectives. Removing 4–5 years of data led to slightly lower estimates of fishing mortality (F) and slightly higher spawning biomass over the last 15 years. In contrast, removing only 1–2 years resulted in higher F and lower biomass estimates. Despite these minor differences,population trends from all retrospective runs were very close, and there were no consistent patterns as years were removed. No concerning patterns were observed in the retrospective analysis.

3.5.5 Likelihood Profiles and key parameters

Likelihood profiles were conducted for R0, steepness (even though it was not estimated in the base case) and over male and female natural mortality 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. There was some difficulty in achieving model convergence for many parameterizations in the likelihood profile. In some cases jittering was required.

As R0 increased, natural mortality also increased and the relative spawning biomass in 2024 was less depleted (Table 31). There was variable support for each likelihood component across the range of R0 evaluated. The total likelihood supported the estimated value (Table 31). Profiles are illustrated in Figure 68.For steepness, the negative log-likelihood was minimized at a steepness of 0.825, but the 95% confidence interval extends over the entire range of possible steepness values (Table 32). Profiles are illustrated in Figure 69. For profiles of natural mortality, the negative log-likelihood was minimized at a value of 0.132 for males, and a value of 0.121 for females (Table 33). Profiles are illustrated in Figure 70.

4 Management

4.1 Reference Points

Reference points were calculated using the estimated selectivities and catch distribution among fleets in the most recent year of the model (2024). Sustainable total yields (landings plus discards) were 5,625 mt when using an SPR50% reference harvest rate and with a 95% confidence interval of 4,326 to 6,925 mt. The spawning biomass equivalent to 40% of the unfished spawning output (SB40%) was 32,766 mt. Catches between the late 1990's and 2016 were well below the point estimate of potential long-term yields calculated using an SPR50% reference point, and the population is estimated to have increased continuously throughout that time period. However, catches from 2017 through 2024 were above the point estimate of potential long-term yields using an SPR50% reference point, exceeding the upper bound of the confidence interval in all years since 2018, and exceeding the point estimate by on average 82%.

The predicted spawning biomass 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 decease through 2000 (Figure 61). Between 2001 and 2016, the spawning biomass increased continuously due to small catches, and several years of high recruitment (though with lower than average recruitment in other recent years). The spawning biomass relative to unfished equilibrium spawning biomass climbed above the target of 40% of unfished spawning biomass in the early 2000's. 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 63). The fishing intensity (relative 1-SPR) exceeded the current estimates of the harvest rate limit (SPR50%) throughout the 1980s and early 1990s, and has again since 2018 (Figure 73). 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 74).

The equilibrium yield plot is shown in Figure 75, based on a steepness value fixed at 0.720. The predicted maximum sustainable yield under the assumptions of this assessment occurs near 25% of equilibrium unfished spawning biomass.

4.2 Unresolved problems and major uncertainties

This is a reconfiguration of a long line of stock assessments for widow rockfish on the U.S. West Coast and although scientifically credible advice is provided by synthesizing many sources of data, there remain data and structural assumptions that contribute to uncertainty in the estimates. Major sources of uncertainty include landings, discards, natural mortality, and recruitment, which are discussed below.

Discards of widow rockfish are even more uncertain than landings, but because widow rockfish is a marketable species, historical discard rates were likely lower than less desirable or smaller species. In this assessment, we 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, and detecting large, but rare, discard events with far less than 100% observer coverage has a low probability. 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, though the 2017 reallocation of quota shares is likely to have influenced discarding practices. The open access fixed-gear fleet is not monitored by the full observer coverage required under trawl rationalization and data from the 2015 assessment show that discarding of widow rockfish has occurred on fixed gear vessels in recent years (limited entry vessel fishing with fixed gear are subject to 100% observer coverage). Uncertainty in recent discards is greatly reduced because of observer coverage, but it is unknown what historical discarding may have been. The model assumes a discard rate of 1% pre-1982, which is arbitrary, but reasonable. Discard mortality is assumed to be 100%, which may overestimate actual mortality (Jarvis & Lowe, 2007), but given the low number of discards, is likely to have a minimal effect on assessment results.

There may also be uncertainty in the ability of bottom trawl surveys to be a reliable measure of widow abundance, which spend a significant portion of their time in mid-water (Wilkins 1986). Uncertainty in the widow rockfish NWFSC WCGBTS estimates was high, and inter-annual variability greater than might be expected for a long-lived rockfish species, so fits to this index were poor. Multiple surveys are used in the assessment, but further consideration of additional surveys is reasonable.

Widow rockfish is a relatively long-lived fish, and natural mortality is likely to be lower than many species of fish, such as 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 natual mortality used in this assessment). However, even with length and age data available back to the late 1970s, natural mortality was estimated at 0.125 for females and 0.137 yr^{-1} for males, with a small amount of uncertainty (e.g., a 6.6% coefficient of variation for females). This assessment attempts to capture that uncertainty by estimating natural mortality (M) and integrating that uncertainty into the derived biomass estimates, as well as additional uncertainty by including levels outside of the predicted interval in a decision table.

Model sensitivities and profiles over M showed that current stock status was highly sensitive to the assumption about natural mortality. Notably, the estimated natural mortality values 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 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.

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 equilibrium spawning biomass increased and current spawning biomass decreased. Sustainable yields at the SPR50% reference harvest rate ranged from approximately 2641 to 5992 mt depending on the value of steepness.

4.3 Harvest Projections and Decision Tables

A twelve year projection of the base model with catches equal to the current ACL in 2025 and 2026 (10,669 mt and 9824 mt, respectively) and catches of 9,000 mt for all later years and a catch allocation equal to the percentages for each fleet in 2024 predicts spawning biomass will decrease over the projection period for all states of nature (Table 36).

Projections with catches based on the predicted annual catch limit (ACL) using the SPR rate of 50%, the 40:10 control rule, and a 0.45 P* adjustment using a sigma of 0.50 from 2027 onward suggest that the spawning biomass will decrease over the projection period for all states of nature (Table 36).Predicted ACL catches range from 3,321 mt in 2027 to 4,392 mt in 2036.

Projections with catches based on the predicted annual catch limit (ACL) using the SPR rate of 50%, the 40:10 control rule, and a 0.25 P* adjustment using a sigma of 0.50 from 2021 onward suggest that the spawning biomass will decrease over the projection period for all states of nature. Predicted ACL catches range from 1,790 mt in 2027 to 1,886 mt in 2036.

Two categories of parameters that greatly contributed to uncertainty in the results were natural mortality (an important estimated parameter) and steepness (not estimated in the model). 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 109 assessment which included a third factor, 2013 recruitment strength. The 12.5% and 87.5% quantiles for female and male natural mortality (independently) were chosen as low and high values (0.115 yr-1 and 0.134 yr-1 for females; 0.127 yr-1 and 0.146 yr-1 for males). Steepness is probably the most important factor since it 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 three factors defined the low state of nature and the high combination of these three factors defined the high state of nature. The predictions of spawning biomass in 2025 from the low and high states of nature are close to the 12.5% and 87.5% lognormal quantiles from the base model.

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

4.4 Evaluation of Scientific Uncertainty

Spawning biomass is estimated to be at 40,603 mt in 2025, with a sigma of 0.2753. OFL is estimated to be 5,667.1 mt in 2019 with a coefficient of variation of 0.3187.

4.5 Regional management considerations

Widow rockfish have shown latitudinal differences in life-history parameters, which has led past assessment authors to pursue a two-area model. Modelling a stock with two areas is difficult because it requires many assumptions about recruitment distribution, movement, and connectivity, while also splitting data into two areas that reduces sample sizes when compared to a coastwide model. The upside is that it can result in a better model that more accurately predicts regional status. This assessment is a coastwide model because not enough is known about the assumptions that would have to be made for a two-area model.

It is still important to consider regional differences when making management decisions. Following recent cohorts through time with survey data showed that older fish showed up in the north after younger fish were observed in the south (Figure 2). This may indicate connectivity between the north and the south and that this is truly one stock. However, more investigation is needed.

Widow rockfish are managed on a coastwide basis and observed more often in the NWFSC WCGBT bottom trawl survey 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. Rockfish Conservation Areas (RCAs) cover a significant proportion of widow rockfish habitat, but a midwater trawl fishery is beginning to re-develop that can fish in these areas. 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. Below, we specifically identify five topics that we believe are most important (order does not indicate importance).

- **Historical landings and discards:** The historical landings and discards are uncertain for widow rockfish and improvements would increase the certainty that fishing removals are applied appropriately. Because landings are assumed to be known exactly in the assessment model, uncertainty in the predictions does not include uncertainty in the landings. A thorough look at historical landings, species compositions, and discarding practices would reduce the potential uncertainty that is not entirely accounted for.

- **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 unread, and improved understanding of the life-history of widow rockfish may reduce that uncertainty.

- **Maturity and fecundity::** There are few studies on the maturity of widow rockfish and even less recent information. There have been no studies that reported results of a histological analysis. Further research on the maturity and fecundity of widow rockfish, the potential differences between areas, the possibility of changes over time would greatly improve the assessment of these species.

- **Age data and error:** There is a considerable amount of error in the age data and potential for bias. Investigating the ageing error and bias would help to understand the influences that the age data have on this assessment. Disagreement between surface reads of age versus break-and-burn reads is worth more investigation.

- **Basin-wide 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.

4.7 Acknowledgements

Thank you to the University of Washington Stock Assessment course instructors Vlada Gertseva, Melissa Haltuch, Kiva Oken and Ian Taylor for their guidance in preparing our model. We want to acknowledge Tanya Rodgers (juvenile survey data), Ian Taylor and Chantel Wetzel (NWFSC survey data), XXX (ASHOP data), XXX (PACFIN data) and XXX (catch reconstruction and composition bridging).

5 Tables

5.1 Data

5.1.1 Fishery-dependent data

Table 2: Landings (mt) from the foreign & domestic at-sea fleet and the domestic shoreside hake fleet.Catches (mt) from the Pacific whiting at-sea fishery as determined by onboard observers.

Year	Foreign & Domestic	Shoreside hake		
	At-sea	CA	OR	WA
1966	3,670.0	0.0	0.0	0.0
1967	3,902.0	0.0	0.0	0.0
1968	1,956.0	0.0	0.0	0.0
1969	358.0	0.0	0.0	0.0
1970	554.0	0.0	0.0	0.0
1971	701.0	0.0	0.0	0.0
1972	421.0	0.0	0.0	0.0
1973	656.0	0.0	0.0	0.0
1974	418.0	0.0	0.0	0.0
1975	391.2	0.0	0.0	0.0
1976	718.5	0.0	0.0	0.0
1977	119.3	0.0	0.0	0.0
1978	191.9	0.0	0.0	0.0
1979	197.9	0.0	0.0	0.0
1980	272.0	0.0	0.0	0.0
1981	227.9	0.0	0.0	0.0
1982	157.5	0.0	0.0	0.0
1983	131.5	0.0	0.0	0.0
1984	294.7	0.0	0.0	0.0
1985	182.6	0.0	0.0	0.0
1986	256.8	0.0	0.0	0.0
1987	181.3	0.0	0.0	0.0
1988	231.6	0.0	0.0	0.0
1989	212.0	0.0	0.0	0.0

Year	Foreign & Domestic	Shoreside hake		
	At-sea	CA	OR	WA
1990	230.2	0.0	0.0	0.0
1991	471.3	42.7	39.0	9.3
1992	389.6	13.5	42.1	6.2
1993	173.2	0.4	91.2	11.0
1994	370.7	2.1	210.8	28.6
1995	228.6	7.2	192.1	36.8
1996	252.2	5.7	475.1	104.7
1997	215.5	7.2	133.9	22.1
1998	268.5	40.4	278.0	28.1
1999	191.8	12.7	166.4	15.2
2000	205.4	7.7	70.9	4.7
2001	174.0	9.2	26.4	9.0
2002	154.9	1.2	2.6	1.4
2003	14.5	0.4	7.6	4.6
2004	21.2	7.4	12.4	8.5
2005	80.1	5.2	59.1	13.6
2006	143.0	3.6	11.3	35.3
2007	146.0	1.0	46.1	35.3
2008	115.2	29.2	36.1	37.5
2009	26.6	2.3	46.6	59.8
2010	44.6	9.0	35.3	17.5
2011	38.4	0.0	79.9	19.5
2012	79.2	0.0	85.1	17.1
2013	31.2	0.0	115.1	29.2
2014	56.2	0.0	250.1	35.9

Table 3: A subset of management actions of importance to fisheries that caught Widow Rockfish.

Year	Management action
1982	Establishment of a 75,000 pound trip limit on Widow Rockfish in October
1983	Per-trip and per-week limits implemented for Sebastes complex coastwide (north and south of 40° N)
1984	30,000 pound Widow Rockfish trip limit at the start of the year adjusted to 1,000 pound trip limit in September
	50,000 pound Widow Rockfish trip limit limited to once per week
	Trip limit lowered to 40,000 pounds once per week in May
	Directed fishery for Widow Rockfish closed in August and a full fishery closure in November
1985	30,000 pound trip limit once per week, or 60,000 pounds once every 2 weeks. Every 2 week option was rescinded in April
	Landings of Sebastes complex and Widow Rockfish smaller than 3,000 pounds unrestricted
	Widow Rockfish trip limit reduced to 3,000 pounds per trip without a trip frequency in July
1986	30,000 pound coastwide Widow Rockfish trip limit with no biweekly option
	Landings of Sebastes complex and Widow Rockfish smaller than 3,000 pounds unrestricted
	3,000 pound coastwide trip limit implemented in September when Widow Rockfish ABC reached
1987	30,000 pound coastwide Widow Rockfish trip limit with no biweekly option. Only one landing per week above 3,000 pounds.
	Reduced Widow Rockfish trip limit to 5,000 pounds in October
	Closed the Widow Rockfish fishery in November
1988	30,000 pound coastwide Widow Rockfish trip limit with no biweekly option. Only one landing per week above 3,000 pounds.
	Reduced Widow Rockfish trip limit to 3,000 pounds in October
	30,000 pound coastwide Widow Rockfish trip limit with no biweekly option. Only one landing per week above 3,000 pounds.

Year	Management action
1989	Reduced Widow Rockfish trip limit to 10,000 pounds in April
	Reduced Widow Rockfish trip limit to 3,000 pounds in October
1990	15,000 pound trip limit once per week, or 25,000 pounds once every 2 weeks. Only one landing per week above 3,000 pounds.
	Closed the Widow Rockfish fishery in December
1991	10,000 pound trip limit once per week, or 20,000 pounds once every 2 weeks. Only one landing per period above 3,000 pounds.
	Reduced Widow Rockfish trip limit to 3,000 pounds on my birthday in September
1992	30,000 pound coastwide Widow Rockfish trip limit per 4-week period. All landings apply to the 30,000 pounds.
	Reduced Widow Rockfish trip limit to 3,000 pounds in August
	Re-established the 30,000 pound cumulative landing limit for December
1993	30,000 pound coastwide Widow Rockfish trip limit per 4-week period. All landings apply to the 30,000 pounds.
	Reduced Widow Rockfish trip limit to 3,000 pounds in December
1994	Divided the commercial groundfish fishery in limited entry and open access fisheries.
	30,000 pound cumulative Widow Rockfish limit per calendar month.
	Reduced Widow Rockfish trip limit to 3,000 pounds in December
	Rockfish limit of 10,000 per vessel per trip in open access fisheries, not to exceed 30,000 pounds of Widow Rockfish (as in limited entry fisheries) cumulative per month.
1995	30,000 pound cumulative Widow Rockfish limit per calendar month.
	Monthly cumulative trip limit increased to 45,000 pounds for Widow Rockfish
1996	70,000 pound cumulative Widow Rockfish limit per two-month period.
	Reduced cumulative two-month period Widow Rockfish limit to 40,000 pounds in September.
	25,000 pound monthly cumulative limit implemented in November.
1997	70,000 pound cumulative Widow Rockfish limit per two-month period.
	Reduced cumulative two-month period Widow Rockfish limit to 60,000 pounds in May.

Year	Management action
1998	25,000 pound cumulative Widow Rockfish limit per two-month period.
	Increased cumulative two-month period Widow Rockfish limit to 30,000 pounds in May.
	Open access monthly cumulative trip limits reduced to 3,000 pounds in July.
1999	Dividing line between north and south management areas moved to 40° 10’ N.
	Three-phase cumulative limit period system introduced.
	Phase 1: 70,000 pounds cumulative limit from January through March for Widow Rockfish.
	Phase 2: 16,000 pounds per 2-month period April through September for Widow Rockfish.
	Phase 3: 30,000 pounds per month October through December for Widow Rockfish.
	Open access limit to 2,000 pounds per month of Widow Rockfish
	Phase 2 two-month limits reduced to 11,000 pounds for Widow Rockfish starting in June.
	Open access month cumulative trip limit increased to 8,000 pounds of Widow Rockfish.
2000	WA and OR restrict landings applied to 30,000 monthly limit to have midwater gear. State imposed cumulative trip limit per month applied otherwise.
	Sorting of Widow Rockfish required before weighing in limited entry and open access fisheries.
	New limited entry trawl gear restrictions implemented for large footrope trawl gear, small footrope trawl gear, and midwater trawl gear.
	Cumulative trip limits allowed for Widow Rockfish only if small footrope or midwater trawl gear were used. Higher cumulative trip limits available to midwater gear.
	30,000 pound two-month cumulative trip limit for Widow Rockfish caught with mid-water gear.
	1,000 pound monthly trip limit allowed for small footrope trawl.
	3,000 pound monthly trip limits for Widow Rockfish caught with limited entry fixed gear, open access gear, and exempted trawl gear. Some closures south of 40° 10’ N latitude in January through April

<table>
<tr><th>Year</th><th>Management action</th></tr>
<tr><td rowspan="4">2001</td><td>Similar actions as in 2000 with the following changes</td></tr>
<tr><td>20,000 pound two-month cumulative trip limit for Widow Rockfish caught with mid-water gear in January through April and September through October. 10,000 pound two-month cumulative trip limit in other periods.</td></tr>
<tr><td>Widow Rockfish limits reduced to 1,000 pounds per month in July-September unless landed with Pacific Whiting, which is 2,000 pounds per month with a 500 pound trip limit.</td></tr>
<tr><td>Retention of Widow Rockfish prohibited beginning in October. For gears other than midwater trawl.</td></tr>
<tr><td>2002</td><td>Rockfish Conservation Areas (RCA) established. Large footrope gear prohibited inside 275 m. Widow fishery closed most of the year except for a small amount of bycatch and small monthly limits in some months.</td></tr>
<tr><td>2003</td><td>Widow fishery closed most of the year except for a small amount of bycatch and small monthly limits in some months.</td></tr>
<tr><td>2004</td><td>Widow fishery closed most of the year except for a small amount of bycatch and small monthly limits in some months</td></tr>
<tr><td>2005</td><td>Widow fishery closed most of the year except for a small amount of bycatch and small monthly limits in some months.</td></tr>
<tr><td>2006</td><td>Amendment 19 established essential fish habitat (EFH) boundaries and conservation areas. Widow bycatch cap in the non-tribal limited entry whiting trawl fishery increased from 200 mt to 220 mt in October</td></tr>
<tr><td rowspan="4">2007</td><td>Seasonal changes of trawl RCA boundaries and periodic closures within certain latitude boundaries (e.g., north of Cape Alava at 48°10’ N latitude to the U.S.-Canada border) started in 2007. Small monthly limits for Widow Rockfish (less than 1,500 pounds per month)</td></tr>
<tr><td>Widow bycatch cap in the non-tribal limited entry whiting trawl fishery increased from 200 mt to 220 mt in May.</td></tr>
<tr><td>Limited entry whiting trawl fishery closed due to attainment of 220 mt widow bycatch in July</td></tr>
<tr><td>Limited entry whiting trawl fishery re-opened with 275 mt widow bycatch cap in October</td></tr>
<tr><td rowspan="2"></td><td>Widow bycatch cap of 275 mt adopted for limited entry whiting trawl fishery.</td></tr>
<tr><td>Limited entry whiting trawl fishery closed due to attainment of canary bycatch in August</td></tr>
</table>

Year	Management action
2008	Limited entry whiting trawl fishery re-opened with 284 mt widow bycatch cap in October
	Small monthly limits for Widow Rockfish (less than 1,500 pounds per month)
2009	Sector specific bycatch caps for Widow Rockfish in the limited entry whiting trawl fishery: 105 mt for shoreside fleet, 85 mt to catcher-processors, 60 mt to motherships
	Small monthly limits for Widow Rockfish (less than 1,500 pounds per month)
2010	Trawl rationalization began, establishing the IFQ fishery.
2011	Small monthly limits for Widow Rockfish (less than 1,500 pounds per month)

Table 4: Management guidelines for Widow Rockfish from 2004 to 2024. Total landings (mt) are also shown.

Year	OFL mt termed ABC prior to 2011	ABC mt	ACL mt termed OY prior to 2011	Commer-cial Landings mt	Estimated Total Catch mt
2004	3,460		284	87	99
2005	3,218		285	195	204
2006	3,059		289	213	221
2007	5,334		368	240	245
2008	5,144		368	264	272
2009	7,728		522	177	186
2010	6,937		509	166	179
2011	5,097	600	4,872	212	213
2012	4,923	600	4,705	270	271
2013	4,841	1,500	4,598	470	473
2014	4,435	1,500	4,212	722	726
2015	4,137	2,000	3,929	880	885
2016	3,990	2,000	3,790	1,039	1,045
2017	14,130	13,508	13,508	6,346	6,395

Year	OFL mt termed ABC prior to 2011	ABC mt	ACL mt termed OY prior to 2011	Commercial Landings mt	Estimated Total Catch mt
2018	13,237	12,655	12,655	10,493	10,588
2019	12,375	11,831	11,831		

:::

Table 5: Depth ranges and limits of the southern latitude in the Triennial survey for the different years.

Years	Depth range (m)	Southern latitude
1977	91-457	34.05
1980-1986	55-366	36.80
1989-1992	55-366	34.50
1995-2004	55-500	34.50

Table 6: Stratifications used for the two surveys.

Triennial					
Strata	Area (km2)	Depth1	Depth2	Latitude1	Latitude2
A	33,730.25	55	183	34.5	49
B	11,062.63	183	400	34.5	49

Table 7: Stratifications used for the two surveys.

NWFSC WCGBT					
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 8: Number of positive tows, lengths, and ages in each year from the Triennial survey (Tri) and the NWFSC WCGBT survey (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					
1978										
1979										
1980	38		3		166		1		22	
1981										
1982										
1983	70		5		385					
1984										
1985										
1986	46		8		317					
1987										
1988										
1989	38		20		713					
1990										
1991										
1992	50		10		708					
1993										
1994										
1995	43		43		500					
1996										
1997										
1998	59		58		738					
1999										
2000										

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
2001	28		28		130					
2002										
2003		20		18		216				
2004	36	12	33	12	219	84		12		43
2005		20		20		78		18		65
2006		26		26		172		26		89
2007		27		27		92		27		83
2008		17		17		26		15		20
2009		31		31		141		31		123
2010		28		28		240		28		116
2011		31		31		313		31		152
2012		32		32		181		32		91
2013		18		18		364		18		246
2014		29		28		349		28		264
2015		21		21		149		21		93
2016		40		40		888		40		556
2017		30		30		310		30		213
2018		34		34		410		34		353
2019		23		23		219		23		161
2020										
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 9: Number of landings sampled for length data by gear and state for non-whiting fisheries.

	Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
		CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
1	1971	0	0	0	0	0	2	0	0	0	0	0
2	1977	0	0	0	25	0	0	0	0	0	0	0
3	1978	50	0	0	0	0	0	10	0	0	0	0
4	1979	32	0	0	0	0	0	4	0	3	0	0
5	1980	101	0	0	6	0	19	0	0	1	0	1
6	1981	72	3	0	59	20	31	0	0	6	0	0
7	1982	88	7	0	89	34	41	1	0	11	0	0
8	1983	158	16	0	46	10	25	18	0	9	0	0
9	1984	146	20	0	29	12	22	25	0	4	0	0
10	1985	149	20	0	25	35	16	81	0	5	0	0
11	1986	108	17	0	25	28	27	59	0	16	0	0
12	1987	88	29	0	49	74	36	37	0	3	0	0
13	1988	79	30	7	37	42	14	43	0	2	0	0
14	1989	81	49	14	30	67	16	81	0	7	0	0
15	1990	80	58	11	39	62	30	74	0	8	0	0
16	1991	74	76	20	17	63	15	23	0	12	0	0
17	1992	55	98	22	5	41	9	31	0	53	1	0

	Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
		CA	**OR**	**WA**	**CA**	**OR**	**WA**	**CA**	**WA**	**CA**	**OR**	**WA**
18	1993	60	69	28	5	49	8	19	0	39	0	0
19	1994	54	67	13	2	21	16	34	0	38	0	0
20	1995	53	47	17	11	14	16	14	0	7	0	0
21	1996	49	33	17	11	12	13	4	0	10	0	0
22	1997	54	49	16	10	21	19	2	0	20	0	0
23	1998	41	43	26	3	11	8	5	0	15	0	0
24	1999	38	28	21	5	19	11	1	0	3	1	0
25	2000	14	0	3	16	44	19	0	0	8	1	0
26	2001	12	6	2	10	38	11	0	0	2	3	0
27	2002	22	8	7	1	15	10	1	0	2	0	0
28	2003	7	0	1	0	0	5	0	0	0	0	0
29	2004	5	1	1	0	0	12	0	0	0	0	0
30	2005	4	2	0	0	0	10	0	0	1	0	0
31	2006	7	3	2	0	0	8	0	0	4	1	0
32	2007	7	16	4	0	0	3	0	0	4	1	0
33	2008	5	18	5	0	0	12	0	0	2	0	0
34	2009	19	30	0	0	0	14	0	0	0	0	0
35	2010	18	22	1	0	0	11	0	0	0	2	0

	Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
		CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
36	2011	6	14	9	0	1	6	0	0	1	0	0
37	2012	14	19	5	0	4	7	0	0	3	1	0
38	2013	20	21	1	0	6	6	0	0	9	1	0
39	2014	18	20	3	0	5	7	0	0	12	2	0
40	2015	37	23	0	0	18	4	0	0	9	7	2
41	2016	27	14	0	0	7	1	0	0	2	4	2
42	2017	22	41	0	3	33	3	0	0	5	2	3
43	2018	31	25	7	10	60	4	0	0	3	4	7
44	2019	34	33	1	2	48	12	0	0	7	3	2
45	2020	29	18	0	2	31	5	0	0	13	8	1
46	2021	42	18	2	4	39	7	0	0	10	2	0
47	2022	13	10	0	12	46	4	0	0	2	5	2
48	2023	20	7	0	7	51	7	0	0	3	7	5
49	2024	27	13	0	0	52	9	0	0	16	9	4

Table 10: Number of lengths of Widow Rockfish by gear and state for non-whiting fisheries.

	Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
		CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
1	1971	0	0	0	0	0	408	0	0	0	0	0
2	1977	0	0	0	96	0	0	0	0	0	0	0
3	1978	303	0	0	0	0	0	66	0	0	0	0
4	1979	436	0	0	0	0	0	34	0	7	0	0
5	1980	727	0	0	13	0	1,900	0	0	1	0	2
6	1981	444	250	0	1,340	1,746	3,100	0	0	19	0	0
7	1982	932	792	0	3,144	3,960	4,100	1	0	84	0	0
8	1983	1,352	478	0	1,411	321	2,500	103	0	31	0	0
9	1984	1,722	2,394	0	1,278	1,525	2,199	126	0	11	0	0
10	1985	1,853	2,233	0	1,176	3,971	1,600	557	0	8	0	0
11	1986	1,740	1,425	0	1,032	2,788	2,650	321	0	120	0	0
12	1987	998	865	0	1,744	2,198	1,942	262	0	11	0	0
13	1988	763	916	350	1,230	1,239	700	334	0	3	0	0
14	1989	1,007	1,099	700	1,325	1,843	800	450	0	23	0	0
15	1990	1,202	1,320	550	1,510	1,454	1,500	612	0	37	0	0
16	1991	1,596	1,569	997	761	1,442	750	268	0	75	0	0
17	1992	1,470	1,982	1,100	222	1,760	450	231	0	689	2	0

	Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
		CA	**OR**	**WA**	**CA**	**OR**	**WA**	**CA**	**WA**	**CA**	**OR**	**WA**
18	1993	1,682	1,410	1,400	231	1,156	400	275	0	238	0	0
19	1994	1,359	1,464	650	112	557	842	410	0	554	0	0
20	1995	1,539	1,066	850	519	296	800	175	0	22	0	0
21	1996	1,364	845	704	437	316	650	132	0	80	0	0
22	1997	2,063	1,231	557	382	620	950	80	0	212	0	0
23	1998	1,368	1,013	865	125	291	400	179	0	318	0	0
24	1999	1,420	727	952	240	514	550	1	0	104	20	0
25	2000	263	0	101	641	1,147	950	0	0	65	1	0
26	2001	139	98	2	349	960	550	0	0	4	20	0
27	2002	318	185	136	39	319	500	2	0	74	0	0
28	2003	234	0	46	0	0	208	0	0	0	0	0
29	2004	26	18	3	0	0	508	0	0	0	0	0
30	2005	27	48	0	0	0	399	0	0	4	0	0
31	2006	79	58	7	0	0	461	0	0	36	1	0
32	2007	12	302	104	0	0	250	0	0	64	1	0
33	2008	8	274	76	0	0	1,086	0	0	27	0	0
34	2009	170	316	0	0	0	1,079	0	0	0	0	0
35	2010	205	233	100	0	0	903	0	0	0	5	0

	Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
		CA	**OR**	**WA**	**CA**	**OR**	**WA**	**CA**	**WA**	**CA**	**OR**	**WA**
36	2011	32	246	93	0	30	550	0	0	17	0	0
37	2012	136	353	241	0	95	688	0	0	9	7	0
38	2013	153	365	39	0	215	486	0	0	102	1	0
39	2014	134	324	106	0	150	700	0	0	242	4	0
40	2015	263	295	0	0	530	400	0	0	45	11	2
41	2016	143	254	0	0	210	100	0	0	38	4	24
42	2017	316	864	0	158	949	125	0	0	73	3	23
43	2018	645	161	12	507	1,492	350	0	0	32	7	10
44	2019	566	346	50	90	1,149	600	0	0	47	6	7
45	2020	593	228	0	83	759	233	0	0	134	15	1
46	2021	850	226	8	183	890	307	0	0	67	3	0
47	2022	272	185	0	502	1,025	180	0	0	11	7	3
48	2023	376	135	0	316	1,125	571	0	0	18	97	13
49	2024	540	164	0	0	1,255	830	0	0	268	86	10

Table 11: Number of landings and number of lengths sampled from the at-sea hake and shoreside hake fisheries.

	Year	Number of hauls (at-sea) or landings (shoreside)		Number of lengths	
		Domestic at-sea	Shoreside	Domestic at-sea	Shoreside
1	1992	214	0	1,474	0
2	1993	239	0	1,468	0
3	1994	361	3	3,458	78
4	1995	304	19	1,789	570
5	1996	332	18	2,620	540
6	1997	397	30	2,841	869
7	1998	481	32	2,431	975
8	1999	598	52	3,070	1,551
9	2000	571	33	2,845	1,004
10	2001	522	19	1,758	576
11	2002	369	3	1,204	70
12	2003	291	2	665	26
13	2004	512	19	1,670	380
14	2005	1,228	1	5,538	50
15	2006	1,295	14	6,104	594
16	2007	1,491	21	10,658	860
17	2008	1,138	36	7,324	966
18	2009	400	24	1,976	845
19	2010	980	43	4,734	1,214
20	2011	982	43	3,605	1,286
21	2012	914	46	4,779	1,291
22	2013	901	40	3,808	1,160
23	2014	773	50	3,970	1,452
24	2015	522	36	2,312	1,313

	Year	Number of hauls (at-sea) or landings (shoreside)		Number of lengths	
		Domestic at-sea	Shoreside	Domestic at-sea	Shoreside
25	2016	801	49	3,934	1,465
26	2017	997	57	5,406	1,353
27	2018	461	65	2,245	1,283
28	2019	469	73	2,642	1,536
29	2020	214	37	902	839
30	2021	310	61	1,776	1,279
31	2022	333	88	1,489	1,745
32	2023	469	68	1,738	1,525
33	2024	83	60	251	1,231

Table 12: Number of landings sampled for ages by gear and state for non-whiting fisheries.

	Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
		CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
1	1978	7	0	0	0	0	0	0	0	0	0	0
2	1979	11	0	0	0	0	0	0	0	0	0	0
3	1980	27	0	0	0	0	18	0	0	0	0	0
4	1981	14	3	0	30	20	31	0	0	0	0	0
5	1982	87	6	0	71	34	40	1	0	4	0	0
6	1983	151	16	0	45	10	25	5	0	2	0	0
7	1984	144	20	0	29	12	22	10	0	2	0	0
8	1985	137	20	0	25	33	16	65	0	3	0	0
9	1986	106	17	0	22	28	27	53	0	3	0	0
10	1987	84	27	0	49	62	36	27	0	0	0	0
11	1988	67	29	6	34	41	14	39	0	2	0	0
12	1989	75	49	14	30	66	16	75	0	3	0	0
13	1990	70	58	11	32	62	30	65	0	2	0	0
14	1991	65	76	20	17	63	15	19	0	9	0	0
15	1992	45	93	22	4	26	9	21	0	15	0	0
16	1993	28	67	28	0	49	8	6	0	3	0	0
17	1994	28	67	13	2	21	15	7	0	1	0	0

	Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
		CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
18	1995	8	45	17	3	13	16	0	0	0	0	0
19	1996	36	32	14	6	11	13	2	0	1	0	0
20	1997	42	46	11	10	20	19	0	0	9	0	0
21	1998	27	42	14	2	11	8	2	0	3	0	0
22	1999	29	27	19	3	18	10	0	0	0	0	0
23	2000	8	0	2	9	42	19	0	0	3	0	0
24	2001	2	6	0	4	35	10	0	0	0	0	0
25	2002	17	8	2	1	15	10	1	0	0	0	0
26	2003	3	0	0	0	0	5	0	0	0	0	0
27	2004	3	0	1	0	0	12	0	0	0	0	0
28	2005	0	2	0	0	0	10	0	0	0	0	0
29	2006	6	3	1	0	0	8	0	0	2	1	0
30	2007	6	16	4	0	0	3	0	0	3	1	0
31	2008	5	18	5	0	0	12	0	0	0	0	0
32	2009	8	29	0	0	0	14	0	0	0	0	0
33	2010	7	21	1	0	0	11	0	0	0	2	0
34	2011	0	5	7	0	1	5	0	0	0	0	0
35	2012	0	8	5	0	0	7	0	0	0	1	0

	Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
		CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
36	2013	0	7	1	0	3	5	0	0	0	0	0
37	2014	0	4	2	0	1	7	0	0	0	0	0
38	2015	0	22	0	0	14	4	0	0	0	0	1
39	2016	0	13	0	0	6	1	0	0	0	0	2
40	2017	0	36	0	0	31	3	0	0	0	0	3
41	2018	0	25	7	0	46	4	0	0	0	0	7
42	2019	0	16	1	0	34	12	0	0	0	0	1
43	2020	0	15	0	0	25	5	0	0	0	2	0
44	2021	0	12	2	0	31	6	0	0	0	0	0
45	2022	0	8	0	0	45	4	0	0	0	0	2
46	2023	0	5	0	0	48	7	0	0	0	1	5
47	2024	0	7	0	0	42	7	0	0	0	0	0

Table 13: Number of landings sampled for ages by gear and state for non-whiting fisheries.

	Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
		CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
1	1978	107	0	0	0	0	0	0	0	0	0	0
2	1979	269	0	0	0	0	0	0	0	0	0	0

	Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
		CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
3	1980	404	0	0	0	0	1,775	0	0	0	0	0
4	1981	205	109	0	598	600	3,050	0	0	0	0	0
5	1982	834	174	0	2,382	1,019	3,944	1	0	18	0	0
6	1983	1,283	475	0	1,365	321	2,480	55	0	3	0	0
7	1984	1,678	600	0	1,278	360	2,194	89	0	5	0	0
8	1985	1,762	589	0	1,176	963	1,591	477	0	4	0	0
9	1986	1,704	680	0	913	939	2,594	188	0	5	0	0
10	1987	968	805	0	1,742	1,837	1,940	186	0	0	0	0
11	1988	692	886	298	1,132	1,209	695	290	0	3	0	0
12	1989	919	1,099	695	1,323	1,794	799	403	0	6	0	0
13	1990	1,051	1,310	550	1,309	1,447	1,497	533	0	8	0	0
14	1991	1,308	1,566	991	761	1,413	748	164	0	23	0	0
15	1992	676	1,889	1,097	82	574	450	87	0	91	0	0
16	1993	472	1,361	1,398	0	1,155	400	57	0	3	0	0
17	1994	516	1,463	650	54	556	749	58	0	1	0	0
18	1995	167	1,027	850	68	276	800	0	0	0	0	0
19	1996	873	827	699	158	292	649	88	0	7	0	0
20	1997	892	1,164	549	187	593	949	0	0	55	0	0

	Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
		CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
21	1998	1,019	987	699	82	291	400	84	0	46	0	0
22	1999	1,026	706	950	133	479	500	0	0	0	0	0
23	2000	157	0	100	353	1,067	948	0	0	12	0	0
24	2001	43	98	0	132	858	485	0	0	0	0	0
25	2002	294	179	99	21	319	488	2	0	0	0	0
26	2003	87	0	0	0	0	208	0	0	0	0	0
27	2004	7	0	3	0	0	506	0	0	0	0	0
28	2005	0	48	0	0	0	399	0	0	0	0	0
29	2006	74	58	6	0	0	361	0	0	5	1	0
30	2007	11	302	54	0	0	150	0	0	23	1	0
31	2008	8	274	75	0	0	600	0	0	0	0	0
32	2009	81	315	0	0	0	759	0	0	0	0	0
33	2010	54	231	50	0	0	539	0	0	0	5	0
34	2011	0	63	84	0	30	250	0	0	0	0	0
35	2012	0	80	73	0	0	163	0	0	0	7	0
36	2013	0	190	26	0	90	153	0	0	0	0	0
37	2014	0	91	52	0	30	229	0	0	0	0	0
38	2015	0	152	0	0	69	195	0	0	0	0	1

	Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
		CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
39	2016	0	156	0	0	36	28	0	0	0	0	24
40	2017	0	209	0	0	223	100	0	0	0	0	23
41	2018	0	161	12	0	495	200	0	0	0	0	10
42	2019	0	55	49	0	176	597	0	0	0	0	1
43	2020	0	61	0	0	134	233	0	0	0	3	0
44	2021	0	53	8	0	135	300	0	0	0	0	0
45	2022	0	44	0	0	281	129	0	0	0	0	3
46	2023	0	28	0	0	312	320	0	0	0	2	13
47	2024	0	33	0	0	248	340	0	0	0	0	0

Table 14: Discard totals (mt) for four fleets derived from Pikitch data, EDCP data, and WCGOP data. Italics indicate years that were not fitted to because they were simply added to the landings (Shoreside hake) or omitted because they were outside of the main study period.

Fleet	Year	Source	Discards	Error	Error Stat	Source 1	Used in Assessment
Bottom Trawl	1981	Pikitch	900.1900	54.26%	CV	2019 report	No
Bottom Trawl	1982	Pikitch	1,450.7400	44.12%	CV	2019 report	No
Bottom Trawl	1983	Pikitch	1,847.1500	43.91%	CV	2019 report	No
Bottom Trawl	1984	Pikitch	586.3600	55.78%	CV	2019 report	No

Fleet	Year	Source	Discards	Error	Error Stat	Source 1	Used in Assessment
Bottom Trawl	1985	Pikitch	462.9000	49.53%	CV	2019 data	Yes
Bottom Trawl	1986	Pikitch	534.8000	53.11%	CV	2019 data	Yes
Bottom Trawl	1987	Pikitch	1,035.5000	42.57%	CV	2019 data	Yes
Bottom Trawl	1988	Pikitch	1,177.0900	43.38%	CV	2019 report	No
Bottom Trawl	1989	Pikitch	1,217.7400	44.70%	CV	2019 report	No
Bottom Trawl	1990	Pikitch	1,010.9500	51.53%	CV	2019 report	No
Bottom Trawl	1991	Pikitch	1,219.2500	42.20%	CV	2019 report	No
Bottom Trawl	1992	Pikitch	1,217.5100	44.62%	CV	2019 report	No
Bottom Trawl	1993	Pikitch	1,430.1800	46.57%	CV	2019 report	No
Bottom Trawl	1994	Pikitch	1,177.7100	43.11%	CV	2019 report	No
Bottom Trawl	1995	EDCP	924.8000	83.18%	CV	2019 data	Yes
Bottom Trawl	1996	EDCP	3,084.5000	67.07%	CV	2019 data	Yes
Bottom Trawl	1997	EDCP	3,353.3000	75.06%	CV	2019 data	Yes
Bottom Trawl	1998	EDCP	42.6000	48.80%	CV	2019 data	Yes
Bottom Trawl	1999	EDCP	4.8000	68.78%	CV	2019 data	Yes
Bottom Trawl	2002	WCGOP	13.2200	43.07%	CV	2019 data	Yes
Bottom Trawl	2003	WCGOP	1.2100	81.96%	CV	2019 data	Yes
Bottom Trawl	2004	WCGOP	5.1300	75.89%	CV	2019 data	Yes
Bottom Trawl	2005	WCGOP	10.1700	44.61%	CV	2019 data	Yes

Fleet	Year	Source	Discards	Error	Error Stat	Source 1	Used in Assessment
Bottom Trawl	2006	WCGOP	0.0300	135.56%	CV	2019 data	Yes
Bottom Trawl	2007	WCGOP	13.8600	61.57%	CV	2019 data	Yes
Bottom Trawl	2008	WCGOP	3.9000	44.54%	CV	2019 data	Yes
Bottom Trawl	2009	WCGOP	26.5700	33.77%	CV	2019 data	Yes
Bottom Trawl	2010	WCGOP	22.7400	54.32%	CV	2019 data	Yes
Bottom Trawl	2011	WCGOP	0.0800	5.00%	CV	2019 data	Yes
Bottom Trawl	2012	WCGOP	0.0100	5.00%	CV	2019 data	Yes
Bottom Trawl	2013	WCGOP	2.4300	5.00%	CV	2019 data	Yes
Bottom Trawl	2014	WCGOP	0.0900	5.00%	CV	2019 data	Yes
Bottom Trawl	2015	WCGOP	0.0300	5.00%	CV	2019 data	Yes
Bottom Trawl	2016	WCGOP	0.0200	5.00%	CV	2019 data	Yes
Bottom Trawl	2017	WCGOP	0.2600	5.00%	CV	2019 data	Yes
Bottom Trawl	2018	WCGOP	0.0143	5.00%	CV	2025 data	Yes
Bottom Trawl	2019	WCGOP	0.7832	5.00%	CV	2025 data	Yes
Bottom Trawl	2020	WCGOP	0.2763	5.00%	CV	2025 data	Yes
Bottom Trawl	2021	WCGOP	0.1440	5.00%	CV	2025 data	Yes
Bottom Trawl	2022	WCGOP	0.0750	5.00%	CV	2025 data	Yes
Bottom Trawl	2023	WCGOP	0.1184	5.00%	CV	2025 data	Yes
Midwater	1981	Pikitch	6,479.8800	23.24%	CV	2019 report	No

Fleet	Year	Source	Discards	Error	Error Stat	Source 1	Used in Assessment
Midwater	1982	Pikitch	5,722.2500	22.84%	CV	2019 report	No
Midwater	1984	Pikitch	1,737.5700	23.33%	CV	2019 report	No
Midwater	1985	Pikitch	1,502.0000	24.09%	CV	2019 data	Yes
Midwater	1986	Pikitch	1,321.2000	23.64%	CV	2019 data	Yes
Midwater	1987	Pikitch	1,798.4000	26.20%	CV	2019 data	Yes
Midwater	1988	Pikitch	1,615.8300	24.82%	CV	2019 report	No
Midwater	1989	Pikitch	1,981.8600	25.26%	CV	2019 report	No
Midwater	1990	Pikitch	1,205.4400	24.51%	CV	2019 report	No
Midwater	1991	Pikitch	565.9400	24.33%	CV	2019 report	No
Midwater	1992	Pikitch	356.0000	25.00%	CV	2019 report	No
Midwater	1993	Pikitch	569.8600	25.34%	CV	2019 report	No
Midwater	1994	Pikitch	536.8000	25.43%	CV	2019 report	No
Midwater	1995	Pikitch	663.2400	23.81%	CV	2019 report	No
Midwater	1996	Pikitch	465.6600	24.84%	CV	2019 report	No
Midwater	1997	Pikitch	663.1400	24.10%	CV	2019 report	No
Midwater	1998	Pikitch	217.1500	25.53%	CV	2019 report	No
Midwater	1997	EDCP	1.0000	83.26%	CV	2019 data	Yes
Midwater	1998	EDCP	18.7000	80.00%	CV	2019 data	Yes
Midwater	2002	WCGOP	39.4000	40.71%	CV	2019 data	Yes

Fleet	Year	Source	Discards	Error	Error Stat	Source 1	Used in Assessment
Midwater	2012	WCGOP	0.0000	5.00%	CV	2025 data	Yes
Midwater	2013	WCGOP	0.0020	5.00%	CV	2025 data	Yes
Midwater	2014	WCGOP	0.0136	5.00%	CV	2025 data	Yes
Midwater	2015	WCGOP	0.8800	5.00%	CV	2025 data	Yes
Midwater	2016	WCGOP	1.5600	5.00%	CV	2025 data	Yes
Midwater	2017	WCGOP	9.7500	5.00%	CV	2025 data	Yes
Midwater	2018	WCGOP	37.2300	5.00%	CV	2025 data	Yes
Midwater	2019	WCGOP	18.7800	5.00%	CV	2025 data	Yes
Midwater	2020	WCGOP	45.4400	5.00%	CV	2025 data	Yes
Midwater	2021	WCGOP	36.3800	5.00%	CV	2025 data	Yes
Midwater	2022	WCGOP	47.6000	5.00%	CV	2025 data	Yes
Midwater	2023	WCGOP	17.3700	5.00%	CV	2025 data	Yes
Hook & Line	2007	WCGOP	0.0160	0.51%	SD	2025 data	Yes, in landings
Hook & Line	2008	WCGOP	0.0120	0.33%	SD	2025 data	Yes, in landings
Hook & Line	2010	WCGOP	0.0080	2.32%	SD	2025 data	Yes, in landings
Hook & Line	2011	WCGOP	0.0110	2.32%	SD	2025 data	Yes, in landings
Hook & Line	2012	WCGOP	0.0010	2.32%	SD	2025 data	Yes, in landings
Hook & Line	2013	WCGOP	0.0010	2.32%	SD	2025 data	Yes, in landings
Hook & Line	2014	WCGOP	0.0090	2.32%	SD	2025 data	Yes, in landings

Fleet	Year	Source	Discards	Error	Error Stat	Source 1	Used in Assessment
Hook & Line	2015	WCGOP	0.0550	3.06%	SD	2025 data	Yes, in landings
Hook & Line	2016	WCGOP	0.1880	2.96%	SD	2025 data	Yes, in landings
Hook & Line	2017	WCGOP	0.0370	1.76%	SD	2025 data	Yes, in landings
Hook & Line	2018	WCGOP	0.1380	8.32%	SD	2025 data	Yes, in landings
Hook & Line	2019	WCGOP	0.0120	2.32%	SD	2025 data	Yes, in landings
Hook & Line	2021	WCGOP	0.0000	2.32%	SD	2025 data	Yes, in landings
Hook & Line	2022	WCGOP	0.0270	1.47%	SD	2025 data	Yes, in landings
Hook & Line	2023	WCGOP	0.0020	0.14%	SD	2025 data	Yes, in landings

Table 15: Ageing error for two labs that was used in the assessment model.

True Age	Standard Deviation CAP	Standard Deviation SWFSC
0.5	0.145	0.111
1.5	0.145	0.111
2.5	0.187	0.147
3.5	0.233	0.187
4.5	0.283	0.233
5.5	0.338	0.284
6.5	0.398	0.341
7.5	0.463	0.406
8.5	0.533	0.478
9.5	0.612	0.560
10.5	0.697	0.651
11.5	0.790	0.755
12.5	0.892	0.871
13.5	1.003	1.001
14.5	1.124	1.148
15.5	1.256	1.313
16.5	1.401	1.499
17.5	1.558	1.708
18.5	1.731	1.943
19.5	1.919	2.207
20.5	2.124	2.504
21.5	2.349	2.839
22.5	2.594	3.215
23.5	2.861	3.638
24.5	3.154	4.113

True Age	Standard Deviation CAP	Standard Deviation SWFSC
25.5	3.473	4.649
26.5	3.821	5.250
27.5	4.202	5.927
28.5	4.618	6.689
29.5	5.072	7.545
30.5	5.568	8.508
31.5	6.109	9.592
32.5	6.700	10.810
33.5	7.346	12.181
34.5	8.052	13.723
35.5	8.822	15.456
36.5	9.663	17.407
37.5	10.582	19.600
38.5	11.585	22.067
39.5	12.680	24.842
40.5	13.877	27.964

Table 16: Specifications of the base assessment model for Widow Rockfish.

Starting year		1916
Population characteristics		
	Maximum age	40
	Genders	2
	Population length bins	6-60 cm by 1 cm bins
	Summary biomass (mt)	Age 4+
Data characteristics		
	Data lengths	8-56 cm by 2 cm bins

	Data ages	14611
	Minimum ages for first growth calcs	3
	Maximum ages for first growth calcs	40
	First mature age	3
	Satrting year of estimated recruitment	1900
Fishery characteristics		
	Fishery timing	0.5
	Triennial survey timing	0.55000000000000004
	NWFSC WCGBT survey timing	0.65
	Fishing mortality methods	Discrete
	maximum F	0.9
	Catchability	Analytical estimate
	Fishery selectivity (not midwater trawl)	Asymptotic Double Normal
	Midwater trawl fishery selectivity	Dome-shaped Double Normal
	Juvenile survey selectivity	Double Normal
	Triennial survey selectivity	Cubic spline with 3 nodes
	NWFSC WCGBT survey selectivity	Cubic spline with 3 nodes
Fishery time blocks		
	Bottom trawl selectiviy	1916 - 2001, 2002 -
	Bottom trawl retention	1916 - 1981, 2011 -
	Midwater trawl selectivtiy	1916–1982, 1983–2001, 2002–2010, 2011–
	Midwater trawl retention	1916–1982, 1983–2001, 2002–2010, 2011–2016, 2017 -
	Hake trawl selectivity	1916 - 2019, 2020 -
	Hook-and-line selectivity	1916–2002, 2003–

Table 17: Description of biological parameters in the base case assessment model. The lognormal (LN) prior distribution is specified with the median of the parameter and the standard deviation of the log of the parameter.

Parameter	**Initial value**	**Number estimated**	**Bounds (low, high)**	**Prior distribution**
Female				
Natural Mortality (M) yr-1	0.1246	1	(0.01-0.3)	LN(-2.3,0.31)
Length at age 3	20.6525	1	(10-40)	
Length at age 40	49.5239	1	(35-60)	
von Bertalanffy K	0.1811	1	(0.01-0.4)	
ln(SD) of length at age 3	0.1158	1	(0.01-0.4)	
ln(SD) of length at age 40	0.0481	1	(0.01-0.4)	
Maturity-at-age inflection	0.0000		(-3-3)	
Maturity-at-age slope	2.9900		(-3-10)	
Fecundity intercept	5.4700		(-3-50)	
Fecundity slope	-0.7747		(-3-3)	
Length-weight intercept	1.0000		(-1-1)	
Length-weight slope	0.0000		(0-1)	
Male				
Natural Mortality (M) yr-1	0.1368	1	(0.01-0.3)	LN(-2.3,0.31)
von Bertalanffy K	21.0408	1	(10-40)	
ln(SD) of length at age 3	43.6366	1	(35-60)	
ln(SD) of length at age 40	0.2446	1	(0.01-0.4)	
Fecundity intercept	0.0941	1	(0.01-0.4)	
Fecundity slope	0.0569	1	(0.01-0.4)	
Length-weight intercept	0.0000		(-3-3)	
Length-weight slope	3.0100		(-3-10)	

```
                                   Parameter Estimate    SD
1                                      LN(R0)   10.437 0.169
```

2			NA	NA
3	Survey		NA	NA
4		Bottom trawl (q)	0.002	NA
5		Bottom trawl (extra SE)	0.164	0.061
6		Domestic at-sea hake (q)	0.000	0.190
7		Domestic at-sea hake (extra SE)	0.371	0.086
8		Juvenile (q)	0.195	NA
9		Juvenile (extra SE)	1.688	0.369
10		Foreign at-sea hake (q)	0.128	0.372
11		Foreign at-sea hake (extra SE)	0.000	NA
12		Triennial (q)	0.043	NA
13		Triennial (extra SE)	0.000	NA
14		NWFSC WCGBT (q)	0.000	NA
15		NWFSC WCGBT (SE)	0.578	0.152
16			NA	NA
17	Biological - Female		NA	NA
18		Natural Mortality (M)	0.125	0.008
19		Length at age 3	20.652	0.457
20		Length at age 40	49.524	0.256
21		Von Bertalanaffy K	0.181	0.006
22		SD (log) at age 3	0.116	0.009
23		SD (log) at age 40	0.048	0.003
24			NA	NA
25	Biological - Female		NA	NA
26		Natural Mortality (M)	0.137	0.008
27		Length at age 3	21.041	0.391
28		Length at age 40	43.637	0.235
29		Von Bertalanaffy K	0.245	0.009
30		SD (log) at age 3	0.094	0.007
31		SD (log) at age 40	0.057	0.003

Table 18: Description of biological parameters in the base case assessment model. The lognormal (LN) prior distribution is specified with the median of the parameter and the standard deviation of the log of the parameter.

	Parameter	**Estimate**	**SD**
	LN(R0)	10.437	0.169
Survey			
	Bottom trawl (q)	0.002	

	Parameter	Estimate	SD
	Bottom trawl (extra SE)	0.164	0.061
	Domestic at-sea hake (q)	0.000	0.190
	Domestic at-sea hake (extra SE)	0.371	0.086
	Juvenile (q)	0.195	
	Juvenile (extra SE)	1.688	0.369
	Foreign at-sea hake (q)	0.128	0.372
	Foreign at-sea hake (extra SE)	0.000	
	Triennial (q)	0.043	
	Triennial (extra SE)	0.000	
	NWFSC WCGBT (q)	0.000	
	NWFSC WCGBT (SE)	0.578	0.152
Biological - Female			
	Natural Mortality (M)	0.125	0.008
	Length at age 3	20.652	0.457
	Length at age 40	49.524	0.256
	Von Bertalanaffy K	0.181	0.006
	SD (log) at age 3	0.116	0.009
	SD (log) at age 40	0.048	0.003
Biological - Female			
	Natural Mortality (M)	0.137	0.008
	Length at age 3	21.041	0.391
	Length at age 40	43.637	0.235
	Von Bertalanaffy K	0.245	0.009
	SD (log) at age 3	0.094	0.007
	SD (log) at age 40	0.057	0.003

Table 19: Parameter estimates and approximate asymptotic standard deviations for the base case model selectivity parameters.

Selectivity Parameter	Estimate	SD	Fleet	Time block
Size_DblN_peak_BottomTrawl(1)	43.3983000	2.7291700	Bottom trawl	
Size_DblN_top_logit_BottomTrawl(1)	2.4998900	167.8350000	Bottom trawl	
Size_DblN_ascend_se_BottomTrawl(1)	4.5926300	0.4274960	Bottom trawl	
Retain_L_infl_BottomTrawl(1)	3.7830300	178.0450000	Bottom trawl	
Retain_L_width_BottomTrawl(1)	0.9966620	21.0925000	Bottom trawl	
Size_DblN_peak_MidwaterTrawl(2)	36.9648000	0.7405830	Midwater trawl	
Size_DblN_top_logit_MidwaterTrawl(2)	-9.4211000	14.6390000	Midwater trawl	
Size_DblN_ascend_se_MidwaterTrawl(2)	2.8657400	0.3105580	Midwater trawl	
Size_DblN_descend_se_MidwaterTrawl(2)	3.9347500	0.7195030	Midwater trawl	
Size_DblN_end_logit_MidwaterTrawl(2)	-1.3852100	1.0710500	Midwater trawl	
Retain_L_asymptote_logit_MidwaterTrawl(2)	5.7650900	0.1751060	Midwater trawl	
Size_DblN_peak_Hake(3)	33.5575000	1.9906400	Hake	
Size_DblN_top_logit_Hake(3)	2.4978700	167.9280000	Hake	
Size_DblN_ascend_se_Hake(3)	2.1154900	1.1588500	Hake	
Size_DblN_peak_Net(4)	42.6002000	0.8970930	Net	
Size_DblN_top_logit_Net(4)	2.5086100	167.8390000	Net	
Size_DblN_ascend_se_Net(4)	3.5559000	0.2133690	Net	
Size_DblN_peak_HnL(5)	23.5538000	0.0714985	Hook and Line	
Size_DblN_top_logit_HnL(5)	2.5022300	167.2550000	Hook and Line	
SizeSpline_GradLo_Triennial(7)	0.1188540	0.0359208	Other	
SizeSpline_GradHi_Triennial(7)	0.0381025	0.0987305	Other	
SizeSpline_Val_1_Triennial(7)	-1.8242300	0.3171830	Other	
SizeSpline_Val_3_Triennial(7)	0.4353670	0.2644300	Other	
SizeSpline_GradLo_NWFSC(8)	0.4671340	0.1121730	NWFSC	
SizeSpline_GradHi_NWFSC(8)	-0.1090470	0.0565052	NWFSC	
SizeSpline_Val_1_NWFSC(8)	-2.2235400	0.2451960	NWFSC	

Selectivity Parameter	Estimate	SD	Fleet	Time block
SizeSpline_Val_3_NWFSC(8)	-0.1144900	0.1505550	NWFSC	
Size_DblN_peak_BottomTrawl(1)_BLK4repl_1916	38.9802000	0.8171940	Bottom trawl	1916
Size_DblN_ascend_se_BottomTrawl(1)_BLK4repl_1916	3.4275900	0.2559120	Bottom trawl	1916
Retain_L_infl_BottomTrawl(1)_BLK2repl_1982	27.2205000	4.0013300	Bottom trawl	1982
Retain_L_infl_BottomTrawl(1)_BLK2repl_1990	27.5208000	3.9962900	Bottom trawl	1990
Retain_L_width_BottomTrawl(1)_BLK2repl_1982	0.9693250	2.1950900	Bottom trawl	1982
Retain_L_width_BottomTrawl(1)_BLK2repl_1990	1.8306400	1.8014400	Bottom trawl	1990
Retain_L_asymptote_logit_BottomTrawl(1)_BLK1repl_1982	1.7188500	0.2667800	Bottom trawl	1982
Retain_L_asymptote_logit_BottomTrawl(1)_BLK1repl_1990	0.7827360	0.3375240	Bottom trawl	1990
Retain_L_asymptote_logit_BottomTrawl(1)_BLK1repl_1998	0.1078120	0.1558330	Bottom trawl	1998
Size_DblN_peak_MidwaterTrawl(2)_BLK7repl_1916	38.6834000	0.9980770	Midwater trawl	1916
Size_DblN_peak_MidwaterTrawl(2)_BLK7repl_1983	38.0162000	0.4415890	Midwater trawl	1983
Size_DblN_peak_MidwaterTrawl(2)_BLK7repl_2002	37.3983000	1.8416200	Midwater trawl	2002
Size_DblN_ascend_se_MidwaterTrawl(2)_BLK7repl_1916	3.3701300	0.2858020	Midwater trawl	1916
Size_DblN_ascend_se_MidwaterTrawl(2)_BLK7repl_1983	3.0805900	0.1391670	Midwater trawl	1983
Size_DblN_ascend_se_MidwaterTrawl(2)_BLK7repl_2002	2.7963600	0.6698470	Midwater trawl	2002
Size_DblN_descend_se_MidwaterTrawl(2)_BLK7repl_1916	4.2416300	0.9673030	Midwater trawl	1916
Size_DblN_descend_se_MidwaterTrawl(2)_BLK7repl_1983	3.0555500	0.5987050	Midwater trawl	1983
Size_DblN_descend_se_MidwaterTrawl(2)_BLK7repl_2002	-1.4174700	10.4129000	Midwater trawl	2002
Size_DblN_end_logit_MidwaterTrawl(2)_BLK7repl_1916	-1.9335200	3.0174900	Midwater trawl	1916
Size_DblN_end_logit_MidwaterTrawl(2)_BLK7repl_1983	-0.4239580	0.3324310	Midwater trawl	1983
Size_DblN_end_logit_MidwaterTrawl(2)_BLK7repl_2002	1.5627700	1.8185000	Midwater trawl	2002
Retain_L_asymptote_logit_MidwaterTrawl(2)_BLK12repl_1983	1.6601500	0.1380750	Midwater trawl	1983
Retain_L_asymptote_logit_MidwaterTrawl(2)_BLK12repl_2002	1.8538000	0.4069920	Midwater trawl	2002
Retain_L_asymptote_logit_MidwaterTrawl(2)_BLK12repl_2011	8.9466000	0.2071300	Midwater trawl	2011
Size_DblN_peak_Hake(3)_BLK11repl_1916	42.7924000	0.6208850	Hake	1916
Size_DblN_top_logit_Hake(3)_BLK11repl_1916	2.5044500	167.7270000	Hake	1916
Size_DblN_ascend_se_Hake(3)_BLK11repl_1916	3.7220800	0.1291490	Hake	1916

Selectivity Parameter	Estimate	SD	Fleet	Time block
Size_DblN_peak_HnL(5)_BLK5repl_1916	37.2194000	2.0179500	Hook and Line	1916
Size_DblN_ascend_se_HnL(5)_BLK5repl_1916	3.7465200	0.4703620	Hook and Line	1916

Table 20: Likelihood components and other quantities related to the minimization of the base case model.

Description	Values
N parameters	214.00000
Log-likelihoods	
Total	7,664.49000
Indices	13.02230
Discard	5,410.79000
Length-frequency data	854.96800
Age-frequency data	1,366.28000
Recruitment	17.84010
Priors	0.60050
Parameter Softbound	0.98329

Table 21: Estimates of key derived parameters and reference points with approximate 95% asymptotic confidence intervals.

Quantity	Estimate	~95% Confidence Interval
Unfished Spawning Biomass (mt)	81,733.60	67571.06 - 95896.14
Unfished Age 4+ Biomass (mt)	151,584.00	125227.97 - 177940.03
Unfished Recruitment (R0)	34,102.80	22838.3 - 45367.3
2025 Spawning Biomass (mt)	40,603.10	18692.07 - 62514.13
2025 Fraction Unfished	0.50	0.3 - 0.69
Reference Points Based SB40%		

Quantity	Estimate	~95% Confidence Interval
Proxy Spawning Biomass (mt) SB40\%	32,693.40	27028.38 - 38358.42
SPR Resulting in SB40\%	0.46	0.46 - 0.46
Exploitation Rate Resulting in SB40\%	0.09	0.08 - 0.1
Yield with SPR Based On SB40\% (mt)	5,902.11	4529.61 - 7274.61
Reference Points Based on SPR Proxy for MSY		
Proxy Spawning Biomass (mt) (SPR50)	36,465.80	30147.13 - 42784.47
SPR50	*0.50*	*NA - NA*
Exploitation Rate Corresponding to SPR50	0.08	0.07 - 0.08
Yield with SPR50 at SB SPR (mt)	5,628.26	4323.47 - 6933.05
Reference Points Based on Estimated MSY Values		
Spawning Biomass (mt) at MSY (SB MSY)	21,666.80	17966.35 - 25367.25
SPR MSY	0.34	0.33 - 0.34
Exploitation Rate Corresponding to SPR MSY	0.13	0.12 - 0.14
MSY (mt)	6,310.24	4827.96 - 7792.52

Table 22: Time series of population estimates from the base case model.

Year	Total Biomass (mt)	Spawning Biomass (mt)	Age 4+ Biomass (mt)	Spawning Depletion(mt)	Age-0 recruits	Estimated Total Catch (mt)	1 - SPR (%)	Relative Exploitation rate (%)
1916	156,922.0	81,591.3	81,591.3	0.9982590	33,824.80	78.3100	0.005889	0.09597837
1917	156,798.0	81,526.4	81,526.4	0.9974649	33,794.60	121.8500	0.009147	0.14946079
1918	156,634.0	81,437.6	81,437.6	0.9963785	33,760.60	140.0700	0.010514	0.17199672
1919	156,456.0	81,340.2	81,340.2	0.9951868	33,723.30	96.7000	0.007286	0.11888341
1920	156,324.0	81,269.4	81,269.4	0.9943206	33,683.60	98.9700	0.007463	0.12178015
1921	156,190.0	81,198.8	81,198.8	0.9934568	33,640.30	82.0600	0.006199	0.10106061
1922	156,072.0	81,138.7	81,138.7	0.9927215	33,593.30	71.2400	0.005389	0.08780027
1923	155,962.0	81,084.6	81,084.6	0.9920596	33,542.10	78.2400	0.005920	0.09649181
1924	155,841.0	81,025.7	81,025.7	0.9913389	33,485.90	50.2600	0.003813	0.06202970

Year	Total Biomass (mt)	Spawning Biomass (mt)	Age 4+ Biomass (mt)	Spawning Depletion(mt)	Age-0 recruits	Estimated Total Catch (mt)	1 - SPR (%)	Relative Exploitation rate (%)
1925	155,741.0	80,980.9	80,980.9	0.9907908	33,424.90	62.2300	0.004722	0.07684528
1926	155,622.0	80,926.5	80,926.5	0.9901252	33,357.60	94.6400	0.007167	0.11694562
1927	155,463.0	80,850.6	80,850.6	0.9891966	33,283.10	78.5500	0.005955	0.09715451
1928	155,311.0	80,780.5	80,780.5	0.9883389	33,201.90	89.4000	0.006776	0.11067027
1929	155,138.0	80,700.3	80,700.3	0.9873577	33,112.70	86.7600	0.006576	0.10750889
1930	154,958.0	80,617.2	80,617.2	0.9863410	33,015.10	112.3600	0.008522	0.13937472
1931	154,740.0	80,515.0	80,515.0	0.9850906	32,907.70	99.9100	0.007591	0.12408868
1932	154,521.0	80,414.7	80,414.7	0.9838634	32,790.80	100.0900	0.007613	0.12446729
1933	154,288.0	80,308.2	80,308.2	0.9825604	32,663.00	85.8700	0.006529	0.10692557
1934	154,050.0	80,202.7	80,202.7	0.9812696	32,523.90	90.9200	0.006927	0.11336277
1935	153,789.0	80,086.4	80,086.4	0.9798467	32,371.90	98.1200	0.007487	0.12251768
1936	153,498.0	79,957.1	79,957.1	0.9782648	32,205.60	110.6500	0.008460	0.13838671
1937	153,171.0	79,810.9	79,810.9	0.9764760	32,022.90	103.5200	0.007920	0.12970659
1938	152,825.0	79,657.6	79,657.6	0.9746004	31,821.60	83.8300	0.006430	0.10523792
1939	152,470.0	79,503.1	79,503.1	0.9727101	31,599.10	76.5800	0.005876	0.09632329
1940	152,088.0	79,338.7	79,338.7	0.9706987	31,354.90	120.6400	0.009239	0.15205694
1941	151,627.0	79,133.6	79,133.6	0.9681893	31,087.20	129.5200	0.009925	0.16367257
1942	151,119.0	78,907.4	78,907.4	0.9654218	30,796.80	146.6400	0.011224	0.18583808
1943	150,553.0	78,653.6	78,653.6	0.9623166	30,491.40	490.6300	0.036814	0.62378581
1944	149,614.0	78,184.8	78,184.8	0.9565809	30,173.70	960.6900	0.070346	1.22874267
1945	148,200.0	77,437.7	77,437.7	0.9474402	29,842.00	1,621.3700	0.114934	2.09377345
1946	146,159.0	76,317.7	76,317.7	0.9337372	29,500.70	1,160.0600	0.085810	1.52004057
1947	144,612.0	75,488.2	75,488.2	0.9235883	29,188.80	643.2100	0.049786	0.85206695
1948	143,577.0	74,968.3	74,968.3	0.9172274	28,903.50	477.6600	0.037595	0.63714930
1949	142,676.0	74,537.0	74,537.0	0.9119505	28,647.80	374.3500	0.029854	0.50223379
1950	141,837.0	74,149.6	74,149.6	0.9072107	28,440.60	423.6100	0.033860	0.57129101
1951	140,906.0	73,711.4	73,711.4	0.9018494	28,306.40	553.9400	0.044094	0.75149841

Year	Total Biomass (mt)	Spawning Biomass (mt)	Age 4+ Biomass (mt)	Spawning Depletion(mt)	Age-0 recruits	Estimated Total Catch (mt)	1 - SPR (%)	Relative Exploitation rate (%)
1952	139,816.0	73,174.5	73,174.5	0.8952805	28,275.20	541.4800	0.043439	0.73998456
1953	138,724.0	72,625.7	72,625.7	0.8885660	28,391.50	469.3000	0.038091	0.64618999
1954	137,704.0	72,102.6	72,102.6	0.8821660	28,699.80	447.9300	0.036687	0.62123973
1955	136,728.0	71,580.9	71,580.9	0.8757830	29,238.80	464.9900	0.038310	0.64960066
1956	135,789.0	71,046.3	71,046.3	0.8692423	30,020.00	600.8800	0.049423	0.84575833
1957	134,818.0	70,444.1	70,444.1	0.8618744	30,973.50	760.7300	0.062359	1.07990591
1958	133,849.0	69,781.0	69,781.0	0.8537615	31,880.70	701.6300	0.058288	1.00547427
1959	133,154.0	69,210.3	69,210.3	0.8467790	32,404.40	671.5800	0.056345	0.97034690
1960	132,741.0	68,740.6	68,740.6	0.8410323	32,333.30	810.8700	0.067762	1.17960856
1961	132,460.0	68,303.1	68,303.1	0.8356796	31,945.60	677.0900	0.057463	0.99130200
1962	132,566.0	68,082.8	68,082.8	0.8329842	31,951.10	757.5500	0.064069	1.11268926
1963	132,800.0	67,965.8	67,965.8	0.8315528	32,897.20	433.4100	0.037578	0.63768837
1964	133,508.0	68,177.3	68,177.3	0.8341404	34,288.70	601.2900	0.051246	0.88195044
1965	134,174.0	68,400.3	68,400.3	0.8368688	35,901.20	259.4600	0.022586	0.37932582
1966	135,317.0	68,894.5	68,894.5	0.8429153	37,707.80	4,287.2600	0.276036	6.22293507
1967	132,867.0	67,091.8	67,091.8	0.8208595	37,601.90	4,821.3400	0.306514	7.18618371
1968	130,427.0	65,184.8	65,184.8	0.7975276	35,264.10	2,388.4800	0.182425	3.66416711
1969	130,789.0	64,943.4	64,943.4	0.7945741	30,232.50	847.4800	0.073362	1.30495170
1970	133,200.0	65,808.1	65,808.1	0.8051536	122,196.00	851.8500	0.072695	1.29444552
1971	136,676.0	66,821.4	66,821.4	0.8175512	99,956.70	1,091.6300	0.090138	1.63365329
1972	141,735.0	67,782.7	67,782.7	0.8293125	13,345.60	918.9200	0.075804	1.35568515
1973	149,014.0	69,398.2	69,398.2	0.8490780	11,233.50	1,155.6700	0.092074	1.66527374
1974	157,532.0	71,765.6	71,765.6	0.8780428	15,183.60	902.6300	0.071891	1.25774744
1975	165,409.0	75,488.5	75,488.5	0.9235920	31,899.00	872.0900	0.066678	1.15526206
1976	170,359.0	80,425.5	80,425.5	0.9839956	10,256.20	1,319.7600	0.091546	1.64097208
1977	171,950.0	85,074.3	85,074.3	1.0408730	58,846.60	1,084.9100	0.069463	1.27524999
1978	171,774.0	88,327.4	88,327.4	1.0806743	89,905.60	1,568.8600	0.094321	1.77618723

Year	Total Biomass (mt)	Spawning Biomass (mt)	Age 4+ Biomass (mt)	Spawning Depletion(mt)	Age-0 recruits	Estimated Total Catch (mt)	1 - SPR (%)	Relative Exploitation rate (%)
1979	170,472.0	89,031.8	89,031.8	1.0892925	28,591.90	9,386.9500	0.394786	10.54336765
1980	161,948.0	83,945.9	83,945.9	1.0270672	49,513.40	21,837.3400	0.662485	26.01358732
1981	143,144.0	71,767.2	71,767.2	0.8780624	82,299.80	27,856.2400	0.777064	38.81472316
1982	121,352.0	57,299.3	57,299.3	0.7010495	43,122.70	25,994.1700	0.821640	45.36559783
1983	103,480.0	45,393.9	45,393.9	0.5553885	27,392.40	10,427.6800	0.682044	22.97154463
1984	102,562.0	43,186.6	43,186.6	0.5283825	53,948.90	10,316.9900	0.681194	23.88933141
1985	102,467.0	42,501.5	42,501.5	0.5200003	39,210.00	9,290.7300	0.644909	21.85976966
1986	103,022.0	42,842.6	42,842.6	0.5241737	18,399.50	9,774.3100	0.647295	22.81446504
1987	102,172.0	43,168.0	43,168.0	0.5281549	46,999.60	13,093.7700	0.713218	30.33212102
1988	96,672.2	41,332.2	41,332.2	0.5056941	29,661.50	10,644.7300	0.669490	25.75408519
1989	92,938.1	40,140.5	40,140.5	0.4911138	21,699.70	12,708.7300	0.723230	31.66061708
1990	85,931.4	37,236.3	37,236.3	0.4555813	33,530.10	10,461.9500	0.720825	28.09610514
1991	79,894.6	34,378.7	34,378.7	0.4206189	60,103.30	6,796.9000	0.633552	19.77067196
1992	78,322.9	33,588.5	33,588.5	0.4109509	22,467.70	6,412.0800	0.630971	19.09010524
1993	77,111.5	32,781.4	32,781.4	0.4010762	28,210.30	8,347.4200	0.704782	25.46389111
1994	73,533.0	30,596.2	30,596.2	0.3743405	25,483.10	6,716.8100	0.661499	21.95308568
1995	72,549.8	29,689.1	29,689.1	0.3632423	15,866.40	6,912.3100	0.681536	23.28231573
1996	70,649.2	28,872.4	28,872.4	0.3532501	11,661.60	6,319.6900	0.660457	21.88834319
1997	68,858.3	28,770.5	28,770.5	0.3520033	17,856.50	6,652.6700	0.671275	23.12323387
1998	65,584.0	28,271.3	28,271.3	0.3458957	32,037.60	4,148.6200	0.597398	14.67431636
1999	63,709.6	28,261.6	28,261.6	0.3457770	42,397.30	4,102.9000	0.563700	14.51757862
2000	62,153.0	28,001.1	28,001.1	0.3425898	34,930.20	4,031.5800	0.493985	14.39793437
2001	62,020.1	27,863.6	27,863.6	0.3409075	19,260.00	1,961.7700	0.312098	7.04061930
2002	64,927.0	28,698.7	28,698.7	0.3511249	17,113.70	429.1800	0.090790	1.49546844
2003	69,966.8	30,632.0	30,632.0	0.3747785	16,640.20	41.5700	0.009036	0.13570776
2004	75,226.7	33,229.4	33,229.4	0.4065574	54,864.10	86.9700	0.017627	0.26172606
2005	79,867.2	36,142.5	36,142.5	0.4421988	10,597.20	195.5000	0.033144	0.54091444

Year	Total Biomass (mt)	Spawning Biomass (mt)	Age 4+ Biomass (mt)	Spawning Depletion(mt)	Age-0 recruits	Estimated Total Catch (mt)	1 - SPR (%)	Relative Exploitation rate (%)
2006	84,059.3	38,933.8	38,933.8	0.4763500	42,738.60	213.6800	0.033337	0.54882904
2007	88,027.0	41,457.6	41,457.6	0.5072284	10,638.30	239.6060	0.034315	0.57795429
2008	92,290.0	43,498.6	43,498.6	0.5321997	100,500.00	263.5217	0.035900	0.60581644
2009	96,621.7	45,463.8	45,463.8	0.5562437	13,201.40	176.6100	0.023812	0.38846291
2010	101,902.0	47,419.0	47,419.0	0.5801653	65,765.90	165.9080	0.021840	0.34987656
2011	107,888.0	49,761.0	49,761.0	0.6088194	9,730.70	212.0011	0.024371	0.42603866
2012	114,657.0	52,230.2	52,230.2	0.6390297	6,415.88	270.3509	0.029834	0.51761411
2013	120,694.0	55,363.4	55,363.4	0.6773640	56,498.80	469.7511	0.045826	0.84848667
2014	125,628.0	58,835.4	58,835.4	0.7198435	23,475.20	721.9387	0.065346	1.22704821
2015	128,843.0	62,101.9	62,101.9	0.7598087	18,395.30	879.6748	0.072213	1.41650227
2016	131,046.0	64,772.2	64,772.2	0.7924795	100,038.00	1,039.4279	0.080599	1.60474390
2017	133,120.0	66,368.3	66,368.3	0.8120075	27,891.70	6,345.9274	0.368104	9.56168437
2018	130,219.0	64,402.2	64,402.2	0.7879526	10,614.70	10,493.1681	0.535068	16.29318270
2019	123,774.0	60,464.7	60,464.7	0.7397778	8,288.55	9,289.4432	0.526768	15.36341571
2020	119,199.0	57,485.1	57,485.1	0.7033227	8,907.34	8,355.2390	0.520389	14.53461672
2021	114,524.0	55,681.8	55,681.8	0.6812596	18,889.10	10,866.8862	0.604943	19.51604682
2022	105,900.0	53,221.5	53,221.5	0.6511582	20,463.80	12,094.4316	0.635148	22.72471019
2023	94,879.6	49,723.9	49,723.9	0.6083655	30,114.30	10,990.5717	0.624140	22.10319732
2024	84,325.2	45,443.2	45,443.2	0.5559917	26,045.50	9,735.1172	0.628531	21.42260492
2025	75,265.3	40,603.1	40,603.1	0.4967737	31,045.40	0.0000	0.708830	0.00000000

Table 23: Time series of log-normal recruitment deviation estimates from the base case model.

Quantity	Estimate	~95% Confidence Interval
1916	-0.00801588	0.5977040
1917	-0.00883276	0.5974720
1918	-0.00973226	0.5972160

Quantity	Estimate	~95% Confidence Interval
1919	-0.01072290	0.5969340
1920	-0.01181430	0.5966240
1921	-0.01301660	0.5962840
1922	-0.01434140	0.5959090
1923	-0.01580060	0.5954960
1924	-0.01740760	0.5950430
1925	-0.01917740	0.5945440
1926	-0.02112590	0.5939960
1927	-0.02326970	0.5933940
1928	-0.02562820	0.5927340
1929	-0.02822110	0.5920090
1930	-0.03107110	0.5912150
1931	-0.03420220	0.5903440
1932	-0.03764070	0.5893900
1933	-0.04141320	0.5883460
1934	-0.04555080	0.5872040
1935	-0.05009090	0.5859530
1936	-0.05508200	0.5845830
1937	-0.06058960	0.5830780
1938	-0.06670370	0.5814170
1939	-0.07352670	0.5795770
1940	-0.08108030	0.5775570
1941	-0.08939430	0.5753510
1942	-0.09849350	0.5729600
1943	-0.10813600	0.5704530
1944	-0.11800700	0.5679110
1945	-0.12808500	0.5653370
1946	-0.13809000	0.5628000

Quantity	Estimate	~95% Confidence Interval
1947	-0.14758600	0.5603980
1948	-0.15668400	0.5580910
1949	-0.16496100	0.5559600
1950	-0.17166700	0.5541500
1951	-0.17576700	0.5528570
1952	-0.17608900	0.5522910
1953	-0.17117100	0.5527060
1954	-0.15959000	0.5543290
1955	-0.14019000	0.5573160
1956	-0.11299700	0.5615790
1957	-0.08078740	0.5664880
1958	-0.05086370	0.5705260
1959	-0.03364610	0.5716440
1960	-0.03507350	0.5686690
1961	-0.04641100	0.5630970
1962	-0.04586950	0.5585700
1963	-0.01514150	0.5577440
1964	0.03820280	0.5610420
1965	0.09605440	0.5630780
1966	0.15660100	0.5578470
1967	0.16910000	0.5426870
1968	0.12056800	0.5137340
1969	-0.02066920	0.5414340
1970	1.38674000	0.2834460
1971	1.19633000	0.2678510
1972	-0.80660500	0.4192060
1973	-0.96929600	0.3679960
1974	-0.65943100	0.3275210

Quantity	Estimate	~95% Confidence Interval
1975	0.08979540	0.2007370
1976	-1.04667000	0.3361080
1977	0.69498100	0.1434470
1978	1.11535000	0.1208750
1979	-0.03100600	0.2057720
1980	0.52354900	0.1597550
1981	1.04765000	0.1280000
1982	0.42854300	0.1755300
1983	0.00908587	0.2106900
1984	0.69512600	0.1355000
1985	0.37874500	0.1571050
1986	-0.37923300	0.2737290
1987	0.55729900	0.1613900
1988	0.10450600	0.2227730
1989	-0.20284600	0.2652930
1990	0.24622700	0.2035970
1991	0.84561500	0.1304840
1992	-0.13358900	0.2294730
1993	0.09912130	0.1983170
1994	0.01245270	0.2156320
1995	-0.45455300	0.2870500
1996	-0.75600700	0.3496570
1997	-0.32912000	0.3086890
1998	0.25955300	0.2286990
1999	0.53980900	0.1858690
2000	0.34828500	0.1960050
2001	-0.24585800	0.2532360
2002	-0.37101900	0.2453490

Quantity	Estimate	~95% Confidence Interval
2003	-0.41400000	0.2767990
2004	0.76143500	0.1259570
2005	-0.89985600	0.3580830
2006	0.48051600	0.1409300
2007	-0.92141800	0.3522990
2008	1.31603000	0.0946919
2009	-0.72110600	0.2994120
2010	0.87796300	0.1159950
2011	-1.04025000	0.3158110
2012	-1.46389000	0.3174210
2013	0.70335800	0.1303400
2014	-0.18304400	0.2276120
2015	-0.43376400	0.2837500
2016	1.25456000	0.1457530
2017	-0.02554160	0.2698030
2018	-1.00652000	0.3390920
2019	-1.26755000	0.3662140
2020	-1.21045000	0.3981660
2021	-0.47591200	0.4246760
2022	-0.41101400	0.5476460
2023	-0.03620120	0.5740210
2024	-0.18875100	0.5794810

Table 24: Quantities of interest from the sensitivity analyses. ‘RSB2018’ refers to depletion in 2018 (SB_{2015}/SB_0)

Label	Base	Fixed natural mortality to 2015 prior	Fixed natural mortality to 2011 prior	Midwatertrawl asymptotic selectivity forced	Logistic selectivity curves for surveys	Inclusing of shrimp trawl	New Washington catch reconstruction	Fixed steepness at 0 4	Fixed steepness at 0 6	Fixed steepness at 0 798 2015 assessment	Exclusion of triennial survey	Francis weighting
M (females)	0.125	0.100	0.124	0.152	0.123	0.125	0.125	0.125	0.111	0.125	0.127	0.135
Lmin (females)	20.652	20.666	20.707	21.313	20.417	20.652	20.652	20.655	21.386	20.655	20.511	20.685
Lmax (females)	49.524	49.403	49.508	49.617	49.364	49.524	49.524	49.526	49.376	49.526	49.464	49.474
k (females)	0.181	0.184	0.182	0.172	0.187	0.181	0.181	0.181	0.179	0.181	0.183	0.177
CV old (females)	0.116	0.116	0.115	0.105	0.119	0.116	0.116	0.116	0.104	0.116	0.118	0.118
CV young (females)	0.048	0.049	0.048	0.051	0.048	0.048	0.048	0.048	0.050	0.048	0.048	0.046
M (males)	0.137	0.100	0.129	0.160	0.136	0.137	0.137	0.137	0.122	0.137	0.140	0.148
Lmin (males)	21.041	21.118	21.092	20.973	21.019	21.041	21.041	21.040	21.119	21.040	21.056	20.607
Lmax (males)	43.637	43.462	43.527	43.054	43.838	43.637	43.637	43.632	43.237	43.632	43.649	43.546
k (males)	0.245	0.245	0.244	0.256	0.244	0.245	0.245	0.245	0.256	0.245	0.243	0.257

Label	Base	Fixed natural mortality to 2015 prior	Fixed natural mortality to 2011 prior	Midwatertrawl asymptotic selectivity forced	Logistic selectivity curves for surveys	Inclusing of shrimp trawl	New Washington catch reconstruction	Fixed steepness at 0 4	Fixed steepness at 0 6	Fixed steepness at 0 798 2015 assessment	Exclusion of triennial survey	Francis weighting
CV old (males)	0.094	0.092	0.093	0.092	0.096	0.094	0.094	0.094	0.092	0.094	0.094	0.102
CV young (males)	0.057	0.058	0.058	0.058	0.055	0.057	0.057	0.057	0.059	0.057	0.057	0.052
lnR0	10.437	9.898	10.349	10.942	10.405	10.437	10.437	10.425	10.319	10.425	10.502	10.704
Virgin recruitment (thousands)	34.103	19.899	31.238	56.483	33.014	34.103	34.103	33.709	30.290	33.709	36.393	44.556
SSB unfished (mt)	151584	139,734.000	145,723.000	174,575.000	150,977.000	151,584.000	151,584.000	149,523.000	164,926.000	149,523.000	156,464.000	170,203.000
SB0 (thousand mt)	81.734	72.835	75.759	88.400	81.910	81.734	81.734	80.640	90.300	80.640	84.482	90.227
SSB 2025 (thousand mt)	40.603	19.951	35.214	62.364	38.632	40.603	40.603	44.088	56.194	44.088	44.929	47.773
B ratio 2025	0.497	0.274	0.465	0.705	0.472	0.497	0.497	0.547	0.622	0.547	0.532	0.529

Label	Base	Fixed natural mortality to 2015 prior	Fixed natural mortality to 2011 prior	Midwatertrawl asymptotic selectivity forced	Logistic selectivity curves for surveys	Inclusing of shrimp trawl	New Washington catch reconstruction	Fixed steepness at 0 4	Fixed steepness at 0 6	Fixed steepness at 0 798 2015 assessment	Exclusion of triennial survey	Francis weighting
SPR ratio 2025	1.257	1.657	1.312	0.852	1.308	1.257	1.257	1.210	1.396	1.210	1.193	1.110
Difference from Base Model Likelihood												
Total	7664.49	21.710	5.400	47.620	0.130	0.000	0.000	-0.220	223.110	-0.220	-94.910	-1,227.440
Survey	13.022	2.609	0.322	1.172	0.238	0.000	0.000	0.085	-1.161	0.085	-1.276	0.424
Length	854.968	1.593	-1.324	11.621	11.797	0.000	0.000	0.427	148.202	0.427	-92.247	-622.004
Age	1366.28	9.670	5.790	35.500	-11.870	0.000	0.000	-0.360	60.690	-0.360	-0.430	-594.783
Discards	5410.79	0.710	0.160	-0.180	-0.010	0.000	0.000	-0.010	-0.140	-0.010	-0.020	0.050
Recruitment	17.84	7.922	0.661	-2.010	0.049	0.000	0.000	-0.302	6.924	-0.302	-0.790	-11.321
Forecast recruitment	0.601	0.138	0.017	-0.063	-0.038	0.000	0.000	-0.038	8.682	-0.038	-0.037	-0.291
Parameter Priors	0.983	-0.924	-0.234	1.577	-0.051	0.000	0.000	-0.033	-0.111	-0.033	-0.128	0.488

Table 25: Results from retrospective runs, sequentially removing data over the last five years using the base case assumptions.

Retrospective	Base Model	Retro 1	Retro 2	Retro 3	Retro 4	Retro 5
M (females)	0.12	0.13	0.14	0.14	0.14	0.14
Lmin (females)	20.65	20.56	20.54	20.40	20.41	20.36
Lmax (females)	49.52	49.70	50.04	50.07	50.18	50.20
k (females)	0.18	0.18	0.18	0.18	0.18	0.18
CV old (females)	0.12	0.12	0.12	0.12	0.12	0.12
CV young (females)	0.05	0.05	0.04	0.04	0.04	0.04
M (males)	0.14	0.14	0.15	0.15	0.15	0.15
Lmin (males)	21.04	21.05	21.02	21.10	21.16	21.16
Lmax (males)	43.64	43.76	43.86	44.05	44.14	44.18
k (males)	0.24	0.24	0.24	0.24	0.24	0.23
CV old (males)	0.09	0.09	0.10	0.10	0.10	0.10
CV young (males)	0.06	0.06	0.06	0.05	0.05	0.05
lnR0	10.44	10.50	10.64	10.66	10.69	10.69
SB0	81734	79,220.00	82,577.00	85,581.00	88,283.00	88,093.00
SB final year	40603	36,546.00	41,101.00	42,587.00	48,218.00	47,517.00
Depletion Final Year (%)	49.68	46.13	49.77	49.76	54.62	53.94
Yield SPR 50	5628	5,736.00	6,329.00	6,514.00	6,727.00	6,702.00
h (steepness)	0.72	0.72	0.72	0.72	0.72	0.72

Retrospective	Base Model	Retro 1	Retro 2	Retro 3	Retro 4	Retro 5
Difference from Base Model Likelihood						
Total	7664.49	7,553.87	7,444.31	7,342.89	7,274.85	7,252.30
Survey	13.02	12.01	12.19	8.73	2.95	3.00
Discard	5410.79	5,410.78	5,402.22	5,384.36	5,376.48	5,374.50
Length	854.97	829.68	788.03	764.60	744.61	733.24
Age	1366.28	1,284.89	1,229.12	1,174.31	1,140.14	1,131.15
Recruitment	17.84	15.03	10.98	9.16	9.05	8.81
Forecast Rec	0.60	0.21	0.15	0.11	0.00	0.00
Priors	0.98	1.26	1.60	1.60	1.60	1.60
Parameter	0.00	0.00	0.00	0.00	0.00	0.00

Table 26: Results from retrospective runs, sequentially removing data over the last five years using the base case assumptions.

log(R0)	R0 10.4	R0 10.2	R0 10	R0 9.8	R0 10.6	R0 10.8	R0 11	R0 11.2	R0 11.4
M (females)	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.15	0.16
Lmin (females)	20.62	20.63	20.64	20.65	20.66	20.67	20.69	20.70	20.72
Lmax (females)	49.38	49.44	49.48	49.52	49.55	49.58	49.61	49.63	49.65
k (females)	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18

log(R0)	R0 10.4	R0 10.2	R0 10	R0 9.8	R0 10.6	R0 10.8	R0 11	R0 11.2	R0 11.4
CV old (females)	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11
CV young (females)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
M (males)	0.11	0.12	0.13	0.14	0.14	0.15	0.16	0.17	0.17
Lmin (males)	21.04	21.04	21.04	21.04	21.04	21.04	21.04	21.04	21.04
Lmax (males)	43.70	43.68	43.66	43.64	43.62	43.60	43.58	43.57	43.56
k (males)	0.24	0.24	0.24	0.24	0.24	0.25	0.25	0.25	0.25
CV old (males)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
CV young (males)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
lnR0	9.80	10.00	10.20	10.40	10.60	10.80	11.00	11.20	11.40
SB0	73122	73888	76459	80765	86546	93669	102177	112272	124362
SB final year	15300	21502	29330	38706	49437	61336	74315	88412	103905
Depletion Final Year (%)	0.21	0.29	0.38	0.48	0.57	0.65	0.73	0.79	0.84
Yield SPR 50	3820.98	4270.68	4820.63	5489.86	6290.92	7239.32	8358.03	9679.25	11249.10

log(R0)	R0 10.4	R0 10.2	R0 10	R0 9.8	R0 10.6	R0 10.8	R0 11	R0 11.2	R0 11.4
h (steepness)	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Difference from Base Model Likelihood									
Total	7674.73	7668.61	7665.58	7664.52	7664.94	7666.59	7669.28	7672.8	7676.92
Survey	15.4531	14.2187	13.4387	13.0554	13.0009	13.2228	13.701	14.4632	15.3798
Discard	5411.74	5411.35	5411.05	5410.83	5410.69	5410.63	5410.67	5410.79	5410.94
Length	852.42	853.706	854.48	854.914	855.129	855.201	855.177	855.092	854.968
Age	1361.89	1362.68	1364.13	1365.92	1367.91	1370.03	1372.26	1374.56	1376.85
Recruit-ment	32.2007	25.6514	21.2814	18.2805	16.2748	15.0651	14.5079	14.4752	14.8684
Forecast Rec	0.931242	0.794112	0.688606	0.611943	0.559064	0.524661	0.504247	0.494571	0.493073
Priors	0.0871177	0.204037	0.498466	0.900147	1.37351	1.89993	2.44272	2.92231	3.40773
Parameter	0	0	0	0	0	0	0	0	0

Table 27: Quantities of interest when profiling over steepness values.

steepness (h)	0.715	0.66	0.605	0.55	0.495	0.44	0.385	0.33	0.275	0.77	0.825	0.88
M (females)	0.144673	0.136564	0.131521	0.128413	0.12656	0.12551	0.124953	0.12469	0.124601	0.1246140	0.1246870	0.1247940

steepness (h)	0.715	0.66	0.605	0.55	0.495	0.44	0.385	0.33	0.275	0.77	0.825	0.88
Lmin (females)	20.6294	20.6292	20.6326	20.637	20.6413	20.6451	20.6481	20.6505	20.6523	20.6538000	20.6550000	20.6560000
Lmax (females)	49.5276	49.5212	49.5184	49.5178	49.5185	49.5198	49.5212	49.5226	49.5238	49.5249000	49.5260000	49.5269000
k (females)	0.180661	0.180935	0.181077	0.181141	0.181162	0.181158	0.181144	0.181126	0.181108	0.1810910	0.1810750	0.1810600
CV old (females)	0.115722	0.115949	0.116026	0.116031	0.116003	0.115962	0.115919	0.115879	0.115843	0.1158110	0.1157830	0.1157590
CV young (females)	0.0478482	0.0479314	0.0479921	0.0480373	0.0480714	0.0480975	0.0481179	0.0481341	0.0481471	0.0481578	0.0481665	0.0481738
M (males)	0.156665	0.148474	0.143422	0.140343	0.138538	0.137541	0.137035	0.13682	0.136773	0.1368230	0.1369270	0.1370620
Lmin (males)	21.0677	21.0597	21.0539	21.0498	21.0468	21.0446	21.043	21.0418	21.0409	21.0403000	21.0398000	21.0395000
Lmax (males)	43.6659	43.6641	43.6604	43.6559	43.6512	43.6468	43.6429	43.6396	43.6368	43.6345000	43.6326000	43.6309000
k (males)	0.243016	0.243271	0.243528	0.243773	0.243997	0.244195	0.244365	0.244508	0.244628	0.2447270	0.2448080	0.2448770
CV old (males)	0.0936934	0.0938668	0.0939785	0.094049	0.0940914	0.0941155	0.0941281	0.0941335	0.0941348	0.0941332	0.0941300	0.0941257
CV young (males)	0.0563484	0.0564508	0.0565401	0.0566173	0.0566828	0.0567374	0.0567821	0.0568184	0.0568478	0.0568716	0.0568912	0.0569073
lnR0	11.1143	10.8718	10.7108	10.6053	10.5372	10.4937	10.4663	10.4489	10.4379	10.4309000	10.4265000	10.4238000
SB0	117988	104576	96247.2	90958.6	87512.1	85221.4	83664.8	82577.6	81793.7	81,209.8000000	80,761.6000000	80,409.0000000

steepness (h)	0.715	0.66	0.605	0.55	0.495	0.44	0.385	0.33	0.275	0.77	0.825	0.88
SB final year	21839.3	23798.5	26113.7	28657.5	31291	33873.5	36293.3	38488.1	40437.9	42,150.9000000	43,649.7000000	44,961.0000000
Depletion Final Year (%)	0.185098	0.227571	0.271319	0.315061	0.357562	0.397477	0.433794	0.466084	0.494388	0.5190370	0.5404760	0.5591540
Yield SPR 50	2.50E-14	1.04E-12	2640.91	3871.49	4521.34	4928.23	5216.11	5436.56	5613.8	5,760.7400000	5,885.1800000	5,992.2400000
h (steepness)	0.275	0.33	0.385	0.44	0.495	0.55	0.605	0.66	0.715	0.7700000	0.8250000	0.8800000
Difference from Base Model Likelihood												
Total	7674.7	7670.81	7668.56	7667.15	7666.21	7665.56	7665.09	7664.75	7664.51	7,664.3500000	7,664.2800000	7,664.3000000
Survey	12.325	12.2616	12.3785	12.5314	12.6736	12.7921	12.8865	12.9603	13.0177	13.0624000	13.0975000	13.1251000
Discard	5410.61	5410.67	5410.73	5410.77	5410.79	5410.8	5410.8	5410.8	5410.79	5,410.7900000	5,410.7900000	5,410.7800000
Length	851.248	851.945	852.57	853.125	853.611	854.031	854.389	854.691	854.947	855.1620000	855.3430000	855.4960000
Age	1370.81	1369.61	1368.73	1368.05	1367.52	1367.11	1366.78	1366.51	1366.29	1,366.1100000	1,365.9700000	1,365.8400000
Recruit-ment	23.5201	21.7009	20.4979	19.6773	19.0905	18.653	18.3181	18.0586	17.8561	17.6972000	17.5719000	17.4725000
Forecast Rec	0.888692	0.854896	0.812813	0.768038	0.724985	0.686338	0.653165	0.625399	0.602386	0.5833030	0.5674390	0.5541630
Priors	5.29564	3.76019	2.83695	2.22346	1.79449	1.48565	1.26065	1.09903	0.990664	0.9334140	0.9345260	1.0185400
Parameter	0	0	0	0	0	0	0	0	0	0.0000000	0.0000000	0.0000000

Table 28: Quantities of interest when profiling over natural mortality values for females

Natural Mortality (females)	0.121	0.11	0.099	0.088	0.132	0.143	0.154	0.165	0.176	0.187	0.198
M (females)	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.17	0.18	0.19	0.20
Lmin (females)	20.67	20.66	20.66	20.65	20.65	20.66	20.67	20.68	20.70	20.74	20.77
Lmax (females)	49.33	49.40	49.45	49.51	49.56	49.61	49.66	49.71	49.75	49.80	49.84
k (females)	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.17	0.17
CV old (females)	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11
CV young (females)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
M (males)	0.10	0.11	0.12	0.13	0.14	0.15	0.17	0.18	0.19	0.20	0.21
Lmin (males)	21.03	21.03	21.04	21.04	21.04	21.04	21.04	21.04	21.04	21.03	21.02
Lmax (males)	43.68	43.67	43.66	43.64	43.62	43.61	43.59	43.56	43.54	43.51	43.48
k (males)	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
CV old (males)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09

Natural Mortality (females)	0.121	0.11	0.099	0.088	0.132	0.143	0.154	0.165	0.176	0.187	0.198
CV young (males)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
lnR0	9.84	10.00	10.18	10.37	10.57	10.76	10.96	11.17	11.38	11.61	11.87
SB0	85925.30	82223.70	80985.70	81367.50	82812.40	85120.20	88450.20	93082.60	99545.50	108692.00	122117.00
SB final year	21441.60	26610.80	32539.80	38661.50	44476.00	49821.40	54986.60	60334.40	66454.20	74191.30	84745.20
Depletion Final Year (%)	0.25	0.32	0.40	0.48	0.54	0.59	0.62	0.65	0.67	0.68	0.69
Yield SPR 50	4153.67	4469.16	4898.71	5432.97	6063.15	6794.88	7660.47	8708.93	10023.80	11741.70	14110.70
h (steepness)	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Difference from Base Model Likelihood											
Total	7676.37	7669.86	7666.15	7664.59	7664.92	7666.9	7670.41	7675.29	7681.38	7688.5	7696.47
Survey	15.7341	14.6707	13.7931	13.1656	12.8216	12.7871	13.0479	13.6267	14.4961	15.5785	16.8619
Discard	5411.3	5411.14	5410.97	5410.83	5410.73	5410.68	5410.67	5410.7	5410.76	5410.84	5410.94
Length	855.428	855.473	855.37	855.093	854.661	854.171	853.676	853.225	852.825	852.458	852.19
Age	1364.77	1364.08	1364.51	1365.73	1367.61	1370.05	1373.03	1376.5	1380.44	1384.83	1389.47

Natural Mortality (females)	0.121	0.11	0.099	0.088	0.132	0.143	0.154	0.165	0.176	0.187	0.198
Recruit-ment	28.2584	23.6781	20.4737	18.3397	17.0951	16.5459	16.5574	17.0207	17.845	18.9496	20.3132
Forecast Rec	0.729468	0.671908	0.629148	0.604573	0.611465	0.620579	0.640323	0.668365	0.702497	0.740785	0.783174
Priors	0.147022	0.142084	0.384432	0.811827	1.37627	2.04151	2.78279	3.53642	4.29542	5.08801	5.90722
Parameter	0	0	0	0	0	0	0	0	0	0	0

Table 29: Quantities of interest when profiling over natural mortality values for males

Natural Mortality (males)	0.132	0.121	0.11	0.099	0.088	0.143	0.154	0.165	0.176	0.187	0.198
M (females)	0.0801684	0.0897233	0.0996306	0.109792	0.120092	0.130502	0.140995	0.151558	0.162185	0.1728750	0.1836280
Lmin (females)	20.6627	20.6683	20.6674	20.6612	20.6553	20.6487	20.6421	20.6367	20.6336	20.6335000	20.6371000
Lmax (females)	49.2653	49.3354	49.3943	49.4508	49.5018	49.553	49.6045	49.6558	49.7062	49.7553000	49.8024000
k (females)	0.185729	0.184598	0.183604	0.182561	0.18156	0.180498	0.179387	0.17824	0.177062	0.1758640	0.1746610
CV old (females)	0.1158	0.115739	0.115711	0.115793	0.115818	0.115878	0.115964	0.11605	0.116116	0.1161410	0.1161100

Natural Mortality (males)	0.132	0.121	0.11	0.099	0.088	0.143	0.154	0.165	0.176	0.187	0.198
CV young (females)	0.0488764	0.0486538	0.0484847	0.0483239	0.0481996	0.0480833	0.0479756	0.0478793	0.0477957	0.0477265	0.0476728
M (males)	0.088	0.099	0.11	0.121	0.132	0.143	0.154	0.165	0.176	0.1870000	0.1980000
Lmin (males)	21.0587	21.0589	21.0571	21.0471	21.0429	21.0381	21.0326	21.0262	21.019	21.0111000	21.0026000
Lmax (males)	43.6129	43.6356	43.6436	43.6442	43.6393	43.6327	43.6248	43.6155	43.6046	43.5919000	43.5772000
k (males)	0.244864	0.244453	0.244377	0.24444	0.24458	0.244706	0.244818	0.24493	0.24505	0.2451840	0.2453300
CV old (males)	0.0939186	0.0940718	0.0941317	0.0941613	0.094145	0.0941199	0.0940962	0.0940777	0.0940661	0.0940611	0.0940620
CV young (males)	0.0571452	0.0569929	0.0569156	0.0568734	0.056856	0.0568428	0.0568293	0.0568163	0.0568042	0.0567943	0.0567882
lnR0	9.69739	9.83786	9.99693	10.1699	10.3551	10.545	10.7381	10.9359	11.1413	11.3585000	11.5944000
SB0	87488.3	83027.1	80722.3	80090.6	81018.7	82899.5	85611.5	89317.6	94345.1	101,289.0000000	111,227.0000000
SB final year	16639.1	20822.9	25974.5	31651.3	37926.1	43983.1	49654.3	55149.6	60842.3	67,332.0000000	75,587.5000000
Depletion Final Year (%)	0.190187	0.250797	0.321776	0.395194	0.468115	0.530559	0.579996	0.617455	0.644891	0.6647480	0.6795780
Yield SPR 50	3960.85	4158.51	4459.32	4860.44	5375	5985.28	6698.61	7545.36	8576.49	9,879.4200000	11,610.2000000

Natural Mortality (males)	0.132	0.121	0.11	0.099	0.088	0.143	0.154	0.165	0.176	0.187	0.198
h (steepness)	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.7200000	0.7200000
Difference from Base Model Likelihood											
Total	7686.25	7676.56	7670.39	7666.33	7664.66	7664.77	7666.52	7669.81	7674.49	7,680.4400000	7,687.4900000
Survey	16.8948	15.7211	14.6694	13.8694	13.2195	12.8486	12.7802	13.0171	13.5837	14.4717000	15.6176000
Discard	5411.53	5411.35	5411.17	5411	5410.85	5410.74	5410.67	5410.66	5410.69	5,410.7600000	5,410.8400000
Length	853.665	854.144	854.585	854.801	854.945	854.971	854.934	854.884	854.851	854.8570000	854.9120000
Age	1368.93	1366.25	1365.18	1365	1365.76	1367.11	1369	1371.41	1374.33	1,377.7000000	1,381.4800000
Recruit-ment	33.8673	28.0796	23.8302	20.6567	18.5067	17.1881	16.5682	16.5214	16.9494	17.7738000	18.9327000
Forecast Rec	0.949187	0.877061	0.813761	0.634383	0.606857	0.596812	0.600822	0.615363	0.637904	0.6663240	0.6990220
Priors	0.401122	0.122614	0.126855	0.354612	0.761645	1.30634	1.95633	2.68767	3.44179	4.1997800	4.9978900
Parameter	0	0	0	0	0	0	0	0	0	0.0000000	0.0000000

Table 30: Estimated Dirichlet-multinomial parameters and the corresponding data weights derived using the McAllister-Ianelli and Francis methods. The Dirichlet-multinomial ln(EffN_mult) parameter was bounded between -7 and 7.

Fleet	Composition data type	Log Mean effN 2025 base model	Log Mean effN Francis	Base model McAllister Ianelli weighting	Francis weighting
Bottom-Trawl	Length	4.366490	4.354044	0.050976	0.045830
Hake	Length	5.036966	4.897631	0.027980	0.019866
HnL	Length	3.104232	3.069252	0.169713	0.147854
Midwater-Trawl	Length	5.101000	4.878999	0.043618	0.037046
Net	Length	3.841918	3.860595	0.115959	0.121900
NWFSC	Length	3.821812	3.757661	0.101232	0.086482
Triennial	Length	3.228367	3.189216	0.092531	0.091771
Bottom-Trawl	Age	4.508326	4.653894	0.206741	0.230360
Hake	Age	4.411991	4.509703	0.180223	0.236138
HnL	Age	1.973299	2.008445	0.517972	0.524997
Midwater-Trawl	Age	4.434078	4.473006	0.131374	0.132665
Net	Age	3.532123	3.563373	0.179957	0.204433
NWFSC	Age	2.373780	1.997263	0.124533	0.129401

Fleet	Composition data type	Log Mean effN 2025 base model	Log Mean effN Francis	Base model McAllister Ianelli weighting	Francis weighting

6 Figures

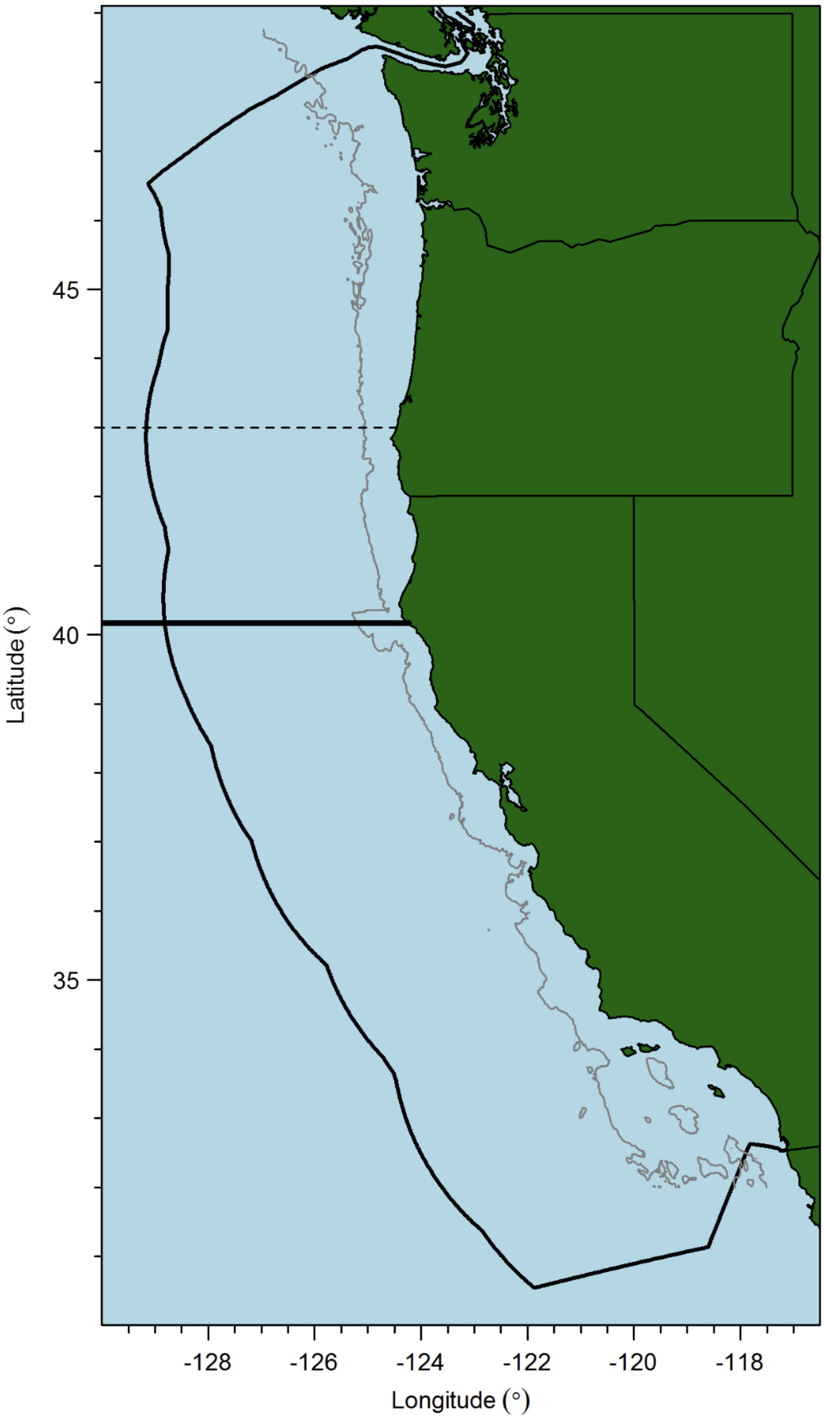


Figure 1: A map of the west coast of the U.S. with the EEZ and the 40° 10 line that divides management into northern and southern regions for some species (although not Widow Rockfish). The line at latitude 43° N latitude is where past assessment models have been stratified into two areas.

6.1 Data

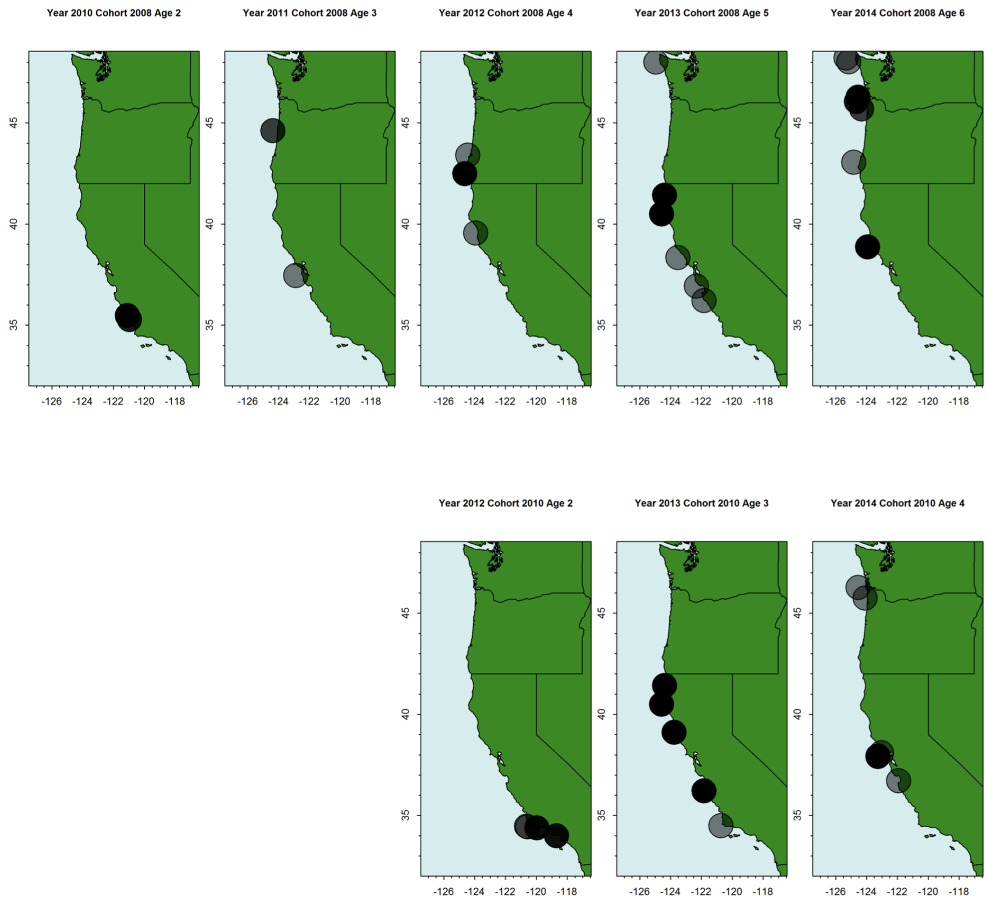


Figure 2: Observations of two cohorts (2008, top and 2010, bottom) from the NWFSC WCGBT survey data. Darker circles indicate more observations (possibly within the same tow).

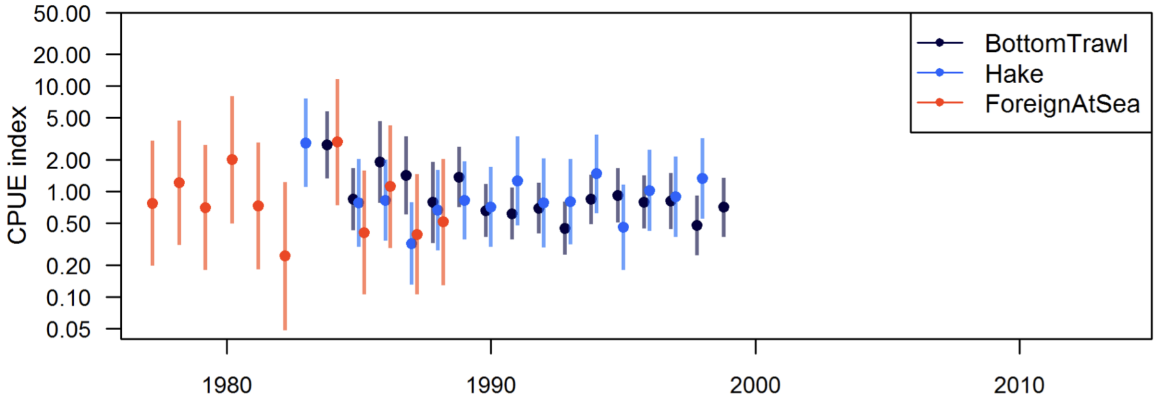


Figure 3: Fishery-dependent indices of abundance from the 2011 assessment scaled to the mean of their own series.

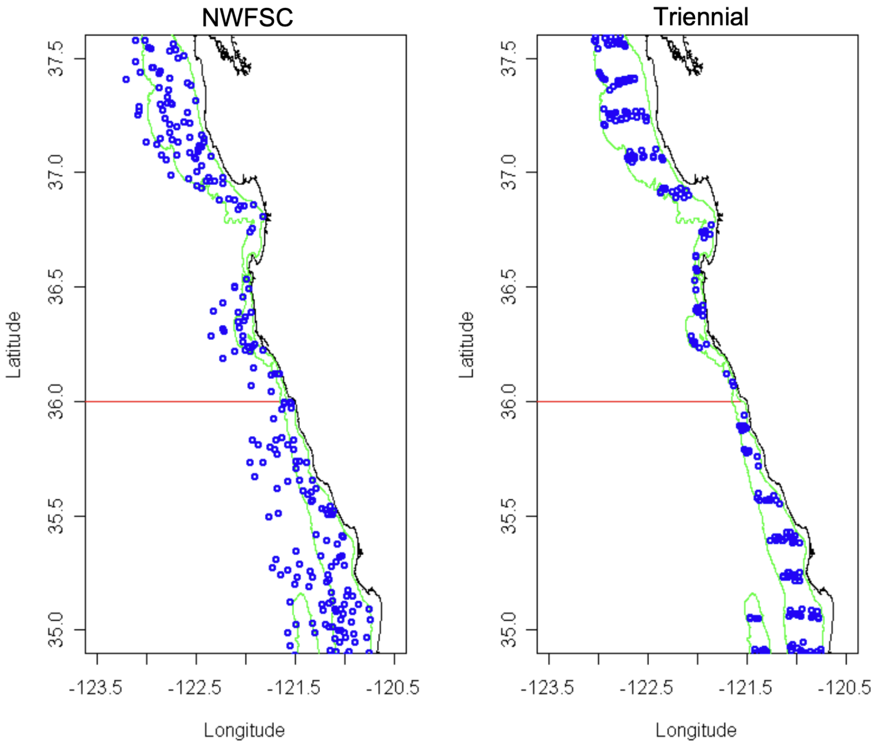


Figure 4: Survey tow locations in 2004, showing the difference in station design for the NWFSC WCBTS survey relative to the Triennial trawl survey (Figure from Stewart (2007)).

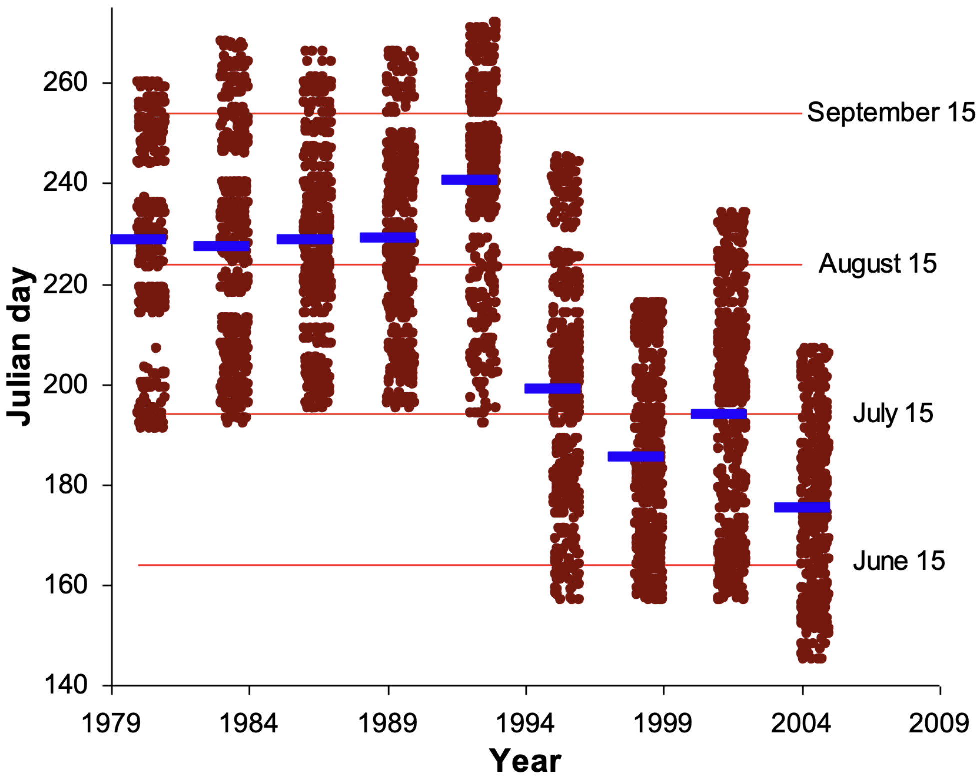


Figure 5: Distribution of dates of operation for the triennial survey (1980-2004). Solid bars show the mean date for each survey year, points represent individual hauls dates, but are jittered to allow better delineation of the distribution of individual points (Figure from (Stewart 2007)).

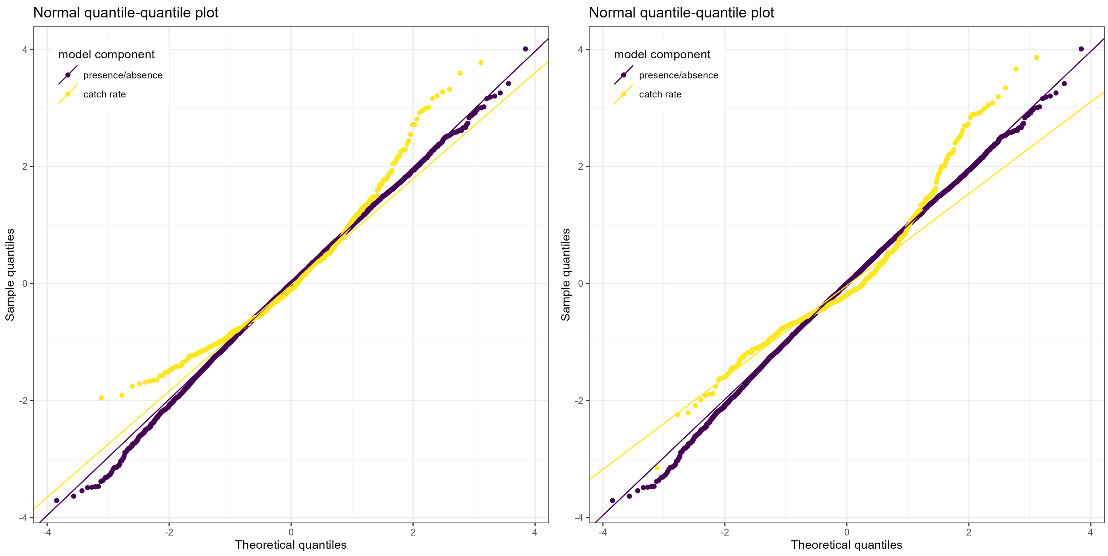


Figure 6: QQ plots for delta-gamma (panel 1) and delta-lognormal (panel 2, used in base model) sdmTMB index.

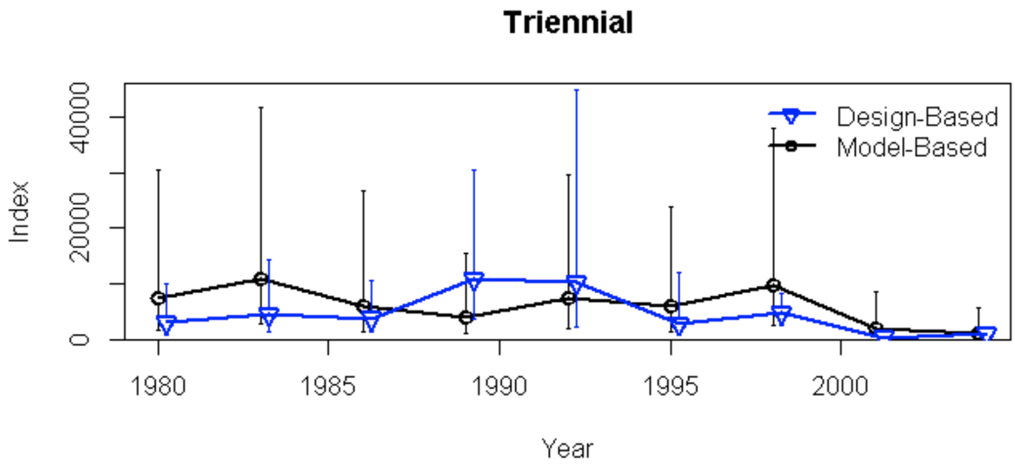


Figure 7: Model-based survey estimates for the Triennial with estimated 95% confidence intervals. based estimates and 95% confidence intervals are shown in blue for comparison.

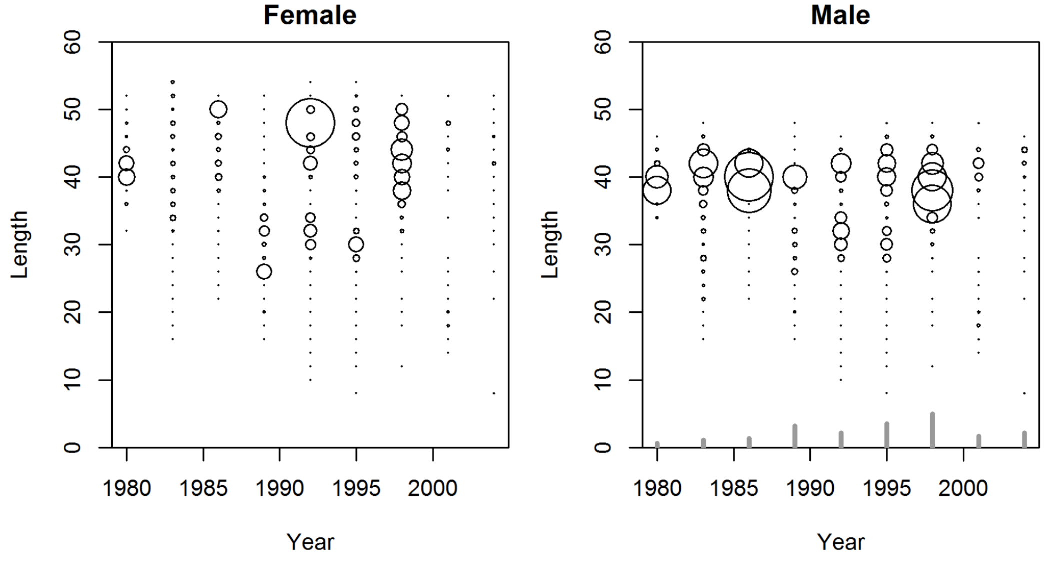


Figure 8: Expanded length compositions weighted by estimated numbers from the GLMM in each strata for the Triennial survey.

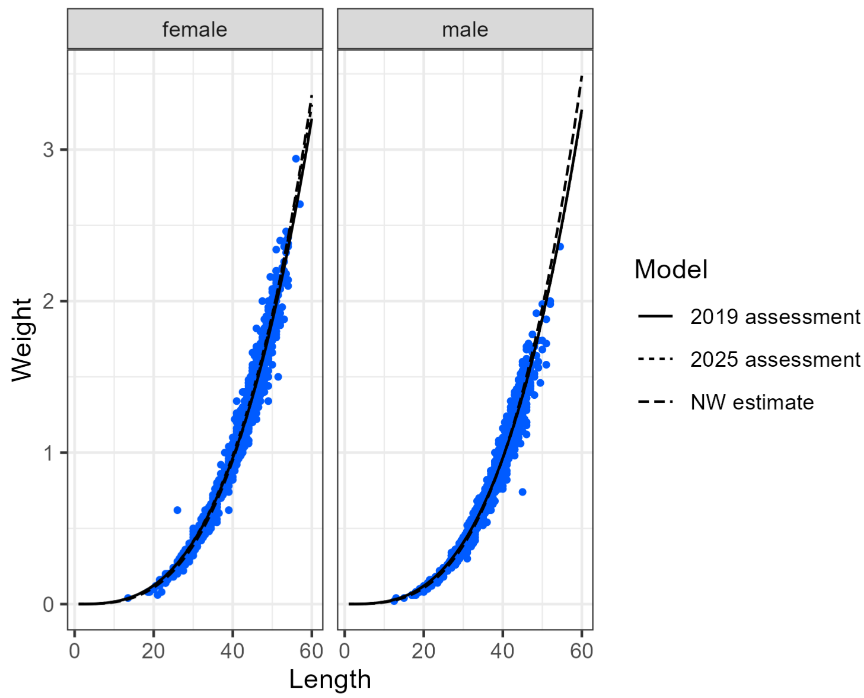


Figure 25: Fits to weight-at-length observations (dashed line) for females (left) and males (right) using observations from all data sources. The weight-at-length curve from the 2019 assessment is inidcated with a solid line.

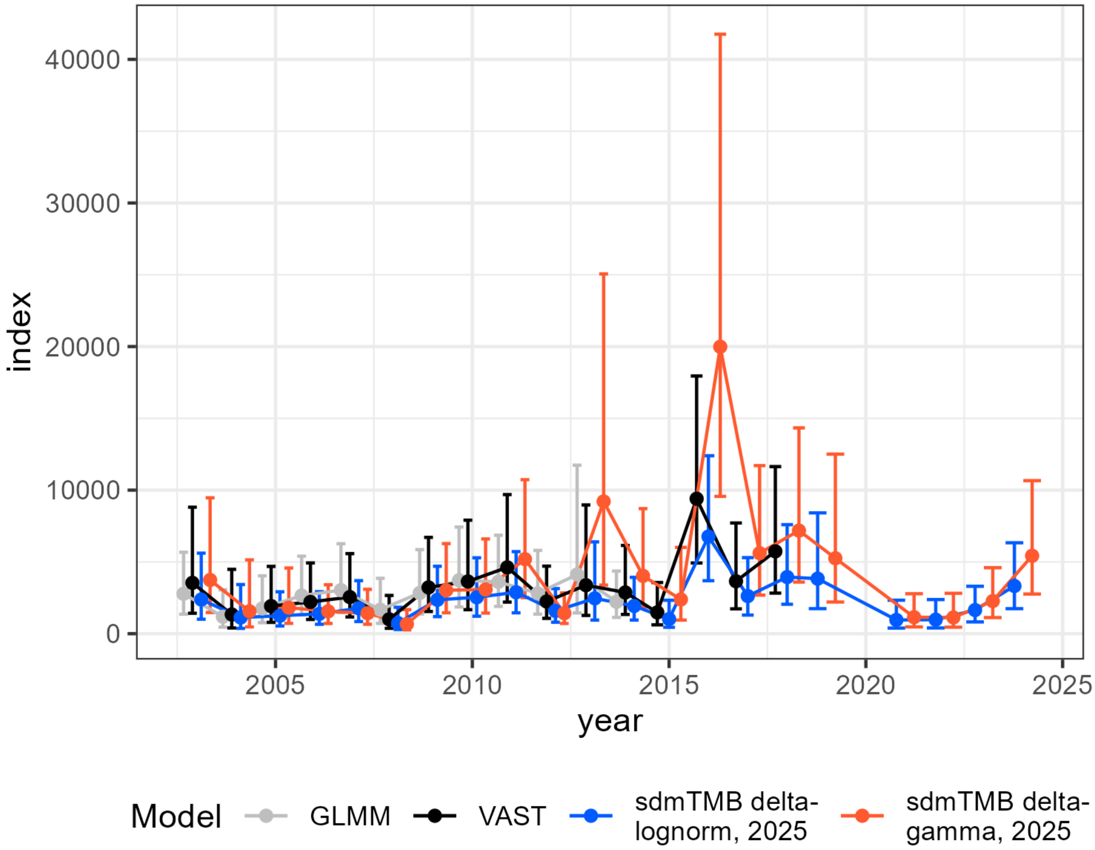


Figure 9: Comparison of the estimated index of relative abundance for the West Coast Groundfish Bottom Trawl Survey using a GLMM (gray line, 2015 stock assessment), VAST (black line, 2019 stock assessment), a delta-gamma sdmTMB index (blue line) and a delta-lognormal sdmTMB index (red line, used in base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

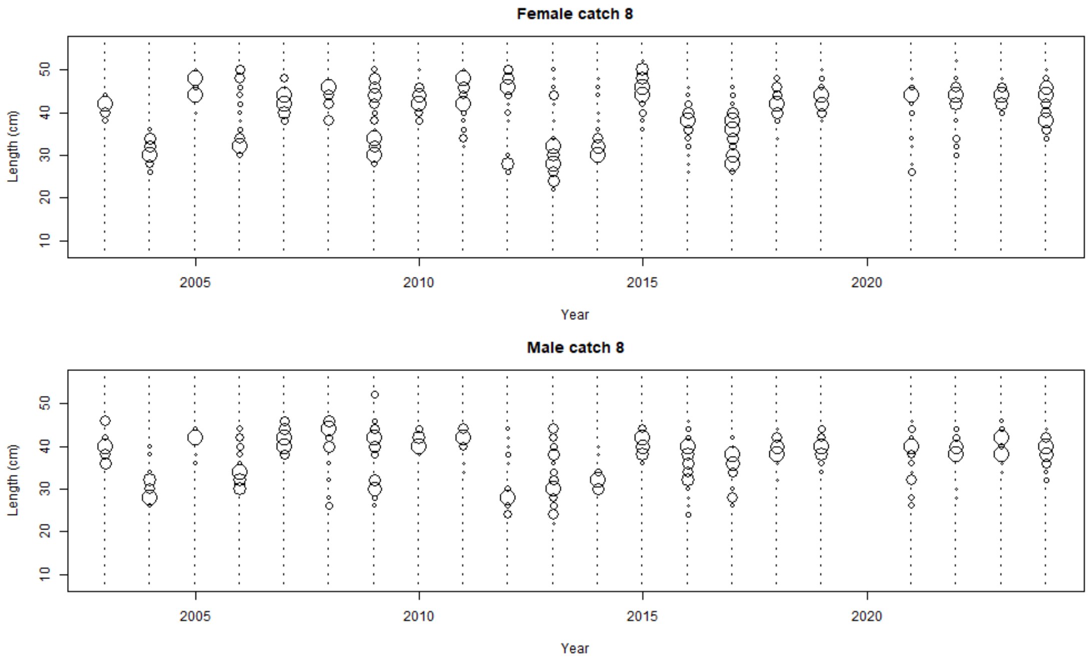


Figure 10: Expanded length compositions for the WCGBTS

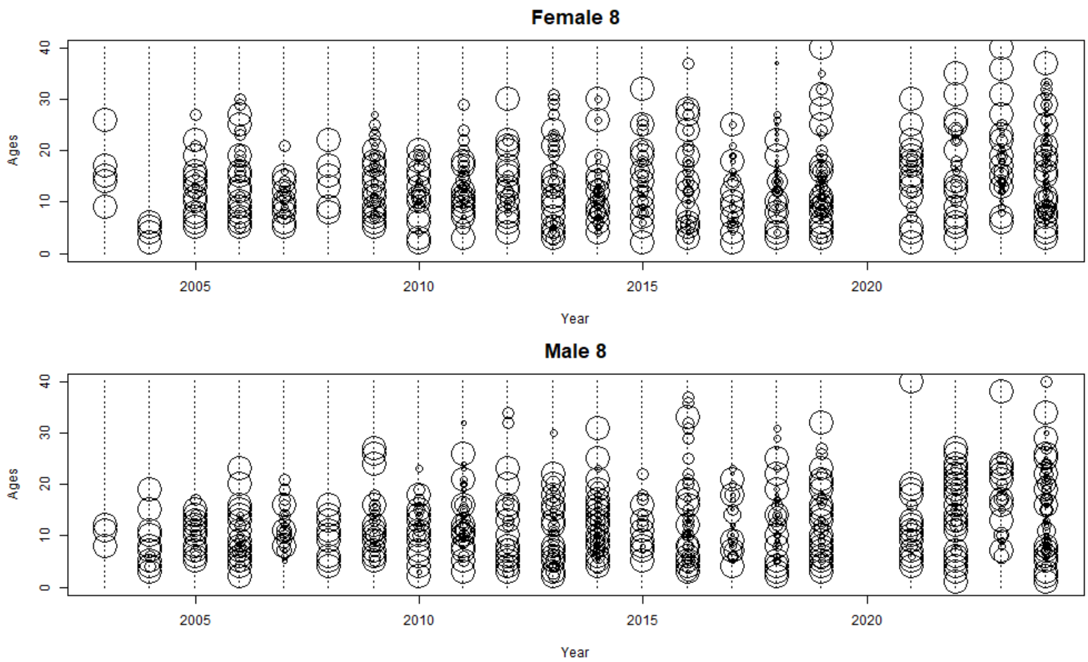


Figure 11: Expanded marginal age compositions from the WCGBTS.

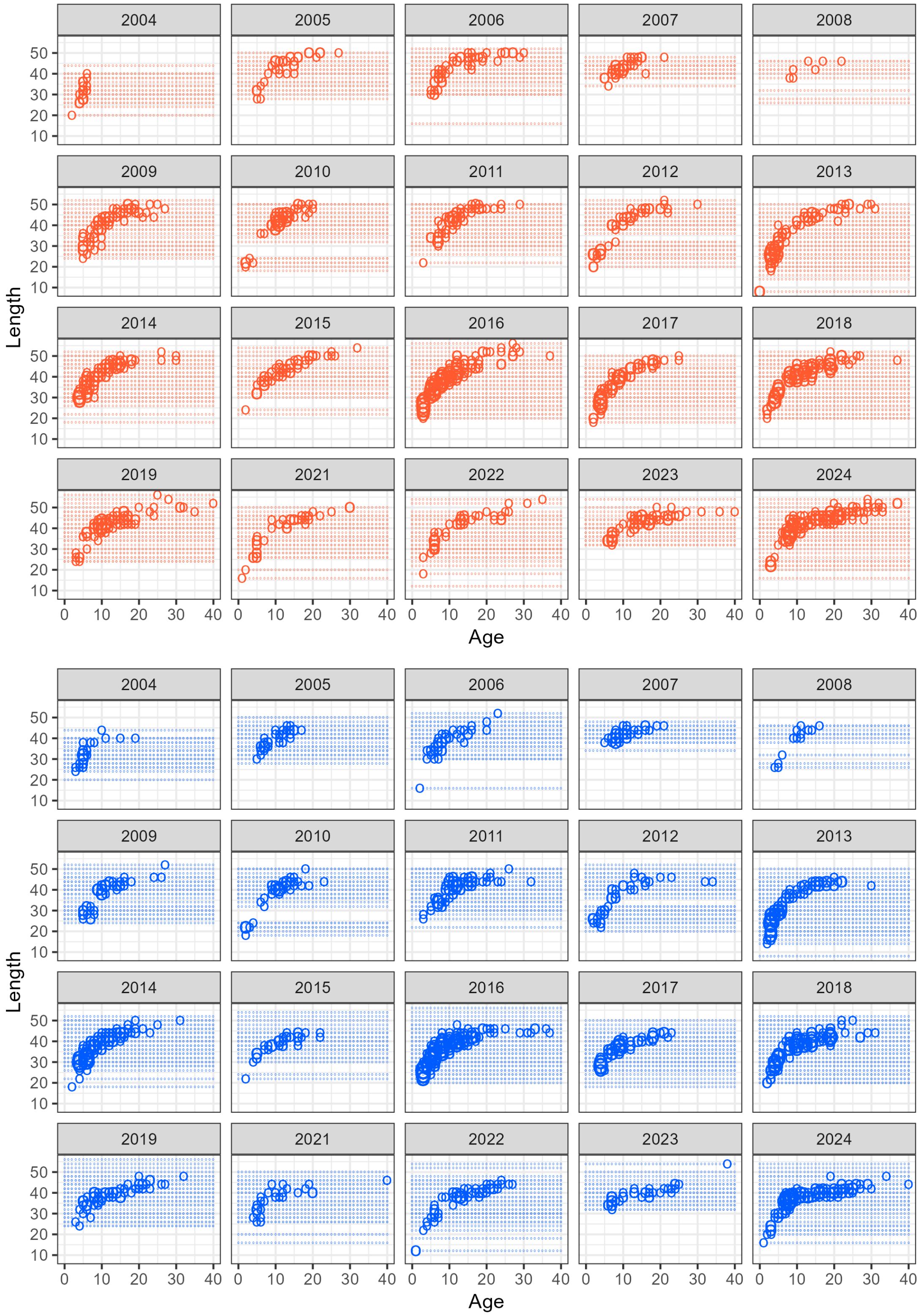


Figure 12: Conditional age-at-length from WCGBTS observations for females (red) and males (blue).

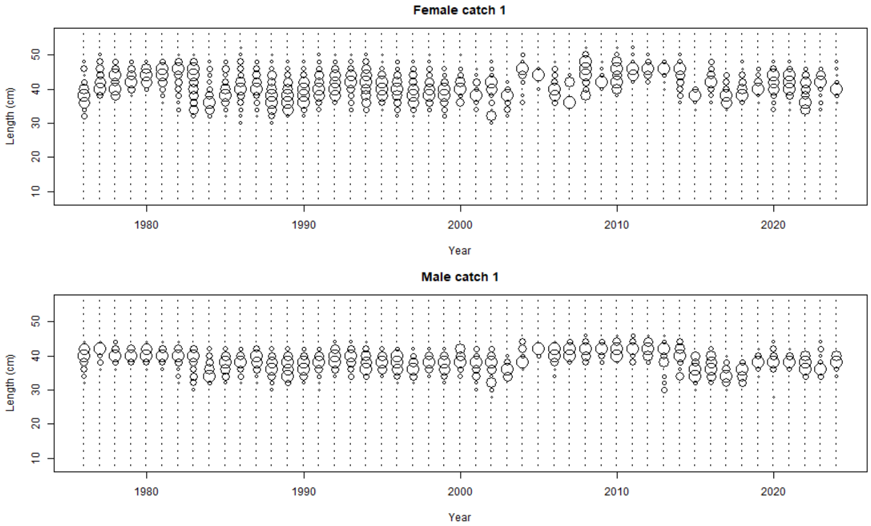


Figure 13: Expanded length compositions for the bottom trawl fishery. The area of the circle is proportional to the proportion-at-length.

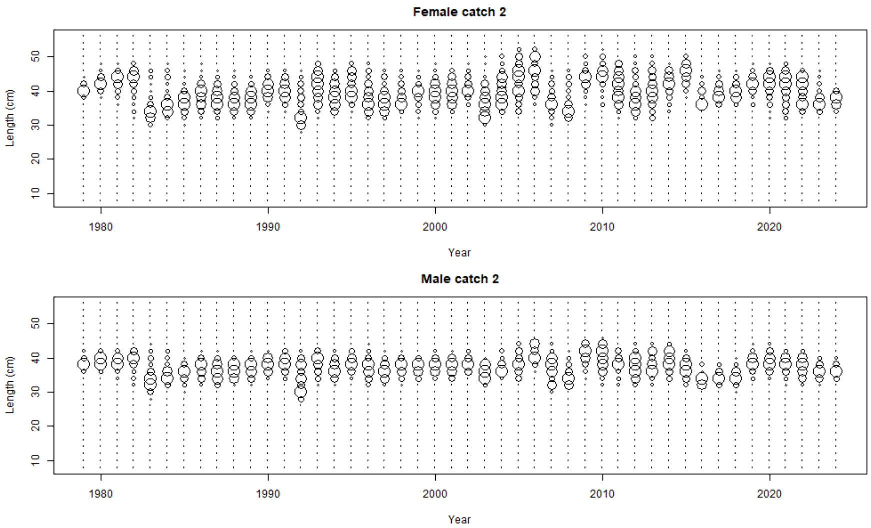


Figure 14: Expanded length compositions for the midwater trawl fishery. The area of the circle is proportional to the proportion-at-length.

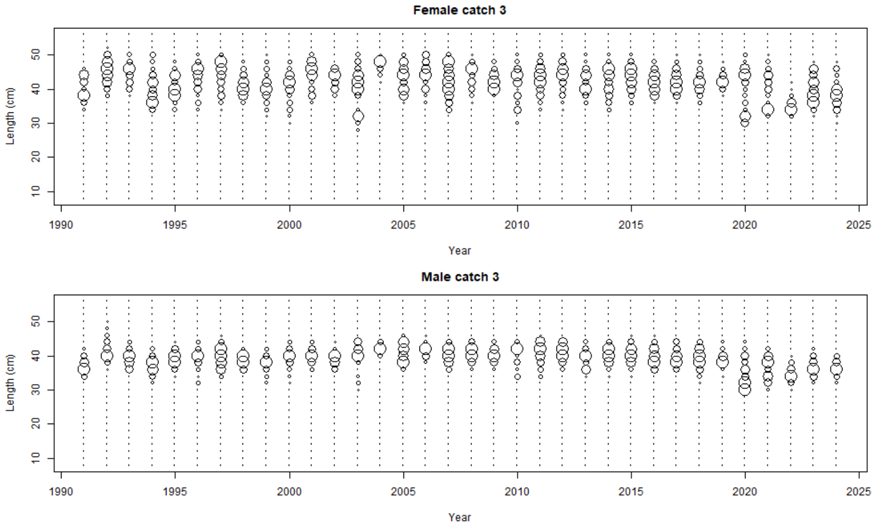


Figure 15: Expanded length compositions for the hake fishery. The area of the circle is proportional to the proportion-at-length.

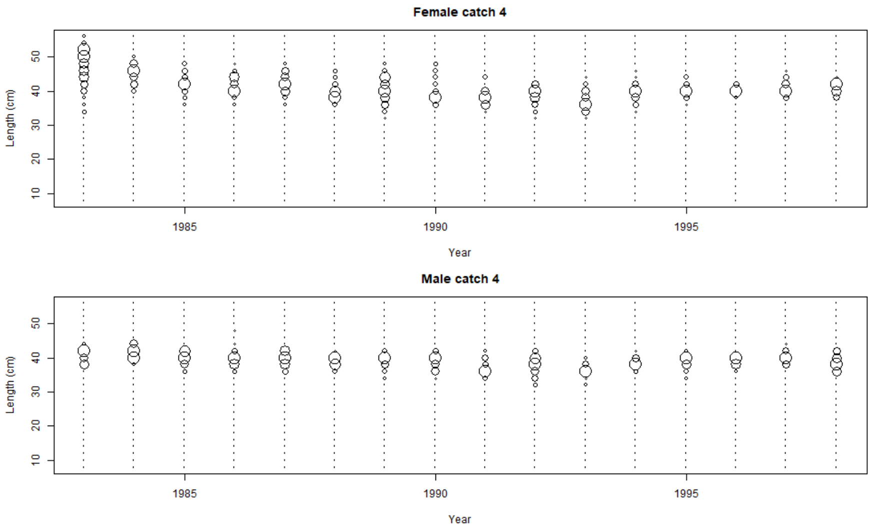


Figure 16: Expanded length compositions for the net fishery. The area of the circle is proportional to the proportion-at-length.

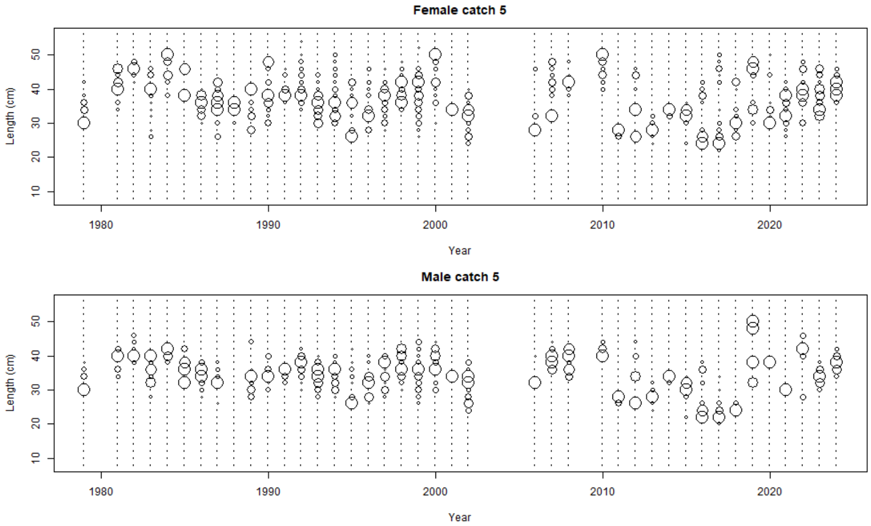


Figure 17: Expanded length compositions for the hook-and-line fishery. The area of the circle is proportional to the proportion-at-length.

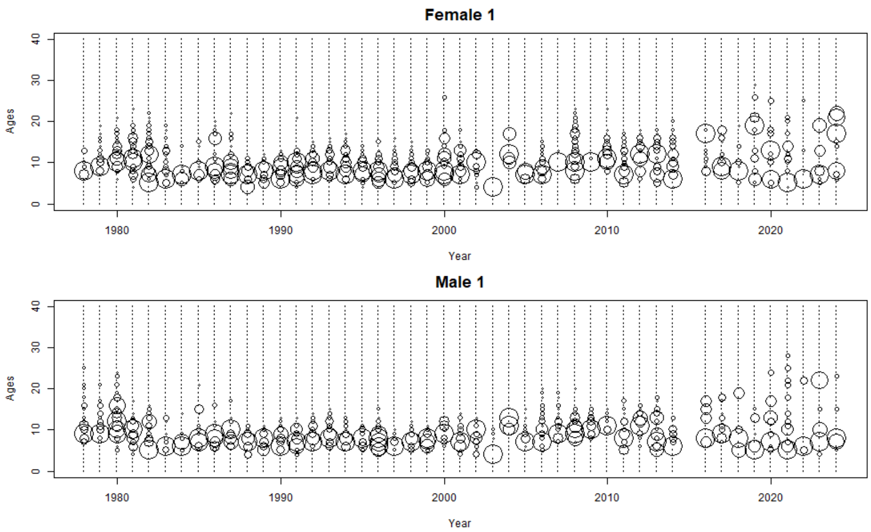


Figure 18: Expanded age compositions for the bottom trawl fishery. The area of the circle is proportional to the proportion-at-age.

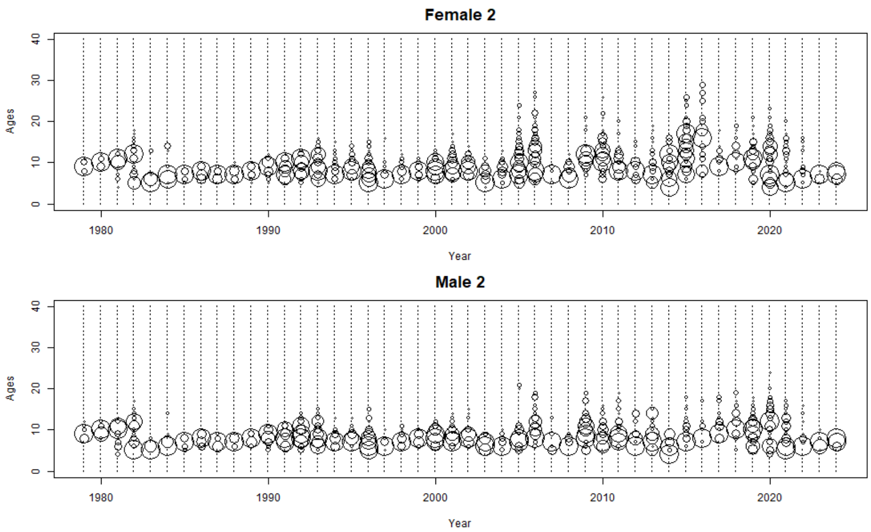


Figure 19: Expanded age compositions for the midwater trawl fishery. The area of the circles is proportional to the proportion-at-age.

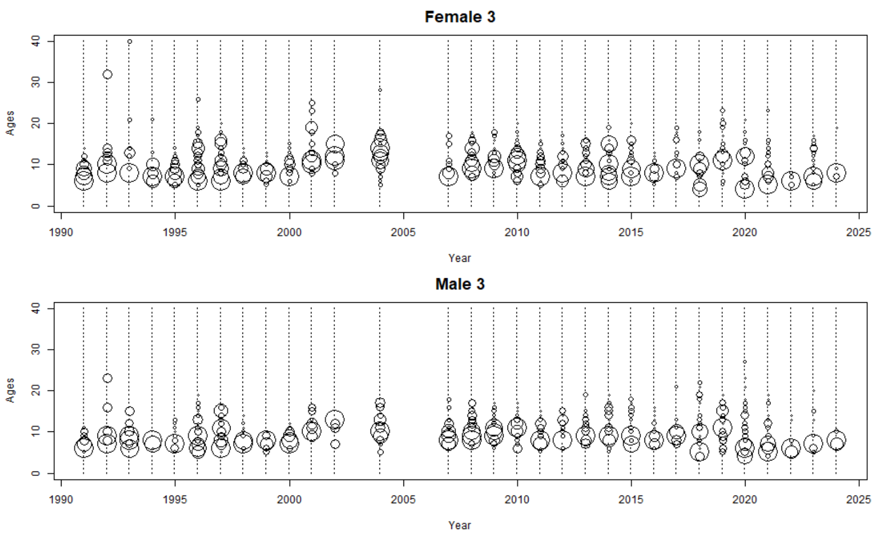


Figure 20: Expanded age compositions for the hake fishery. The area of the circles is proportional to the proportion-at-age.

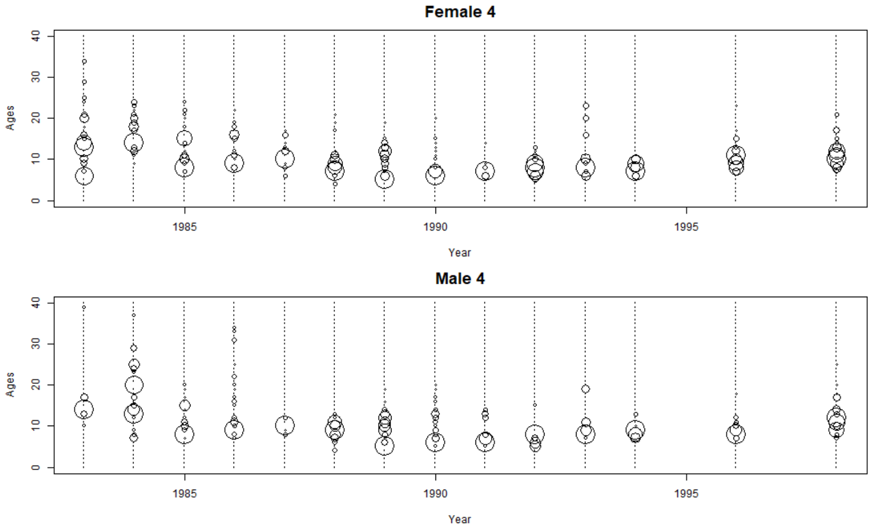


Figure 21: Expanded age compositions for the net fishery. The area of the circles is proportional to the proportion-at-age.

Figure 22: Expanded age compositions for the hook-and-line fishery. The area of the circles is proportional to the proportion-at-age.

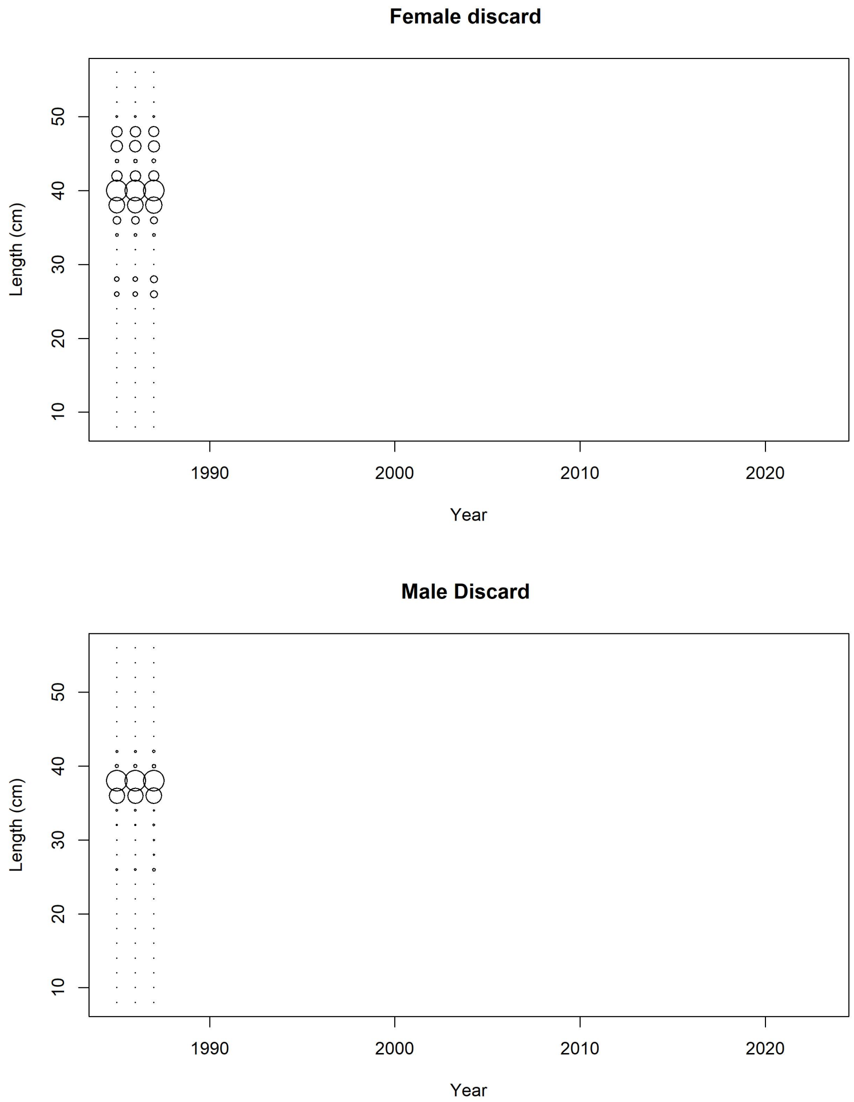


Figure 23: Length compositions for discards from the Pikitch study. The discard length comps were fitted into the model.

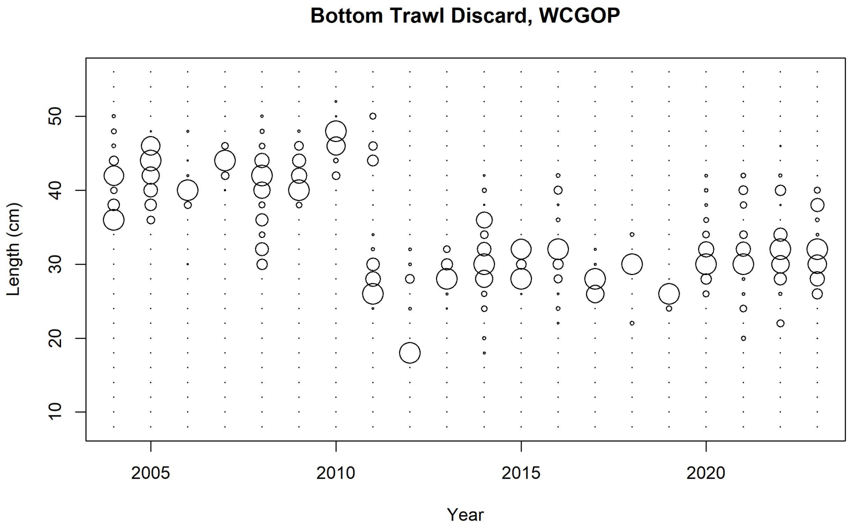
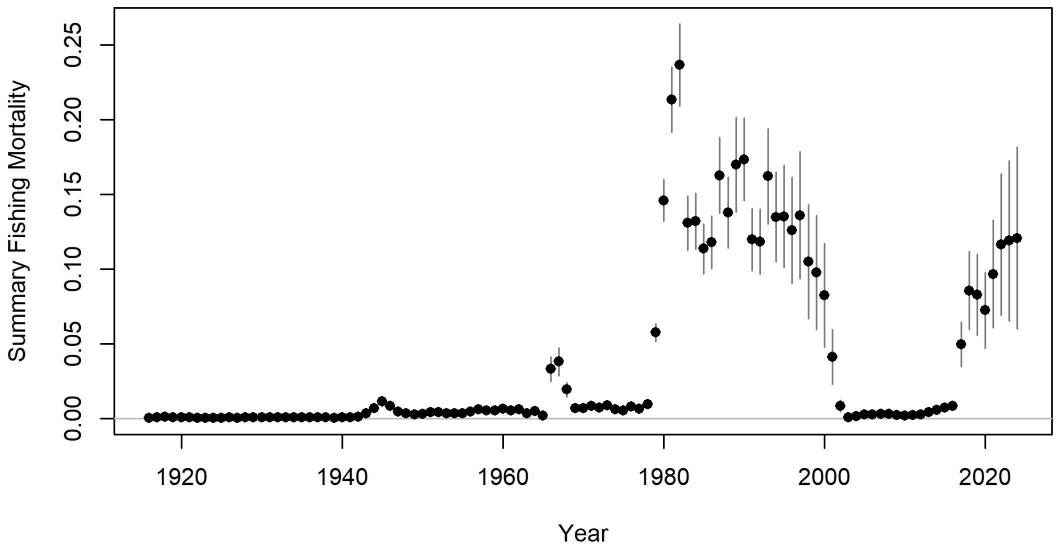


Figure 24: Length compositions of the discards for the bottom trawl.



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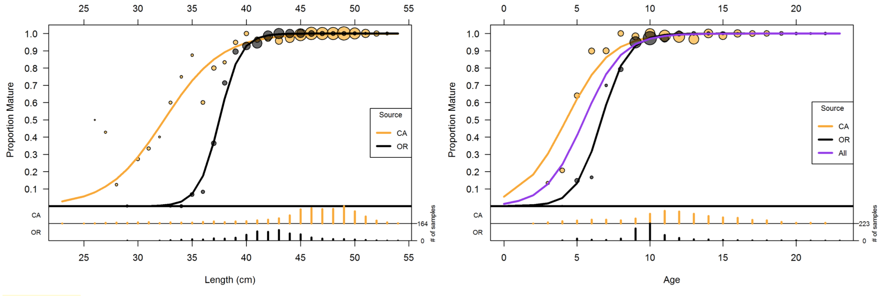


Figure 26: Maturity-at-length (left) and maturity-at-age (right) from data reported by Barss & Echeverria (1987). Circles are proportional to the number of observations at that length or age. Lines are estimated logistic curves fitted to the data. The bars at the bottom are the number of samples by each state. The purple line is the estimated maturity-at-age using all data with each state equally weighted, and is used in the assessment model with maturity-at-age for ages 2 and lower set equal to zero.

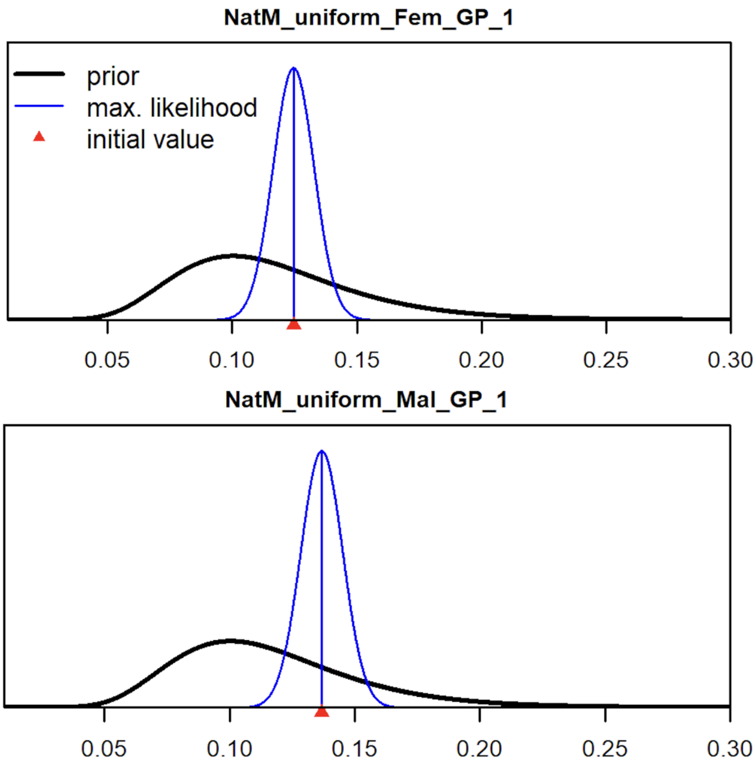


Figure 27: Prior distributions for natural mortality (M).

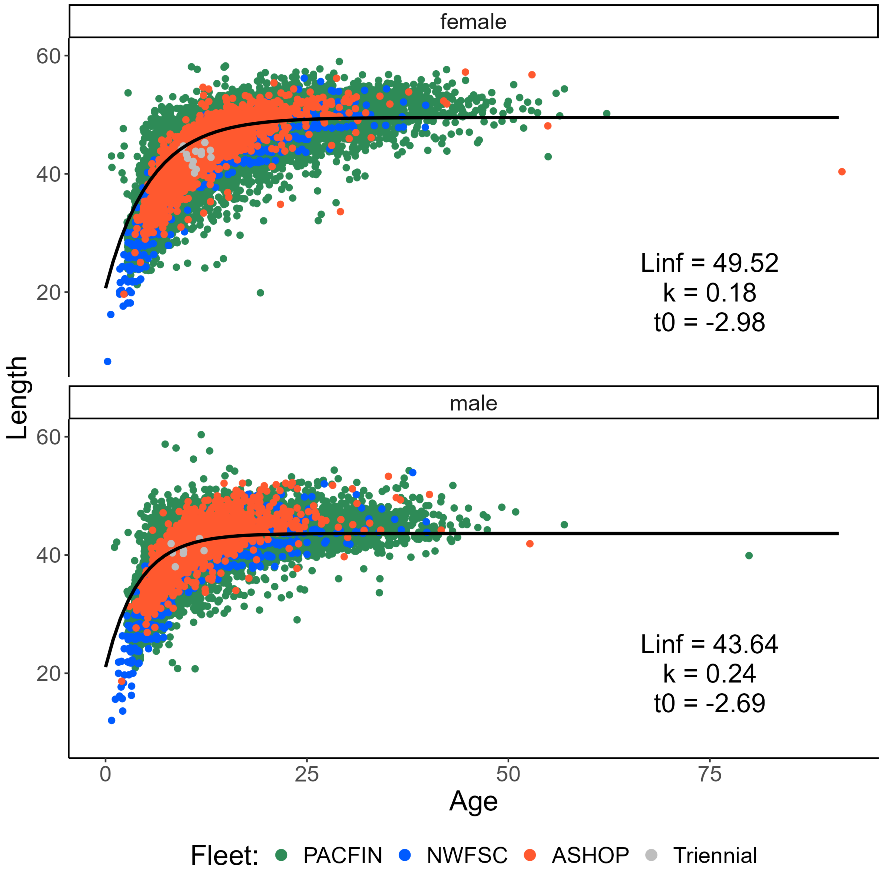


Figure 28: Length-at-age observations (points, slightly jittered) and predicted length-at-age von Bertalanffy curves for female (top) and male (bottom) Widow Rockfish collected from all fishery (BDS and At-Sea) and survey (Triennial and NWFSC) data.

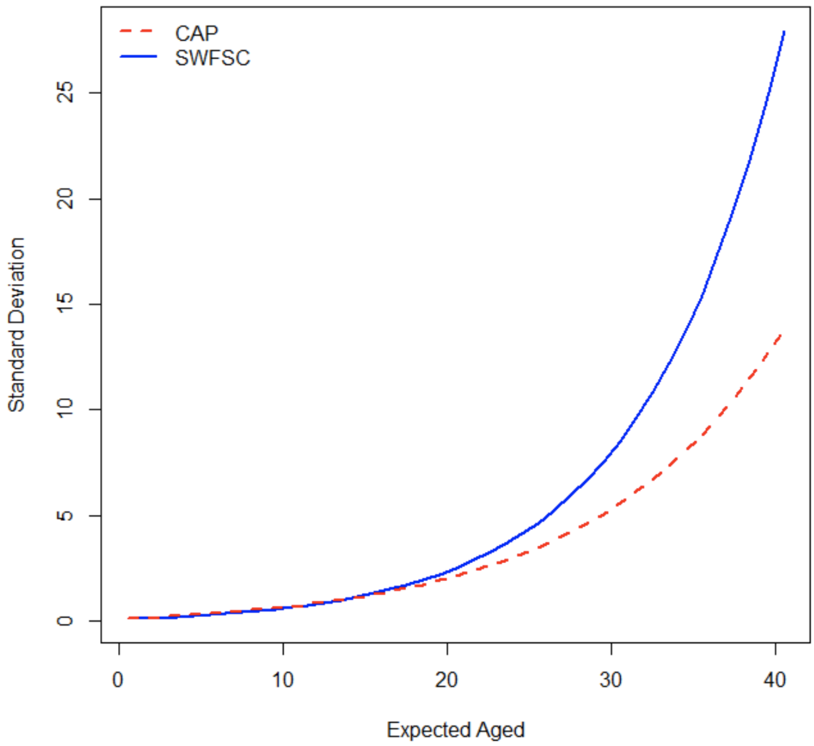


Figure 29: Estimated ageing error for the Cooperative Ageing Project lab and the SWFSC.

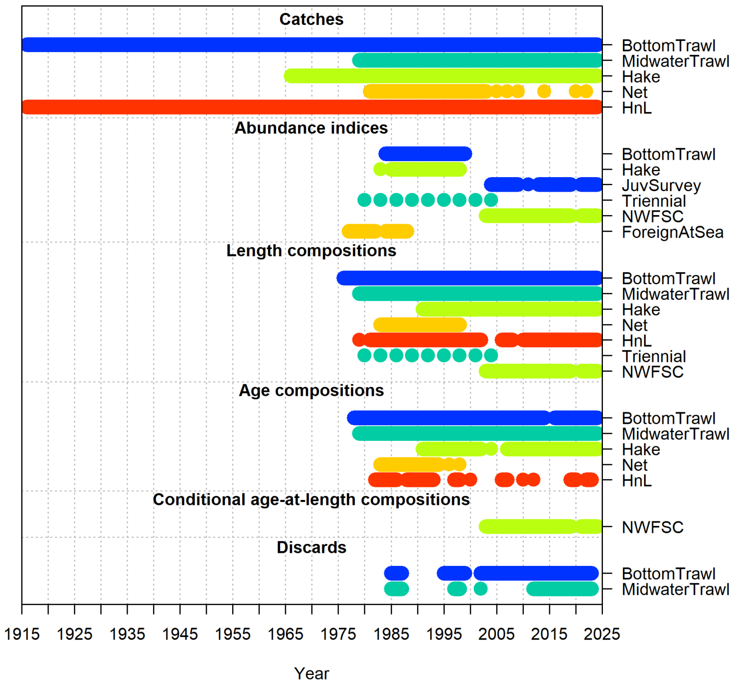


Figure 30: Data sources by type and year that were used in the base model.

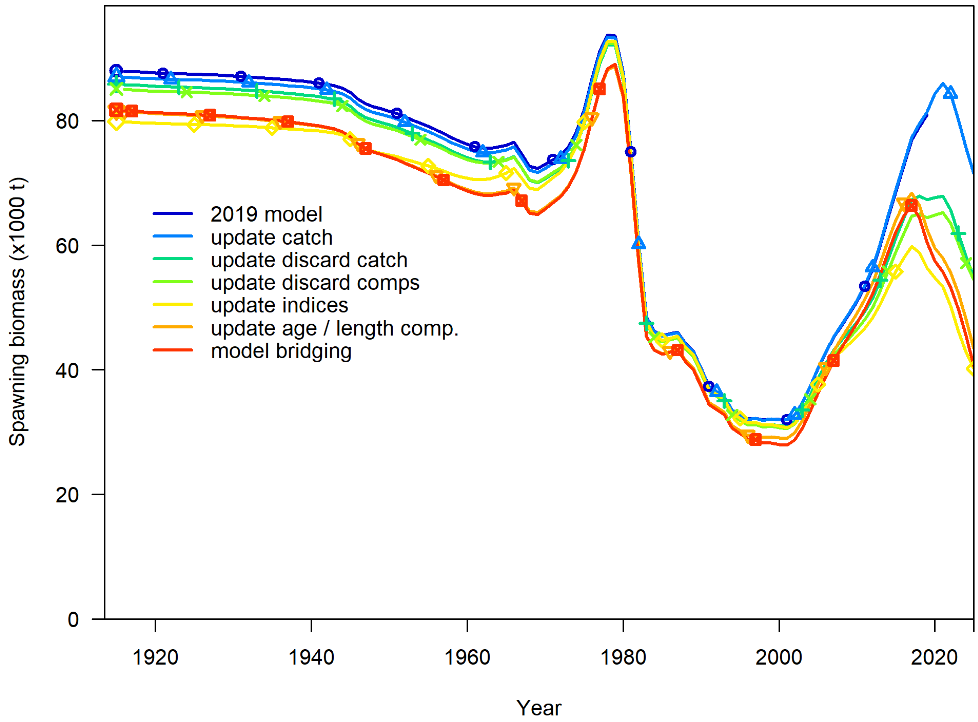


Figure 31: Bridging from the 2019 assessment model with updated data and bridging steps.

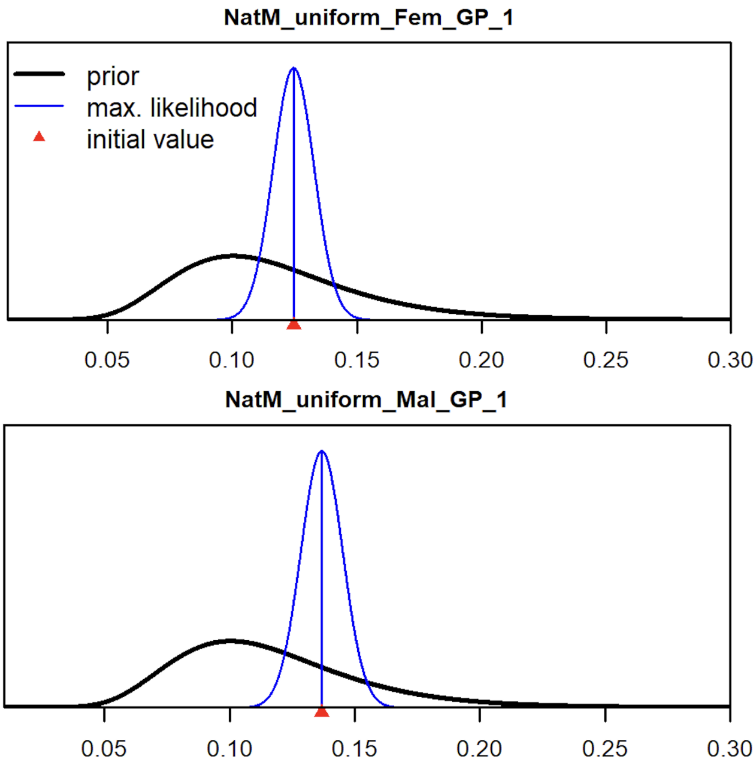


Figure 32: The prior for natural mortality (M, yr-1) and the estimated M for females (top) and males (bottom) with asymptotic uncertainty based on maximum likelihood theory. The median of the prior is shown by the red triangle and the maximum likelihood estimate is shown by the vertical blue line.

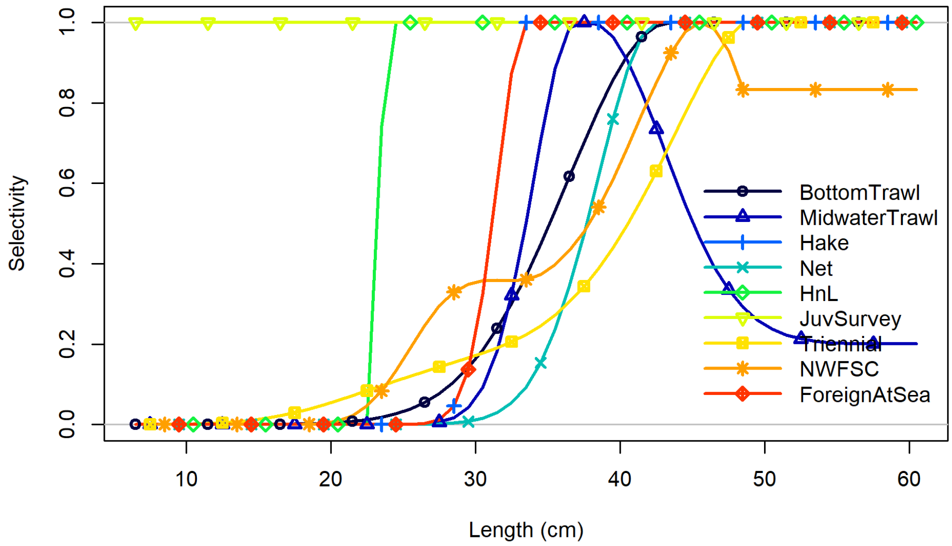


Figure 33: Estimated selectivity for different fleets and surveys.

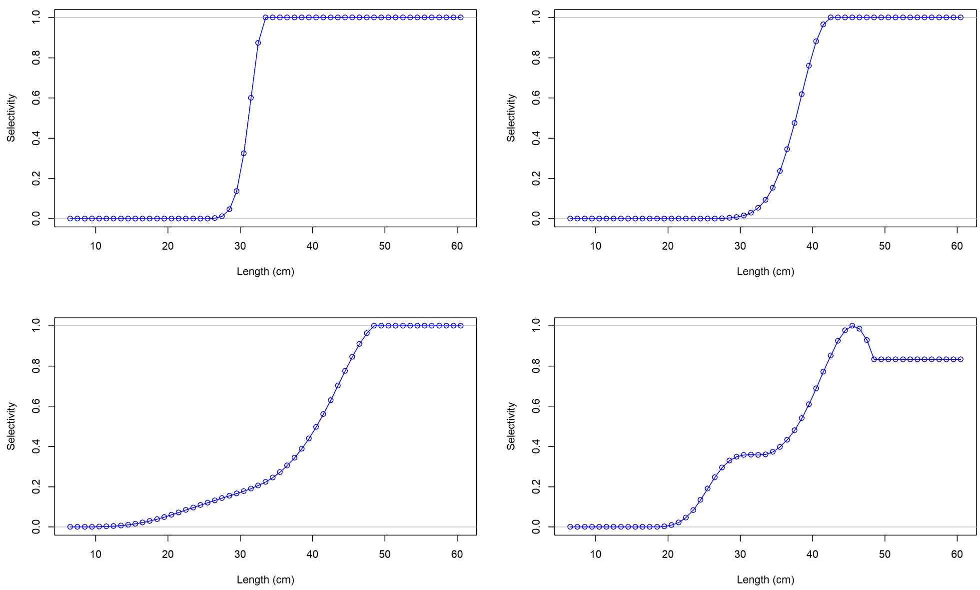


Figure 34: Estimated selectivity curves for 2018 of the hake fleet (topleft), net fishing fleets (topright), the triennial survey (bottomleft), and the NWFSC survey (bottomright).

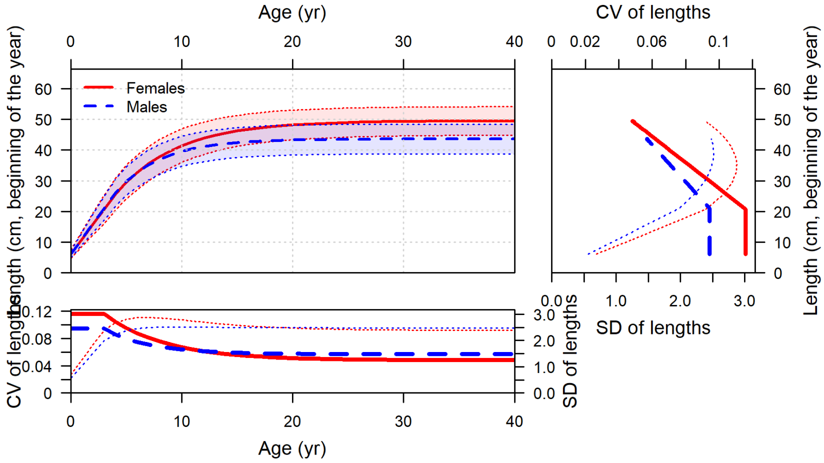
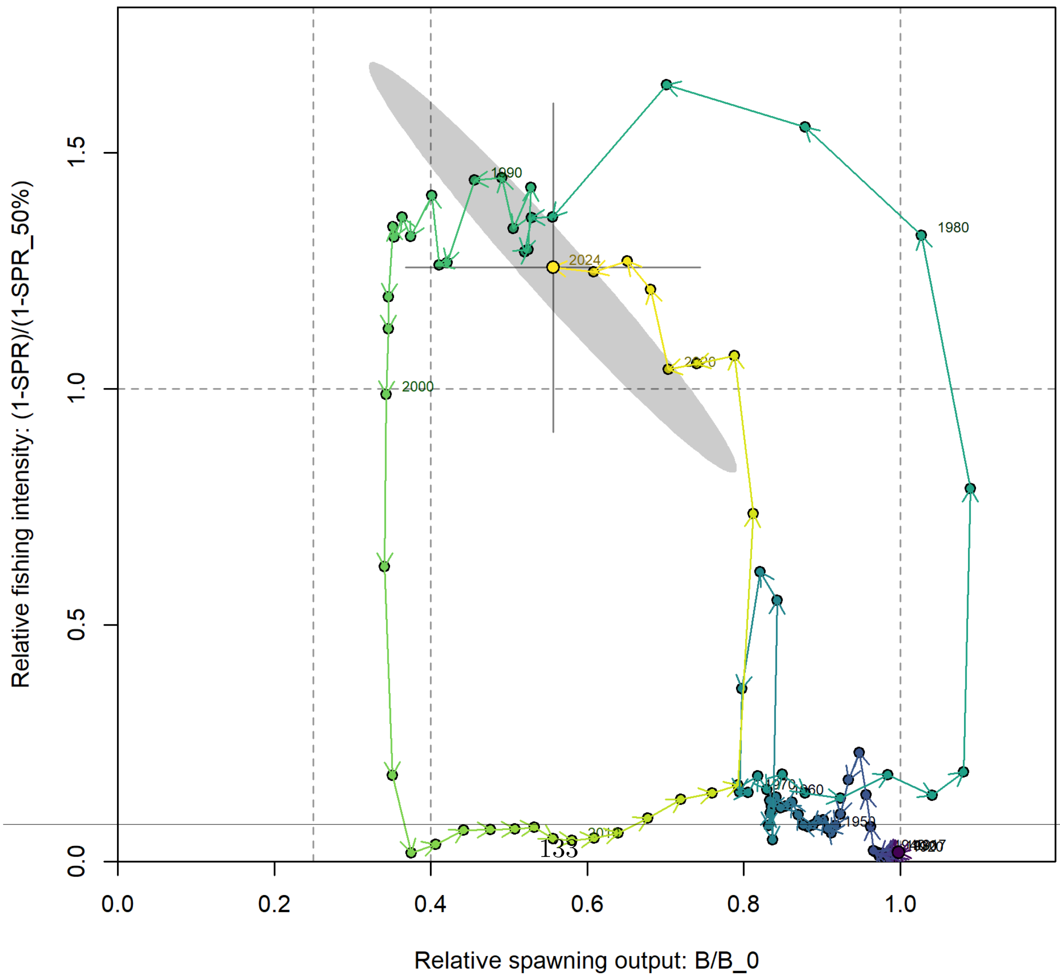


Figure 35: Length at age (top-left panel) with estimated coefficient of variation (CV, thick line) and calculated standard deviation (SD, thin line) versus length at age in the top-right panel and versus age in the lower-left panel.



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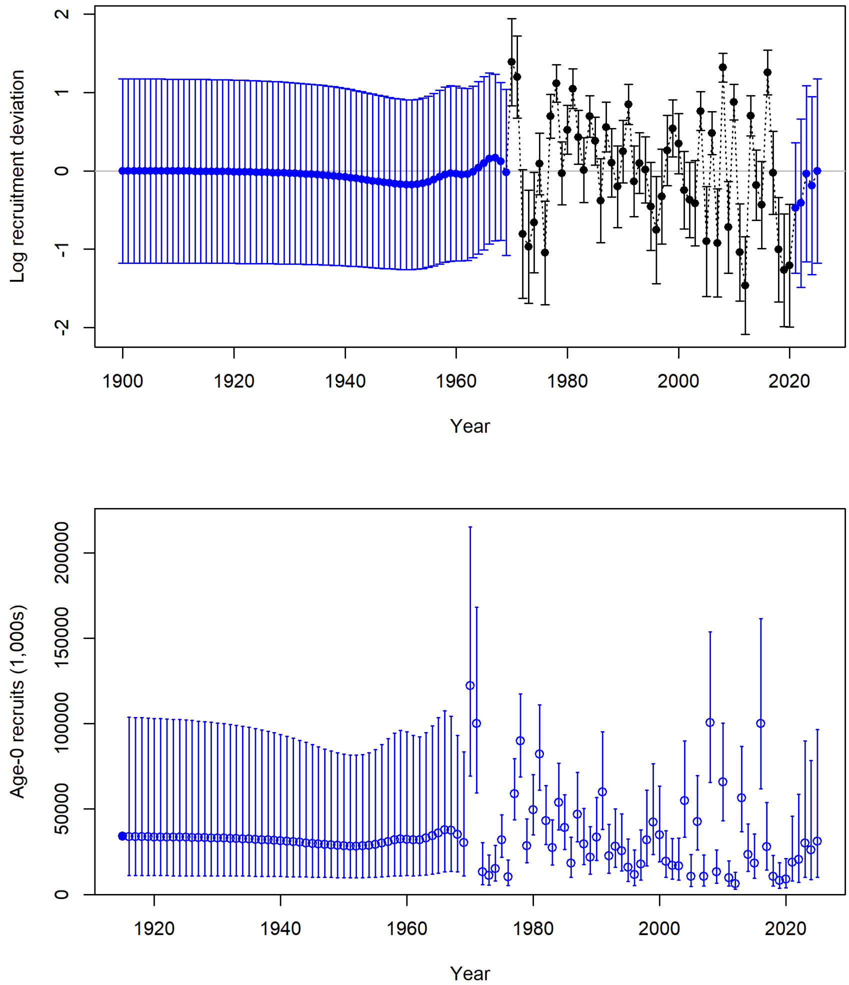


Figure 36: Estimates of recruitment (upper) and recruitment deviates (lower) with approximate asymptotic 95% confidence intervals (vertical lines) from the MLE estimates.

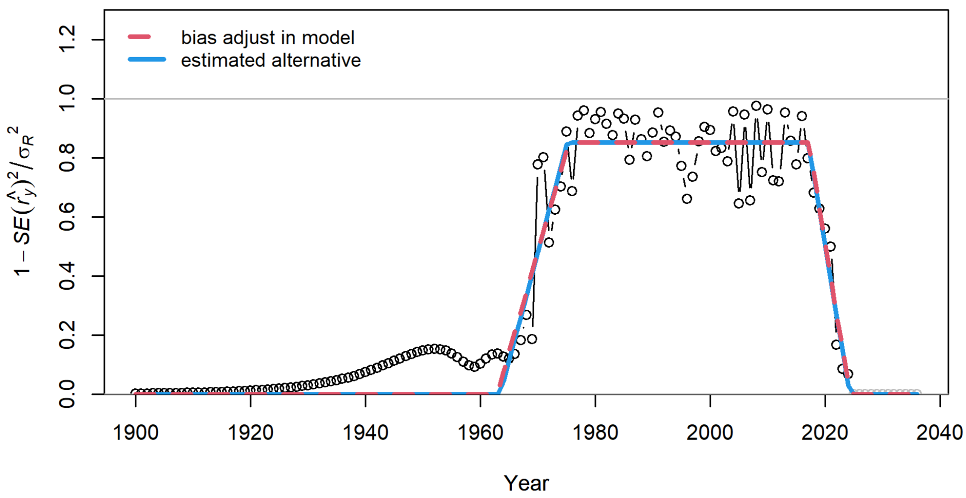


Figure 37: Estimated and input recruitment bias adjustment ramp. Red line shows current settings for bias adjustment ramp. Red line shows current settings for bias adjustment specified in the model. Blue line shows least squares estimate of alternative bias adjustment relationship for recruitment deviations.

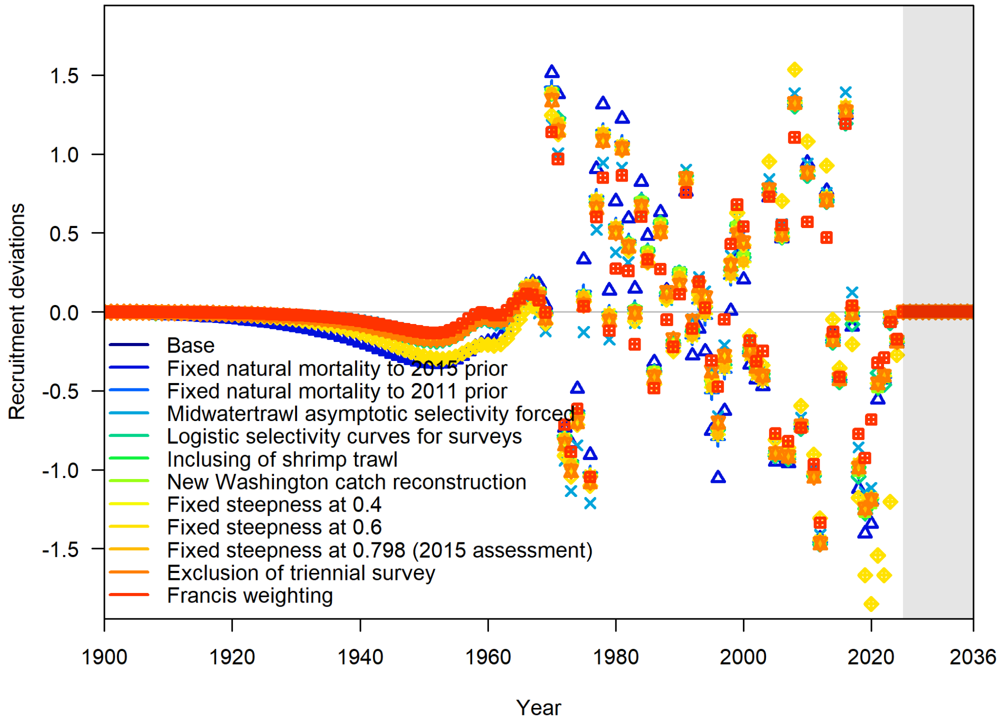


Figure 38: Estimates of recruitment deviations for sensitivity models.

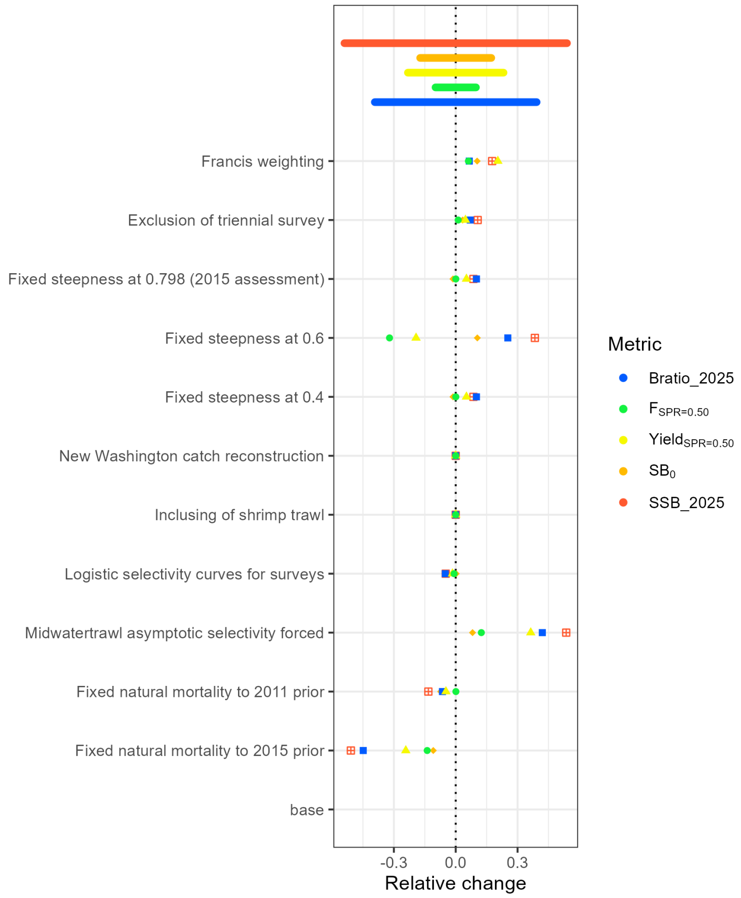


Figure 39: Comparision of model estimated values by sensitivity run

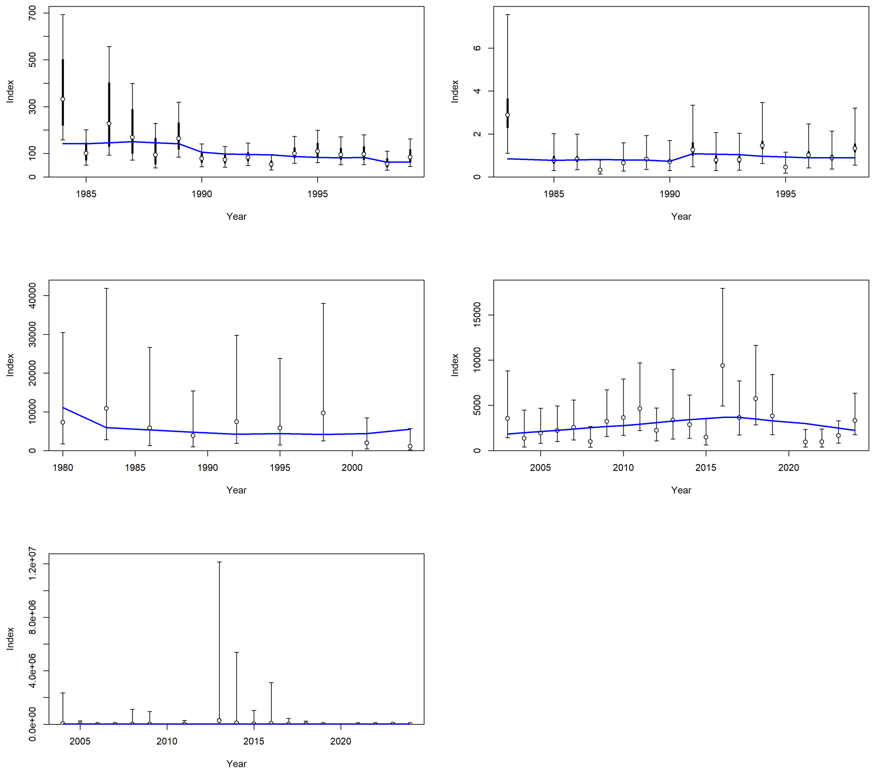


Figure 40: Fits (lines) to the abundance estimates (points) for the base model. Bottom trawl is in the top left, hake indices are in the top right (a separate q is estimated for the Hake series starting in 1991), the triennial trawl survey index is on the middle left, the NWFSC survey index is on the middle right, and the juvenile survey index (in numbers) is on the bottom. 95% confidence intervals are shown in the input standard errors. Thicker lines (if present) indicate input uncertainty before addition of the estimated additional uncertainty parameter.

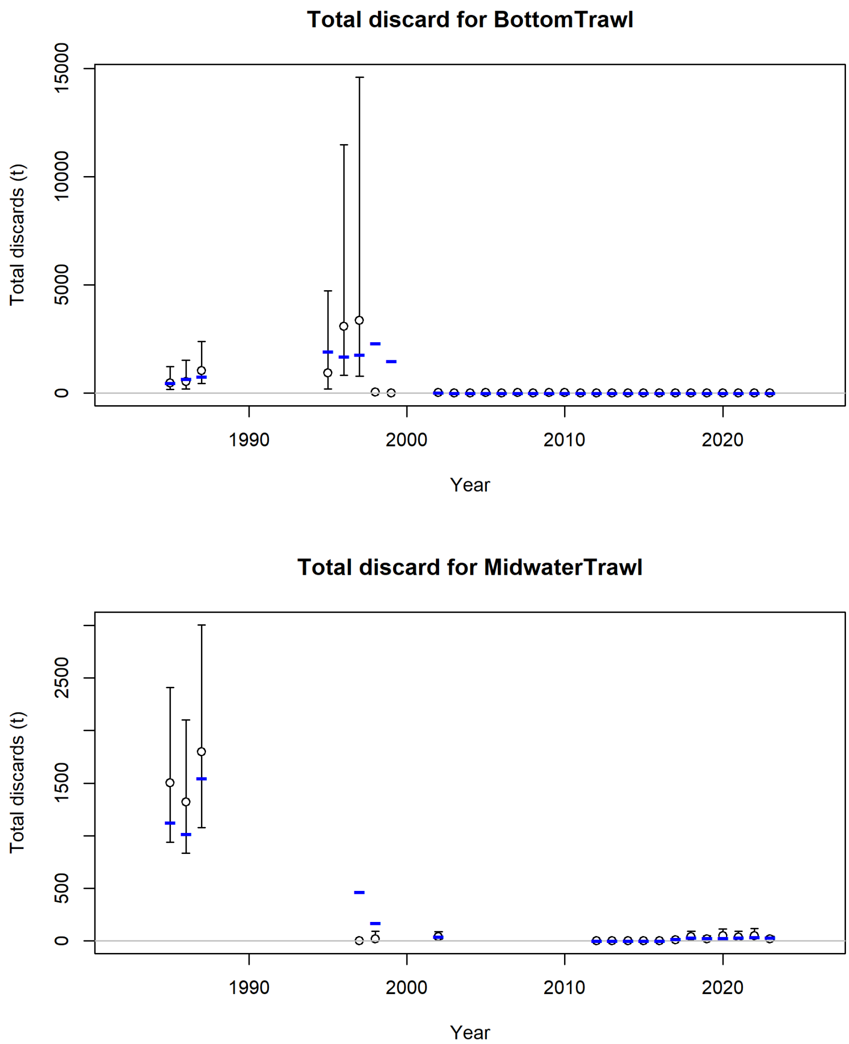


Figure 41: Predicted (blue line) and observed (open circles) discards for the bottom trawl (top) and midwater trawl (bottom) fleets from the base model. 95% confidence intervals are shown for the observations.

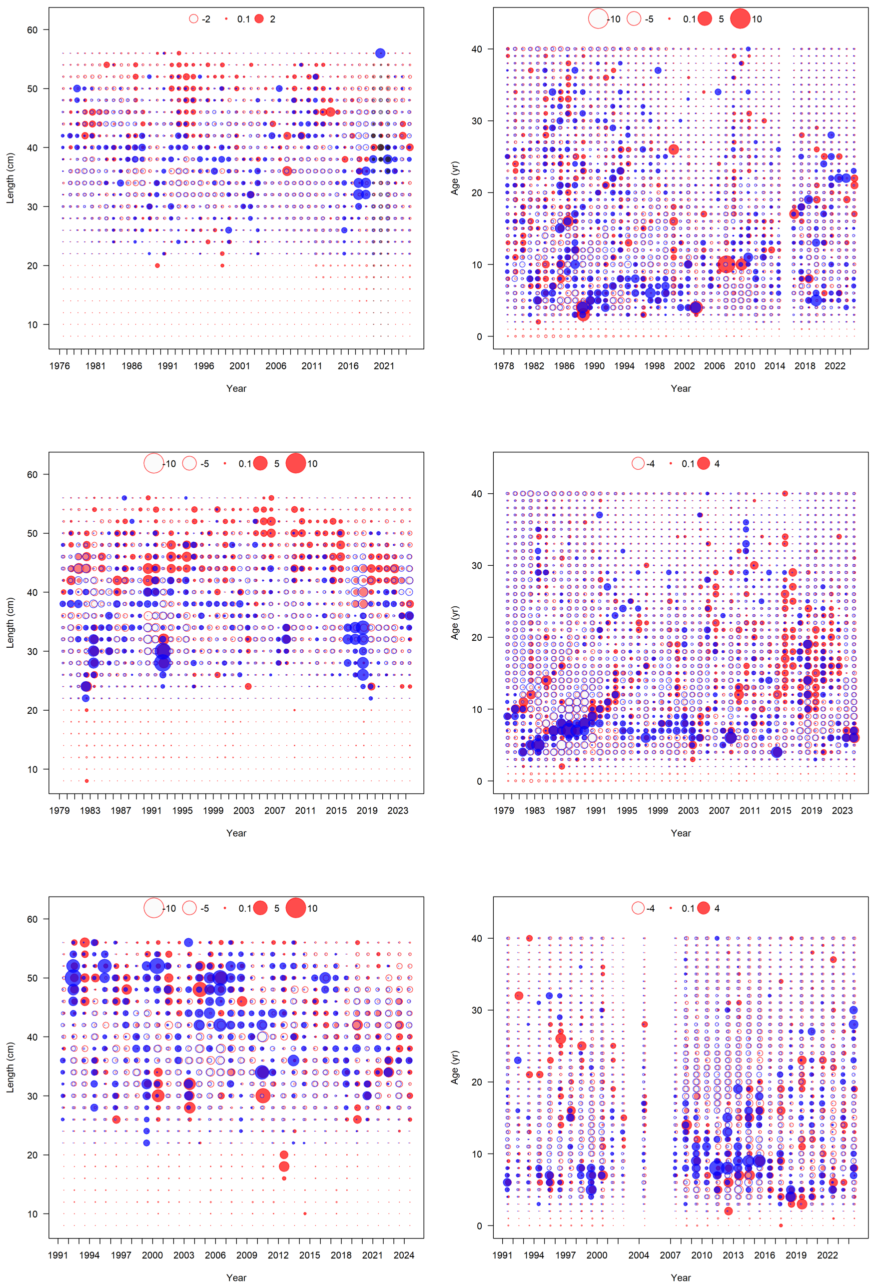


Figure 42: Pearson residuals for fits to length frequency data (left) and age frequency data (right) for landings from the trawl commercial fleets (rows). Filled circles indicate that the fitted proportion was less than the observed proportion. Red indicates females, blue males, and gray unsexed.

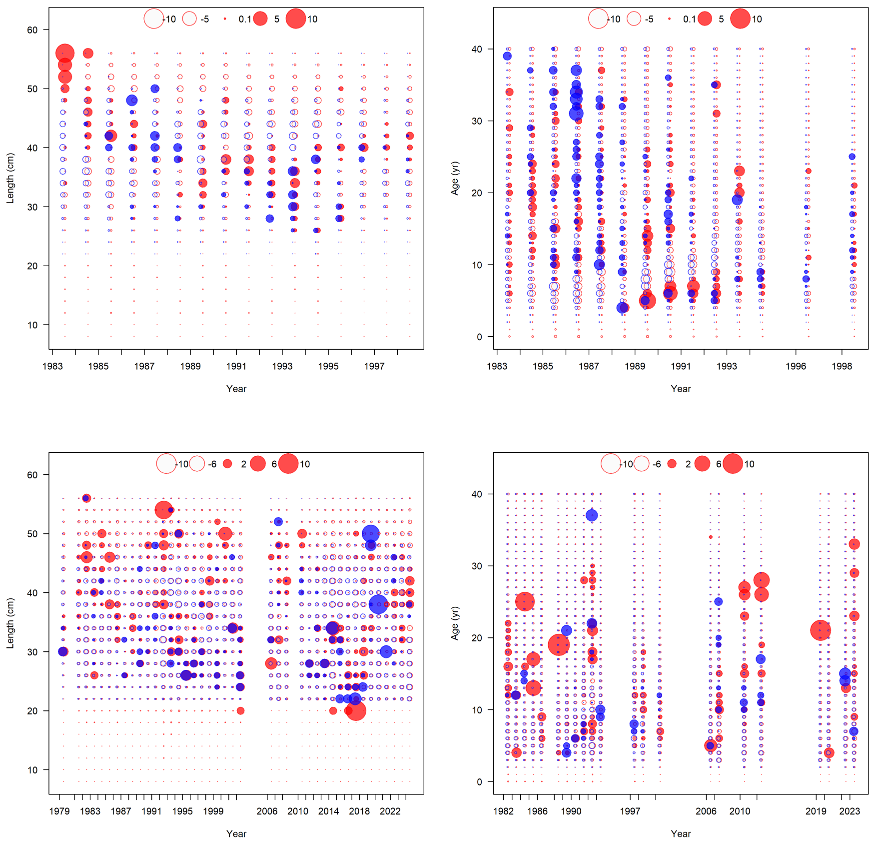


Figure 43: Pearson residuals for fits to length frequency data (left) and age frequency data (right) for landings from the net and hook-and-line commercial fleets (rows). Filled circles indicate that the fitted proportion was less than the observed proportion. Red indicates females, blue males, and gray unsexed.

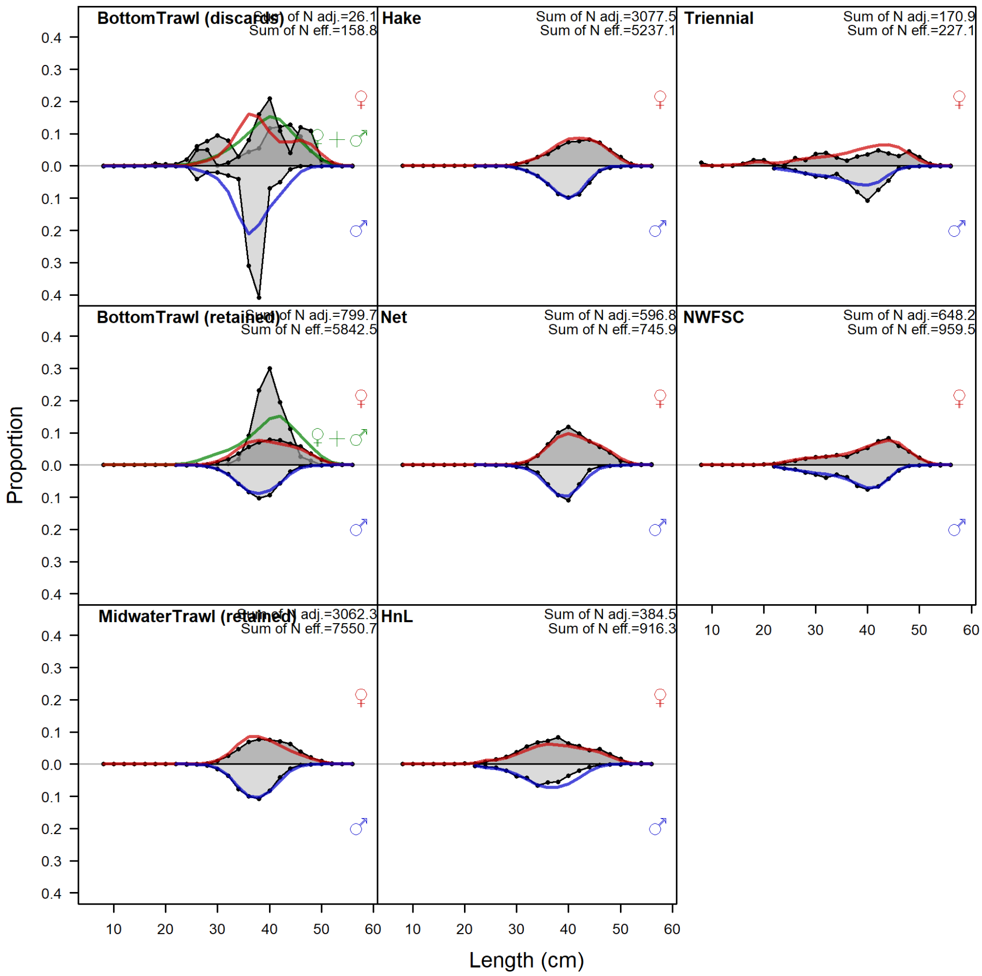


Figure 44: Combined length frequencies for all years from fishery (retained catch) and survey length frequency data (points). Fits are shown by the red line (females) and blue line (males).

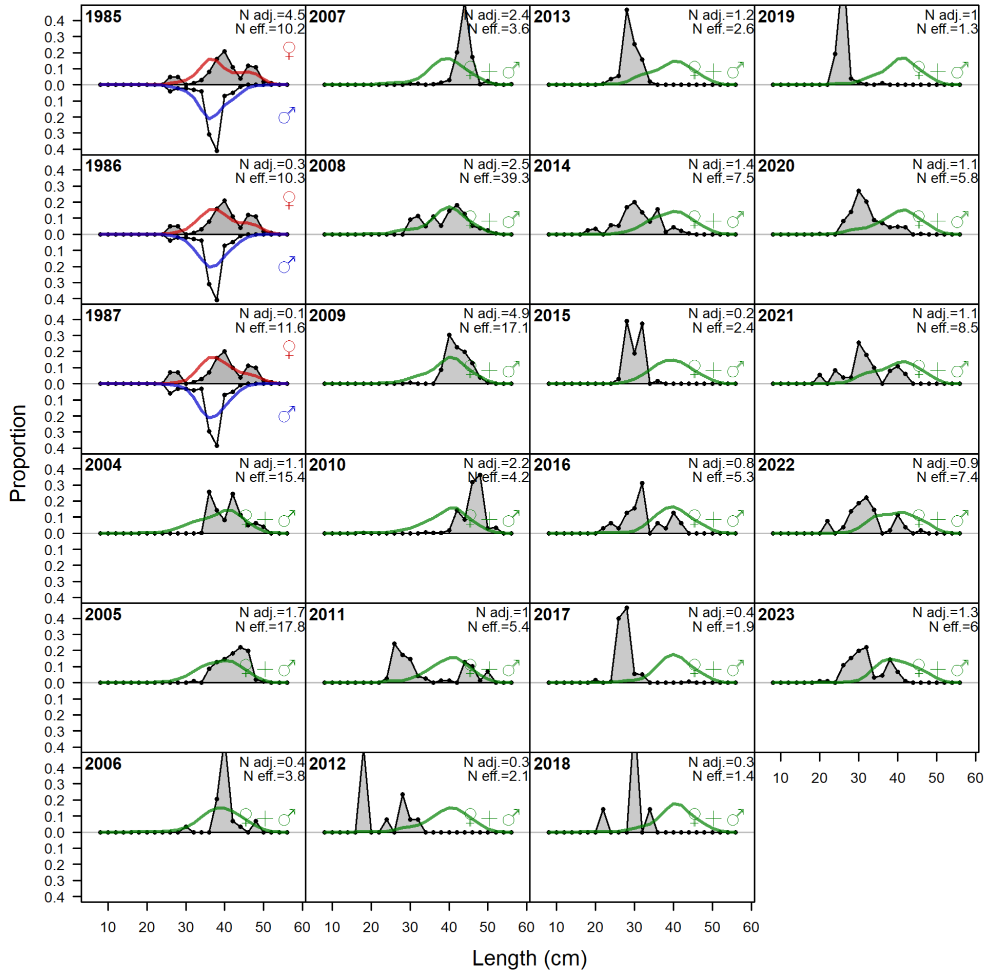


Figure 45: Pearson residuals for fits to the discard length frequencies from the bottom trawl (left) and hook-and-line (right) fleets. Filled circles indicate that the fitted proportion was less than the observed proportion. Red indicates females, blue males, and gray unsexed.

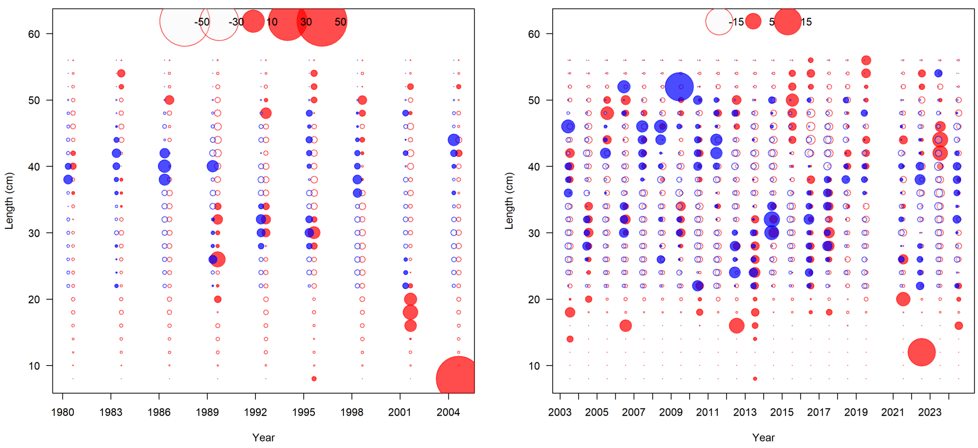


Figure 46: Pearson residuals for fits to the triennial survey length frequency data (left) and NWFSC WCGBT (shelf/slope) survey length frequency data (right). Filled circles indicate that the fitted proportion was less than the observed proportion. Red indicates females, blue males, and gray unsexed.

relative-(1-SPR) fig-align='center' width=90%}

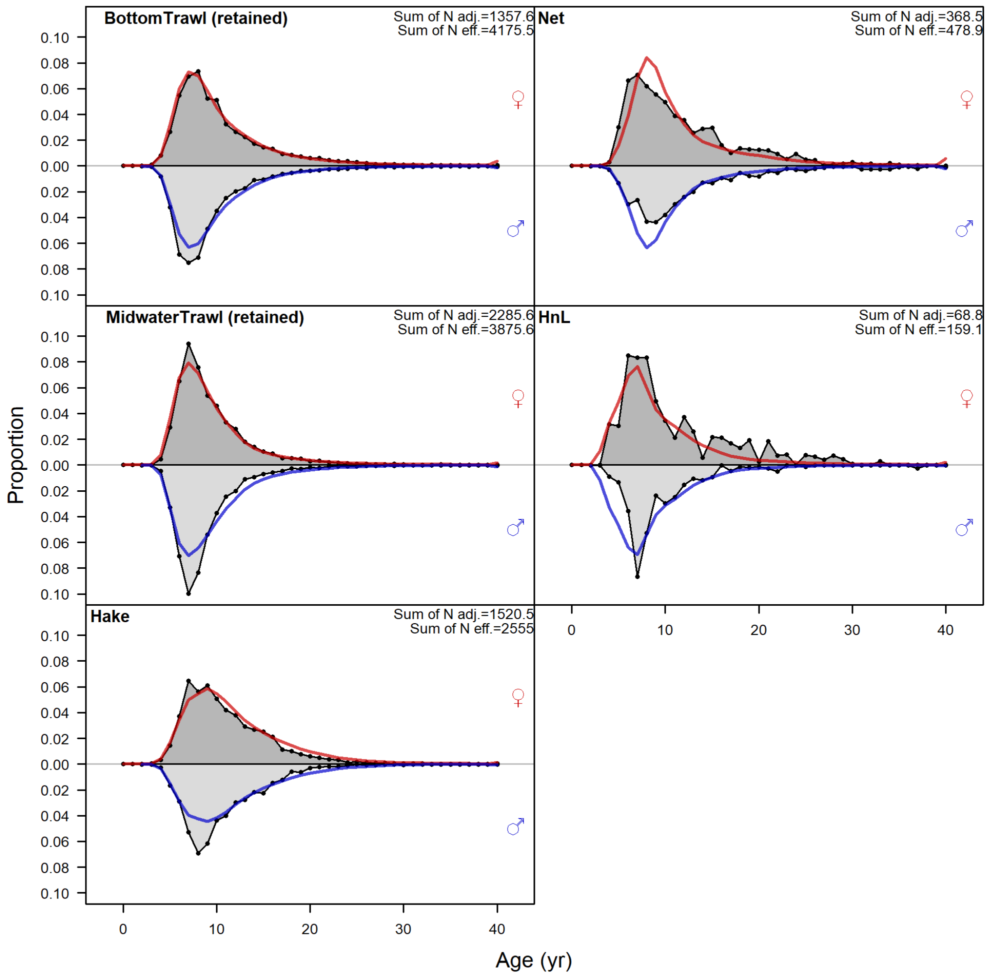


Figure 47: Combined age frequencies for all years from fishery (retained catch) and survey length frequency data (points). Fits are shown by the red line (females) and blue line (males).

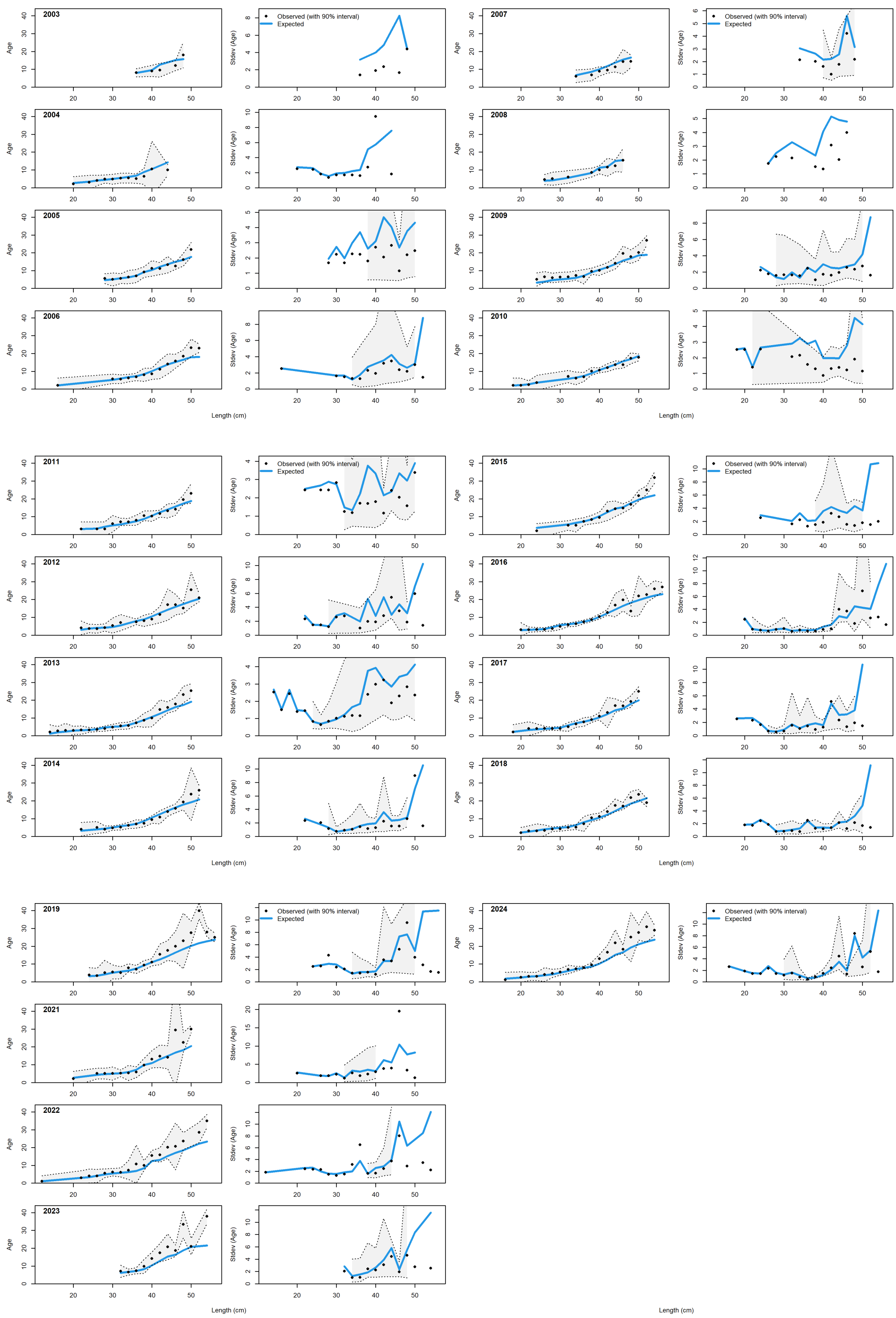


Figure 48: Observed and expected age-at-length with 95% confidence intervals (left) and observed and expected standard deviation of age-at-length with 95% confidence intervals (right) for the NWFSC WCGBT survey data.

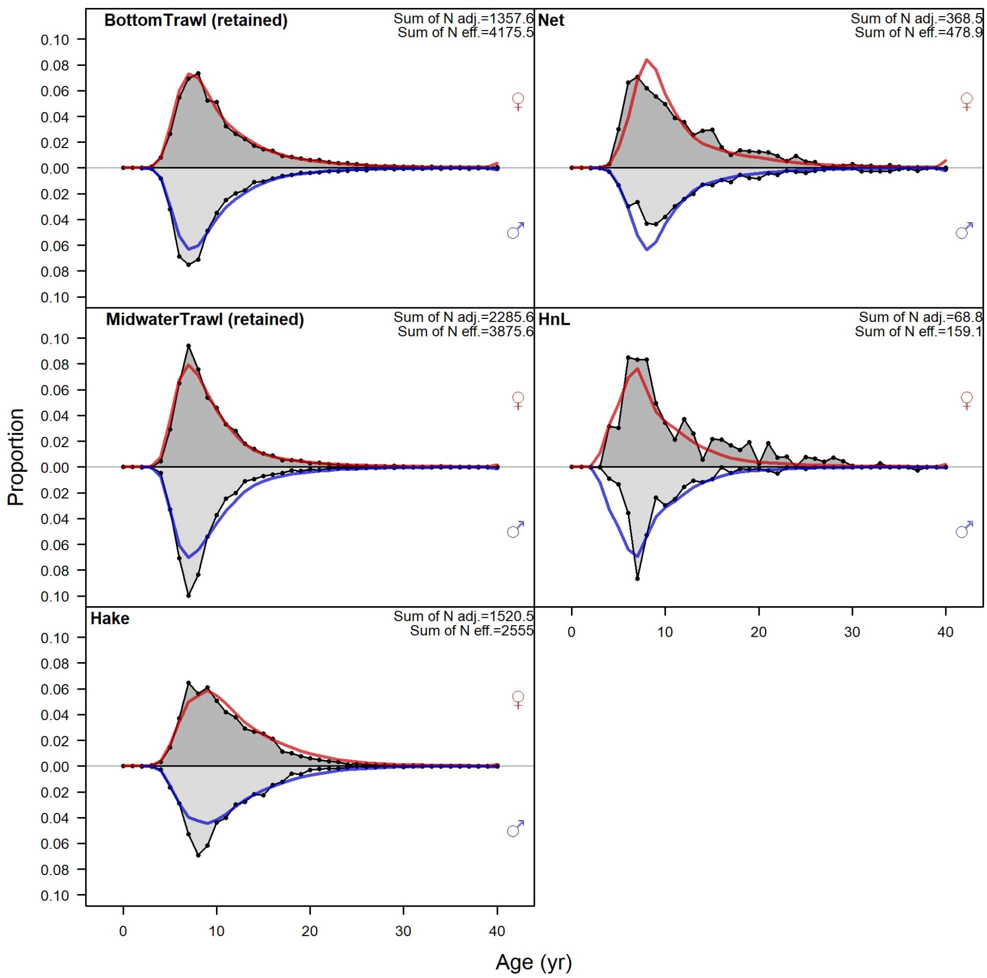


Figure 49: Combined age frequencies for all years from fishery (retained catch) and survey length frequency data (points). Fits are shown by the red line (females) and blue line (males).

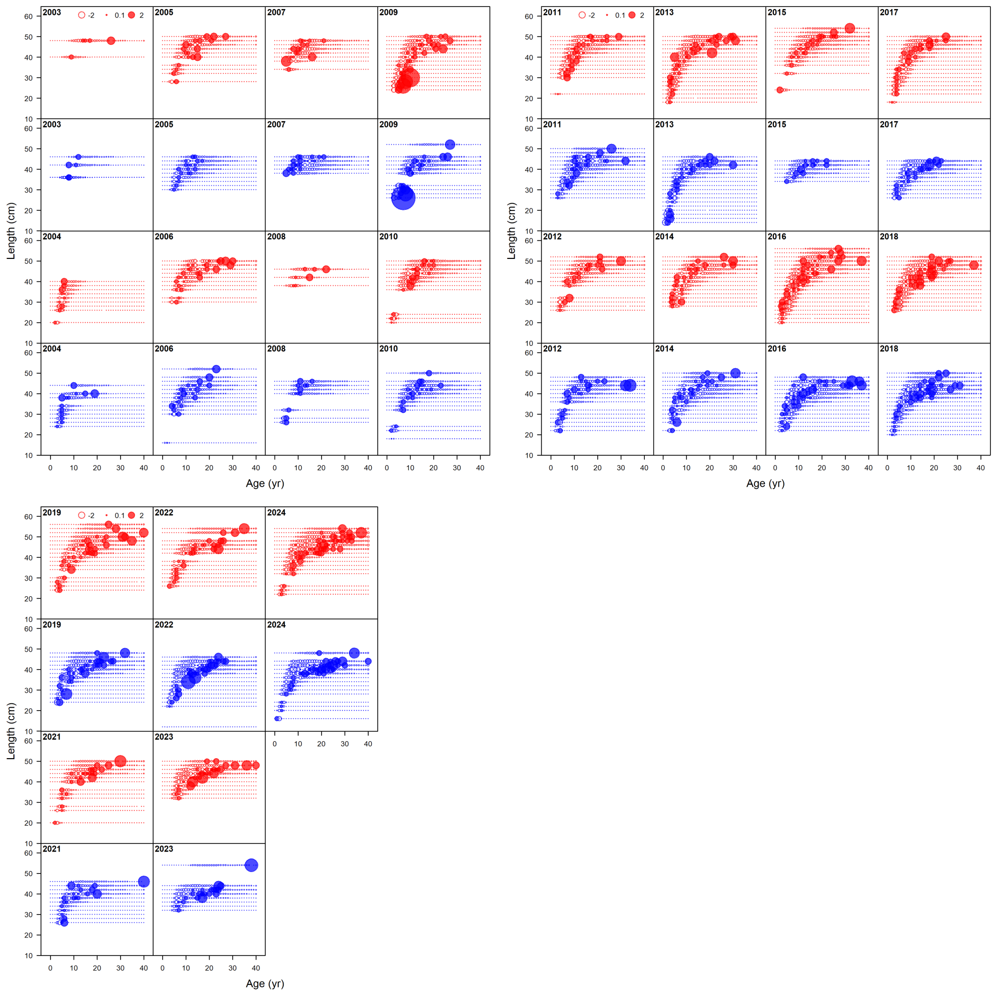


Figure 50: Combined age frequencies for all years from fishery (retained catch) and survey length frequency data (points). Fits are shown by the red line (females) and blue line (males).

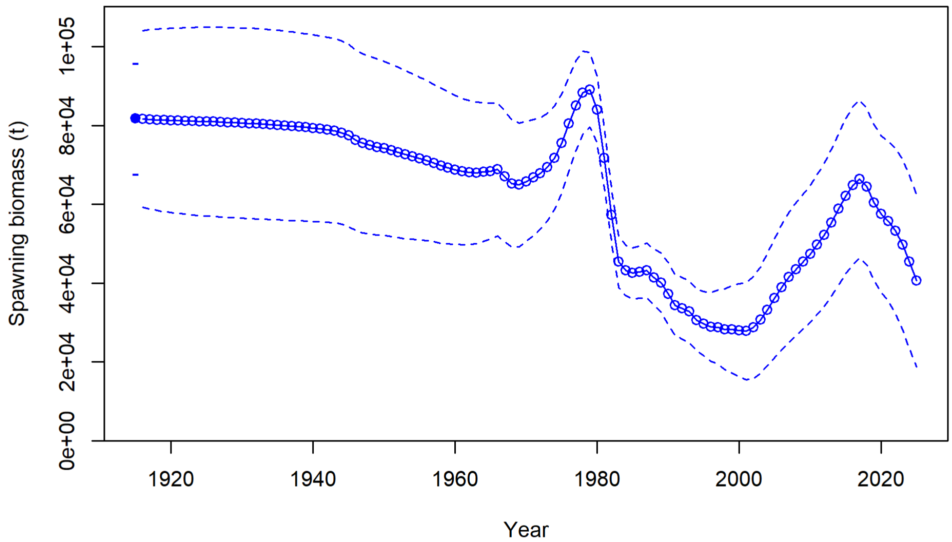


Figure 51: Predicted spawning biomass (thousand mt) for Widow Rockfish using the base assessment. The solid line is the MLE estimate, and the dashed lines depict the approximate asymptotic 95% confidence intervals.

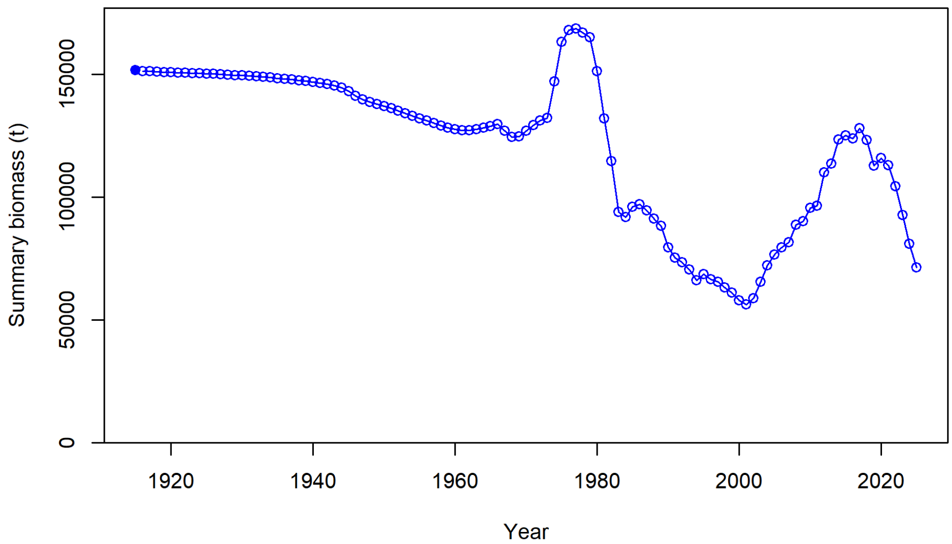


Figure 52: Predicted summary biomass (age 4+) from the base model.

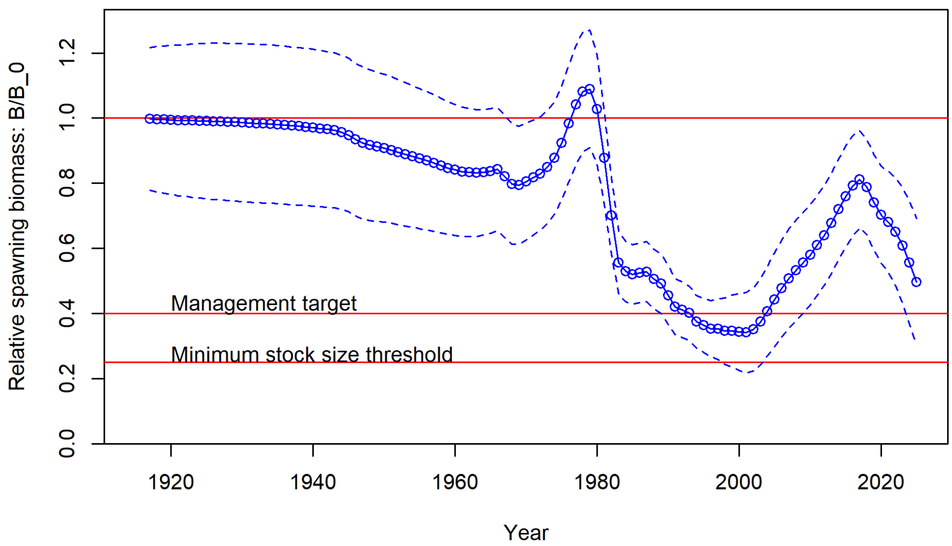


Figure 53: Predicted relative spawning biomass from the Widow Rockfish base case assessment. The solid blue line is the MLE estimate, and the dashed lines depict the approximate asymptotic 95% confidence intervals. The red lines show the equilibrium level (100%), the management target of 40% of unfished biomass, and the minimum stock size threshold of 25% of unfished biomass.

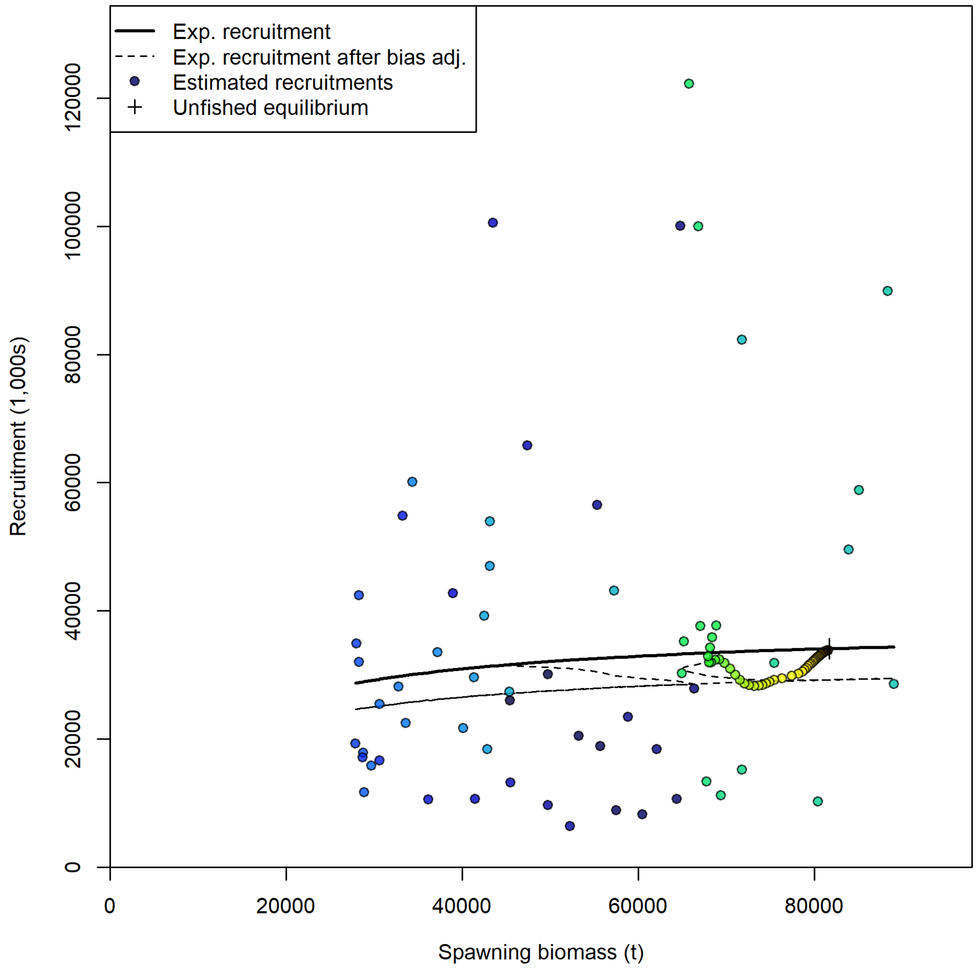


Figure 54: Estimated recruitment and the assumed stock-recruit relationship (black line). The dashed line shows the effect of the bias correction for the lognormal distribution.

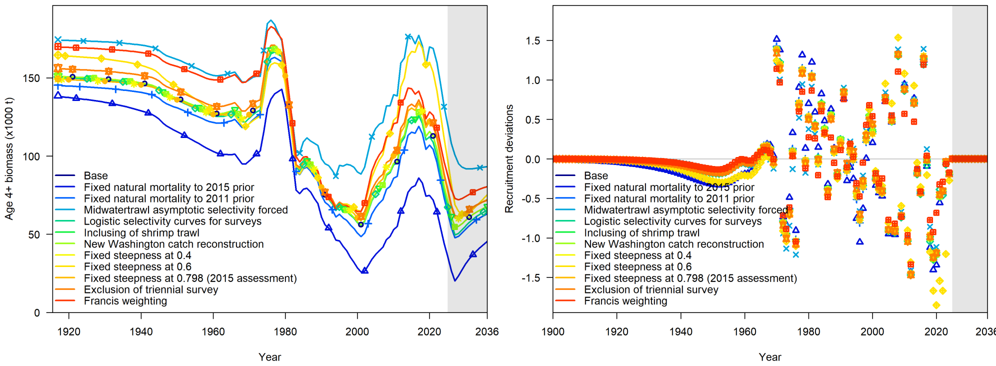
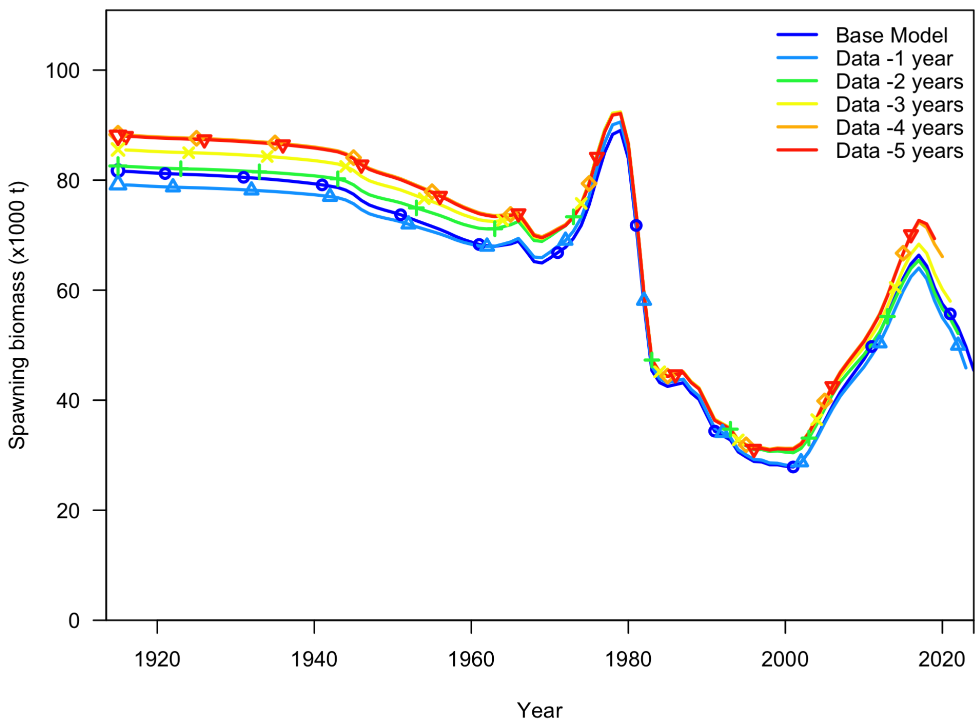


Figure 55: Spawning biomass (with 95% confidence interval around the base model) for the base model and sensitivity runs. (no rec dev)

6.2 References



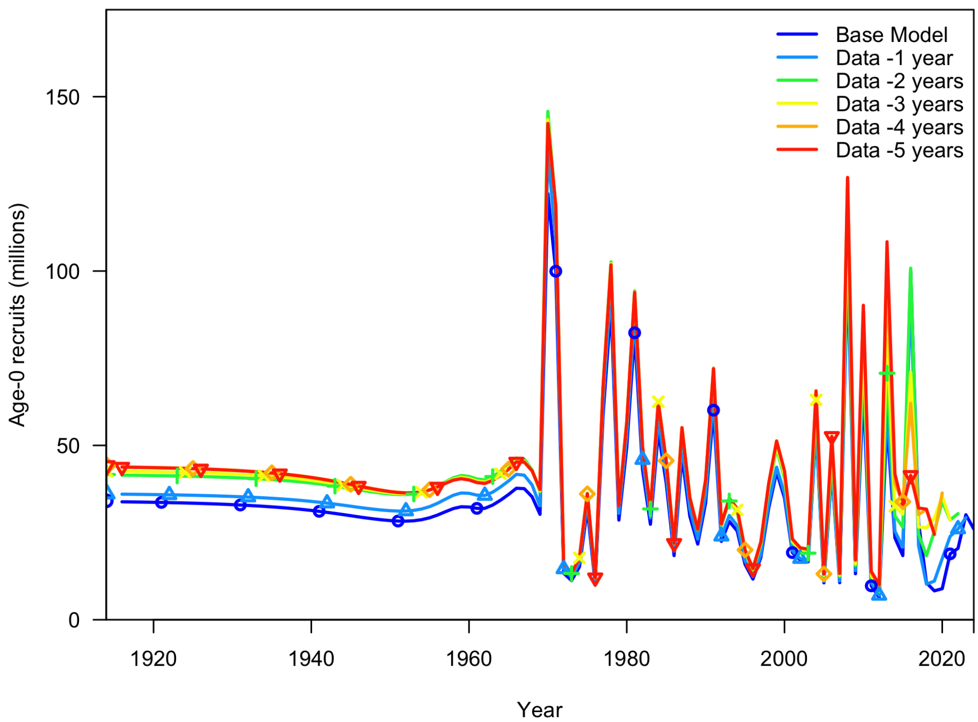


Figure 56: Five-year retrospective estimates of spawning biomass (top) and recruitment deviations (bottom).

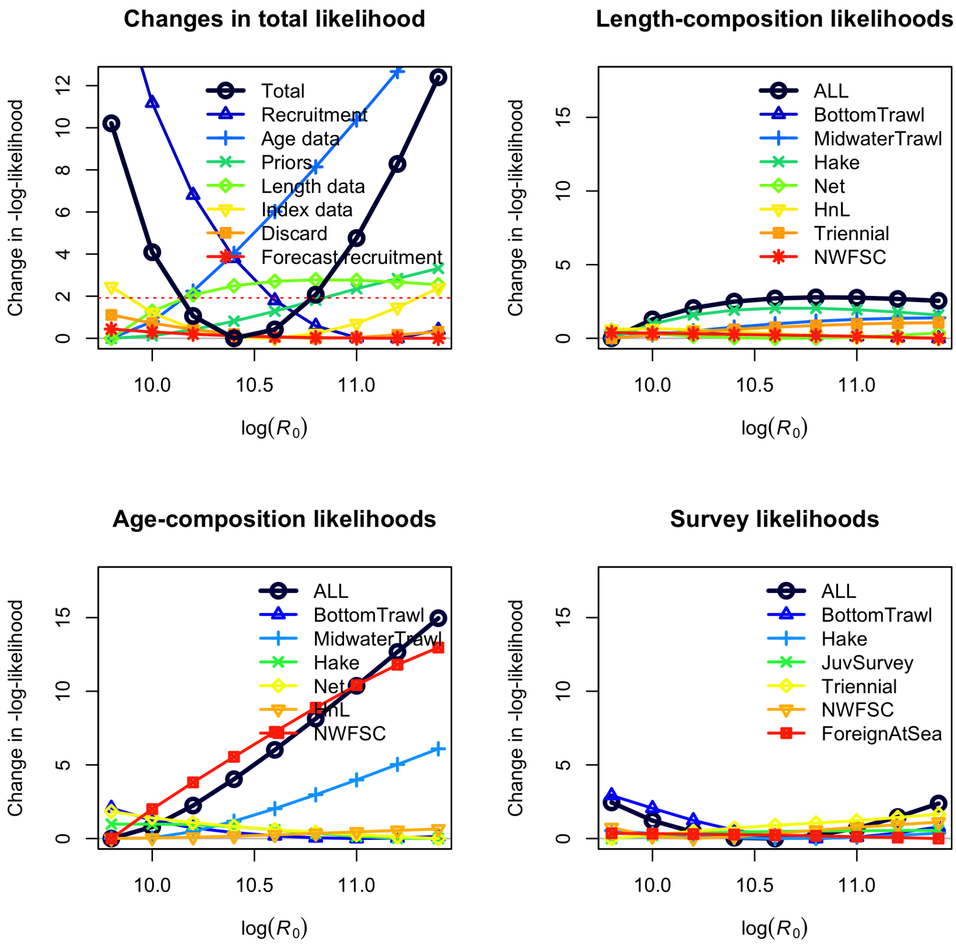


Figure 57: Likelihood components in the likelihood profile for unfished equilibrium recruitment (R0)

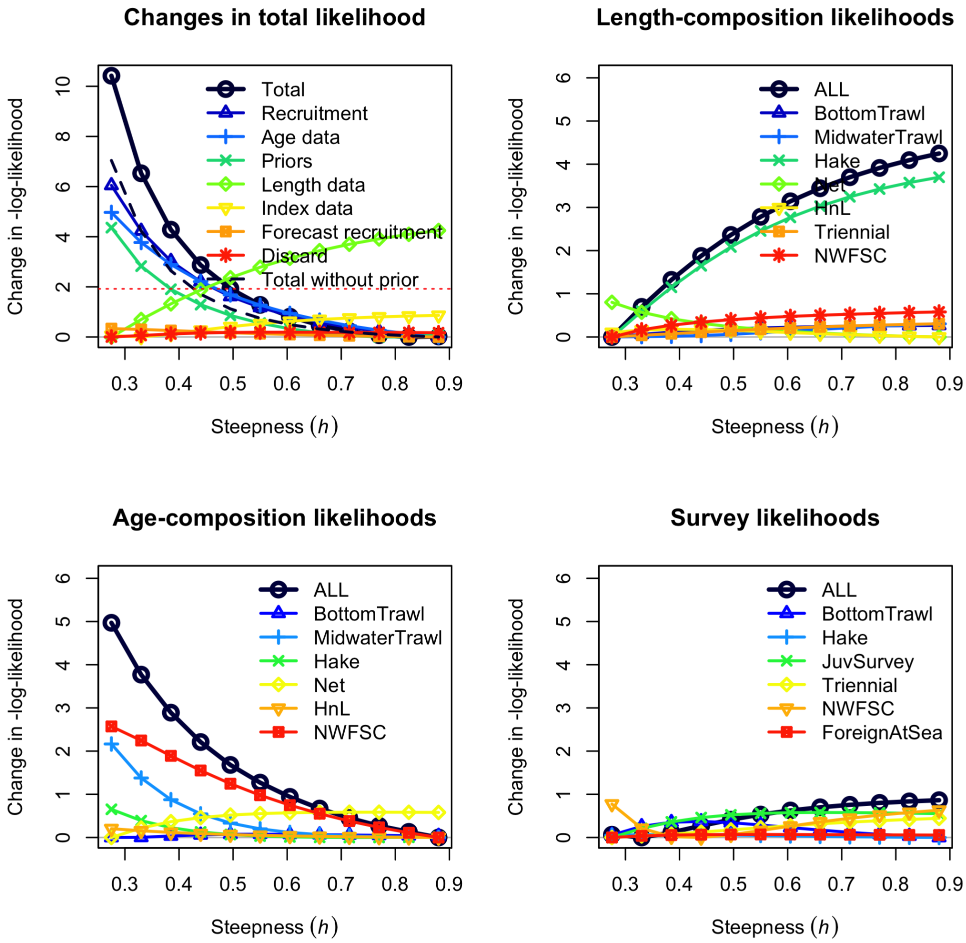


Figure 58: Likelihood components in the likelihood profile for steepness (h).

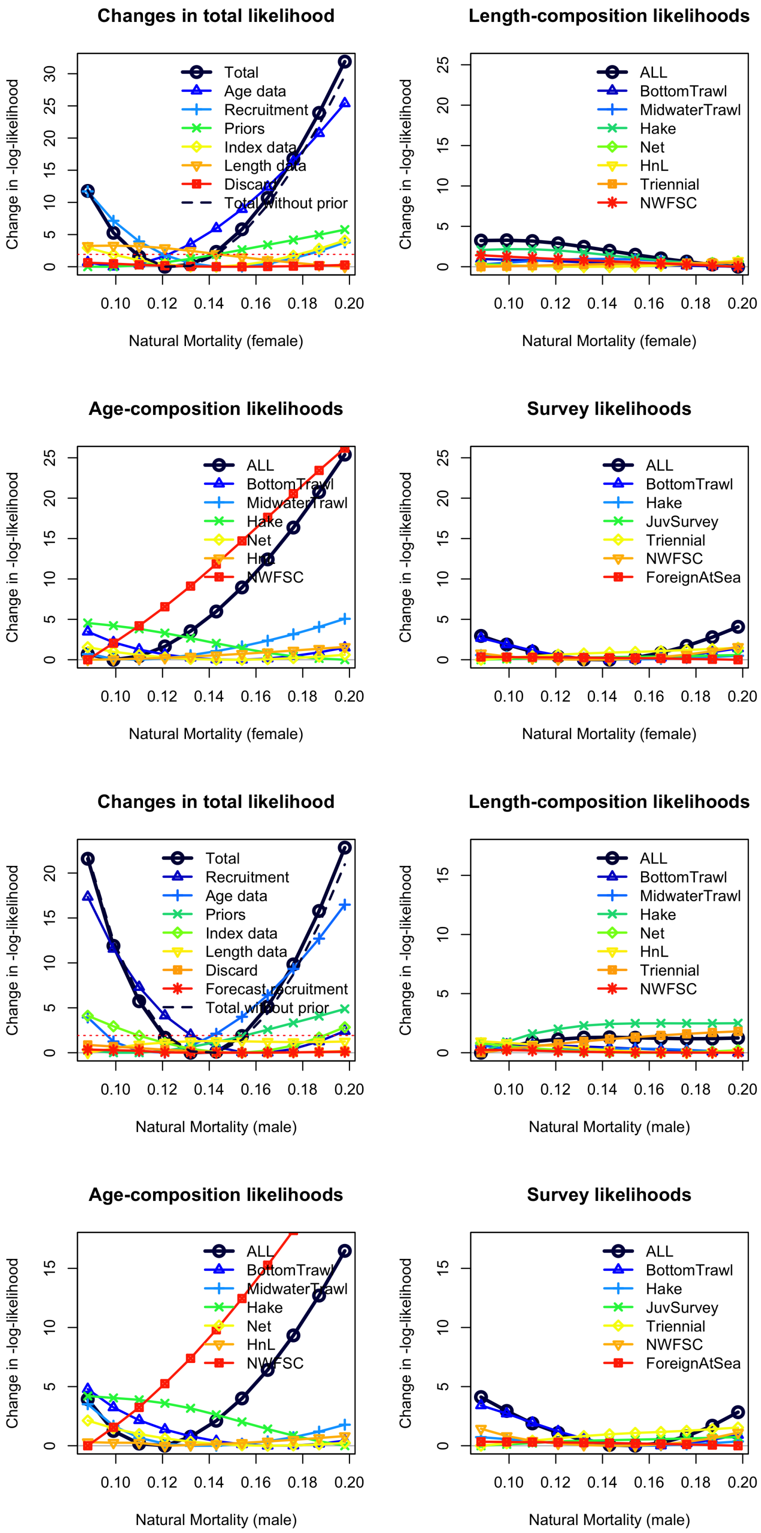


Figure 59: Likelihood components in the likelihood profile for natural mortality (M). Note: male and female natural mortality are set to the same value.

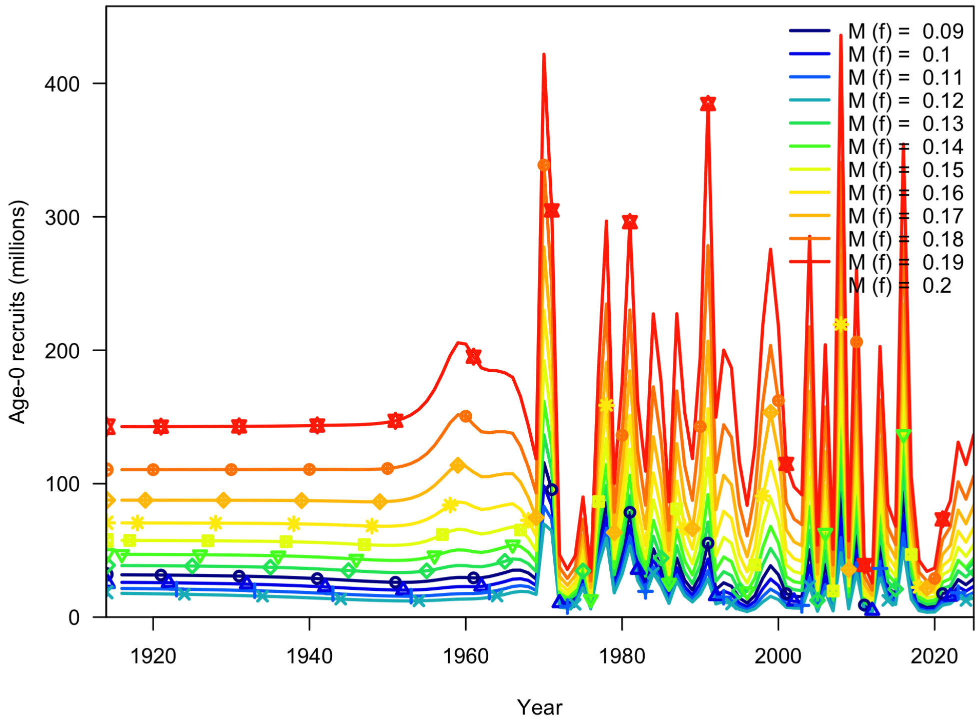


Figure 60: Time series of recruitment estimates for models with different fixed values of natural mortality (M)

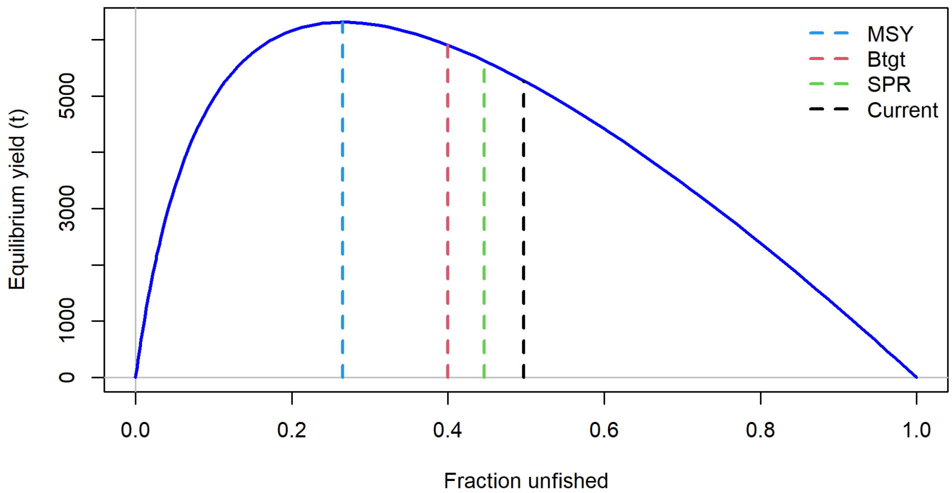


Figure 61: Estimated plot of equilibrium yield vs the fraction of unfished biomass.

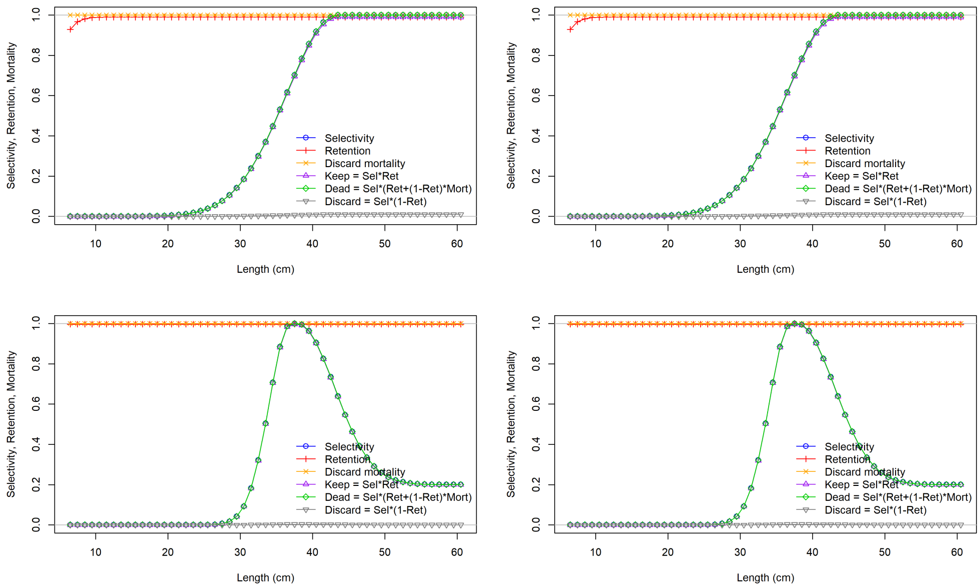


Figure 62: Estimated selectivity for Bottom Trawl (top row) and Midwater Trawl (bottom row) for males (left column) and females (right column)

7 Appendix A: Year-specific fits to the length and age compositions

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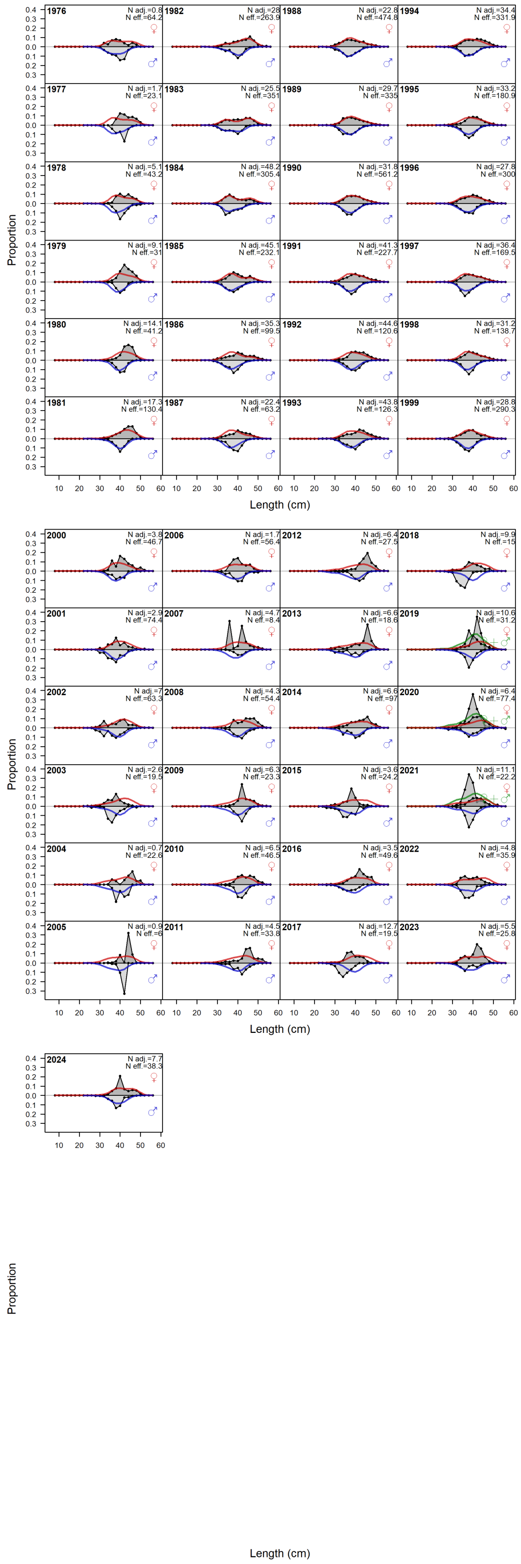

Figure A1: Fits to the retained length compositions for the bottom trawl fleet.

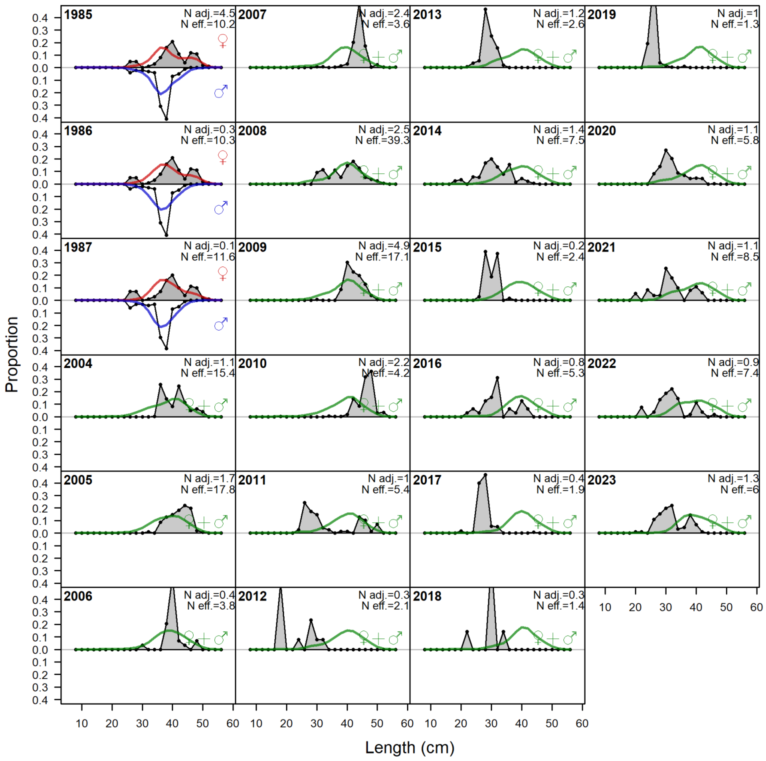

Figure A2: Fits to the discarded length compositions for the bottom trawl fleet.

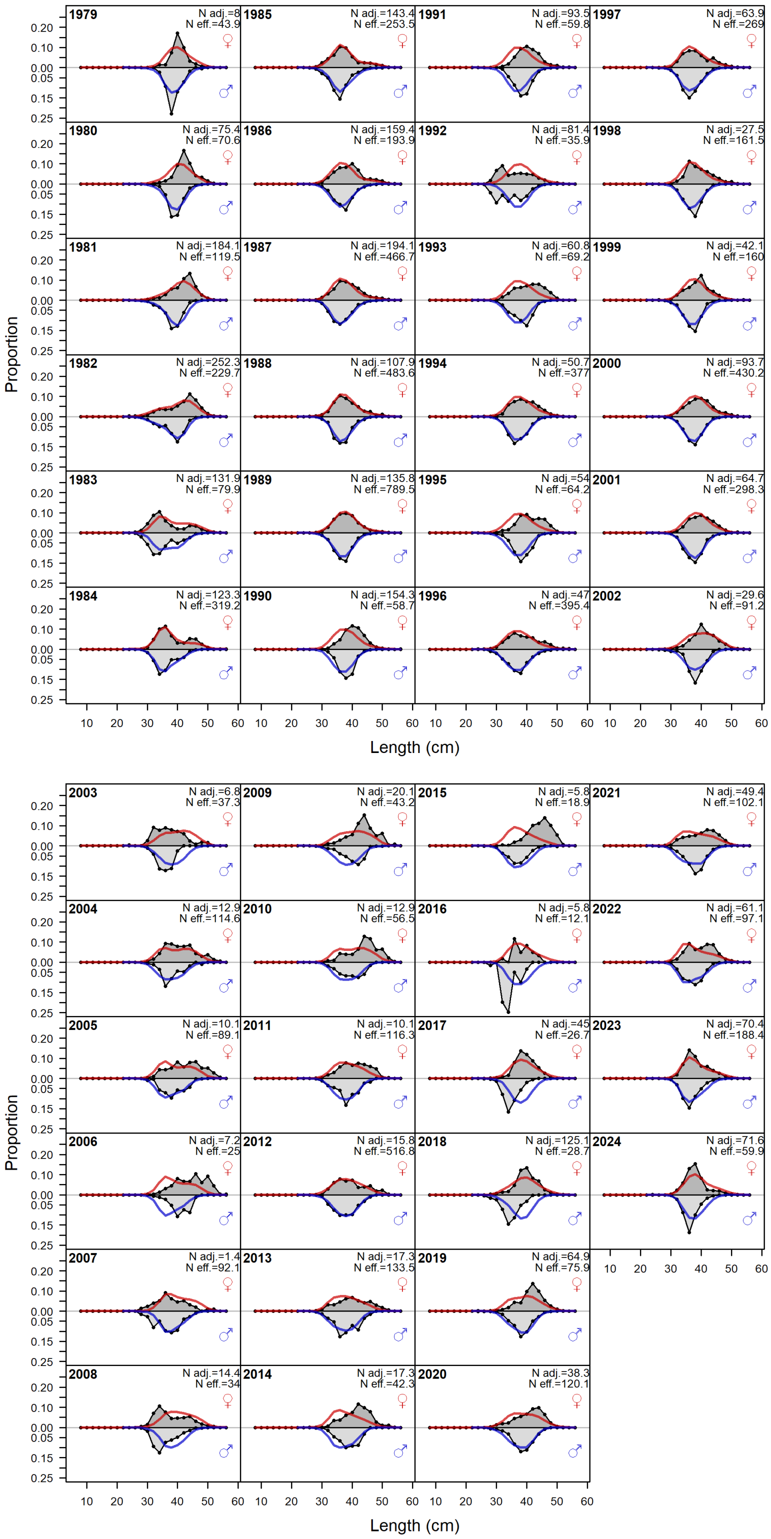

Figure A3: Fits to the retained length compositions for the midwater trawl fleet.

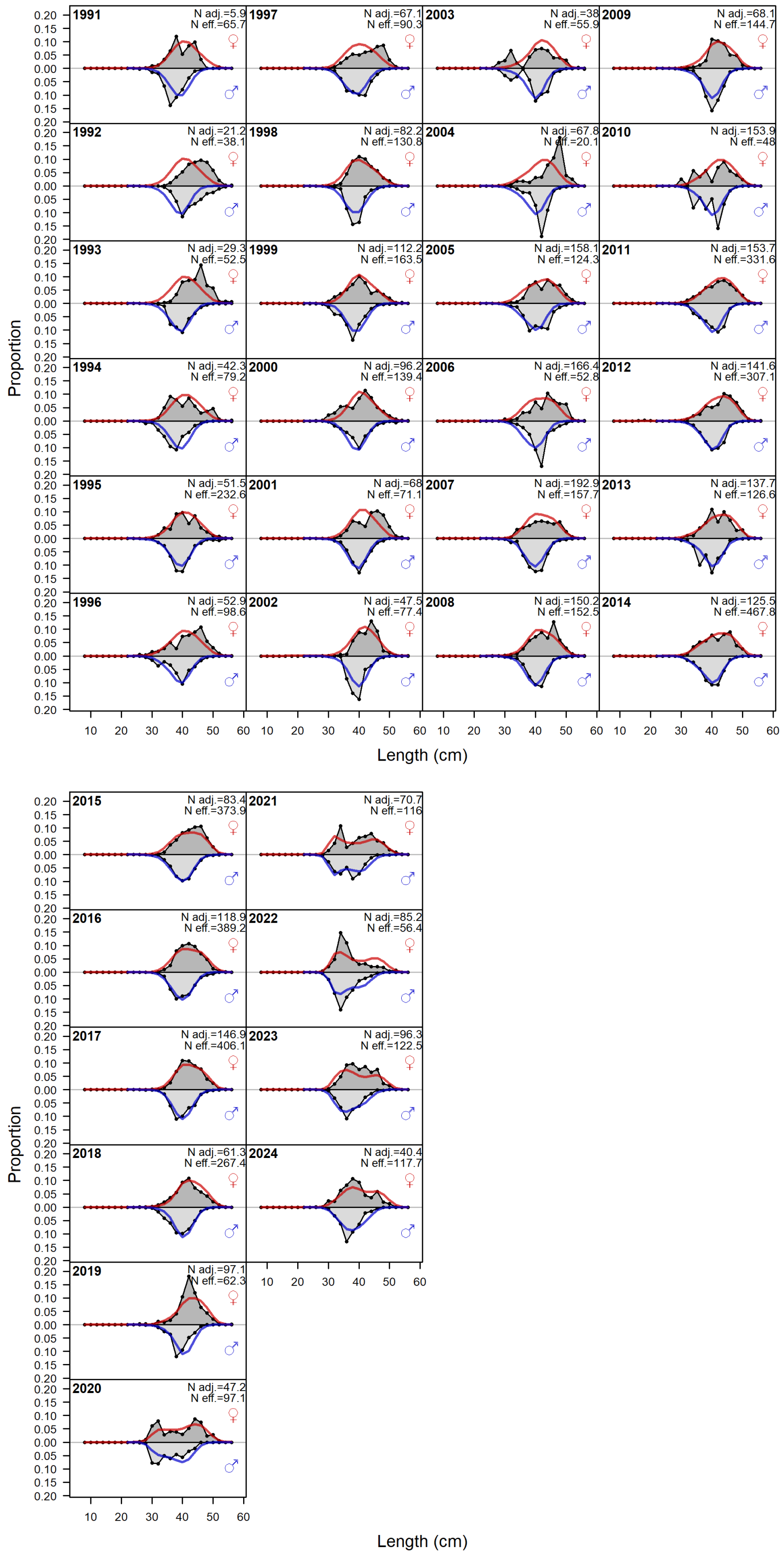

Figure A4: Fits to the retained length compositions for the hake fleet.

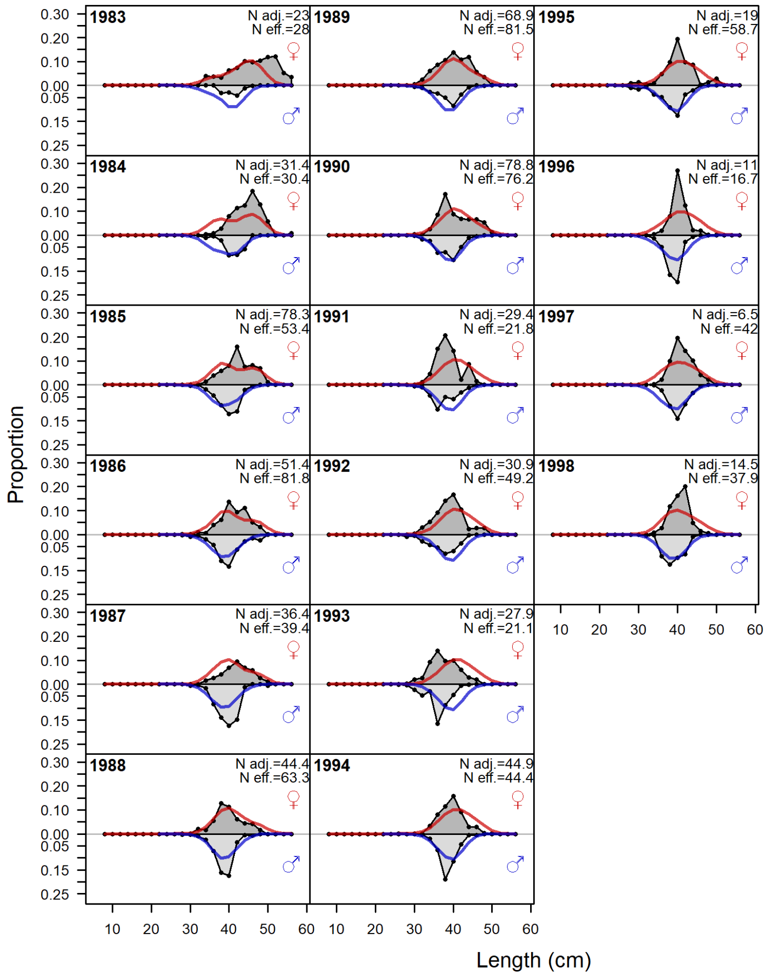

Figure A5: Fits to the retained length compositions for the net fleet.

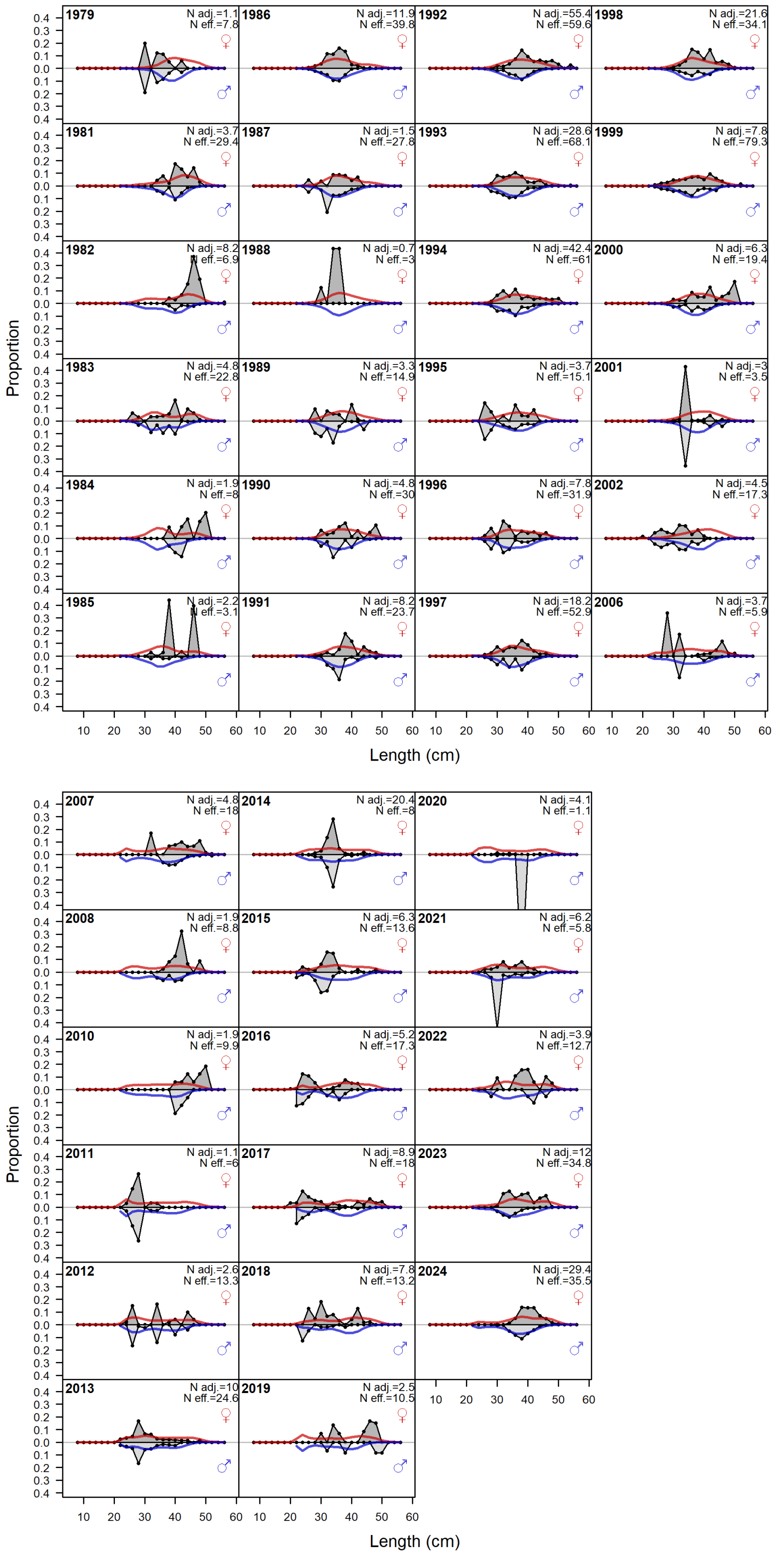

Figure A6: Fits to the retained length compositions for the hook-and-line fleet.

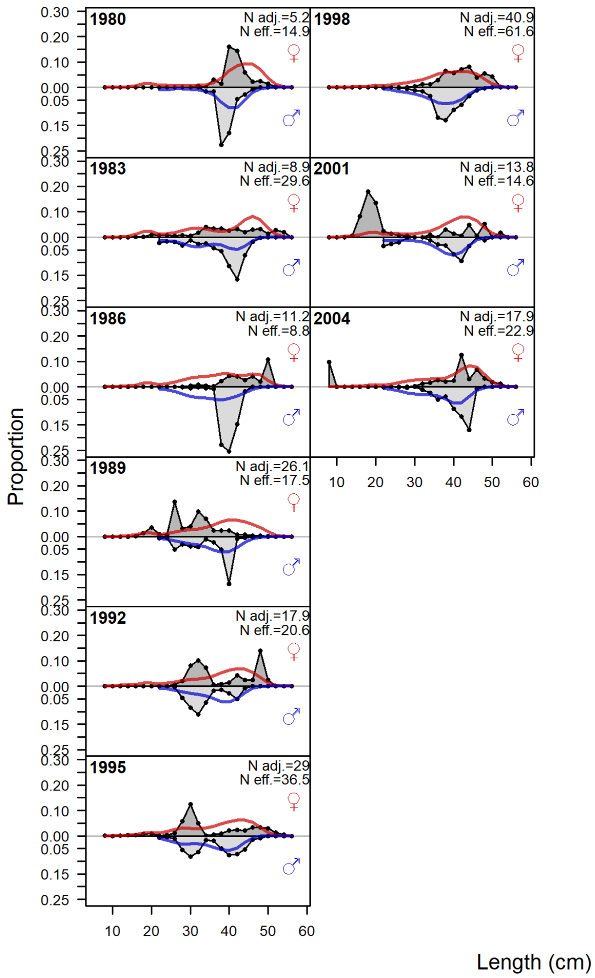

Figure A7: Fits to the length compositions for the triennial survey.

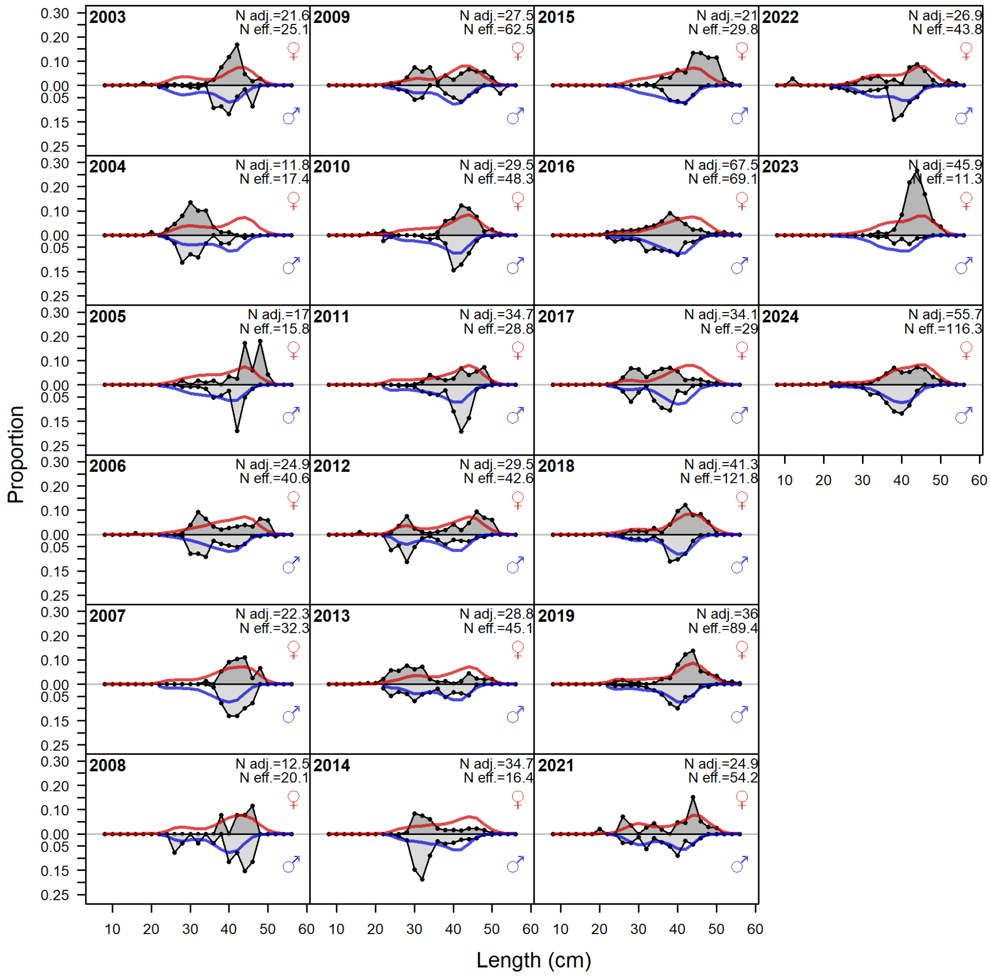

Figure A8: Fits to the length compositions for the NWFSC WCGBT survey.

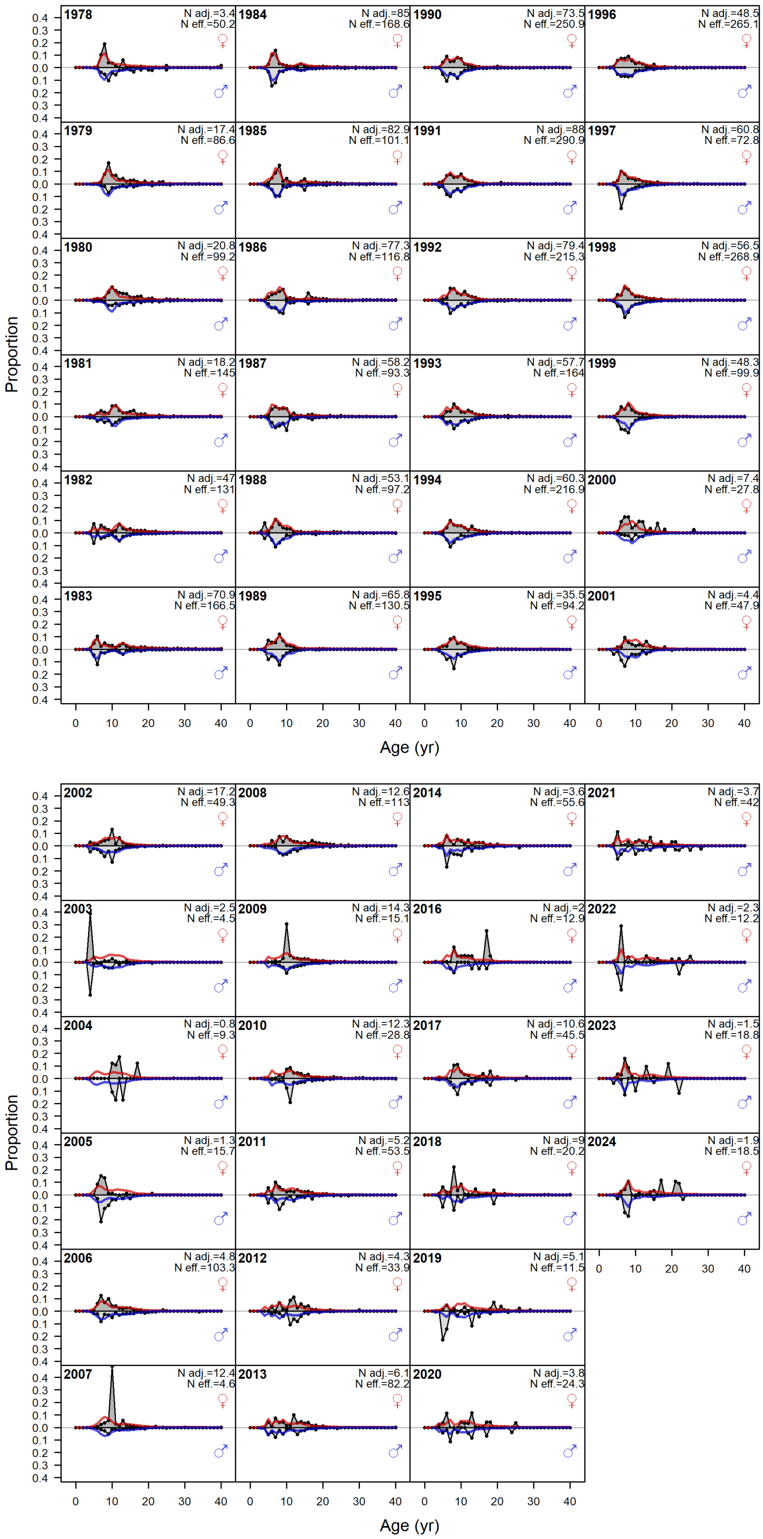

Figure A9: Fits to the retained age compositions for the bottom trawl fleet.

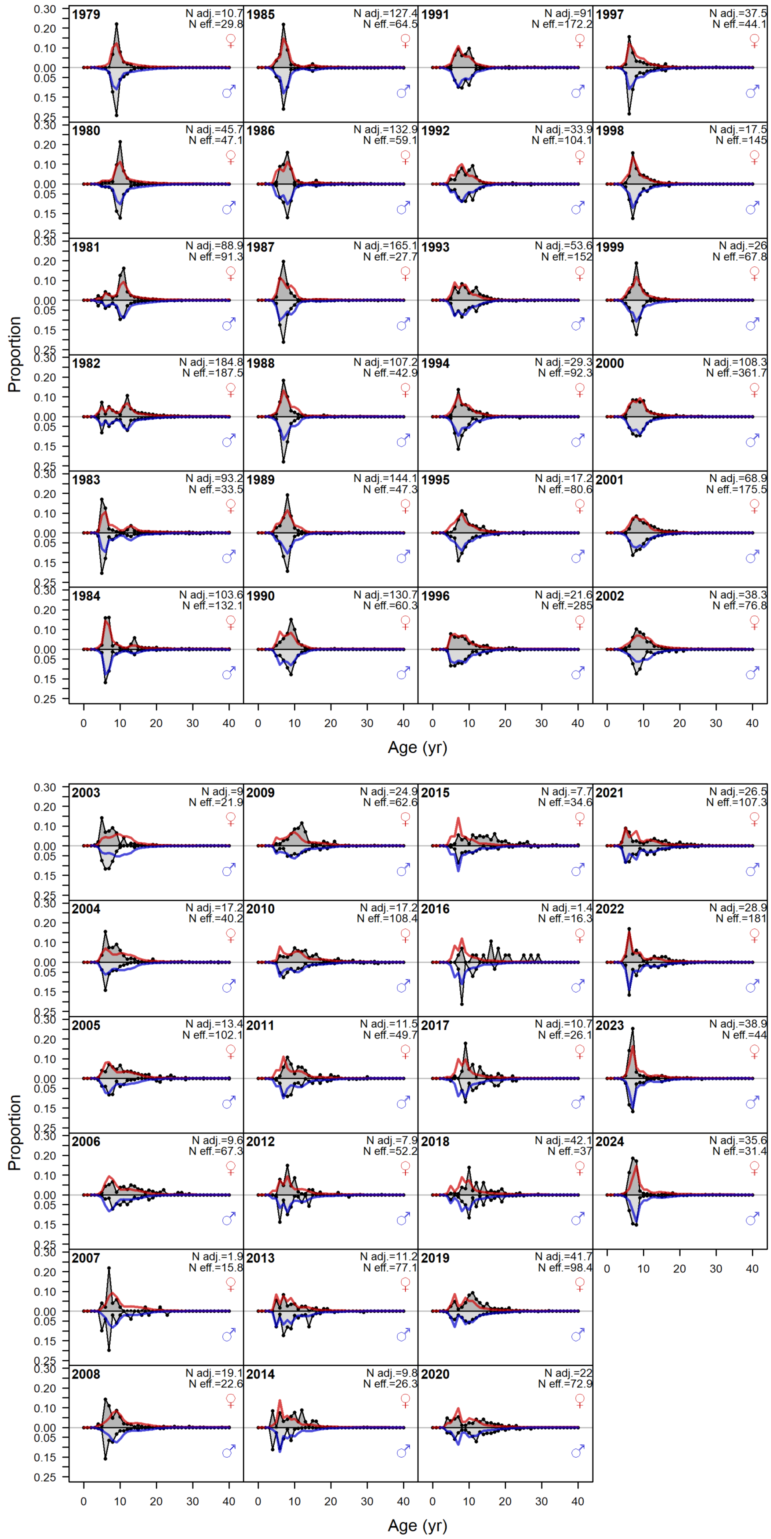

Figure A10: Fits to the retained age compositions for the midwater trawl fleet.

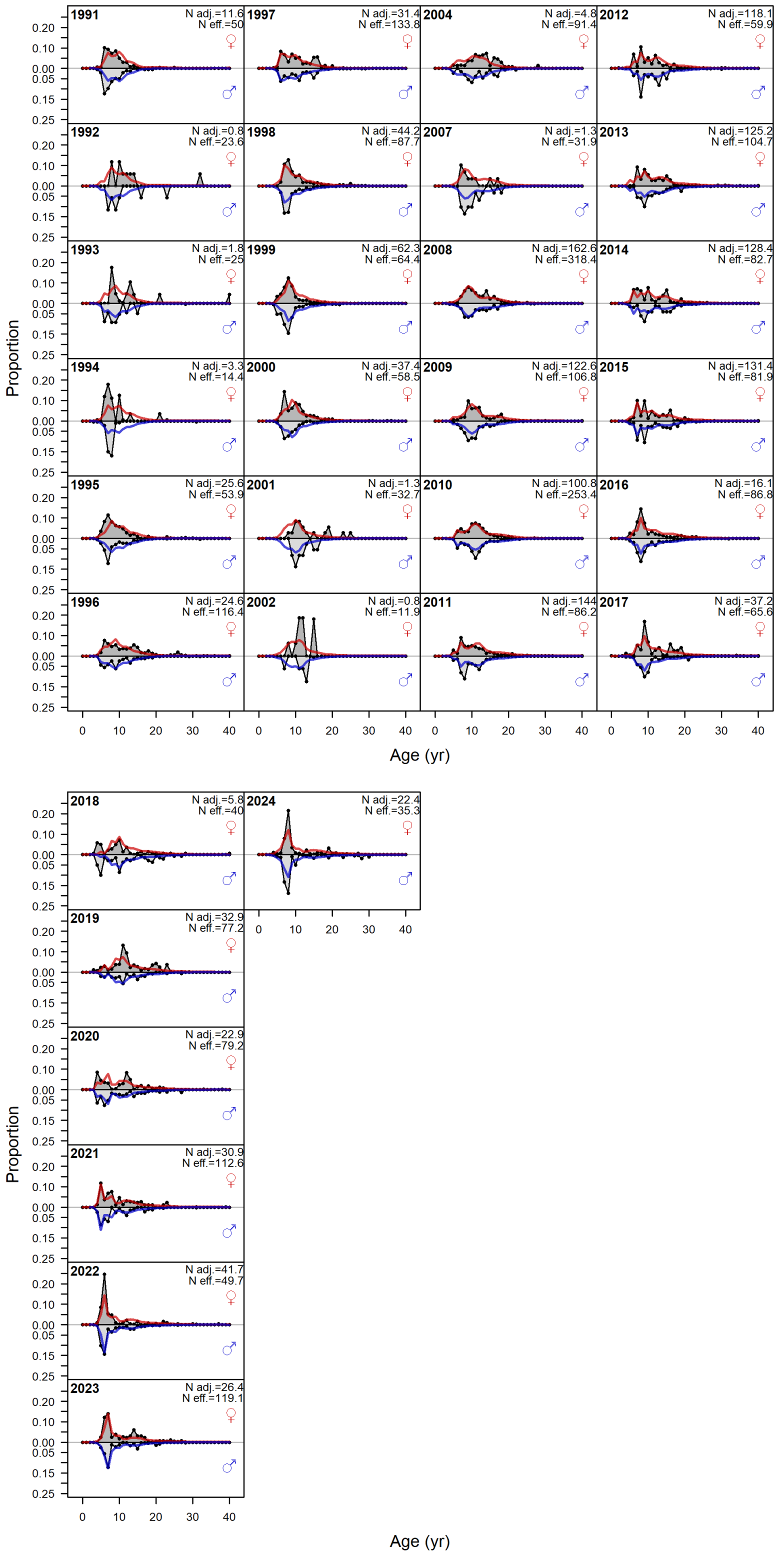

Figure A11: Fits to the retained age compositions for the hake fleet.

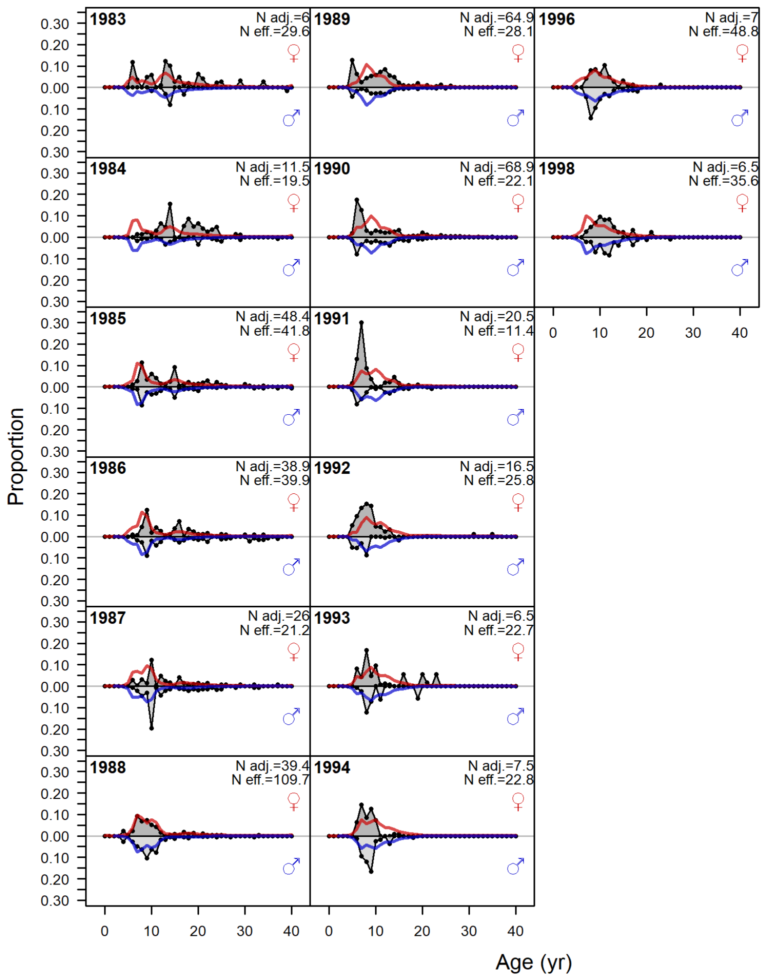

Figure A12: Fits to the retained age compositions for the net fleet.

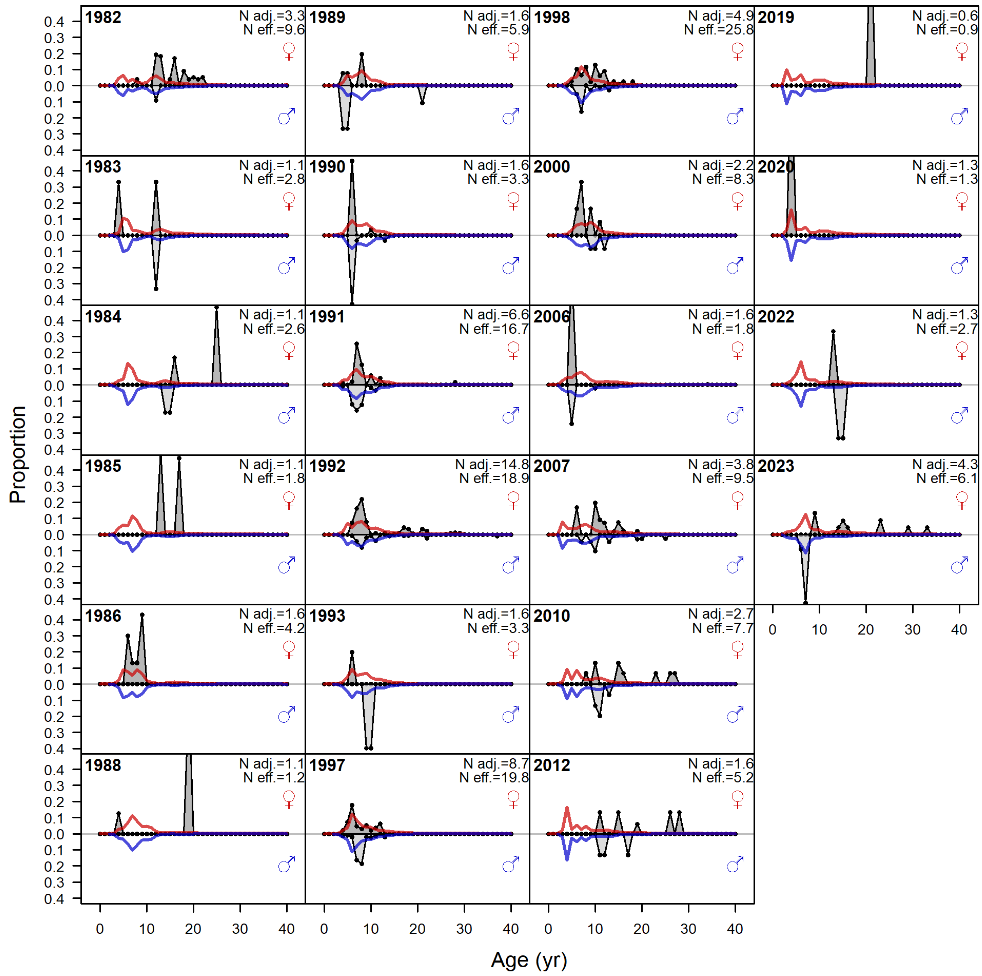

Figure A13: Fits to the retained age compositions for the hook-and-line fleet.

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