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

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Disclaimer

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. The 2015 benchmark was first updated in 2019 (Adams et al. (2019)) and this assessment represents the second update assessment of this stock. 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. Following the 2015 benchmark assessment, this update assessment is based on a single area model (Hicks and Wetzel 2015).

Catches

Historically, 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 2024 very little discarding of widow rockfish is estimated to have occurred. Recent discards 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	12.2	479.2	386.2	0.0	2.1	879.7	879.9
2016	9.6	588.0	440.8	0.0	1.0	1,039.4	1,039.6
2017	35.9	4,852.1	1,455.2	0.0	2.7	6,345.9	6,361.5
2018	35.9	9,374.3	1,081.3	0.0	1.6	10,493.2	10,522.9
2019	27.9	8,157.9	1,101.6	0.0	2.1	9,289.4	9,315.3
2020	73.6	7,532.2	746.7	0.0	2.7	8,355.2	8,379.6
2021	103.7	10,141.3	617.3	0.0	4.5	10,866.9	10,899.7
2022	126.8	10,839.8	1,119.0	0.1	8.8	12,094.4	12,129.7
2023	82.3	10,228.0	673.2	0.0	7.1	10,990.6	11,023.5
2024	27.6	9,160.8	533.8	0.0	12.9	9,735.1	9,764.1

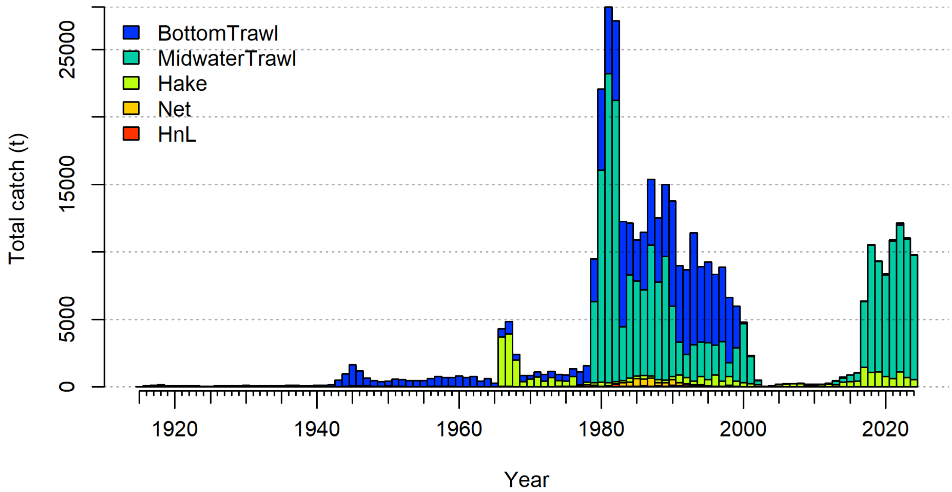

Figure i: Landings of Widow Rockfish from 1916 to 2018 for bottom trawl, midwater trawl, net, and hook- and-line fisheries, and catches of Widow Rockfish for the foreign (1966–1976) and Pacific Whiting (hake) fisheries (green).

Data and Assessment

This assessment uses the length- and age-structured modeling software Stock Synthesis (version 3.30.23.1), while the update assessment in 2019 used 3.30.13. 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.

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 from 2004-2024, 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. Three fishery-dependent CPUE indices were used as in the 2015 and 2019 assessments, derived from 1) Oregon bottom trawl (1984-1999), 2) Pacific Whiting at-sea foreign (1977-1988), and 3) Pacific whiting at-sea domestic fleets (1983-1998).

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 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. A target fishery for widow rockfish was reestablished in 2017. The stock exhibits a decline in most recent years with the increased catches since 2017, and lack of evidence for recent large recruitment events.

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 45,634 mt in 2024, 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%.

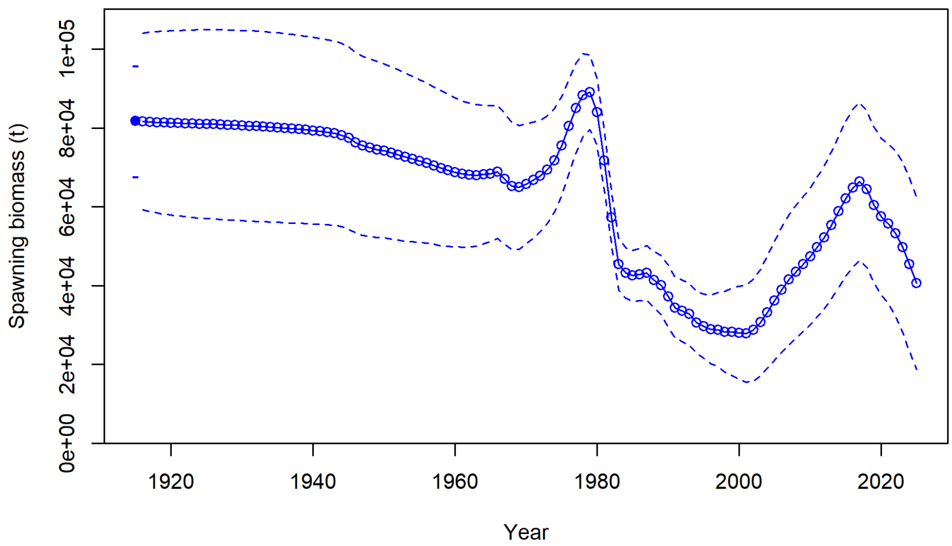

Figure ii: Estimated female spawning biomass time-series from the base model (solid line) with an approximate asymptotic 95% confidence interval (dashed lines).

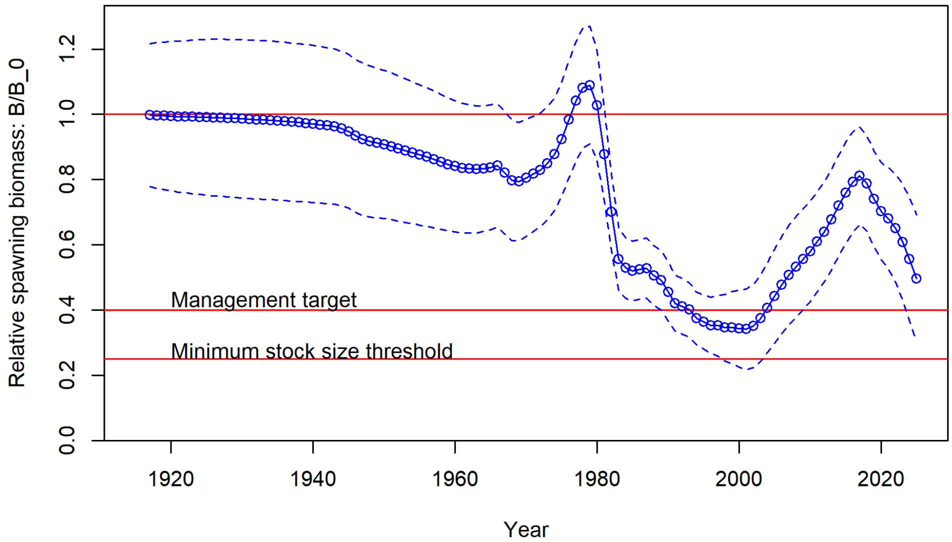

Figure iii: Estimated relative spawning biomass (depletion) with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model.

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 several 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.

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.

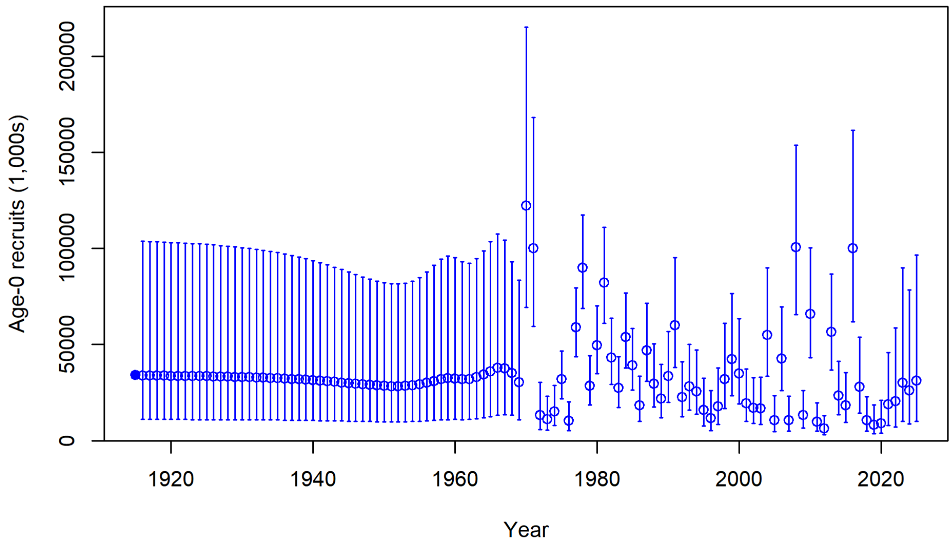

Figure iv: Time-series of estimated recruitments (medians as open circles) for the base case model with approximate asymptotic 95% confidence interval (vertical bars). Estimated mean unfished equilibrium recruitment (R0) is shown as the closed circle with a 95% confidence interval at the beginning of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

Table iii: Recent estimated trend in Widow Rockfish recruitment with approximate 95% confidence intervals determined from the base model.

Year	Estimated recruitment (number in thousands)	~95% Confidence Interval	Recruitment Deviations	~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 point 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

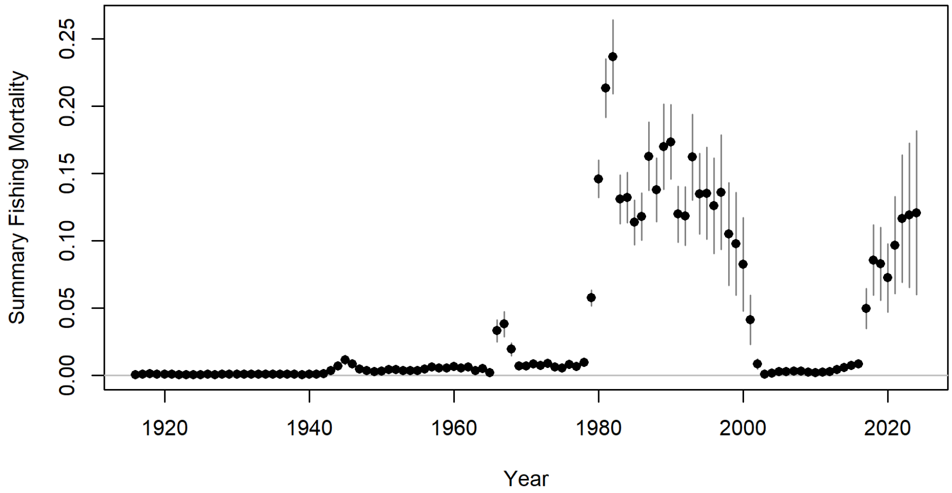

Figure v: Time-series of estimated summary harvest rate (catch divided by age 4+ biomass) for the base case model (round points) with approximate 95% asymptotic confidence intervals (gray lines).

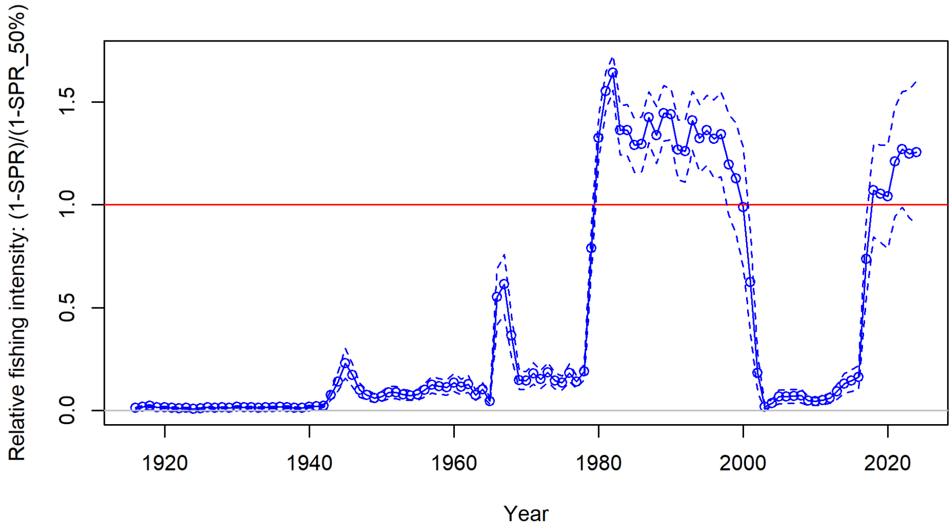

Figure vi: Trend in estimated fishing intensity (relative to the SPR management target) through 2024 with 95% asymptotic confidence intervals. One minus SPR is used so that higher exploitation rates occur on the upper portion of the y-axis. The relative management target is plotted as a horizontal line and values above this reflect harvests in excess of the overfishing proxy based on SPR50%.

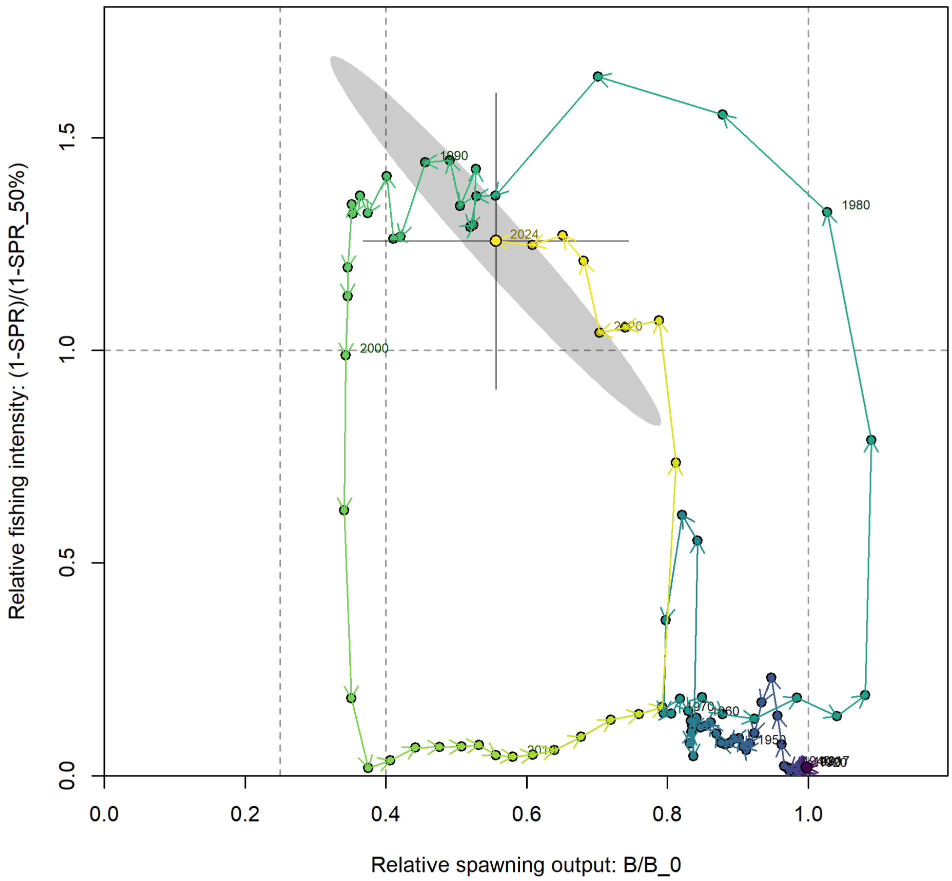

Figure vii: Phase plot of estimated relative (1-SPR) vs. relative biomass for the base case model. The relative (1- SPR) is (1-SPR) divided by 0.5 (one minus the SPR target). Lines through the final point (2024) show 95% intervals based on the asymptotic uncertainty for each dimension. The shaded ellipse is a 95% region which accounts for the estimated correlation between the two quantities.

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 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.

Reference points

Reference points were calculated using the estimated selectivities and average catch distribution among fleets in the most recent five years of the model (2019-2024). Total yields (landings plus discards) were 5,628 mt when using an SPR50% reference harvest rate and with a 95% confidence interval of 4,323 to 6,933 mt. The spawning biomass equivalent to 40% of the unfished spawning output (SB40%) was 32,693 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 NaN%.

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 iii). 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 iii). 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 v). 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 vii).

The equilibrium yield plot is shown in Figure viii, 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.

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

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

Quantity	Estimate	Lower Interval	Upper Interval
MSY (mt)	6,310.24	4,827.96	7,792.52

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.

Year	OFL (mt) (termed ABC prior to 2011)	ABC (mt)	ACL (mt) (termed OY prior to 2011)	Estimated Total Catch (mt)	Estimated Total Mortality (mt)
2015	4,137	3,929.00	2,000	879.67	879.86
2016	3,990	3,790.00	2,000	1,039.43	1,039.60
2017	14,130	13,508.28	13,508	6,345.93	6,361.50
2018	13,237	12,654.57	12,655	10,493.17	10,522.92
2019	12,375	11,830.50	11,831	9,289.44	9,315.29
2020	11,714	11,198.58	11,199	8,355.24	8,379.59
2021	15,749	14,725.32	14,725	10,866.89	10,899.73
2022	14,826	13,788.18	13,788	12,094.43	12,129.71
2023	13,633	12,624.16	12,624	10,990.57	11,023.50
2024	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

Year	Predicted OFL mt	ABC Catch mt	Age 4 Biomass mt	Spawning Biomass mt	Fraction Unfished
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
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 2027 for alternate states of nature based on the axis of uncertainty (a combination of M, h). Columns range over low, mid, and high state of nature, and rows range over different assumptions of total catch levels (discards + retained). Catches in 2025 and 2026 are allocated using the percentage of landings for each fleet in 2019-2024.

			State of nature					
			Low		**Base**		**High**	
Management decision	Year	catch (mt)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)	Depletion (%)
Constant catch (9,000 K)	2027	9,000	17,024	19.5	34,918	42.7	38,407	46.6
	2028	9,007	13,360	15.3	30,977	37.9	34,351	41.7
	2029	9,068	10,428	12.0	27,812	34.0	31,280	38.0
	2030	9,067	7,962	9.1	25,315	31.0	29,056	35.3
	2031	7,419	5,757	6.6	23,321	28.5	27,478	33.4
	2032	6,404	4,389	5.0	21,690	26.5	26,373	32.0
	2033	5,494	3,396	3.9	20,279	24.8	25,570	31.0
	2034	4,662	2,631	3.0	18,981	23.2	24,949	30.3
	2035	3,901	2,019	2.3	17,736	21.7	24,442	29.7
	2036	3,187	1,509	1.7	16,511	20.2	24,011	29.1
ACLp*=0.25, sigma=0.50	2027	1,790	24,754	28.4	29,822	36.5	41,750	50.7
	2028	1,750	24,698	28.3	29,349	35.9	41,257	50.1
	2029	1,791	25,148	28.9	29,596	36.2	41,522	50.4
	2030	1,863	25,952	29.8	30,369	37.2	42,422	51.5
	2031	1,939	26,957	30.9	31,461	38.5	43,786	53.2
	2032	1,991	28,047	32.2	32,692	40.0	45,448	55.2
	2033	1,993	29,155	33.5	33,935	41.5	47,258	57.4
	2034	1,969	30,261	34.7	35,143	43.0	49,121	59.6
	2035	1,929	31,364	36.0	36,298	44.4	50,970	61.9
	2036	1,886	32,473	37.3	37,406	45.8	52,765	64.1

			State of nature					
			Low		Base		High	
Management decision	Year	catch (mt)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)	Depletion (%)
ACLp*=0.45, sigma=0.50	2027	3,231	24,754	28.4	34,918	42.7	41,750	50.7
	2028	3,204	23,939	27.5	33,924	41.5	40,507	49.2
	2029	3,351	23,652	27.1	33,609	41.1	40,062	48.6
	2030	3,574	23,687	27.2	33,792	41.3	40,237	48.8
	2031	3,808	23,860	27.4	34,288	42.0	40,838	49.6
	2032	4,020	24,056	27.6	34,944	42.8	41,693	50.6
	2033	4,180	24,202	27.8	35,642	43.6	42,657	51.8
	2034	4,279	24,280	27.9	36,319	44.4	43,638	53.0
	2035	4,350	24,303	27.9	36,957	45.2	44,593	54.1
	2036	4,392	24,286	27.9	37,550	45.9	45,497	55.2

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.

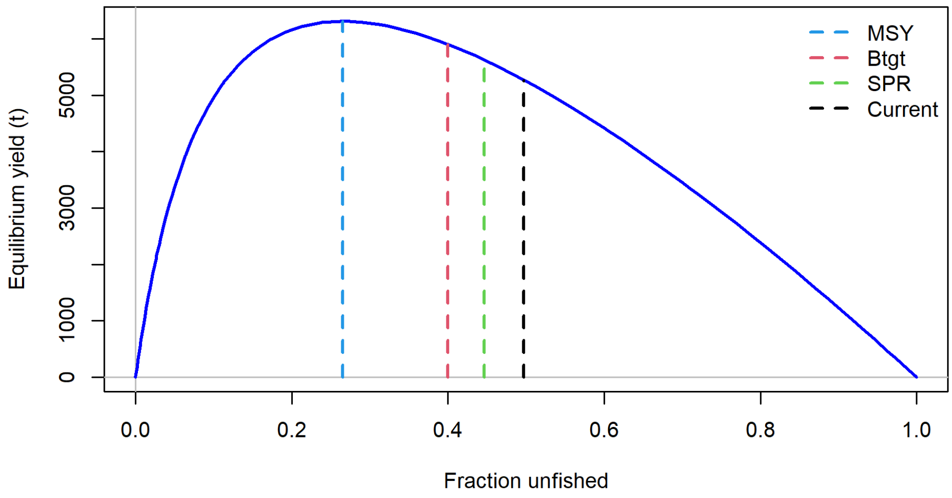

Figure viii: Equilibrium yield curve for the base case model and associated target and limit reference points. Values are based on 2019 fishery selectivity and distribution with steepness fixed at 0.720. The fraction unfished is relative to unfished spawning biomass.

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.

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

This section is not required for an update assessment; please refer to the most recent full assessment Adams et al. (2019) for additional information.

1.3 Ecosystem Considerations

This section is not required for an update assessment; please refer to the most recent full assessment Adams et al. (2019) for additional information.

1.4 Fishery description

This section is not required for an update assessment; please refer to the most recent full assessment Adams et al. (2019) for additional information.

1.5 Management History and Performance

This section is not required for an update assessment; please refer to the most recent full assessment Adams et al. (2019) for additional information.

1.6 Fisheries off Canada and Alaska

This section is not required for an update assessment; please refer to the most recent full assessment Adams et al. (2019) for additional information.

2 Data

Many sources of data were available for this assessment (Figure 31), including indices of abundance, landings, discards, and length and age observations from fishery-dependent and fishery-independent sources. Data that have changed since the 2019 assessment ((Adams et al. 2019)) are described below. No new data sources were considered in this update assessment.

2.1 Fishery-independent data

Data from three fishery-independent surveys were used in this assessment: 1) the SWFSC and NWFSC/PWCC Midwater Trawl Survey (hereafter, “juvenile survey”); 2) the Alaska Fisheries Science Center (AFSC)/NWFSC Triennial Shelf Trawl Survey (hereafter, “triennial survey”); and 3) the NWFSC West Coast Groundfish Bottom Trawl Survey (hereafter, “WCGBTS”). Depth and latitude strata used to analyze the catch-rates, length compositions, and age compositions are the same as in the 2019 assessment (Table 5 & Table 7).

2.1.1 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, ending 2004. Data from the Alaska Fisheries Science Center/Northwest Fisheries Science Center West Coast Triennial Shelf Survey (Triennial Survey) was not updated in this assessment; please refer to Hicks and Wetzel (2015) for further details.

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. Length compositions from the Triennial survey were not used in the base model.

2.1.2 Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey

The Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey (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)). Further details on the survey can be found in the 2015 and 2019 assessments ((Hicks and Wetzel 2015; Adams et al. 2019)) No survey occurred in 2020 due to Coronavirus disease (COVID-19). 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 2). 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 et al. 2022)). This approach reflects an updated approach compared to the 2015 assessment (non-spatial delta-GLMM) and the 2019 update assessment (VAST delta-lognormal model). The `sdmTMB` model used a 200 knot mesh of the survey area ((Thorson et al. 2015)). The prediction grid was truncated to only include available survey locations in depths between 55–500 m to limit extrapolating beyond the data and edge effects. Tweedie, delta-binomial, delta-gamma, and mixture distributions, which allow for extreme catch events, were investigated. The positive catch weight model includes survey pass ('first' for early season or 'second' for late season) and year. Vessel-year effects, which have traditionally been included in index standardization for this survey, were not included as the estimated variance for the random effect was close to zero. Vessel-year effects were more prominent when models did not include spatial effects and were included for each unique combination of vessel and year in the data to account for the random selection of commercial vessels used during sampling ((Helser, 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 (Figure 6). 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. 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 et al. 2022)).

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 9.

Length, age, and conditional age-at-length compositions were processed using the nwfscSurvey package. 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. Age distributions were included in the model as conditional-age-at-length (CAAL) observations. The marginal age-compositions were also included, but only for easier viewing of strong cohorts. The CAAL data were not expanded and were binned according to length, age, sex, and year.

Expanded length frequencies from this survey show intermittent years of small fish; the 2018–2024 period generally suggests most fish are around 40–45cm in length (Figure 10). Strong cohorts are not immediately apparent and it seems that ageing error may result in some variability between years. Conditional age-at-length proportions (Figure 12) show relatively consistent length-at-age with few outliers.

2.1.3 SWFSC and NWFSC/PWCC Midwater Trawl Survey

An updated coastwide pre-recruit index of abundance for widow rockfish was created (2001-2024) 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. Sampling in 2020 was limited due to the COVID-19 pandemic and excluded from all models. In 2010 and 2012, coverage was incomplete, so these years excluded from the final model to align with the 2019 assessment. Following the 2015 and 2019 assessments, data from 2001–2003 were also excluded due to limited spatial coverage (36°30 to 38°20 N latitude).

The index was built using a spatial GLM with the sdmTMB package ((Anderson et al. 2022)), modeling 100-day standardized catch-per-tow as a function of year (fixed effect), Julian date (GAM smoother, k = 4), spatial random field, and spatiotemporal random effects. Models with Tweedie, delta-lognormal, and delta-gamma error structures were compared; DHARMa residuals and simulation-based diagnostics indicated the Tweedie model performed best. The index shows a strong increasing trend in juvenile abundance from 2017 to 2023, with a slight decline in 2024. Recent values remain high relative to the previous decade, and uncertainty estimates support the robustness of this trend.

2.2 Fishery-dependent data

2.2.1 Landings

Widow rockfish is primarily caught by bottom trawl and midwater trawl gears (Table 1). This species also commonly bycaught by fishery targeting Pacific hake. Minimal amounts are also taken by non-trawl gears such as hook-and-line and net (Table 14).

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).

Landings from all years (1916-2018) were carried forward into this assessment with slight modifications to the midwater and bottom trawl catches from California. Because PacFIN appear to underestimate midwater trawl catches in California in 1979-1980 when midwater trawl fishery for widow rockfish developed (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.

Recent catches (2019-onward) were extracted from PacFIN and NORPAC (ASHOP data), and were otherwise appended onto the 1916-2018 landings and apportioned among fleets using the same criteria as those documented in the 2015 assessment ((**hicks-status-2015?**)).

2.2.2 Fishery catch-per-unit-effort

Three fishery-dependent CPUE indices were used as the last assessment ((**adams-status-2019?**)). Indices were derived from 1) Oregon bottom trawl (1984-1999), 2) Pacific Whiting at-sea foreign (1977-1988), and 3) Pacific whiting at-sea domestic fleets (1983-1998). These were not updated; see (**adams-status-2019?**) for details.

2.2.3 Fishery length and age data

Biological data from commercial fisheries that caught Widow Rockfish were extracted from PacFIN on March 25, 2025 and from the NORPAC database. Lengths and age samples taken during port sampling in California, Oregon, and Washington were used to generate length and age compositions. The data were classified into bottom trawl, midwater trawl, hake trawl, net, and hook-and-line fleets using pacfintools package in R. For each fleet, the raw observations were expanded to the trip level, to account for differences in samples sizes relative catch weights among trips (first stage expansion). The expanded length observations were then further expanded to state level, to account for differences in sampling intensity of widow rockfish landings among states combined into a single fleet (second stage expansion).

Table 9 shows the number of landings sampled and Table 10 shows the number of lengths taken for each year, gear, and fleet from the three states. Table 11 shows these numbers for the at-sea fleet. Length and age samples from PacFIN were expanded using the same methods described in (**adams-status-2019?**). Table 9 shows the number of landings sampled and Table 10 shows the number of lengths taken for each year, gear, and fleet from the three states. Table 11 shows these numbers for the at-sea fleet. Expanded length compositions for bottom trawl, midwater trawl, hake fisheries, net, and hook-and-line are shown in Figure 13 to Figure 17. Age compositions for the five fleets are shown in Figure 18 and Figure 22. Occasional cohorts appear to move through the population, indicating that widow rockfish population dynamics may be characterized by episodic recruitment events.

2.2.4 Discards

Data on discards on Widow Rockfish are available from three different sources. Historical sources included Pikitch et al. (1988) and Enhanced Data Collected Project (EDCP, Sampson 2002). These historical sources were not reanalyzed for this update assessment, and discard amounts were not changed from the last assessment. 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. Discard estimates are shown in Table 14 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 23).

The West Coast Groundfish Observer Program (WCGOP) provided information on recent discard of widow rockfish between 2002–2023. 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.

Widow Rockfish discard lengths composition data are available for the bottom trawl and midwater fleets, and is unchanged from the 2019 assessment. Discard length data for 2004-2023 was provided by 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; 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 (Table 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 14). 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. 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 erroneously. This change resulted in changes to the discard length distribution and years for which data was available. The hook-and-line removals comprised only approximately 0.2% of the total removals over the last twenty years (Table 1), 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) 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.

Figure 23 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. Length compositions of the discards for the bottom trawl are in Figure 24.

2.2.5 Biological data

The approach to the estimation of all biological parameters was the same as in ((**adams-status-2019?**)).

2.2.5.1 Weight-length relationship

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

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 parameters were used in the assessment as fixed.

2.2.5.2 Maturity schedule

Maturity parameters in this update assessment were carried over from 2015 benchmark and 2019 update assessments. Please refer to Hicks and Wetzel (2015) for further details.

2.2.5.3 Fecundity

Fecundity parameters remain unchanged from previous assessment. Please refer to Hicks and Wetzel (2015) for further details.

2.2.5.4 Natural Mortality

Natural mortality used in this update differed from the (**adams-status-2019?**) in the treatment of the prior. 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.

2.2.5.5 Length-at-age

Growth parameters were fully estimated within the assessment model, for females and males separately.

2.2.5.6 Ageing bias and imprecision

Ageing error matrices were unchanged from the previous assessment. Please refer to (Hicks and Wetzel 2015), Table 15, and Figure 30 for futher details.

2.3 Environmental and Ecosystem Data

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

3 Assessment model

The assessment followed the same model structure as the 2015 base assessment ((Hicks and Wetzel 2015)) and 2019 update assessment ((Adams et al. 2019)).

3.1 History of modeling approaches

This section is not required for an update assessment; please refer to the most recent full assessment ((Adams et al. 2019)) for additional information.

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 16 and are unchanged from the previous assessment ((Adams et al. 2019)), 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 included 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 32). 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 2025 model estimates retention in the midwater trawl in late years (2017 onward), whereas retention 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.

3.3.1.1 Model Bridging

Due to significant impact of updating data on estimated absolute stock biomass (SSB), bridging steps are detailed below.

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 32). 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 32). 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.

To estimate discards in the model, time blocks for changes in selectivity and retention in discard data were used. Except for the aforementioned addition of blocks to the midwater trawl and hake fleets, the same structure for time blocks was used as in the previous assessment ((Adams et al. 2019)) 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.

3.3.2 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

The assessment uses a single-area model, consistent with previous assessments ((Adams et al. 2019)). Multiple fisheries encounter Widow Rockfish. The definitions of fishing fleets have not been changed from previous assessments ((Adams et al. 2019)).

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. Consistent with ((Adams et al. 2019)), steepness was fixed at 0.72 as was 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 ((Adams et al. 2019)). Length-weight parameters were fixed at estimates using length-weight observations from the NWFSC WCGBT survey (Figure 25 and Table 17).

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 16.

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

As previous full assessment used the McAllister & Ianelli method ((Hicks and Wetzel 2015)) and changing the weighting method is outside the TORs for an update, Francis weighting method is presented as a sensitivity.

The 2019 update assessment weighted composition data via the lambdas ((Adams et al. 2019)). 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

This section is not required for an update assessment; please refer to the most recent full assessment ((Adams et al. 2019)) for additional information.

3.4 Base Model Results

The base model parameter estimates along with approximate asymptotic standard errors are shown in Table 19 and the likelihood components are shown in Table 20. Estimates of key derived parameters and approximate 95% asymptotic confidence intervals are shown in Table 21.

3.4.1 Parameter Estimates

The estimates of natural mortality (0.124273 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 28.

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 24). Uncertainty in the estimated M was also much less than the range of the prior (Figure 28). 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 24).

Selectivity curves were estimated for commercial and survey fleets and parameter estimates are provided in Table 19. 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 50) 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 (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 34). The NWFSC WCGBT survey exhibited a more pronounced dome-shaped selectivity compared to the 2015 assessment.

In the 2015 assessment, 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 ((Hicks and Wetzel 2015)). 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 19) were not unexpected given the data in Figure 29. Estimates of k were slightly different in the model, but that is expected when accounting for selectivity. Estimated growth curves are shown in (Figure 35).

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 36, Table 21). 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

Fits to data are discussed for 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) are shown in Figure 41. The Triennial Shelf Survey treatment was consistent with ((Adams et al. 2019)). Extra standard error was estimated for all of the series except for the two survey series (Table 19). None of the series showed patterns in residuals, and with the large amount of error, none of the series showed serious lack of fit. The recent 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 41, middle right). Low (2015, 2021, 2022) and high (2016) estimates of abundance did not fit well in the model.

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, 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 42). 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. Previous assessments added samples from nearshore pot and net gears to hook-and-line.

Nearshore pot and net gears 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 43, Figure 44) 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 43, 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. The model fits the marginal length composition integrated among years for each fleet well (Figure 45).

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 43 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 47). 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 45). 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 43 and Figure 44. For the trawl fisheries in Figure 43, 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 44) 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 48). 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 49 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 52). 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 22 and plotted in Figure 53. 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 55). 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 55).

Recruitment deviations were estimated for the entire time series that was modeled (Figure 36 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 37).

The stock-recruit curve resulting from a fixed value of steepness is shown in Figure 37 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.

3.5 Model Diagnostics

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 17, Table 18, and Table 23 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 21 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. 8 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. Forcing asymptotic selectivity on the midwater trawl fleet
4. Fitting logistic curves for NWFSC WCGBT survey selectivities
5. Weighting the composition data using the Francis method
6. Updated Washington catch reconstruction
7. Inclusion of previously excluded shrimp trawl data
8. Exclusion of triennial survey data

Likelihood values and estimates of key parameters are shown in Table 24. Predicted spawning biomass trajectories, estimated recruitment deviations and comparisons of model estimates for 2025 are shown in Figure 38, Figure 39 and Figure 40. 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).

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 (138.4% 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 25 and Figure 57). 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.

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 28 and Table 29). Profiles for natural mortality for each sex are illustrated in (Figure 60). 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 27). Profiles for steepness are illustrated in (Figure 59). For R0, the total likelihood supported the estimated value, though there was variable support for each likelihood component across the range of R0 evaluated (Table 26). As R0 increased, natural mortality also increased and the relative spawning biomass in 2024 was less depleted (Table 26). Profiles for R0 are illustrated in Figure 58.

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 55). 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 55). 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 62). 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 63).

The equilibrium yield plot is shown in Figure 64, 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 0.124 for females and 0.136 yr^{-1} for males, with a small amount of uncertainty (e.g., a 0% 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

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.

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 32, Figure 66).

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.Predicted ACL catches range from 3,321 mt in 2027 to 4,392 mt in 2036 Table 32, Figure 66).

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 32, Figure 66).

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

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5 Tables

5.1 Data

5.1.1 Fishery-dependent data

Table 1: Landings for bottom trawl, midwater trawl, net, and hook-and-line (mt) fisheries from Washington, Oregon, and California.

Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
	CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
1916	6.20	0.00	0.00	0.00	0.00	0.00	0.0	0.0	71.80	0.30	0.00
1917	9.60	0.00	0.00	0.00	0.00	0.00	0.0	0.0	111.90	0.30	0.00
1918	11.20	0.00	0.00	0.00	0.00	0.00	0.0	0.0	128.50	0.30	0.00
1919	7.80	0.00	0.00	0.00	0.00	0.00	0.0	0.0	88.60	0.30	0.00
1920	8.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	90.70	0.40	0.00
1921	6.60	0.00	0.00	0.00	0.00	0.00	0.0	0.0	75.10	0.40	0.00
1922	5.70	0.00	0.00	0.00	0.00	0.00	0.0	0.0	65.20	0.40	0.00
1923	6.10	0.00	0.00	0.00	0.00	0.00	0.0	0.0	71.70	0.40	0.00
1924	3.60	0.00	0.00	0.00	0.00	0.00	0.0	0.0	46.20	0.40	0.00
1925	3.10	0.00	0.00	0.00	0.00	0.00	0.0	0.0	58.70	0.40	0.00
1926	8.70	0.00	0.00	0.00	0.00	0.00	0.0	0.0	85.50	0.40	0.00
1927	11.70	0.00	0.00	0.00	0.00	0.00	0.0	0.0	66.40	0.50	0.00
1928	16.60	0.00	0.00	0.00	0.00	0.00	0.0	0.0	72.00	0.80	0.00
1929	23.40	0.00	0.00	0.00	0.00	0.00	0.0	0.0	62.10	1.30	0.00
1930	20.80	0.00	0.00	0.00	0.00	0.00	0.0	0.0	90.40	1.20	0.00
1931	20.40	0.00	0.00	0.00	0.00	0.00	0.0	0.0	78.60	0.90	0.00
1932	21.70	0.40	0.00	0.00	0.00	0.00	0.0	0.0	77.70	0.30	0.00
1933	34.30	0.20	0.00	0.00	0.00	0.00	0.0	0.0	50.90	0.50	0.00
1934	30.70	0.00	0.00	0.00	0.00	0.00	0.0	0.0	59.70	0.50	0.00
1935	28.90	0.20	0.70	0.00	0.00	0.00	0.0	0.0	67.90	0.50	0.00

Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
	CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
1936	23.40	0.70	1.10	0.00	0.00	0.00	0.0	0.0	84.30	1.20	0.00
1937	33.60	1.30	0.90	0.00	0.00	0.00	0.0	0.0	66.30	1.30	0.00
1938	32.20	0.00	1.10	0.00	0.00	0.00	0.0	0.0	49.60	1.00	0.00
1939	38.80	1.90	1.00	0.00	0.00	0.00	0.0	0.0	34.20	0.70	0.00
1940	30.60	43.70	1.00	0.00	0.00	0.00	0.0	0.0	43.90	1.50	0.00
1941	24.80	67.30	1.40	0.00	0.00	0.00	0.0	0.0	34.10	1.90	0.00
1942	5.40	126.10	1.80	0.00	0.00	0.00	0.0	0.0	10.20	3.10	0.00
1943	28.30	439.20	1.20	0.00	0.00	0.00	0.0	0.0	18.00	3.90	0.00
1944	148.60	770.70	2.00	0.00	0.00	0.00	0.0	0.0	38.00	1.40	0.00
1945	353.40	1,196.60	3.40	0.00	0.00	0.00	0.0	0.0	66.80	1.10	0.00
1946	353.20	735.00	0.80	0.00	0.00	0.00	0.0	0.0	69.70	1.30	0.00
1947	98.10	452.80	0.20	0.00	0.00	0.00	0.0	0.0	91.30	0.70	0.00
1948	139.40	297.30	0.10	0.00	0.00	0.00	0.0	0.0	39.60	1.20	0.00
1949	75.10	254.70	0.00	0.00	0.00	0.00	0.0	0.0	43.90	0.60	0.00
1950	70.90	286.80	1.80	0.00	0.00	0.00	0.0	0.0	63.40	0.80	0.00
1951	249.40	252.90	2.00	0.00	0.00	0.00	0.0	0.0	49.10	0.60	0.00
1952	236.60	264.20	0.20	0.00	0.00	0.00	0.0	0.0	39.90	0.60	0.00
1953	242.60	211.50	1.20	0.00	0.00	0.00	0.0	0.0	13.70	0.30	0.00
1954	155.80	267.30	3.10	0.00	0.00	0.00	0.0	0.0	21.30	0.40	0.00
1955	166.30	277.50	2.50	0.00	0.00	0.00	0.0	0.0	18.20	0.40	0.00
1956	196.80	361.30	0.70	0.00	0.00	0.00	0.0	0.0	41.80	0.30	0.00
1957	233.10	489.50	0.10	0.00	0.00	0.00	0.0	0.0	37.40	0.60	0.00
1958	284.30	380.40	0.20	0.00	0.00	0.00	0.0	0.0	36.60	0.10	0.00
1959	229.90	412.80	0.10	0.00	0.00	0.00	0.0	0.0	28.60	0.20	0.00
1960	180.00	608.60	0.20	0.00	0.00	0.00	0.0	0.0	21.90	0.20	0.00
1961	118.40	543.10	0.20	0.00	0.00	0.00	0.0	0.0	15.00	0.50	0.00
1962	115.90	623.80	2.00	0.00	0.00	0.00	0.0	0.0	15.40	0.40	0.00

Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
	CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
1963	221.20	190.20	2.10	0.00	0.00	0.00	0.0	0.0	19.60	0.40	0.00
1964	104.10	480.90	3.20	0.00	0.00	0.00	0.0	0.0	13.00	0.10	0.00
1965	155.90	80.60	2.20	0.00	0.00	0.00	0.0	0.0	20.20	0.60	0.00
1966	123.00	455.80	0.60	0.00	0.00	0.00	0.0	0.0	37.40	0.40	0.00
1967	141.90	743.90	0.60	0.00	0.00	0.00	0.0	0.0	31.90	1.10	0.00
1968	155.00	240.60	16.70	0.00	0.00	0.00	0.0	0.0	19.00	1.00	0.00
1969	223.50	229.30	16.70	0.00	0.00	0.00	0.0	0.0	17.60	2.30	0.00
1970	257.30	27.70	3.00	0.00	0.00	0.00	0.0	0.0	9.00	0.90	0.00
1971	316.20	50.60	11.70	0.00	0.00	0.00	0.0	0.0	10.20	1.80	0.00
1972	411.90	51.80	14.10	0.00	0.00	0.00	0.0	0.0	17.80	2.30	0.00
1973	428.10	20.90	32.40	0.00	0.00	0.00	0.0	0.0	15.80	2.50	0.00
1974	426.40	7.30	6.50	0.00	0.00	0.00	0.0	0.0	41.30	3.10	0.00
1975	429.90	9.00	12.00	0.00	0.00	0.00	0.0	0.0	28.40	1.60	0.00
1976	467.30	56.00	36.20	0.00	0.00	0.00	0.0	0.0	39.50	2.20	0.00
1977	459.00	340.00	125.80	0.00	0.00	0.00	0.0	0.0	38.10	2.60	0.00
1978	538.90	340.10	336.70	0.00	0.00	0.00	0.0	0.0	157.40	3.80	0.00
1979	2,315.40	519.40	305.00	0.00	3,746.00	2,199.80	0.0	0.0	97.10	6.40	0.00
1980	5,175.60	410.80	338.40	150.80	8,460.70	6,969.40	0.0	3.4	55.90	3.70	0.00
1981	2,660.20	1,527.10	681.20	2,627.40	13,861.90	6,183.50	15.5	3.2	67.50	4.00	0.00
1982	3,656.70	782.80	522.00	7,008.10	8,184.40	5,458.00	38.1	37.1	180.60	5.90	0.00
1983	3,667.10	1,403.60	1,554.60	205.10	1,495.60	1,656.50	280.0	14.5	23.50	10.20	0.00
1984	1,434.60	1,428.50	381.80	1,378.60	3,982.80	1,064.60	324.8	26.6	22.80	3.80	0.00
1985	1,363.00	895.10	317.60	1,281.60	3,423.40	1,214.60	585.8	40.2	26.10	1.10	0.00
1986	1,640.40	1,230.10	716.10	362.20	3,150.50	1,834.10	500.8	0.0	81.50	1.90	0.00
1987	2,261.10	1,185.50	698.40	0.00	5,114.50	3,013.10	584.6	0.0	52.40	2.70	0.00
1988	1,585.30	1,152.80	1,290.30	0.00	4,305.60	1,785.00	220.7	0.0	72.30	1.00	0.20
1989	1,838.30	2,027.50	647.70	0.00	4,957.70	2,726.90	253.6	0.1	44.70	0.40	0.00

Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
	CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
1990	1,812.70	2,289.30	1,210.40	0.00	3,352.80	1,021.10	411.2	0.0	126.90	7.30	0.20
1991	996.40	1,989.20	878.90	0.00	1,779.90	260.20	234.8	0.0	89.70	5.20	0.30
1992	917.40	2,709.50	646.50	0.00	1,183.80	282.50	45.4	0.0	165.80	9.20	0.50
1993	1,088.30	3,457.00	1,109.80	1.20	1,706.80	547.90	51.6	0.0	63.70	44.70	0.50
1994	557.90	2,600.70	644.10	210.00	1,564.40	387.50	58.4	0.0	71.70	9.60	0.40
1995	1,361.10	2,386.70	339.00	292.70	1,283.40	700.70	57.6	0.0	19.00	7.20	0.10
1996	1,056.80	2,292.10	237.90	238.80	998.20	609.40	16.1	0.0	21.60	11.00	0.10
1997	1,032.50	2,502.80	241.70	253.60	1,453.10	735.80	16.4	0.0	22.40	15.60	0.00
1998	686.20	1,641.10	188.40	81.60	493.40	307.80	48.7	0.0	62.40	24.10	0.00
1999	485.00	945.00	182.70	100.10	1,634.20	315.90	10.0	0.0	29.00	14.70	0.10
2000	34.20	19.60	2.90	680.80	2,604.80	379.40	6.8	0.0	11.90	2.50	0.00
2001	9.30	28.80	1.00	310.30	1,092.40	287.10	7.0	0.0	6.40	0.70	0.00
2002	8.70	6.00	2.40	40.00	151.70	59.80	0.0	0.0	0.40	0.10	0.00
2003	3.10	0.30	0.20	0.40	0.00	9.30	0.4	0.0	0.30	0.60	0.00
2004	5.90	2.40	0.10	7.50	0.00	21.30	0.0	0.0	0.20	0.10	0.00
2005	2.76	0.19	0.24	0.00	0.00	27.59	0.0	0.0	0.43	0.76	0.07
2005	2.70	0.20	0.20	5.20	0.00	27.60	0.1	0.0	0.40	0.80	0.10
2006	3.79	2.02	0.26	0.00	0.00	9.28	0.0	0.0	0.84	0.02	0.02
2007	2.75	1.81	0.29	0.00	0.00	0.53	0.0	0.0	1.59	0.33	0.01
2008	0.23	1.86	0.20	0.00	0.00	12.95	0.0	0.0	1.21	0.02	0.01
2009	1.91	2.10	0.19	0.00	0.00	33.89	0.0	0.0	0.40	0.01	0.00
2010	1.16	2.88	0.19	0.04	0.00	46.35	0.0	0.0	0.05	0.08	0.03
2011	1.12	10.57	2.81	0.00	13.83	35.69	0.0	0.0	0.05	0.04	0.03
2012	2.29	27.31	14.04	0.00	5.96	41.69	0.0	0.0	0.20	0.08	0.04
2013	4.85	44.07	2.39	0.00	210.48	36.62	0.0	0.0	0.89	0.08	0.00
2014	2.72	46.59	22.46	0.00	260.00	46.92	0.0	0.0	1.59	0.08	0.03
2015	1.80	10.38	0.00	0.00	409.44	97.92	0.0	0.0	0.49	0.22	0.01

Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
	CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
2016	0.41	8.44	0.77	0.00	587.14	13.77	0.0	0.0	0.70	0.09	0.03
2017	2.34	474.24	1.93	47.30	4,345.04	27.23	0.0	0.0	2.28	0.26	0.09
2018	21.20	14.40	0.54	215.59	7,593.68	1,564.13	0.0	0.0	1.54	0.03	0.14
2019	9.44	26.31	0.84	142.61	6,752.51	1,463.44	0.0	0.0	2.08	0.03	0.02
2020	8.49	70.99	0.12	84.78	5,834.06	1,613.33	0.0	0.0	2.40	0.16	0.26
2021	20.02	85.63	0.23	169.34	8,395.52	1,576.48	0.0	0.0	4.18	0.02	0.35
2022	59.96	78.19	0.00	499.09	8,794.53	1,546.21	0.0	0.0	8.41	0.06	0.31
2023	35.52	49.97	0.00	493.37	8,108.36	1,626.31	0.0	0.0	6.32	0.98	0.02
2024	16.00	42.95	0.00	0.00	7,449.84	1,710.99	0.0	0.0	12.08	0.94	0.07
2025	7.12	0.14	0.00	0.00	1,439.06	270.36	0.0	0.0	1.24	0.27	8.17

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

Year	Foreign & Domestic	Shoreside hake		
	At-sea	CA	OR	WA
1989	212.0	0.0	0.0	0.0
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
1989	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 10,000 pounds in April
	Reduced Widow Rockfish trip limit to 3,000 pounds in October
	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.

Year	Management action
1990	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.
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.
	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.

Year	Management action
1999	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
2001	Similar actions as in 2000 with the following changes
	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.
	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.
	Retention of Widow Rockfish prohibited beginning in October. For gears other than midwater trawl.
2002	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.
2003	Widow fishery closed most of the year except for a small amount of bycatch and small monthly limits in some months.
2004	Widow fishery closed most of the year except for a small amount of bycatch and small monthly limits in some months

Year	Management action
2005	Widow fishery closed most of the year except for a small amount of bycatch and small monthly limits in some months.
2006	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
2007	Seasonal changes of trawl RCA boundaries and periodic closures within certain latitude boundaries (e.g., north of Cape Alava at 48°10' N latitude to the U.S.-Canada border) started in 2007. Small monthly limits for Widow Rockfish (less than 1,500 pounds per month)
	Widow bycatch cap in the non-tribal limited entry whiting trawl fishery increased from 200 mt to 220 mt in May.
	Limited entry whiting trawl fishery closed due to attainment of 220 mt widow bycatch in July
	Limited entry whiting trawl fishery re-opened with 275 mt widow bycatch cap in October
2008	Widow bycatch cap of 275 mt adopted for limited entry whiting trawl fishery.
	Limited entry whiting trawl fishery closed due to attainment of canary bycatch in August
	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)	Commercial 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

Year	OFL (mt) (termed ABC prior to 2011)	ABC (mt)	ACL (mt) (termed OY prior to 2011)	Commercial Landings (mt)	Estimated Total Catch (mt)
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
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
1971	0	0	0	0	0	2	0	0	0	0	0
1977	0	0	0	25	0	0	0	0	0	0	0
1978	50	0	0	0	0	0	10	0	0	0	0
1979	32	0	0	0	0	0	4	0	3	0	0
1980	101	0	0	6	0	19	0	0	1	0	1
1981	72	3	0	59	20	31	0	0	6	0	0
1982	88	7	0	89	34	41	1	0	11	0	0
1983	158	16	0	46	10	25	18	0	9	0	0
1984	146	20	0	29	12	22	25	0	4	0	0
1985	149	20	0	25	35	16	81	0	5	0	0
1986	108	17	0	25	28	27	59	0	16	0	0
1987	88	29	0	49	74	36	37	0	3	0	0
1988	79	30	7	37	42	14	43	0	2	0	0
1989	81	49	14	30	67	16	81	0	7	0	0
1990	80	58	11	39	62	30	74	0	8	0	0
1991	74	76	20	17	63	15	23	0	12	0	0
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
1993	60	69	28	5	49	8	19	0	39	0	0
1994	54	67	13	2	21	16	34	0	38	0	0
1995	53	47	17	11	14	16	14	0	7	0	0
1996	49	33	17	11	12	13	4	0	10	0	0
1997	54	49	16	10	21	19	2	0	20	0	0
1998	41	43	26	3	11	8	5	0	15	0	0
1999	38	28	21	5	19	11	1	0	3	1	0
2000	14	0	3	16	44	19	0	0	8	1	0
2001	12	6	2	10	38	11	0	0	2	3	0
2002	22	8	7	1	15	10	1	0	2	0	0
2003	7	0	1	0	0	5	0	0	0	0	0
2004	5	1	1	0	0	12	0	0	0	0	0
2005	4	2	0	0	0	10	0	0	1	0	0
2006	7	3	2	0	0	8	0	0	4	1	0
2007	7	16	4	0	0	3	0	0	4	1	0
2008	5	18	5	0	0	12	0	0	2	0	0
2009	19	30	0	0	0	14	0	0	0	0	0
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
2011	6	14	9	0	1	6	0	0	1	0	0
2012	14	19	5	0	4	7	0	0	3	1	0
2013	20	21	1	0	6	6	0	0	9	1	0
2014	18	20	3	0	5	7	0	0	12	2	0
2015	37	23	0	0	18	4	0	0	9	7	2
2016	27	14	0	0	7	1	0	0	2	4	2
2017	22	41	0	3	33	3	0	0	5	2	3
2018	31	25	7	10	60	4	0	0	3	4	7
2019	34	33	1	2	48	12	0	0	7	3	2
2020	29	18	0	2	31	5	0	0	13	8	1
2021	42	18	2	4	39	7	0	0	10	2	0
2022	13	10	0	12	46	4	0	0	2	5	2
2023	20	7	0	7	51	7	0	0	3	7	5
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
1971	0	0	0	0	0	408	0	0	0	0	0
1977	0	0	0	96	0	0	0	0	0	0	0
1978	303	0	0	0	0	0	66	0	0	0	0
1979	436	0	0	0	0	0	34	0	7	0	0
1980	727	0	0	13	0	1,900	0	0	1	0	2
1981	444	250	0	1,340	1,746	3,100	0	0	19	0	0
1982	932	792	0	3,144	3,960	4,100	1	0	84	0	0
1983	1,352	478	0	1,411	321	2,500	103	0	31	0	0
1984	1,722	2,394	0	1,278	1,525	2,199	126	0	11	0	0
1985	1,853	2,233	0	1,176	3,971	1,600	557	0	8	0	0
1986	1,740	1,425	0	1,032	2,788	2,650	321	0	120	0	0
1987	998	865	0	1,744	2,198	1,942	262	0	11	0	0
1988	763	916	350	1,230	1,239	700	334	0	3	0	0
1989	1,007	1,099	700	1,325	1,843	800	450	0	23	0	0
1990	1,202	1,320	550	1,510	1,454	1,500	612	0	37	0	0
1991	1,596	1,569	997	761	1,442	750	268	0	75	0	0
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
1993	1,682	1,410	1,400	231	1,156	400	275	0	238	0	0
1994	1,359	1,464	650	112	557	842	410	0	554	0	0
1995	1,539	1,066	850	519	296	800	175	0	22	0	0
1996	1,364	845	704	437	316	650	132	0	80	0	0
1997	2,063	1,231	557	382	620	950	80	0	212	0	0
1998	1,368	1,013	865	125	291	400	179	0	318	0	0
1999	1,420	727	952	240	514	550	1	0	104	20	0
2000	263	0	101	641	1,147	950	0	0	65	1	0
2001	139	98	2	349	960	550	0	0	4	20	0
2002	318	185	136	39	319	500	2	0	74	0	0
2003	234	0	46	0	0	208	0	0	0	0	0
2004	26	18	3	0	0	508	0	0	0	0	0
2005	27	48	0	0	0	399	0	0	4	0	0
2006	79	58	7	0	0	461	0	0	36	1	0
2007	12	302	104	0	0	250	0	0	64	1	0
2008	8	274	76	0	0	1,086	0	0	27	0	0
2009	170	316	0	0	0	1,079	0	0	0	0	0
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**
2011	32	246	93	0	30	550	0	0	17	0	0
2012	136	353	241	0	95	688	0	0	9	7	0
2013	153	365	39	0	215	486	0	0	102	1	0
2014	134	324	106	0	150	700	0	0	242	4	0
2015	263	295	0	0	530	400	0	0	45	11	2
2016	143	254	0	0	210	100	0	0	38	4	24
2017	316	864	0	158	949	125	0	0	73	3	23
2018	645	161	12	507	1,492	350	0	0	32	7	10
2019	566	346	50	90	1,149	600	0	0	47	6	7
2020	593	228	0	83	759	233	0	0	134	15	1
2021	850	226	8	183	890	307	0	0	67	3	0
2022	272	185	0	502	1,025	180	0	0	11	7	3
2023	376	135	0	316	1,125	571	0	0	18	97	13
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
1992	214	0	1,474	0
1993	239	0	1,468	0
1994	361	3	3,458	78
1995	304	19	1,789	570
1996	332	18	2,620	540
1997	397	30	2,841	869
1998	481	32	2,431	975
1999	598	52	3,070	1,551
2000	571	33	2,845	1,004
2001	522	19	1,758	576
2002	369	3	1,204	70
2003	291	2	665	26
2004	512	19	1,670	380
2005	1,228	1	5,538	50
2006	1,295	14	6,104	594
2007	1,491	21	10,658	860
2008	1,138	36	7,324	966
2009	400	24	1,976	845
2010	980	43	4,734	1,214
2011	982	43	3,605	1,286
2012	914	46	4,779	1,291
2013	901	40	3,808	1,160
2014	773	50	3,970	1,452

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

Table 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
1978	7	0	0	0	0	0	0	0	0	0	0
1979	11	0	0	0	0	0	0	0	0	0	0
1980	27	0	0	0	0	18	0	0	0	0	0
1981	14	3	0	30	20	31	0	0	0	0	0
1982	87	6	0	71	34	40	1	0	4	0	0
1983	151	16	0	45	10	25	5	0	2	0	0
1984	144	20	0	29	12	22	10	0	2	0	0
1985	137	20	0	25	33	16	65	0	3	0	0
1986	106	17	0	22	28	27	53	0	3	0	0
1987	84	27	0	49	62	36	27	0	0	0	0
1988	67	29	6	34	41	14	39	0	2	0	0
1989	75	49	14	30	66	16	75	0	3	0	0
1990	70	58	11	32	62	30	65	0	2	0	0
1991	65	76	20	17	63	15	19	0	9	0	0
1992	45	93	22	4	26	9	21	0	15	0	0
1993	28	67	28	0	49	8	6	0	3	0	0
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
1995	8	45	17	3	13	16	0	0	0	0	0
1996	36	32	14	6	11	13	2	0	1	0	0
1997	42	46	11	10	20	19	0	0	9	0	0
1998	27	42	14	2	11	8	2	0	3	0	0
1999	29	27	19	3	18	10	0	0	0	0	0
2000	8	0	2	9	42	19	0	0	3	0	0
2001	2	6	0	4	35	10	0	0	0	0	0
2002	17	8	2	1	15	10	1	0	0	0	0
2003	3	0	0	0	0	5	0	0	0	0	0
2004	3	0	1	0	0	12	0	0	0	0	0
2005	0	2	0	0	0	10	0	0	0	0	0
2006	6	3	1	0	0	8	0	0	2	1	0
2007	6	16	4	0	0	3	0	0	3	1	0
2008	5	18	5	0	0	12	0	0	0	0	0
2009	8	29	0	0	0	14	0	0	0	0	0
2010	7	21	1	0	0	11	0	0	0	2	0
2011	0	5	7	0	1	5	0	0	0	0	0
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
2013	0	7	1	0	3	5	0	0	0	0	0
2014	0	4	2	0	1	7	0	0	0	0	0
2015	0	22	0	0	14	4	0	0	0	0	1
2016	0	13	0	0	6	1	0	0	0	0	2
2017	0	36	0	0	31	3	0	0	0	0	3
2018	0	25	7	0	46	4	0	0	0	0	7
2019	0	16	1	0	34	12	0	0	0	0	1
2020	0	15	0	0	25	5	0	0	0	2	0
2021	0	12	2	0	31	6	0	0	0	0	0
2022	0	8	0	0	45	4	0	0	0	0	2
2023	0	5	0	0	48	7	0	0	0	1	5
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
1978	107	0	0	0	0	0	0	0	0	0	0
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
1980	404	0	0	0	0	1,775	0	0	0	0	0
1981	205	109	0	598	600	3,050	0	0	0	0	0
1982	834	174	0	2,382	1,019	3,944	1	0	18	0	0
1983	1,283	475	0	1,365	321	2,480	55	0	3	0	0
1984	1,678	600	0	1,278	360	2,194	89	0	5	0	0
1985	1,762	589	0	1,176	963	1,591	477	0	4	0	0
1986	1,704	680	0	913	939	2,594	188	0	5	0	0
1987	968	805	0	1,742	1,837	1,940	186	0	0	0	0
1988	692	886	298	1,132	1,209	695	290	0	3	0	0
1989	919	1,099	695	1,323	1,794	799	403	0	6	0	0
1990	1,051	1,310	550	1,309	1,447	1,497	533	0	8	0	0
1991	1,308	1,566	991	761	1,413	748	164	0	23	0	0
1992	676	1,889	1,097	82	574	450	87	0	91	0	0
1993	472	1,361	1,398	0	1,155	400	57	0	3	0	0
1994	516	1,463	650	54	556	749	58	0	1	0	0
1995	167	1,027	850	68	276	800	0	0	0	0	0
1996	873	827	699	158	292	649	88	0	7	0	0
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
1998	1,019	987	699	82	291	400	84	0	46	0	0
1999	1,026	706	950	133	479	500	0	0	0	0	0
2000	157	0	100	353	1,067	948	0	0	12	0	0
2001	43	98	0	132	858	485	0	0	0	0	0
2002	294	179	99	21	319	488	2	0	0	0	0
2003	87	0	0	0	0	208	0	0	0	0	0
2004	7	0	3	0	0	506	0	0	0	0	0
2005	0	48	0	0	0	399	0	0	0	0	0
2006	74	58	6	0	0	361	0	0	5	1	0
2007	11	302	54	0	0	150	0	0	23	1	0
2008	8	274	75	0	0	600	0	0	0	0	0
2009	81	315	0	0	0	759	0	0	0	0	0
2010	54	231	50	0	0	539	0	0	0	5	0
2011	0	63	84	0	30	250	0	0	0	0	0
2012	0	80	73	0	0	163	0	0	0	7	0
2013	0	190	26	0	90	153	0	0	0	0	0
2014	0	91	52	0	30	229	0	0	0	0	0
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
2016	0	156	0	0	36	28	0	0	0	0	24
2017	0	209	0	0	223	100	0	0	0	0	23
2018	0	161	12	0	495	200	0	0	0	0	10
2019	0	55	49	0	176	597	0	0	0	0	1
2020	0	61	0	0	134	233	0	0	0	3	0
2021	0	53	8	0	135	300	0	0	0	0	0
2022	0	44	0	0	281	129	0	0	0	0	3
2023	0	28	0	0	312	320	0	0	0	2	13
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
25.5	3.473	4.649

True Age	Standard Deviation CAP	Standard Deviation SWFSC
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				

Parameter	Initial value	Number estimated	Bounds (low, high)	Prior distribution
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)	

Parameter	Initial value	Number estimated	Bounds (low, high)	Prior distribution
Length-weight slope	3.0100		(-3-10)	

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	
	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

	Parameter	Estimate	SD
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)	43.398	2.729	Bottom trawl	
Size_DblN_top_-logit_-BottomTrawl(1)	2.500	167.835	Bottom trawl	

Selectivity Parameter	Estimate	SD	Fleet	Time block
Size_DblN_-ascend_se_-BottomTrawl(1)	4.593	0.427	Bottom trawl	
Retain_L_infl_-BottomTrawl(1)	3.783	178.045	Bottom trawl	
Retain_L_width_-BottomTrawl(1)	0.997	21.093	Bottom trawl	
Size_DblN_peak_-MidwaterTrawl(2)	36.965	0.741	Midwater trawl	
Size_DblN_top_-logit_-MidwaterTrawl(2)	-9.421	14.639	Midwater trawl	
Size_DblN_-ascend_se_-MidwaterTrawl(2)	2.866	0.311	Midwater trawl	
Size_DblN_-descend_se_-MidwaterTrawl(2)	3.935	0.720	Midwater trawl	
Size_DblN_end_-logit_-MidwaterTrawl(2)	-1.385	1.071	Midwater trawl	
Retain_L_-asymptote_logit_-MidwaterTrawl(2)	5.765	0.175	Midwater trawl	
Size_DblN_peak_-Hake(3)	33.557	1.991	Hake	
Size_DblN_top_-logit_Hake(3)	2.498	167.928	Hake	
Size_DblN_-ascend_se_Hake(3)	2.115	1.159	Hake	
Size_DblN_peak_-Net(4)	42.600	0.897	Net	
Size_DblN_top_-logit_Net(4)	2.509	167.839	Net	

Selectivity Parameter	Estimate	SD	Fleet	Time block
Size_DblN_-ascend_se_Net(4)	3.556	0.213	Net	
Size_DblN_peak_-HnL(5)	23.554	0.071	Hook and Line	
Size_DblN_top_-logit_HnL(5)	2.502	167.255	Hook and Line	
SizeSpline_-GradLo_-Triennial(7)	0.119	0.036	Other	
SizeSpline_-GradHi_-Triennial(7)	0.038	0.099	Other	
SizeSpline_Val_1_-Triennial(7)	-1.824	0.317	Other	
SizeSpline_Val_3_-Triennial(7)	0.435	0.264	Other	
SizeSpline_-GradLo_-NWFSC(8)	0.467	0.112	NWFSC	
SizeSpline_-GradHi_-NWFSC(8)	-0.109	0.057	NWFSC	
SizeSpline_Val_1_-NWFSC(8)	-2.224	0.245	NWFSC	
SizeSpline_Val_3_-NWFSC(8)	-0.114	0.151	NWFSC	
Size_DblN_peak_-BottomTrawl(1)_-BLK4repl_1916	38.980	0.817	Bottom trawl	1916
Size_DblN_-ascend_se_-BottomTrawl(1)_-BLK4repl_1916	3.428	0.256	Bottom trawl	1916

Selectivity Parameter	Estimate	SD	Fleet	Time block
Retain_L_infl_-BottomTrawl(1)_-BLK2repl_1982	27.221	4.001	Bottom trawl	1982
Retain_L_infl_-BottomTrawl(1)_-BLK2repl_1990	27.521	3.996	Bottom trawl	1990
Retain_L_width_-BottomTrawl(1)_-BLK2repl_1982	0.969	2.195	Bottom trawl	1982
Retain_L_width_-BottomTrawl(1)_-BLK2repl_1990	1.831	1.801	Bottom trawl	1990
Retain_L_-asymptote_logit_-BottomTrawl(1)_-BLK1repl_1982	1.719	0.267	Bottom trawl	1982
Retain_L_-asymptote_logit_-BottomTrawl(1)_-BLK1repl_1990	0.783	0.338	Bottom trawl	1990
Retain_L_-asymptote_logit_-BottomTrawl(1)_-BLK1repl_1998	0.108	0.156	Bottom trawl	1998
Size_DblN_peak_-MidwaterTrawl(2)_-BLK7repl_1916	38.683	0.998	Midwater trawl	1916
Size_DblN_peak_-MidwaterTrawl(2)_-BLK7repl_1983	38.016	0.442	Midwater trawl	1983
Size_DblN_peak_-MidwaterTrawl(2)_-BLK7repl_2002	37.398	1.842	Midwater trawl	2002

Selectivity Parameter	Estimate	SD	Fleet	Time block
Size_DblN_-ascend_se_-MidwaterTrawl(2)_-BLK7repl_1916	3.370	0.286	Midwater trawl	1916
Size_DblN_-ascend_se_-MidwaterTrawl(2)_-BLK7repl_1983	3.081	0.139	Midwater trawl	1983
Size_DblN_-ascend_se_-MidwaterTrawl(2)_-BLK7repl_2002	2.796	0.670	Midwater trawl	2002
Size_DblN_-descend_se_-MidwaterTrawl(2)_-BLK7repl_1916	4.242	0.967	Midwater trawl	1916
Size_DblN_-descend_se_-MidwaterTrawl(2)_-BLK7repl_1983	3.056	0.599	Midwater trawl	1983
Size_DblN_-descend_se_-MidwaterTrawl(2)_-BLK7repl_2002	-1.417	10.413	Midwater trawl	2002
Size_DblN_end_-logit_-MidwaterTrawl(2)_-BLK7repl_1916	-1.934	3.017	Midwater trawl	1916
Size_DblN_end_-logit_-MidwaterTrawl(2)_-BLK7repl_1983	-0.424	0.332	Midwater trawl	1983
Size_DblN_end_-logit_-MidwaterTrawl(2)_-BLK7repl_2002	1.563	1.818	Midwater trawl	2002

Selectivity Parameter	Estimate	SD	Fleet	Time block
Retain_L_-asymptote_logit_-MidwaterTrawl(2)_-BLK12repl_1983	1.660	0.138	Midwater trawl	1983
Retain_L_-asymptote_logit_-MidwaterTrawl(2)_-BLK12repl_2002	1.854	0.407	Midwater trawl	2002
Retain_L_-asymptote_logit_-MidwaterTrawl(2)_-BLK12repl_2011	8.947	0.207	Midwater trawl	2011
Size_DblN_peak_-Hake(3)_-BLK11repl_1916	42.792	0.621	Hake	1916
Size_DblN_top_-logit_Hake(3)_-BLK11repl_1916	2.504	167.727	Hake	1916
Size_DblN_-ascend_se_-Hake(3)_-BLK11repl_1916	3.722	0.129	Hake	1916
Size_DblN_peak_-HnL(5)_-BLK5repl_1916	37.219	2.018	Hook and Line	1916
Size_DblN_-ascend_se_-HnL(5)_-BLK5repl_1916	3.747	0.470	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

Description	Values
Log-likelihoods	
Total	7,664.490
Indices	13.022
Discard	5,410.790
Length-frequency data	854.968
Age-frequency data	1,366.280
Recruitment	17.840
Priors	0.601
Parameter Softbound	0.983

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%		
Proxy Spawning Biomass (mt) SB40\%	32,693.40	27028.38 - 38358.42

Quantity	Estimate	~95% Confidence Interval
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 (number)	Estiamted total catch (mt)	1-SPR (%)	Relative exploitation rate (%)
1916	156,922.0	81,591.3	81,591.3	0.998	33,824.8	78.3	0.006	0.096
1917	156,798.0	81,526.4	81,526.4	0.997	33,794.6	121.8	0.009	0.149
1918	156,634.0	81,437.6	81,437.6	0.996	33,760.6	140.1	0.011	0.172
1919	156,456.0	81,340.2	81,340.2	0.995	33,723.3	96.7	0.007	0.119
1920	156,324.0	81,269.4	81,269.4	0.994	33,683.6	99.0	0.007	0.122
1921	156,190.0	81,198.8	81,198.8	0.993	33,640.3	82.1	0.006	0.101
1922	156,072.0	81,138.7	81,138.7	0.993	33,593.3	71.2	0.005	0.088
1923	155,962.0	81,084.6	81,084.6	0.992	33,542.1	78.2	0.006	0.096
1924	155,841.0	81,025.7	81,025.7	0.991	33,485.9	50.3	0.004	0.062
1925	155,741.0	80,980.9	80,980.9	0.991	33,424.9	62.2	0.005	0.077
1926	155,622.0	80,926.5	80,926.5	0.990	33,357.6	94.6	0.007	0.117
1927	155,463.0	80,850.6	80,850.6	0.989	33,283.1	78.6	0.006	0.097
1928	155,311.0	80,780.5	80,780.5	0.988	33,201.9	89.4	0.007	0.111
1929	155,138.0	80,700.3	80,700.3	0.987	33,112.7	86.8	0.007	0.108
1930	154,958.0	80,617.2	80,617.2	0.986	33,015.1	112.4	0.009	0.139
1931	154,740.0	80,515.0	80,515.0	0.985	32,907.7	99.9	0.008	0.124

Year	Total biomass (mt)	Spawning biomass (mt)	Age 4+ biomass (mt)	Spawning depletion (mt)	Age-0 recruits (number)	Estiamted total catch (mt)	1-SPR (%)	Relative exploitation rate (%)
1932	154,521.0	80,414.7	80,414.7	0.984	32,790.8	100.1	0.008	0.124
1933	154,288.0	80,308.2	80,308.2	0.983	32,663.0	85.9	0.007	0.107
1934	154,050.0	80,202.7	80,202.7	0.981	32,523.9	90.9	0.007	0.113
1935	153,789.0	80,086.4	80,086.4	0.980	32,371.9	98.1	0.007	0.123
1936	153,498.0	79,957.1	79,957.1	0.978	32,205.6	110.7	0.008	0.138
1937	153,171.0	79,810.9	79,810.9	0.976	32,022.9	103.5	0.008	0.130
1938	152,825.0	79,657.6	79,657.6	0.975	31,821.6	83.8	0.006	0.105
1939	152,470.0	79,503.1	79,503.1	0.973	31,599.1	76.6	0.006	0.096
1940	152,088.0	79,338.7	79,338.7	0.971	31,354.9	120.6	0.009	0.152
1941	151,627.0	79,133.6	79,133.6	0.968	31,087.2	129.5	0.010	0.164
1942	151,119.0	78,907.4	78,907.4	0.965	30,796.8	146.6	0.011	0.186
1943	150,553.0	78,653.6	78,653.6	0.962	30,491.4	490.6	0.037	0.624
1944	149,614.0	78,184.8	78,184.8	0.957	30,173.7	960.7	0.070	1.229
1945	148,200.0	77,437.7	77,437.7	0.947	29,842.0	1,621.4	0.115	2.094
1946	146,159.0	76,317.7	76,317.7	0.934	29,500.7	1,160.1	0.086	1.520
1947	144,612.0	75,488.2	75,488.2	0.924	29,188.8	643.2	0.050	0.852
1948	143,577.0	74,968.3	74,968.3	0.917	28,903.5	477.7	0.038	0.637

Year	Total biomass (mt)	Spawning biomass (mt)	Age 4+ biomass (mt)	Spawning depletion (mt)	Age-0 recruits (number)	Estiamted total catch (mt)	1-SPR (%)	Relative exploitation rate (%)
1949	142,676.0	74,537.0	74,537.0	0.912	28,647.8	374.4	0.030	0.502
1950	141,837.0	74,149.6	74,149.6	0.907	28,440.6	423.6	0.034	0.571
1951	140,906.0	73,711.4	73,711.4	0.902	28,306.4	553.9	0.044	0.751
1952	139,816.0	73,174.5	73,174.5	0.895	28,275.2	541.5	0.043	0.740
1953	138,724.0	72,625.7	72,625.7	0.889	28,391.5	469.3	0.038	0.646
1954	137,704.0	72,102.6	72,102.6	0.882	28,699.8	447.9	0.037	0.621
1955	136,728.0	71,580.9	71,580.9	0.876	29,238.8	465.0	0.038	0.650
1956	135,789.0	71,046.3	71,046.3	0.869	30,020.0	600.9	0.049	0.846
1957	134,818.0	70,444.1	70,444.1	0.862	30,973.5	760.7	0.062	1.080
1958	133,849.0	69,781.0	69,781.0	0.854	31,880.7	701.6	0.058	1.005
1959	133,154.0	69,210.3	69,210.3	0.847	32,404.4	671.6	0.056	0.970
1960	132,741.0	68,740.6	68,740.6	0.841	32,333.3	810.9	0.068	1.180
1961	132,460.0	68,303.1	68,303.1	0.836	31,945.6	677.1	0.057	0.991
1962	132,566.0	68,082.8	68,082.8	0.833	31,951.1	757.5	0.064	1.113
1963	132,800.0	67,965.8	67,965.8	0.832	32,897.2	433.4	0.038	0.638
1964	133,508.0	68,177.3	68,177.3	0.834	34,288.7	601.3	0.051	0.882
1965	134,174.0	68,400.3	68,400.3	0.837	35,901.2	259.5	0.023	0.379

Year	Total biomass (mt)	Spawning biomass (mt)	Age 4+ biomass (mt)	Spawning depletion (mt)	Age-0 recruits (number)	Estiamted total catch (mt)	1-SPR (%)	Relative exploitation rate (%)
1966	135,317.0	68,894.5	68,894.5	0.843	37,707.8	4,287.3	0.276	6.223
1967	132,867.0	67,091.8	67,091.8	0.821	37,601.9	4,821.3	0.307	7.186
1968	130,427.0	65,184.8	65,184.8	0.798	35,264.1	2,388.5	0.182	3.664
1969	130,789.0	64,943.4	64,943.4	0.795	30,232.5	847.5	0.073	1.305
1970	133,200.0	65,808.1	65,808.1	0.805	122,196.0	851.9	0.073	1.294
1971	136,676.0	66,821.4	66,821.4	0.818	99,956.7	1,091.6	0.090	1.634
1972	141,735.0	67,782.7	67,782.7	0.829	13,345.6	918.9	0.076	1.356
1973	149,014.0	69,398.2	69,398.2	0.849	11,233.5	1,155.7	0.092	1.665
1974	157,532.0	71,765.6	71,765.6	0.878	15,183.6	902.6	0.072	1.258
1975	165,409.0	75,488.5	75,488.5	0.924	31,899.0	872.1	0.067	1.155
1976	170,359.0	80,425.5	80,425.5	0.984	10,256.2	1,319.8	0.092	1.641
1977	171,950.0	85,074.3	85,074.3	1.041	58,846.6	1,084.9	0.069	1.275
1978	171,774.0	88,327.4	88,327.4	1.081	89,905.6	1,568.9	0.094	1.776
1979	170,472.0	89,031.8	89,031.8	1.089	28,591.9	9,387.0	0.395	10.543
1980	161,948.0	83,945.9	83,945.9	1.027	49,513.4	21,837.3	0.662	26.014
1981	143,144.0	71,767.2	71,767.2	0.878	82,299.8	27,856.2	0.777	38.815
1982	121,352.0	57,299.3	57,299.3	0.701	43,122.7	25,994.2	0.822	45.366

Year	Total biomass (mt)	Spawning biomass (mt)	Age 4+ biomass (mt)	Spawning depletion (mt)	Age-0 recruits (number)	Estiamted total catch (mt)	1-SPR (%)	Relative exploitation rate (%)
1983	103,480.0	45,393.9	45,393.9	0.555	27,392.4	10,427.7	0.682	22.972
1984	102,562.0	43,186.6	43,186.6	0.528	53,948.9	10,317.0	0.681	23.889
1985	102,467.0	42,501.5	42,501.5	0.520	39,210.0	9,290.7	0.645	21.860
1986	103,022.0	42,842.6	42,842.6	0.524	18,399.5	9,774.3	0.647	22.814
1987	102,172.0	43,168.0	43,168.0	0.528	46,999.6	13,093.8	0.713	30.332
1988	96,672.2	41,332.2	41,332.2	0.506	29,661.5	10,644.7	0.669	25.754
1989	92,938.1	40,140.5	40,140.5	0.491	21,699.7	12,708.7	0.723	31.661
1990	85,931.4	37,236.3	37,236.3	0.456	33,530.1	10,462.0	0.721	28.096
1991	79,894.6	34,378.7	34,378.7	0.421	60,103.3	6,796.9	0.634	19.771
1992	78,322.9	33,588.5	33,588.5	0.411	22,467.7	6,412.1	0.631	19.090
1993	77,111.5	32,781.4	32,781.4	0.401	28,210.3	8,347.4	0.705	25.464
1994	73,533.0	30,596.2	30,596.2	0.374	25,483.1	6,716.8	0.661	21.953
1995	72,549.8	29,689.1	29,689.1	0.363	15,866.4	6,912.3	0.682	23.282
1996	70,649.2	28,872.4	28,872.4	0.353	11,661.6	6,319.7	0.660	21.888
1997	68,858.3	28,770.5	28,770.5	0.352	17,856.5	6,652.7	0.671	23.123
1998	65,584.0	28,271.3	28,271.3	0.346	32,037.6	4,148.6	0.597	14.674
1999	63,709.6	28,261.6	28,261.6	0.346	42,397.3	4,102.9	0.564	14.518

Year	Total biomass (mt)	Spawning biomass (mt)	Age 4+ biomass (mt)	Spawning depletion (mt)	Age-0 recruits (number)	Estiamted total catch (mt)	1-SPR (%)	Relative exploitation rate (%)
2000	62,153.0	28,001.1	28,001.1	0.343	34,930.2	4,031.6	0.494	14.398
2001	62,020.1	27,863.6	27,863.6	0.341	19,260.0	1,961.8	0.312	7.041
2002	64,927.0	28,698.7	28,698.7	0.351	17,113.7	429.2	0.091	1.495
2003	69,966.8	30,632.0	30,632.0	0.375	16,640.2	41.6	0.009	0.136
2004	75,226.7	33,229.4	33,229.4	0.407	54,864.1	87.0	0.018	0.262
2005	79,867.2	36,142.5	36,142.5	0.442	10,597.2	195.5	0.033	0.541
2006	84,059.3	38,933.8	38,933.8	0.476	42,738.6	213.7	0.033	0.549
2007	88,027.0	41,457.6	41,457.6	0.507	10,638.3	239.6	0.034	0.578
2008	92,290.0	43,498.6	43,498.6	0.532	100,500.0	263.5	0.036	0.606
2009	96,621.7	45,463.8	45,463.8	0.556	13,201.4	176.6	0.024	0.388
2010	101,902.0	47,419.0	47,419.0	0.580	65,765.9	165.9	0.022	0.350
2011	107,888.0	49,761.0	49,761.0	0.609	9,730.7	212.0	0.024	0.426
2012	114,657.0	52,230.2	52,230.2	0.639	6,415.9	270.4	0.030	0.518
2013	120,694.0	55,363.4	55,363.4	0.677	56,498.8	469.8	0.046	0.848
2014	125,628.0	58,835.4	58,835.4	0.720	23,475.2	721.9	0.065	1.227
2015	128,843.0	62,101.9	62,101.9	0.760	18,395.3	879.7	0.072	1.417
2016	131,046.0	64,772.2	64,772.2	0.792	100,038.0	1,039.4	0.081	1.605

Year	Total biomass (mt)	Spawning biomass (mt)	Age 4+ biomass (mt)	Spawning depletion (mt)	Age-0 recruits (number)	Estiamted total catch (mt)	1-SPR (%)	Relative exploitation rate (%)
2017	133,120.0	66,368.3	66,368.3	0.812	27,891.7	6,345.9	0.368	9.562
2018	130,219.0	64,402.2	64,402.2	0.788	10,614.7	10,493.2	0.535	16.293
2019	123,774.0	60,464.7	60,464.7	0.740	8,288.5	9,289.4	0.527	15.363
2020	119,199.0	57,485.1	57,485.1	0.703	8,907.3	8,355.2	0.520	14.535
2021	114,524.0	55,681.8	55,681.8	0.681	18,889.1	10,866.9	0.605	19.516
2022	105,900.0	53,221.5	53,221.5	0.651	20,463.8	12,094.4	0.635	22.725
2023	94,879.6	49,723.9	49,723.9	0.608	30,114.3	10,990.6	0.624	22.103
2024	84,325.2	45,443.2	45,443.2	0.556	26,045.5	9,735.1	0.629	21.423
2025	75,265.3	40,603.1	40,603.1	0.497	31,045.4	0.0	0.709	0.000

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
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

Quantity	Estimate	~95% Confidence Interval
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
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

Quantity	Estimate	~95% Confidence Interval
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
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

Quantity	Estimate	~95% Confidence Interval
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
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

Quantity	Estimate	~95% Confidence Interval
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)

	Base model	**M = 0.1**	**M = 0.124 female, M = 0.129 male**	**MWT asymptotic selex**	**WCGBTS logistic selex**	**Including shrimp trawl**	**New WA catch recon.**	**h = 0.4**	**h = 0.6**	**h = 0.798**	**Excluding triennial**	**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
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

	Base model	M = 0.1	M = 0.124 female, M = 0.129 male	MWT asymptotic selex	WCGBTS logistic selex	Including shrimp trawl	New WA catch recon.	h = 0.4	h = 0.6	h = 0.798	Excluding triennial	Francis weighting
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	145,723	174,575	150,977	151,584	151,584	149,523	164,926	149,523	156,464	170,203
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
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

	Base model	M = 0.1	M = 0.124 female, M = 0.129 male	MWT asymptotic selex	WCGBTS logistic selex	Including shrimp trawl	New WA catch recon.	h = 0.4	h = 0.6	h = 0.798	Excluding triennial	Francis weighting
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.

Retro-spective	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

Retro-spective	Base Model	Retro 1	Retro 2	Retro 3	Retro 4	Retro 5
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
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

Retro-spective	Base Model	Retro 1	Retro 2	Retro 3	Retro 4	Retro 5
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)	10.4	10.2	10	9.8	10.6	10.8	11	11.2	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
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

log(R0)	**10.4**	**10.2**	**10**	**9.8**	**10.6**	**10.8**	**11**	**11.2**	**11.4**
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
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

log(R0)	10.4	10.2	10	9.8	10.6	10.8	11	11.2	11.4
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
Recruitment	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
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

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
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
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

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**
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
Recruitment	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
Recruitment	28.2584	23.6781	20.4737	18.3397	17.0951	16.5459	16.5574	17.0207	17.845	18.9496	20.3132

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
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

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**
Yield SPR 50	3960.85	4158.51	4459.32	4860.44	5375	5985.28	6698.61	7545.36	8576.49	9,879.4200000	10,610.2000000
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
Recruitment	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), McAllister Ianelli weighting	Log(Mean effN), Francis weighting	McAllister Ianelli weighting (base model)	Francis weighting (alternative)
BottomTrawl	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
MidwaterTrawl	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
BottomTrawl	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
MidwaterTrawl	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

Table 31: 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 F SPR=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
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 32: Summary table of 12-year projections beginning in 2021 for alternate states of nature based on the axis of uncertainty (a combination of M, h, and 2013 recruitment strength). Columns range over low, mid, and high state of nature, and rows range over different assumptions of total catch levels (discards + retained). Catches in 20XX and 20XX are allocated using the percentage of landings for each fleet in 20XX.

			State of nature					
			Low		**Base**		**High**	
Management decision	Year	catch (mt)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)	Depletion (%)
Constant catch (9,000 K)	2027	9,000	17,024	19.5	34,918	42.7	38,407	46.6
	2028	9,007	13,360	15.3	30,977	37.9	34,351	41.7
	2029	9,068	10,428	12.0	27,812	34.0	31,280	38.0
	2030	9,067	7,962	9.1	25,315	31.0	29,056	35.3
	2031	7,419	5,757	6.6	23,321	28.5	27,478	33.4
	2032	6,404	4,389	5.0	21,690	26.5	26,373	32.0
	2033	5,494	3,396	3.9	20,279	24.8	25,570	31.0
	2034	4,662	2,631	3.0	18,981	23.2	24,949	30.3
	2035	3,901	2,019	2.3	17,736	21.7	24,442	29.7
	2036	3,187	1,509	1.7	16,511	20.2	24,011	29.1
ACLp*=0.25, sigma=0.50	2027	1,790	24,754	28.4	29,822	36.5	41,750	50.7
	2028	1,750	24,698	28.3	29,349	35.9	41,257	50.1
	2029	1,791	25,148	28.9	29,596	36.2	41,522	50.4
	2030	1,863	25,952	29.8	30,369	37.2	42,422	51.5
	2031	1,939	26,957	30.9	31,461	38.5	43,786	53.2
	2032	1,991	28,047	32.2	32,692	40.0	45,448	55.2
	2033	1,993	29,155	33.5	33,935	41.5	47,258	57.4
	2034	1,969	30,261	34.7	35,143	43.0	49,121	59.6
	2035	1,929	31,364	36.0	36,298	44.4	50,970	61.9
	2036	1,886	32,473	37.3	37,406	45.8	52,765	64.1

			State of nature					
			Low		Base		High	
Management decision	Year	catch (mt)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)	Depletion (%)
ACLp*=0.45, sigma=0.50	2027	3,231	24,754	28.4	34,918	42.7	41,750	50.7
	2028	3,204	23,939	27.5	33,924	41.5	40,507	49.2
	2029	3,351	23,652	27.1	33,609	41.1	40,062	48.6
	2030	3,574	23,687	27.2	33,792	41.3	40,237	48.8
	2031	3,808	23,860	27.4	34,288	42.0	40,838	49.6
	2032	4,020	24,056	27.6	34,944	42.8	41,693	50.6
	2033	4,180	24,202	27.8	35,642	43.6	42,657	51.8
	2034	4,279	24,280	27.9	36,319	44.4	43,638	53.0
	2035	4,350	24,303	27.9	36,957	45.2	44,593	54.1
	2036	4,392	24,286	27.9	37,550	45.9	45,497	55.2

6 Figures

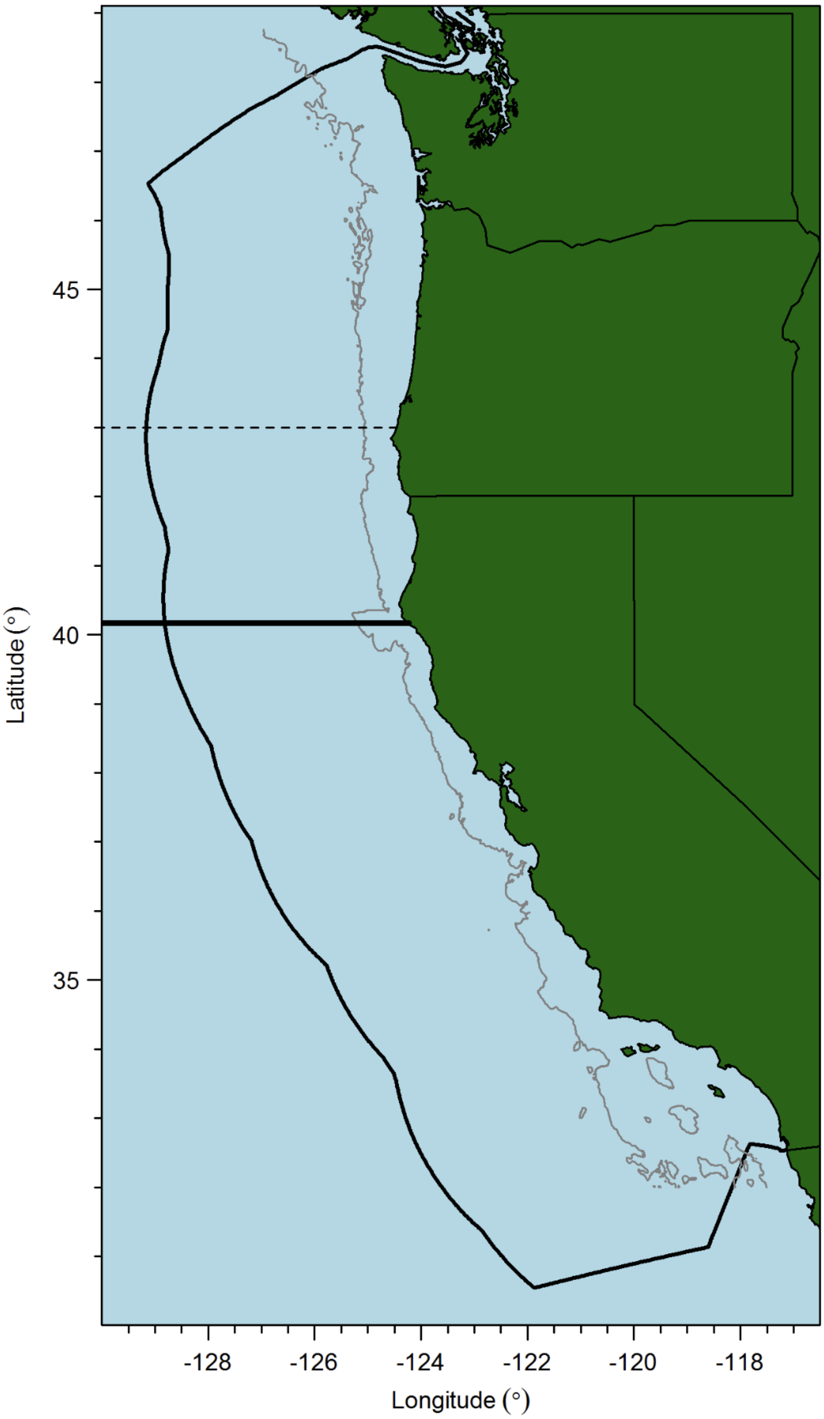


Figure 1: A map of the west coast of the U.S. with the EEZ and the 40° 10 line that divides management into northern and southern regions for some species (although not Widow Rockfish). The line at latitude 43° N latitude is where past assessment models have been stratified into two areas.

6.1 Data

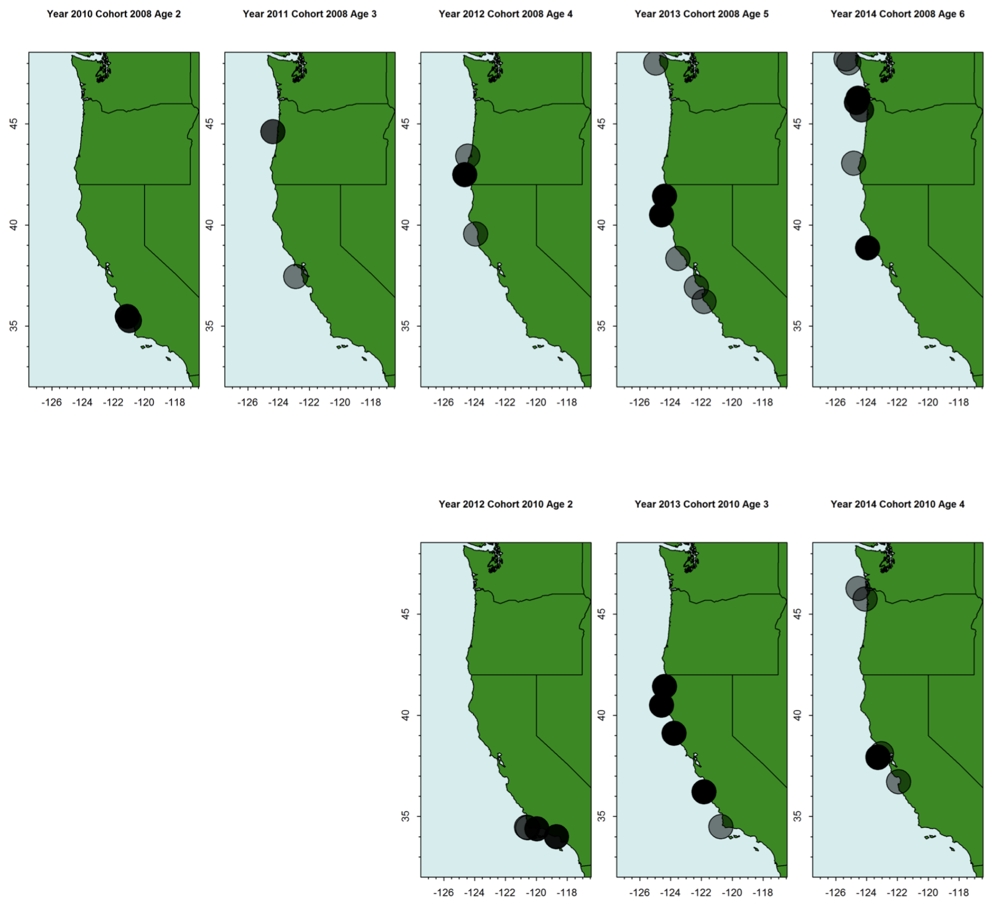


Figure 2: Observations of two cohorts (2008, top and 2010, bottom) from the NWFSC WCGBT survey data. Darker circles indicate more observations (possibly within the same tow).

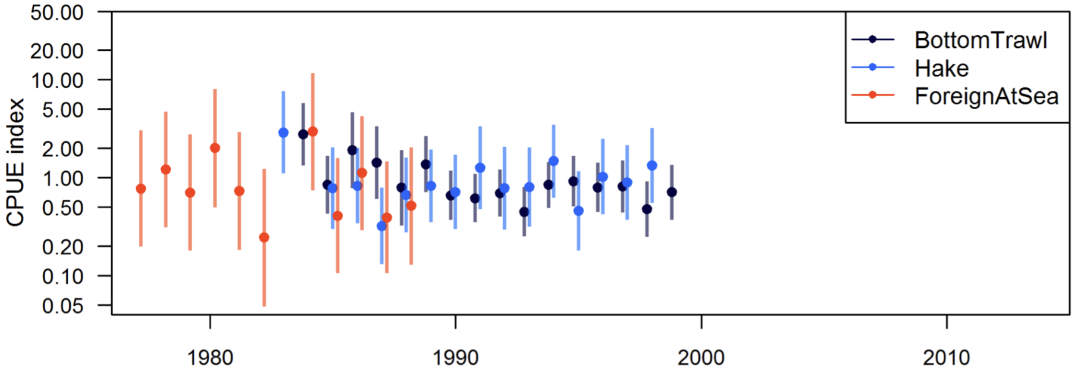


Figure 3: Fishery-dependent indices of abundance from the 2011 assessment scaled to the mean of their own series.

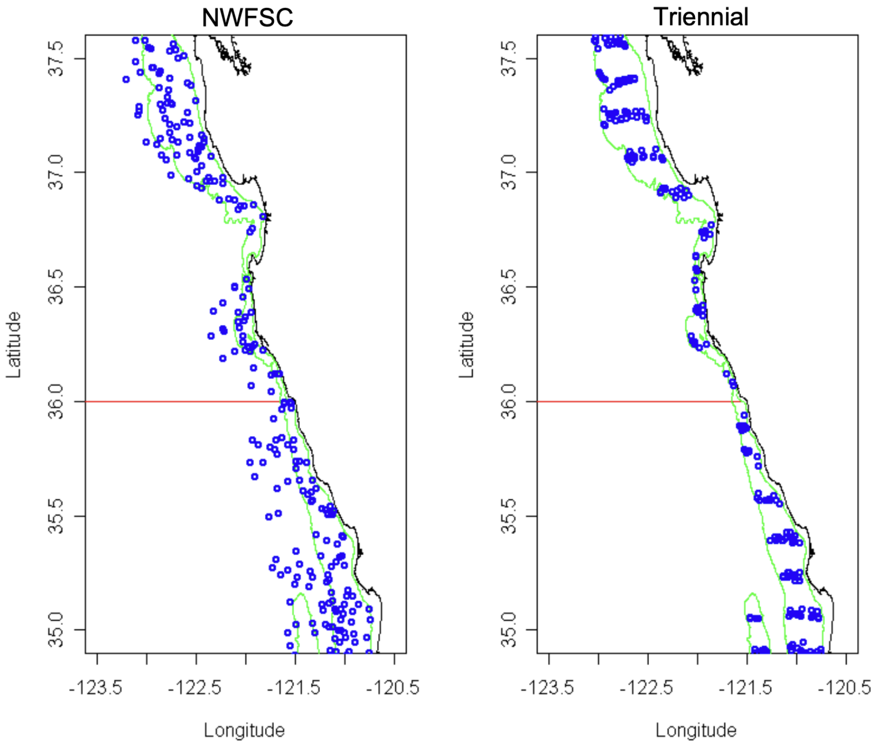


Figure 4: Survey tow locations in 2004, showing the difference in station design for the NWFSC WCBTS survey relative to the Triennial trawl survey (Figure from Stewart (2007)).

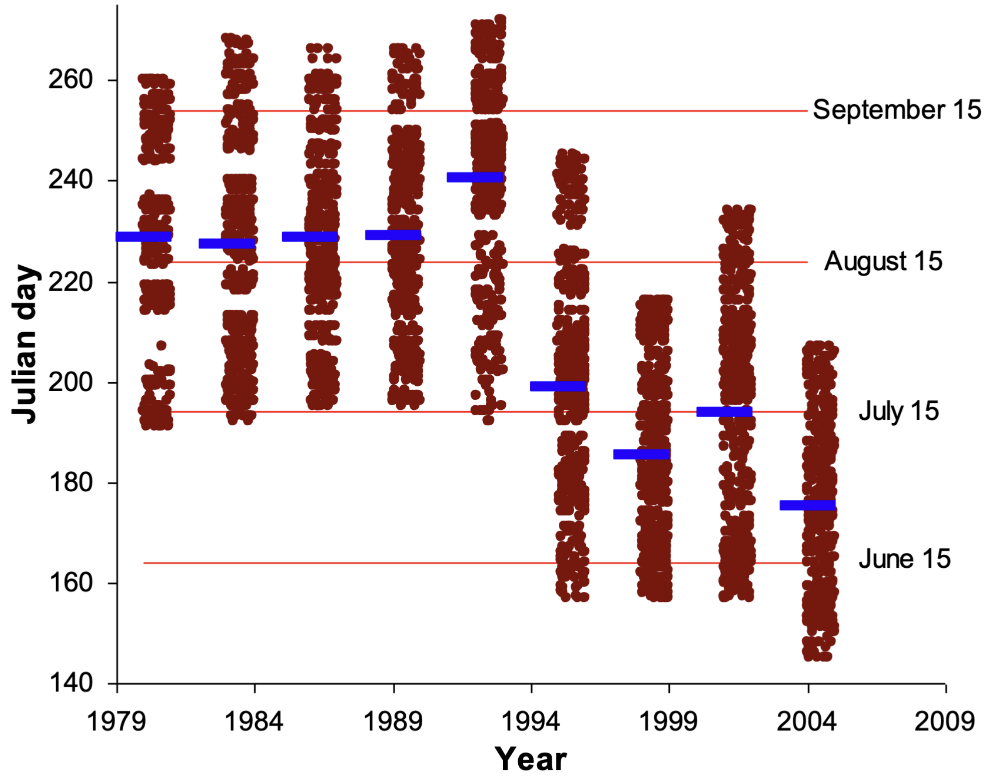


Figure 5: Distribution of dates of operation for the triennial survey (1980-2004). Solid bars show the mean date for each survey year, points represent individual hauls dates, but are jittered to allow better delineation of the distribution of individual points (Figure from (Stewart 2007)).

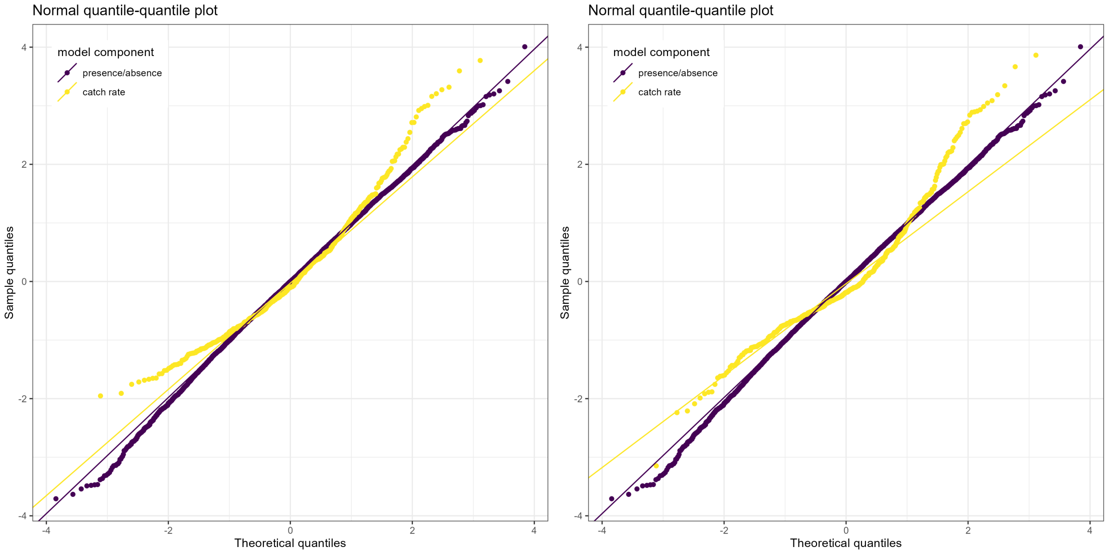


Figure 6: QQ plots for delta-gamma (panel 1) and delta-lognormal (panel 2, used in base model) sdmTMB index.

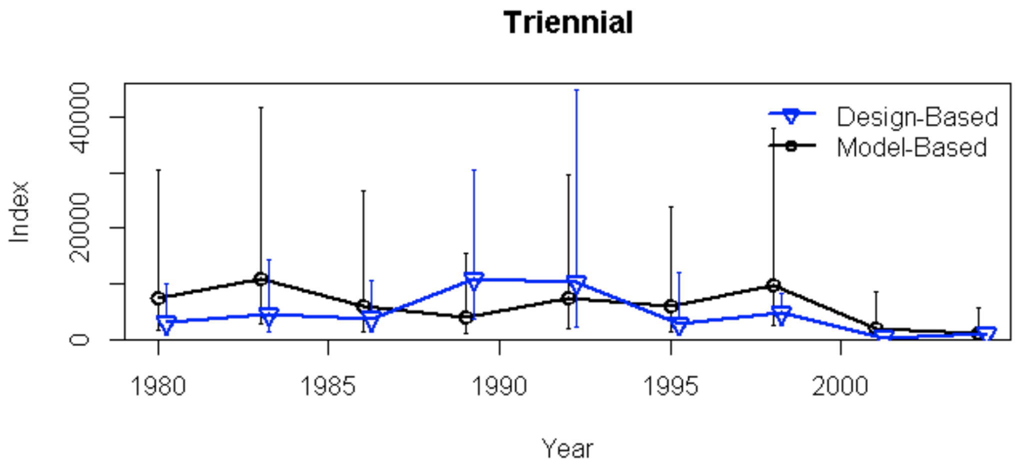


Figure 7: Model-based survey estimates for the Triennial with estimated 95% confidence intervals. based estimates and 95% confidence intervals are shown in blue for comparison.

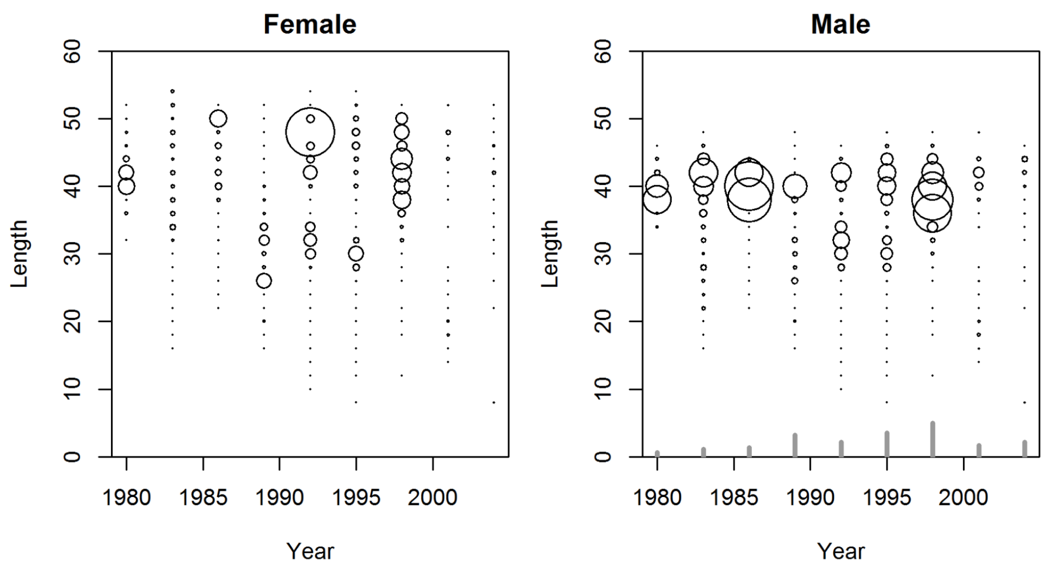


Figure 8: Expanded length compositions weighted by estimated numbers from the GLMM in each strata for the Triennial survey.

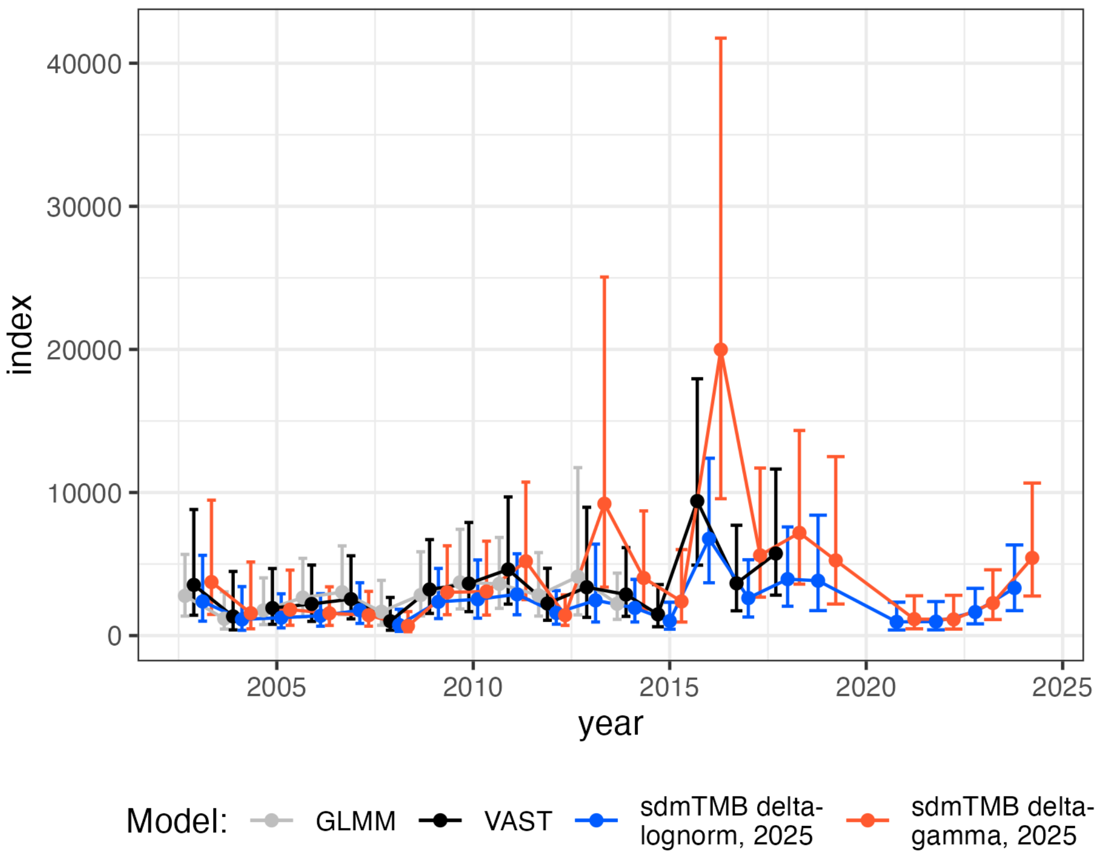


Figure 9: Comparison of the estimated index of relative abundance for the West Coast Groundfish Bottom Trawl Survey using a GLMM (gray line, 2015 stock assessment), VAST (black line, 2019 stock assessment), a delta-gamma sdmTMB index (blue line) and a delta-lognormal sdmTMB index (red line, used in base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

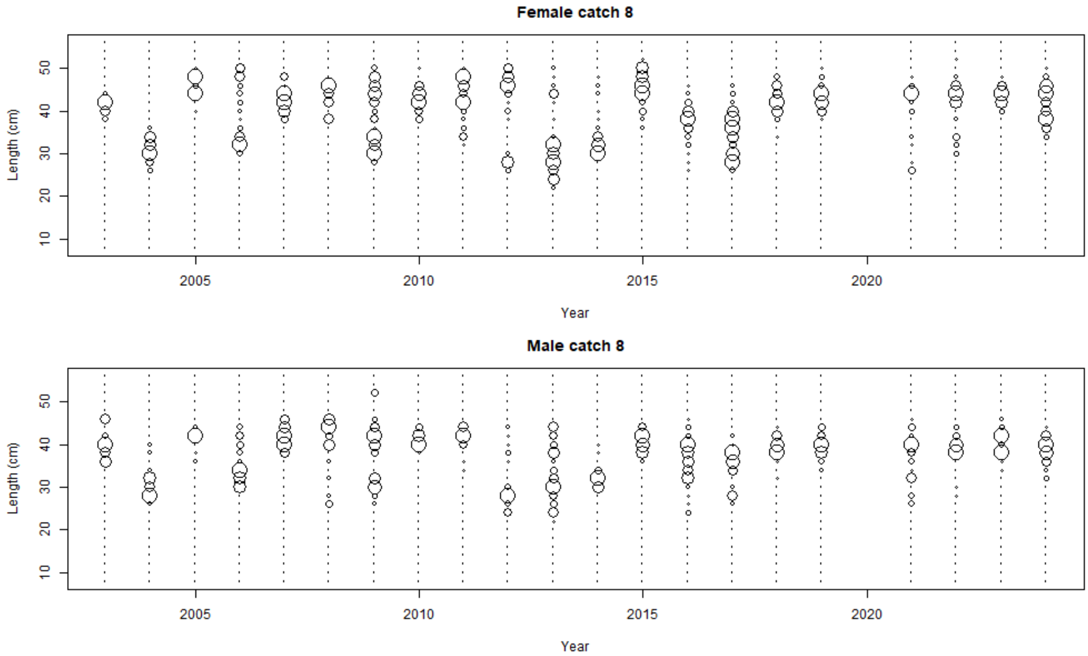


Figure 10: Expanded length compositions for the WCGBTS

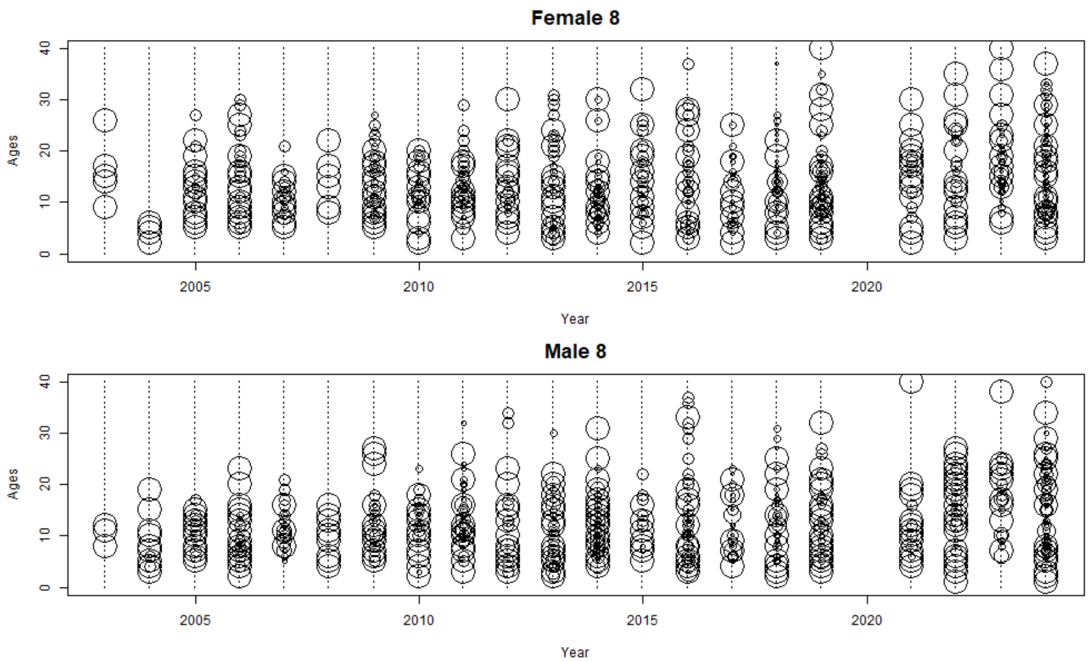
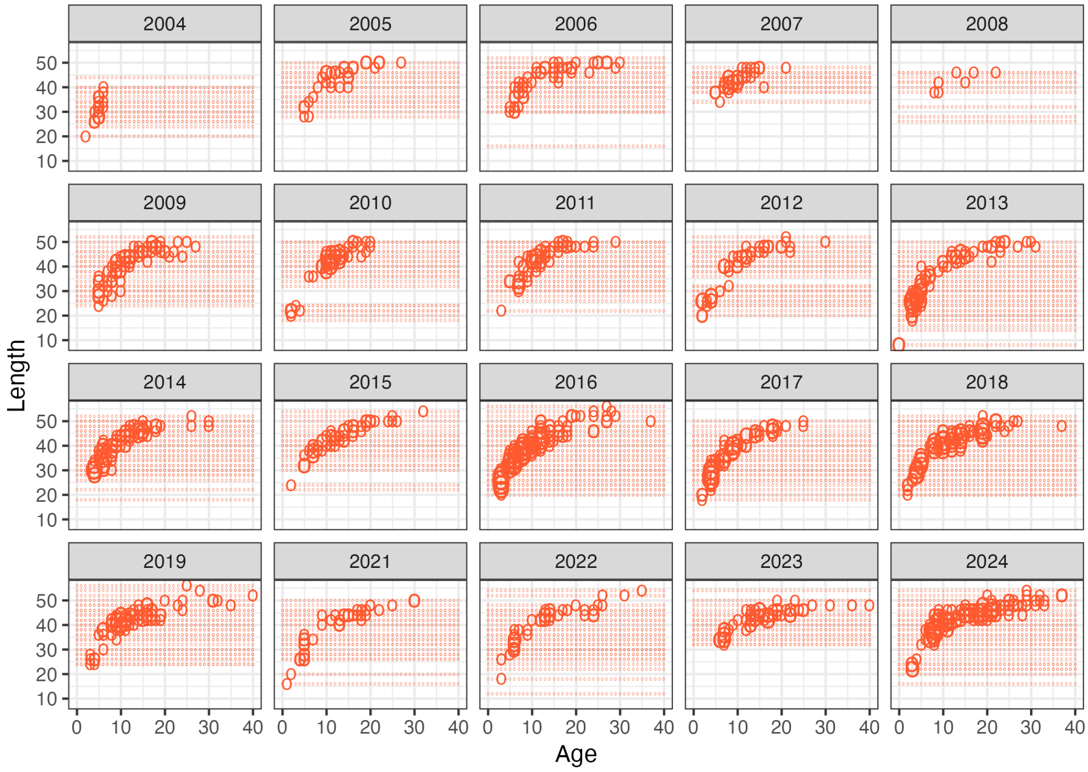


Figure 11: Expanded marginal age compositions from the WCGBTS.



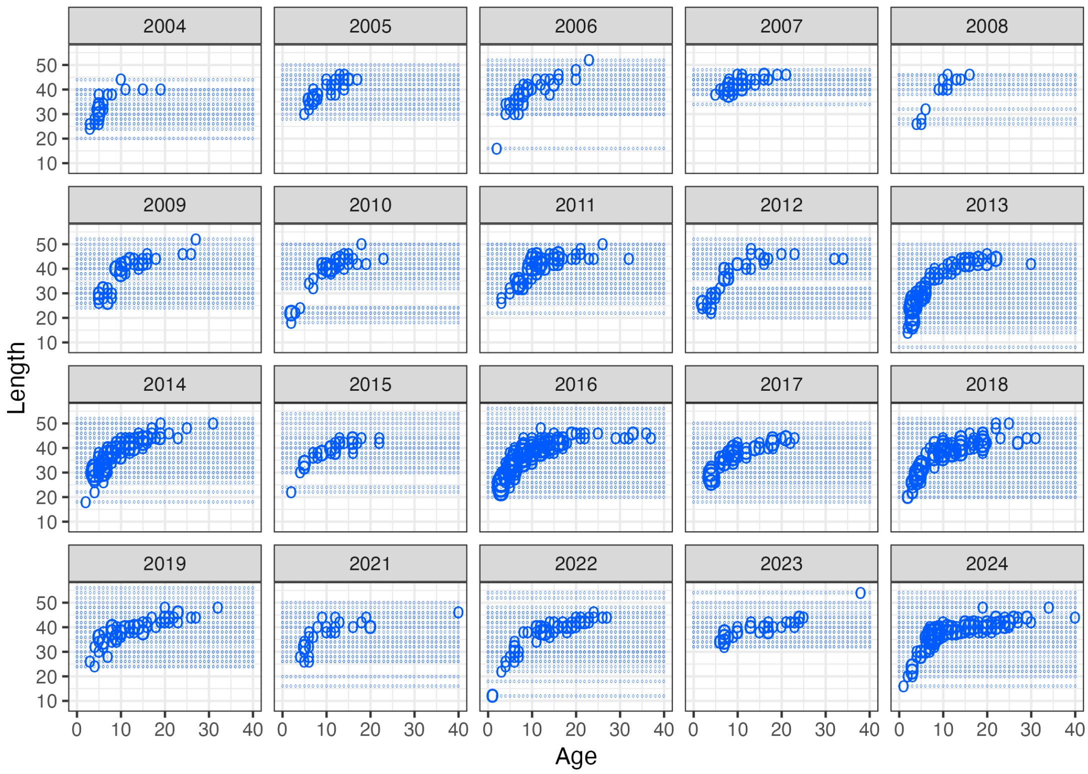


Figure 12: Conditional age-at-length from WCGBTS observations for females (red) and males (blue).

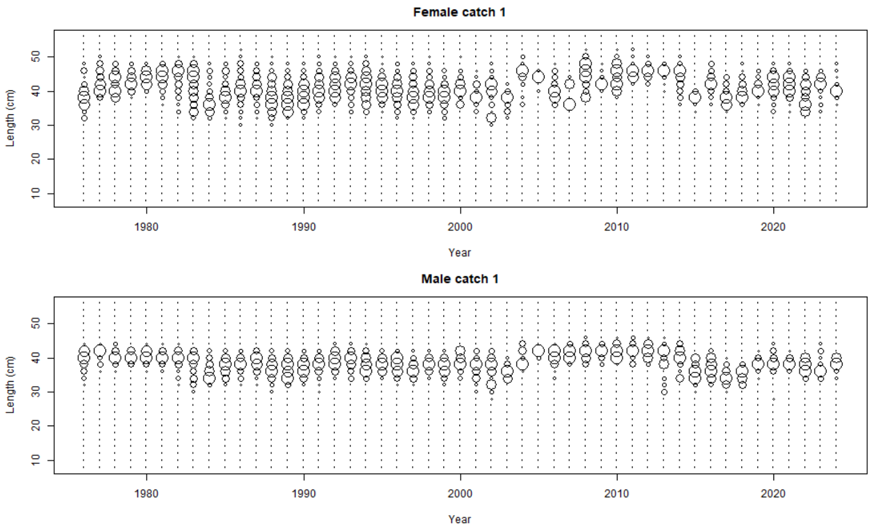


Figure 13: Expanded length compositions for the bottom trawl fishery. The area of the circle is proportional to the proportion-at-length.

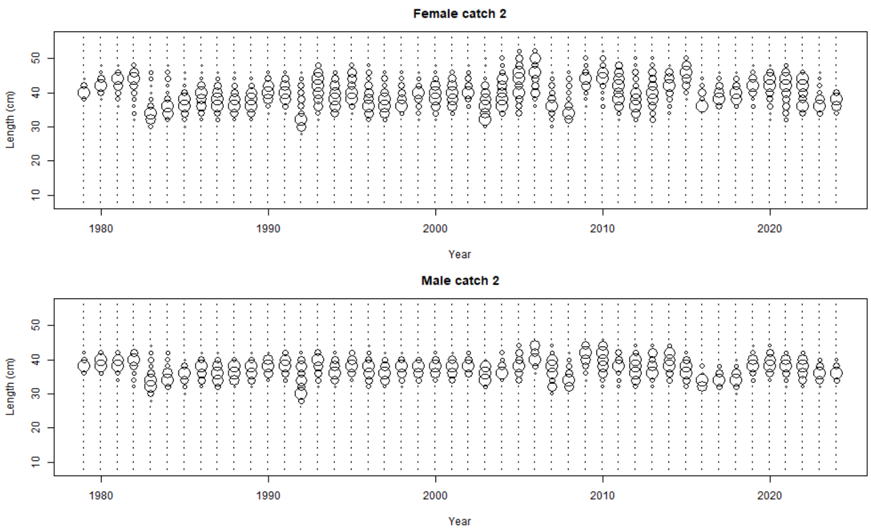


Figure 14: Expanded length compositions for the midwater trawl fishery. The area of the circle is proportional to the proportion-at-length.

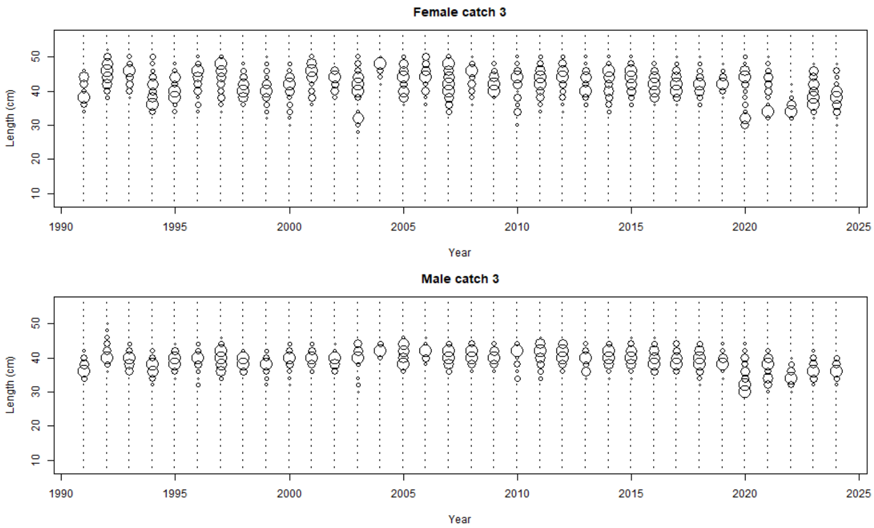


Figure 15: Expanded length compositions for the hake fishery. The area of the circle is proportional to the proportion-at-length.

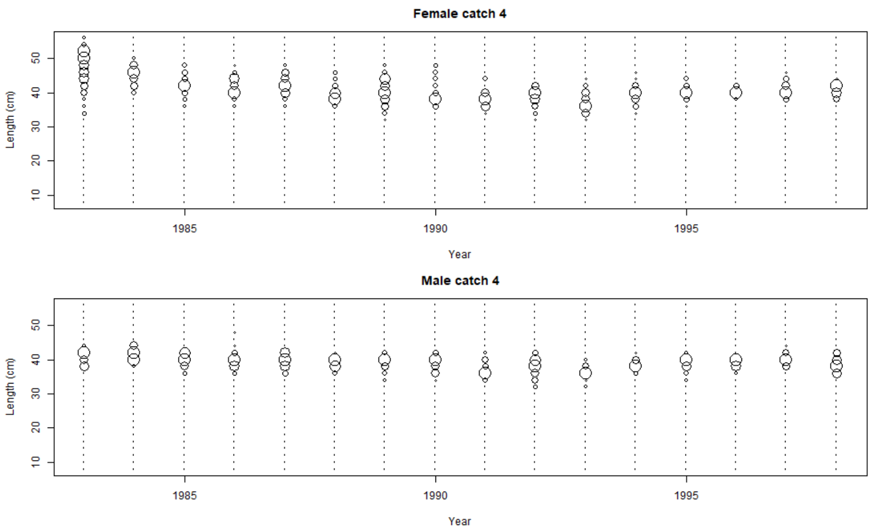


Figure 16: Expanded length compositions for the net fishery. The area of the circle is proportional to the proportion-at-length.

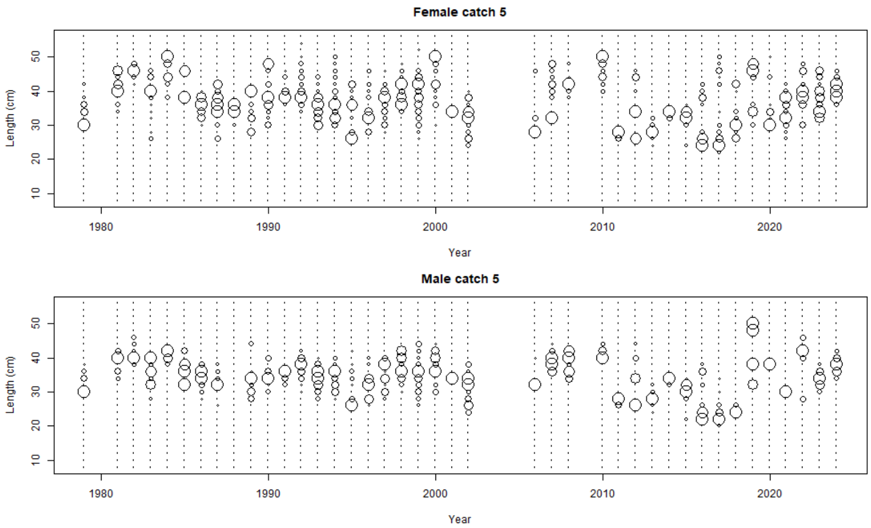


Figure 17: Expanded length compositions for the hook-and-line fishery. The area of the circle is proportional to the proportion-at-length.

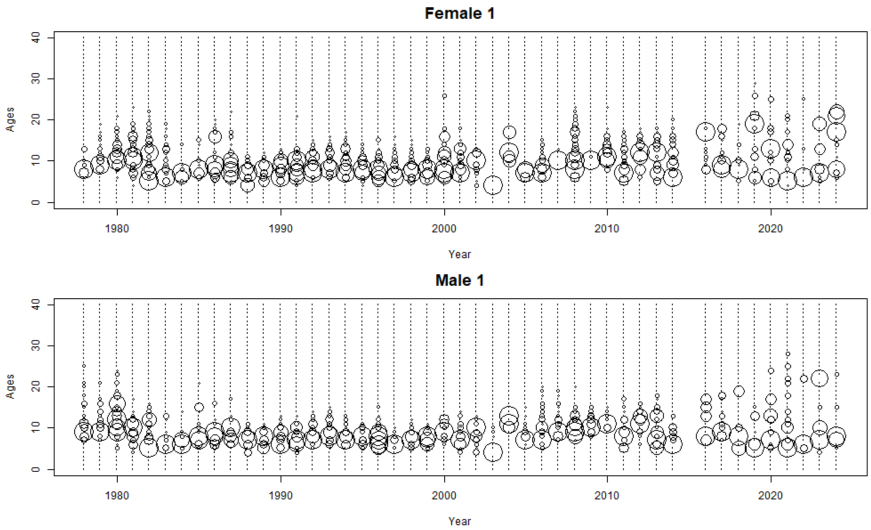


Figure 18: Expanded age compositions for the bottom trawl fishery. The area of the circle is proportional to the proportion-at-age.

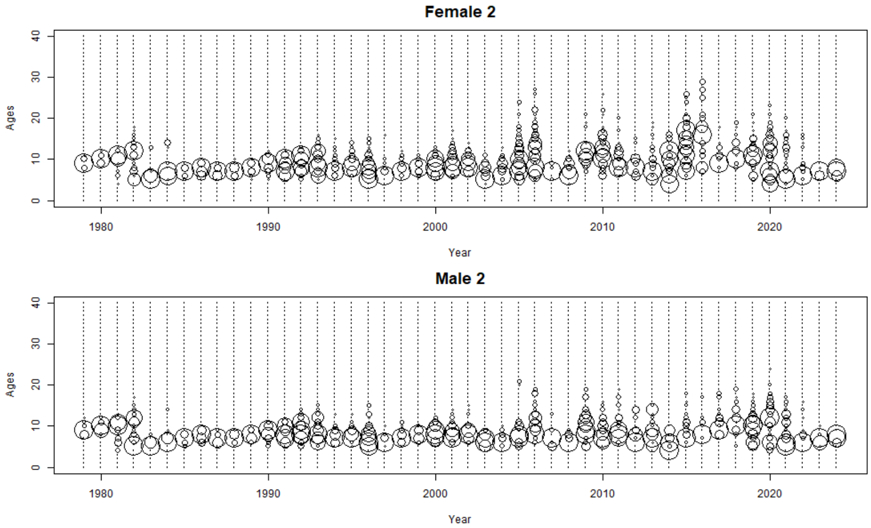


Figure 19: Expanded age compositions for the midwater trawl fishery. The area of the circles is proportional to the proportion-at-age.

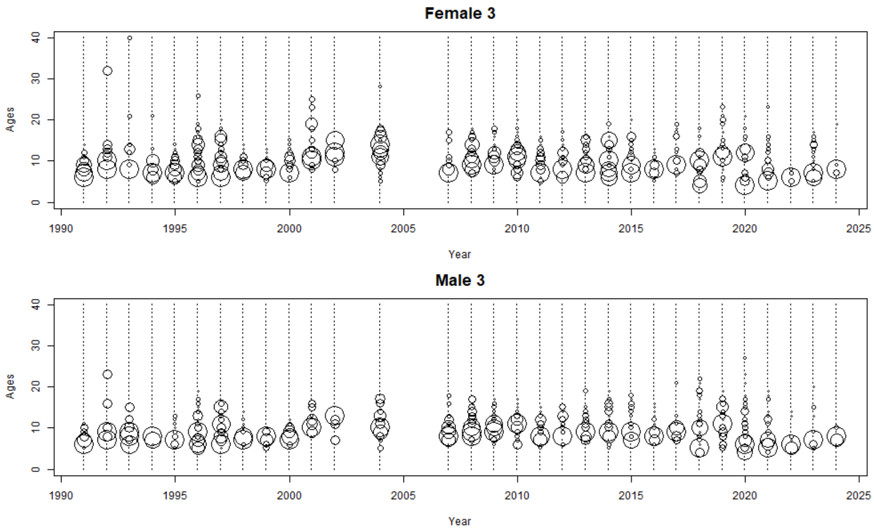


Figure 20: Expanded age compositions for the hake fishery. The area of the circles is proportional to the proportion-at-age.

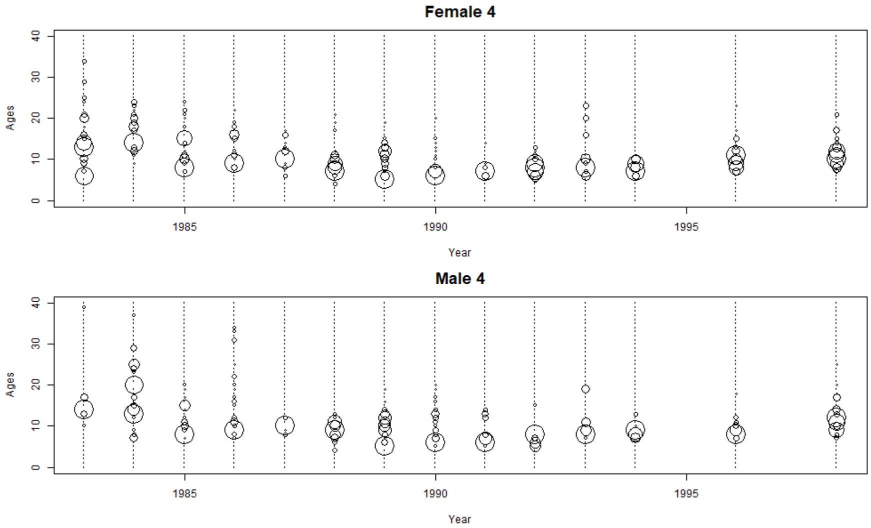


Figure 21: Expanded age compositions for the net fishery. The area of the circles is proportional to the proportion-at-age.

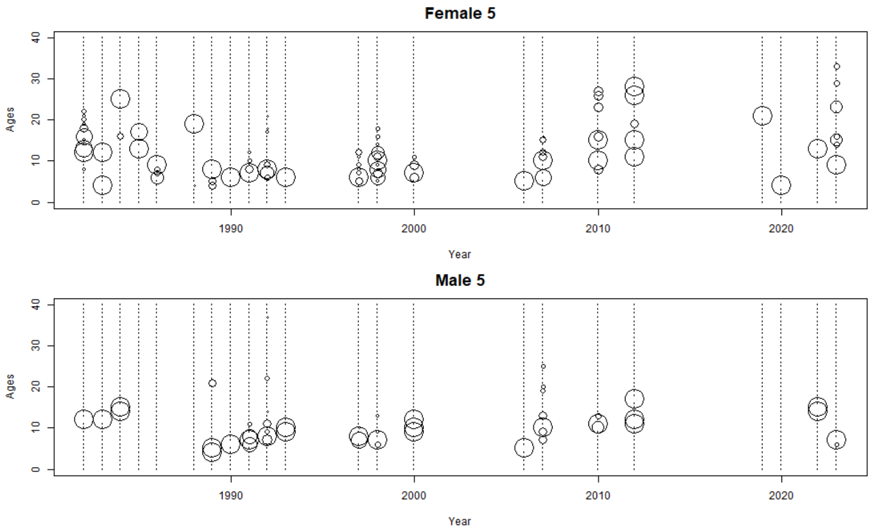


Figure 22: Expanded age compositions for the hook-and-line fishery. The area of the circles is proportional to the proportion-at-age.

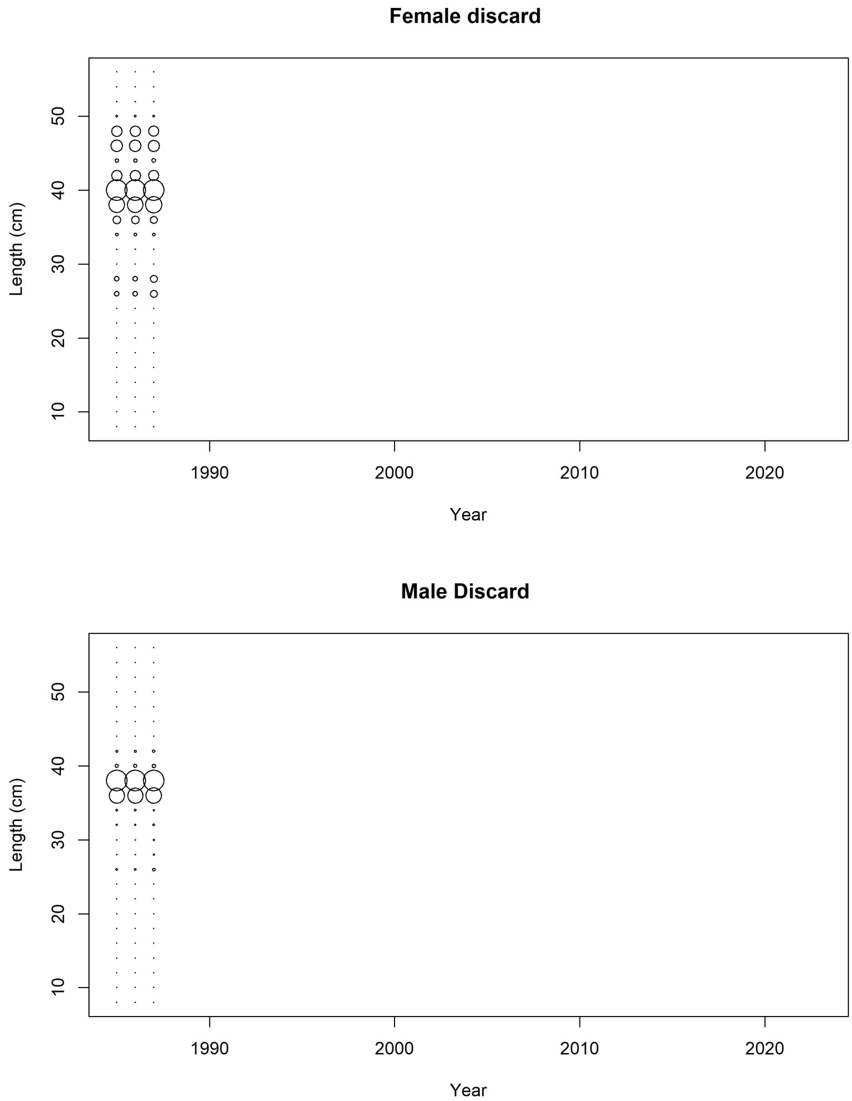


Figure 23: Length compositions for discards from the Pikitch study. The discard length comps were fitted into the model.

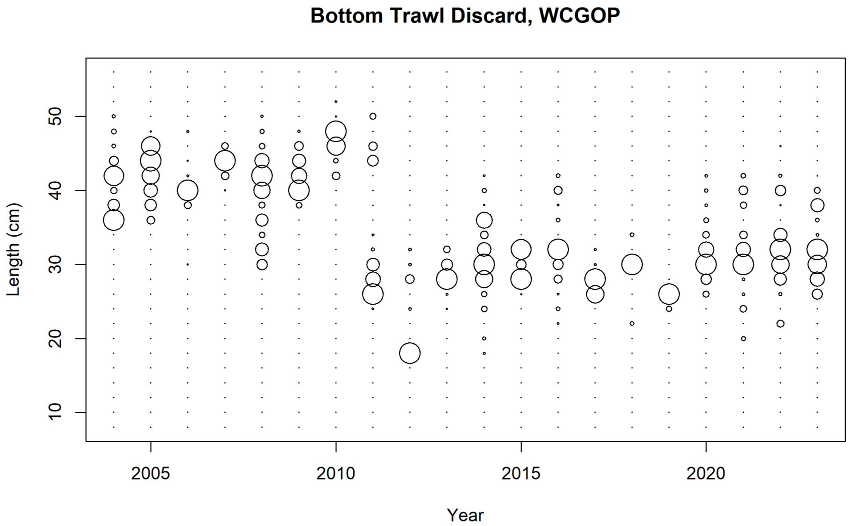


Figure 24: Length compositions of the discards for the bottom trawl.

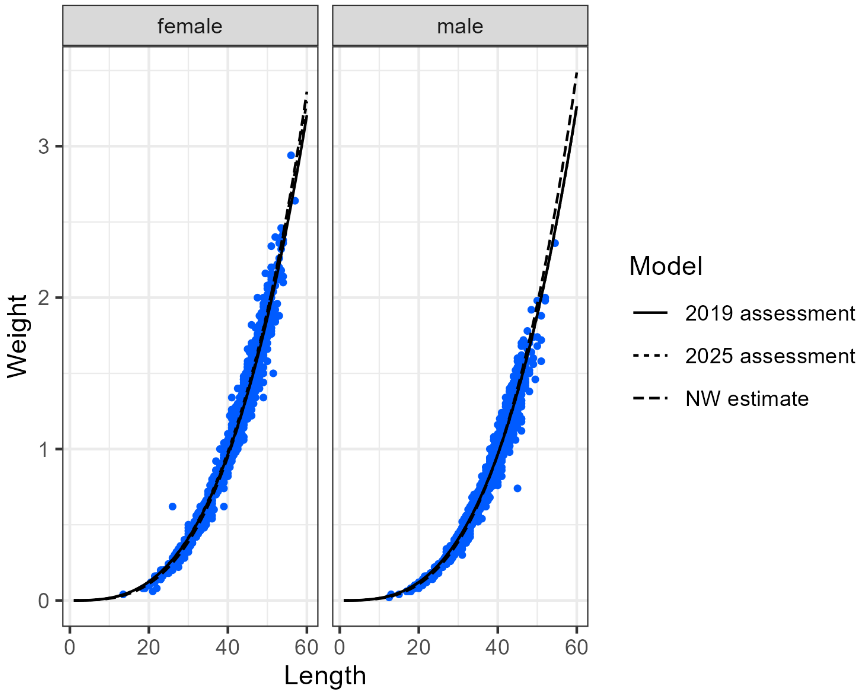


Figure 25: Fits to weight-at-length observations (dashed line) for females (left) and males (right) using observations from all data sources. The weight-at-length curve from the 2019 assessment is inidcated with a solid line.

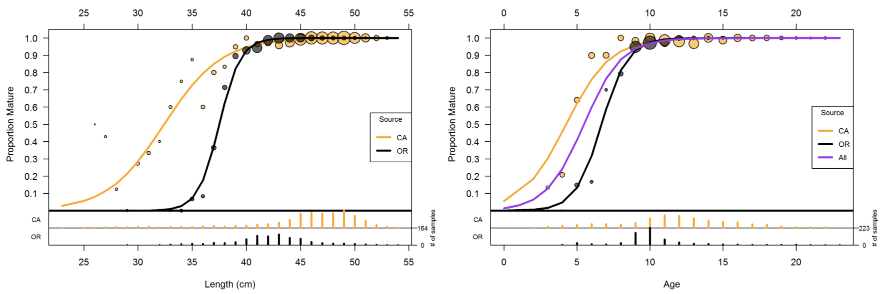


Figure 26: Maturity-at-length (left) and maturity-at-age (right) from data reported by Barss & Echeverria (1987). Circles are proportional to the number of observations at that length or age. Lines are estimated logistic curves fitted to the data. The bars at the bottom are the number of samples by each 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.

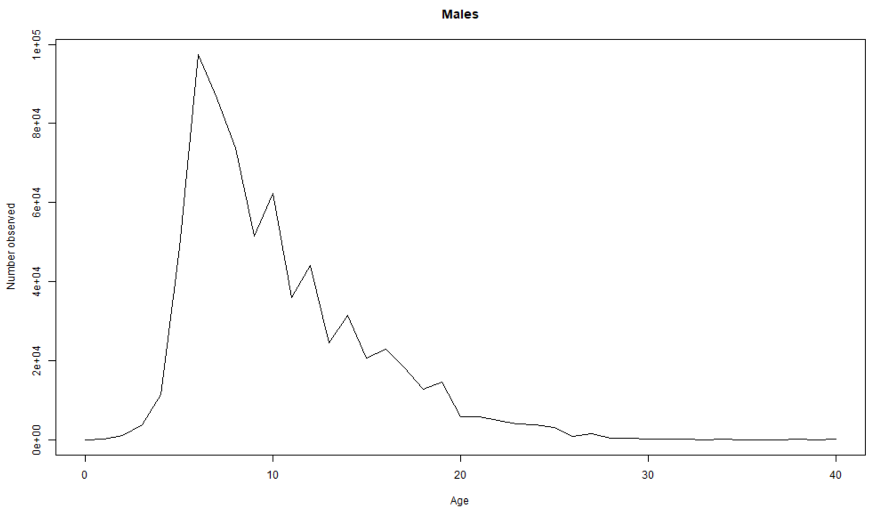


Figure 27: Number at age observed from all data for female and male Widow Rockfish.

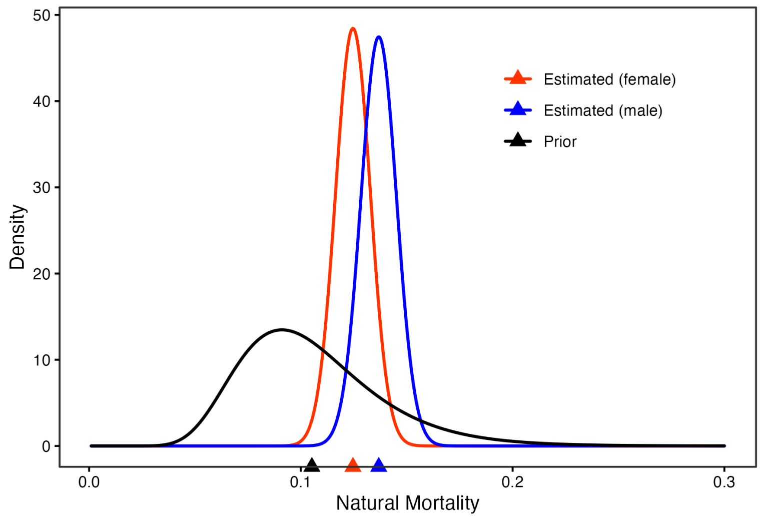


Figure 28: The prior for natural mortality (black, M, yr-1) and the estimated M for females (red) and males (blue) with asymptotic approximation to the sampling distribution. The means of each distribution are shown with triangles.

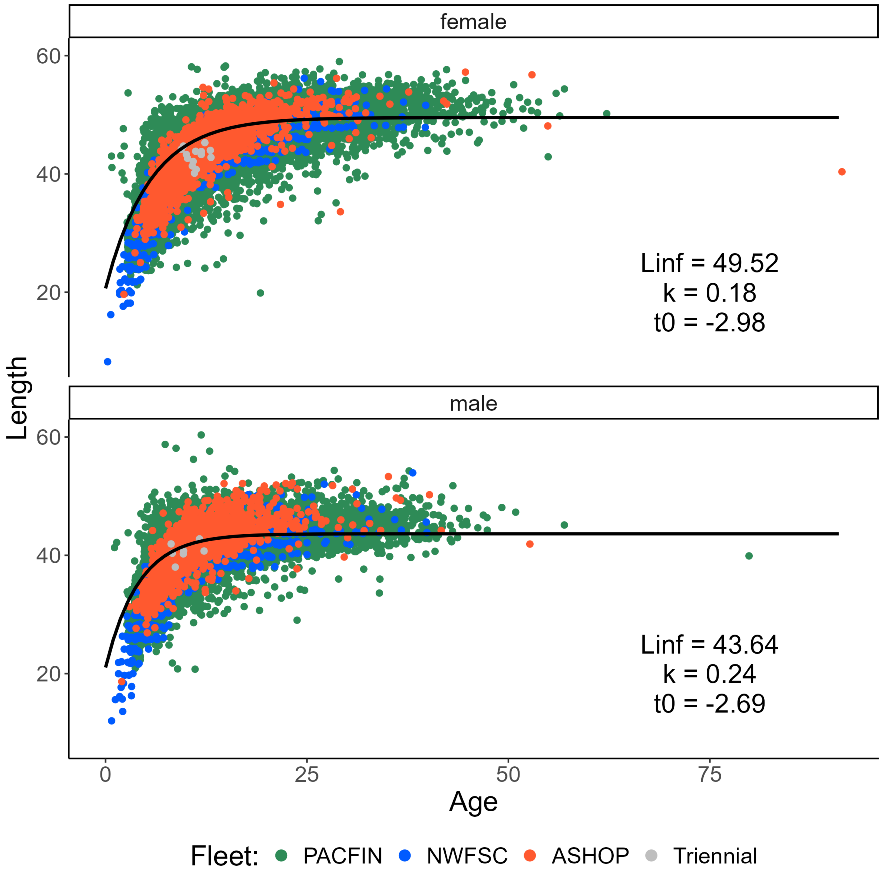


Figure 29: Length-at-age observations (points, slightly jittered) and predicted length-at-age von Bertalanffy curves for female (top) and male (bottom) Widow Rockfish collected from all fishery (BDS and At-Sea) and survey (Triennial and NWFSC) data.

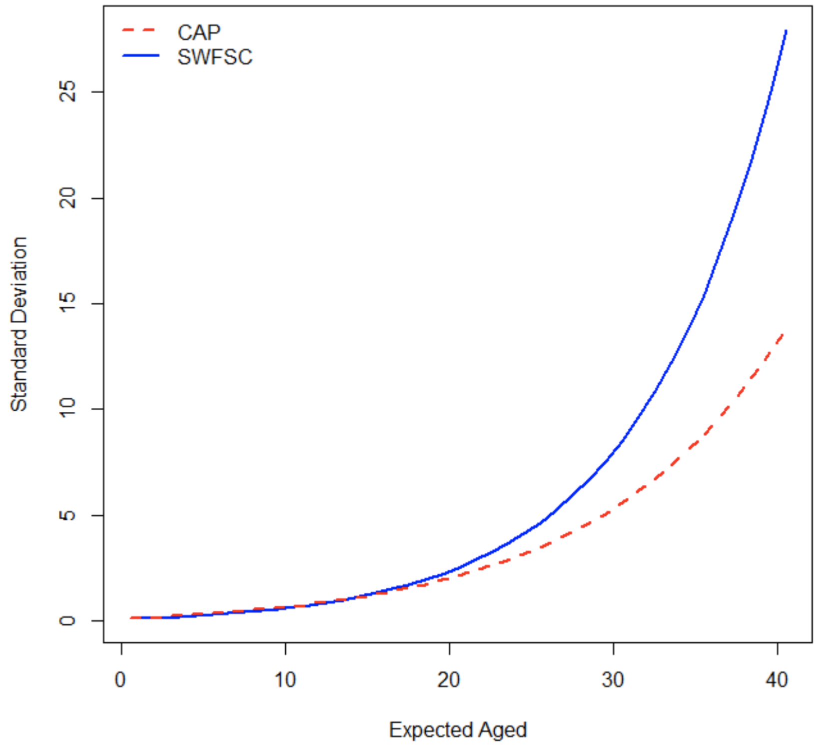


Figure 30: Estimated ageing error for the Cooperative Ageing Project lab and the SWFSC.

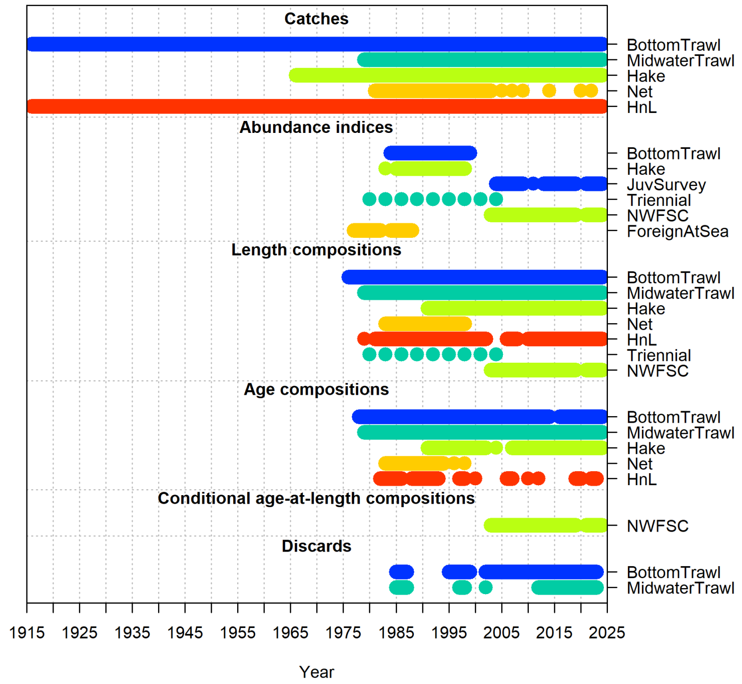


Figure 31: Data sources by type and year that were used in the base model.

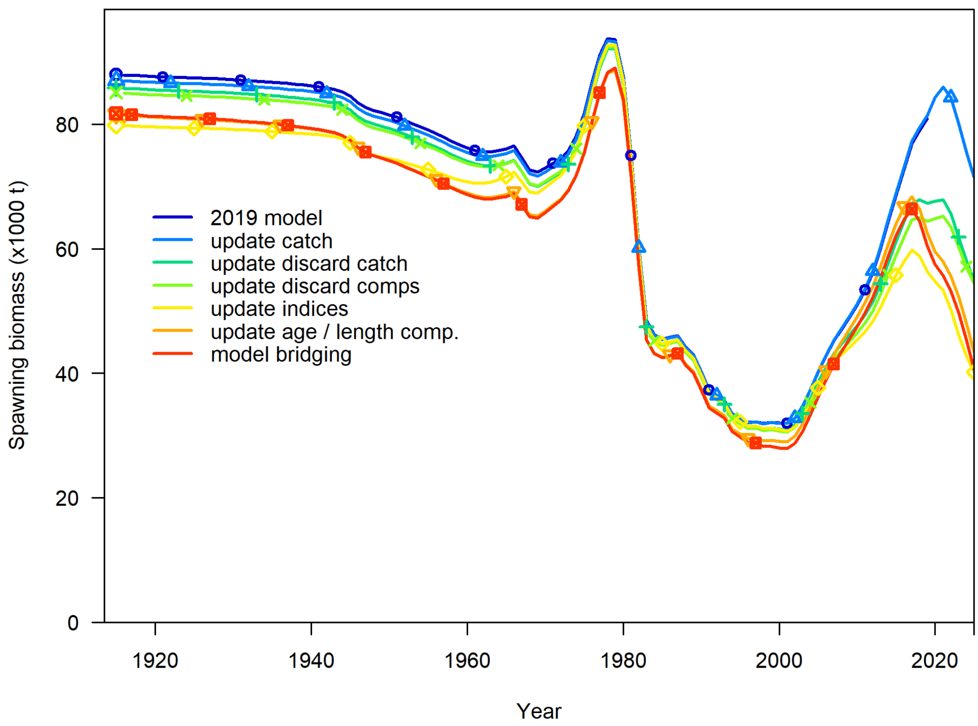


Figure 32: Bridging from the 2019 assessment model with updated data and bridging steps.

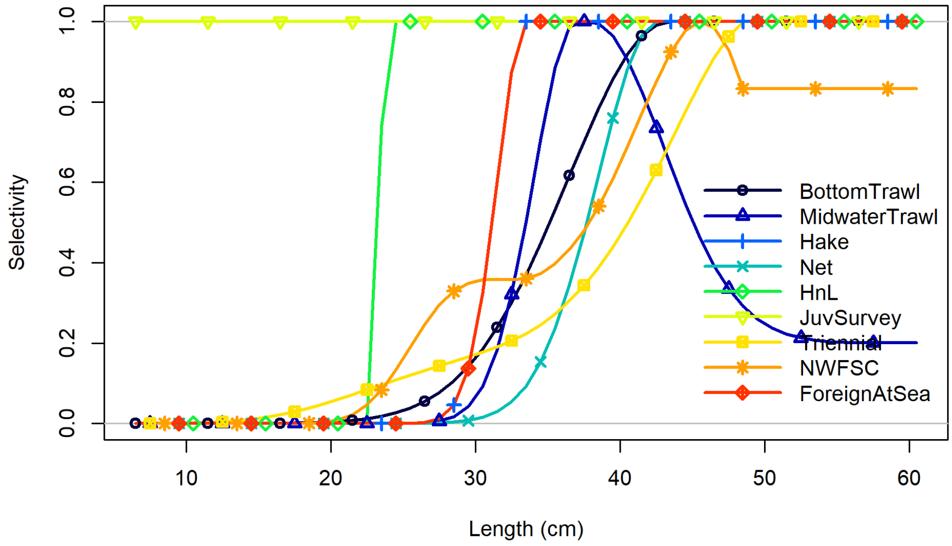


Figure 33: Estimated selectivity for different fleets and surveys.

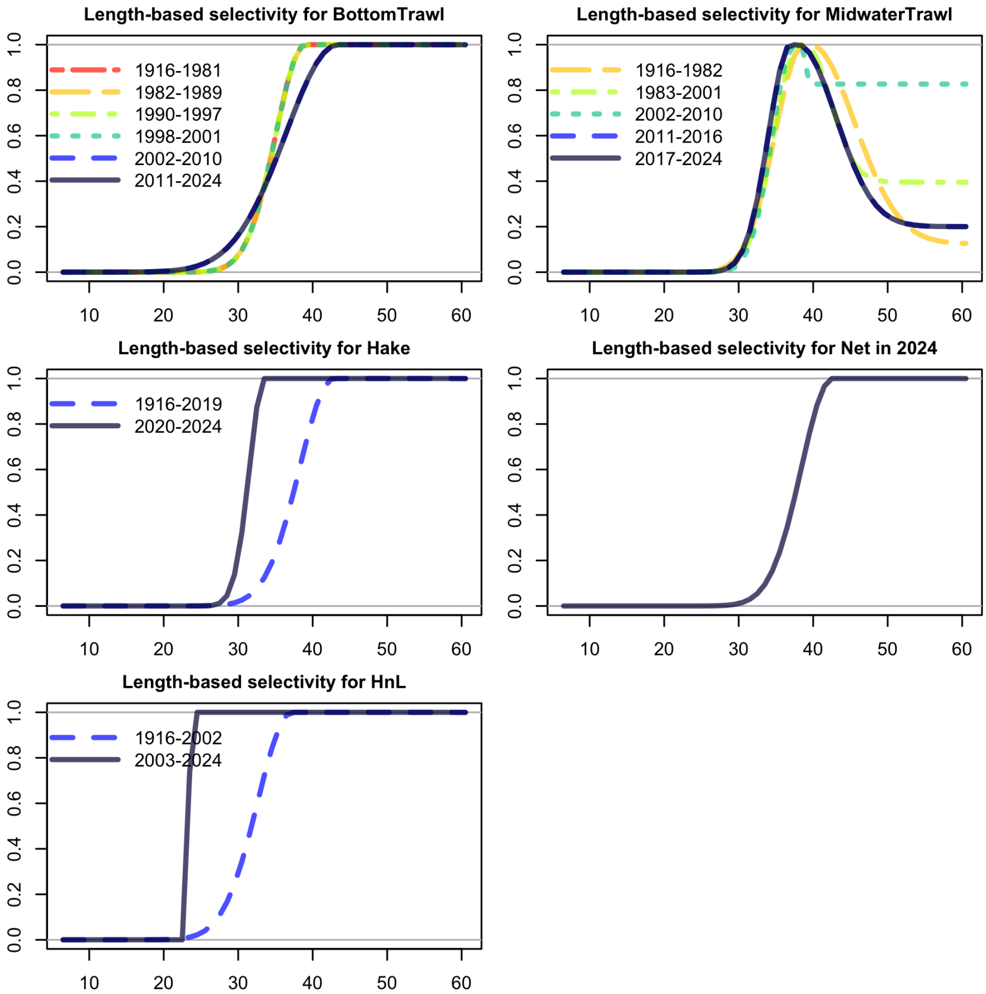


Figure 34: Estimated selectivity curves for 2018 of the hake fleet (topleft), net fishing fleets (topright), the triennial survey (bottomleft), and the NWFSC survey (bottomright).

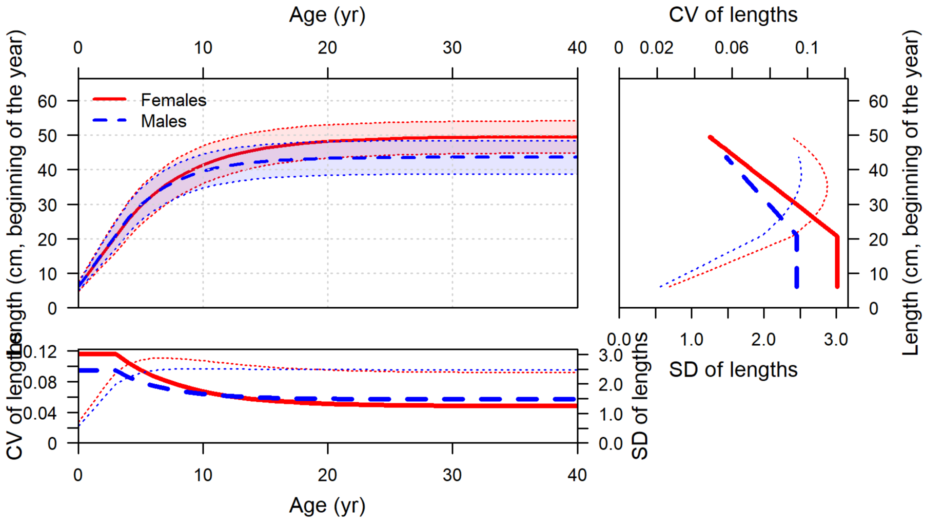


Figure 35: Length at age (top-left panel) with estimated coefficient of variation (CV, thick line) and calculated standard deviation (SD, thin line) versus length at age in the top-right panel and versus age in the lower-left panel.

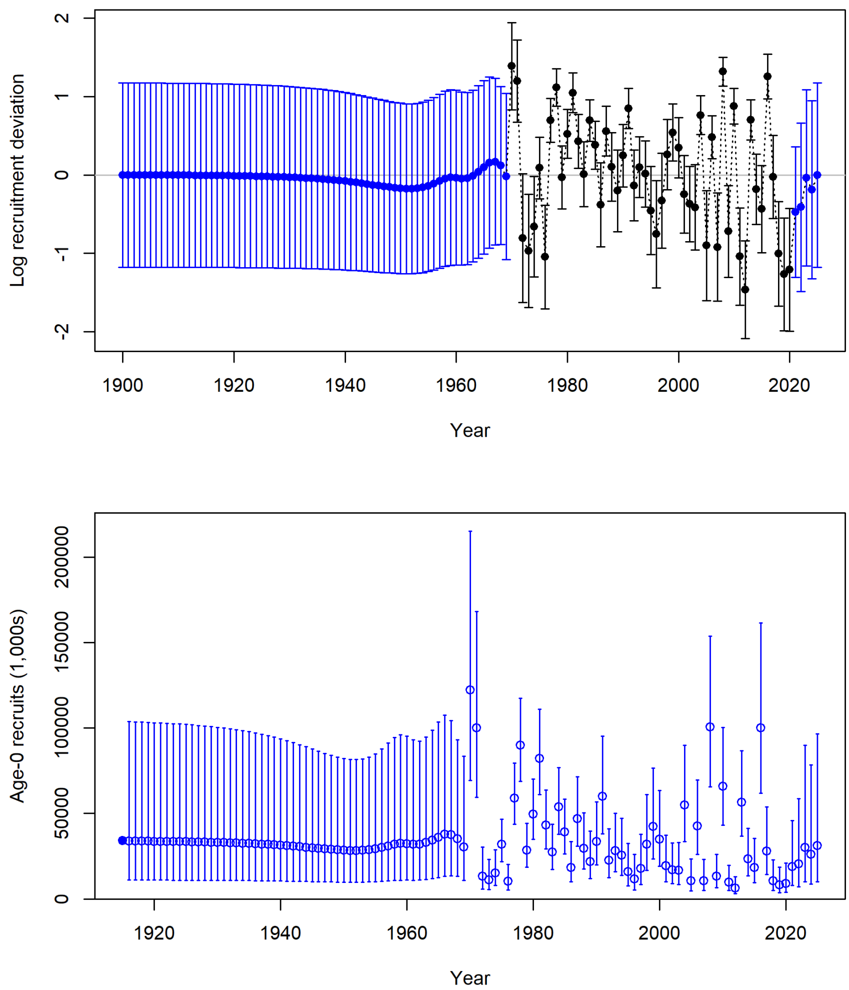


Figure 36: Estimates of recruitment (upper) and recruitment deviates (lower) with approximate asymptotic 95% confidence intervals (vertical lines) from the MLE estimates.

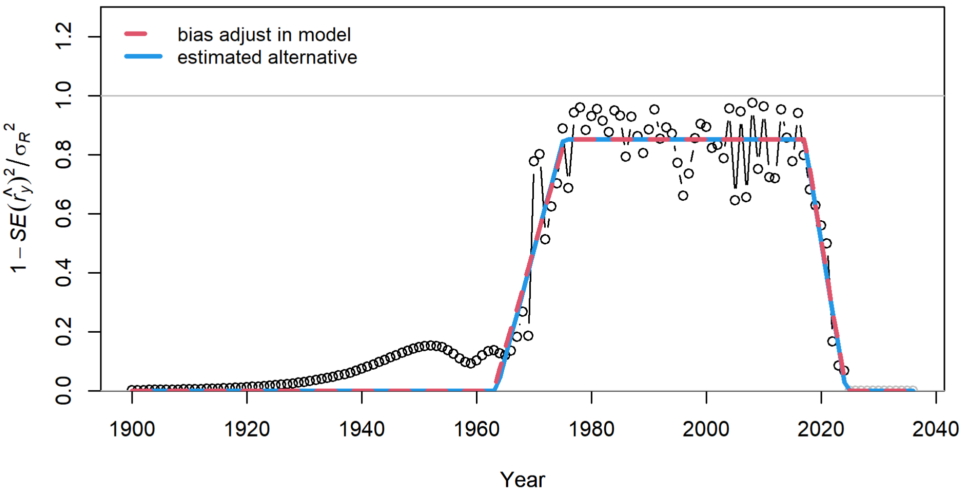


Figure 37: Estimated and input recruitment bias adjustment ramp. Red line shows current settings for bias adjustment ramp. Red line shows current settings for bias adjustment specified in the model. Blue line shows least squares estimate of alternative bias adjustment relationship for recruitment deviations.

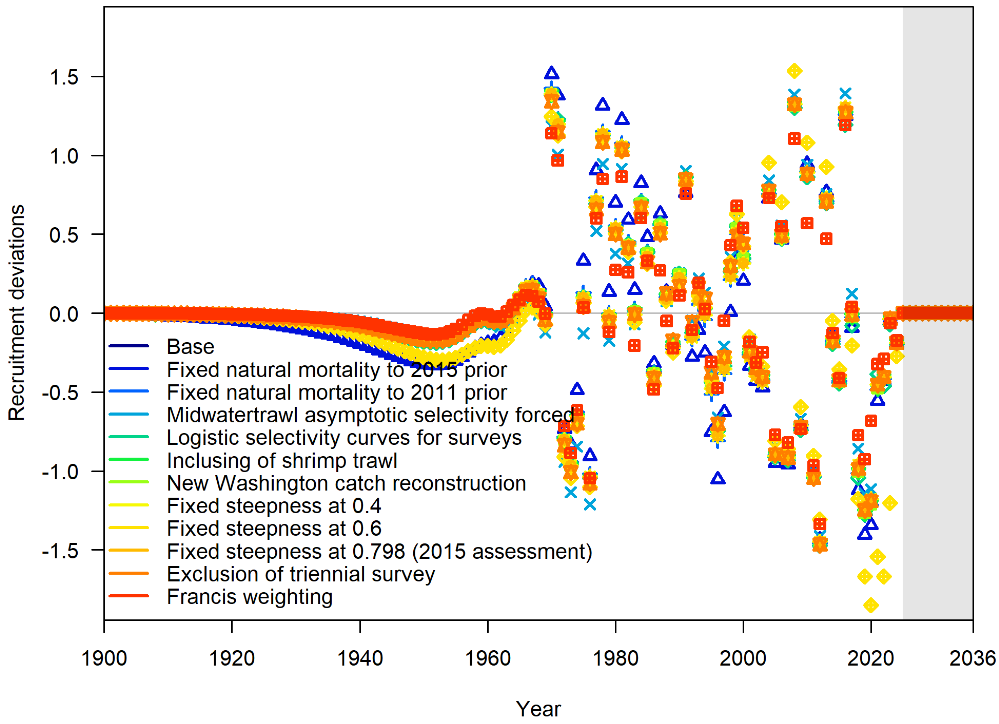


Figure 38: Estimates of recruitment deviations for sensitivity models.

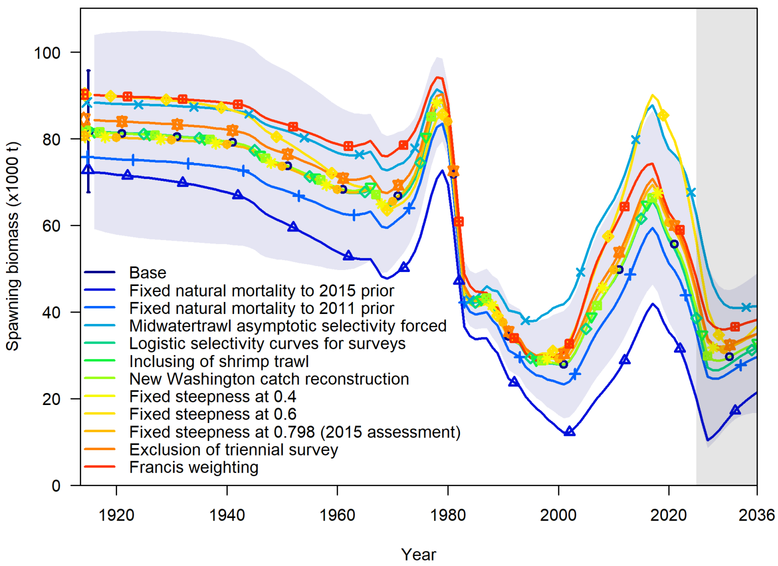


Figure 39: Spawning biomass (with 95% confidence interval around the base model) for the base model and sensitivity runs. (no rec dev)

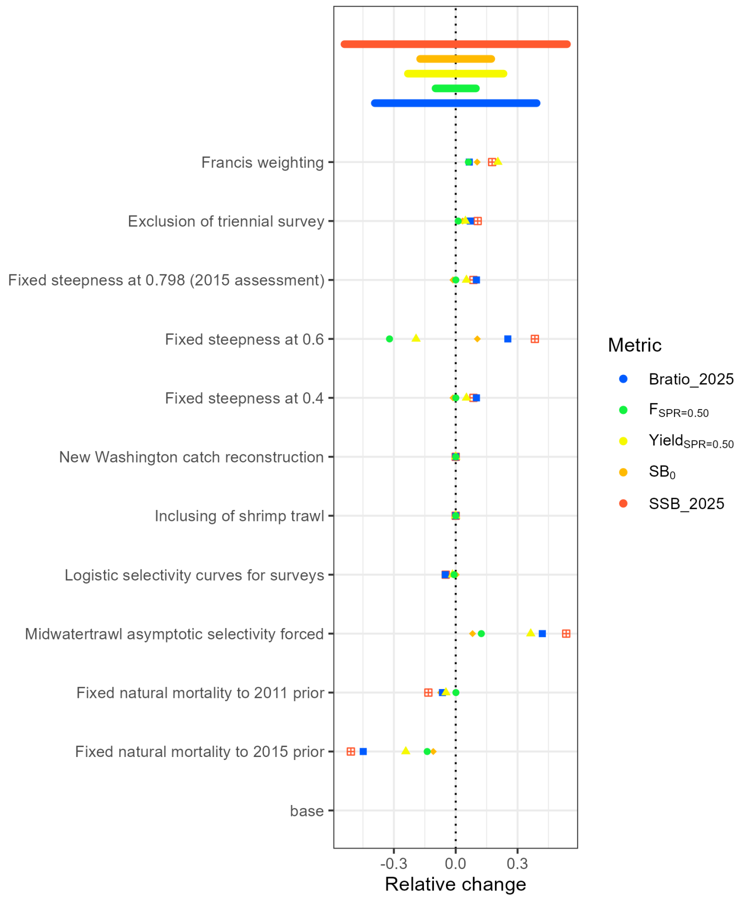


Figure 40: Comparision of model estimated quantities for 2025, given as percent of the base model estimated value, by sensitivity run.

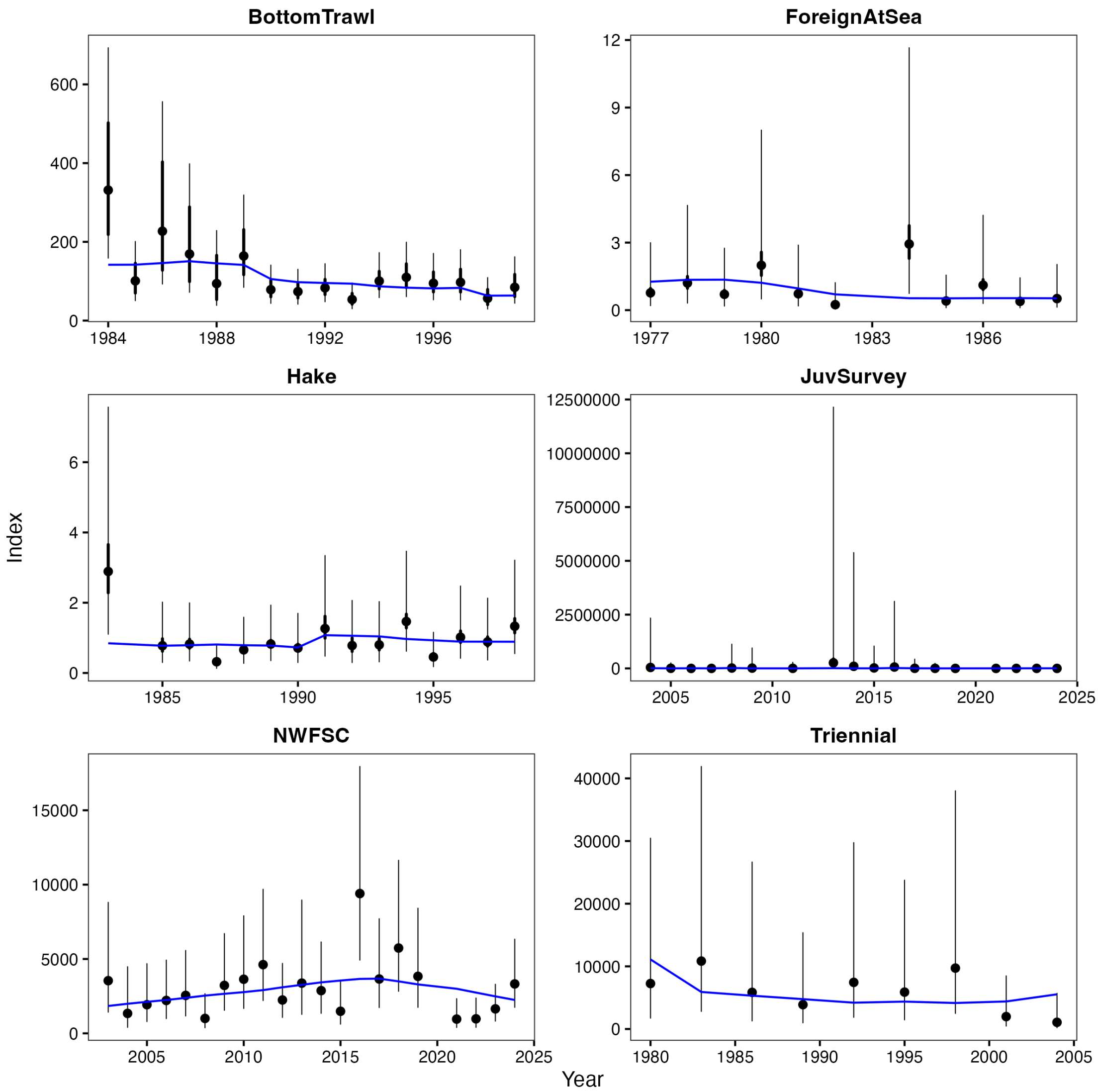


Figure 41: Fits (blue lines) to the abundance estimates (black points) for the base model. A separate q is estimated for the Hake series starting in 1991. Juvenile survey index (in numbers) is on the bottom. 95% confidence intervals are shown in the input standard errors. Thicker lines (if present) indicate input uncertainty before addition of the estimated additional uncertainty parameter.

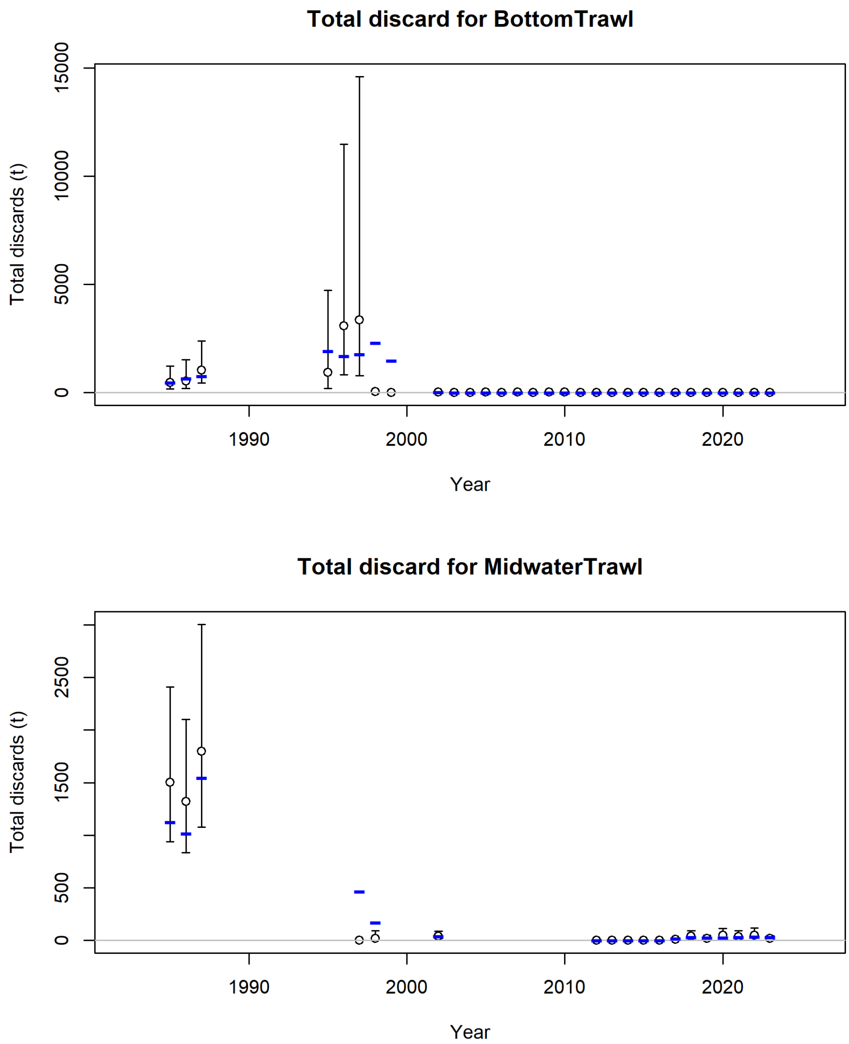


Figure 42: Predicted (blue line) and observed (open circles) discards for the bottom trawl (top) and midwater trawl (bottom) fleets from the base model. 95% confidence intervals are shown for the observations.

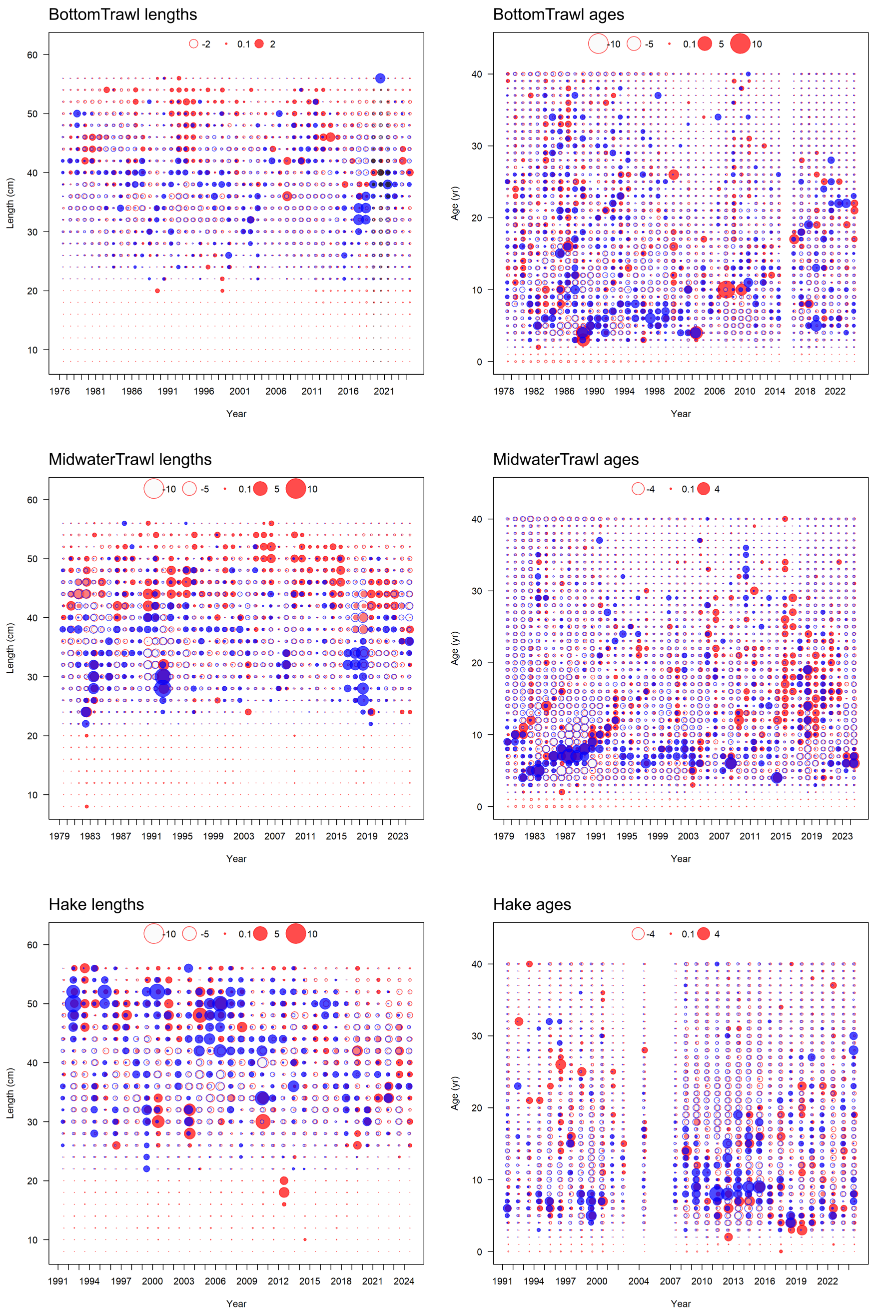


Figure 43: Pearson residuals for fits to length frequency data (left) and age frequency data (right) for landings from the trawl commercial fleets (rows). Filled circles indicate that the fitted proportion was less than the observed proportion. Red indicates females, blue males, and gray unsexed.

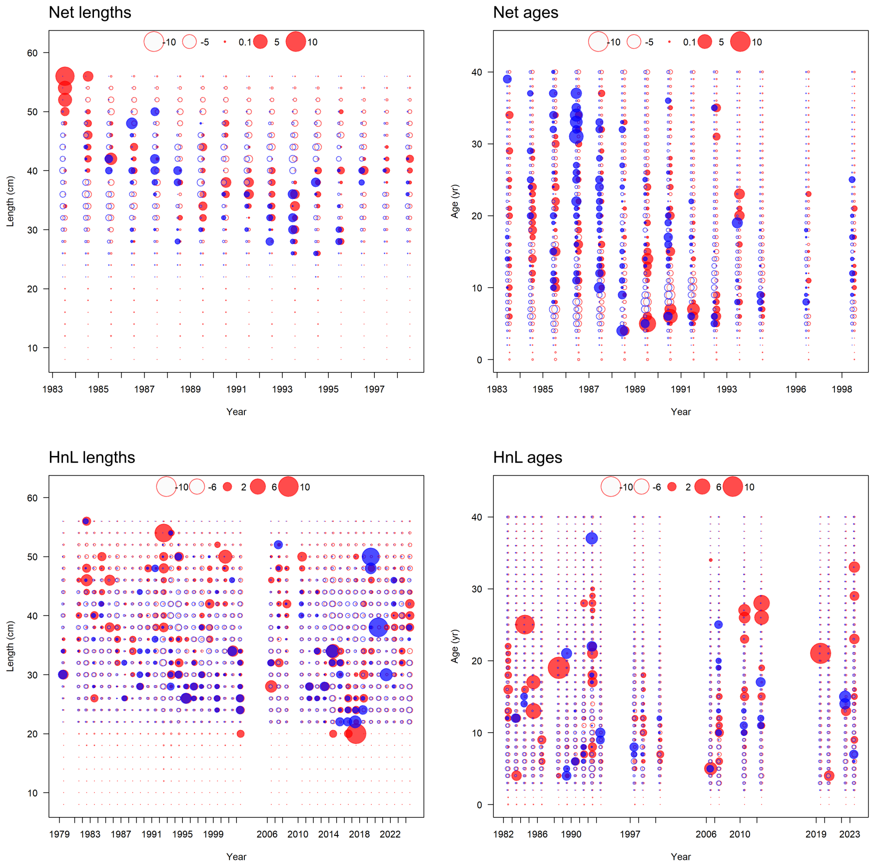


Figure 44: Pearson residuals for fits to length frequency data (left) and age frequency data (right) for landings from the net and hook-and-line commercial fleets (rows). Filled circles indicate that the fitted proportion was less than the observed proportion. Red indicates females, blue males, and gray unsexed.

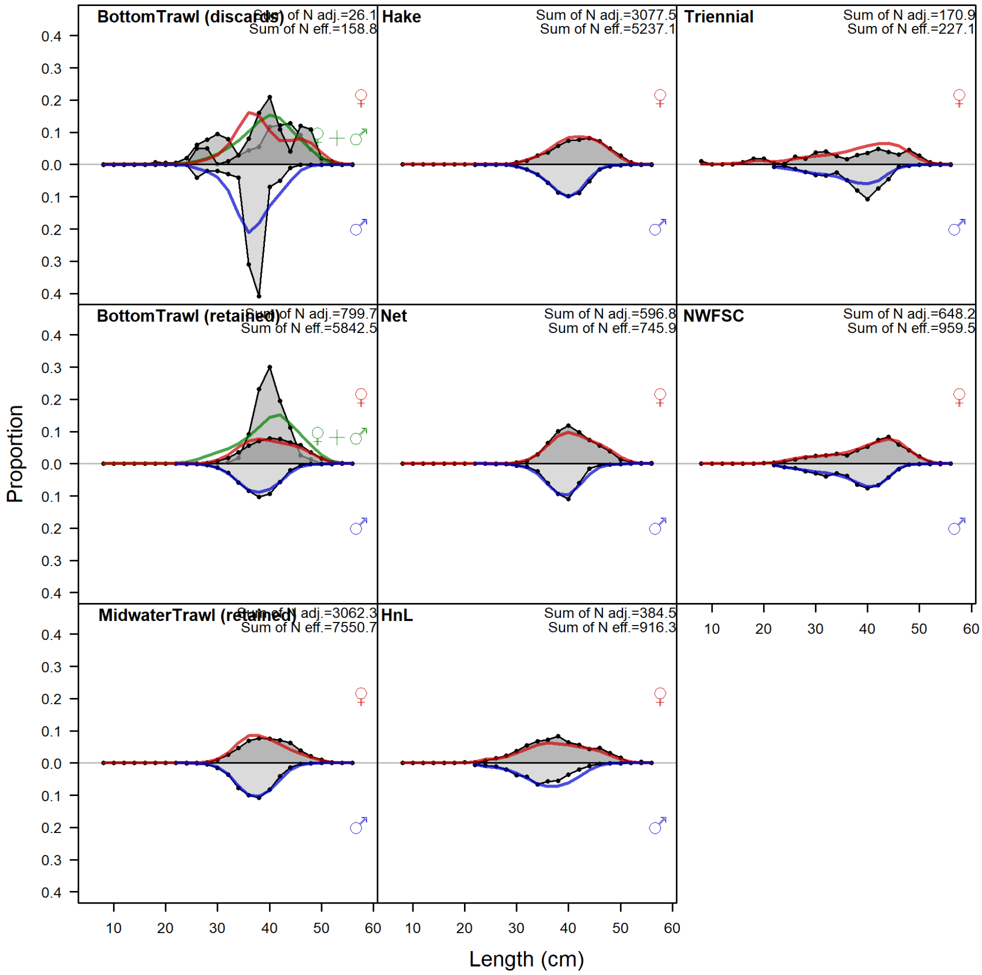


Figure 45: Combined length frequencies for all years from fishery (retained catch) and survey length frequency data (points). Fits are shown by the red line (females) and blue line (males).

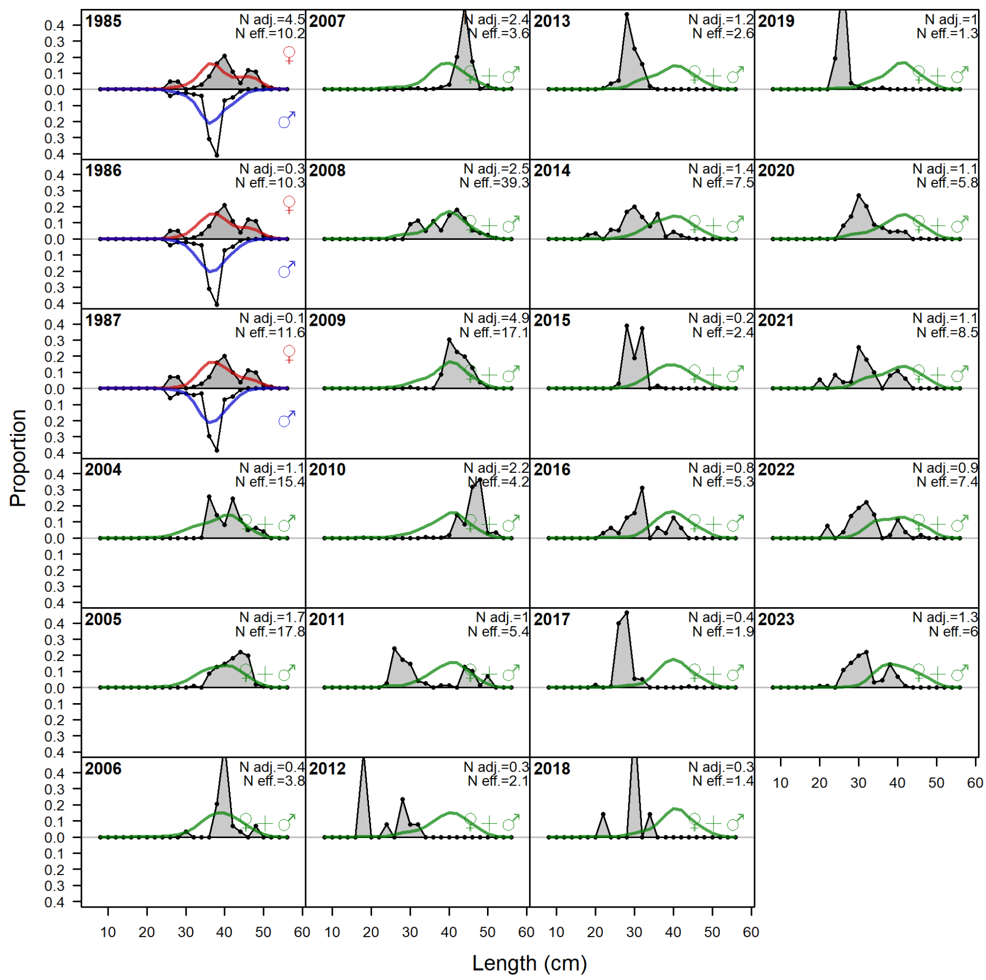


Figure 46: Pearson residuals for fits to the discard length frequencies from the bottom trawl (left) and hook-and-line (right) fleets. Filled circles indicate that the fitted proportion was less than the observed proportion. Red indicates females, blue males, and gray unsexed.

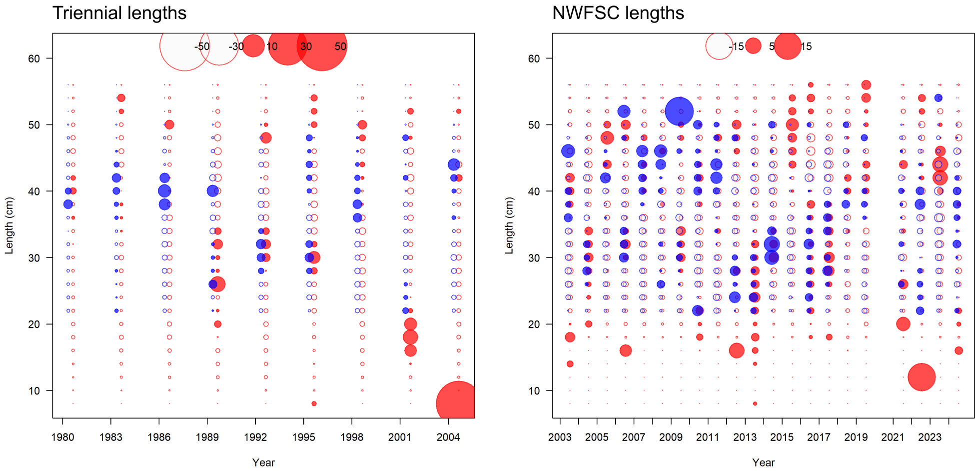


Figure 47: Pearson residuals for fits to the triennial survey length frequency data (left) and NWFSC WCGBT (shelf/slope) survey length frequency data (right). Filled circles indicate that the fitted proportion was less than the observed proportion. Red indicates females, blue males, and gray unsexed.

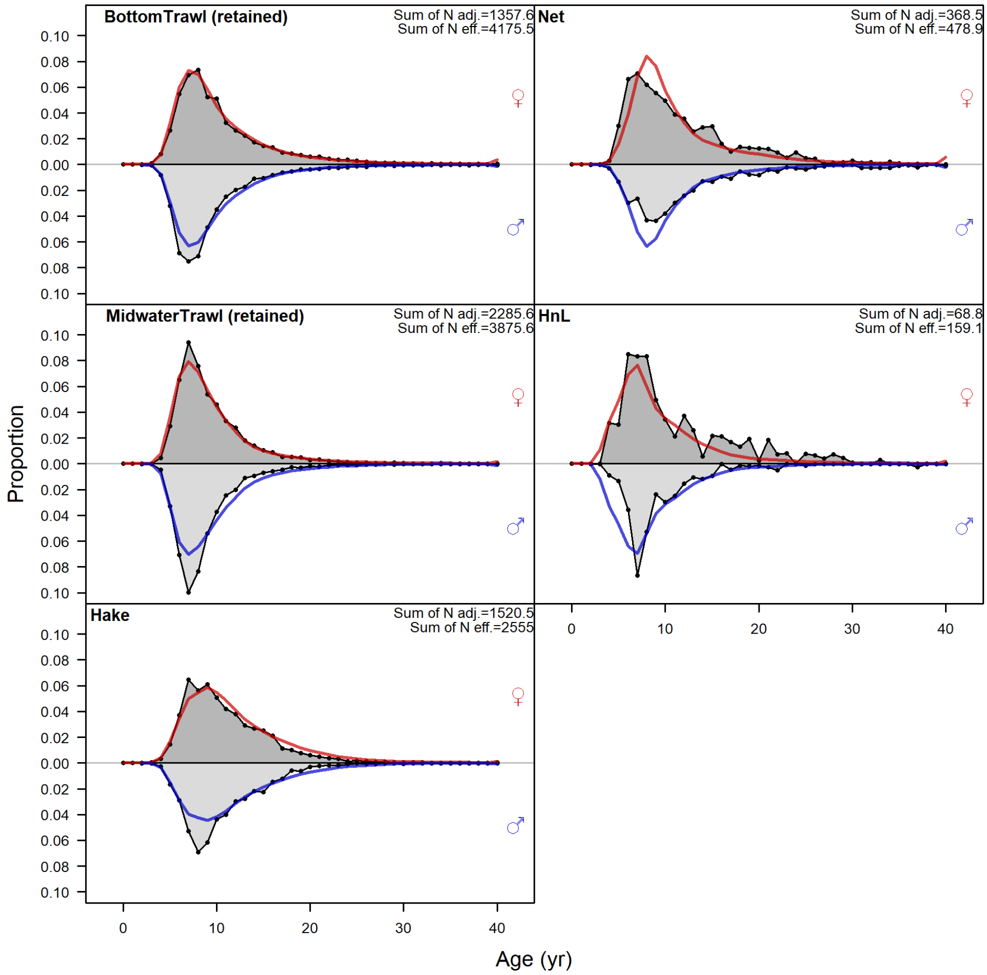


Figure 48: Combined age frequencies for all years from fishery (retained catch) and survey length frequency data (points). Fits are shown by the red line (females) and blue line (males).

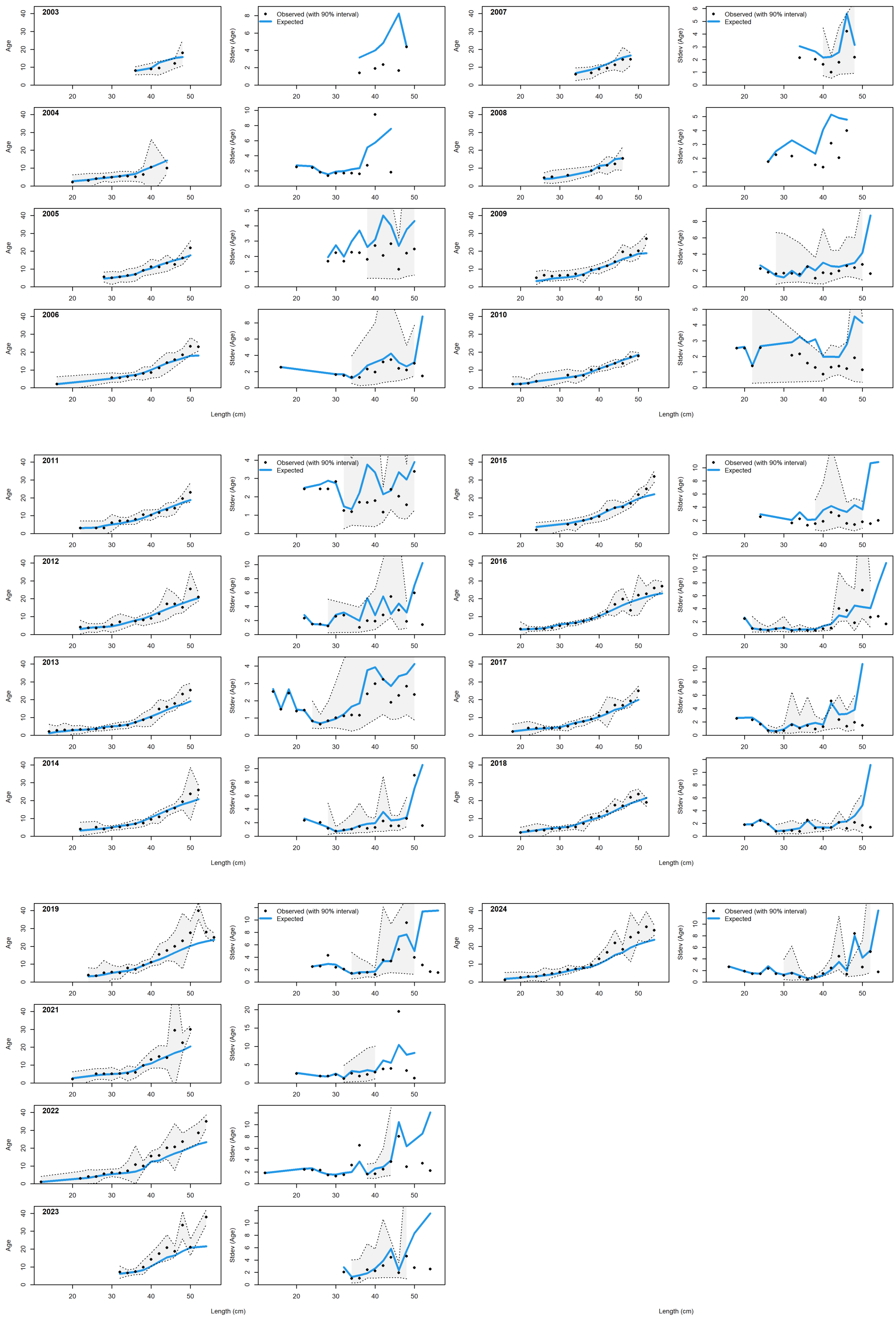


Figure 49: Observed and expected age-at-length with 95% confidence intervals (left) and observed and expected standard deviation of age-at-length with 95% confidence intervals (right) for the NWFSC WCGBT survey data.

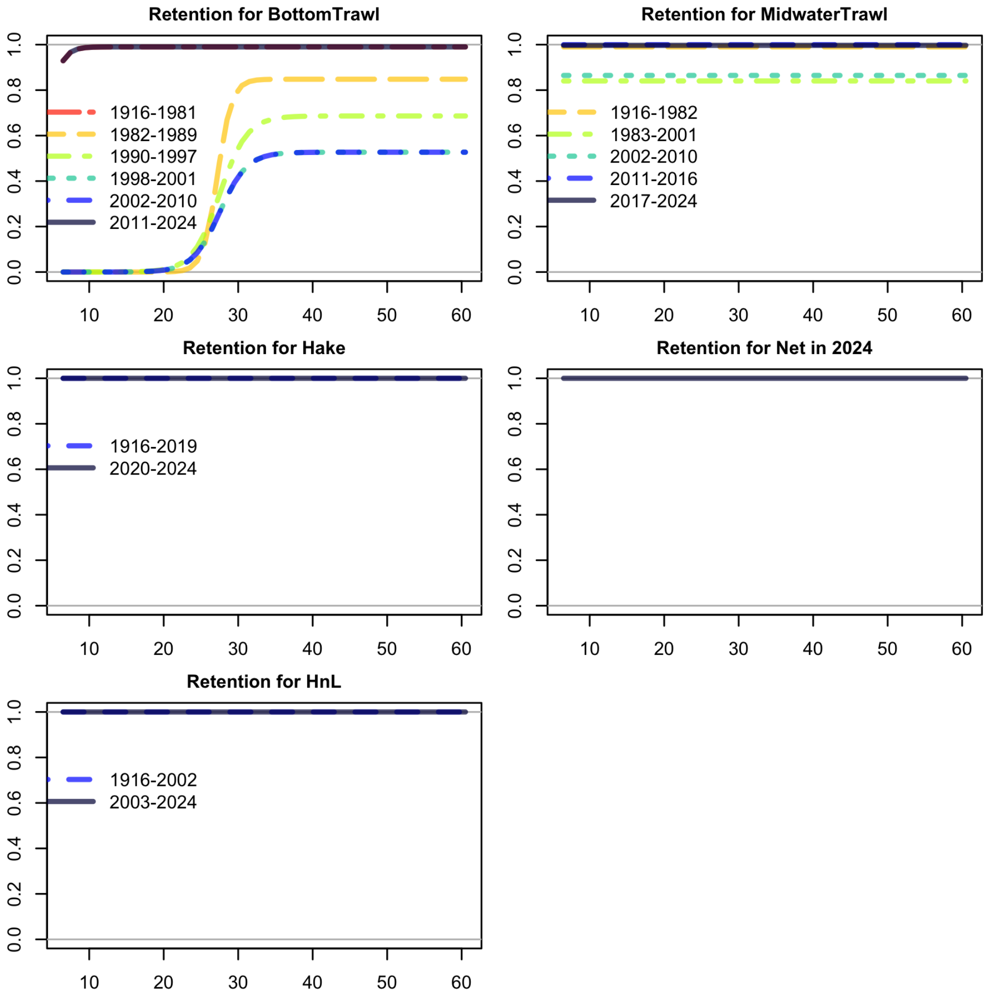


Figure 50: Estimated retention curves by time block (if applicable) for each of the five fleets in the model.

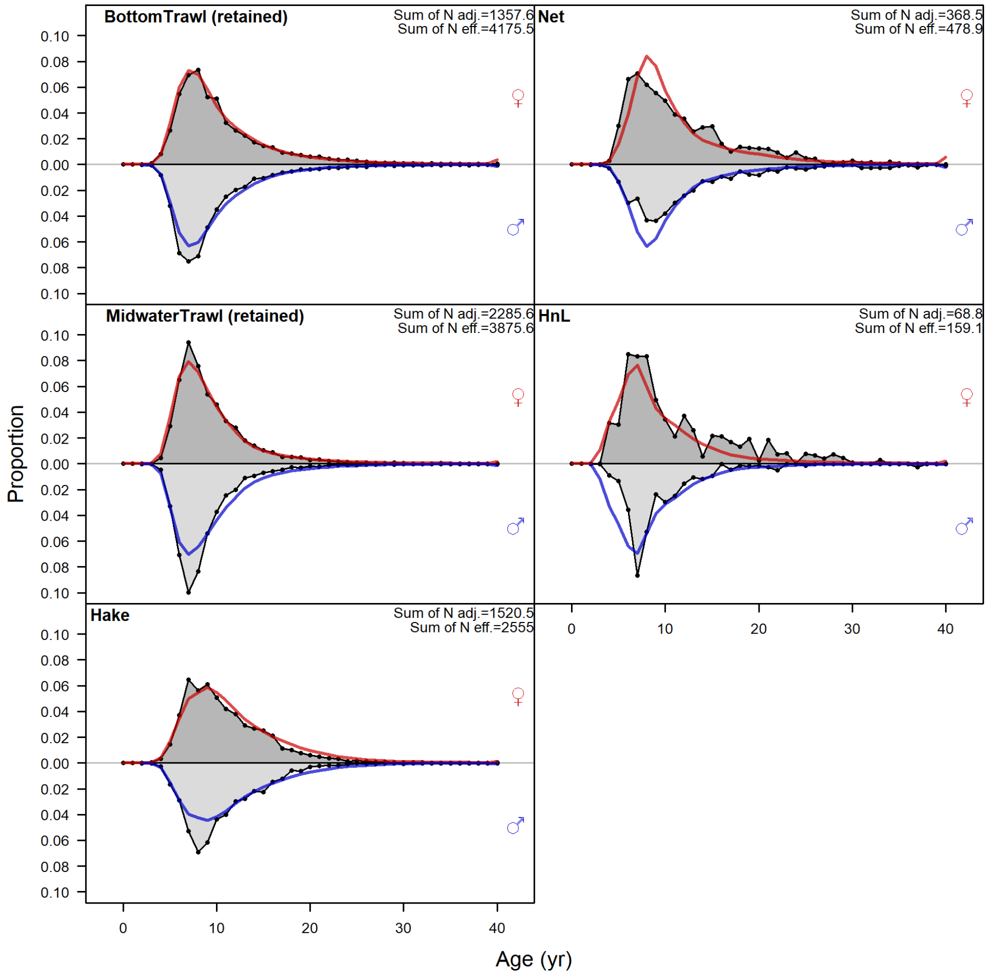


Figure 51: Combined age frequencies for all years from fishery (retained catch) and survey length frequency data (points). Fits are shown by the red line (females) and blue line (males).

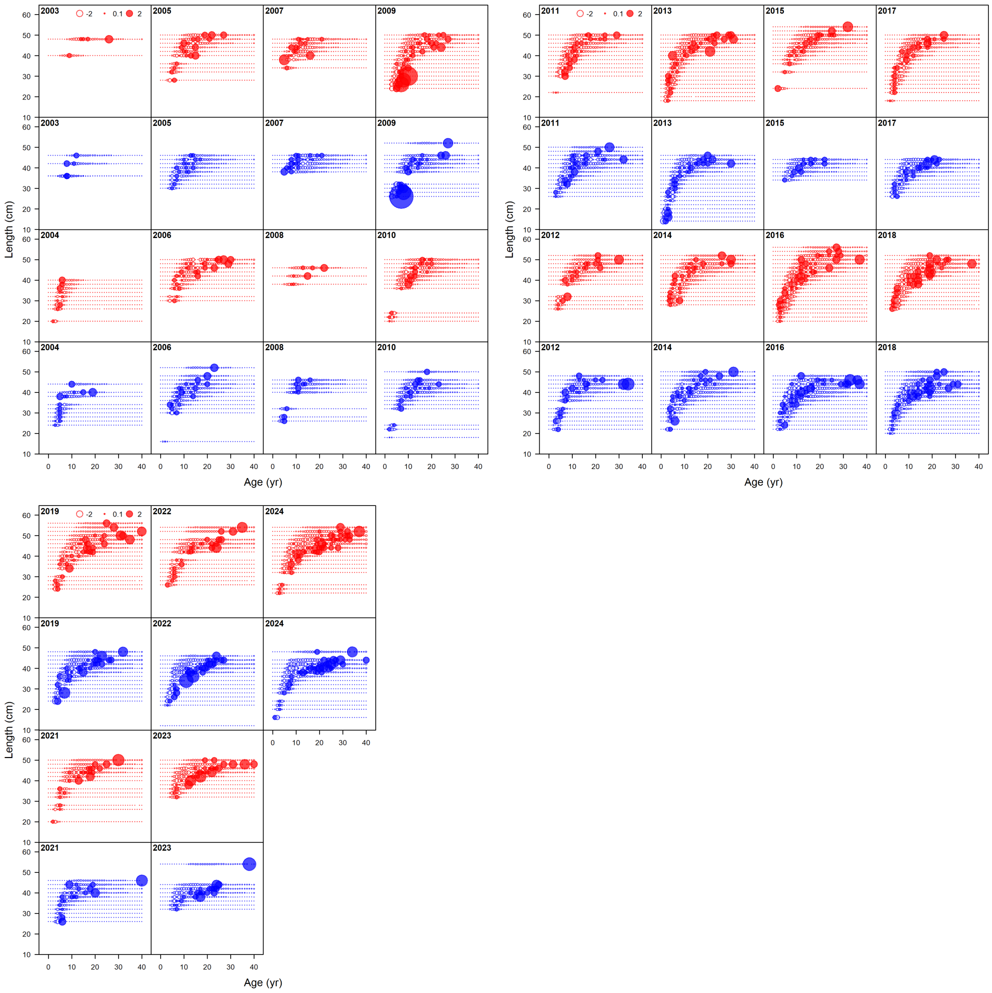


Figure 52: Combined age frequencies for all years from fishery (retained catch) and survey length frequency data (points). Fits are shown by the red line (females) and blue line (males).

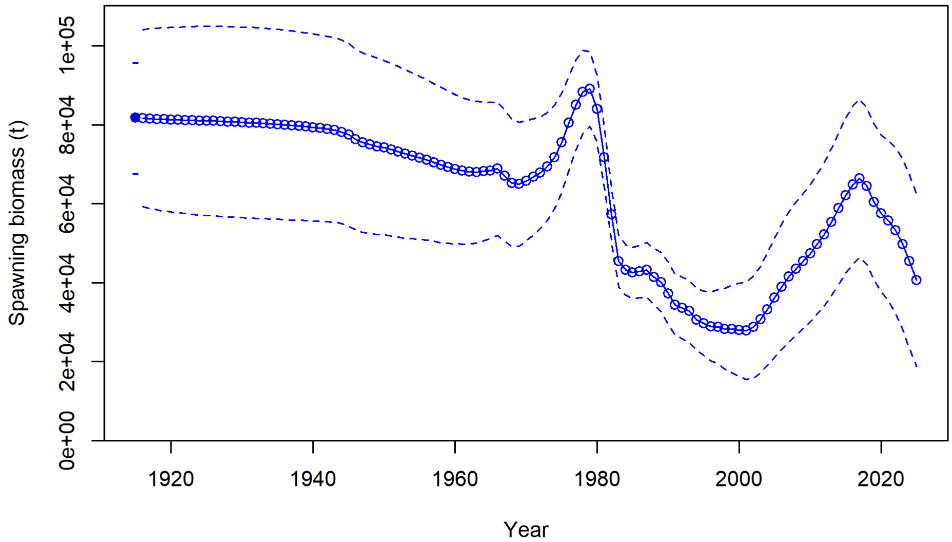


Figure 53: Predicted spawning biomass (thousand mt) for Widow Rockfish using the base assessment. The solid line is the MLE estimate, and the dashed lines depict the approximate asymptotic 95% confidence intervals.

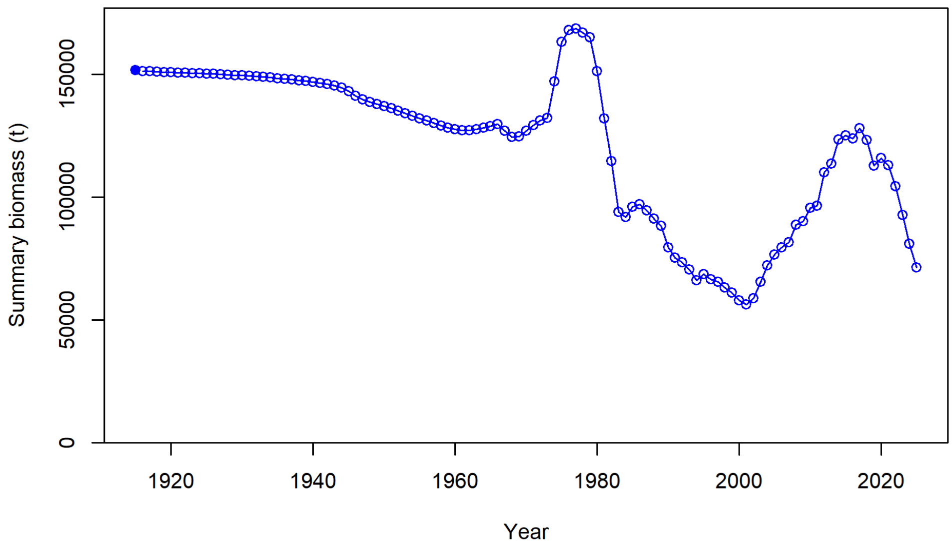


Figure 54: Predicted summary biomass (age 4+) from the base model.

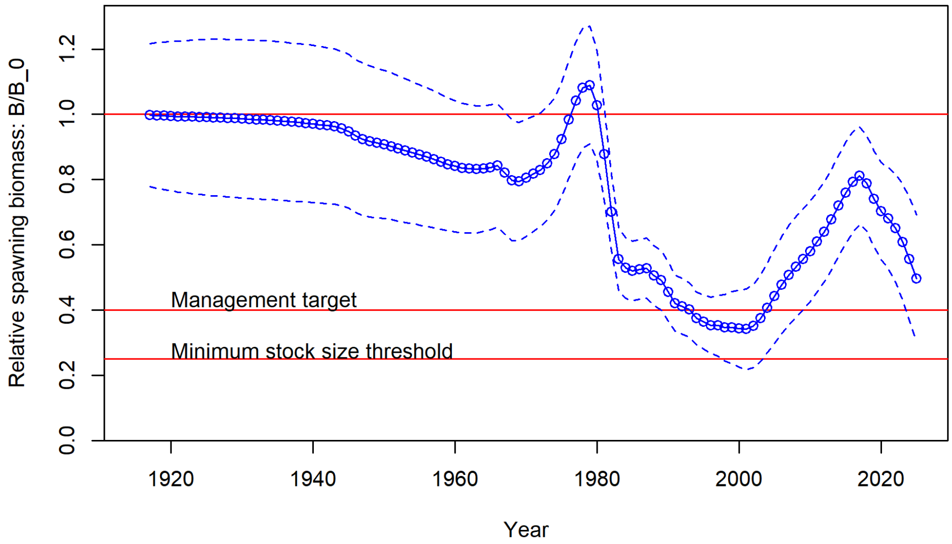


Figure 55: Predicted relative spawning biomass from the Widow Rockfish base case assessment. The solid blue line is the MLE estimate, and the dashed lines depict the approximate asymptotic 95% confidence intervals. The red lines show the equilibrium level (100%), the management target of 40% of unfished biomass, and the minimum stock size threshold of 25% of unfished biomass.

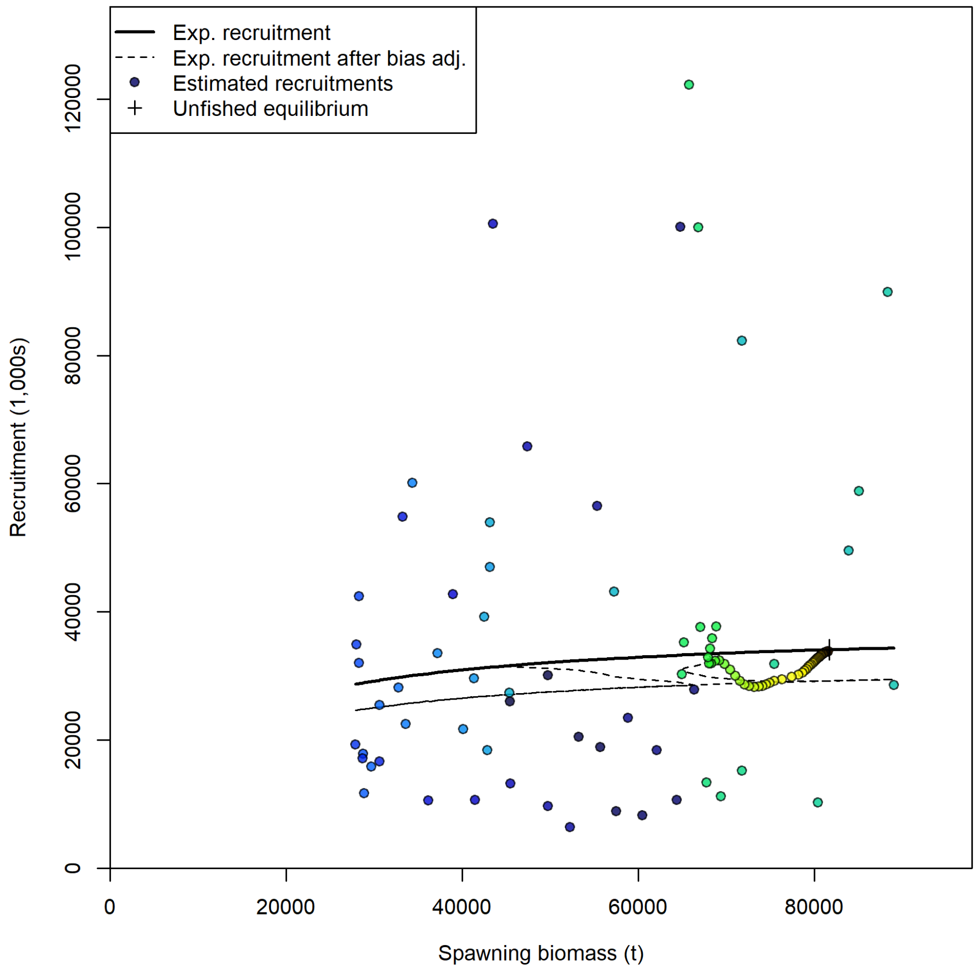
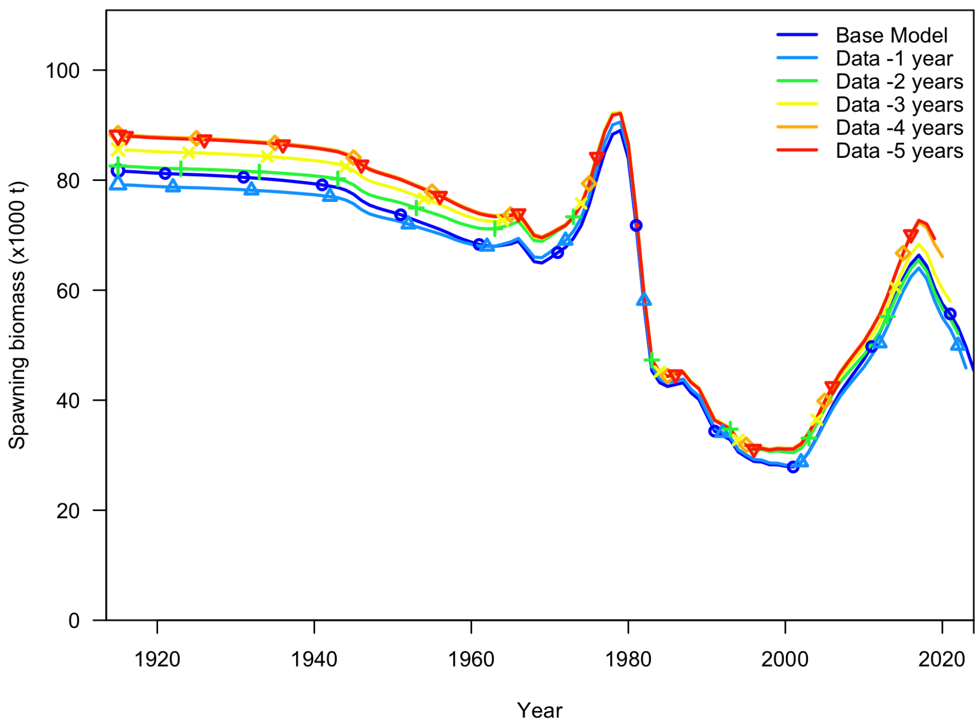


Figure 56: Estimated recruitment and the assumed stock-recruit relationship (black line). The dashed line shows the effect of the bias correction for the lognormal distribution.



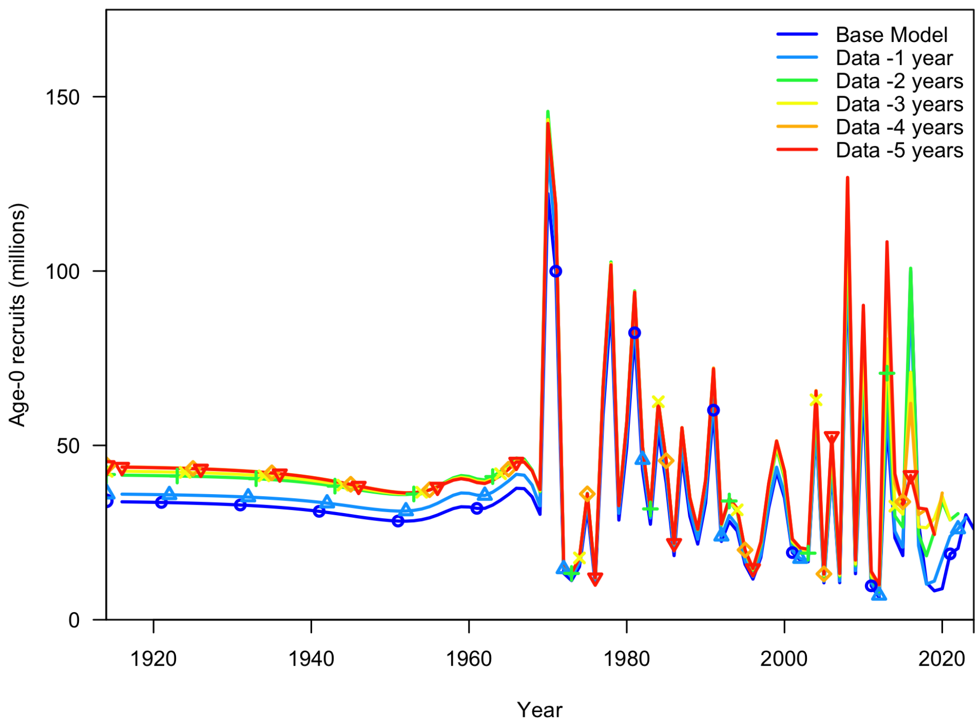


Figure 57: Five-year retrospective estimates of spawning biomass (top) and recruitment deviations (bottom).

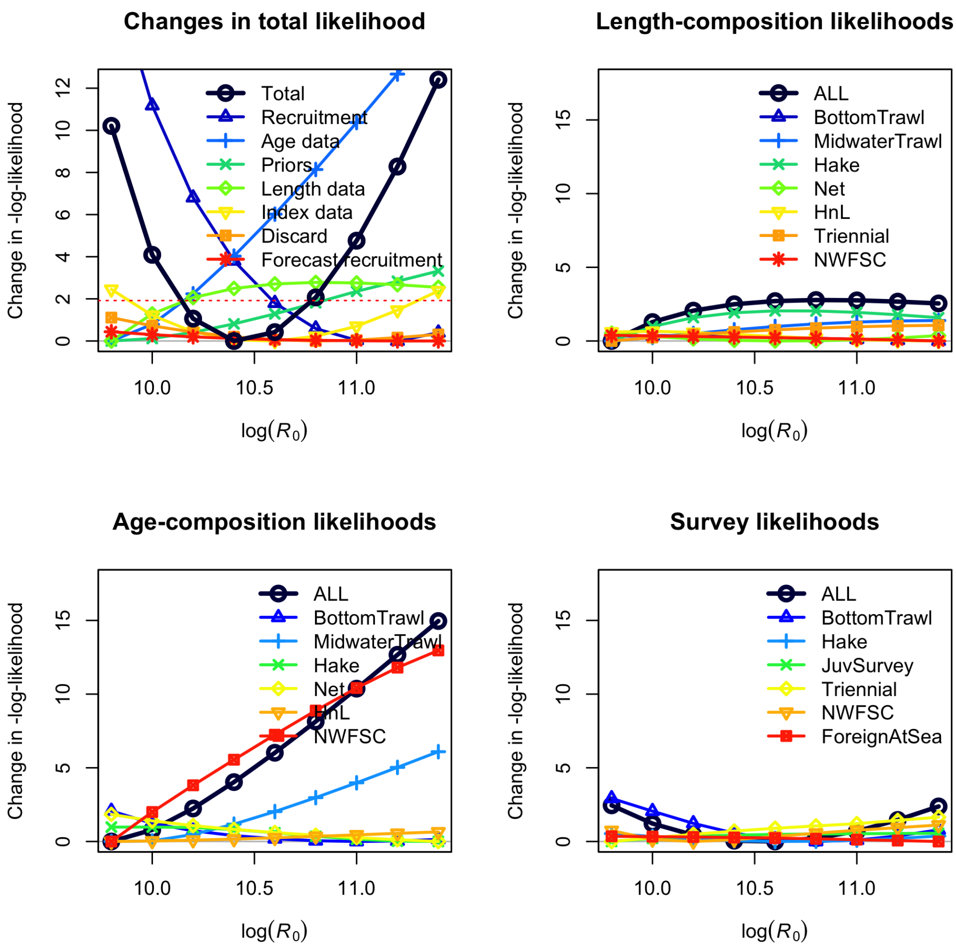


Figure 58: Likelihood components in the likelihood profile for unfished equilibrium recruitment (R0)

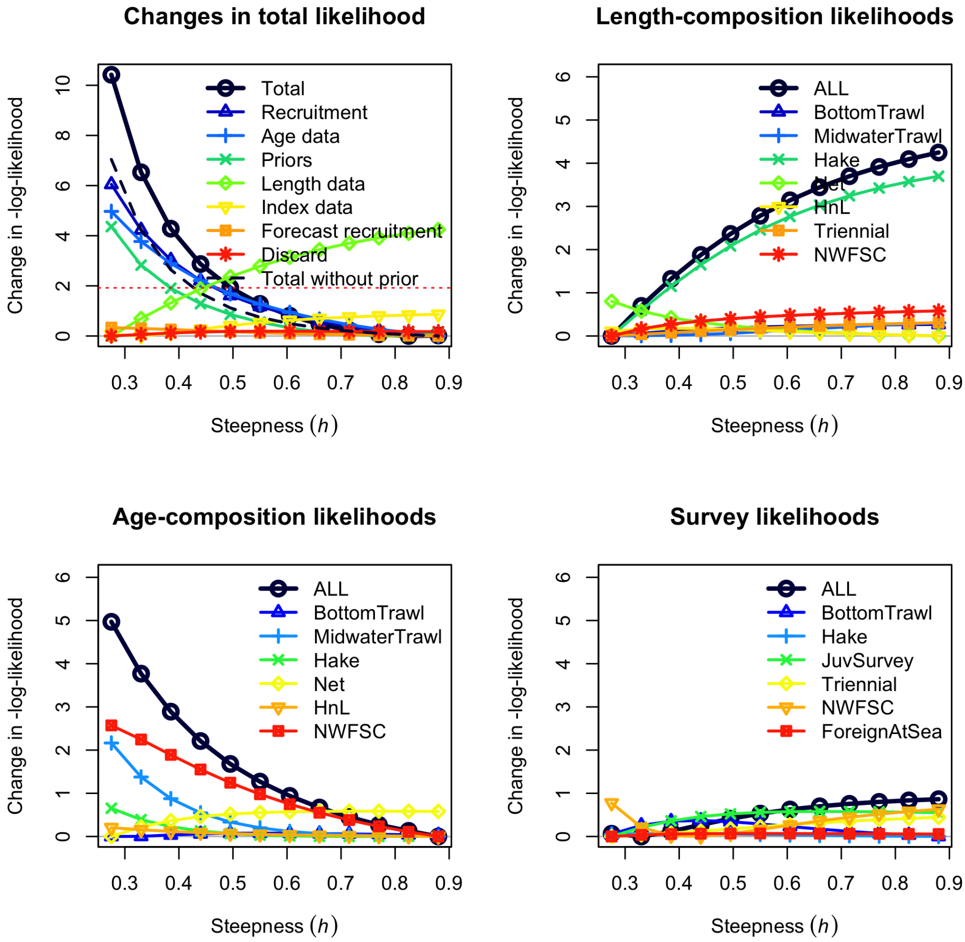


Figure 59: Likelihood components in the likelihood profile for steepness (h).

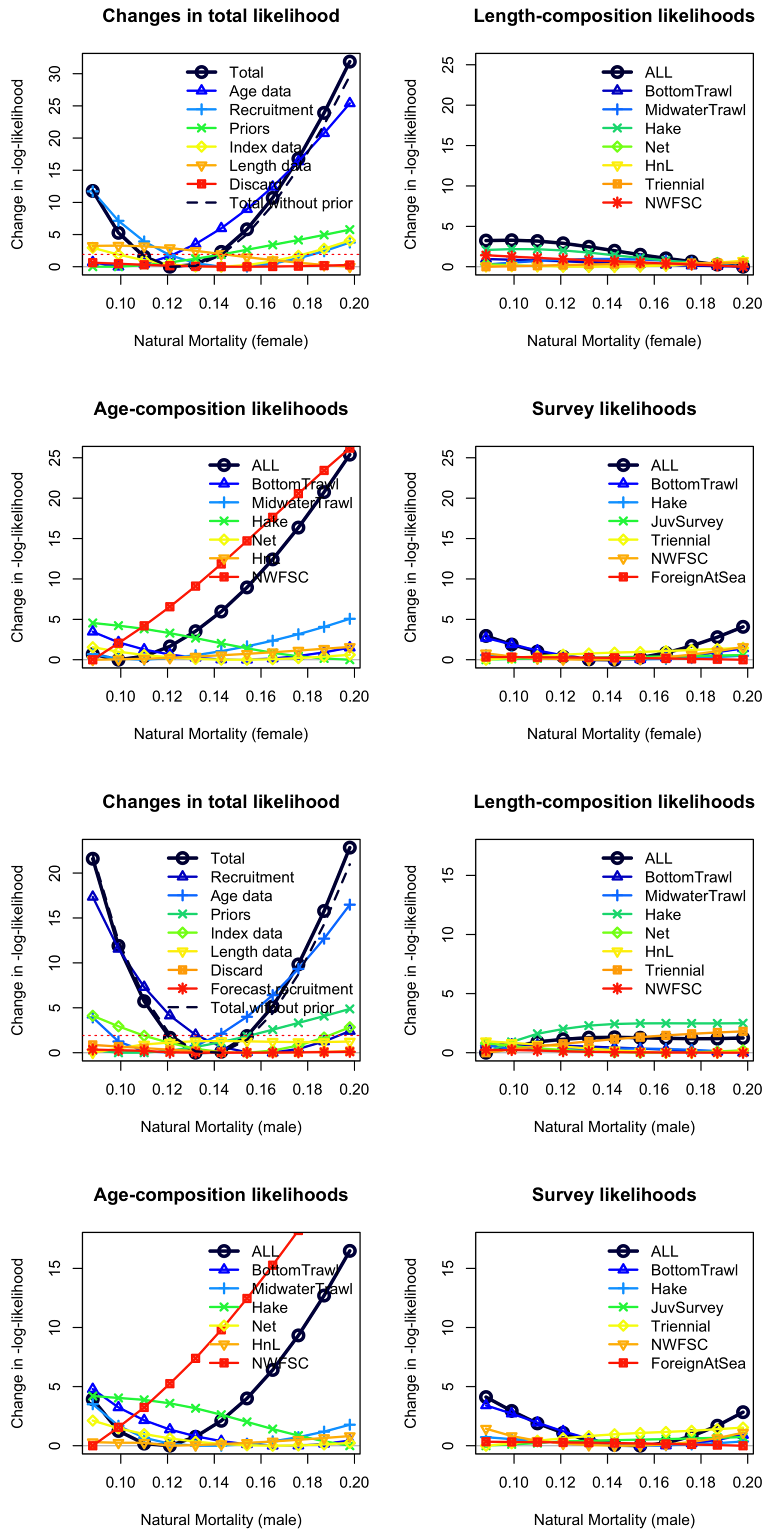


Figure 60: Likelihood components in the likelihood profile for natural mortality (M). Note: male and female natural mortality are set to the same value.

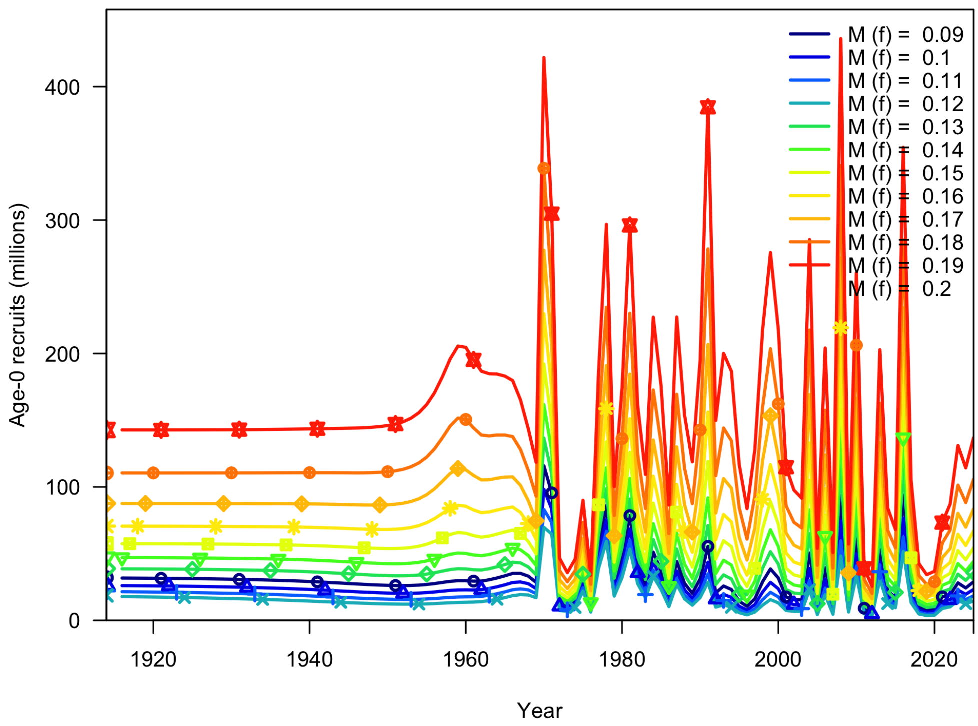


Figure 61: Time series of recruitment estimates for models with different fixed values of natural mortality (M)

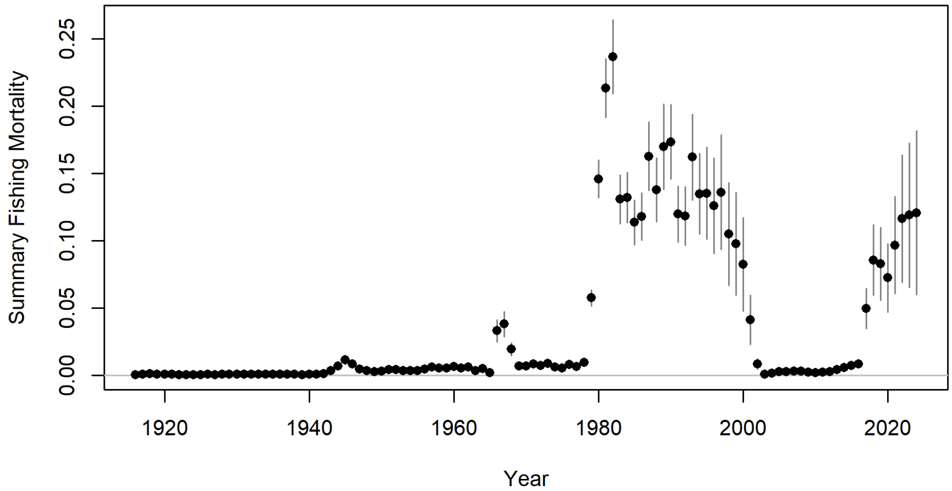


Figure 62: Plot of the summary fishing mortality for each year of the model with 95% confidence intervals.

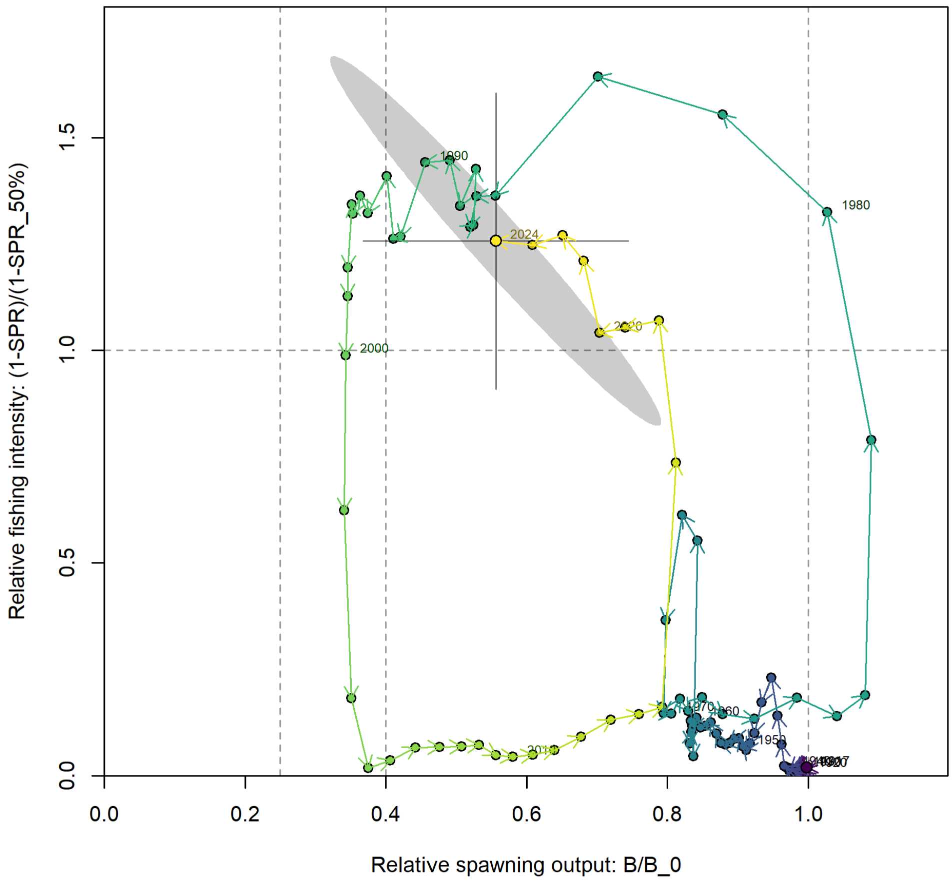


Figure 63: Phase plot of relative (1-SPR)/(1-SPR_50%) (y-axis) and depletion (x-axis) for Widow Rockfish.

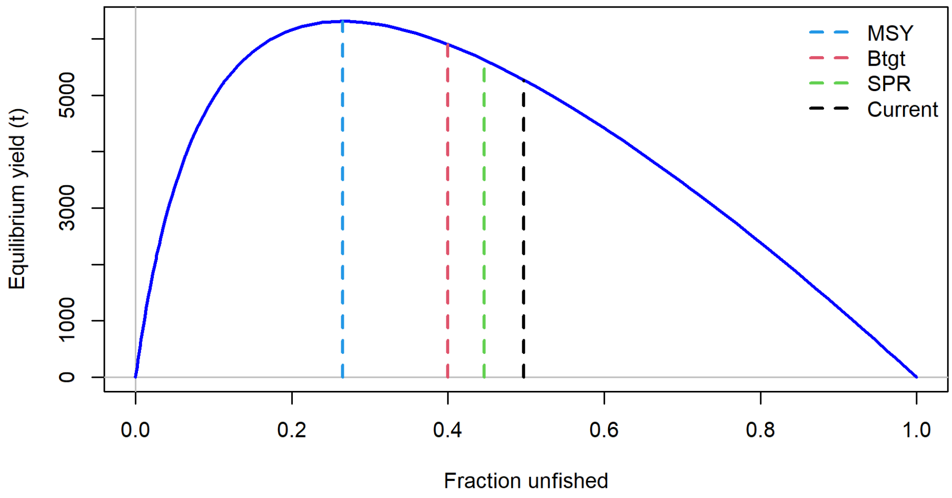


Figure 64: Estimated plot of equilibrium yield vs the fraction of unfished biomass.

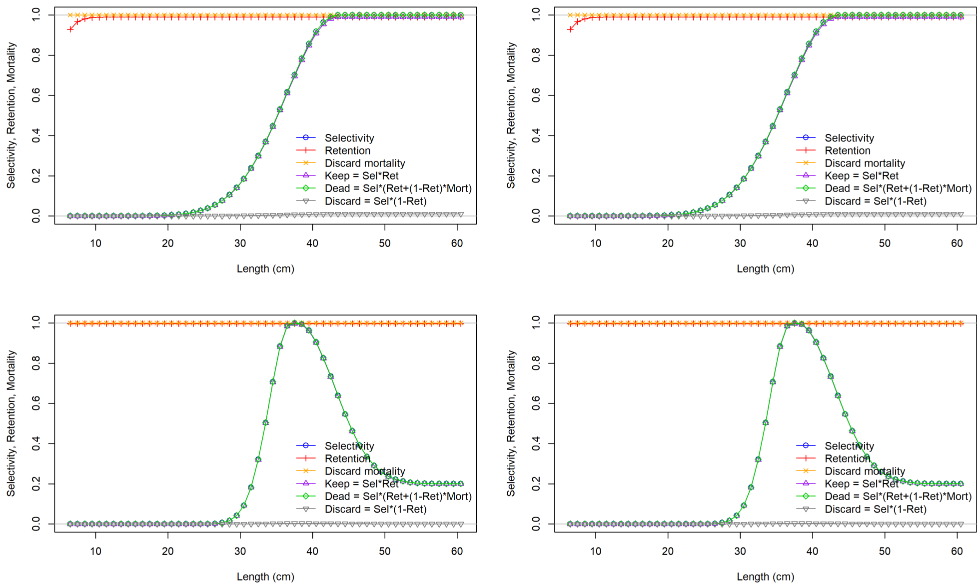


Figure 65: Estimated selectivity for Bottom Trawl (top row) and Midwater Trawl (bottom row) for males (left column) and females (right column)

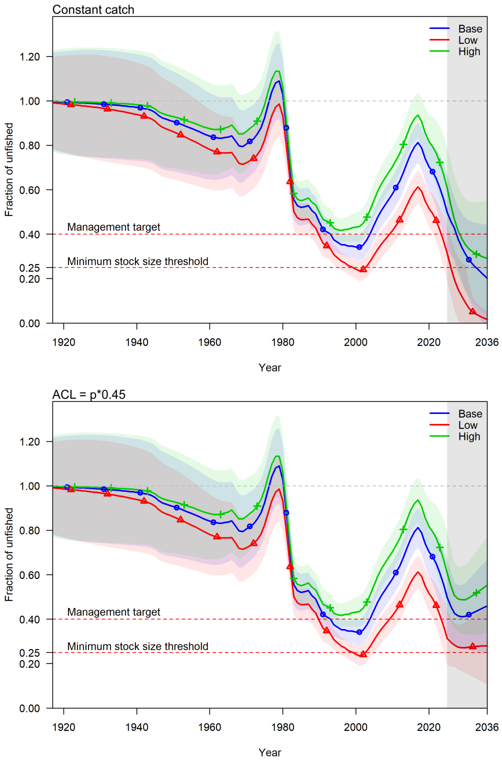


Figure 66: Base model, low state of nature, and high state of nature spawning biomass trajectories under three catch scenarios: constant catch of 9000 mt, ACL = p*0.25, ACL = p*0.45 for 2027 to 2036. The shaded areas indicate the 12.5% and 87.5% lognormal quantiles of spawning biomass.

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8 Appendix A: Annual fits to length and age composition

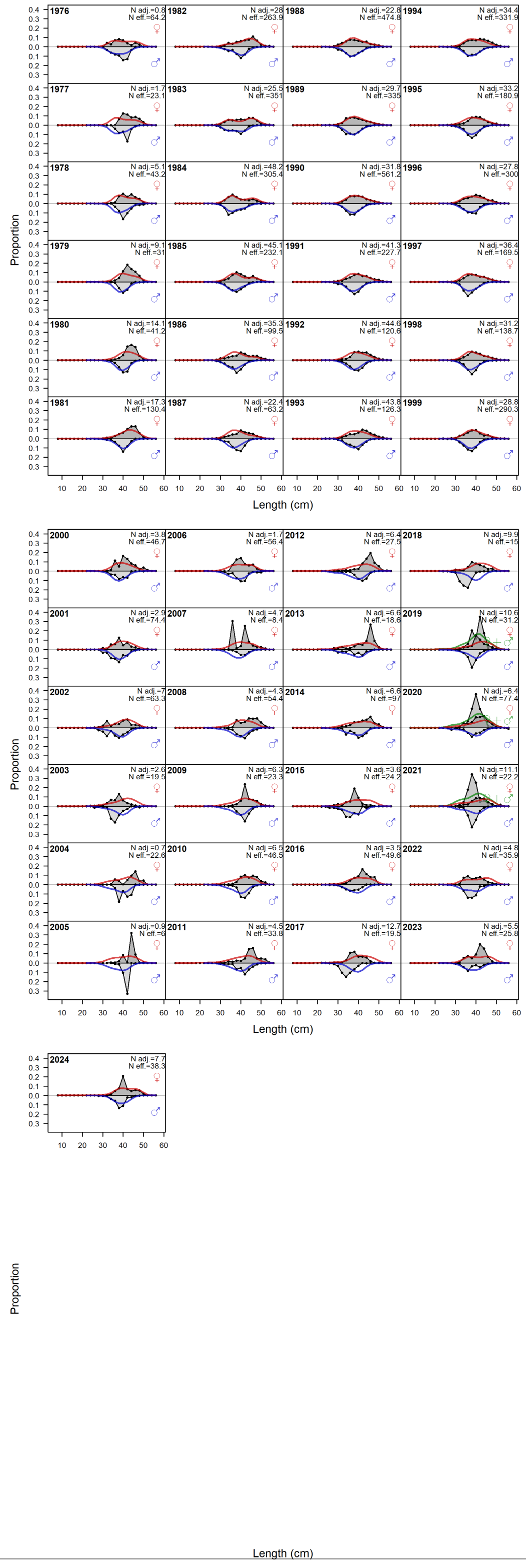

Figure A1: Fits to the retained length compositions for the bottom trawl fleet.

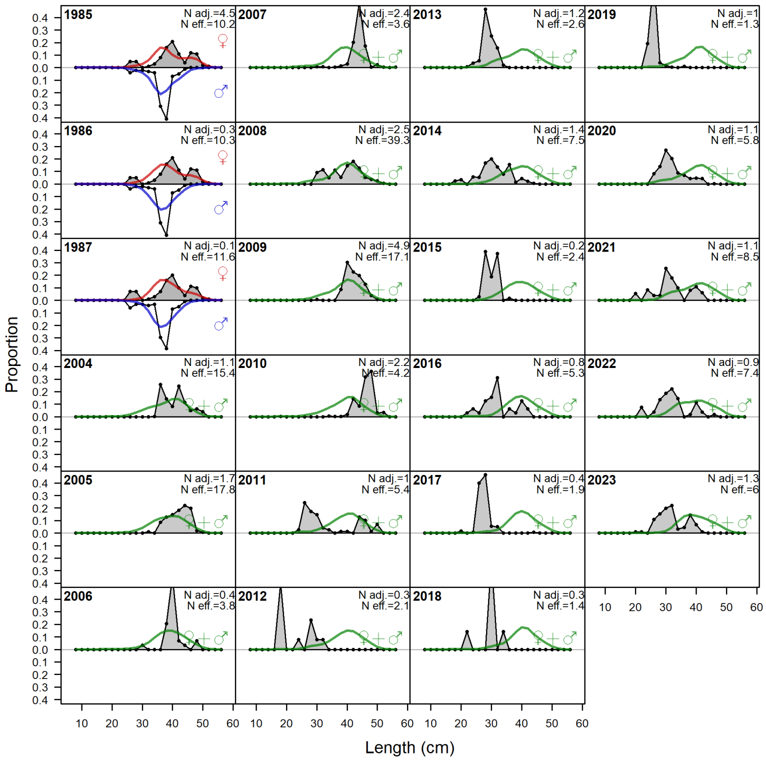

Figure A2: Fits to the discarded length compositions for the bottom trawl fleet.

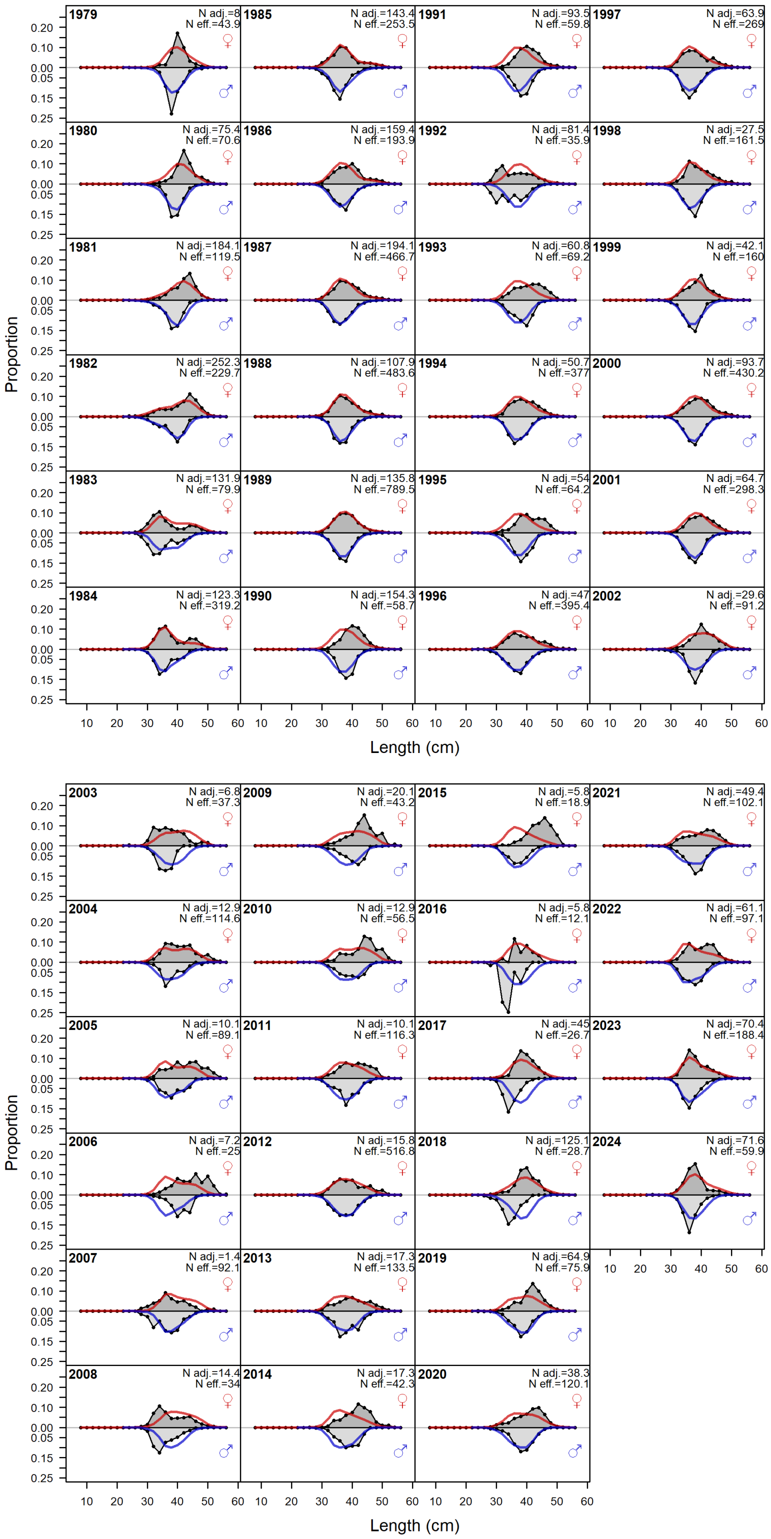

Figure A3: Fits to the retained length compositions for the midwater trawl fleet.

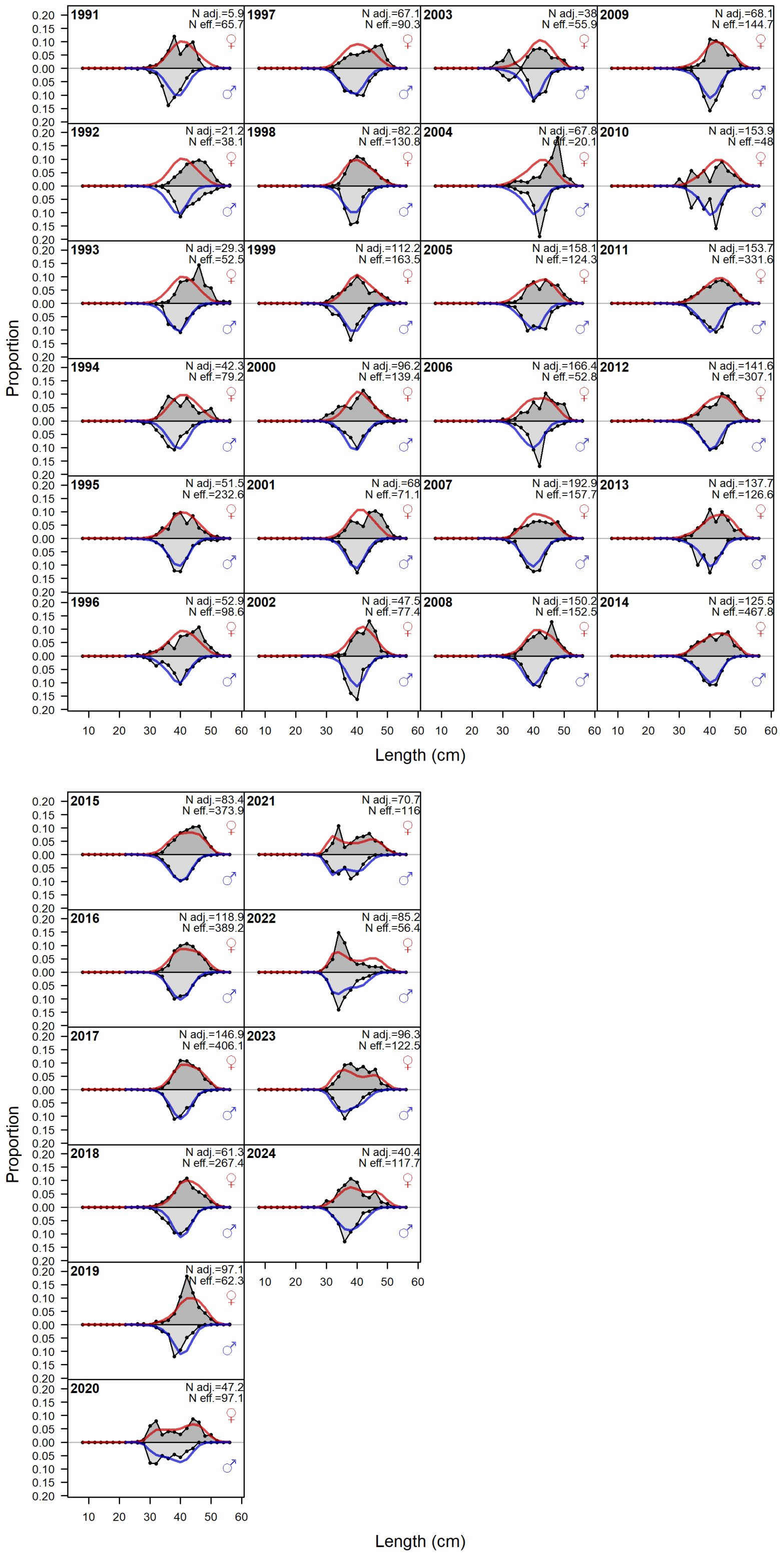

Figure A4: Fits to the retained length compositions for the hake fleet.

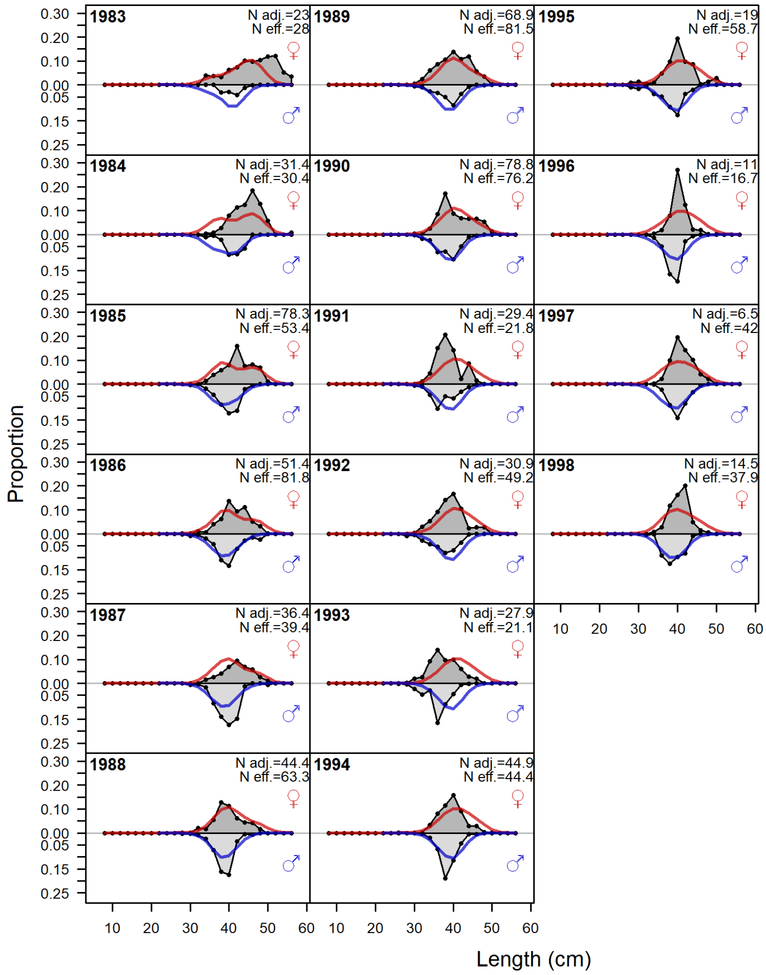

Figure A5: Fits to the retained length compositions for the net fleet.

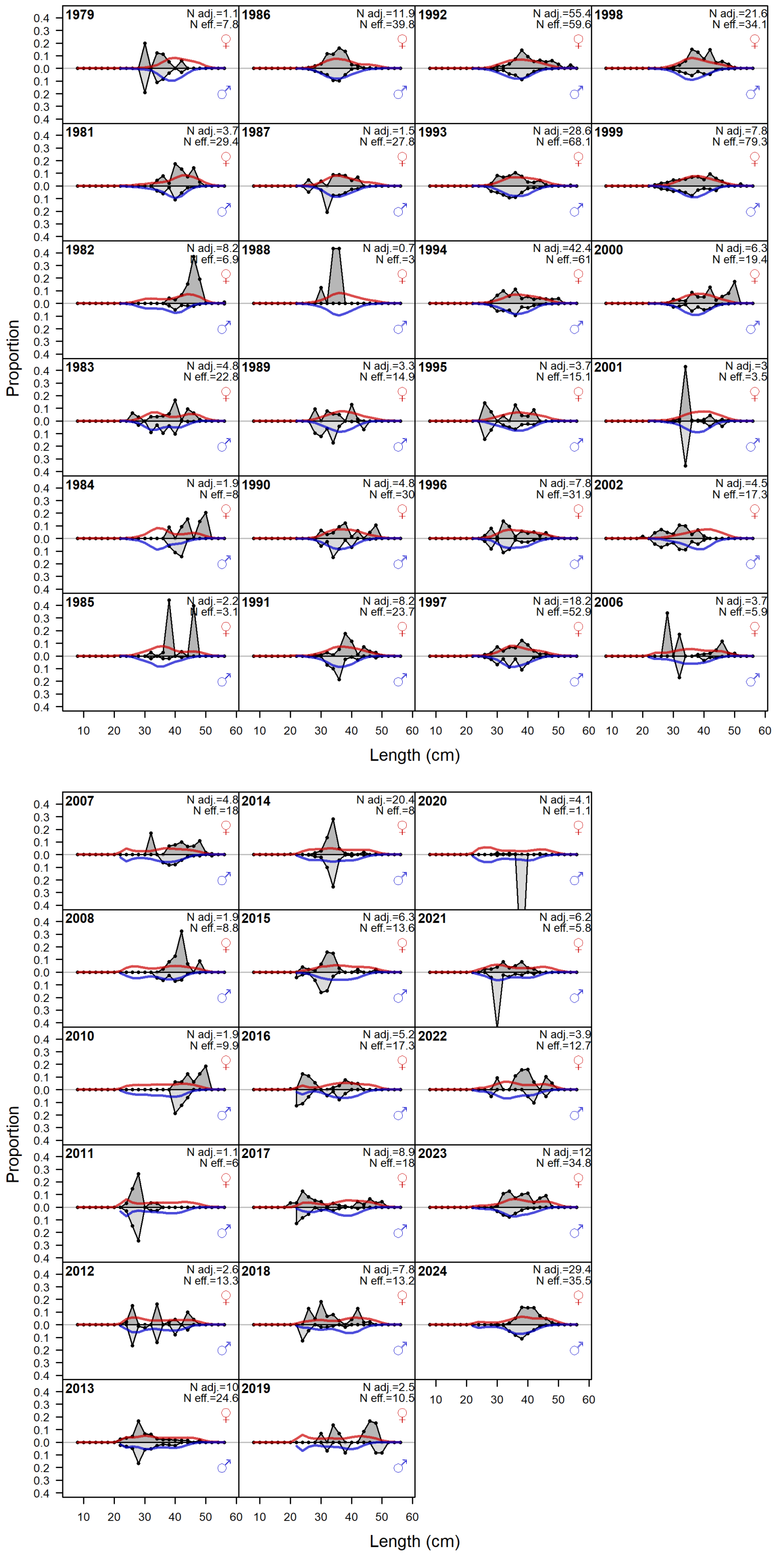

Figure A6: Fits to the retained length compositions for the hook-and-line fleet.

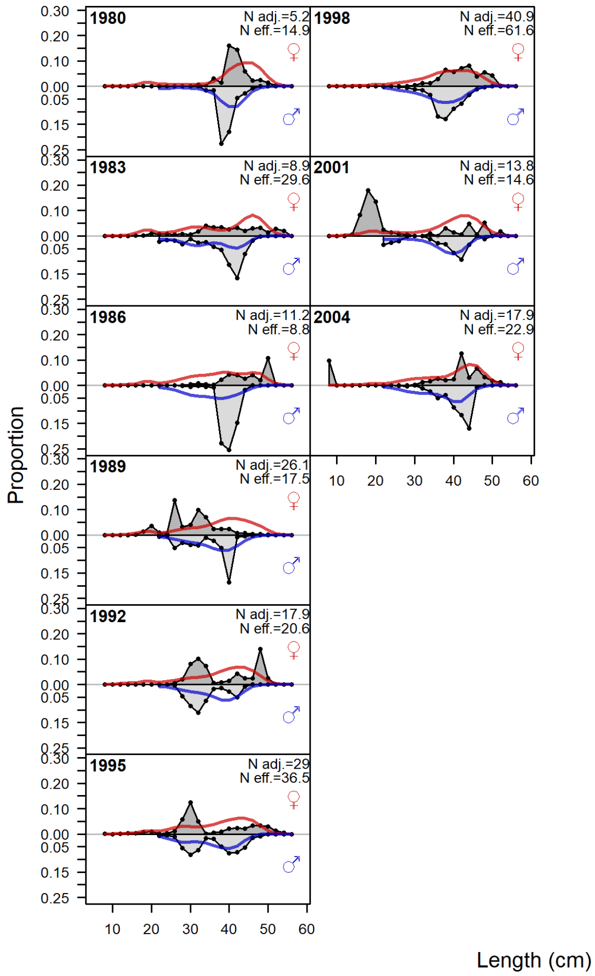

Figure A7: Fits to the length compositions for the triennial survey.

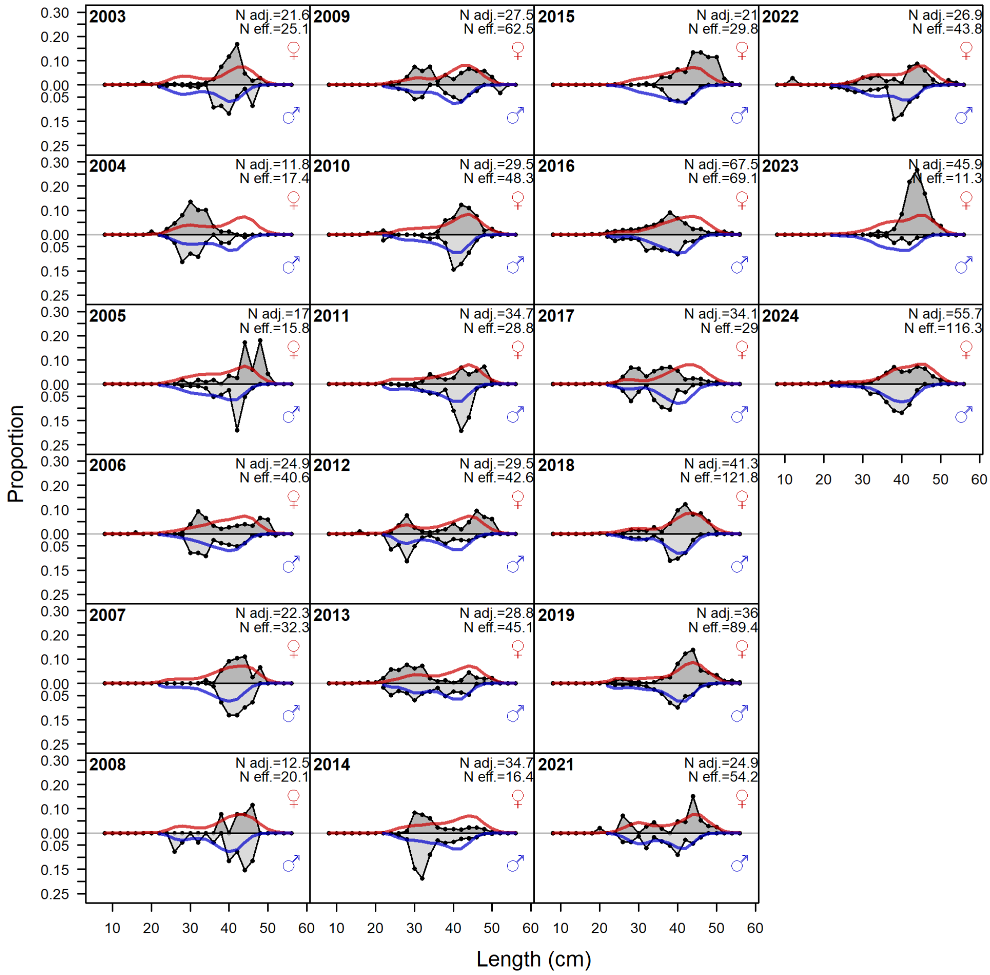

Figure A8: Fits to the length compositions for the NWFSC WCGBT survey.

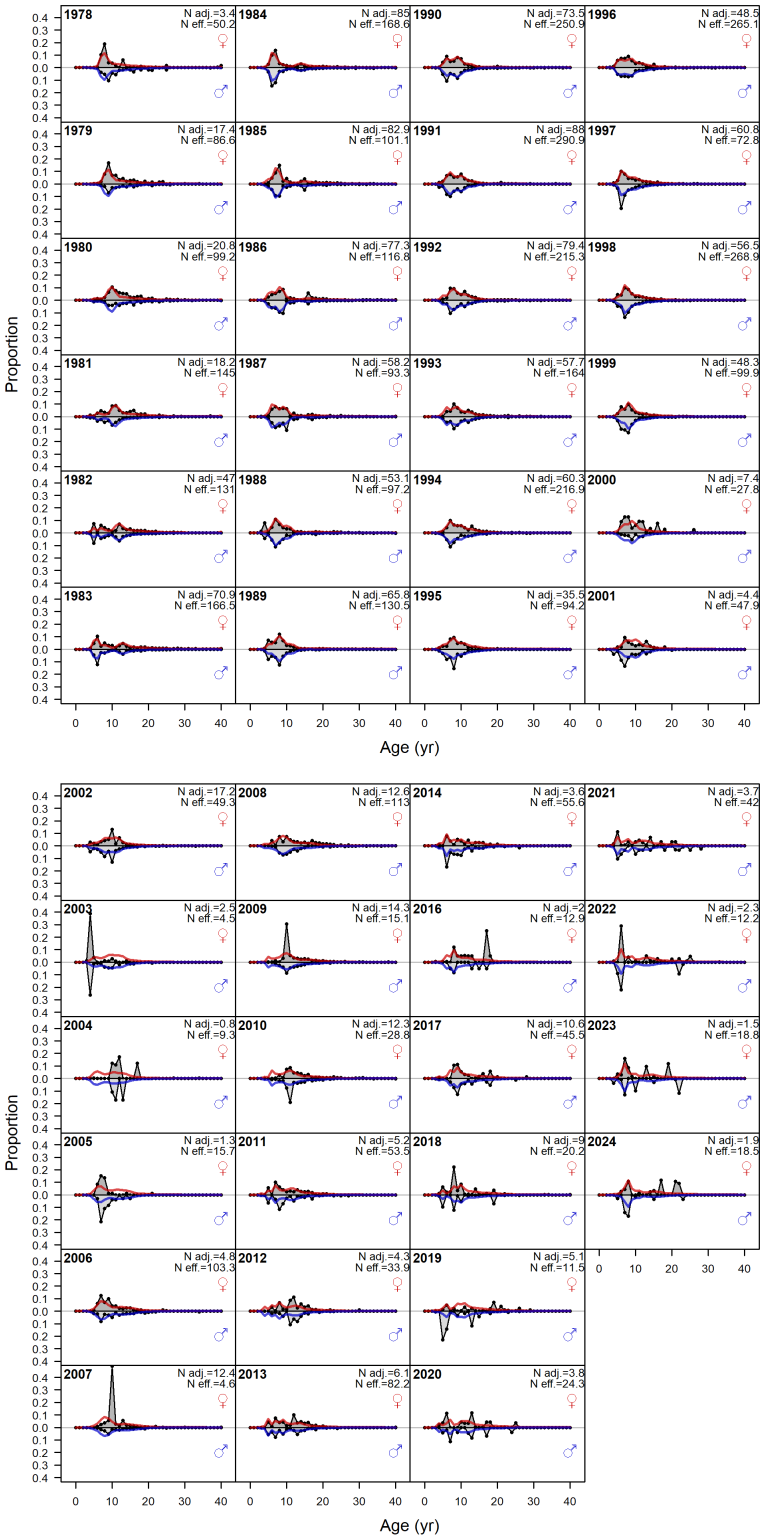

Figure A9: Fits to the retained age compositions for the bottom trawl fleet.

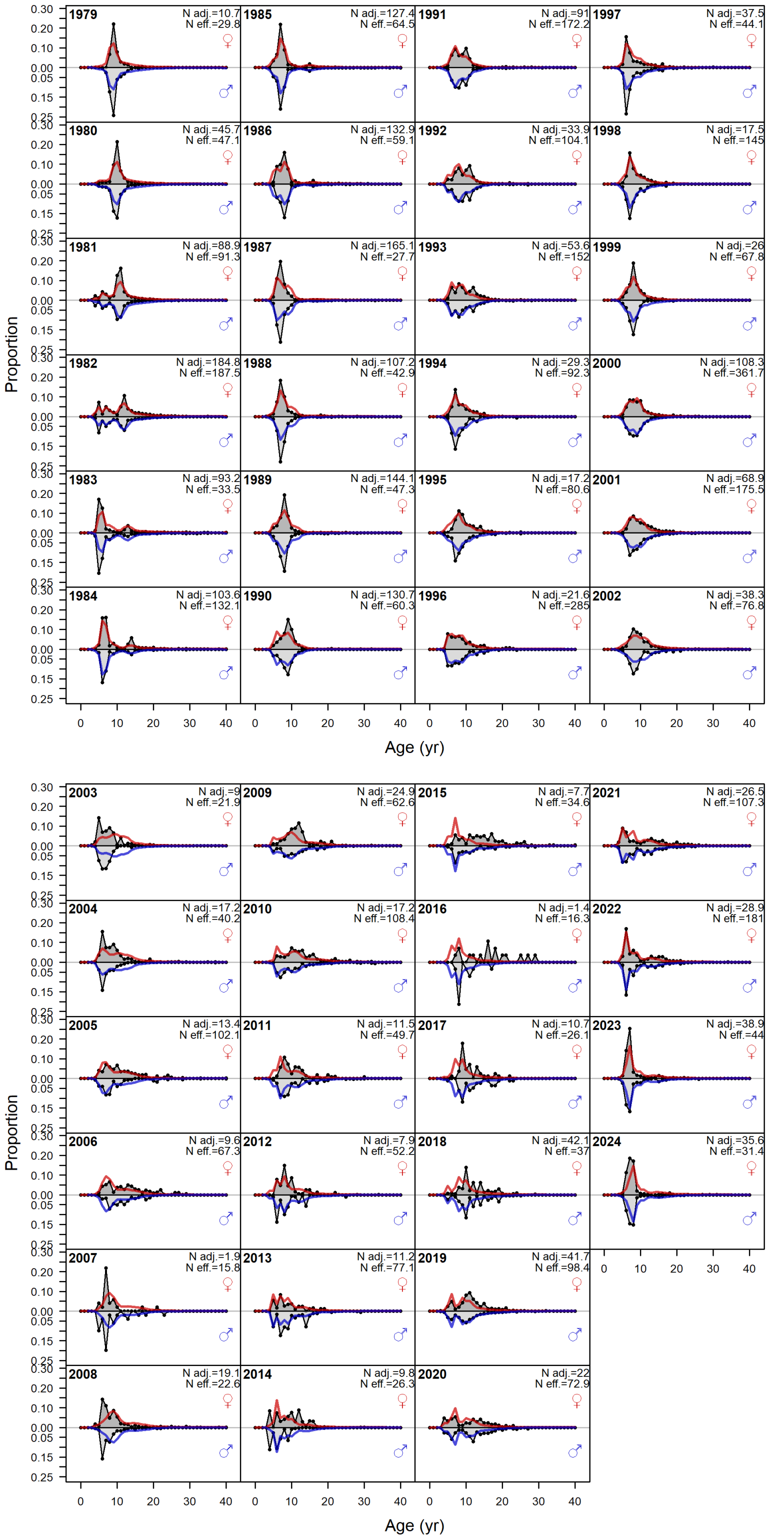

Figure A10: Fits to the retained age compositions for the midwater trawl fleet.

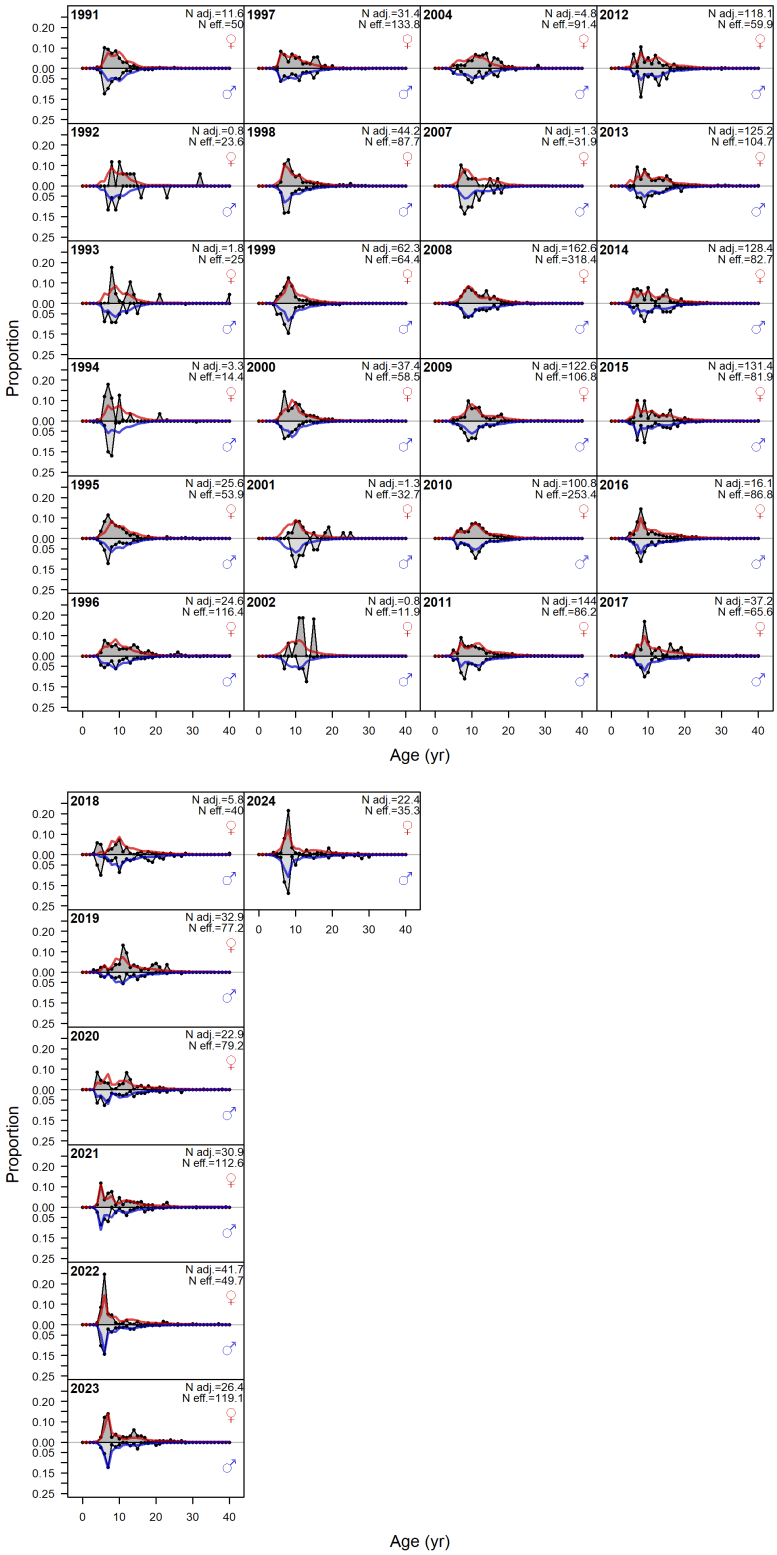

Figure A11: Fits to the retained age compositions for the hake fleet.

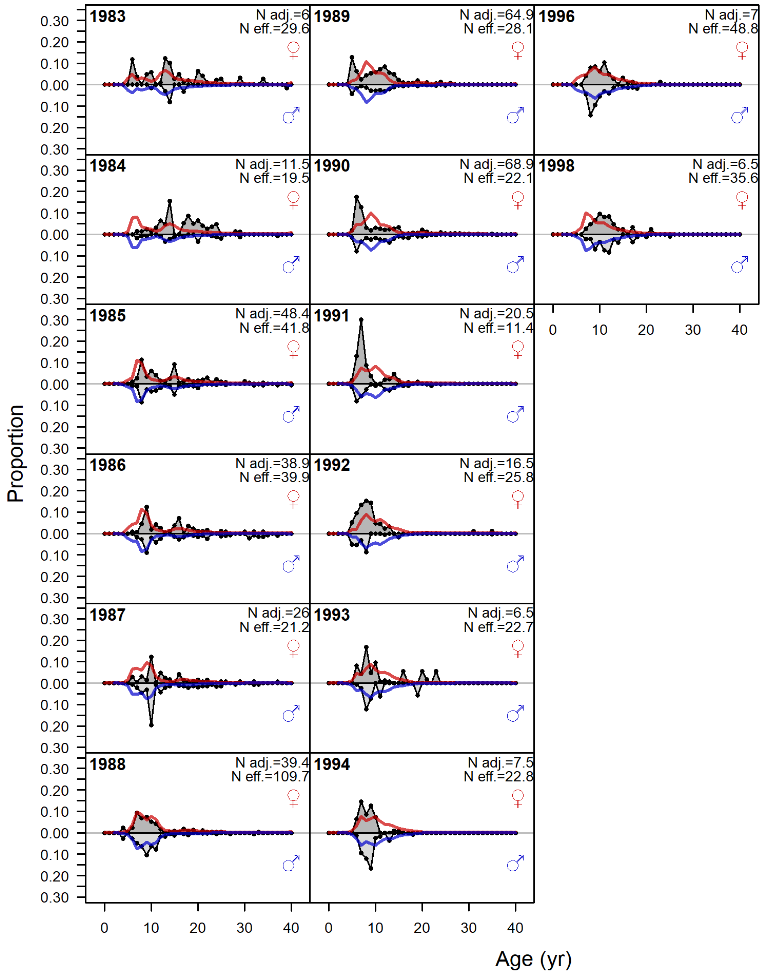

Figure A12: Fits to the retained age compositions for the net fleet.

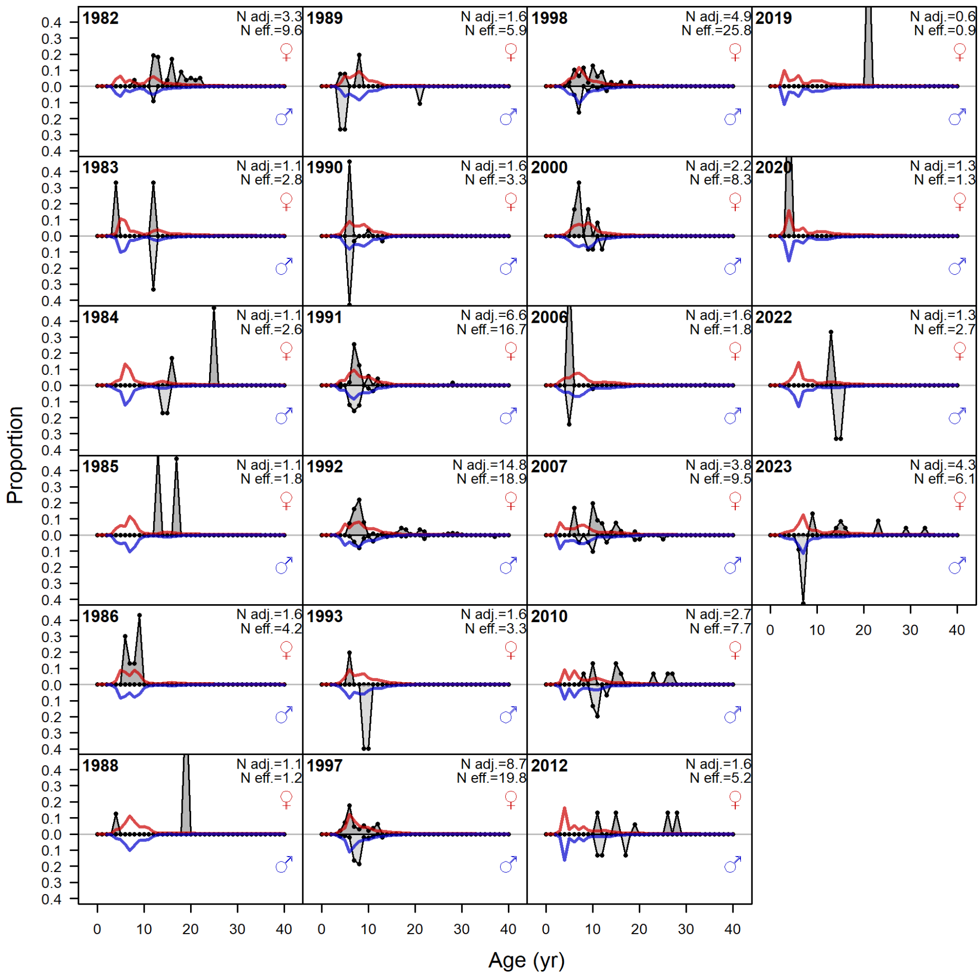

Figure A13: Fits to the retained age compositions for the hook-and-line fleet.