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

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

1. School of Aquatic & Fishery Sciences (SAFS), University of Washington, 1122 NE Boat St, Seattle, WA, 98195
2. Department of Environmental Science and Policy, University of California Davis, Wickson Hall, 350 N Quad, Davis, CA, 95616
3. UW Puget Sound Institute, Center for Urban Waters, 326 East D Street, Tacoma, WA, 98421
4. California Department of Fish and Wildlife, 1740 North Market Boulevard, Sacramento, CA, 95834
5. Southwest Fisheries Science Center, 8901 La Jolla Shores Drive, La Jolla, CA, 92037
6. Coastal Oregon Marine Experiment Station, Oregon State University, 430 Strand Agriculture Hall, Corvallis, OR, 97331
7. University of California, Santa Cruz, Institute of Marine Sciences' Fisheries Collaborative Program, 1156 High Street, Santa Cruz, CA, 95064
8. NOAA Fisheries Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, WA, 98112
9. NOAA Alaska Fisheries Science Center, 7600 Sand Point Way N.E., Building 4, Seattle, WA, 98115

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest Fisheries Science Center

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Please cite this publication as:

M. Kinneen, M. Goodman, A. Sulc, L. Balstad, R. Diaz, K. Randrup, W. Patrone, L. Spencer, A. Morell, A. Rovellini, A. Dedrick, N. Grunloh, M.Bargas, S.Hopkins, V. Gersteva, K. Oken, I. Taylor, M. Haltuch, O. Hamel (2025) Stock Assessment Update: Status of Widow Rockfish (Sebastes entomelas) Along the U.S. West Coast in 2025. Pacific Fishery Management Council, Portland, Oregon.

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.-Canada border in the north to the U.S.-Mexico border in the south. The most recent benchmark was conducted in 2015 (Hicks and Wetzel 2015) and first updated in 2019 (Adams et al. 2019). This assessment represents the second update of the 2015 benchmark stock assessment. 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 (Hicks and Wetzel 2015), this update assessment is based on a single costwide area model.

Catches

Historically, fisheries have caught widow rockfish since the turn of the 20th century. Landings in the trawl fishery are estimated to have increased into the 1940s and remained relatively constant and small (below 1,000 mt per year) throughout the 1950s and into the 1960s before 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. 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 hake/whiting (*Merluccius productus*, hereafter "hake'') fisheries account for the majority of the recent catch.

Widow rockfish are a desirable market species and it is believed that discarding was low historically. However, management restrictions (e.g., trip limits) resulted in a substantial amount of discarding beginning in the early 1980s. Trawl rationalization was introduced in 2011. Between 2011 and 2024 very little discarding of widow rockfish is estimated to have occurred. Recent discards in the model informed by data from the West Coast Observer Program (WCGOP), and total catches (discards plus landings) are reported in addition to landings. Landings for the past ten years are in Table i and for the entire time series in Figure i.

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	2.0	879.6	879.8
2016	9.6	588.0	440.8	0.0	0.8	1,039.2	1,039.4
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	1.5	10,493.0	10,522.8
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	8.7	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

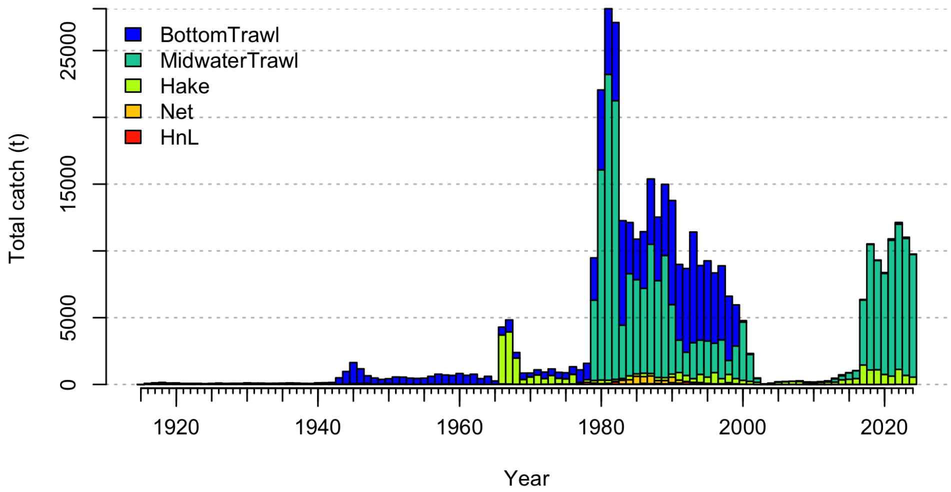


Figure i: Landings of widow rockfish from 1916 to 2024 for bottom trawl, midwater trawl, net, and hook- and-line fisheries, and catches of widow rockfish for the foreign (1966–1976) and Pacific Whiting (hake) fisheries (green).

Data and Assessment

This assessment uses the length- and age-structured modeling software Stock Synthesis (version 3.30.23.1). The coastwide population was modeled assuming separate growth and mortality parameters for males and females from 1916 to 2024.

The model includes catch, age, and length data for five fishing fleets: 1) a coastwide shore-based bottom trawl fleet (1916–2024), 2) a coastwide shore-based midwater trawl fleet (1979–2024), 3) a mostly midwater trawl fleet that targets hake and includes a foreign and at-sea fleet (1975–2024), a domestic shore-based fleet (1991–2024), and foreign vessels that targeted hake and rockfish between 1966–1976, 4) a net fishery consisting of catches mostly from California (1981–2024), and 5) a coastwide hook-and-line fishery (1916–2024). There are three older fishery-dependent CPUE indices retained from the 2015 benchmark: 1) Oregon bottom trawl (1984-1999), 2) hake at-sea foreign (1977-1988), and 3) hake at-sea domestic fleets (1983-1998).

The 2015 benchmark and 2019 update assessments estimated discards using retention curves for the bottom trawl, midwater trawl, and hook-and-line fleets based on discard biomass and length composition data from the West Coast Groundfish Observer Program (WCGOP). Changes to the underlying discard length composition data for the hook-and-line fleet from WCGOP illustrated that very large recruitment events in 2013 and 2014 were mainly driven by very small amounts of composition data for a minor fleet responsible for less than one-tenth of a percent of the catch in the last decade. With the updated data, this led to implausible population dynamics, so the decision was made to add discard biomass from the Groundfish Expanded Mortality Multi-Year (GEMM) to the landed catch for the hook-and-line fleet, rather than estimating retention. Retention is still estimated for the midwater and bottom trawl fleets, which have more available data.

Data from three fishery-independent surveys were also included in the model: 1) length compositions and an index for the Alaska Fisheries Science Center/Northwest Fisheries Science Center West Coast Triennial Shelf Survey (Triennial Survey) were retained from the 2015 benchmark (1977–2004), 2) age-at-length, length, and an index for the Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey (WCGBTS) (2003-2024), and 3) a recruitment index from the National Marine Fisheries Service (NMFS) Southwest Fisheries Science Center (SWFSC) and Northwest Fisheries Science Center (NWFSC)/Pacific Whiting Conservation Cooperative (PWCC) Midwater Trawl Survey (2004-2024).

The base model estimated parameters for length-based selectivity for all fleets and surveys, retention curves for the bottom trawl and midwater trawl fleets, a sex-specific length-at-age relationship, sex-specific natural mortality, and recruitment deviations. A Beverton-Holt stock-recruitment function was used to model productivity, and the steepness parameter was fixed at 0.72 based on a steepness meta-analysis (Thorson et al. 2019) for west coast rockfishes.

Natural mortality and steepness are major sources of uncertainty. We used high and low combinations of these parameters to define a range of states of nature, with results presented in a decision table.

Stock biomass and dynamics

The time series of estimated spawning biomass and relative spawning biomass is in Figure ii and Figure iii, respectively, and for the most recent year in Table ii. The spawning biomass declined rapidly with the developing domestic midwater fishery in the late 1970s and early 1980s. Low abundance continued 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.

The 2025 spawning biomass relative to unfished equilibrium spawning biomass is 50, above the target of 40% (95% confidence interval of 30 - 69%).

Spawning biomass is estimated to be at 40,604 mt in 2025 (95% confidence interval of 18,692 - 62,515 mt). The uncertainty in the estimated spawning biomass is high, especially in the early years.

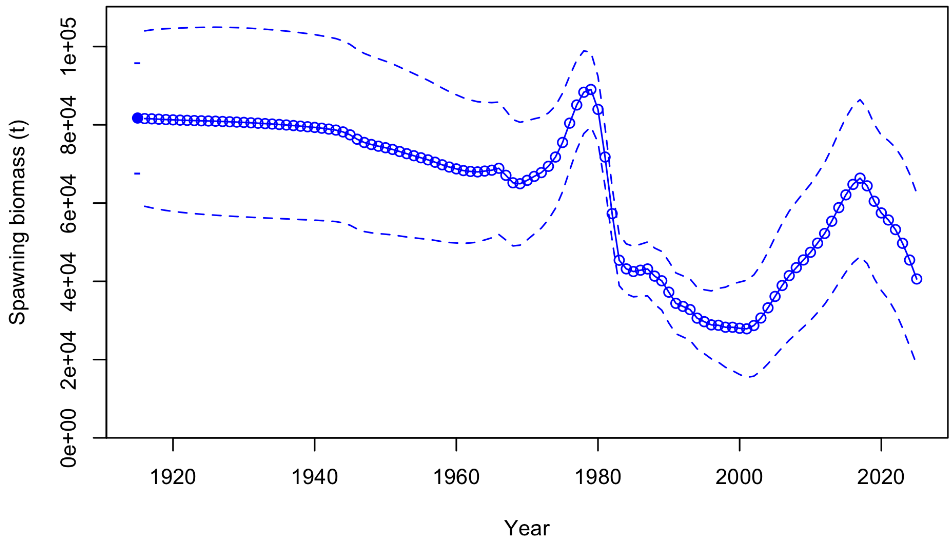


Figure ii: Estimated female spawning biomass time-series from the base model (solid line) with an approximate asymptotic 95% confidence interval (dashed lines).

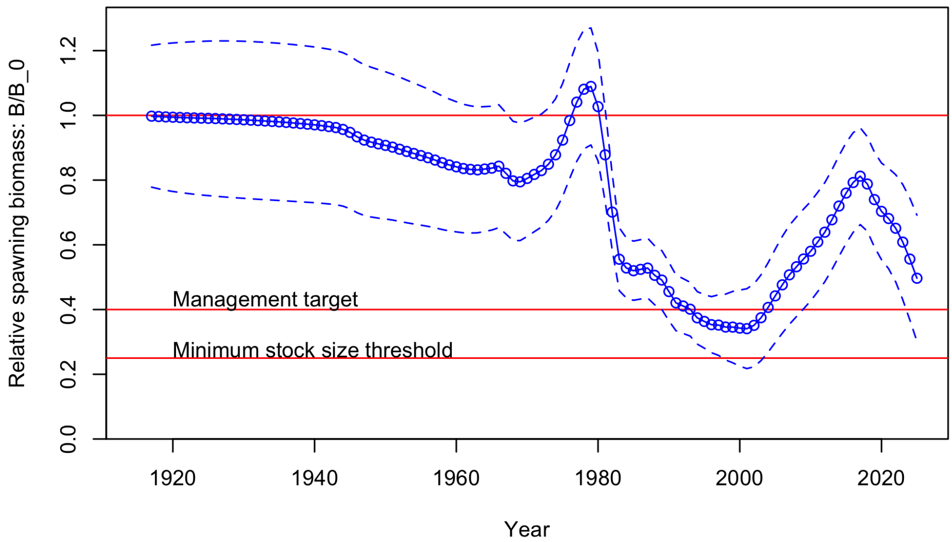


Figure iii: Estimated relative spawning biomass (depletion) with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model.

Table ii: Recent trend in estimated female spawning biomass (mt) and relative spawning biomass (depletion).

Year	Spawning Biomass (mt)	Lower Interval (mt)	Upper Interval (mt)	Fraction Unfished	Lower Interval	Upper Interval
2015	62,102.2	42,367.71	81,836.68	0.760	0.604	0.915
2016	64,772.5	44,724.42	84,820.58	0.792	0.639	0.946
2017	66,368.7	46,318.86	86,418.54	0.812	0.663	0.962
2018	64,402.6	44,578.35	84,226.85	0.788	0.642	0.934
2019	60,465.2	40,745.02	80,185.38	0.740	0.593	0.886
2020	57,485.6	37,654.29	77,316.91	0.703	0.554	0.853
2021	55,682.2	35,407.55	75,956.85	0.681	0.526	0.836
2022	53,221.9	32,240.29	74,203.51	0.651	0.486	0.817
2023	49,724.4	28,075.62	71,373.18	0.608	0.430	0.786
2024	45,443.7	23,459.96	67,427.44	0.556	0.368	0.744
2025	40,603.5	18,692.47	62,514.53	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. 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, Figure v).

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

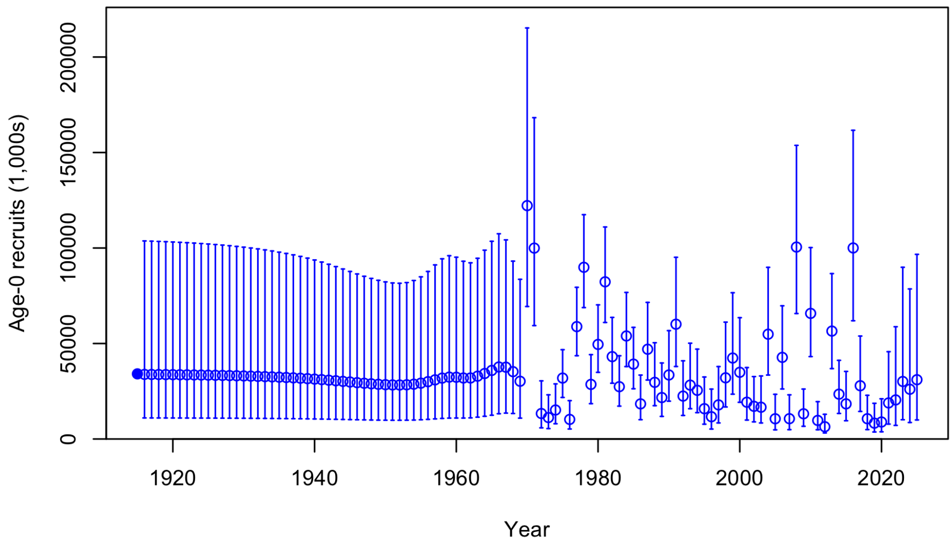


Figure iv: Time-series of estimated recruitments (medians as open circles) for the base case model with approximate asymptotic 95% confidence interval (vertical bars). Estimated mean unfished equilibrium recruitment (R0) is shown as the closed circle with a 95% confidence interval at the beginning of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

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

Year	Recruit-ment (1,000s)	Lower Interval (Rec, 1,000s)	Upper Interval (Rec, 1,000s)	Recruit-ment Deviations	Lower Interval (Rec Devs)	Upper Interval (Rec Devs)
2015	18,395	9,562	35,389	-0.434	-0.990	0.122
2016	100,039	61,911	161,648	1.255	0.969	1.540
2017	27,892	14,432	53,906	-0.026	-0.554	0.503
2018	10,615	4,923	22,886	-1.007	-1.671	-0.342
2019	8,289	3,676	18,688	-1.268	-1.985	-0.550
2020	8,907	3,771	21,042	-1.210	-1.991	-0.430
2021	18,889	7,804	45,721	-0.476	-1.308	0.356
2022	20,464	7,124	58,784	-0.411	-1.484	0.662
2023	30,115	10,086	89,912	-0.036	-1.161	1.089
2024	26,046	8,634	78,568	-0.189	-1.325	0.947
2025	31,046	9,969	96,684	0.000	-1.176	1.176

Exploitation status

The population declined throughout the 1980s and 1990s when fishing intensity was above the management target and overfishing was occurring. The population then increased from around 2000 to 2016 when fishing intensity was well below the management management target. Fishing intensity has increased substantially since 2017, and is estimated to have been above the management target since 2018 (i.e., overfishing is occurring), though the relative spawning output remains above the management target of 40% (i.e., the population is not overfished). Recent fishing intensities are in Table iv, and a full time series of relative spawning output and fishing intensity is in Figure v.

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

Year	(1-SPR)/(1-SPR50%)	Lower Interval (SPR)	Upper Interval (SPR)	Exploitation Rate	Lower Interval (Rate)	Upper Interval (Rate)
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	0.110
2020	1.041	0.790	1.291	0.072	0.047	0.098
2021	1.210	0.944	1.476	0.097	0.060	0.133
2022	1.270	0.989	1.551	0.116	0.069	0.164
2023	1.248	0.936	1.560	0.119	0.065	0.173
2024	1.257	0.909	1.605	0.121	0.060	0.181

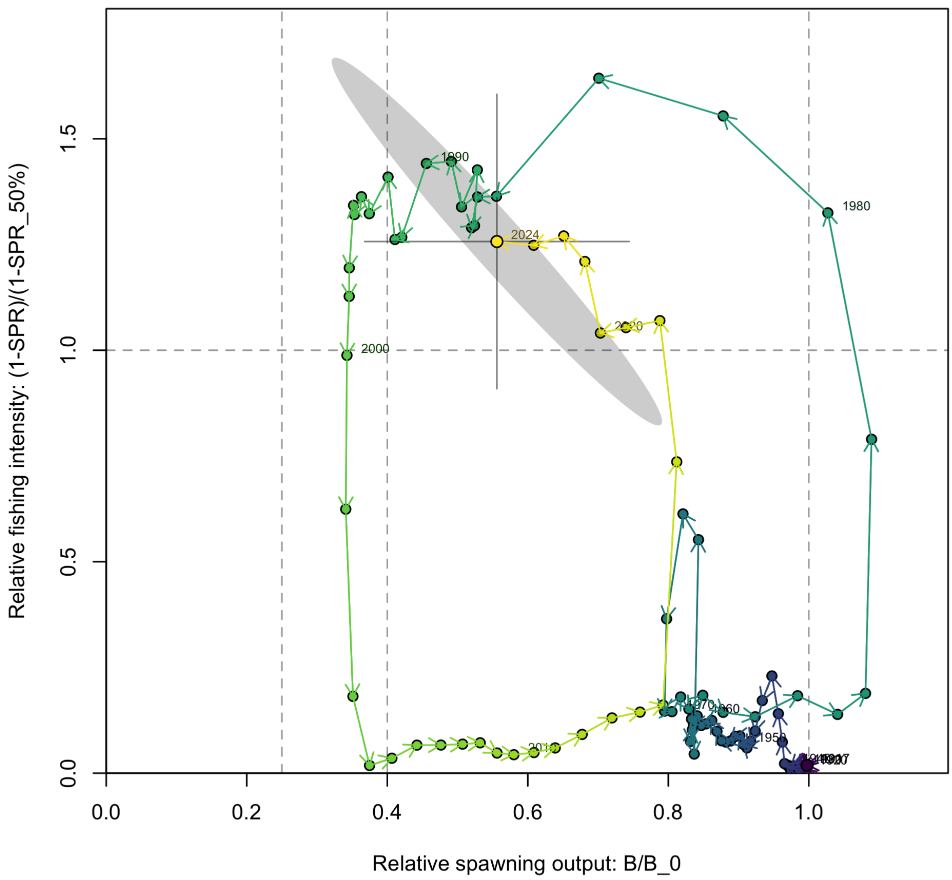


Figure v: Phase plot of fishing intensity versus fraction unfished. Each point represents the spawning biomass ratio at the start of the year and the relative fishing intensity in that same year. Lines through the final point show 95% intervals based on the asymptotic uncertainty for each dimension. The shaded ellipse is a 95% region which accounts for the estimated correlation between the two quantities.

Ecosystem considerations

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

Fishing has effects on habitats, in addition to the population itself. Rockfish are often associated with habitats containing living structures such as sponges and corals, and fishing may alter that habitat to a less desirable state. 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). A list of estimates of the current state of the population, as well as reference points based on 1) a target unfished spawning output of 40%, 2) a spawning potential ratio of 0.5, and 3) the model estimate of maximum sustainable yield (MSY), are all listed in Table v. SPR, or the spawning potential ratio, is the fraction of expected lifetime reproductive output under a given fishing intensity divided by unfished expected lifetime reproductive output. While the estimate of total population scale has remained relatively steady across the 2015, 2019, and 2025 assessments, unfished recruitment and natural mortality, which are positively correlated, have declined from 2015 (female natural mortality of 0.157 yr^{-1}) to 2019 (0.144 yr^{-1}) to 2025 (0.125 yr^{-1}). Thus, although the scale is estimated consistently, additional years of data (in particular, age composition data) following the re-opening of the fishery have led the model to estimate that the population is less productive, which results in lower yields at all three reference points (proxy based on spawning output, proxy based on fishing intensity, and model estimate of MSY).

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

Reference Point	Estimate	Lower Interval	Upper Interval
Unfished Spawning Biomass (mt)	81,733.40	67,570.82	95,895.98
Unfished Age 4+ Biomass (mt)	151,584.00	125,227.97	177,940.03
Unfished Recruitment (R0)	34,103.00	22,838.42	45,367.58
2025 Spawning Biomass (mt)	40,603.50	18,692.47	62,514.53
2025 Fraction Unfished	0.50	0.30	0.69
Reference Points Based SB40%			
Proxy Spawning Biomass (mt) SB40%	32,693.40	27,028.36	38,358.44
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)	5,902.00	4,529.86	7,274.14
Reference Points Based on SPR Proxy for MSY			
Proxy Spawning Biomass (mt) (SPR50)	36,465.70	30,147.01	42,784.39
SPR50	0.50		
Exploitation Rate Corresponding to SPR50	0.08	0.07	0.08
Yield with SPR50 at SB SPR (mt)	5,627.95	4,323.51	6,932.39
Reference Points Based on Estimated MSY Values			
Spawning Biomass (mt) at MSY (SB MSY)	21,667.40	17,966.58	25,368.22
SPR MSY	0.34	0.33	0.34
Exploitation Rate Corresponding to SPR MSY	0.13	0.12	0.14
MSY (mt)	6,310.43	4,828.58	7,792.28

Management performance

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

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

Year	OFL (mt)	ABC (mt)	ACL (mt)	Landings (mt)	Total Mortality (mt)
2015	4,137	3,929.00	2,000	879.62	879.80
2016	3,990	3,790.00	2,000	1,039.24	1,039.41
2017	14,130	13,508.28	13,508	6,345.89	6,361.45
2018	13,237	12,654.57	12,655	10,493.03	10,522.76
2019	12,375	11,830.50	11,831	9,289.43	9,315.27
2020	11,714	11,198.58	11,199	8,355.24	8,379.58
2021	15,749	14,725.32	14,725	10,866.89	10,899.73
2022	14,826	13,788.18	13,788	12,094.40	12,129.69
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	9,764.11

0.1 Unresolved problems and major uncertainties

Discuss fit to survey data and natural mortality.

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 2013 year class is no longer a major source of uncertainty, and there is no recent similarly large estimate of recruitment.

The 12.5% and 87.5% quantiles for female and male natural mortality (independently) were chosen as low and high values (0.115 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 two factors defined the low state of nature and the high combination of these two factors defined the high state of nature. The predictions of spawning 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 two catch streams based on ACL adjustments of 0.45 P* and 0.40 P* were conducted (Table viii).

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 in 2027 suggest that the spawning biomass will decrease over the projection period for all states of nature (Table viii). Predicted ACL catches range from 3,031 mt in 2027 to 4,254 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 0.40 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 mt in 2027 to mt in 2036.

Table vii: Potential OFLs (mt), ABCs (mt), ACLs (mt), the buffer between the OFL and ABC, estimated spawning biomass (mt), and fraction of unfished spawning biomass with adopted OFLs and ACLs and assumed catch for the first two years of the projection period. The predicted OFL is the calculated total catch determined by FSPR=50%.

Year	Adopted OFL (mt)	Adopted ACL (mt)	Assumed Catch (mt)	OFL (mt)	Buffer	ABC (mt)	ACL (mt)	Spawning Biomass (mt)	Fraction Unfished
2025	12254	11237	10669	-	-	-	-	40,604	0.497
2026	11382	10392	9823.6	-	-	-	-	34,837	0.426
2027	-	-	-	3582	0.935	3349.17	3241.8	29,822	0.365
2028	-	-	-	3651.6	0.93	3395.988	3252.7	29,021	0.355
2029	-	-	-	3888.8	0.926	3601.0288	3445.9	28,950	0.354
2030	-	-	-	4191.3	0.922	3864.3786	3719.1	29,381	0.359
2031	-	-	-	4499.4	0.917	4125.9498	4006.9	30,089	0.368

Year	Adopted OFL (mt)	Adopted ACL (mt)	Assumed Catch (mt)	OFL (mt)	Buffer	ABC (mt)	ACL (mt)	Spawning Biomass (mt)	Fraction Unfished
2032	-	-	-	4765.7	0.913	4351.0841	4266.8	30,898	0.378
2033	-	-	-	4967.5	0.909	4515.4575	4467.3	31,679	0.388
2034	-	-	-	5112	0.904	4621.248	4606.2	32,379	0.396
2035	-	-	-	5217.2	0.9	4695.4	4695.4	32,995	0.404
2036	-	-	-	5299.3	0.896	4748.2	4748.2	33,547	0.410

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 (%)
ACLp*=0.45, sigma=0.50	2025	10,669	28,278	32.7	40,552	49.6	49,907	60.6
	2026	9,824	22,726	26.3	34,788	42.6	43,767	53.1
	2027	3,031	17,921	20.7	29,775	36.4	38,407	46.6
	2028	3,025	17,418	20.2	29,085	35.6	37,432	45.4
	2029	3,191	17,549	20.3	29,127	35.6	37,281	45.3
	2030	3,429	18,026	20.9	29,680	36.3	37,755	45.8
	2031	3,674	18,595	21.5	30,525	37.4	38,644	46.9
	2032	3,896	19,077	22.1	31,488	38.5	39,766	48.3
	2033	4,061	19,374	22.4	32,439	39.7	40,972	49.7
	2034	4,164	19,486	22.6	33,322	40.8	42,170	51.2
	2035	4,226	19,477	22.5	34,133	41.8	43,322	52.6
	2036	4,254	19,415	22.5	34,889	42.7	44,412	53.9
	2025	10,669	28,278	32.7	40,552	49.6	49,907	60.6

			State of nature					
			Low		**Base**		**High**	
Management decision	Year	catch (mt)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)	Depletion (%)
ACLp*=0.40, sigma=0.50	2026	9,824	22,726	26.3	34,788	42.6	43,767	53.1
	2027	2,642	17,921	20.7	29,775	36.4	38,407	46.6
	2028	2,627	17,624	20.4	29,288	35.8	37,633	45.7
	2029	2,757	17,957	20.8	29,527	36.1	37,675	45.7
	2030	2,947	18,650	21.6	30,288	37.1	38,351	46.6
	2031	3,145	19,459	22.5	31,360	38.4	39,456	47.9
	2032	3,312	20,206	23.4	32,567	39.9	40,810	49.5
	2033	3,430	20,794	24.1	33,783	41.3	42,264	51.3
	2034	3,492	21,221	24.6	34,947	42.8	43,722	53.1
	2035	3,505	21,549	24.9	36,052	44.1	45,141	54.8
	2036	3,502	21,845	25.3	37,113	45.4	46,506	56.5

Scientific uncertainty

The model estimate of the log-scale standard deviation of the overfishing limit (OFL) in 2025 is 0.315. This is less than the default SSC value of 0.5 for a category 1 assessment, so harvest projections assume an initial sigma of 0.5.

0.2 Unresolved problems and major uncertainties

Major sources of uncertainty include landings, discards, natural mortality, and recruitment, which are discussed below.

Because widow rockfish is a marketable species, historical discard rates were likely lower than less desirable or smaller species. This assessment assumed that discarding was nearly negligible before management restrictions began in 1982. Once trip limits were introduced, discarding tended to be an all or none event, 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. The open access fixed-gear fleet is not monitored by the full observer coverage required under trawl rationalization. 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). Multiple surveys are used in the assessment, but further consideration of additional surveys is reasonable.

Widow rockfish is a relatively long-lived fish, and natural mortality is likely to be lower than many species of fish, such as gadoids. Ages above 50 years have been observed and it is expected that natural mortality could be less than 0.10 yr^{-1} (the median of the prior for natual mortality used in this assessment). However, even with length and age data available back to the late 1970s, natural mortality was estimated at 0.125 for females and 0.137 yr^{-1} for males, with a small amount of uncertainty (e.g., a 6.6% coefficient of variation for females). This assessment attempts to capture that uncertainty by estimating natural mortality (M) and integrating that uncertainty into the derived biomass estimates, as well as additional uncertainty by including levels outside of the predicted interval in a decision table. One contributing factor to this change is the increase in the mean age of the catch observed by the WCGBTS survey in recent years. These observations are poorly fit by the model, and considertation should be given in future to structural changes which may improve the fit to WCGBTS CAAL data. One possible explanation as to the increased observation of older fish is that successfully rebounding of the stock as a result of reduced fishing pressure form 2003-2016 allowed year classes to grow older and are now being fully observed by WCGBTS.

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.

0.3 Research and Data Needs

- **Natural mortality:** Uncertainty in natural mortality translates into uncertain estimates of status and sustainable fishing levels for widow rockfish. The collection of additional age data, re-reading of older age samples, reading old age samples that are unread, and improved understanding of the life-history of widow rockfish may reduce that uncertainty. Investigating the ageing error and bias would help to understand the influences that the age data have on this assessment, particularly the influence of age data on natural mortality.
- **Historical landings and discards:** Although progress has been made in reconstructing historical landings of rockfish on the U.S. West Coast, the historical landings and discards continue to be 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. In addition, discard composition data have become available for the midwater trawl fleet in recent years and should be included in future assessments.
- **Sex-specific selectivity:** The midwater and bottom trawl length-composition data fits showed divergent residual patterns between male and female fish. The underlying mechanism driving this pattern is unclear, and could be related to growth, sexing error, or to sex-specific selectivity (e.g., when widow rockfish aggregate,

sexes possibly may be aggregating separately). Sex-specific selectivity for these two fleets could be explored or included to address this.

- **Coastwide understanding of stock structure, biology, connectivity, and distribution:** This is a stock assessment for widow rockfish off of the west coast of the U.S. and does not consider data from British Columbia or Alaska. Further investigating and comparing the data and predictions from British Columbia and Alaska to determine if there are similarities with the U.S. West Coast observations would help to define the connectivity between widow rockfish north and south of the U.S.-Canada border.

1 Introduction

This is an assessment of widow rockfish that inhabit the waters off California, Oregon, and Washington from the U.S.-Canadian border in the north to the U.S.-Mexico border in the south, and does not include Puget Sound.

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

1.1 Distribution and Stock Structure

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

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

1.2 Life History

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

1.3 Ecosystem Considerations

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

1.4 Fishery description

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

1.5 Management History

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

1.6 Management performance

Total mortality estimates from the WCGOP and from the stock assessment may differ due to the use of different methods. Investigation into how these methods differ is beyond the scope of an update assessment. Table 3 shows that recent landings have been below recommended catch levels. Landings are a considerable amount below the ACL, and it is unlikely that total mortality has exceeded the ACL in the last 10 years.

1.7 Fisheries off Canada and Alaska

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

2 Data

Many sources of data were available for this assessment (Figure 23), including indices of abundance, landings, discards, and length and age observations from fishery-dependent and fishery-independent sources. Data used in this assessment are described below. No new data sources were considered in this update assessment.

2.1 Fishery-independent data

Data from three fishery-independent surveys were used in this assessment: 1) the SWFSC and NWFSC/PWCC Midwater Trawl Survey (hereafter, "juvenile survey"); 2) the Alaska Fisheries Science Center (AFSC)/NWFSC Triennial Shelf Trawl Survey (hereafter, "triennial survey"); and 3) the NWFSC West Coast Groundfish Bottom Trawl Survey (hereafter, "WCGBTS"). Depth and latitude strata used to analyze the catch-rates, length compositions, and age compositions are the same as in the 2019 update assessment (Adams et al. 2019) and shown in Table 10.

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. The survey's design and sampling methods are most recently described in (Weinberg et al. 2002).

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

2.1.2 Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey

The Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey (WCGBTS) has been conducted annually, since 2003. It is based on a random-grid design; covering the coastal waters between depths of 55–1,280 m (Bradburn et al. 2011). No survey occurred in 2020 due to Coronavirus pandemic (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. Few large fish are found shallower than 100 m and few small fish are found in the deeper water of the slope. There is no clear trend in length with latitude other than smaller fish tend to occur south of approximately 36° N latitude, and there appears to be some very small fish found near 39° N latitude.

For this assessment, geostatistical models of biomass density were fit to survey data using the R package Species Distribution Models with Template Model Builder (`sdmTMB`) (Anderson et al. 2022). This is an updated approach compared to the 2015 benchmark assessment (non-spatial delta-GLMM) and the 2019 update assessment (VAST delta-lognormal model). The `sdmTMB` model used a 200 knot mesh of the survey area (Thorson et al. 2015). The prediction grid was truncated to only include available survey locations in depths between 55–500 m to limit extrapolating beyond the data and edge effects. Tweedie, delta-binomial, delta-gamma, and mixture distributions, which allow for extreme catch events, were investigated. The positive catch weight model includes survey pass ('first' for early season or 'second' for late season) and year. Vessel-year effects, which have traditionally been included in index standardization for this survey, were not included as the estimated variance for the random effect was close to zero. Vessel-year effects were more prominent when models did not include spatial effects and were included for each unique combination of vessel and year in the data to account for the random selection of commercial vessels used during sampling (Helser et al. 2004; Thorson and Ward 2014).

Results are shown for the delta-gamma and delta-lognormal distributions, which reported the best diagnostics among the explored models (Figure 2). Both models converged (positive definite Hessian matrix) but predicted data from both models showed slightly right-heavy tails compared to the assumed likelihoods, with the gamma model having stronger divergence. Spatiotemporal estimates of biomass from the delta-lognormal model were then converted into annual indices using sdmtmb::get_index() function by integrating across the spatial domain of the survey (Anderson et al. 2022).

Overall, the delta-lognormal index estimates is more comparable to the 2019 spatiotemporal VAST-based index than the delta-gamma index, and less influenced by extreme catch events, particularly in 2013 and 2016; for these reasons, in addition to better model performance observed above, the delta-lognormal sdmTMB-based index was used for the base model in this assessment. The delta-lognormal mean value (2262.824) was slightly lower than the means of the index values used in the 2015 benchmark assessment (2701.12) and the 2019 update assessment (3301.765). However, since these are used as relative indices, these differences in mean values have no impact in themselves on the outcome of the assessment. Comparisons of the different error structures, design-based estimate and the VAST index used in 2019 are in Figure 3.

Length, age, and conditional age-at-length compositions were processed using the nwfscSurvey package in R publicly available on GitHub (Wetzel et al. 2025). Length compositions were created by expanding to the tow and summing to give a strata specific composition Table 7. Strata definition was retained from the benchmark assessment. The strata compositions were combined to a coastwide composition using a design-based index of abundance from each stratum. The design based index is constructed by taking the average catch per unit effort (CPUE) defined as catch per area swept across tows in each stratum and year. The sum of strata specific composition data was then calculated, weighting by the average CPUE per stratum multiplied by the area of each stratum. Age distributions were included in the model as conditional-age-at-length (CAAL) observations. The marginal age-compositions were also included, but only for easier viewing of strong cohorts. The CAAL data were not expanded and were binned according to length, age, sex, and year.

The input sample sizes for length and marginal age-composition data were calculated based on (Stewart and Hamel 2014). The input sample size of CAAL data was set at the number of fish at each length by sex and by year. Expanded length frequencies from this survey show intermittent years of small fish; the 2018–2024 period generally suggests most fish are around 40–45cm in length (Figure 4). 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 6) 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 2001-2024 for widow rockfish was created 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 (Figure 36). 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/whiting (*Merluccius productus*, hereafter "hake' '). Minimal amounts are also taken by non-trawl gears such as hook-and-line and net (Table 9).

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 hake 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 the 1916-2018 period 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 for commercial shorebased data and NORPAC for at-sea hake fishery bycatch, and were otherwise appended onto the 1916-2018 landings and apportioned among fleets using the same criteria as those documented in the 2015 benchmark assessment Hicks and Wetzel (2015).

2.2.2 Fishery catch-per-unit-effort

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

2.2.3 Fishery length and age data

Biological data from commercial fisheries that caught widow rockfish were extracted from PacFIN on March 25, 2025 and from the NORPAC database on February 3, 2025. Lengths and age samples taken during port sampling in California, Oregon, and Washington were used to generate length and age compositions. The data were classified into bottom trawl, midwater trawl, hake trawl, net, and hook-and-line. For each fleet, the raw observations were expanded to the trip level, to account for differences in samples sizes relative to catch weights among trips (first stage expansion). The expanded length observations were then further expanded to state level, to account for differences in sampling intensity of widow rockfish landings among states combined into a single fleet (second stage expansion).

Table 4 shows the number of trips sampled and Table 5 shows the number of lengths taken for each year, gear, and fleet from the three states. Table 6 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 7 to Figure 11. Age compositions for the five fleets are shown in Figure 12 and Figure 16. 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. Sex-specific length frequencies were also available from (Pikitch et al. 1988).Length compositions for discards show a wide range of sizes being discarded, with a peak around 40 cm (Figure 17).

The West Coast Groundfish Observer Program (WCGOP) provided information on recent discard of widow rockfish between 2002–2023. Since 2011, under trawl rationalization, 100% observer coverage is required for the limited entry trawl sectors, which resulted in a large increase in data and ability to determine discard behavior.Discard estimates are shown in Table 9 and range from 463 to 1,847 mt.

Discard length data for 2004-2023 was provided by WCGOP. In 2015 and 2019 assessments, these data were used to estimate retention curves for bottom trawl and hook-and-like fleets. WCGOP discard lengths for the bottom trawl fleet from 2004-2017 are unchanged from the 2019 assessment, and new data were added for 2018-2023.

Major changes occurred only in the treatment of the hook-and-line discard data. Previous assessments in 2015 and 2019 erroneously combined WCGOP length composition data for the hook-and-line fleet with data from nearshore fixed gear fleets (pot, net).The current assessment omitted these nearshore fixed gear data from the hook-and-line data in the model. This change resulted in changes to the discard length distribution and years for which data was available (Figure 18). 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 amounts to hook-and-line landings.

The commencement of trawl rationalization in 2011 led to 100% observer coverage for the bottom and midwater trawl fleets. As a result coefficients of variation (CV) were fixed at 5% for observed discards. For years preceding this, CV were fixed at values used in the 2015 benchmark assessment Table 9. Length compositions of the discards for the bottom trawl fleet can be seen in Figure 19.

Discard length composition data became available this year for the midwater trawl fleet, but was not available for previous assessments. These newly available data for midwater trawl 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.

2.2.5 Biological data

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

2.2.5.1 Weight-length relationship

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

The following relationships between weight and length for females and males 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 the most recent benchmark assessment (Hicks and Wetzel 2015) and most recent update assessment (Adams et al. 2019) for information.

2.2.5.3 Fecundity

Fecundity parameters remain unchanged from previous assessment; please refer to the most recent benchmark assessment (Hicks and Wetzel 2015) and most recent update assessment (Adams et al. 2019) for information.

2.2.5.4 Natural Mortality

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

2.2.5.5 Length-at-age

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

2.2.5.6 Ageing bias and imprecision

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

2.3 Environmental and Ecosystem Data

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

3 Assessment model

3.1 History of modeling approaches

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

3.2 Responses to most recent past STAR Panel recommendations

There are no recommendations from the most recent STAR Panel to address.

3.3 Responses to SSC Groundfish Subcommittee requests

There are no requests from the SSC Groundfish Subcommittee.

3.4 Model Structure and Assumptions

3.4.1 Model Changes from the Last Assessment

The assessment followed the same model structure as the 2015 benchmark assessment (Hicks and Wetzel 2015) and 2019 update assessment (Adams et al. 2019). The changes made to the previous assessment model include:

- **Adding most recent data from commercial fleets** (as described in Data section of this report).
- **Updating WCGBTS index using current methodology** (as described in Data section of this report).
- **Updating the prior for natural mortality** based on Hamel and Cope (2022).
- **Updating length-weight parameters estimated** while including most recent data.
- **Extending the main period for estimating recruitment deviations and updating recruitment bias adjustment parameters** based on Methot and Taylor (2011).

- **Adding a block to the retention curve for the midwater trawl fleet and a block to hake fleet selectivity to account for recent changes in fleet behavior.** Adding a block to the retention curve for midwater trawl allowed for recent increases in midwater trawl discards (from 2017 forward), and improved fit to discard amounts modeled in the assessment. Adding a block to hake fleet selectivity accounted for a change in fish mean length (2020-2024) due to shifts in the spatial distribution of the hake fleet and to improve fit to length compositions. Neither change had a discernible influence on the estimated SSB. See Model Bridging section for detail.
- **Adding hook-and-line discards to landings in the hook-and-line fleet.** The change to the treatment of hook-and-line discard was necessary since discard lengths for the hook-and-line fleet provided by WCGOP this year were corrected to omit nearshore fixed gear fleets samples, which were erroneously included with the hook-and-line fleet in the previous benchmark and update assessments. This change resulted in changes to the discard length distribution and years for which data was available Figure 18. With decreased sample sizes of hook-and-line discard length data available, 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. Correction of the hook-and-line discard lengths translated into lower estimated recruitment in the 2010s than that of in 2019 update assessment (higher recruitment estimates in the 2019 assessment were previously informed by erroneous estimates of smaller fish, which were corrected in this assessment). Lower recruitment in turn contribiuted to a decrease in stock size in recent years.

Comparison of spawning biomass and relative fraction unfished between 2019 and 2025 models are shown in Figure 29 to Figure 32. See "Model Bridging" section for further details.

3.4.1.1 Model Bridging

The exploration of models began by bridging from the 2019 update assessment to SS3 version 3.30.2, which produced no discernible difference. We then focused on data bridging. Updating the catch series did not have a substantial effect on the historical biomass, and estimated the stock biomass increasing from 2000 to 2020 before decreasing up to the current period. Updating the model discards had the most significant impact on the absolute stock biomass (SSB), with a small decrease in absolute SSB prior to 1980 and a large decrease in absolute SSB from the mid 2010s through the current year (Figure 24). 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 other model bridging steps had a substantial effect on the estimates of stock biomass (Figure 24). 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 WCGBTS, 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 full 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 fleet between years, as the fleet moves to avoid bycatch (Holland and Martin 2019). Poor fit to midwater trawl discards is thought to be due to (1) the previous decision to fix late-year retention to 0.99 which represented an overestimate of the (very low) discards in 2011-2016, and (2) the reallocation of quota shares and subsequent increase in midwater trawl discards in 2017. These choices are described in more detail in the "fits to data" section.

3.4.2 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 1.52.0, 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 23.

3.4.3 Model Overview

The model is a two-sex, age-structured model starting in 1916 with an accumulated age group at 40 years. Sex-specific growth and natural mortality were estimated. The lengths in the population were tracked by 1 cm intervals and the length data were binned into 2 cm intervals. Ageing error was retained from the 2015 benchmark assessment (Hicks and Wetzel 2015). Fecundity was assumed to be proportional to body weight, thus spawning biomass was used as the measure of spawning output.

3.4.3.1 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).

3.4.4 Model Parameters

3.4.4.1 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 the previous full assessment (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 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 WCGBTS (Figure 20 and Table 13).

The final base model assumed asymptotic selectivity (using the double-normal formulation in SS3) for each fishery, except for the midwater trawl fishery. The WCGBTS 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 WCGBTS survey fleet. The

WCGBTS survey fleet selectivity was estimated to be slightly lower at lengths greater than 45 cm, compared to the selectivity estimated in 2019.

Time blocks were used for selectivity and retention parameters in the bottom trawl, midwater trawl, hake and hook-and-line fisheries as indicated in Table 12.

3.4.4.2 Priors

The prior on natural mortality (M) in the previous assessment was defined as a lognormal with mean on the log-scale of ln(5.4/Amax) and SD(ln(M)) = 0.4384343 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.

3.4.4.3 Recruitment deviations

The specification of when to estimate recruitment deviations is an assumption that likely affects model uncertainty. Recruitment deviations from 1900–2024 were estimated 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 2019. The period from 1900-1970 was fit using an early series with little or no bias adjustment, the main period of recruitment deviates was 1971–2020 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 35).

3.4.4.4 Sample weights

As the most recent benchmark assessment used the McAllister & Ianelli method (Hicks and Wetzel 2015) and changing the weighting method is outside the TOR 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.

3.4.5 Key Assumptions and Structural Choices

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

3.5 Base Model Results

As a supplement to the model results figures included in this report and described below, a full set of diagnostic plots created by the r4ss package (Taylor et al. (2021)) is available on the assessment GitHub repository (github.com/mcgoodman/widow-assessment-update) along with the Stock Synthesis input files.

3.5.1 Parameter Estimates

The base model parameter estimates along with approximate asymptotic standard errors are shown in Table 13 and the likelihood components are shown in Table 14. Estimates of key derived parameters and approximate 95% asymptotic confidence intervals are shown in Table 15.

The estimates of natural mortality (0.125 yr^{-1} and 0.137 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 (0.055– 0.184), and are shown in Figure 22. This is a decrease from the 2015 benchmark assessment (Female: 0.1572, Male: 0.1705; Hicks and Wetzel (2015)) and the 2019 update assessment (Female 0.1444, Male: 0.1549; Adams et al. (2019), Figure 22).

Updating age composition data resulted in the largest decrease in M among the various intermediate models bridging from the 2019 assessment. This is broadly consistent with observations of older individuals in updated age composition data. For instance, the maximum age for widow rockfish in the WCGBTS data prior to 2019 was 37 yrs with a 99^{th} percentile of 29, while data collected since include individuals up to 51 with a 99^{th} percentile of 34. Updating that natural mortality prior resulted in a comparatively small decrease in M (Figure 22).

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 not higher than 0.13 yr^{-1} (Table 17), except when forcing asymptotic selectivity on the midwater trawl fleet (Table 17). Uncertainty in the estimated M was also much less than the range of the prior (Figure 22).

Selectivity curves were estimated for commercial and survey fleets and parameter estimates are provided in Table 13. 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 26. The selectivity curves showed a shift to larger fish in 2002 for the bottom trawl fishery, a shift to smaller fish in 2003 for the hook-and-line fishery, and a strong dome-shaped selectivity for the midwater fleet. The bottom trawl shift is consistent with the introduction of the Rockfish Conservation Area (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 strong dome-shape of the midwater fleet suggests a lack of observations of older females, and, to some extent, older males as well. Due to it consistently approaching 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.

The retention curves (Figure 44) showed a shift to retaining a lower percentage of fish since trip limits were introduced. The asymptote of the retention curve for the bottom trawl fishery sequentially decreased as more management restrictions were introduced to about 50% retention of larger fish in the 1998-2010 period. In recent years, bottom trawl retention is estimated at approximately 99%.

Midwater trawl and hook-and-line fisheries estimated an asymptote to retention just above 80% for the period 1983-2010. Both the selectivity for the hake fleet and the selectivity of the net fleet did not support dome-shaped selectivity (Figure 26). The estimated selectivity curves for the Triennial and WCGBTS were similar to each other except that the triennial survey selected larger fish (Figure 27). The WCGBTS 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 WCGBTS 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 1.69, giving the index very little weight in the model.

The estimates of maximum size for both females and males (Table 13) did not differ substantially from Adams et al. (2019). Estimates of k were slightly different in the model, but that is expected when accounting for selectivity. Estimated growth curves are shown in (Figure 33).

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 34, Table 15). There is little information regarding recruitment prior to 1965.

3.5.2 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 WCGBTS.

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 36. 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 13). None of the series showed patterns in residuals, and with the large amount of error, none of the series showed serious lack of fit. The recent WCGBTS showed a general increase from 2003 - 2015 followed by a general decrease from 2016 - 2024, which was also estimated in the base model (Figure 36). The model did not fit the indices variability well, particularly years with relatively low (2015, 2021, 2022) or high (2016) estimates of abundance.

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 37). EDCP data in 1997 and 1998 were underfit. The second time block was from 2002-2010, 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.

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 38, Figure 39) 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 38, 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 40).

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 38 shows the prediction of discarding smaller females than observed and a more peaked observed distribution of discarded males than predicted.

The Triennial Shelf and WCGBTS surveys length frequencies showed underfitting of older fish in some years and underfitting of younger fish in others (Figure 41). 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 40). 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 WCGBTS, which were expanded by tow and then by strata. Expanded age-at-length data were used, following the 2015 benchmark assessment (Hicks and Wetzel (2015)). Pearson residuals for the commercial fleets are shown in Figure 38 and Figure 39. For the trawl fisheries in Figure 38, 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 39) 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 42). 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 43 for the twelve years of the WCGBTS 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 45). Some outliers are apparent, with large residuals mostly at smaller lengths for a given age.

3.5.3 Population Trajectory

The predicted spawning biomass (in metric tons) is given in Table 16 and plotted in Figure 46. 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 48). 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 48).

Recruitment deviations (Figure 34 and discussed in Section 3.3.1) 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, and 1991. 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 35).

The stock-recruit curve resulting from a fixed value of steepness is shown in Figure 35 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.

3.6 Model Diagnostics

3.6.1 Convergence

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 (using a convergence threshold of 0.01) a better minimum was not found. 11% of the jittered models achieved the minimum negative log-likelihood and 23% were within two likelihood units. 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.

3.6.2 Parameter Uncertainty

Parameter estimates are shown in Table 13 and Table 16 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 15 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 mostly above the management target of 40% of the unfished spawning biomass.

3.6.3 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 WCGBTS 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 17. Predicted spawning biomass trajectories, estimated recruitment deviations and comparisons of model estimates for 2025 are shown in Figure 53, Figure 54 and Figure 55. The estimates of SSB in 2025 ranged from 3.83 to 50.23 thousand metric tons across the sensitivity runs, with exclusion of the triennial survey 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.

Forcing asymptotic selectivity on the midwater fleet decreased estimated SSB in the early years, but had little effect in recent years. Forcing logistic selectivity on the WCGBTS increased peak SSB estimates in 2017 but likely had little effect on recent estimates. Excluding the triennial survey decreased estimated spawning biomass dramatically and decreased recruitment deviations in the 2019-2025 period Figure 53. Updating WA catch reconstruction and adding shrimp trawl data to the historical landings had almost no impact on the estimated spawning biomass.

The alternative weighting using the Francis method generally increased the estimate of spawning biomass across the timeseries. While the spawning biomass from the Francis weighted model is higher than that from the base model, the OFL from the Francis weighted model is actually lower than the base model.

3.6.4 Retrospective Analysis

First, a 5-year retrospective analysis was conducted by running the model using data only through 2020, 2021, 2022, 2023, and 2024 progressively (Figure 56). 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.

Second, a comparison of biomass time series across multiple previous assessments was conducted Figure 49 and shows that the base model biomass follows the same trajectory as previous assessment, and estimated stock scale is in the middle range of previous assessments.

3.6.5 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.

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. Profiles for natural mortality for each sex are illustrated in (Figure 59). 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. Profiles for steepness are illustrated in (Figure 58). For R0, the total likelihood supported the estimated value, though there was variable support for each likelihood component across the range of R0 evaluated. As R0 increased, natural mortality also increased and the relative spawning biomass in 2024 was less depleted. Profiles for R0 are illustrated in Figure 57.

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 5,628 mt when using an SPR50% reference harvest rate and with a 95% confidence interval of 4,324 to 6,932 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 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 48). 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 48). 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 51). Exploitation rates on widow rockfish between 2001 and 2016 were predicted to be far below target levels. In recent years, the stock has experienced exploitation rates that have been above the target level while the biomass level has remained above the target level (Figure 52).

The equilibrium yield plot is shown in Figure 61, based on a steepness value fixed at 0.720. The predicted maximum sustainable yield under the assumptions of this assessment occurs near 27% of equilibrium unfished spawning biomass, however this represents only 12% more yield, with considerably more risk, than under the 50% SPR policy, which occurs near 45% of unfished spawning biomass.

4.2 Unresolved problems and major uncertainties

Major sources of uncertainty include landings, discards, natural mortality, and recruitment, which are discussed below.

Because widow rockfish is a marketable species, historical discard rates were likely lower than less desirable or smaller species. This assessment assumed that discarding was nearly negligible before management restrictions began in 1982. Once trip limits were introduced, discarding tended to be an all or none event, 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. The open access fixed-gear fleet is not monitored by the full observer coverage required under trawl rationalization. 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). Multiple surveys are used in the assessment, but further consideration of additional surveys is reasonable.

Widow rockfish is a relatively long-lived fish, and natural mortality is likely to be lower than many species of fish, such as gadoids. Ages above 50 years have been observed and it is expected that natural mortality could be less than 0.10 yr^{-1} (the median of the prior for natual mortality used in this assessment). However, even with length and age data available back to the late 1970s, natural mortality was estimated at 0.125 for females and 0.137 yr^{-1} for males, with a small amount of uncertainty (e.g., a 6.6% coefficient of variation for females). This assessment attempts to capture that uncertainty by estimating natural mortality (M) and integrating that uncertainty into the derived biomass estimates, as well as additional uncertainty by including levels outside of the predicted interval in a decision table. One contributing factor to this change is the increase in the mean age of the catch observed by the WCGBTS survey in recent years. These observations are poorly fit by the model, and considertation should be given in future to structural changes which may improve the fit to WCGBTS CAAL data. One possible explanation as to the increased observation of older fish is that successfully rebounding of the stock as a result of reduced fishing pressure form 2003-2016 allowed year classes to grow older and are now being fully observed by WCGBTS.

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. 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 two factors defined the low state of nature and the high combination of these two factors defined the high state of nature. The predictions of spawning 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.

Previous assessments included recent large recruitments as a third axis of uncertainty. As no large recruitments occured in the recent period, this axis was not included in the harvest projection.

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

A twelve year projection of the base model with two catch streams based on ACL adjustments of 0.45 P* and 0.40 P* were conducted (Table 20).

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 20). Predicted ACL catches range from 3,031 mt in 2027 to 4,254 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 0.40 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 mt in 2027 to mt in 2036 Table 20, Figure 62).

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 40,604 mt in 2025, with a sigma of 0.2753. OFL is estimated to be 5,376 mt in 2025 with a coefficient of variation of 0.3149.

4.5 Regional management considerations

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

4.6 Research and Data Needs

There are many areas of research that could be improved to benefit the understanding and assessment of widow rockfish:

- **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. Investigating the ageing error and bias would help to understand the influences that the age data have on this assessment, particularly the influence of age data on natural mortality.

- **Historical landings and discards:** Although progress has been made in reconstructing historical landings of rockfish on the U.S. West Coast, the historical landings and discards continue to be 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. In addition, discard composition data have become available for the midwater trawl fleet in recent years and should be included in future assessments.

- **Sex-specific selectivity:** The midwater and bottom trawl length-composition data fits showed divergent residual patterns between male and female fish. The underlying mechanism driving this pattern is unclear, and could be related to growth, sexing error, or to sex-specific selectivity (e.g., when widow rockfish aggregate, sexes possibly may be aggregating separately). Sex-specific selectivity for these two fleets could be explored or included to address this.

- **Coastwide understanding of stock structure, biology, connectivity, and distribution:** This is a stock assessment for widow rockfish off of the west coast of the U.S. and does not consider data from British Columbia or Alaska. Further investigating and comparing the data and predictions from British Columbia and Alaska to determine if there are similarities with the U.S. West Coast observations would help to define the connectivity between widow rockfish north and south of the U.S.-Canada border.

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	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71.8	0.3	0.0
1917	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	111.9	0.3	0.0
1918	11.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	128.5	0.3	0.0
1919	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	88.6	0.3	0.0
1920	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.7	0.4	0.0
1921	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.1	0.4	0.0
1922	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.2	0.4	0.0
1923	6.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71.7	0.4	0.0
1924	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.2	0.4	0.0
1925	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58.7	0.4	0.0
1926	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	85.5	0.4	0.0
1927	11.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.4	0.5	0.0
1928	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72.0	0.8	0.0
1929	23.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.1	1.3	0.0
1930	20.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.4	1.2	0.0
1931	20.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	78.6	0.9	0.0
1932	21.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	77.7	0.3	0.0
1933	34.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	50.9	0.5	0.0
1934	30.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59.7	0.5	0.0
1935	28.9	0.2	0.7	0.0	0.0	0.0	0.0	0.0	67.9	0.5	0.0

Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
	CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
1936	23.4	0.7	1.1	0.0	0.0	0.0	0.0	0.0	84.3	1.2	0.0
1937	33.6	1.3	0.9	0.0	0.0	0.0	0.0	0.0	66.3	1.3	0.0
1938	32.2	0.0	1.1	0.0	0.0	0.0	0.0	0.0	49.6	1.0	0.0
1939	38.8	1.9	1.0	0.0	0.0	0.0	0.0	0.0	34.2	0.7	0.0
1940	30.6	43.7	1.0	0.0	0.0	0.0	0.0	0.0	43.9	1.5	0.0
1941	24.8	67.3	1.4	0.0	0.0	0.0	0.0	0.0	34.1	1.9	0.0
1942	5.4	126.1	1.8	0.0	0.0	0.0	0.0	0.0	10.2	3.1	0.0
1943	28.3	439.2	1.2	0.0	0.0	0.0	0.0	0.0	18.0	3.9	0.0
1944	148.6	770.7	2.0	0.0	0.0	0.0	0.0	0.0	38.0	1.4	0.0
1945	353.4	1,196.6	3.4	0.0	0.0	0.0	0.0	0.0	66.8	1.1	0.0
1946	353.2	735.0	0.8	0.0	0.0	0.0	0.0	0.0	69.7	1.3	0.0
1947	98.1	452.8	0.2	0.0	0.0	0.0	0.0	0.0	91.3	0.7	0.0
1948	139.4	297.3	0.1	0.0	0.0	0.0	0.0	0.0	39.6	1.2	0.0
1949	75.1	254.7	0.0	0.0	0.0	0.0	0.0	0.0	43.9	0.6	0.0
1950	70.9	286.8	1.8	0.0	0.0	0.0	0.0	0.0	63.4	0.8	0.0
1951	249.4	252.9	2.0	0.0	0.0	0.0	0.0	0.0	49.1	0.6	0.0
1952	236.6	264.2	0.2	0.0	0.0	0.0	0.0	0.0	39.9	0.6	0.0
1953	242.6	211.5	1.2	0.0	0.0	0.0	0.0	0.0	13.7	0.3	0.0
1954	155.8	267.3	3.1	0.0	0.0	0.0	0.0	0.0	21.3	0.4	0.0
1955	166.3	277.5	2.5	0.0	0.0	0.0	0.0	0.0	18.2	0.4	0.0
1956	196.8	361.3	0.7	0.0	0.0	0.0	0.0	0.0	41.8	0.3	0.0
1957	233.1	489.5	0.1	0.0	0.0	0.0	0.0	0.0	37.4	0.6	0.0
1958	284.3	380.4	0.2	0.0	0.0	0.0	0.0	0.0	36.6	0.1	0.0
1959	229.9	412.8	0.1	0.0	0.0	0.0	0.0	0.0	28.6	0.2	0.0
1960	180.0	608.6	0.2	0.0	0.0	0.0	0.0	0.0	21.9	0.2	0.0
1961	118.4	543.1	0.2	0.0	0.0	0.0	0.0	0.0	15.0	0.5	0.0
1962	115.9	623.8	2.0	0.0	0.0	0.0	0.0	0.0	15.4	0.4	0.0

Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
	CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
1963	221.2	190.2	2.1	0.0	0.0	0.0	0.0	0.0	19.6	0.4	0.0
1964	104.1	480.9	3.2	0.0	0.0	0.0	0.0	0.0	13.0	0.1	0.0
1965	155.9	80.6	2.2	0.0	0.0	0.0	0.0	0.0	20.2	0.6	0.0
1966	123.0	455.8	0.6	0.0	0.0	0.0	0.0	0.0	37.4	0.4	0.0
1967	141.9	743.9	0.6	0.0	0.0	0.0	0.0	0.0	31.9	1.1	0.0
1968	155.0	240.6	16.7	0.0	0.0	0.0	0.0	0.0	19.0	1.0	0.0
1969	223.5	229.3	16.7	0.0	0.0	0.0	0.0	0.0	17.6	2.3	0.0
1970	257.3	27.7	3.0	0.0	0.0	0.0	0.0	0.0	9.0	0.9	0.0
1971	316.2	50.6	11.7	0.0	0.0	0.0	0.0	0.0	10.2	1.8	0.0
1972	411.9	51.8	14.1	0.0	0.0	0.0	0.0	0.0	17.8	2.3	0.0
1973	428.1	20.9	32.4	0.0	0.0	0.0	0.0	0.0	15.8	2.5	0.0
1974	426.4	7.3	6.5	0.0	0.0	0.0	0.0	0.0	41.3	3.1	0.0
1975	429.9	9.0	12.0	0.0	0.0	0.0	0.0	0.0	28.4	1.6	0.0
1976	467.3	56.0	36.2	0.0	0.0	0.0	0.0	0.0	39.5	2.2	0.0
1977	459.0	340.0	125.8	0.0	0.0	0.0	0.0	0.0	38.1	2.6	0.0
1978	538.9	340.1	336.7	0.0	0.0	0.0	0.0	0.0	157.4	3.8	0.0
1979	916.9	519.4	305.0	1,398.5	3,746.0	2,199.8	0.0	0.0	97.1	6.4	0.0
1980	2,109.2	410.8	338.4	3,217.2	8,460.7	6,969.4	0.0	3.4	55.9	3.7	0.0
1981	2,660.2	1,527.1	681.2	2,627.4	13,861.9	6,183.5	15.5	3.2	67.5	4.0	0.0
1982	3,656.7	782.8	522.0	7,008.1	8,184.4	5,458.0	38.1	37.1	180.6	5.9	0.0
1983	3,667.1	1,403.6	1,554.6	205.1	1,495.6	1,656.5	280.0	14.5	23.5	10.2	0.0
1984	1,434.6	1,428.5	381.8	1,378.6	3,982.8	1,064.6	324.8	26.6	22.8	3.8	0.0
1985	1,363.0	895.1	317.6	1,281.6	3,423.4	1,214.6	585.8	40.2	26.1	1.1	0.0
1986	1,640.4	1,230.1	716.1	362.2	3,150.5	1,834.1	500.8	0.0	81.5	1.9	0.0
1987	2,261.1	1,185.5	698.4	0.0	5,114.5	3,013.1	584.6	0.0	52.4	2.7	0.0
1988	1,585.3	1,152.8	1,290.3	0.0	4,305.6	1,785.0	220.7	0.0	72.3	1.0	0.2
1989	1,838.3	2,027.5	647.7	0.0	4,957.7	2,726.9	253.6	0.1	44.7	0.4	0.0

Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
	CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
1990	1,812.7	2,289.3	1,210.4	0.0	3,352.8	1,021.1	411.2	0.0	126.9	7.3	0.2
1991	996.4	1,989.2	878.9	0.0	1,779.9	260.2	234.8	0.0	89.7	5.2	0.3
1992	917.4	2,709.5	646.5	0.0	1,183.8	282.5	45.4	0.0	165.8	9.2	0.5
1993	1,088.3	3,457.0	1,109.8	1.2	1,706.8	547.9	51.6	0.0	63.7	44.7	0.5
1994	557.9	2,600.7	644.1	210.0	1,564.4	387.5	58.4	0.0	71.7	9.6	0.4
1995	1,361.1	2,386.7	339.0	292.7	1,283.4	700.7	57.6	0.0	19.0	7.2	0.1
1996	1,056.8	2,292.1	237.9	238.8	998.2	609.4	16.1	0.0	21.6	11.0	0.1
1997	1,032.5	2,502.8	241.7	253.6	1,453.1	735.8	16.4	0.0	22.4	15.6	0.0
1998	686.2	1,641.1	188.4	81.6	493.4	307.8	48.7	0.0	62.4	24.1	0.0
1999	485.0	945.0	182.7	100.1	1,634.2	315.9	10.0	0.0	29.0	14.7	0.1
2000	34.2	19.6	2.9	680.8	2,604.8	379.4	6.8	0.0	11.9	2.5	0.0
2001	9.3	28.8	1.0	310.3	1,092.4	287.1	7.0	0.0	6.4	0.7	0.0
2002	8.7	6.0	2.4	40.0	151.7	59.8	0.0	0.0	0.4	0.1	0.0
2003	3.1	0.3	0.2	0.4	0.0	9.3	0.4	0.0	0.3	0.6	0.0
2004	5.9	2.4	0.1	7.5	0.0	21.3	0.0	0.0	0.2	0.1	0.0
2005	2.7	0.2	0.2	5.2	0.0	27.6	0.1	0.0	0.4	0.8	0.1
2006	3.8	2.0	0.3	3.6	0.0	9.3	0.0	0.0	0.8	0.0	0.0
2007	2.7	1.8	0.3	1.0	0.0	0.5	2.9	0.0	1.6	0.3	0.0
2008	0.2	1.7	0.2	29.2	0.0	12.9	0.0	0.0	1.2	0.0	0.0
2009	1.9	2.1	0.2	2.3	0.0	34.1	0.2	0.0	0.4	0.0	0.0
2010	1.2	2.9	0.7	9.0	0.0	45.7	0.0	0.0	0.0	0.1	0.0
2011	1.1	10.0	7.2	0.0	12.4	31.5	0.0	0.0	0.0	0.0	0.0
2012	2.3	27.0	12.0	0.0	5.9	41.5	0.0	0.0	0.2	0.1	0.0
2013	4.8	44.0	2.4	0.0	204.5	36.6	0.0	0.0	0.9	0.1	0.0
2014	2.7	46.1	22.5	0.0	259.7	46.9	0.0	0.0	1.7	0.1	0.0
2015	1.8	10.4	0.0	0.0	386.7	92.5	0.0	0.0	1.6	0.4	0.0
2016	0.4	8.4	0.8	0.0	574.5	13.5	0.0	0.0	0.7	0.0	0.0

Year	Bottom Trawl			Midwater Trawl			Net		Hook-and-Line		
	CA	OR	WA	CA	OR	WA	CA	WA	CA	OR	WA
2017	1.0	34.3	0.6	51.9	4,770.3	29.9	0.0	0.0	2.3	0.3	0.1
2018	21.4	14.5	0.1	215.9	7,605.9	1,552.4	0.0	0.0	1.5	0.0	0.0
2019	10.3	17.6	0.0	142.6	6,752.5	1,262.8	0.0	0.0	2.1	0.0	0.0
2020	8.7	64.9	0.0	84.8	5,834.1	1,613.3	0.0	0.0	2.3	0.2	0.3
2021	20.1	83.4	0.2	169.3	8,395.5	1,576.5	0.0	0.0	4.2	0.0	0.4
2022	60.0	66.8	0.0	499.1	8,794.5	1,546.2	0.0	0.0	8.4	0.0	0.3
2023	35.5	46.8	0.0	493.4	8,108.4	1,626.3	0.0	0.0	6.1	1.0	0.0
2024	16.0	11.6	0.0	0.0	7,449.8	1,711.0	0.0	0.0	11.9	0.9	0.1

Table 2: Catch (mt) from the foreign & domestic at-sea fleet and the domestic shoreside hake fleet. Catches (mt) from the hake 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

Year	Foreign & Domestic	Shoreside hake		
	At-sea	CA	OR	WA
2015	37.4	0.0	267.9	80.8
2016	193.8	0.0	187.6	59.3
2017	481.3	0.0	791.1	182.8
2018	207.6	0.0	720.3	153.4
2019	198.9	0.0	605.6	297.0
2020	86.1	0.0	474.4	186.2
2021	115.5	0.0	419.7	82.1
2022	187.1	0.0	728.8	203.1
2023	206.5	0.0	368.8	98.0
2024	66.6	0.0	408.3	59.0

Table 3: Recent trend in the overfishing limits (OFLs), the acceptable biological catches (ABCs), the annual catch limits (ACLs), the total landings, and total mortality all in metric tons (mt).

Year	OFL (mt)	ABC (mt)	ACL (mt)	Landings (mt)	Total Mortality (mt)
2015	4,137	3,929.00	2,000	879.62	879.80
2016	3,990	3,790.00	2,000	1,039.24	1,039.41
2017	14,130	13,508.28	13,508	6,345.89	6,361.45
2018	13,237	12,654.57	12,655	10,493.03	10,522.76
2019	12,375	11,830.50	11,831	9,289.43	9,315.27
2020	11,714	11,198.58	11,199	8,355.24	8,379.58
2021	15,749	14,725.32	14,725	10,866.89	10,899.73
2022	14,826	13,788.18	13,788	12,094.40	12,129.69
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	9,764.11

Table 4: Number of trips sampled for length data by gear and state for non-hake 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 5: Number of lengths of widow rockfish by gear and state for non-hake 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 6: Number of hauls or trips and number of lengths sampled from the at-sea hake and shoreside hake fisheries.

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

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

Table 7: Number of trips sampled for ages by gear and state for non-hake 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 8: Number of trips sampled for ages by gear and state for non-hake 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 9: 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	CV
Bottom Trawl	1985	Pikitch	462.9000	49.53%
Bottom Trawl	1986	Pikitch	534.8000	53.11%
Bottom Trawl	1987	Pikitch	1,035.5000	42.57%
Bottom Trawl	1995	EDCP	924.8000	83.18%

Fleet	Year	Source	Discards	CV
Bottom Trawl	1996	EDCP	3,084.5000	67.07%
Bottom Trawl	1997	EDCP	3,353.3000	75.06%
Bottom Trawl	1998	EDCP	42.6000	48.80%
Bottom Trawl	1999	EDCP	4.8000	68.78%
Bottom Trawl	2002	WCGOP	13.2200	43.07%
Bottom Trawl	2003	WCGOP	1.2100	81.96%
Bottom Trawl	2004	WCGOP	5.1300	75.89%
Bottom Trawl	2005	WCGOP	10.1700	44.61%
Bottom Trawl	2006	WCGOP	0.0300	135.56%
Bottom Trawl	2007	WCGOP	13.8600	61.57%
Bottom Trawl	2008	WCGOP	3.9000	44.54%
Bottom Trawl	2009	WCGOP	26.5700	33.77%
Bottom Trawl	2010	WCGOP	22.7400	54.32%
Bottom Trawl	2011	WCGOP	0.0800	5.00%
Bottom Trawl	2012	WCGOP	0.0100	5.00%
Bottom Trawl	2013	WCGOP	2.4300	5.00%
Bottom Trawl	2014	WCGOP	0.0900	5.00%
Bottom Trawl	2015	WCGOP	0.0300	5.00%
Bottom Trawl	2016	WCGOP	0.0200	5.00%

Fleet	Year	Source	Discards	CV
Bottom Trawl	2017	WCGOP	0.2600	5.00%
Bottom Trawl	2018	WCGOP	0.0143	5.00%
Bottom Trawl	2019	WCGOP	0.7832	5.00%
Bottom Trawl	2020	WCGOP	0.2763	5.00%
Bottom Trawl	2021	WCGOP	0.1440	5.00%
Bottom Trawl	2022	WCGOP	0.0750	5.00%
Bottom Trawl	2023	WCGOP	0.1184	5.00%
Midwater	1985	Pikitch	1,502.0000	24.09%
Midwater	1986	Pikitch	1,321.2000	23.64%
Midwater	1987	Pikitch	1,798.4000	26.20%
Midwater	1997	EDCP	1.0000	83.26%
Midwater	1998	EDCP	18.7000	80.00%
Midwater	2002	WCGOP	39.4000	40.71%
Midwater	2012	WCGOP	0.0000	5.00%
Midwater	2013	WCGOP	0.0020	5.00%
Midwater	2014	WCGOP	0.0136	5.00%
Midwater	2015	WCGOP	0.8800	5.00%
Midwater	2016	WCGOP	1.5600	5.00%
Midwater	2017	WCGOP	9.7500	5.00%

Fleet	Year	Source	Discards	CV
Midwater	2018	WCGOP	37.2300	5.00%
Midwater	2019	WCGOP	18.7800	5.00%
Midwater	2020	WCGOP	45.4400	5.00%
Midwater	2021	WCGOP	36.3800	5.00%
Midwater	2022	WCGOP	47.6000	5.00%
Midwater	2023	WCGOP	17.3700	5.00%

5.1.2 Fishery-independent data

Table 10: Stratifications used for the WCGBTS.

Strata	Area (km2)	Depth1	Depth2	Latitude1	Latitude2
A	10,687.86	55	183	34.5	40.5
B	3,394.82	183	400	34.5	40.5
C	23,042.39	55	183	40.5	49.0
D	7,667.81	183	400	40.5	49.0

Table 11: Number of positive tows, lengths, and ages in each year from the Triennial survey (Tri) and the WCGBTS (NW).

Year	Number of positive tows		Number of tows with lengths		Number of lengths		Number of tows with ages		Number of ages	
	Tri	NW	Tri	NW	Tri	NW	Tri	NW	Tri	NW
1977	80		1		9					
1980	38		3		166		1		22	
1983	70		5		385					
1986	46		8		317					
1989	38		20		713					
1992	50		10		708					
1995	43		43		500					
1998	59		58		738					
2001	28		28		130					
2003		20		18		216				
2004	36	12	33	12	219	84		12		43
2005		20		20		78		18		65
2006		26		26		172		26		89
2007		27		27		92		27		83
2008		17		17		26		15		20
2009		31		31		141		31		123
2010		28		28		240		28		116
2011		31		31		313		31		152
2012		32		32		181		32		91
2013		18		18		364		18		246
2014		29		28		349		28		264
2015		21		21		149		21		93
2016		40		40		888		40		556
2017		30		30		310		30		213

Year	Number of positive tows		Number of tows with lengths		Number of lengths		Number of tows with ages		Number of ages	
	Tri	NW	Tri	NW	Tri	NW	Tri	NW	Tri	NW
2018		34		34		410		34		353
2019		23		23		219		23		161
2021		18		17		66		17		66
2022		18		18		125		18		109
2023		30		29		159		29		110
2024		35		35		485		35		347

5.2 Model results

Table 12: 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
	First reference age for growth calcs	3
	Second reference age for growth calcs	40
	First mature age	3
	Starting year of estimated recruitment	1900
Fishery characteristics		
	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
	WCGBTS 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 13: Parameter estimates, parameter bounds (low, high), estimation status, estimated standard deviation (SD), prior information [distribution(mean, SD)] used in the base model.

Label	Value	Bounds	Status	SD	Prior
NatM_uniform_Fem_GP_1	0.125	(0.01, 0.3)	ok	0.00823	lognormal(0.100, 0.310)
L_at_Amin_Fem_GP_1	20.7	(10, 40)	ok	0.457	none
L_at_Amax_Fem_GP_1	49.5	(35, 60)	ok	0.256	none
VonBert_K_Fem_GP_1	0.181	(0.01, 0.4)	ok	0.00621	none
CV_young_Fem_GP_1	0.116	(0.01, 0.4)	ok	0.0093	none
CV_old_Fem_GP_1	0.0481	(0.01, 0.4)	ok	0.00266	none
Wtlen_1_Fem_GP_1	1.59e-05	(-3, 3)	fixed	0	none
Wtlen_2_Fem_GP_1	2.99	(-3, 10)	fixed	0	none
Mat50%_Fem_GP_1	5.47	(-3, 50)	fixed	0	none
Mat_slope_Fem_GP_1	-0.775	(-3, 3)	fixed	0	none
Eggs/kg_inter_Fem_GP_1	1	(-1, 1)	fixed	0	none
Eggs/kg_slope_wt_Fem_GP_1	0	(0, 1)	fixed	0	none
NatM_uniform_Mal_GP_1	0.137	(0.01, 0.3)	ok	0.0084	lognormal(0.100, 0.310)
L_at_Amin_Mal_GP_1	21	(10, 40)	ok	0.391	none
L_at_Amax_Mal_GP_1	43.6	(35, 60)	ok	0.235	none
VonBert_K_Mal_GP_1	0.245	(0.01, 0.4)	ok	0.00931	none
CV_young_Mal_GP_1	0.0941	(0.01, 0.4)	ok	0.00704	none

Label	Value	Bounds	Status	SD	Prior
CV_old_Mal_GP_1	0.0569	(0.01, 0.4)	ok	0.00275	none
Wtlen_1_Mal_GP_1	1.45e-05	(-3, 3)	fixed	0	none
Wtlen_2_Mal_GP_1	3.01	(-3, 10)	fixed	0	none
CohortGrowDev	1	(0, 2)	fixed	0	none
FracFemale_GP_1	0.5	(1e-06, 1)	fixed	0	none
SR_LN(R0)	10.4	(1, 20)	ok	0.169	none
SR_BH_steep	0.72	(0.2, 1)	fixed	0	beta(0.720, 0.160)
SR_sigmaR	0.6	(0, 2)	fixed	0	none
SR_regime	0	(-5, 5)	fixed	0	none
SR_autocorr	0	(0, 0.5)	fixed	0	none
Early_InitAge_16	-0.00143	(-5, 5)	dev	0.6	normal(0.00, 0.60)
Early_InitAge_15	-0.00161	(-5, 5)	dev	0.6	normal(0.00, 0.60)
Early_InitAge_14	-0.00182	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_13	-0.00204	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_12	-0.0023	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_11	-0.00258	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_10	-0.0029	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_9	-0.00324	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_8	-0.00362	(-5, 5)	dev	0.599	normal(0.00, 0.60)

Label	Value	Bounds	Status	SD	Prior
Early_InitAge_7	-0.00402	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_6	-0.00446	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_5	-0.00492	(-5, 5)	dev	0.599	normal(0.00, 0.60)
Early_InitAge_4	-0.00543	(-5, 5)	dev	0.598	normal(0.00, 0.60)
Early_InitAge_3	-0.00599	(-5, 5)	dev	0.598	normal(0.00, 0.60)
Early_InitAge_2	-0.0066	(-5, 5)	dev	0.598	normal(0.00, 0.60)
Early_InitAge_1	-0.00727	(-5, 5)	dev	0.598	normal(0.00, 0.60)
Early_RecrDev_1916	-0.00801	(-5, 5)	dev	0.598	normal(0.00, 0.60)
Early_RecrDev_1917	-0.00883	(-5, 5)	dev	0.597	normal(0.00, 0.60)
Early_RecrDev_1918	-0.00973	(-5, 5)	dev	0.597	normal(0.00, 0.60)
Early_RecrDev_1919	-0.0107	(-5, 5)	dev	0.597	normal(0.00, 0.60)
Early_RecrDev_1920	-0.0118	(-5, 5)	dev	0.597	normal(0.00, 0.60)
Early_RecrDev_1921	-0.013	(-5, 5)	dev	0.596	normal(0.00, 0.60)
Early_RecrDev_1922	-0.0143	(-5, 5)	dev	0.596	normal(0.00, 0.60)
Early_RecrDev_1923	-0.0158	(-5, 5)	dev	0.595	normal(0.00, 0.60)
Early_RecrDev_1924	-0.0174	(-5, 5)	dev	0.595	normal(0.00, 0.60)
Early_RecrDev_1925	-0.0192	(-5, 5)	dev	0.595	normal(0.00, 0.60)
Early_RecrDev_1926	-0.0211	(-5, 5)	dev	0.594	normal(0.00, 0.60)
Early_RecrDev_1927	-0.0233	(-5, 5)	dev	0.593	normal(0.00, 0.60)

Label	Value	Bounds	Status	SD	Prior
Early_RecrDev_1928	-0.0256	(-5, 5)	dev	0.593	normal(0.00, 0.60)
Early_RecrDev_1929	-0.0282	(-5, 5)	dev	0.592	normal(0.00, 0.60)
Early_RecrDev_1930	-0.0311	(-5, 5)	dev	0.591	normal(0.00, 0.60)
Early_RecrDev_1931	-0.0342	(-5, 5)	dev	0.59	normal(0.00, 0.60)
Early_RecrDev_1932	-0.0376	(-5, 5)	dev	0.589	normal(0.00, 0.60)
Early_RecrDev_1933	-0.0414	(-5, 5)	dev	0.588	normal(0.00, 0.60)
Early_RecrDev_1934	-0.0455	(-5, 5)	dev	0.587	normal(0.00, 0.60)
Early_RecrDev_1935	-0.0501	(-5, 5)	dev	0.586	normal(0.00, 0.60)
Early_RecrDev_1936	-0.0551	(-5, 5)	dev	0.585	normal(0.00, 0.60)
Early_RecrDev_1937	-0.0606	(-5, 5)	dev	0.583	normal(0.00, 0.60)
Early_RecrDev_1938	-0.0667	(-5, 5)	dev	0.581	normal(0.00, 0.60)
Early_RecrDev_1939	-0.0735	(-5, 5)	dev	0.58	normal(0.00, 0.60)
Early_RecrDev_1940	-0.0811	(-5, 5)	dev	0.578	normal(0.00, 0.60)
Early_RecrDev_1941	-0.0894	(-5, 5)	dev	0.575	normal(0.00, 0.60)
Early_RecrDev_1942	-0.0985	(-5, 5)	dev	0.573	normal(0.00, 0.60)
Early_RecrDev_1943	-0.108	(-5, 5)	dev	0.57	normal(0.00, 0.60)
Early_RecrDev_1944	-0.118	(-5, 5)	dev	0.568	normal(0.00, 0.60)
Early_RecrDev_1945	-0.128	(-5, 5)	dev	0.565	normal(0.00, 0.60)
Early_RecrDev_1946	-0.138	(-5, 5)	dev	0.563	normal(0.00, 0.60)

Label	Value	Bounds	Status	SD	Prior
Early_RecrDev_1947	-0.148	(-5, 5)	dev	0.56	normal(0.00, 0.60)
Early_RecrDev_1948	-0.157	(-5, 5)	dev	0.558	normal(0.00, 0.60)
Early_RecrDev_1949	-0.165	(-5, 5)	dev	0.556	normal(0.00, 0.60)
Early_RecrDev_1950	-0.172	(-5, 5)	dev	0.554	normal(0.00, 0.60)
Early_RecrDev_1951	-0.176	(-5, 5)	dev	0.553	normal(0.00, 0.60)
Early_RecrDev_1952	-0.176	(-5, 5)	dev	0.552	normal(0.00, 0.60)
Early_RecrDev_1953	-0.171	(-5, 5)	dev	0.553	normal(0.00, 0.60)
Early_RecrDev_1954	-0.16	(-5, 5)	dev	0.554	normal(0.00, 0.60)
Early_RecrDev_1955	-0.14	(-5, 5)	dev	0.557	normal(0.00, 0.60)
Early_RecrDev_1956	-0.113	(-5, 5)	dev	0.562	normal(0.00, 0.60)
Early_RecrDev_1957	-0.0808	(-5, 5)	dev	0.566	normal(0.00, 0.60)
Early_RecrDev_1958	-0.0509	(-5, 5)	dev	0.571	normal(0.00, 0.60)
Early_RecrDev_1959	-0.0336	(-5, 5)	dev	0.572	normal(0.00, 0.60)
Early_RecrDev_1960	-0.0351	(-5, 5)	dev	0.569	normal(0.00, 0.60)
Early_RecrDev_1961	-0.0464	(-5, 5)	dev	0.563	normal(0.00, 0.60)
Early_RecrDev_1962	-0.0459	(-5, 5)	dev	0.559	normal(0.00, 0.60)
Early_RecrDev_1963	-0.0152	(-5, 5)	dev	0.558	normal(0.00, 0.60)
Early_RecrDev_1964	0.0382	(-5, 5)	dev	0.561	normal(0.00, 0.60)
Early_RecrDev_1965	0.0961	(-5, 5)	dev	0.563	normal(0.00, 0.60)

Label	Value	Bounds	Status	SD	Prior
Early_RecrDev_1966	0.157	(-5, 5)	dev	0.558	normal(0.00, 0.60)
Early_RecrDev_1967	0.169	(-5, 5)	dev	0.543	normal(0.00, 0.60)
Early_RecrDev_1968	0.121	(-5, 5)	dev	0.514	normal(0.00, 0.60)
Early_RecrDev_1969	-0.0207	(-5, 5)	dev	0.541	normal(0.00, 0.60)
Main_RecrDev_1970	1.39	(-5, 5)	dev	0.283	normal(0.00, 0.60)
Main_RecrDev_1971	1.2	(-5, 5)	dev	0.268	normal(0.00, 0.60)
Main_RecrDev_1972	-0.807	(-5, 5)	dev	0.419	normal(0.00, 0.60)
Main_RecrDev_1973	-0.969	(-5, 5)	dev	0.368	normal(0.00, 0.60)
Main_RecrDev_1974	-0.659	(-5, 5)	dev	0.328	normal(0.00, 0.60)
Main_RecrDev_1975	0.0898	(-5, 5)	dev	0.201	normal(0.00, 0.60)
Main_RecrDev_1976	-1.05	(-5, 5)	dev	0.336	normal(0.00, 0.60)
Main_RecrDev_1977	0.695	(-5, 5)	dev	0.143	normal(0.00, 0.60)
Main_RecrDev_1978	1.12	(-5, 5)	dev	0.121	normal(0.00, 0.60)
Main_RecrDev_1979	-0.031	(-5, 5)	dev	0.206	normal(0.00, 0.60)
Main_RecrDev_1980	0.524	(-5, 5)	dev	0.16	normal(0.00, 0.60)
Main_RecrDev_1981	1.05	(-5, 5)	dev	0.128	normal(0.00, 0.60)
Main_RecrDev_1982	0.429	(-5, 5)	dev	0.176	normal(0.00, 0.60)
Main_RecrDev_1983	0.00909	(-5, 5)	dev	0.211	normal(0.00, 0.60)
Main_RecrDev_1984	0.695	(-5, 5)	dev	0.136	normal(0.00, 0.60)

Label	Value	Bounds	Status	SD	Prior
Main_RecrDev_1985	0.379	(-5, 5)	dev	0.157	normal(0.00, 0.60)
Main_RecrDev_1986	-0.379	(-5, 5)	dev	0.274	normal(0.00, 0.60)
Main_RecrDev_1987	0.557	(-5, 5)	dev	0.161	normal(0.00, 0.60)
Main_RecrDev_1988	0.105	(-5, 5)	dev	0.223	normal(0.00, 0.60)
Main_RecrDev_1989	-0.203	(-5, 5)	dev	0.265	normal(0.00, 0.60)
Main_RecrDev_1990	0.246	(-5, 5)	dev	0.204	normal(0.00, 0.60)
Main_RecrDev_1991	0.846	(-5, 5)	dev	0.13	normal(0.00, 0.60)
Main_RecrDev_1992	-0.134	(-5, 5)	dev	0.229	normal(0.00, 0.60)
Main_RecrDev_1993	0.0991	(-5, 5)	dev	0.198	normal(0.00, 0.60)
Main_RecrDev_1994	0.0124	(-5, 5)	dev	0.216	normal(0.00, 0.60)
Main_RecrDev_1995	-0.455	(-5, 5)	dev	0.287	normal(0.00, 0.60)
Main_RecrDev_1996	-0.756	(-5, 5)	dev	0.35	normal(0.00, 0.60)
Main_RecrDev_1997	-0.329	(-5, 5)	dev	0.309	normal(0.00, 0.60)
Main_RecrDev_1998	0.26	(-5, 5)	dev	0.229	normal(0.00, 0.60)
Main_RecrDev_1999	0.54	(-5, 5)	dev	0.186	normal(0.00, 0.60)
Main_RecrDev_2000	0.348	(-5, 5)	dev	0.196	normal(0.00, 0.60)
Main_RecrDev_2001	-0.246	(-5, 5)	dev	0.253	normal(0.00, 0.60)
Main_RecrDev_2002	-0.371	(-5, 5)	dev	0.245	normal(0.00, 0.60)
Main_RecrDev_2003	-0.414	(-5, 5)	dev	0.277	normal(0.00, 0.60)

Label	Value	Bounds	Status	SD	Prior
Main_RecrDev_2004	0.761	(-5, 5)	dev	0.126	normal(0.00, 0.60)
Main_RecrDev_2005	-0.9	(-5, 5)	dev	0.358	normal(0.00, 0.60)
Main_RecrDev_2006	0.481	(-5, 5)	dev	0.141	normal(0.00, 0.60)
Main_RecrDev_2007	-0.921	(-5, 5)	dev	0.352	normal(0.00, 0.60)
Main_RecrDev_2008	1.32	(-5, 5)	dev	0.0947	normal(0.00, 0.60)
Main_RecrDev_2009	-0.721	(-5, 5)	dev	0.299	normal(0.00, 0.60)
Main_RecrDev_2010	0.878	(-5, 5)	dev	0.116	normal(0.00, 0.60)
Main_RecrDev_2011	-1.04	(-5, 5)	dev	0.316	normal(0.00, 0.60)
Main_RecrDev_2012	-1.46	(-5, 5)	dev	0.317	normal(0.00, 0.60)
Main_RecrDev_2013	0.703	(-5, 5)	dev	0.13	normal(0.00, 0.60)
Main_RecrDev_2014	-0.183	(-5, 5)	dev	0.228	normal(0.00, 0.60)
Main_RecrDev_2015	-0.434	(-5, 5)	dev	0.284	normal(0.00, 0.60)
Main_RecrDev_2016	1.25	(-5, 5)	dev	0.146	normal(0.00, 0.60)
Main_RecrDev_2017	-0.0255	(-5, 5)	dev	0.27	normal(0.00, 0.60)
Main_RecrDev_2018	-1.01	(-5, 5)	dev	0.339	normal(0.00, 0.60)
Main_RecrDev_2019	-1.27	(-5, 5)	dev	0.366	normal(0.00, 0.60)
Main_RecrDev_2020	-1.21	(-5, 5)	dev	0.398	normal(0.00, 0.60)
Late_RecrDev_2021	-0.476	(-5, 5)	dev	0.425	normal(0.00, 0.60)
Late_RecrDev_2022	-0.411	(-5, 5)	dev	0.548	normal(0.00, 0.60)

Label	Value	Bounds	Status	SD	Prior
Late_RecrDev_2023	-0.0362	(-5, 5)	dev	0.574	normal(0.00, 0.60)
Late_RecrDev_2024	-0.189	(-5, 5)	dev	0.579	normal(0.00, 0.60)
LnQ_base_BottomTrawl(1)	-6	(-25, 25)	fixed	0	none
Q_extraSD_BottomTrawl(1)	0.164	(0, 2)	ok	0.0608	none
LnQ_base_Hake(3)	-11.1	(-20, 2)	ok	0.19	none
Q_extraSD_Hake(3)	0.371	(0, 2)	ok	0.0863	none
LnQ_base_JuvSurvey(6)	-1.64	(-25, 25)	fixed	0	none
Q_extraSD_JuvSurvey(6)	1.69	(0, 2)	ok	0.369	none
LnQ_base_Triennial(7)	-2.06	(-4, 4)	ok	0.372	none
Q_extraSD_Triennial(7)	0	(0, 2)	fixed	0	none
LnQ_base_WCGBTS(8)	-3.14	(-25, 25)	fixed	0	none
Q_extraSD_WCGBTS(8)	0	(0, 2)	fixed	0	none
LnQ_base_ForeignAtSea(9)	-11.4	(-25, 25)	fixed	0	none
Q_extraSD_ForeignAtSea(9)	0.578	(0, 2)	ok	0.152	none
LnQ_base_Hake(3)_BLK10add_1991	0.465	(1e-04, 2)	ok	0.224	normal(0.500, 0.500)
LnQ_base_Triennial(7)_BLK9add_1995	0.159	(1e-04, 2)	ok	0.357	normal(0.500, 0.500)
Size_DblN_peak_BottomTrawl(1)	43.4	(10, 59)	ok	2.73	none
Size_DblN_top_logit_BottomTrawl(1)	2.5	(-5, 10)	ok	168	none
Size_DblN_ascend_se_BottomTrawl(1)	4.59	(-4, 12)	ok	0.427	none

Label	Value	Bounds	Status	SD	Prior
Size_DblN_descend_se_BottomTrawl(1)	9	(-2, 10)	fixed	0	none
Size_DblN_start_logit_BottomTrawl(1)	-9	(-9, 10)	fixed	0	none
Size_DblN_end_logit_BottomTrawl(1)	8	(-9, 9)	fixed	0	none
Retain_L_infl_BottomTrawl(1)	3.68	(-5, 60)	ok	176	none
Retain_L_width_BottomTrawl(1)	0.948	(0.01, 8)	ok	20	none
Retain_L_asymptote_logit_BottomTrawl(1)	4.6	(-10, 10)	fixed	0	none
Retain_L_maleoffset_BottomTrawl(1)	0	(-10, 10)	fixed	0	none
Size_DblN_peak_MidwaterTrawl(2)	37	(10, 59)	ok	0.741	none
Size_DblN_top_logit_MidwaterTrawl(2)	-9.42	(-10, 10)	ok	14.6	none
Size_DblN_ascend_se_MidwaterTrawl(2)	2.87	(-4, 12)	ok	0.311	none
Size_DblN_descend_se_MidwaterTrawl(2)	3.93	(-2, 10)	ok	0.72	none
Size_DblN_start_logit_MidwaterTrawl(2)	-9	(-9, 10)	fixed	0	none
Size_DblN_end_logit_MidwaterTrawl(2)	-1.39	(-9, 9)	ok	1.07	none
Retain_L_infl_MidwaterTrawl(2)	-5	(-5, 60)	fixed	0	none
Retain_L_width_MidwaterTrawl(2)	1.2	(0.01, 8)	fixed	0	none
Retain_L_asymptote_logit_MidwaterTrawl(2)	5.77	(-10, 10)	ok	0.0189	none
Retain_L_maleoffset_MidwaterTrawl(2)	0	(-10, 10)	fixed	0	none
Size_DblN_peak_Hake(3)	33.6	(10, 59)	ok	1.99	none
Size_DblN_top_logit_Hake(3)	2.5	(-5, 10)	ok	168	none

Label	Value	Bounds	Status	SD	Prior
Size_DblN_ascend_se_Hake(3)	2.12	(-4, 12)	ok	1.16	none
Size_DblN_descend_se_Hake(3)	9	(-2, 10)	fixed	0	none
Size_DblN_start_logit_Hake(3)	-9	(-9, 10)	fixed	0	none
Size_DblN_end_logit_Hake(3)	8	(-9, 9)	fixed	0	none
Size_DblN_peak_Net(4)	42.6	(10, 59)	ok	0.897	none
Size_DblN_top_logit_Net(4)	2.51	(-5, 10)	ok	168	none
Size_DblN_ascend_se_Net(4)	3.56	(-4, 12)	ok	0.213	none
Size_DblN_descend_se_Net(4)	9	(-2, 10)	fixed	0	none
Size_DblN_start_logit_Net(4)	-9	(-9, 10)	fixed	0	none
Size_DblN_end_logit_Net(4)	8	(-9, 9)	fixed	0	none
Size_DblN_peak_HnL(5)	23.6	(10, 59)	ok	0.0715	none
Size_DblN_top_logit_HnL(5)	2.5	(-5, 10)	ok	167	none
Size_DblN_ascend_se_HnL(5)	-5	(-5, 12)	fixed	0	none
Size_DblN_descend_se_HnL(5)	9	(-2, 10)	fixed	0	none
Size_DblN_start_logit_HnL(5)	-9	(-9, 10)	fixed	0	none
Size_DblN_end_logit_HnL(5)	8	(-9, 9)	fixed	0	none
SizeSpline_Code_Triennial(7)	0	(0, 2)	fixed	0	none
SizeSpline_GradLo_Triennial(7)	0.119	(-0.001, 1)	ok	0.0359	none
SizeSpline_GradHi_Triennial(7)	0.0381	(-1, 1)	ok	0.0987	none

Label	Value	Bounds	Status	SD	Prior
SizeSpline_Knot_1_Triennial(7)	24	(8, 56)	fixed	0	none
SizeSpline_Knot_2_Triennial(7)	34	(8, 56)	fixed	0	none
SizeSpline_Knot_3_Triennial(7)	48	(8, 56)	fixed	0	none
SizeSpline_Val_1_Triennial(7)	-1.82	(-10, 10)	ok	0.317	none
SizeSpline_Val_2_Triennial(7)	-1	(-10, 10)	fixed	0	none
SizeSpline_Val_3_Triennial(7)	0.435	(-10, 10)	ok	0.264	none
SizeSpline_Code_WCGBTS(8)	0	(0, 2)	fixed	0	none
SizeSpline_GradLo_WCGBTS(8)	0.467	(-0.001, 1)	ok	0.112	none
SizeSpline_GradHi_WCGBTS(8)	-0.109	(-1, 1)	ok	0.0565	none
SizeSpline_Knot_1_WCGBTS(8)	24	(8, 56)	fixed	0	none
SizeSpline_Knot_2_WCGBTS(8)	34	(8, 56)	fixed	0	none
SizeSpline_Knot_3_WCGBTS(8)	48	(8, 56)	fixed	0	none
SizeSpline_Val_1_WCGBTS(8)	-2.22	(-10, 10)	ok	0.245	none
SizeSpline_Val_2_WCGBTS(8)	-1	(-10, 10)	fixed	0	none
SizeSpline_Val_3_WCGBTS(8)	-0.114	(-10, 10)	ok	0.151	none
SizeSel_P1_ForeignAtSea(9)	1	(-2, 60)	fixed	0	none
SizeSel_P2_ForeignAtSea(9)	-1	(-2, 60)	fixed	0	none
minage@sel=1_JuvSurvey(6)	0	(0, 1)	fixed	0	none
maxage@sel=1_JuvSurvey(6)	0	(0, 1)	fixed	0	none

Label	Value	Bounds	Status	SD	Prior
minage@sel=1_WCGBTS(8)	0	(0, 1)	fixed	0	none
maxage@sel=1_WCGBTS(8)	40	(0, 50)	fixed	0	none
Size_DblN_peak_BottomTrawl(1)_BLK4repl_1916	39	(10, 59)	ok	0.817	none
Size_DblN_ascend_se_BottomTrawl(1)_BLK4repl_1916	3.43	(-4, 12)	ok	0.256	none
Retain_L_infl_BottomTrawl(1)_BLK2repl_1982	27.2	(-5, 50)	ok	4	none
Retain_L_infl_BottomTrawl(1)_BLK2repl_1990	27.5	(-5, 50)	ok	4	none
Retain_L_width_BottomTrawl(1)_BLK2repl_1982	0.969	(0.01, 5)	ok	2.19	none
Retain_L_width_BottomTrawl(1)_BLK2repl_1990	1.83	(0.01, 5)	ok	1.8	none
Retain_L_asymptote_logit_BottomTrawl(1)_BLK1repl_-1982	1.72	(-10, 10)	ok	0.267	none
Retain_L_asymptote_logit_BottomTrawl(1)_BLK1repl_-1990	0.783	(-10, 10)	ok	0.338	none
Retain_L_asymptote_logit_BottomTrawl(1)_BLK1repl_-1998	0.108	(-10, 10)	ok	0.156	none
Size_DblN_peak_MidwaterTrawl(2)_BLK7repl_1916	38.7	(10, 59)	ok	0.998	none
Size_DblN_peak_MidwaterTrawl(2)_BLK7repl_1983	38	(10, 59)	ok	0.442	none
Size_DblN_peak_MidwaterTrawl(2)_BLK7repl_2002	37.4	(10, 59)	ok	1.84	none
Size_DblN_ascend_se_MidwaterTrawl(2)_BLK7repl_1916	3.37	(-4, 12)	ok	0.286	none
Size_DblN_ascend_se_MidwaterTrawl(2)_BLK7repl_1983	3.08	(-4, 12)	ok	0.139	none
Size_DblN_ascend_se_MidwaterTrawl(2)_BLK7repl_2002	2.8	(-4, 12)	ok	0.67	none

Label	Value	Bounds	Status	SD	Prior
Size_DblN_descend_se_MidwaterTrawl(2)_BLK7repl_-1916	4.24	(-2, 10)	ok	0.967	none
Size_DblN_descend_se_MidwaterTrawl(2)_BLK7repl_-1983	3.06	(-2, 10)	ok	0.599	none
Size_DblN_descend_se_MidwaterTrawl(2)_BLK7repl_-2002	-1.42	(-2, 10)	ok	10.4	none
Size_DblN_end_logit_MidwaterTrawl(2)_BLK7repl_1916	-1.93	(-9, 9)	ok	3.02	none
Size_DblN_end_logit_MidwaterTrawl(2)_BLK7repl_1983	-0.424	(-9, 9)	ok	0.332	none
Size_DblN_end_logit_MidwaterTrawl(2)_BLK7repl_2002	1.56	(-9, 9)	ok	1.82	none
Retain_L_asymptote_logit_MidwaterTrawl(2)_-BLK12repl_1916	4.59	(-10, 10)	fixed	0	none
Retain_L_asymptote_logit_MidwaterTrawl(2)_-BLK12repl_1983	1.66	(-10, 10)	ok	0.138	none
Retain_L_asymptote_logit_MidwaterTrawl(2)_-BLK12repl_2002	1.85	(-10, 10)	ok	0.407	none
Retain_L_asymptote_logit_MidwaterTrawl(2)_-BLK12repl_2011	8.95	(-10, 10)	ok	0.0224	none
Size_DblN_peak_Hake(3)_BLK11repl_1916	42.8	(10, 59)	ok	0.621	none
Size_DblN_top_logit_Hake(3)_BLK11repl_1916	2.5	(-5, 10)	ok	168	none
Size_DblN_ascend_se_Hake(3)_BLK11repl_1916	3.72	(-4, 12)	ok	0.129	none
Size_DblN_peak_HnL(5)_BLK5repl_1916	37.2	(15, 59)	ok	2.02	none
Size_DblN_ascend_se_HnL(5)_BLK5repl_1916	3.75	(-4, 12)	ok	0.47	none

Label	Value	Bounds	Status	SD	Prior

Table 14: Likelihood components and other quantities related to the minimization of the base case model.

component	log.likelihood	lambdas
Total	19,047	
Survey	13.022	
Discard	16,793.300	
Length composition	854.968	
Age composition	1,366.280	
Recruitment	17.840	1
Forecast Recruitment	0.600	1
Priors	0.983	1
Softbounds	0.010	

Table 15: Estimates of key derived parameters and reference points with approximate 95% asymptotic confidence intervals.

Reference Point	Estimate	95% Confidence Interval
Unfished Spawning Biomass (mt)	**81733.4**	**67570.818 - 95895.982**
Unfished Age 4+ Biomass (mt)	151584	125227.972 - 177940.028
Unfished Recruitment (R0)	34103	22838.421 - 45367.579
2025 Spawning Biomass (mt)	40603.5	18692.475 - 62514.525
2025 Fraction Unfished	0.497	0.302 - 0.692
Reference Points Based SB40%		
Proxy Spawning Biomass (mt) SB40%	**32693.4**	**27028.359 - 38358.441**
SPR Resulting in SB40%	0.458	0.458 - 0.458
Exploitation Rate Resulting in SB40%	0.087	0.079 - 0.096
Yield with SPR Based On SB40% (mt)	5902	4529.857 - 7274.143

Reference Point	Estimate	95% Confidence Interval
Reference Points Based on SPR Proxy for MSY		
Proxy Spawning Biomass (mt) (SPR50)	36465.7	30147.011 - 42784.389
SPR50	0.5	
Exploitation Rate Corresponding to SPR50	0.076	0.069 - 0.084
Yield with SPR50 at SB SPR (mt)	5627.95	4323.512 - 6932.388
Reference Points Based on Estimated MSY Values		
Spawning Biomass (mt) at MSY (SB MSY)	**21667.4**	**17966.576 - 25368.224**
SPR MSY	0.337	0.333 - 0.34
Exploitation Rate Corresponding to SPR MSY	0.131	0.118 - 0.145
MSY (mt)	6310.43	4828.58 - 7792.28

Table 16: Time series of population estimates from the base case model.

Year	Total Biomass (mt)	Spawning Biomass (mt)	Total Biomass 4+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR_50%)	Exploitation Rate
1916	156,921.0	81,591.1	151,259.0	0.998	33,825.0	78.4	0.012	0.0
1917	156,798.0	81,526.3	151,139.0	0.997	33,794.8	121.9	0.018	0.0
1918	156,634.0	81,437.4	150,980.0	0.996	33,760.8	140.2	0.021	0.0
1919	156,456.0	81,340.1	150,807.0	0.995	33,723.4	96.8	0.015	0.0
1920	156,324.0	81,269.3	150,680.0	0.994	33,683.8	99.1	0.015	0.0
1921	156,190.0	81,198.7	150,552.0	0.993	33,640.4	82.1	0.012	0.0
1922	156,072.0	81,138.6	150,441.0	0.993	33,593.4	71.3	0.011	0.0
1923	155,962.0	81,084.5	150,337.0	0.992	33,542.2	78.3	0.012	0.0
1924	155,841.0	81,025.6	150,224.0	0.991	33,486.0	50.3	0.008	0.0
1925	155,741.0	80,980.7	150,133.0	0.991	33,424.9	62.3	0.009	0.0
1926	155,622.0	80,926.4	150,022.0	0.990	33,357.6	94.7	0.014	0.0
1927	155,462.0	80,850.5	149,873.0	0.989	33,283.1	78.7	0.012	0.0
1928	155,311.0	80,780.4	149,732.0	0.988	33,201.8	89.6	0.014	0.0
1929	155,138.0	80,700.2	149,572.0	0.987	33,112.6	87.0	0.013	0.0
1930	154,957.0	80,617.0	149,404.0	0.986	33,015.1	112.6	0.017	0.0
1931	154,740.0	80,514.8	149,200.0	0.985	32,907.8	100.1	0.015	0.0
1932	154,521.0	80,414.5	148,998.0	0.984	32,790.8	100.3	0.015	0.0

Year	Total Biomass (mt)	Spawning Biomass (mt)	Total Biomass 4+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR_50%)	Exploitation Rate
1933	154,287.0	80,308.0	148,781.0	0.983	32,663.2	86.2	0.013	0.0
1934	154,050.0	80,202.5	148,563.0	0.981	32,524.2	91.2	0.014	0.0
1935	153,788.0	80,086.2	148,321.0	0.980	32,372.4	98.4	0.015	0.0
1936	153,497.0	79,956.8	148,053.0	0.978	32,206.1	110.9	0.017	0.0
1937	153,171.0	79,810.6	147,751.0	0.976	32,023.5	103.9	0.016	0.0
1938	152,825.0	79,657.2	147,432.0	0.975	31,822.2	84.2	0.013	0.0
1939	152,469.0	79,502.8	147,106.0	0.973	31,599.6	77.0	0.012	0.0
1940	152,088.0	79,338.4	146,757.0	0.971	31,355.2	121.4	0.018	0.0
1941	151,627.0	79,133.4	146,331.0	0.968	31,087.4	130.5	0.020	0.0
1942	151,119.0	78,907.1	145,863.0	0.965	30,797.0	148.0	0.022	0.0
1943	150,553.0	78,653.5	145,340.0	0.962	30,491.8	495.4	0.074	0.0
1944	149,614.0	78,184.7	144,448.0	0.957	30,174.1	970.0	0.141	0.0
1945	148,200.0	77,437.6	143,084.0	0.947	29,842.3	1,637.1	0.230	0.0
1946	146,159.0	76,317.7	141,096.0	0.934	29,500.9	1,171.1	0.172	0.0
1947	144,613.0	75,488.2	139,603.0	0.924	29,188.9	648.8	0.100	0.0
1948	143,578.0	74,968.3	138,623.0	0.917	28,903.7	482.1	0.075	0.0
1949	142,677.0	74,537.1	137,777.0	0.912	28,648.2	377.7	0.060	0.0
1950	141,837.0	74,149.7	136,986.0	0.907	28,440.9	427.2	0.068	0.0
1951	140,906.0	73,711.5	136,100.0	0.902	28,306.6	559.0	0.088	0.0

Year	Total Biomass (mt)	Spawning Biomass (mt)	Total Biomass 4+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR_50%)	Exploitation Rate
1952	139,816.0	73,174.6	135,047.0	0.895	28,275.3	546.5	0.087	0.0
1953	138,724.0	72,625.8	133,981.0	0.889	28,391.8	473.9	0.076	0.0
1954	137,705.0	72,102.7	132,973.0	0.882	28,700.0	452.2	0.073	0.0
1955	136,728.0	71,581.0	131,986.0	0.876	29,238.9	469.5	0.077	0.0
1956	135,790.0	71,046.5	131,008.0	0.869	30,020.3	606.5	0.099	0.0
1957	134,818.0	70,444.2	129,962.0	0.862	30,973.8	768.0	0.125	0.0
1958	133,849.0	69,781.2	128,882.0	0.854	31,880.8	708.3	0.117	0.0
1959	133,154.0	69,210.4	128,047.0	0.847	32,404.6	678.1	0.113	0.0
1960	132,741.0	68,740.8	127,489.0	0.841	32,333.5	818.8	0.136	0.0
1961	132,460.0	68,303.2	127,099.0	0.836	31,945.9	683.8	0.115	0.0
1962	132,566.0	68,082.9	127,165.0	0.833	31,951.7	765.0	0.128	0.0
1963	132,800.0	67,965.9	127,420.0	0.832	32,896.9	437.6	0.075	0.0
1964	133,508.0	68,177.4	128,142.0	0.834	34,289.6	607.2	0.102	0.0
1965	134,174.0	68,400.4	128,729.0	0.837	35,901.6	261.9	0.045	0.0
1966	135,317.0	68,894.6	129,677.0	0.843	37,707.6	4,293.1	0.552	0.0
1967	132,868.0	67,091.9	126,983.0	0.821	37,602.1	4,830.3	0.613	0.0
1968	130,427.0	65,185.0	124,312.0	0.798	35,264.9	2,392.6	0.365	0.0
1969	130,789.0	64,943.5	124,570.0	0.795	30,232.4	852.2	0.147	0.0
1970	133,200.0	65,808.2	126,800.0	0.805	122,196.0	854.8	0.145	0.0

Year	Total Biomass (mt)	Spawning Biomass (mt)	Total Biomass 4+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR_50%)	Exploitation Rate
1971	136,676.0	66,821.6	129,175.0	0.818	99,957.2	1,095.5	0.180	0.0
1972	141,735.0	67,782.8	131,024.0	0.829	13,345.6	923.7	0.152	0.0
1973	149,014.0	69,398.4	132,124.0	0.849	11,233.6	1,160.5	0.184	0.0
1974	157,533.0	71,765.8	147,009.0	0.878	15,183.7	907.1	0.144	0.0
1975	165,410.0	75,488.6	163,169.0	0.924	31,899.2	876.6	0.133	0.0
1976	170,359.0	80,425.7	167,920.0	0.984	10,256.2	1,325.4	0.183	0.0
1977	171,951.0	85,074.5	168,503.0	1.041	58,846.9	1,094.3	0.139	0.0
1978	171,775.0	88,327.5	166,758.0	1.081	89,906.0	1,581.1	0.189	0.0
1979	170,472.0	89,031.9	164,876.0	1.089	28,592.0	9,479.0	0.790	0.1
1980	161,948.0	83,946.0	151,193.0	1.027	49,513.6	22,055.2	1.325	0.1
1981	143,145.0	71,767.3	131,865.0	0.878	82,300.1	28,135.3	1.554	0.2
1982	121,352.0	57,299.4	114,523.0	0.701	43,122.9	27,100.0	1.643	0.2
1983	103,480.0	45,393.9	93,824.4	0.555	27,392.5	12,263.6	1.364	0.1
1984	102,562.0	43,186.6	91,830.0	0.528	53,949.1	12,125.3	1.362	0.1
1985	102,467.0	42,501.5	95,846.4	0.520	39,210.2	10,882.5	1.290	0.1
1986	103,022.0	42,842.7	96,979.2	0.524	18,399.5	11,439.2	1.295	0.1
1987	102,173.0	43,168.0	94,547.6	0.528	46,999.8	15,386.9	1.426	0.2
1988	96,672.3	41,332.3	91,031.6	0.506	29,661.7	12,529.9	1.339	0.1
1989	92,938.3	40,140.5	88,255.9	0.491	21,699.8	14,984.2	1.446	0.2

Year	Total Biomass (mt)	Spawning Biomass (mt)	Total Biomass 4+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR_50%)	Exploitation Rate
1990	85,931.5	37,236.4	79,436.6	0.456	33,530.2	13,772.0	1.442	0.2
1991	79,894.8	34,378.7	75,124.2	0.421	60,103.4	8,987.5	1.267	0.1
1992	78,323.0	33,588.6	73,423.4	0.411	22,467.7	8,685.0	1.262	0.1
1993	77,111.6	32,781.5	70,440.8	0.401	28,210.4	11,412.8	1.410	0.2
1994	73,533.1	30,596.2	66,045.2	0.374	25,483.1	8,901.3	1.323	0.1
1995	72,549.9	29,689.1	68,490.3	0.363	15,866.5	9,257.7	1.363	0.1
1996	70,649.3	28,872.4	66,362.6	0.353	11,661.7	8,352.7	1.321	0.1
1997	68,858.4	28,770.6	65,350.6	0.352	17,856.5	8,884.6	1.343	0.1
1998	65,584.0	28,271.3	63,031.5	0.346	32,037.6	6,606.6	1.195	0.1
1999	63,709.6	28,261.6	60,958.6	0.346	42,397.2	5,958.2	1.127	0.1
2000	62,152.9	28,001.1	57,962.2	0.343	34,930.2	4,779.7	0.988	0.1
2001	62,020.1	27,863.5	56,165.8	0.341	19,259.9	2,318.4	0.624	0.0
2002	64,926.9	28,698.6	58,732.9	0.351	17,113.7	484.4	0.182	0.0
2003	69,966.7	30,632.0	65,292.5	0.375	16,640.3	46.4	0.018	0.0
2004	75,226.5	33,229.3	72,006.7	0.407	54,864.6	99.1	0.035	0.0
2005	79,867.0	36,142.4	76,374.6	0.442	10,597.3	203.3	0.066	0.0
2006	84,059.3	38,933.7	79,418.4	0.476	42,739.0	220.4	0.066	0.0
2007	88,027.7	41,457.9	81,420.5	0.507	10,638.4	244.2	0.069	0.0
2008	92,290.8	43,499.0	88,570.5	0.532	100,500.0	272.1	0.072	0.0

Year	Total Biomass (mt)	Spawning Biomass (mt)	Total Biomass 4+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR_50%)	Exploitation Rate
2009	96,622.4	45,464.2	90,121.3	0.556	13,201.5	186.1	0.048	0.0
2010	101,902.0	47,419.4	95,474.5	0.580	65,766.3	178.8	0.044	0.0
2011	107,889.0	49,761.4	96,356.7	0.609	9,730.8	212.2	0.049	0.0
2012	114,658.0	52,230.5	109,990.0	0.639	6,415.9	270.8	0.060	0.0
2013	120,695.0	55,363.7	113,543.0	0.677	56,499.1	470.3	0.092	0.0
2014	125,628.0	58,835.8	123,257.0	0.720	23,475.4	722.7	0.131	0.0
2015	128,844.0	62,102.2	124,977.0	0.760	18,395.4	879.8	0.144	0.0
2016	131,047.0	64,772.5	123,713.0	0.792	100,039.0	1,039.4	0.161	0.0
2017	133,121.0	66,368.7	128,040.0	0.812	27,891.9	6,361.5	0.736	0.0
2018	130,220.0	64,402.6	123,040.0	0.788	10,614.8	10,522.8	1.070	0.1
2019	123,775.0	60,465.2	112,578.0	0.740	8,288.6	9,315.3	1.054	0.1
2020	119,200.0	57,485.6	115,815.0	0.703	8,907.4	8,379.6	1.041	0.1
2021	114,525.0	55,682.2	112,860.0	0.681	18,889.2	10,899.7	1.210	0.1
2022	105,901.0	53,221.9	104,241.0	0.651	20,463.9	12,129.7	1.270	0.1
2023	94,880.5	49,724.4	92,606.5	0.608	30,114.6	11,023.5	1.248	0.1
2024	84,326.0	45,443.7	80,859.1	0.556	26,045.8	9,764.1	1.257	0.1
2025	75,266.1	40,603.5	71,231.1	0.497	31,045.5	10,668.6	1.418	0.1
2026	66,206.5	34,837.1	61,355.1	0.426	30,156.2	9,823.6	1.493	0.2
2027	59,376.9	29,822.4	54,693.9	0.365	29,167.0	3,241.8	0.939	0.1

Year	Total Biomass (mt)	Spawning Biomass (mt)	Total Biomass 4+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/(1-SPR_50%)	Exploitation Rate
2028	60,375.7	29,021.0	55,274.1	0.355	28,984.6	3,252.7	0.929	0.1
2029	62,165.0	28,949.9	57,200.2	0.354	28,968.0	3,445.9	0.926	0.1
2030	64,269.6	29,380.6	59,408.6	0.359	29,067.4	3,719.1	0.927	0.1
2031	66,366.7	30,089.1	61,521.6	0.368	29,226.0	4,006.9	0.929	0.1
2032	68,280.7	30,897.5	63,428.7	0.378	29,400.1	4,266.8	0.932	0.1
2033	69,943.7	31,679.0	65,070.6	0.388	29,561.8	4,467.3	0.935	0.1
2034	71,371.3	32,378.6	66,471.0	0.396	29,701.4	4,606.2	0.936	0.1
2035	72,613.2	32,994.8	67,685.2	0.404	29,820.4	4,695.4	0.936	0.1
2036	73,720.6	33,547.4	68,767.8	0.410	29,924.2	4,748.2	0.933	0.1

Table 17: Quantities of interest from the sensitivity analyses.

	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.	Excluding triennial	Francis weighting
Difference from Base Model Likelihood									
Total	19,047.000	21.700	5.400	234.900	239.200	0.800	685.000	90.100	-1,230.400
Survey	13.022	2.609	0.323	1.504	-1.633	-0.010	-0.056	7.917	0.458
Length	854.968	1.593	-1.324	98.820	165.732	-0.218	-0.175	56.533	-626.370
Age	1,366.280	9.670	5.790	54.800	56.900	-0.040	-0.200	62.350	-593.479
Discards	16,793.300	0.700	0.100	0.600	-0.200	1.000	685.300	-74.100	0.000
Recruitment	17.840	7.922	0.661	0.516	9.204	0.038	0.064	20.120	-11.260
Forecast recruitment	0.600	0.139	0.018	0.022	9.591	0.002	0.013	17.968	-0.292
Parameter priors	0.983	-0.924	-0.234	0.530	-0.387	0.007	-0.017	-0.886	0.490
Parameter values									
Natural mortality (female)	0.125	0.100	0.124	0.137	0.110	0.125	0.124	0.091	0.135
Length at Amin (female)	20.652	20.666	20.707	21.556	21.079	20.651	20.653	21.523	20.707

	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.	Excluding triennial	Francis weighting
Length at Amax (female)	49.524	49.403	49.508	49.463	49.224	49.522	49.522	49.314	49.468
CV young (female)	0.116	0.116	0.115	0.104	0.107	0.116	0.116	0.103	0.118
CV old (female)	0.048	0.049	0.048	0.048	0.049	0.048	0.048	0.049	0.046
vBL k (female)	0.181	0.184	0.182	0.173	0.185	0.181	0.181	0.179	0.177
Natural mortality (male)	0.137	0.100	0.129	0.145	0.123	0.137	0.137	0.102	0.148
Length at Amin (male)	21.041	21.118	21.092	21.156	21.050	21.041	21.042	21.272	20.602
Length at Amax (male)	43.637	43.462	43.527	43.019	43.482	43.636	43.636	43.290	43.541
CV young (male)	0.094	0.092	0.093	0.090	0.094	0.094	0.094	0.090	0.102
CV old (male)	0.057	0.058	0.058	0.058	0.057	0.057	0.057	0.059	0.051
vBL k (male)	0.245	0.245	0.244	0.257	0.255	0.245	0.245	0.252	0.257

Quantity

	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.	Excluding triennial	Francis weighting
Virgin recruitment (thousands)	34.103	19.899	31.238	43.525	30.869	34.194	34.107	15.749	44.630
ln(R0)	10.437	9.898	10.349	10.681	10.338	10.440	10.437	9.665	10.706
SSB unfished (mt)	151,584	139,733	145,722	164,658	170,327	151,575	152,017	119,637	170,256
SB0 (thousand mt)	81.733	72.834	75.759	85.258	93.885	81.659	81.930	68.011	90.250
SSB 2025 (thousand mt)	40.603	19.952	35.214	50.233	48.287	40.539	40.586	3.827	47.805
B ratio 2025	0.497	0.274	0.465	0.589	0.514	0.496	0.495	0.056	0.530
SPR ratio 2025	1.257	1.657	1.312	1.023	1.489	1.257	1.257	1.974	1.109

Table 18: Estimated data weights derived using the McAllister-Ianelli and Francis methods.

Fleet	Composition data type	McAllister Ianelli weighting (base model)	Francis weighting (alternative)
BottomTrawl	Length	0.050958	0.045433
Hake	Length	0.028033	0.019501
HnL	Length	0.163500	0.147225
MidwaterTrawl	Length	0.043643	0.036830
Net	Length	0.115958	0.122032
Triennial	Length	0.092524	0.091813
WCGBTS	Length	0.101291	0.086056
BottomTrawl	Age	0.206402	0.230204
Hake	Age	0.180382	0.238157
HnL	Age	0.526129	0.524539
MidwaterTrawl	Age	0.131189	0.132073
Net	Age	0.179522	0.205100
WCGBTS	Age	0.124021	0.129885

5.3 Management

Table 19: Potential OFLs (mt), ABCs (mt), ACLs (mt), the buffer between the OFL and ABC, estimated spawning biomass (mt), and fraction of unfished spawning biomass with adopted OFLs and ACLs and assumed catch for the first two years of the projection period. The predicted OFL is the calculated total catch determined by FSPR=50%.

Year	Adopted OFL (mt)	Adopted ACL (mt)	Assumed Catch (mt)	OFL (mt)	Buffer	ABC (mt)	ACL (mt)	Spawning Biomass (mt)	Fraction Unfished
2025	12254	11237	10669	-	-	-	-	40,604	0.497
2026	11382	10392	9823.6	-	-	-	-	34,837	0.426
2027	-	-	-	3582	0.935	3349.17	3241.8	29,822	0.365
2028	-	-	-	3651.6	0.93	3395.988	3252.7	29,021	0.355
2029	-	-	-	3888.8	0.926	3601.0288	3445.9	28,950	0.354
2030	-	-	-	4191.3	0.922	3864.3786	3719.1	29,381	0.359
2031	-	-	-	4499.4	0.917	4125.9498	4006.9	30,089	0.368
2032	-	-	-	4765.7	0.913	4351.0841	4266.8	30,898	0.378
2033	-	-	-	4967.5	0.909	4515.4575	4467.3	31,679	0.388
2034	-	-	-	5112	0.904	4621.248	4606.2	32,379	0.396
2035	-	-	-	5217.2	0.9	4695.4	4695.4	32,995	0.404
2036	-	-	-	5299.3	0.896	4748.2	4748.2	33,547	0.410

Table 20: 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 (%)
ACLp*=0.45, sigma=0.50	2025	10,669	28,278	32.7	40,552	49.6	49,907	60.6
	2026	9,824	22,726	26.3	34,788	42.6	43,767	53.1
	2027	3,031	17,921	20.7	29,775	36.4	38,407	46.6
	2028	3,025	17,418	20.2	29,085	35.6	37,432	45.4
	2029	3,191	17,549	20.3	29,127	35.6	37,281	45.3
	2030	3,429	18,026	20.9	29,680	36.3	37,755	45.8
	2031	3,674	18,595	21.5	30,525	37.4	38,644	46.9
	2032	3,896	19,077	22.1	31,488	38.5	39,766	48.3
	2033	4,061	19,374	22.4	32,439	39.7	40,972	49.7
	2034	4,164	19,486	22.6	33,322	40.8	42,170	51.2
	2035	4,226	19,477	22.5	34,133	41.8	43,322	52.6
	2036	4,254	19,415	22.5	34,889	42.7	44,412	53.9
	2025	10,669	28,278	32.7	40,552	49.6	49,907	60.6
	2026	9,824	22,726	26.3	34,788	42.6	43,767	53.1
	2027	2,642	17,921	20.7	29,775	36.4	38,407	46.6
	2028	2,627	17,624	20.4	29,288	35.8	37,633	45.7
	2029	2,757	17,957	20.8	29,527	36.1	37,675	45.7
	2030	2,947	18,650	21.6	30,288	37.1	38,351	46.6
	2031	3,145	19,459	22.5	31,360	38.4	39,456	47.9
	2032	3,312	20,206	23.4	32,567	39.9	40,810	49.5
	2033	3,430	20,794	24.1	33,783	41.3	42,264	51.3

ACLp*=0.40, sigma=0.50			**State of nature**					
			Low		**Base**		**High**	
Management decision	Year	catch (mt)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)	Depletion (%)
	2034	3,492	21,221	24.6	34,947	42.8	43,722	53.1
	2035	3,505	21,549	24.9	36,052	44.1	45,141	54.8
	2036	3,502	21,845	25.3	37,113	45.4	46,506	56.5

6 Figures

6.1 Data

6.1.1 Indices

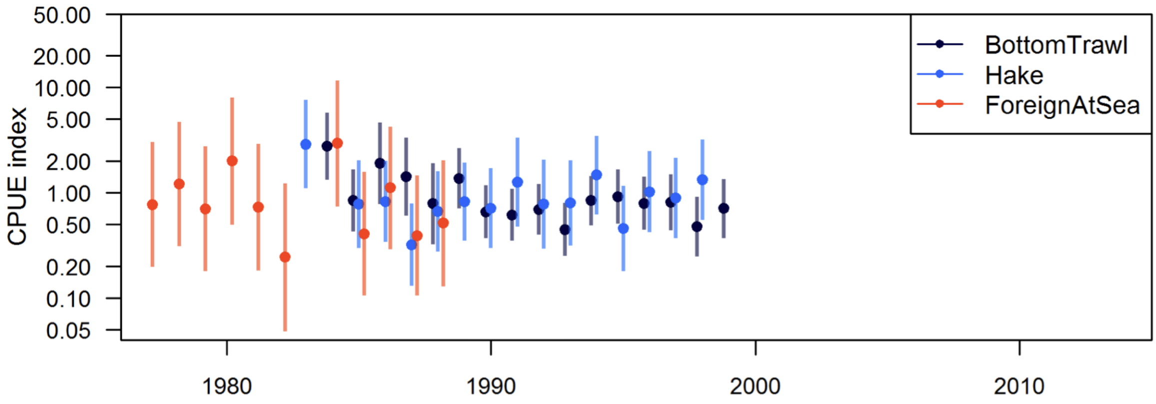


Figure 1: Fishery-dependent indices of abundance from the 2011 assessment scaled to the mean of their own series.

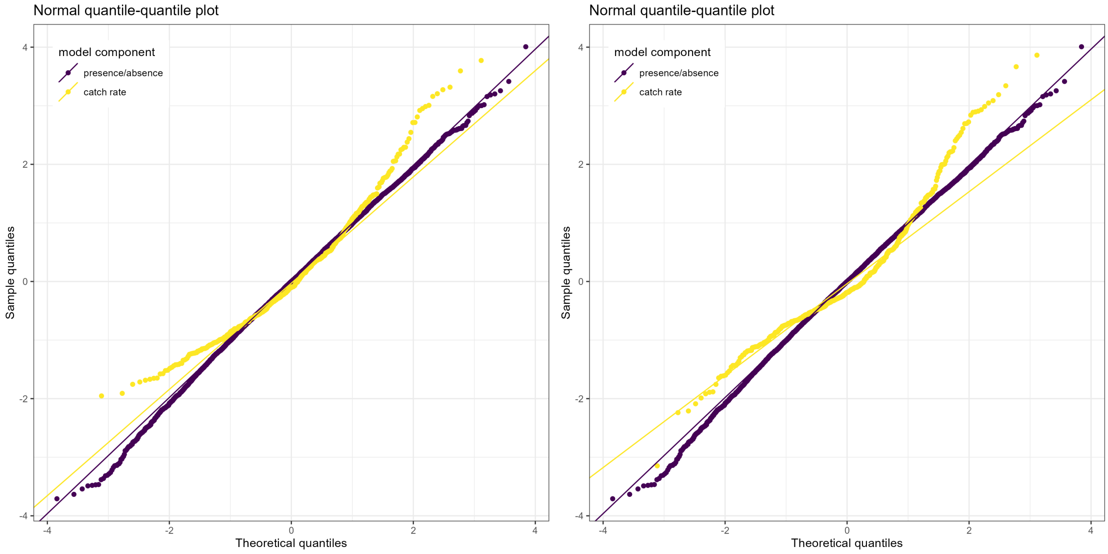


Figure 2: QQ plots for delta-gamma (panel 1) and delta-lognormal (panel 2, used in base model) sdmTMB index.

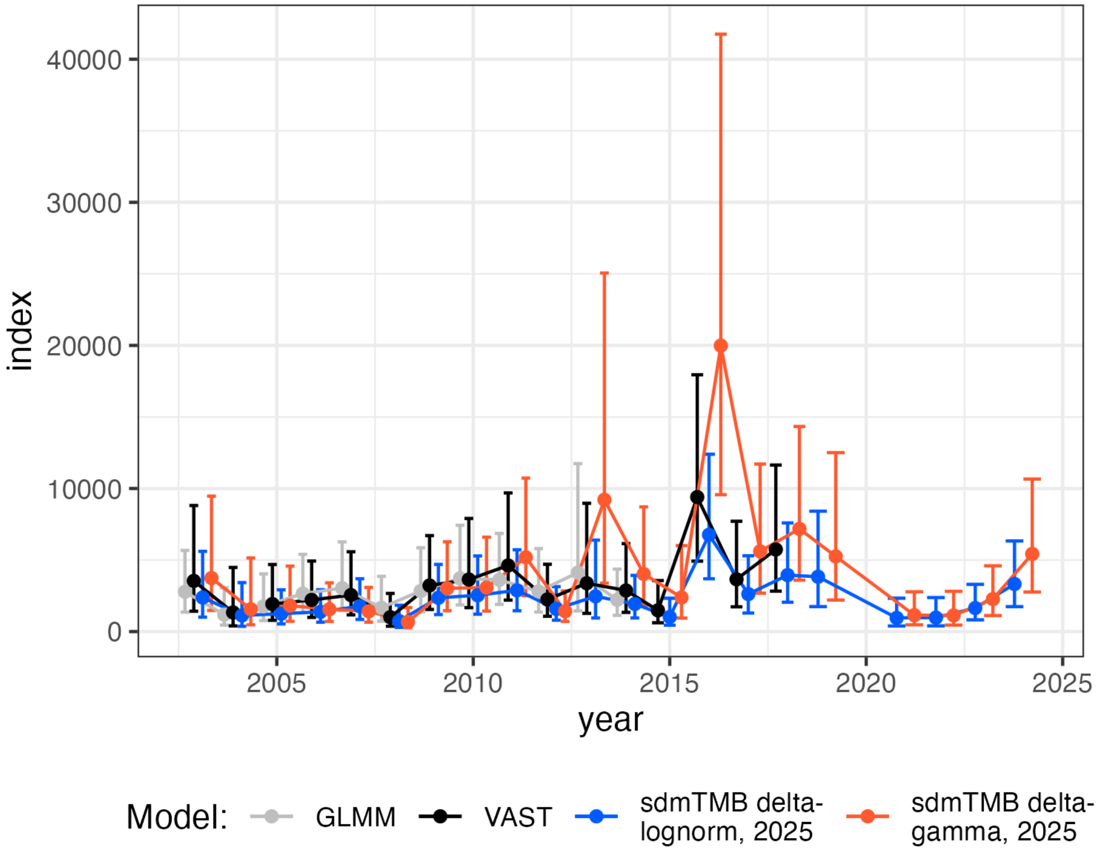


Figure 3: Comparison of the estimated index of relative abundance for the West Coast Groundfish Bottom Trawl Survey using a GLMM (gray line, 2015 stock assessment), VAST (black line, 2019 stock assessment), a delta-gamma sdmTMB index (blue line) and a delta-lognormal sdmTMB index (red line, used in base model). The error bars give 5 and 95% intervals for each survey.

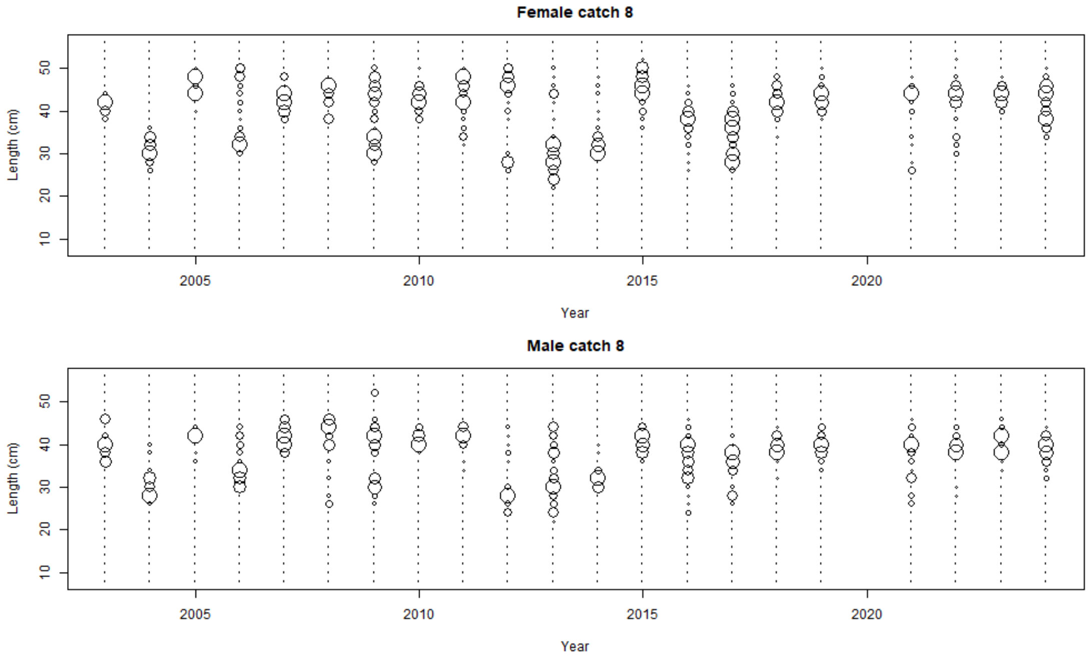


Figure 4: Expanded length compositions for the WCGBTS

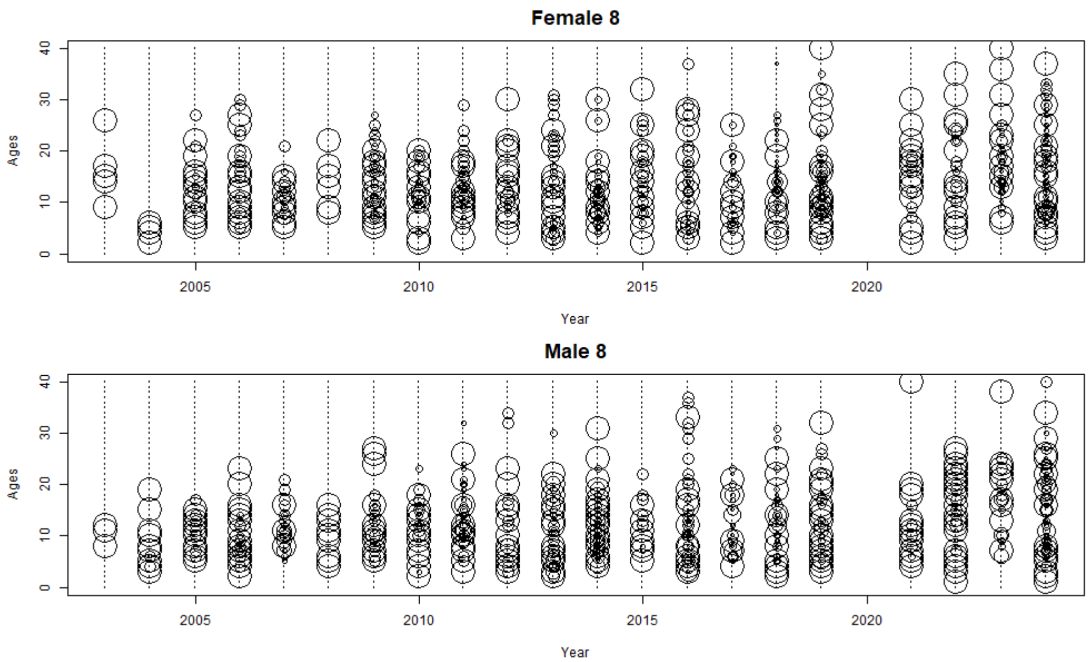


Figure 5: Expanded marginal age compositions from the WCGBTS.

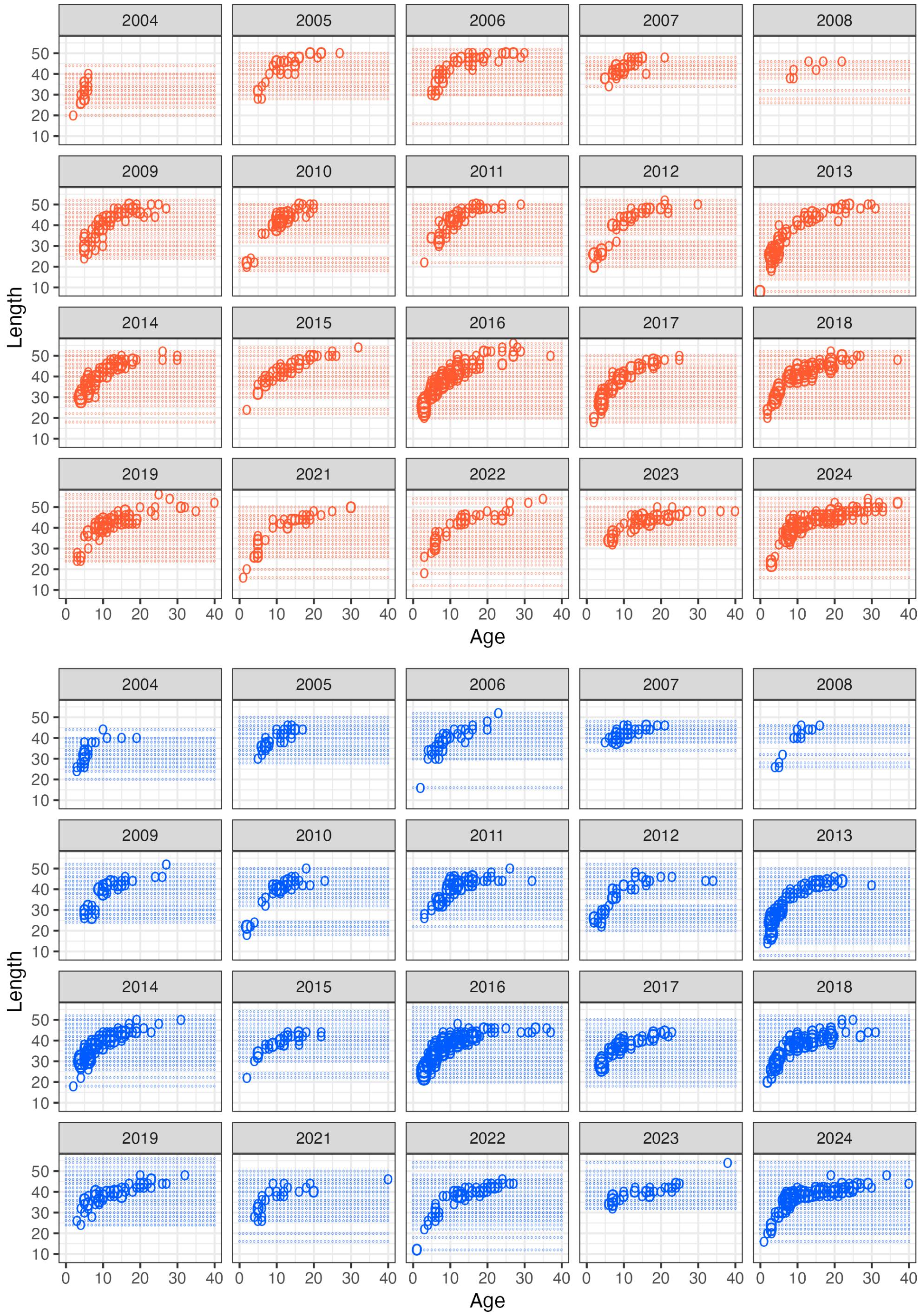


Figure 6: Conditional age-at-length from WCGBTS observations for females (red) and males (blue).

6.1.2 Composition data

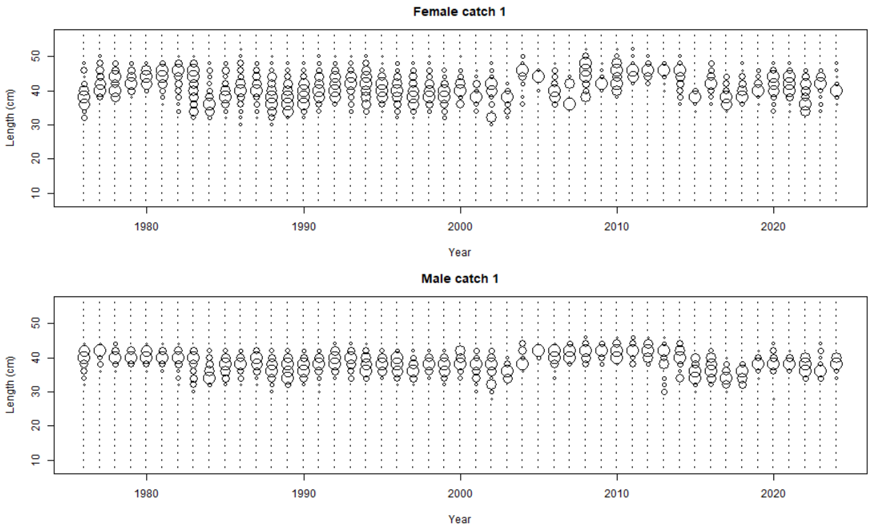


Figure 7: Expanded length compositions for the bottom trawl fishery. The area of the circle is proportional to the proportion-at-length.

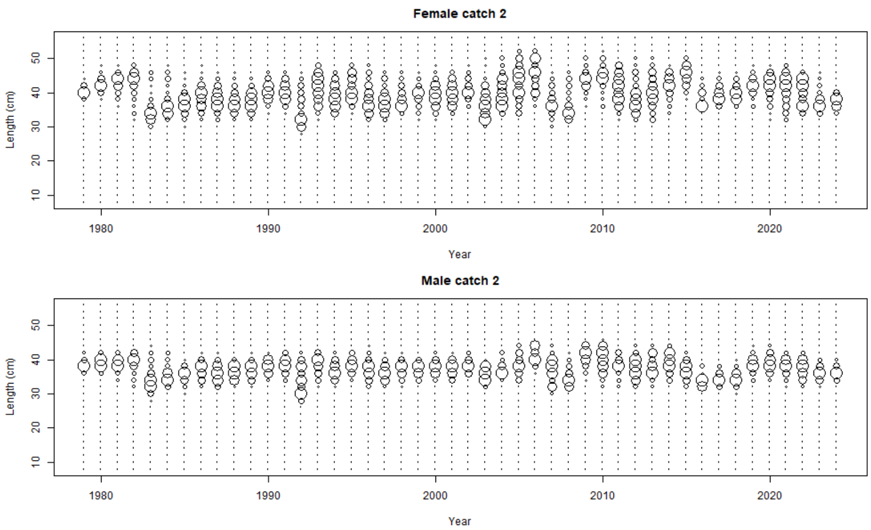


Figure 8: Expanded length compositions for the midwater trawl fishery. The area of the circle is proportional to the proportion-at-length.

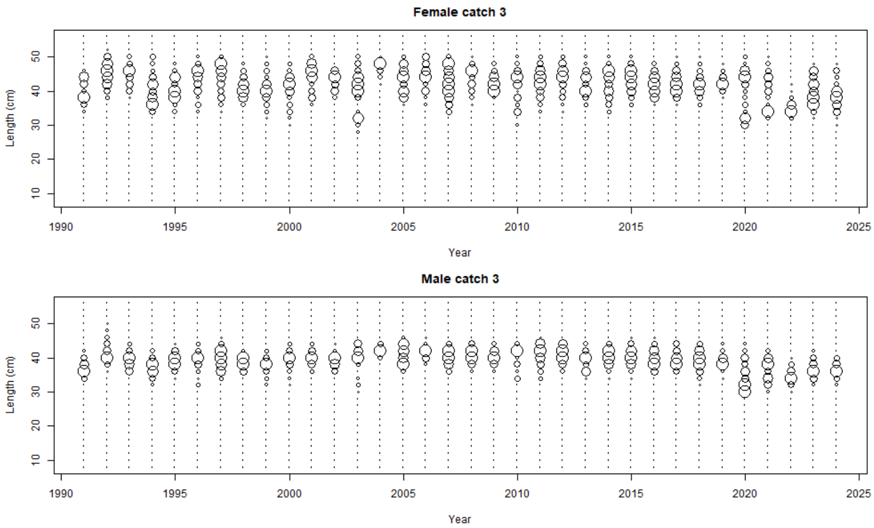


Figure 9: Expanded length compositions for the hake fishery. The area of the circle is proportional to the proportion-at-length.

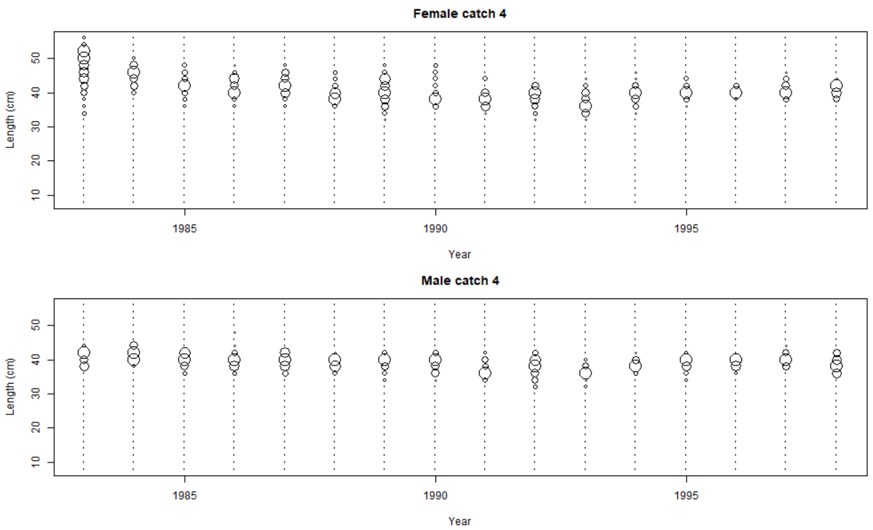


Figure 10: Expanded length compositions for the net fishery. The area of the circle is proportional to the proportion-at-length.

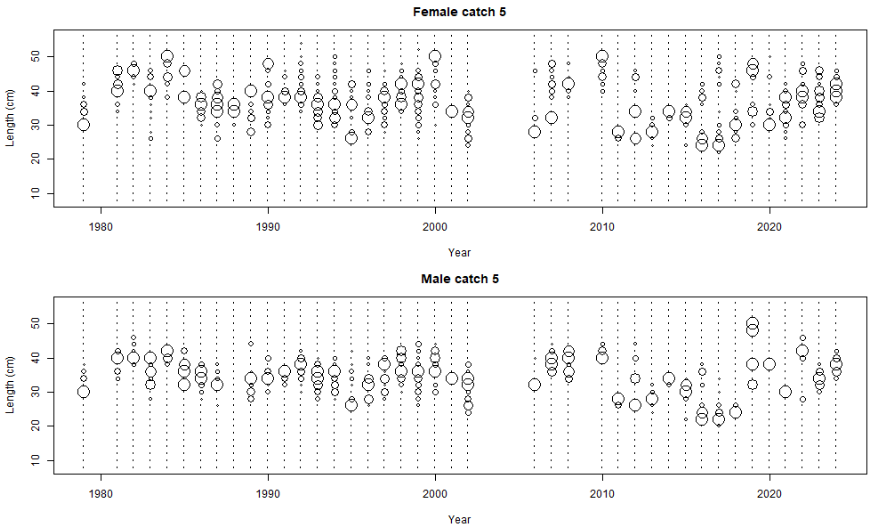


Figure 11: Expanded length compositions for the hook-and-line fishery. The area of the circle is proportional to the proportion-at-length.

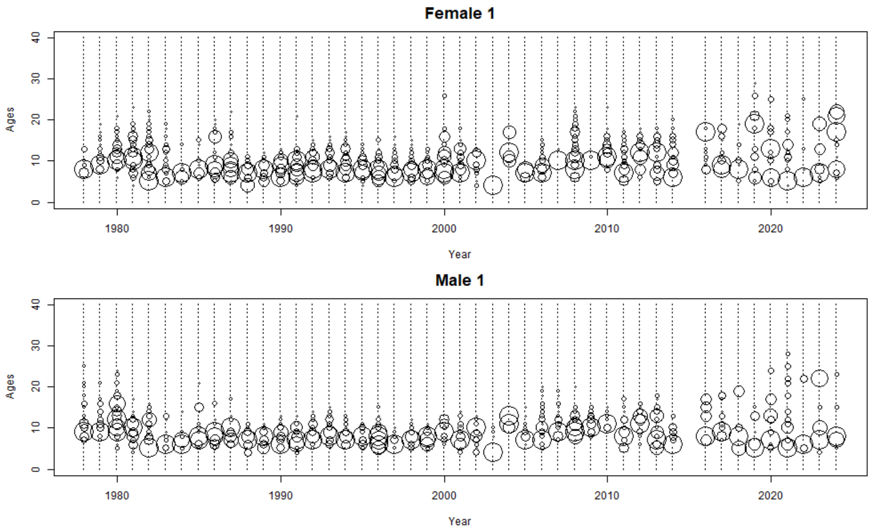


Figure 12: Expanded age compositions for the bottom trawl fishery. The area of the circle is proportional to the proportion-at-age.

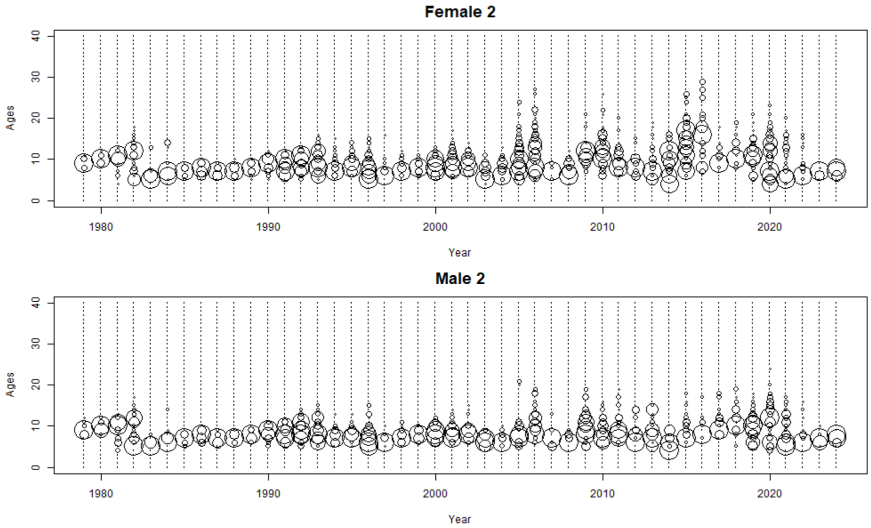


Figure 13: Expanded age compositions for the midwater trawl fishery. The area of the circles is proportional to the proportion-at-age.

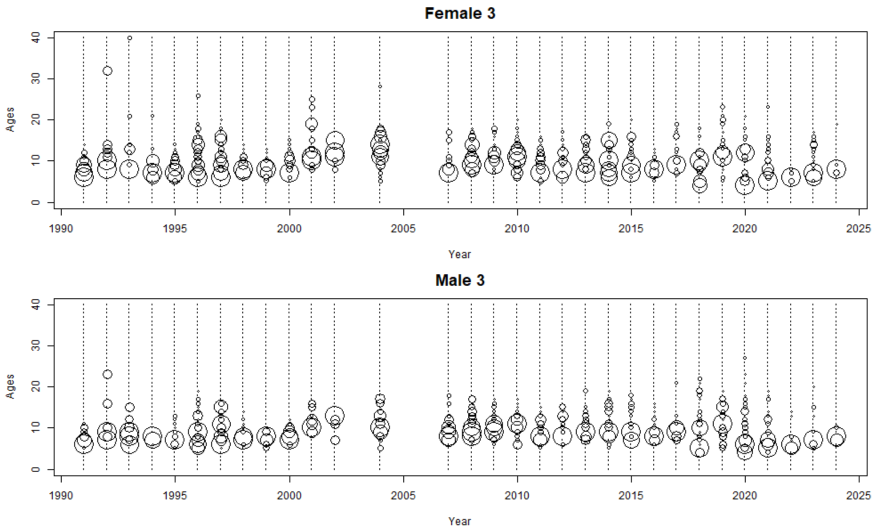


Figure 14: Expanded age compositions for the hake fishery. The area of the circles is proportional to the proportion-at-age.

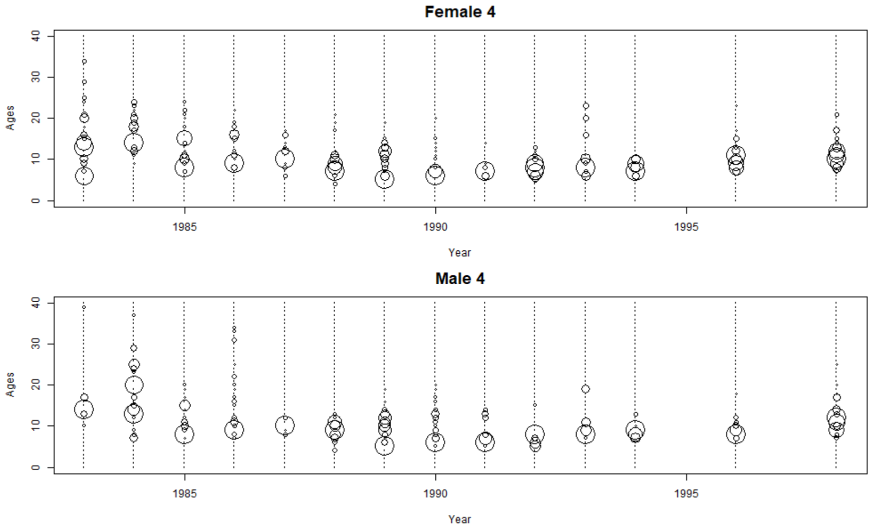


Figure 15: Expanded age compositions for the net fishery. The area of the circles is proportional to the proportion-at-age.

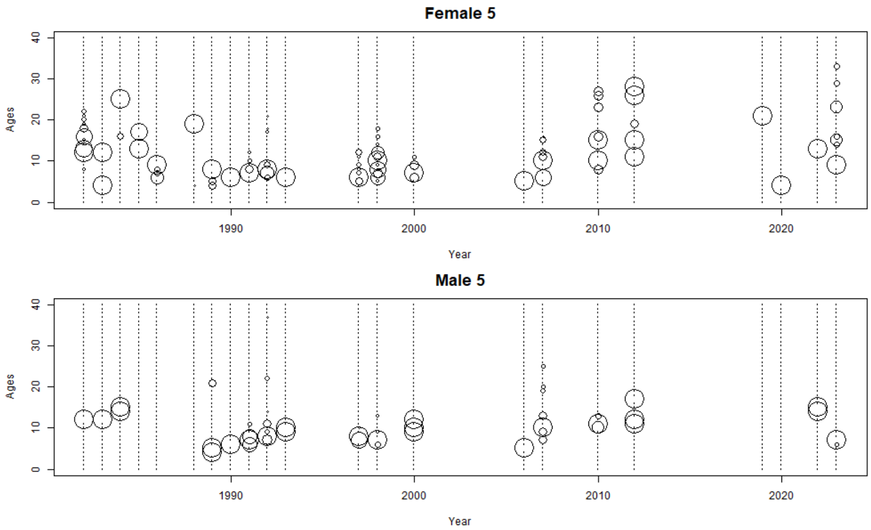


Figure 16: Expanded age compositions for the hook-and-line fishery. The area of the circles is proportional to the proportion-at-age.

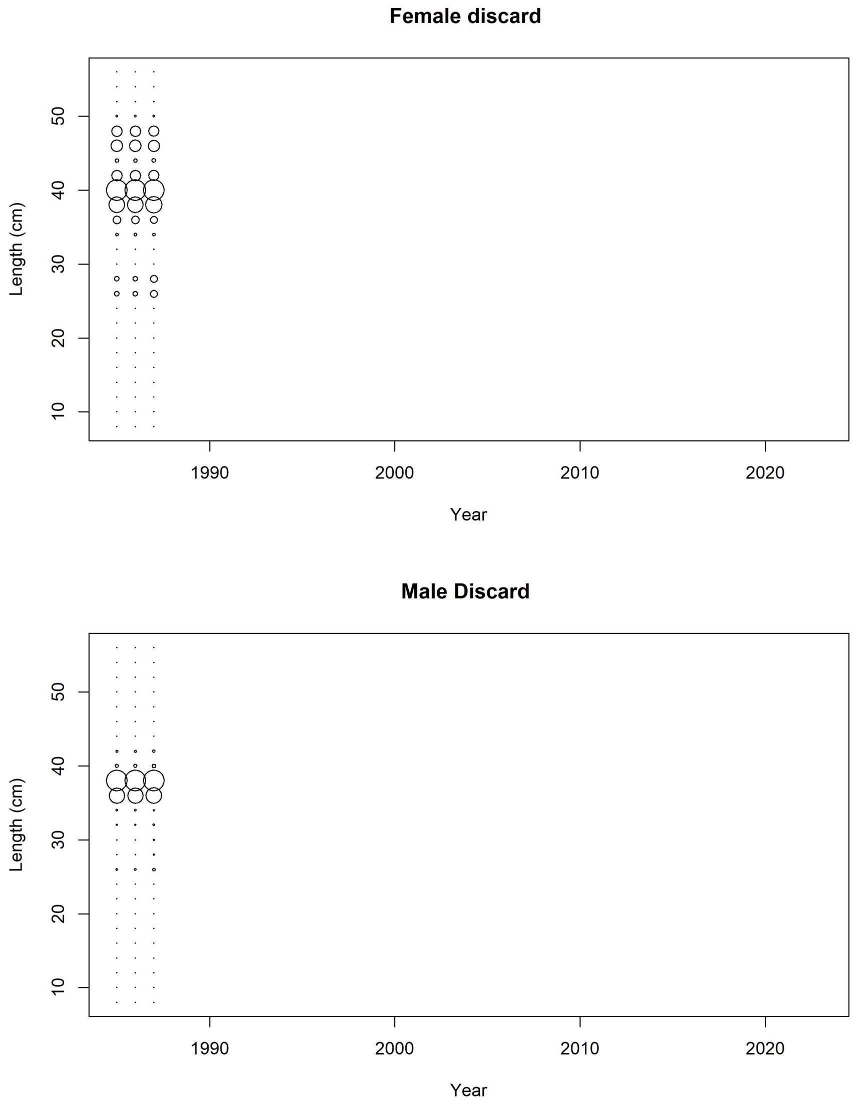


Figure 17: Length compositions for discards from the Pikitch study. The discard length comps were fitted into the model.

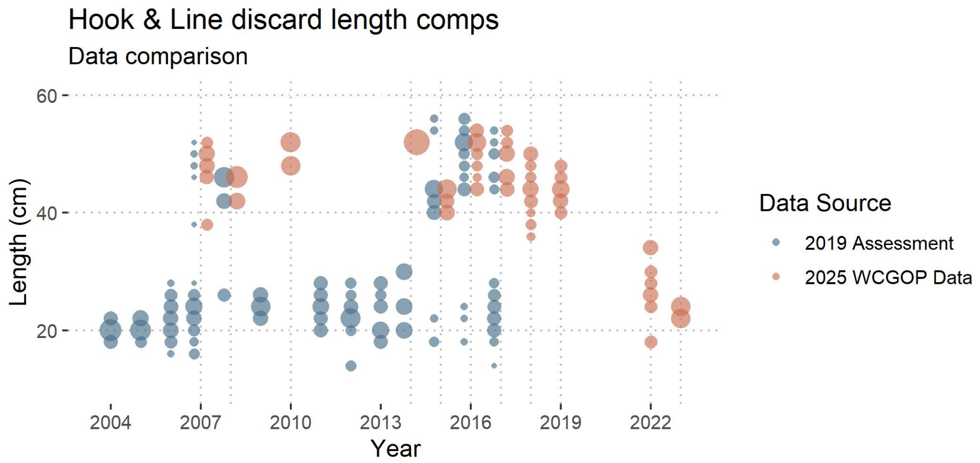


Figure 18: Comparison between discard data for the Hook & Line fleet from the 2019 assessment, which included nearshore fixed gear fleets, and discards queried from WCGOP for this assessment.

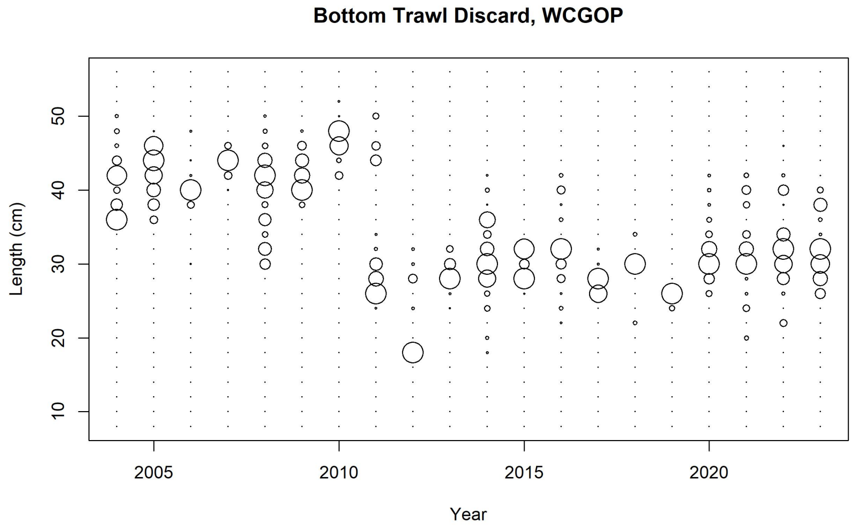


Figure 19: Length compositions of the discards for the bottom trawl.

6.1.3 Biological data

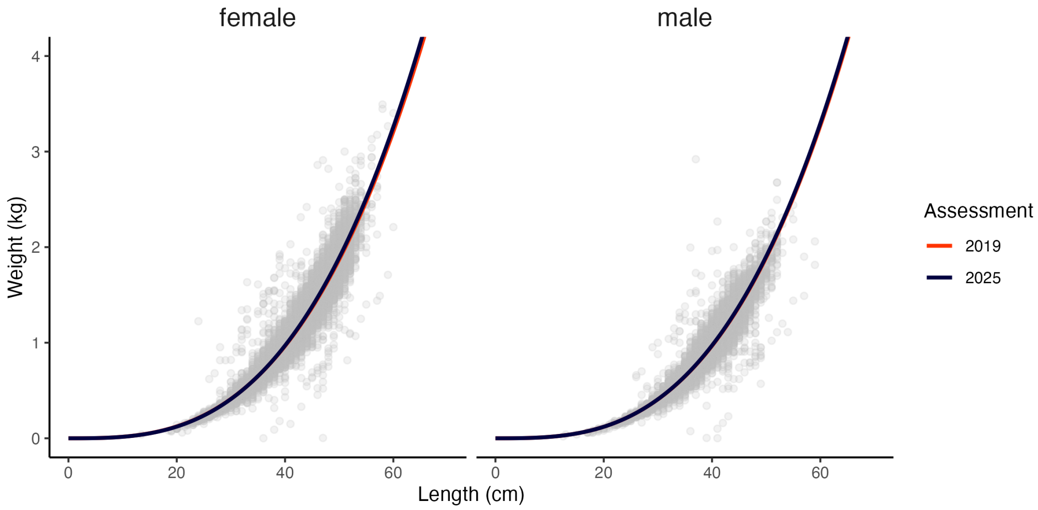


Figure 20: Fits to weight-at-length observations (dashed line) for females (left) and males (right) from the previous and current assessments. Fits to the current assessment use observations from all data sources (points)

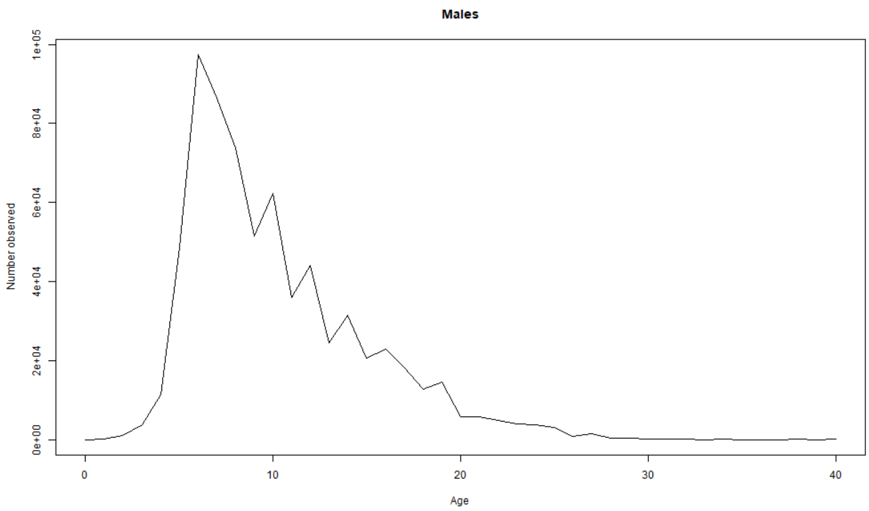


Figure 21: Number at age observed from all data for female and male widow rockfish.

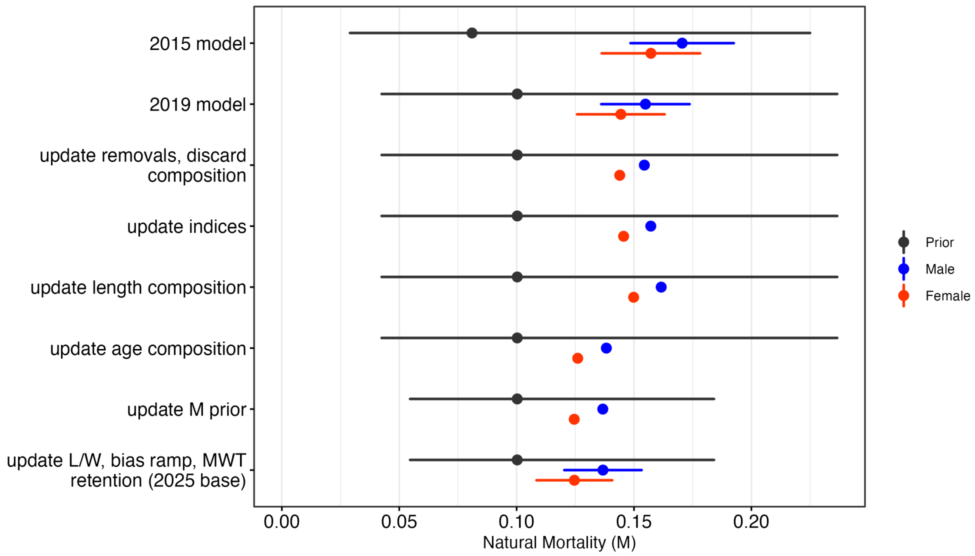


Figure 22: The prior for natural mortality (grey, M, yr-1) and the estimated M for females (red) and males (blue) from the 2015 base model, 2019 base model, and selected intermediate models bridging to the 2025 base model. Prior 95% quantiles are based on the assumed lognormal distribution. Confidence intervals for estimated male and female M are shown only for the 2015, 2019, and 2025 base models and are based on a normal asymptotic approximation to the sampling distribution. Depicted bridging models are selected to highlight changes with a notable impact on M.

6.2 Model

6.2.1 Bridging

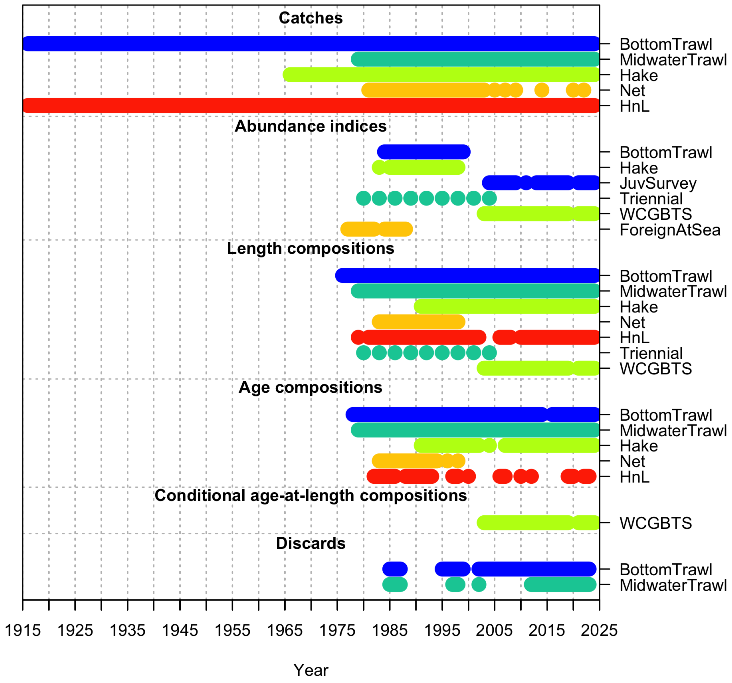


Figure 23: Data sources by type and year that were used in the base model.

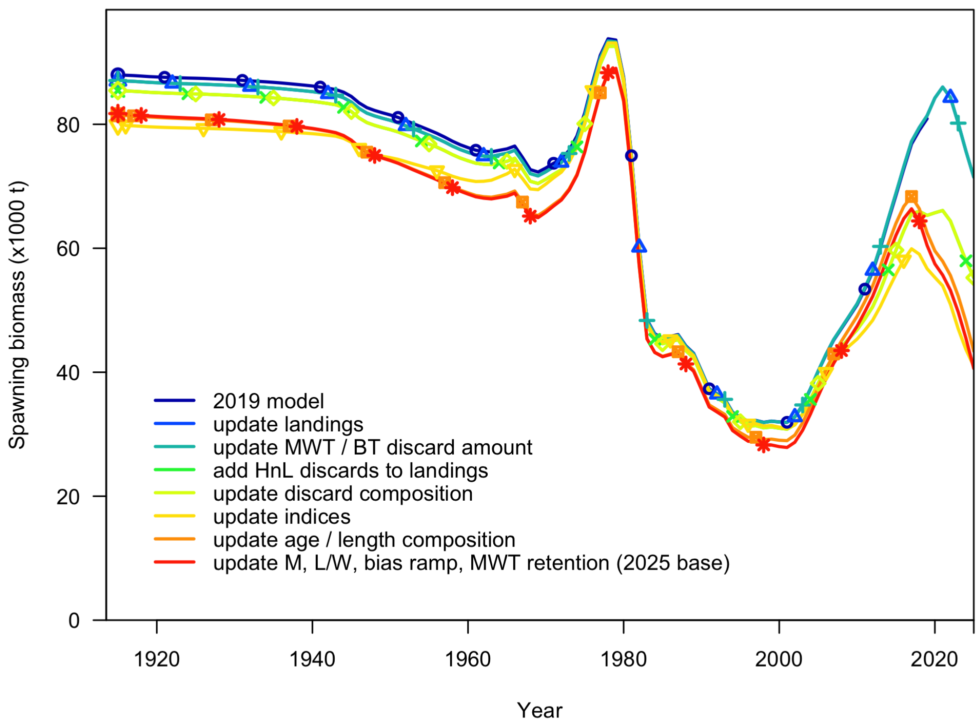


Figure 24: Time series of spawning stock biomass (SSB) estimates from model runs bridging from the 2019 assessment (dark blue) to the current base model (red). For illustration purposes, the addition of midwater and bottom trawl discards (without updating hook-and-line discards) precedes the addition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

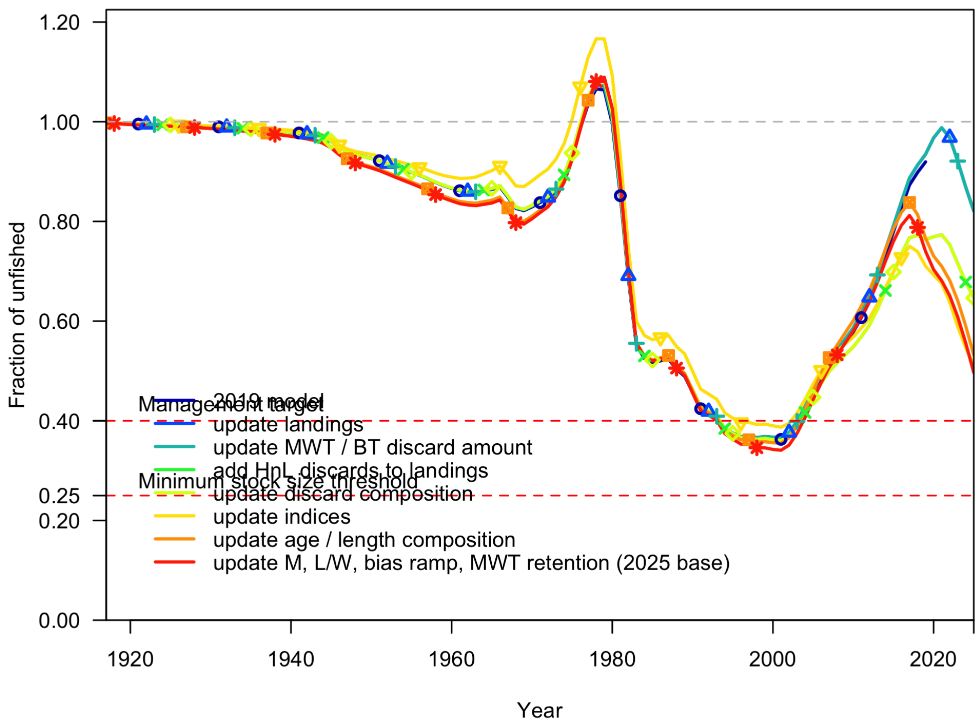


Figure 25: Time series of relative spawning stock biomass (fraction unfished / depletion) estimates from model runs bridging from the 2019 assessment (dark blue) to the current base model (red).

6.2.2 Selectivity

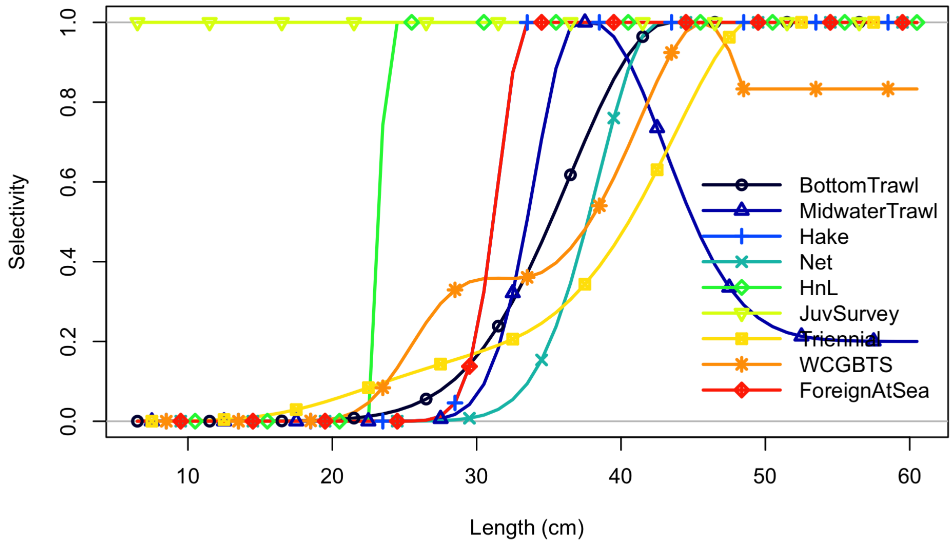


Figure 26: Estimated selectivity for different fleets and surveys.

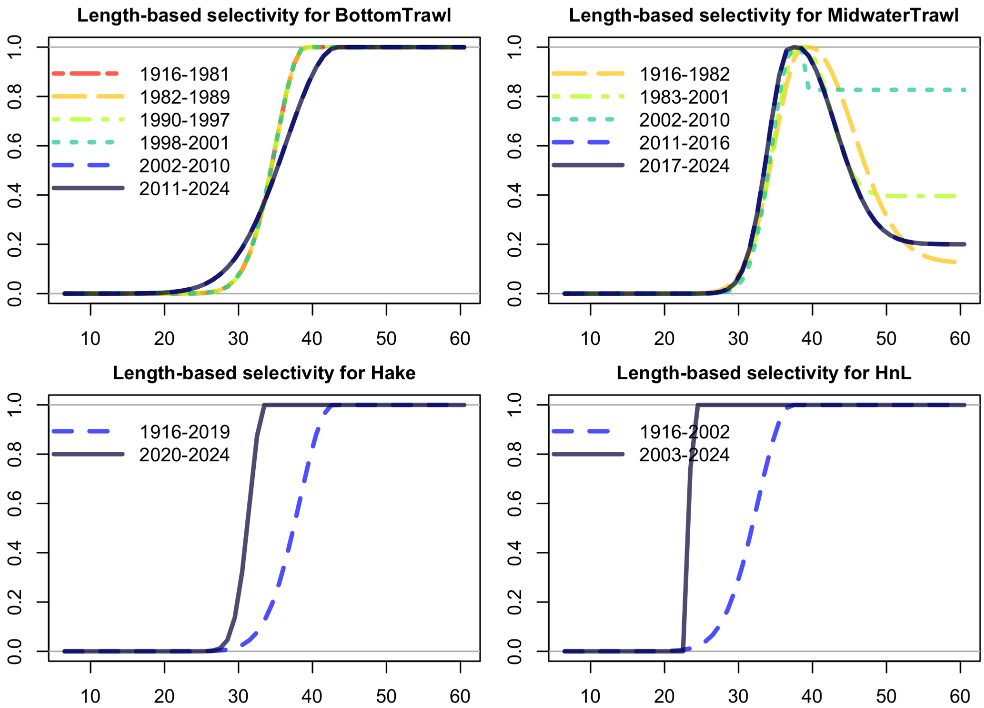


Figure 27: Estimated selectivity curves by time block for bottom trawl, midwater trawl, hake, and hook-and-line fleets.

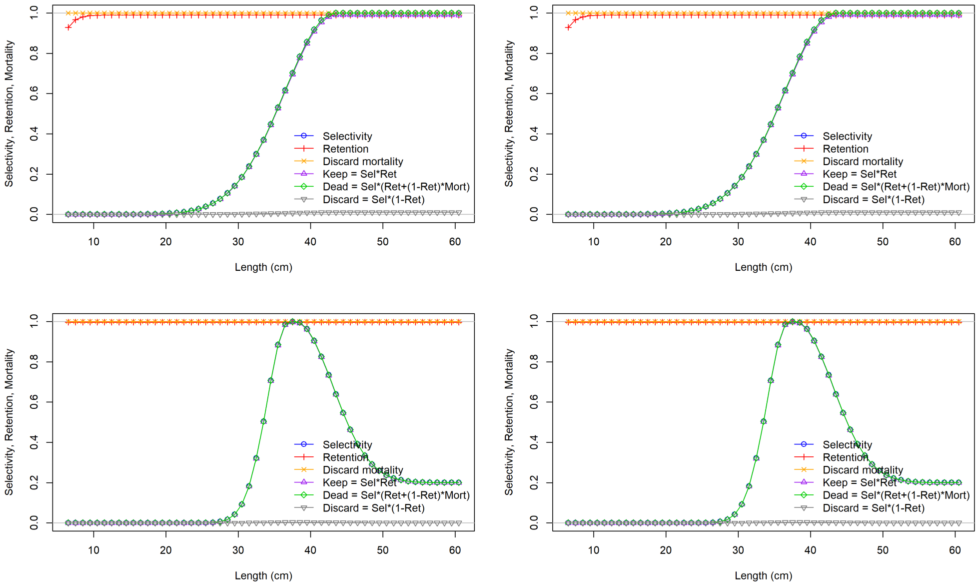


Figure 28: Estimated selectivity for Bottom Trawl (top row) and Midwater Trawl (bottom row) for males (left column) and females (right column)

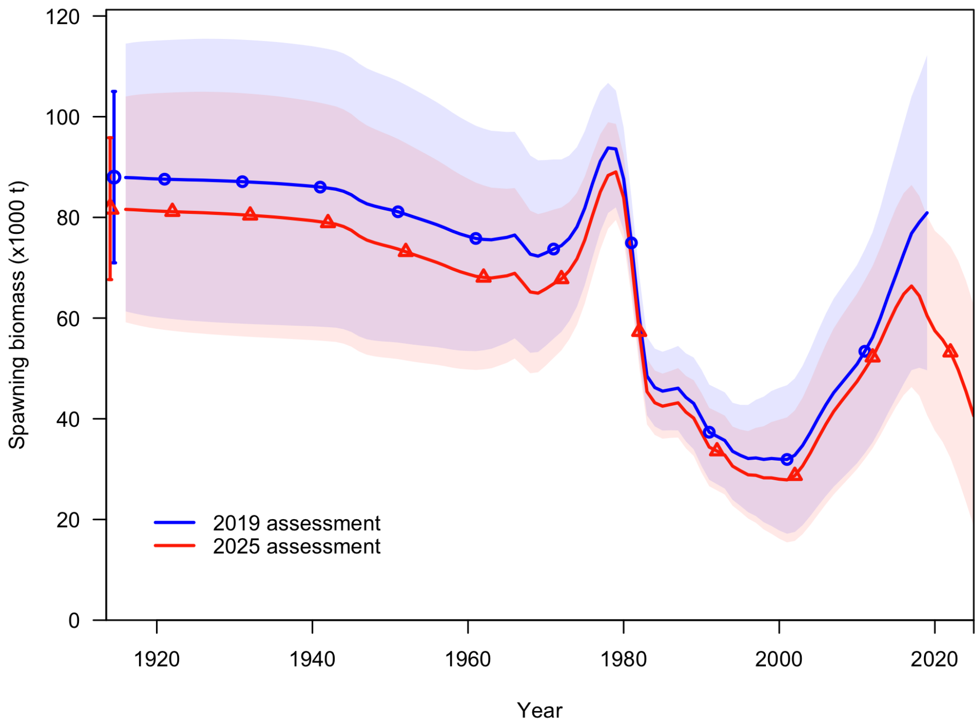


Figure 29: Time series of spawning stock biomass (SSB) estimates and asymptotic 95% confidence intervals estimates from 2019 and 2025 base models.

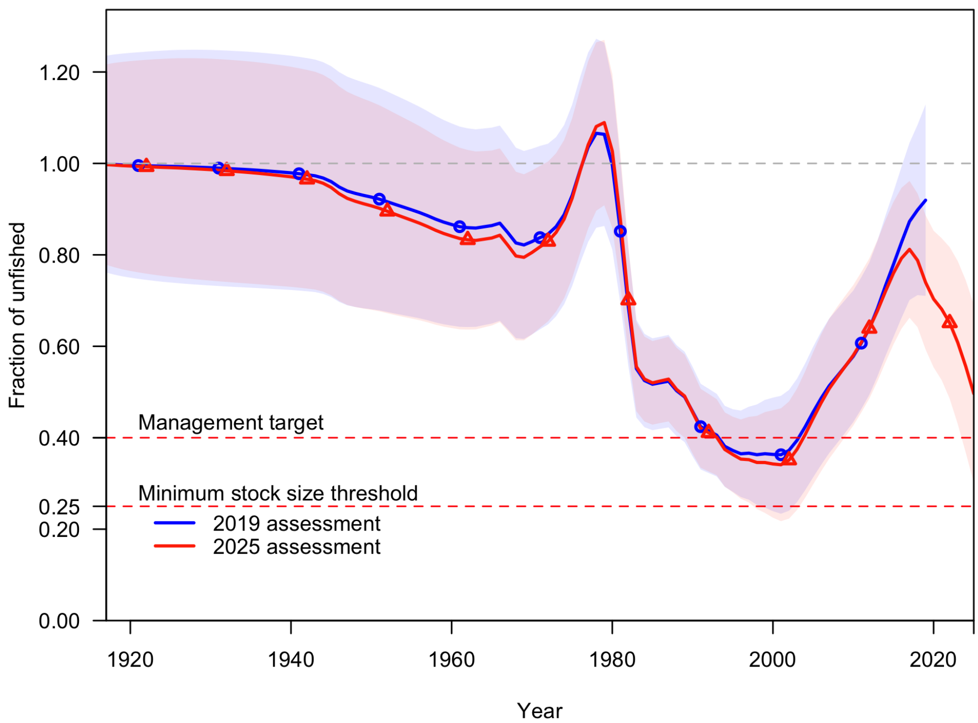


Figure 30: Time series of fraction of unfished spawning stock biomass estimates and asymptotic 95% confidence intervals estimates from 2019 and 2025 base models.

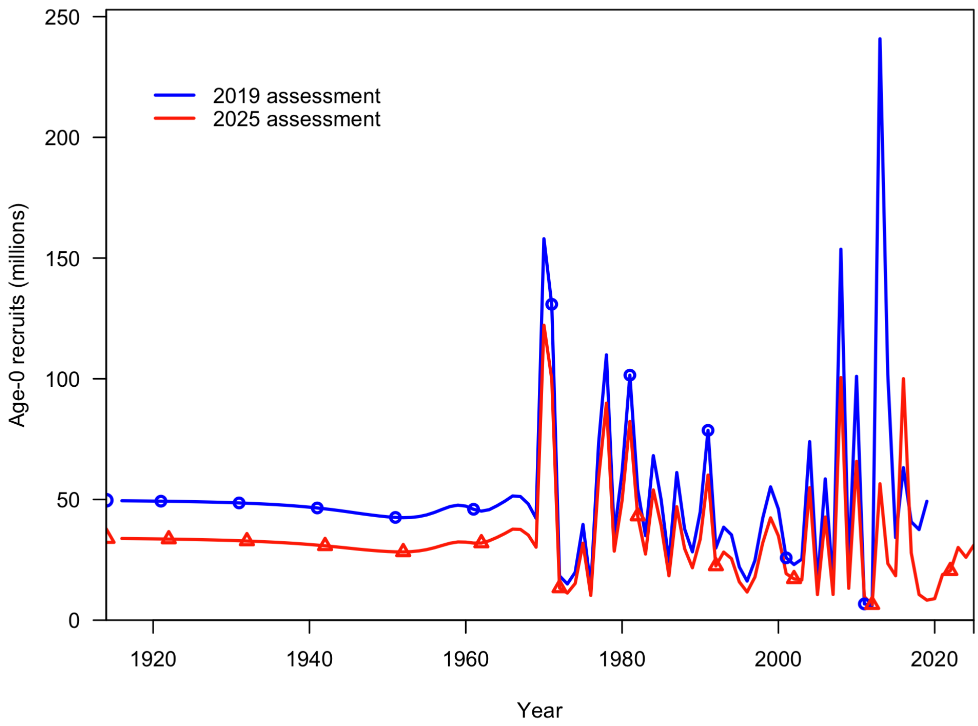


Figure 31: Estimates of age-0 recruits (in millions of individuals) from 2019 and 2025 base models.

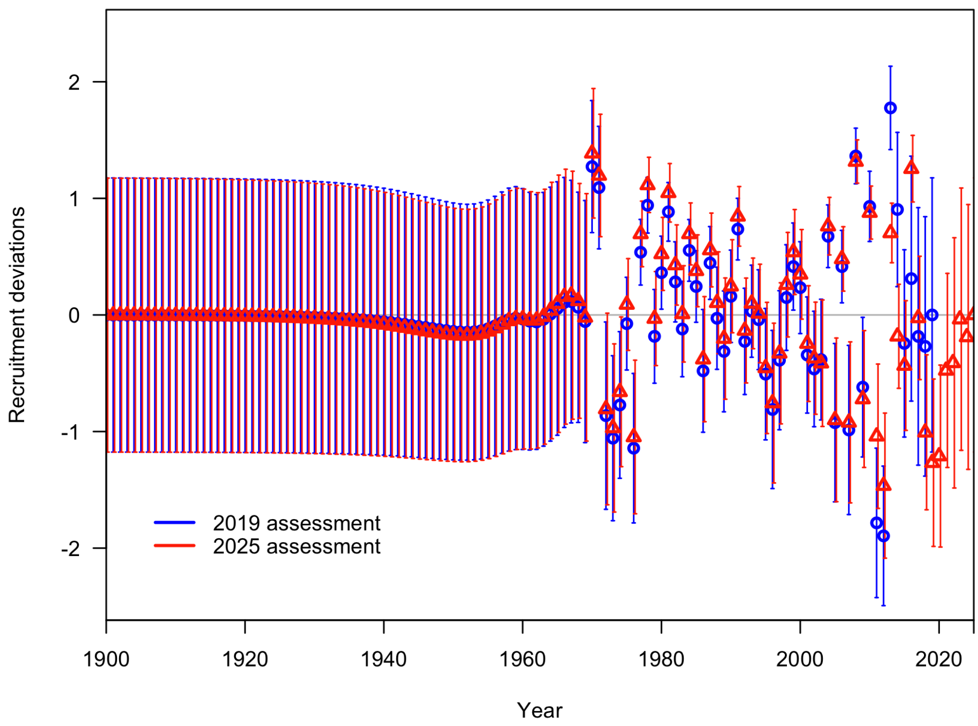


Figure 32: Estimates of age-0 (log-)recruitment deviations from 2019 and 2025 base models, with asymptotic 95% confidence intervals.

6.2.3 Biology

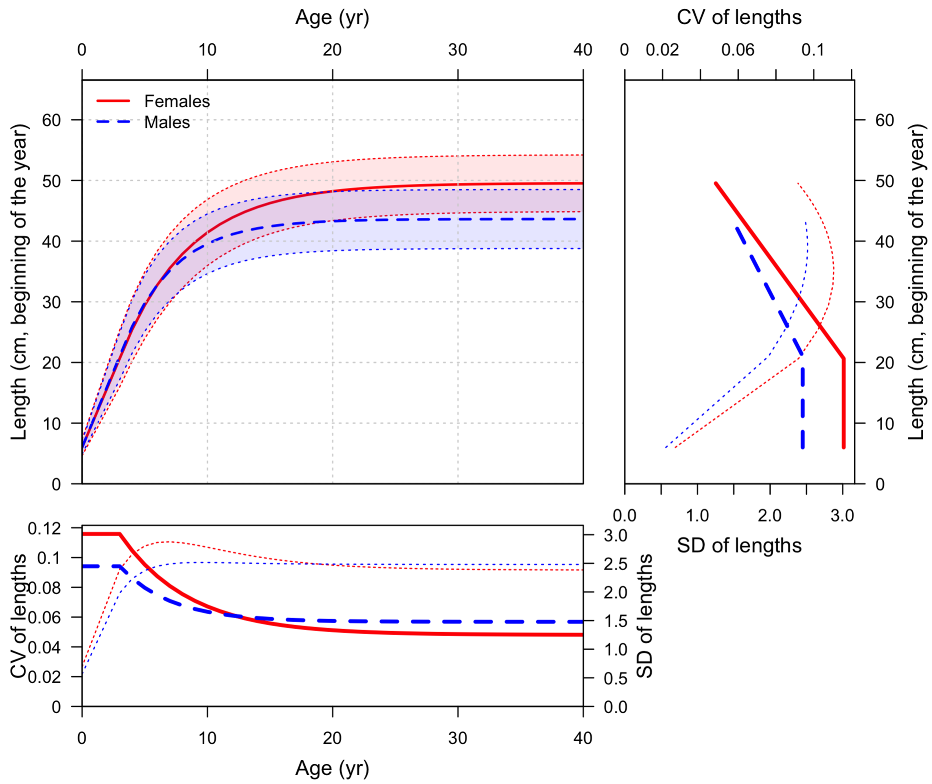


Figure 33: Length at age (top-left panel) with estimated coefficient of variation (CV, thick line) and calculated standard deviation (SD, thin line) versus length at age in the top-right panel and versus age in the lower-left panel.

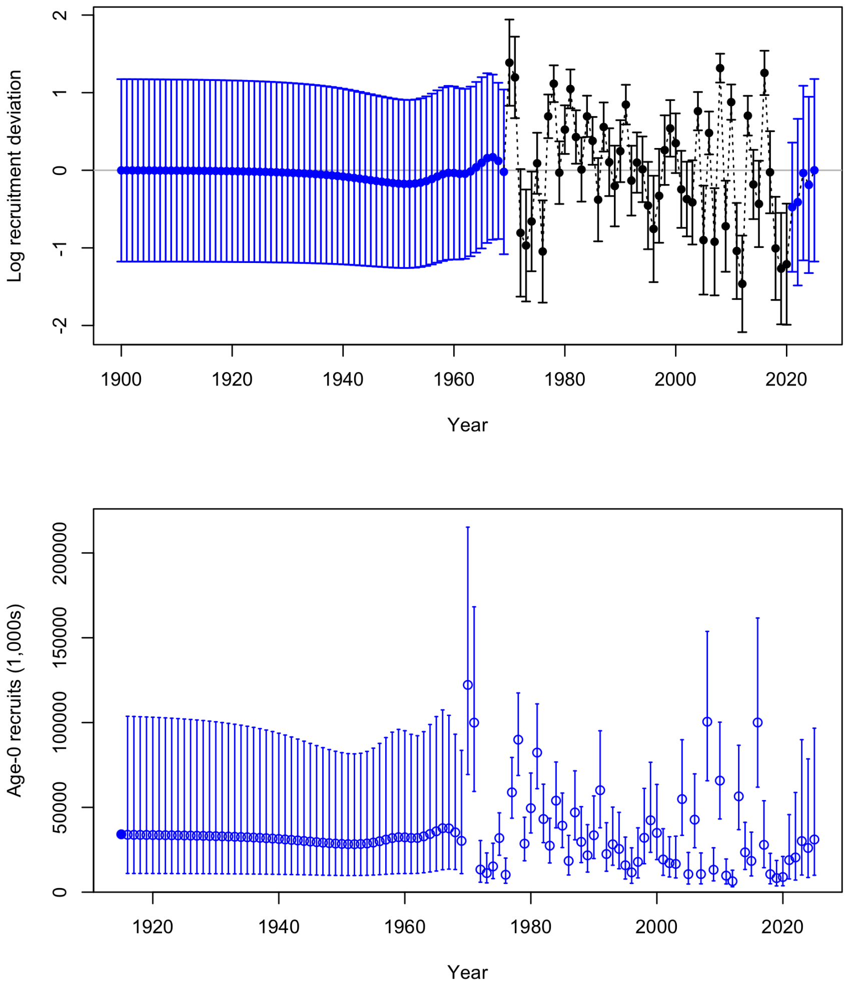


Figure 34: Estimates of recruitment (upper) and recruitment deviates (lower) with approximate asymptotic 95% confidence intervals (vertical lines) from the MLE estimates.

6.2.4 Fits to data

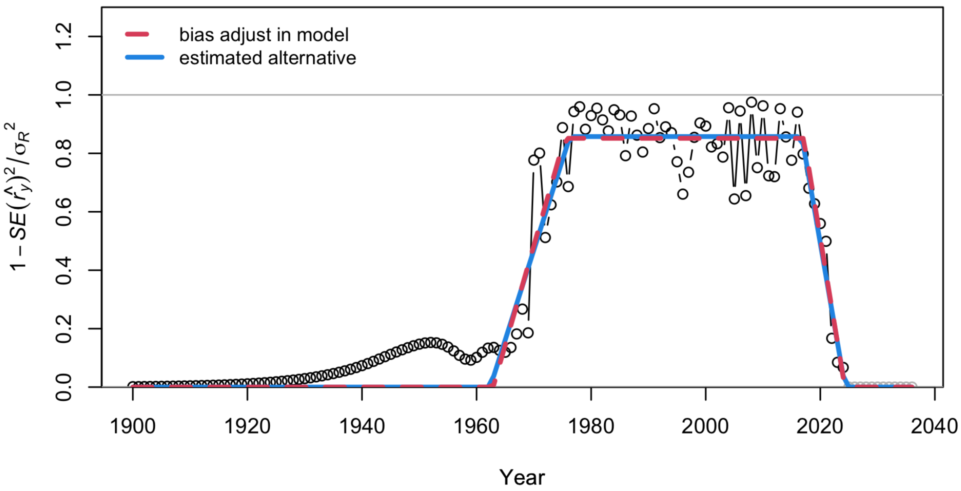


Figure 35: Estimated and input recruitment bias adjustment ramp. Red line shows current settings for bias adjustment ramp. Red line shows current settings for bias adjustment specified in the model. Blue line shows least squares estimate of alternative bias adjustment relationship for recruitment deviations.

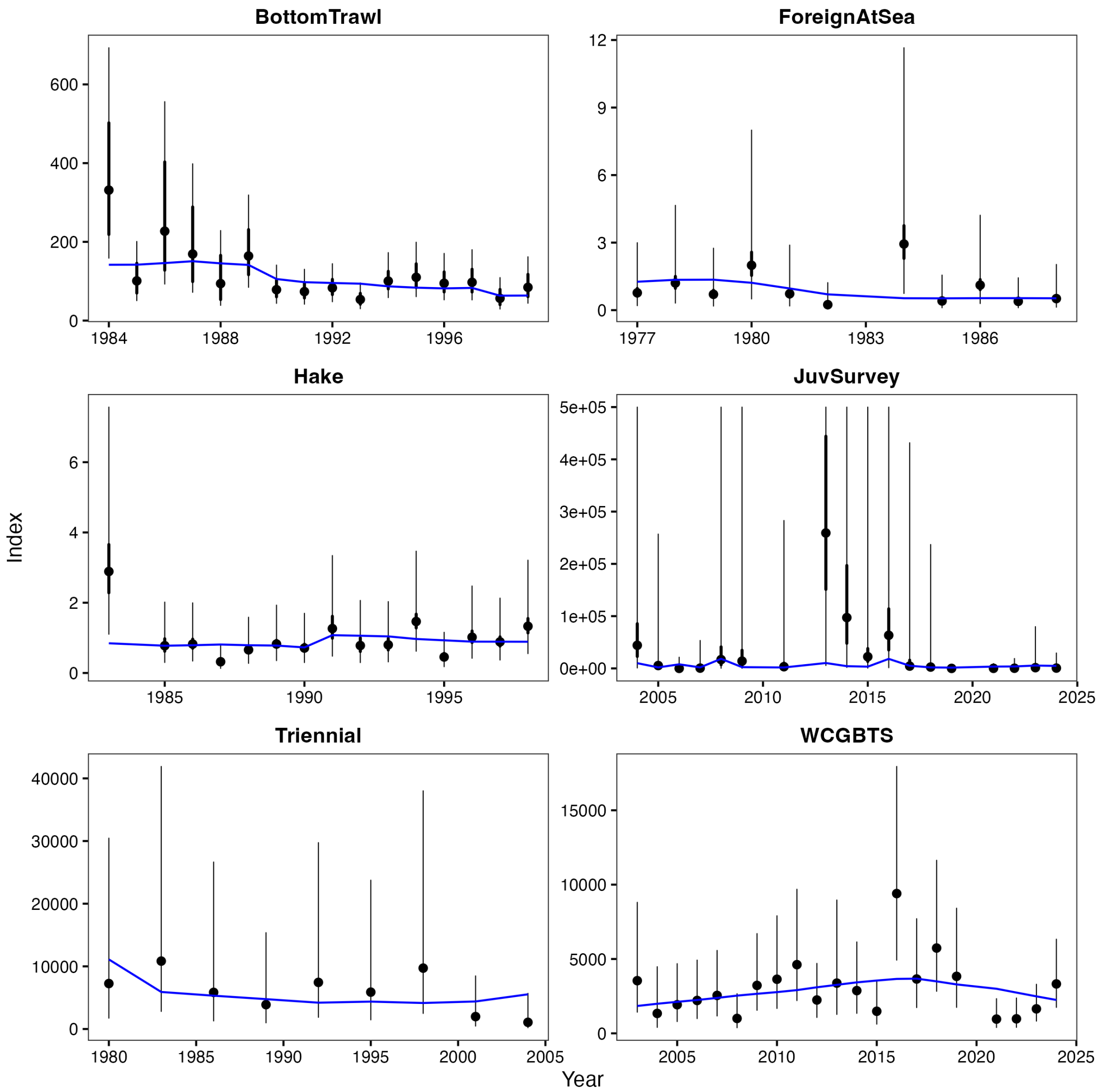


Figure 36: Fits (blue lines) to the abundance estimates (black points) for the base model. A separate q is estimated for the Hake series starting in 1991. Except the juvenile survey (counts) all indices are biomass-based. 95% confidence intervals are shown assuming a normal distribution of the log-estimates. Thicker lines (if present) indicate input uncertainty before addition of the estimated additional uncertainty parameter. The y-axis of the juvenile survey is truncated to highlight interannual variability in counts.

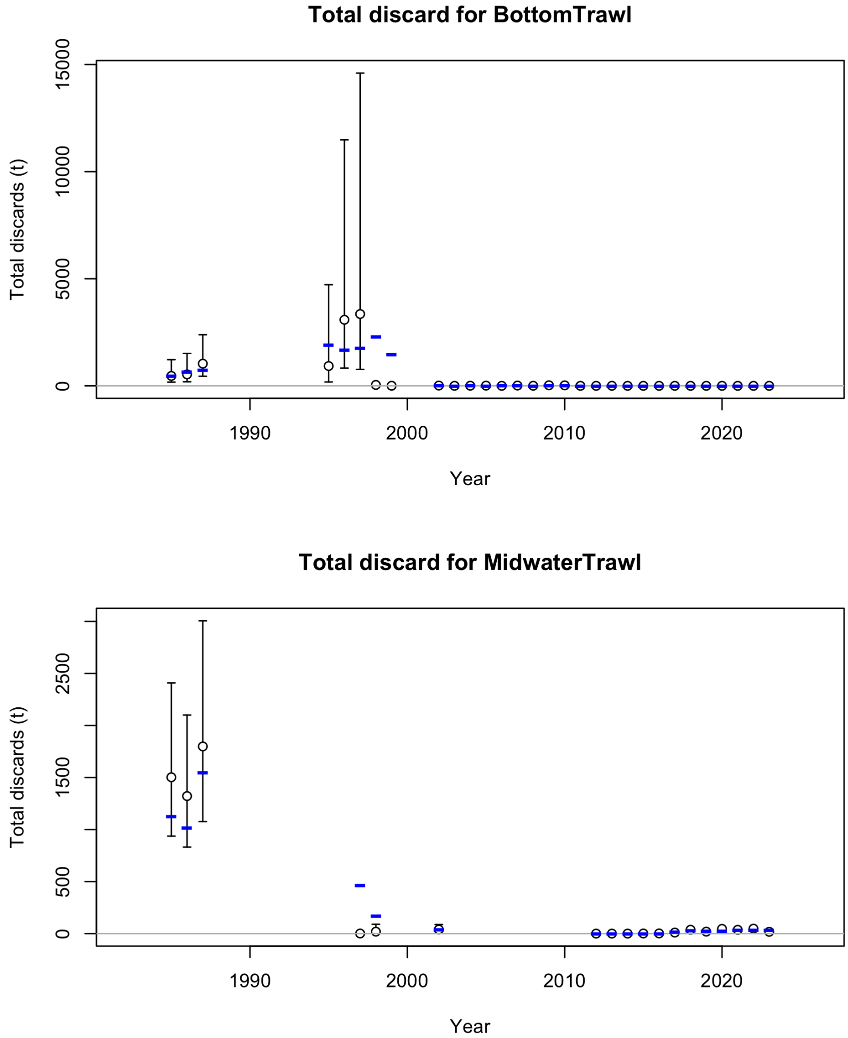


Figure 37: Predicted (blue line) and observed (open circles) discards for the bottom trawl (top) and midwater trawl (bottom) fleets from the base model. 95% confidence intervals are shown for the observations.

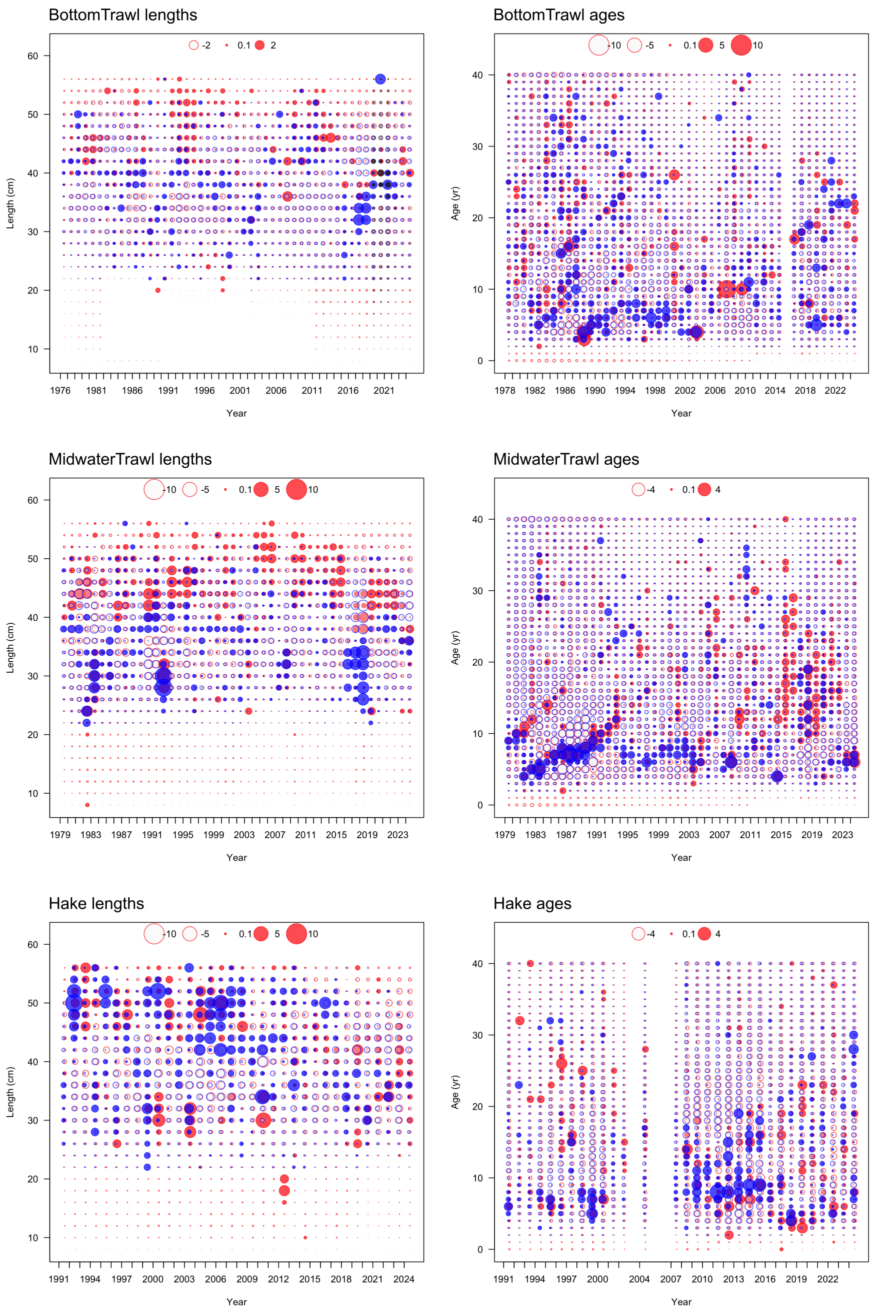


Figure 38: Pearson residuals for fits to length frequency data (left) and age frequency data (right) for landings from the trawl commercial fleets (rows). Filled circles indicate that the fitted proportion was less than the observed proportion. Red indicates females, blue males, and gray unsexed.

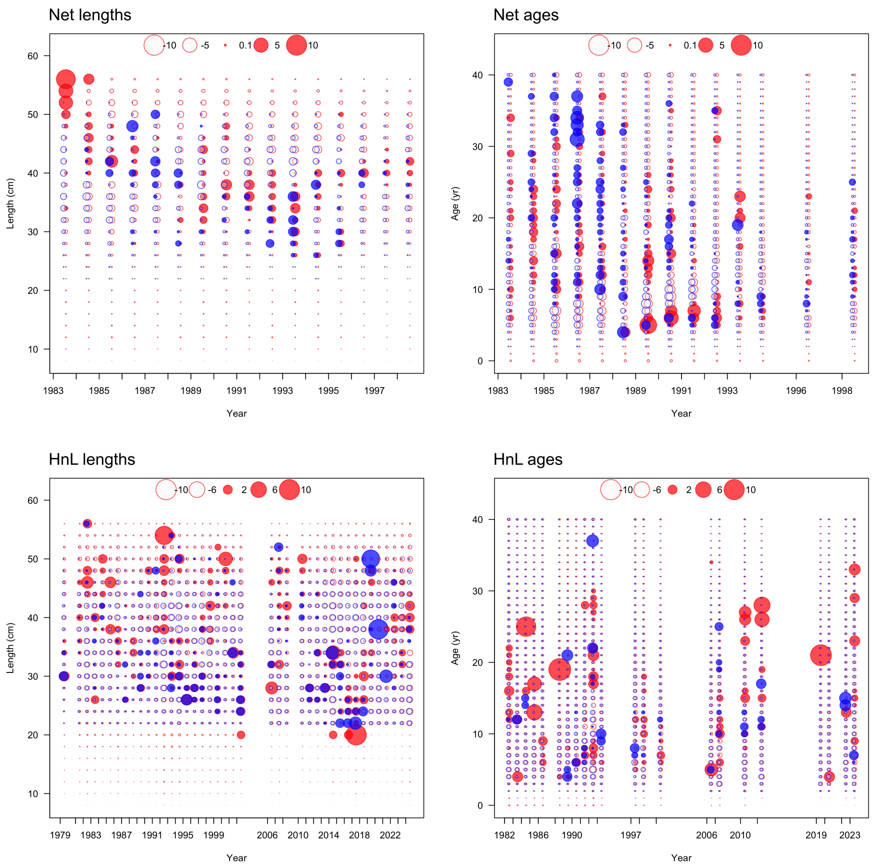


Figure 39: Pearson residuals for fits to length frequency data (left) and age frequency data (right) for landings from the net and hook-and-line commercial fleets (rows). Filled circles indicate that the fitted proportion was less than the observed proportion. Red indicates females, blue males, and gray unsexed.

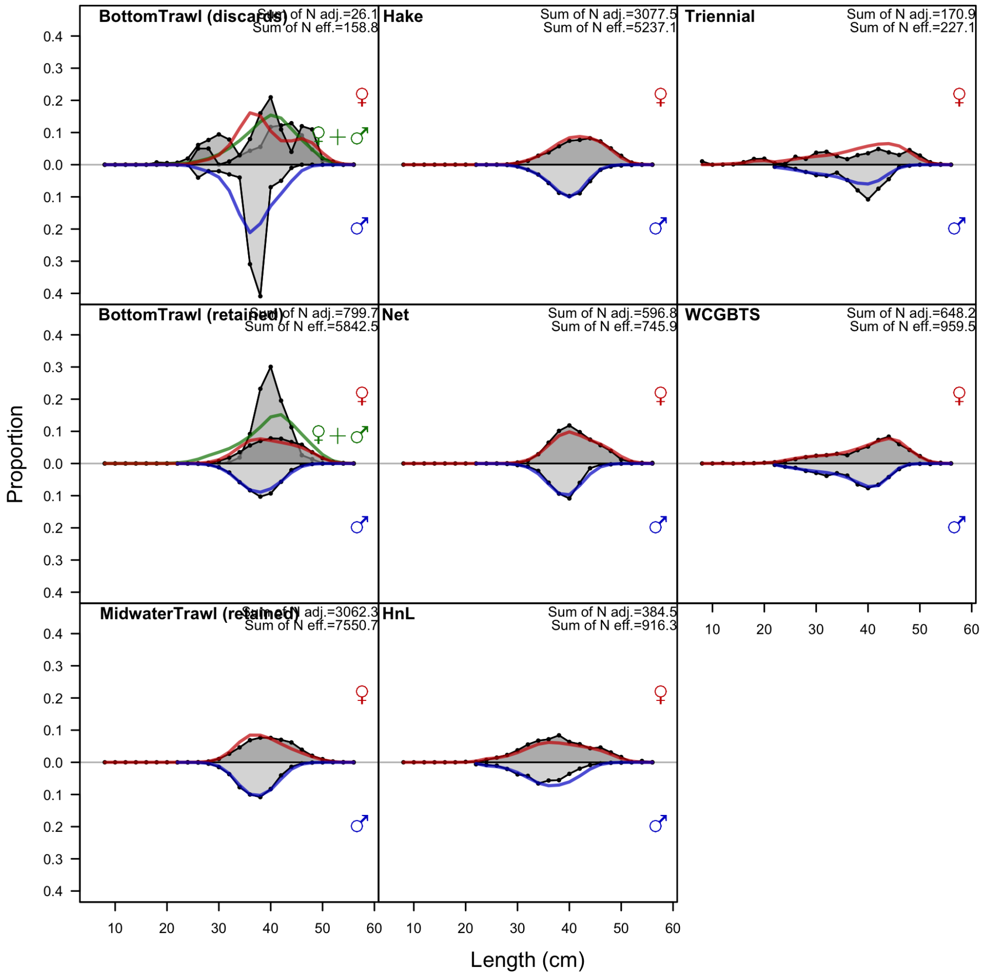


Figure 40: Combined length frequencies for all years from fishery (retained catch) and survey length frequency data (points). Fits are shown by the red line (females) and blue line (males).

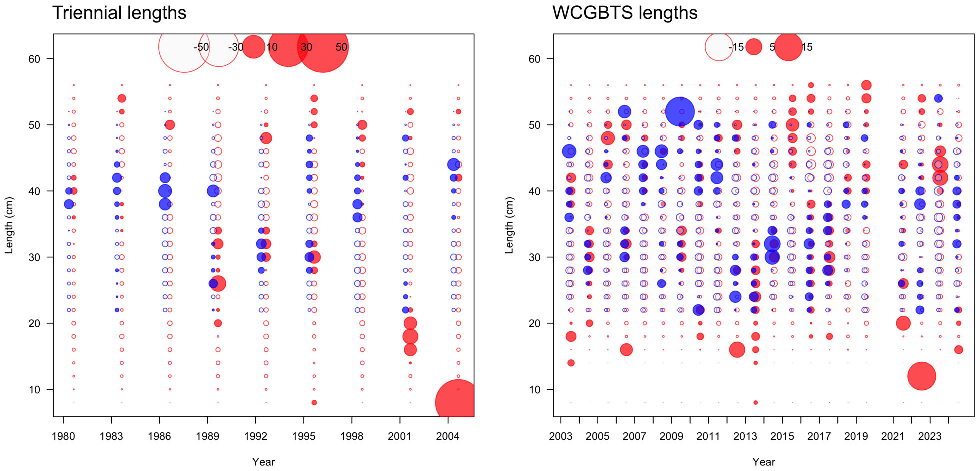


Figure 41: Pearson residuals for fits to the triennial survey length frequency data (left) and WCGBTS length frequency data (right). Filled circles indicate that the fitted proportion was less than the observed proportion. Red indicates females, blue males, and gray unsexed.

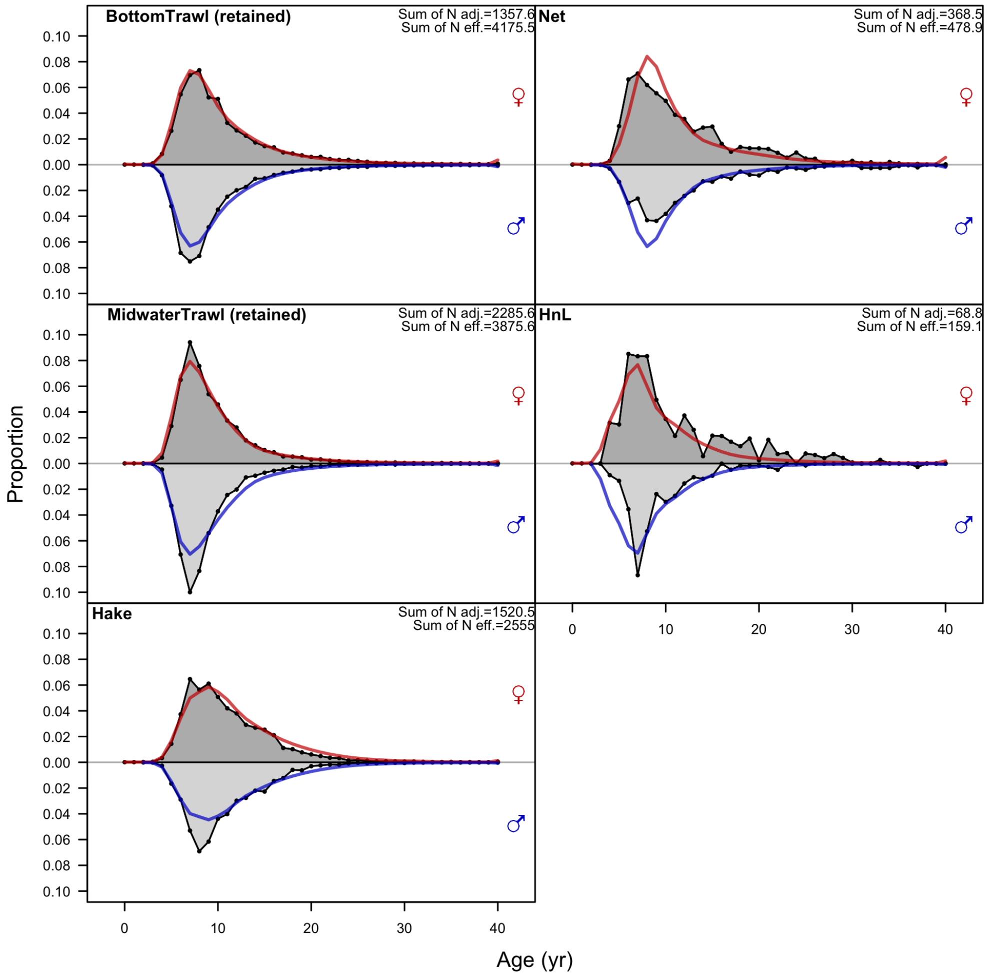


Figure 42: Combined age frequencies for all years from fishery (retained catch) and survey length frequency data (points). Fits are shown by the red line (females) and blue line (males).

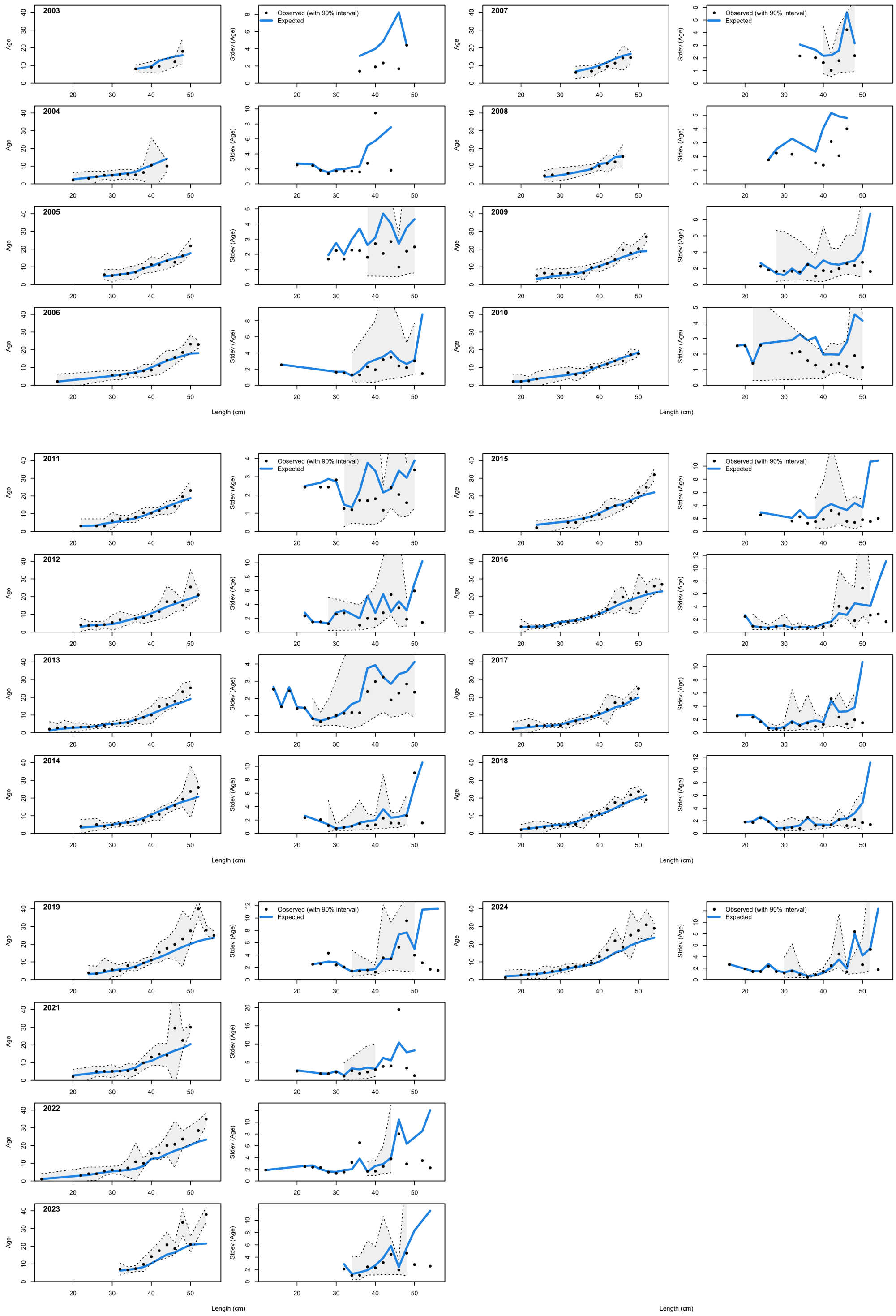


Figure 43: Observed and expected age-at-length with 95% confidence intervals (left) and observed and expected standard deviation of age-at-length with 95% confidence intervals (right) for the WCGBTS.

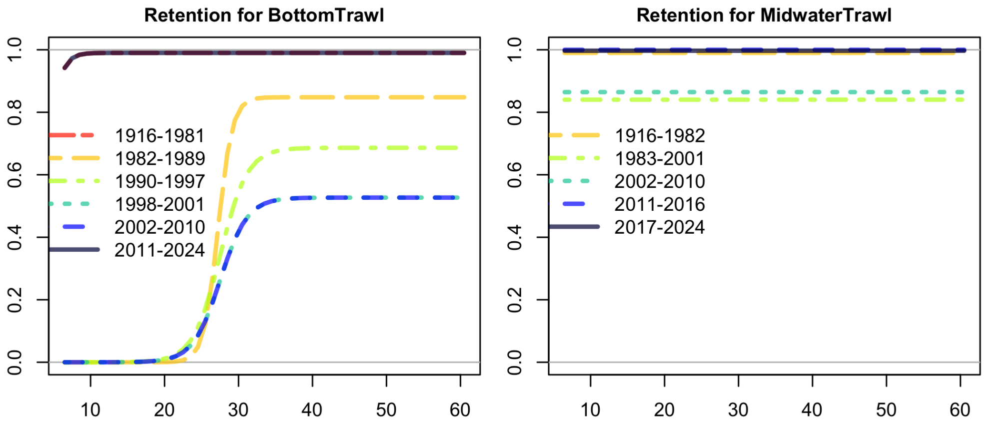


Figure 44: Estimated retention curves by time block for bottom and midwater trawl fleets.

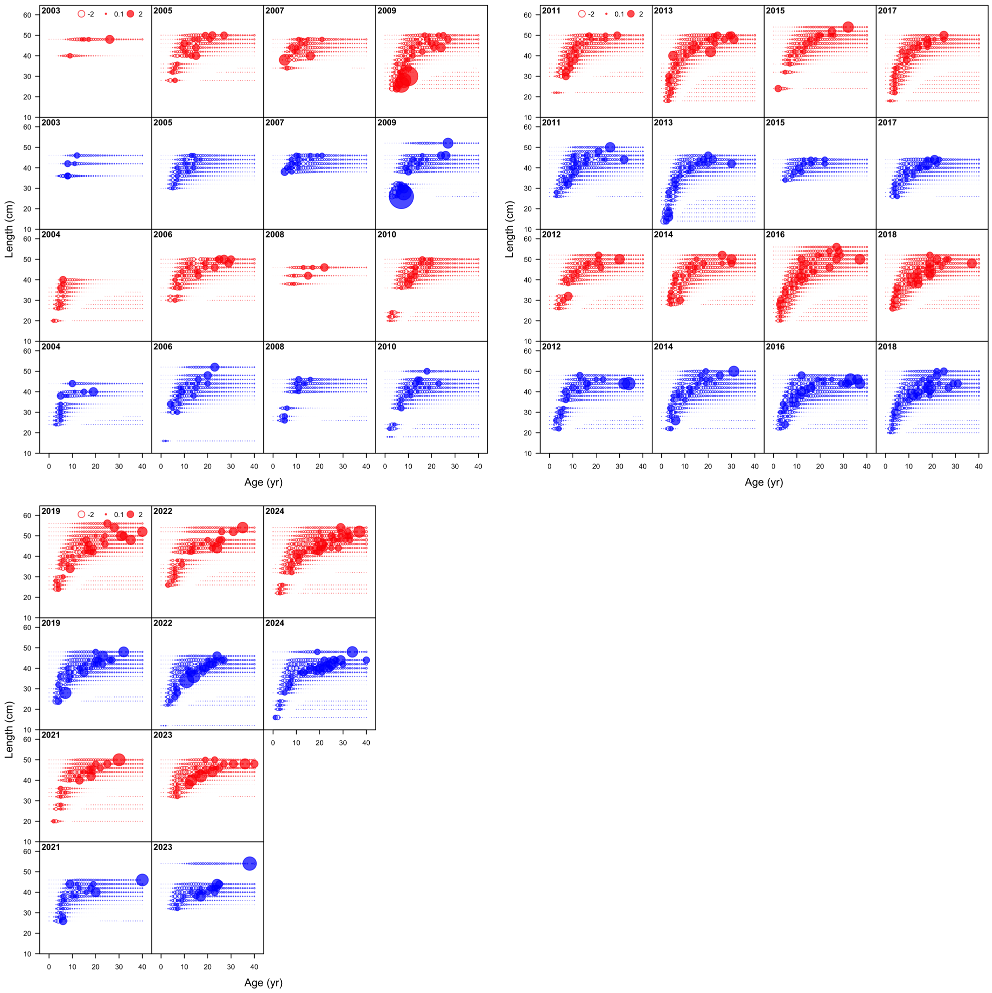


Figure 45: Combined age and length frequency data for all years from fishery (retained catch) and survey length frequency data (points) for females (red) and males (blue).

6.2.5 Timeseries

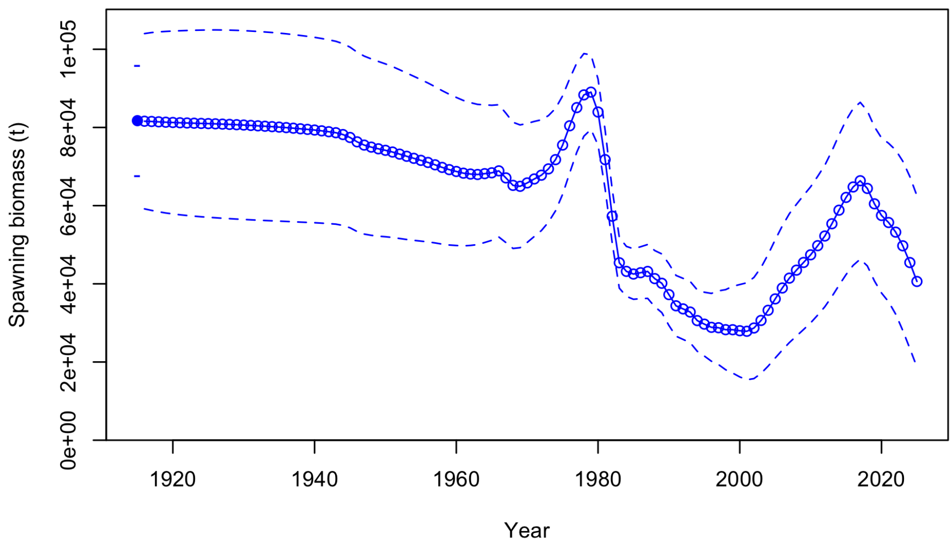


Figure 46: Predicted spawning biomass (thousand mt) for widow rockfish using the base assessment. The solid line is the MLE estimate, and the dashed lines depict the approximate asymptotic 95% confidence intervals.

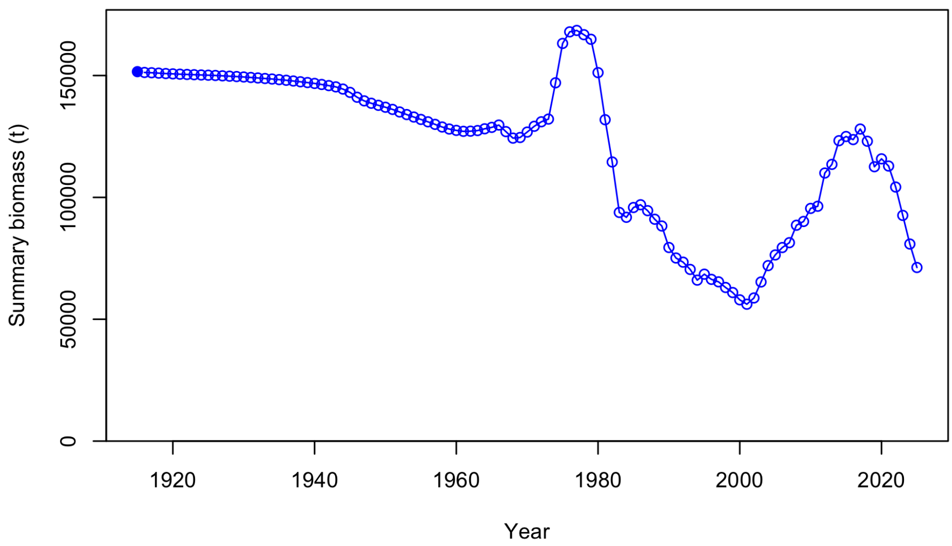


Figure 47: Predicted summary biomass (age 4+) from the base model.

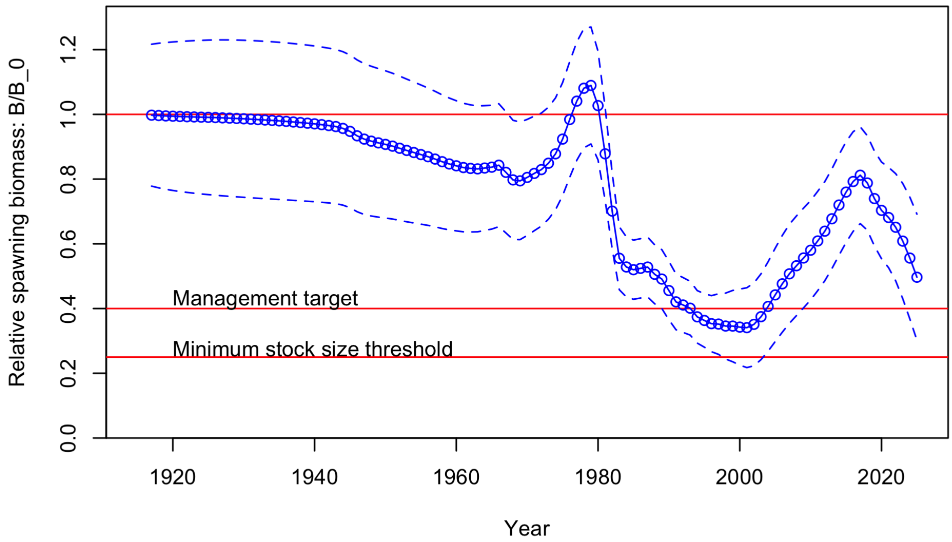


Figure 48: Predicted relative spawning biomass from the widow rockfish base case assessment. The solid blue line is the MLE estimate, and the dashed lines depict the approximate asymptotic 95% confidence intervals. The red lines show the equilibrium level (100%), the management target of 40% of unfished biomass, and the minimum stock size threshold of 25% of unfished biomass.

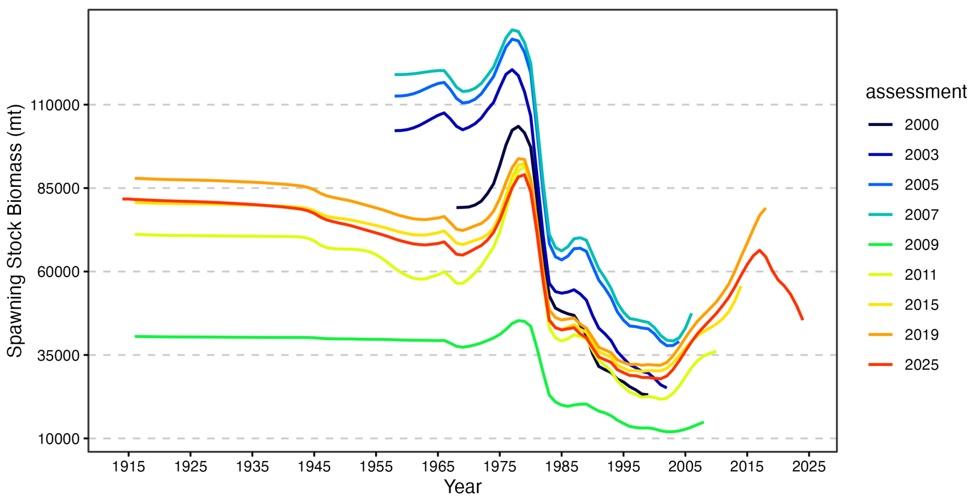


Figure 49: Predicted spawning biomass (2011 onward) or spawning output (2000-2009) from past assessments in comparison with the current assessment.

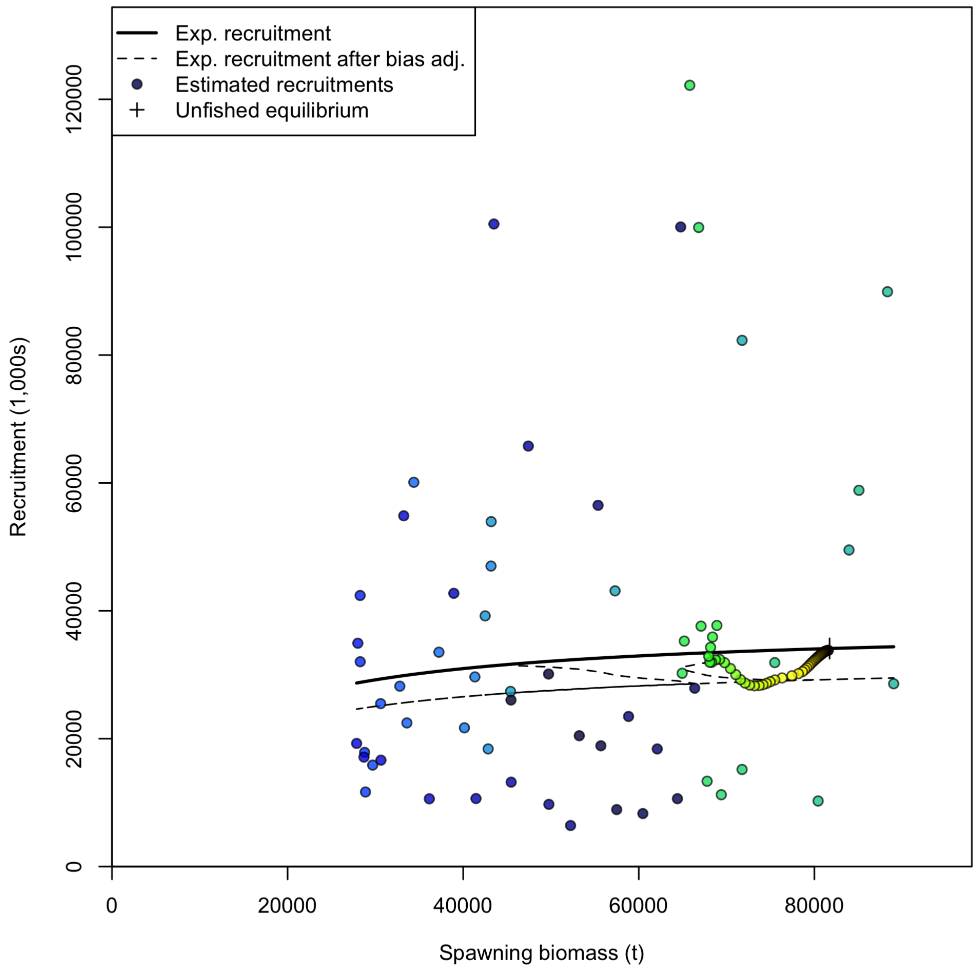


Figure 50: Estimated recruitment and the assumed stock-recruit relationship (black line). The dashed line shows the effect of the bias correction for the lognormal distribution.

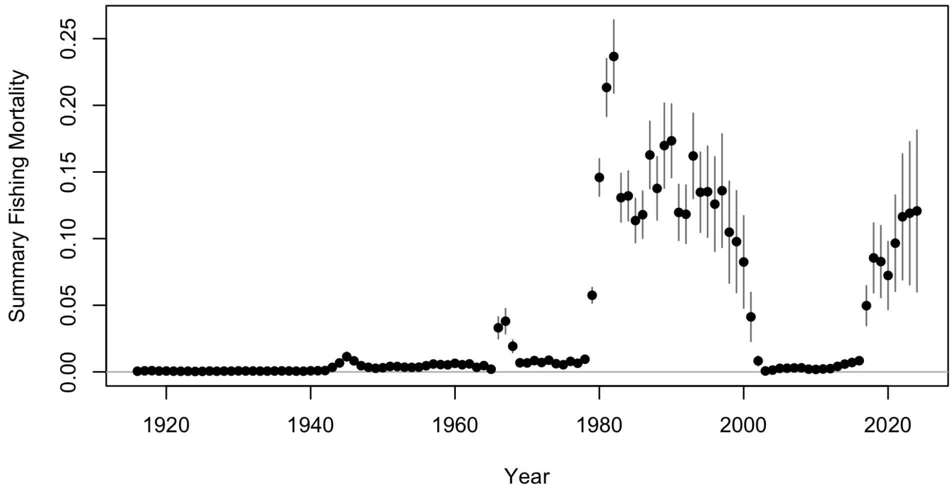


Figure 51: Plot of the summary fishing mortality for each year of the model with 95% confidence intervals.

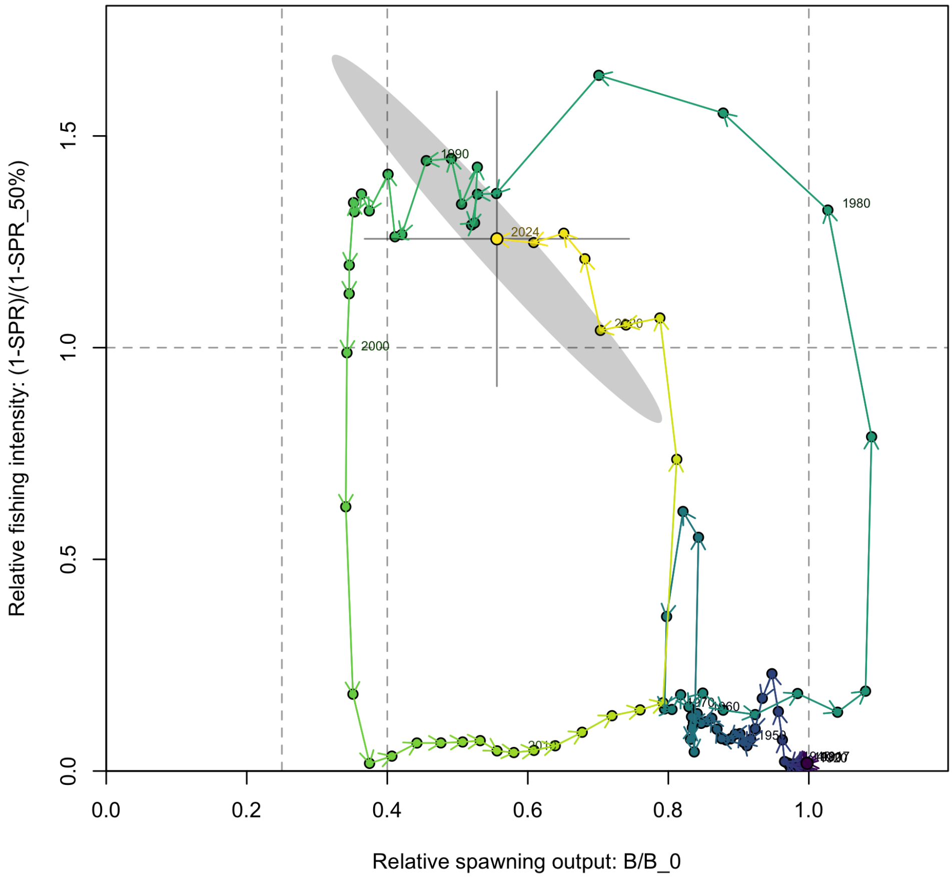


Figure 52: Phase plot of relative (1-SPR)/(1-SPR_50%) (y-axis) and depletion (x-axis) for widow rockfish.

6.3 Model Diganostics

6.3.1 Sensitivity analyses

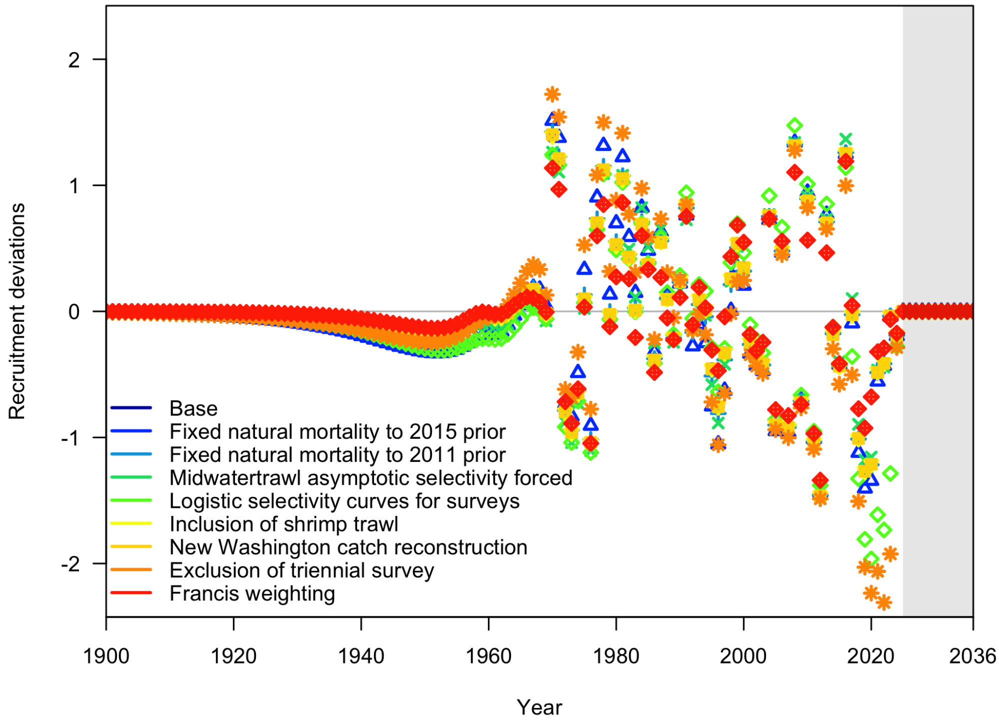


Figure 53: Estimates of recruitment deviations for sensitivity models.

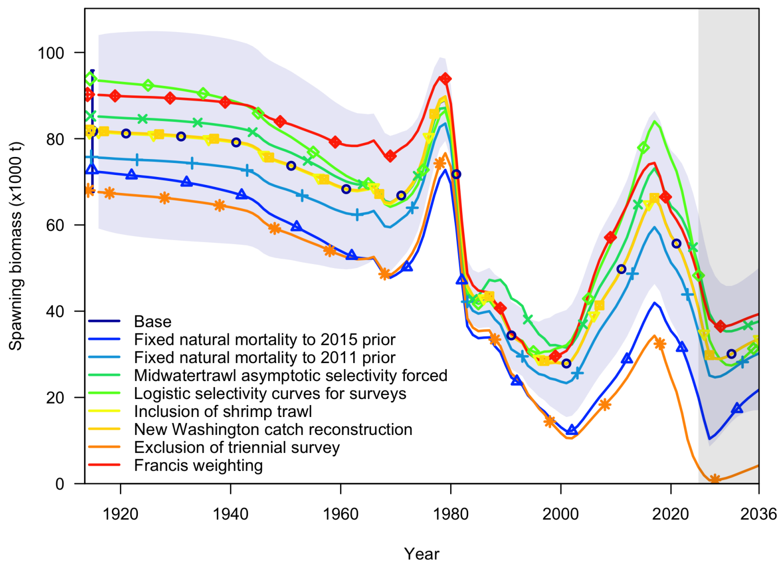


Figure 54: Spawning biomass (with 95% confidence interval around the base model) for the base model and sensitivity runs.

Figure 55: Comparision of model estimated quantities for 2025, given as percent of the base model estimated value, by sensitivity run.

6.3.2 Retrospective analysis

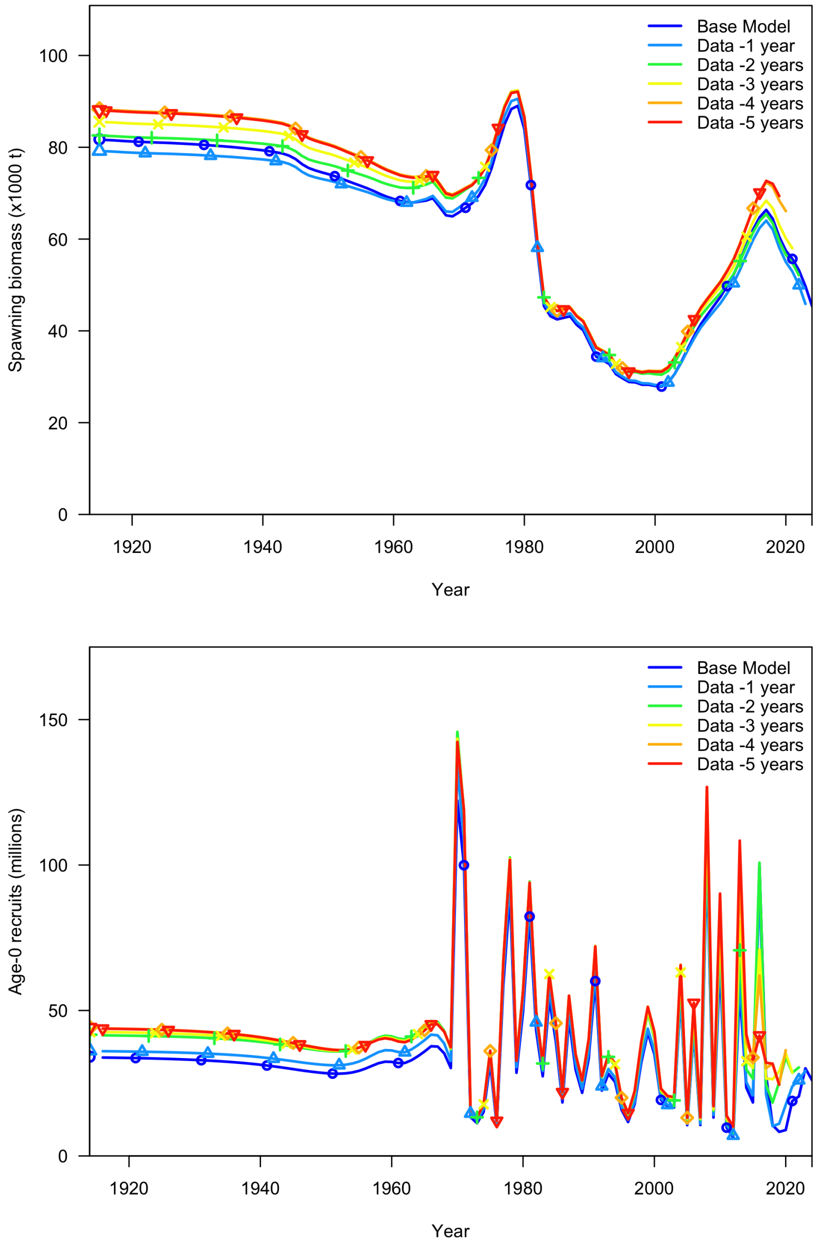


Figure 56: Five-year retrospective estimates of spawning biomass (top) and recruitment deviations (bottom).

6.3.3 Likelihood profiles

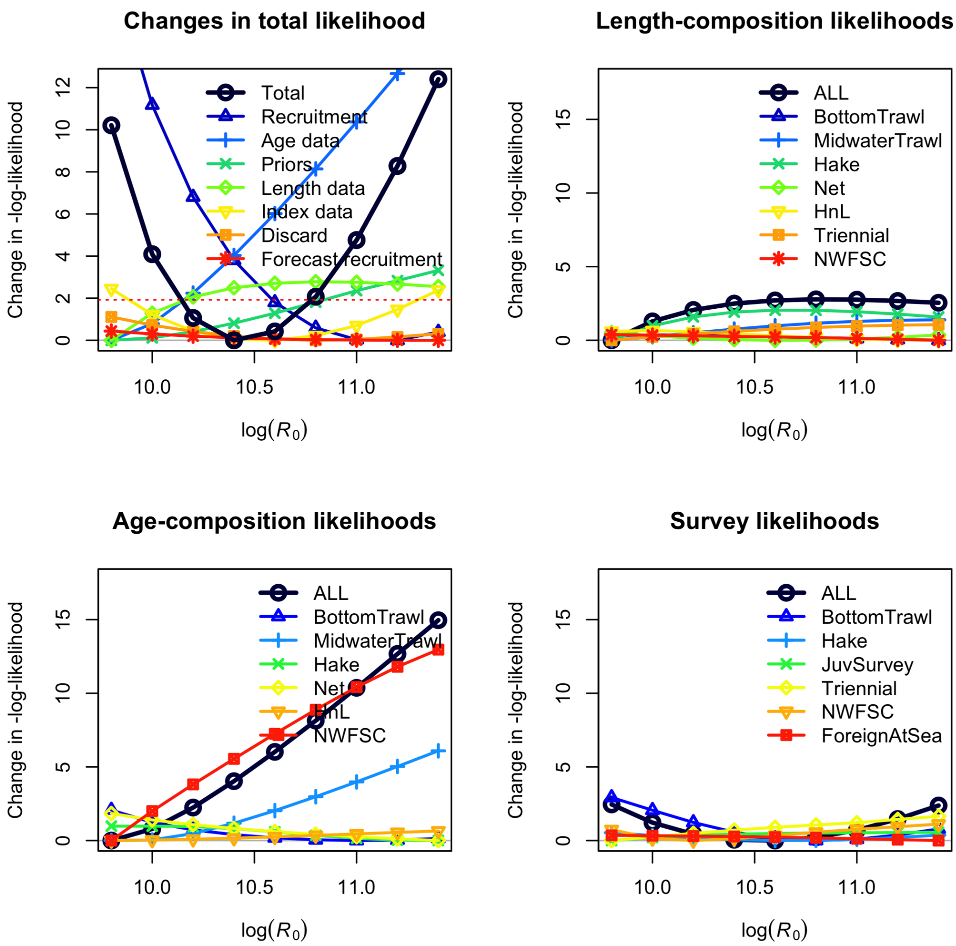


Figure 57: Likelihood components in the likelihood profile for unfished equilibrium recruitment (R0)

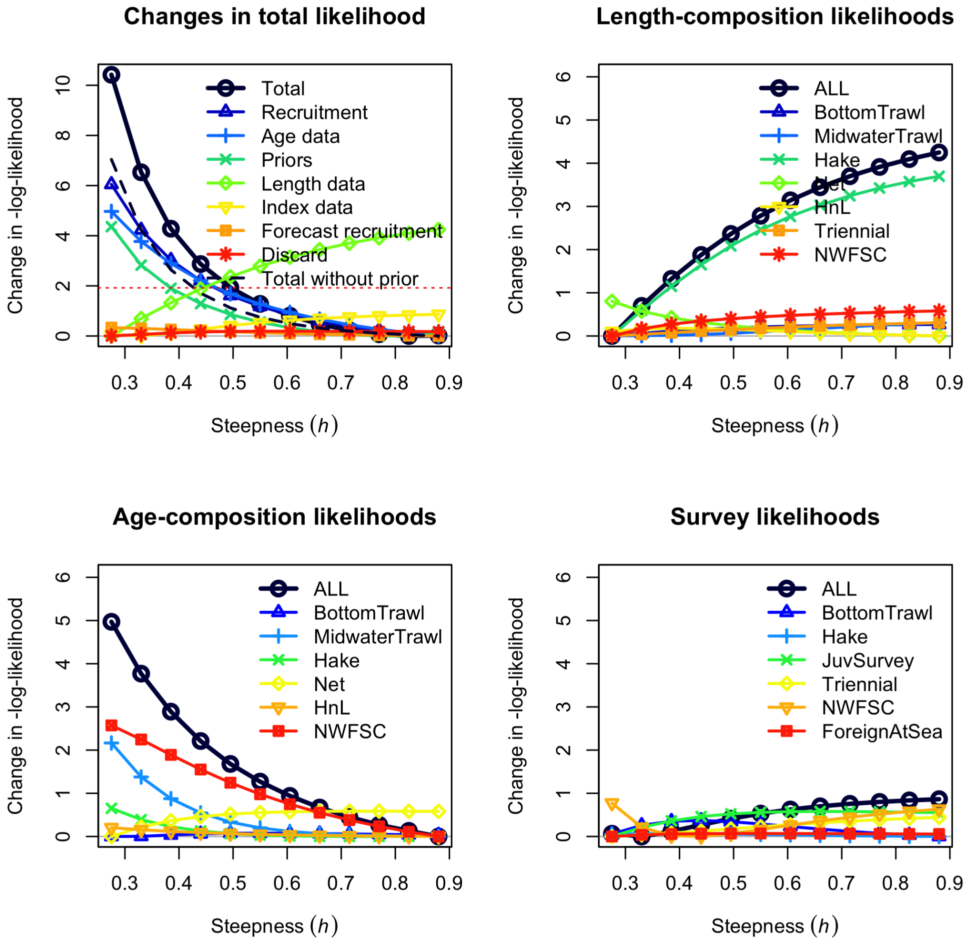


Figure 58: Likelihood components in the likelihood profile for steepness (h).

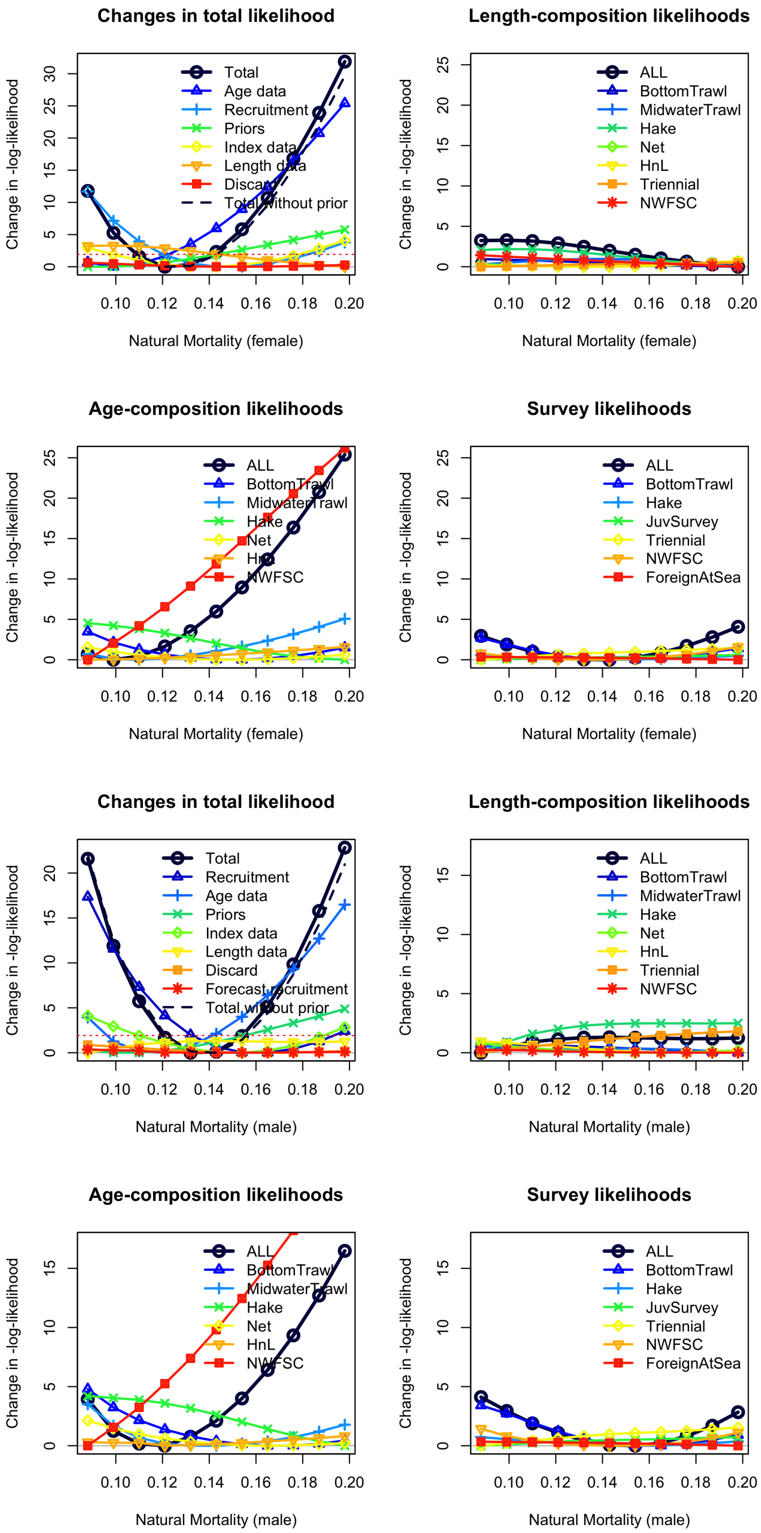


Figure 59: Likelihood components in the likelihood profile for natural mortality (M). Note: male and female natural mortality are set to the same value.

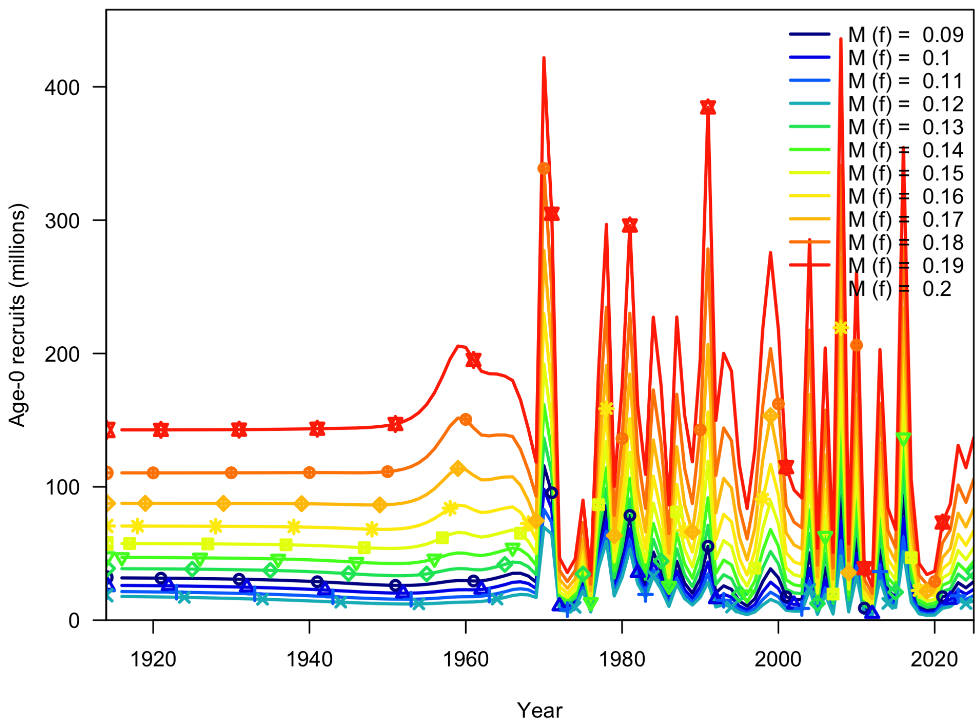


Figure 60: Time series of recruitment estimates for models with different fixed values of natural mortality (M)

6.4 Management

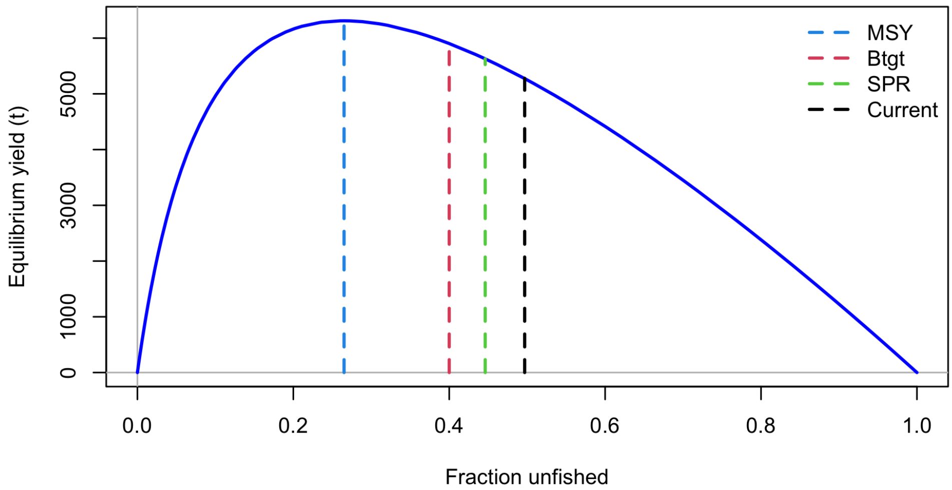
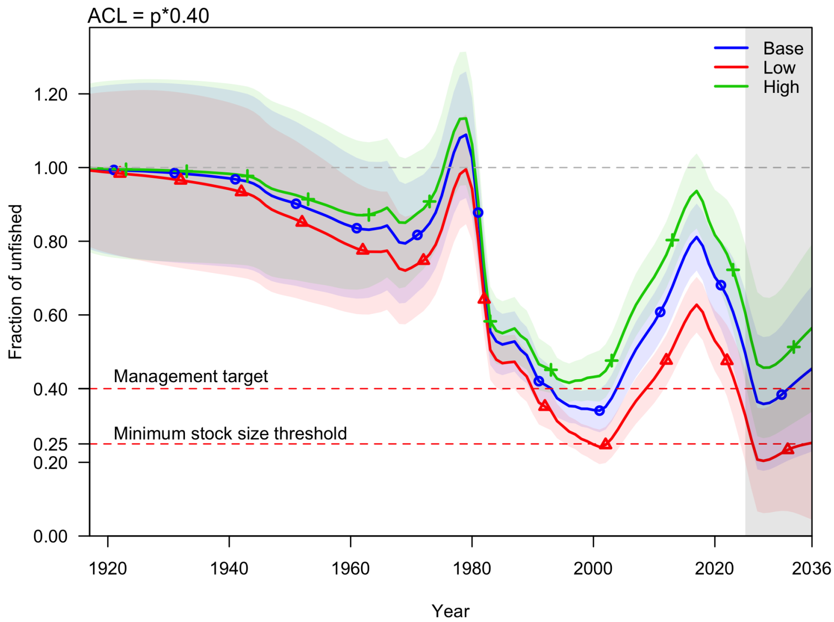


Figure 61: Estimated plot of equilibrium yield vs the fraction of unfished biomass.



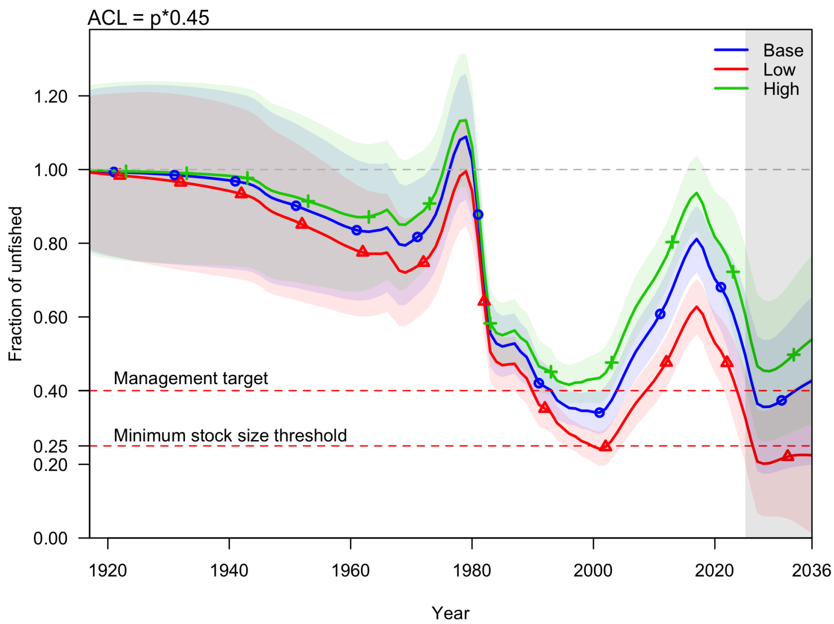


Figure 62: Base model, low state of nature, and high state of nature spawning biomass trajectories under three catch scenarios: constant catch of 9000 mt, ACL = p*0.25, ACL = p*0.45 for 2027 to 2036. The shaded areas indicate the 12.5% and 87.5% lognormal quantiles of spawning biomass.

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8 Appendix A: Annual fits to length and age composition

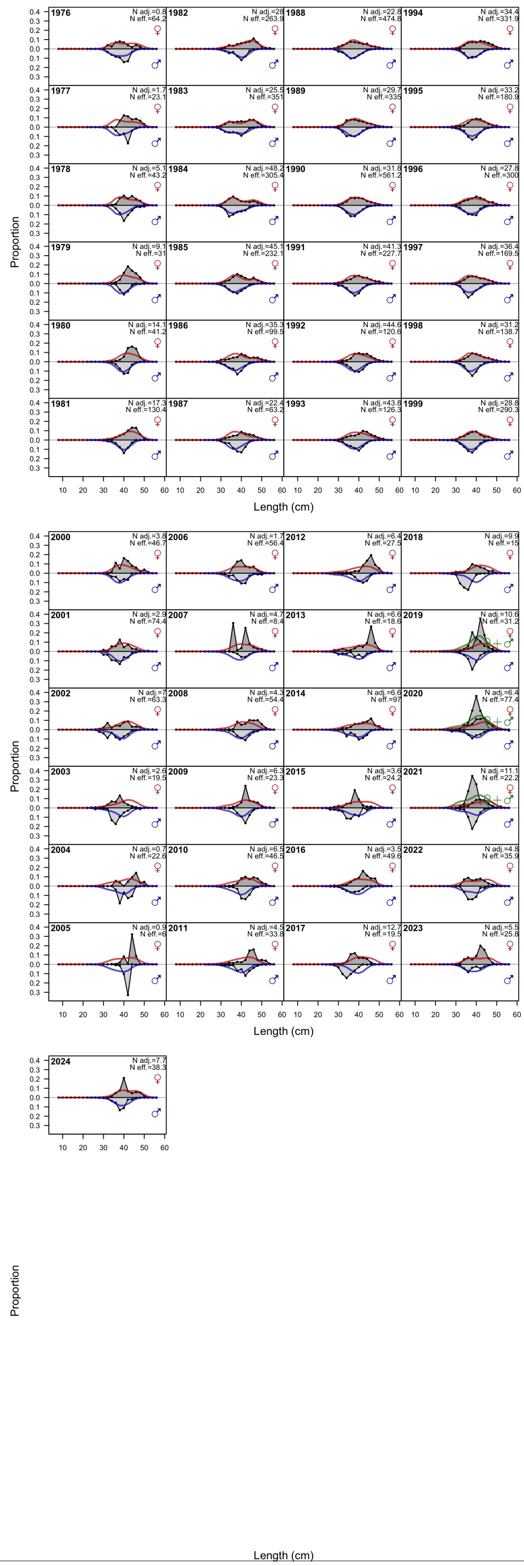


Figure A1: Fits to the retained length compositions for the bottom trawl fleet.

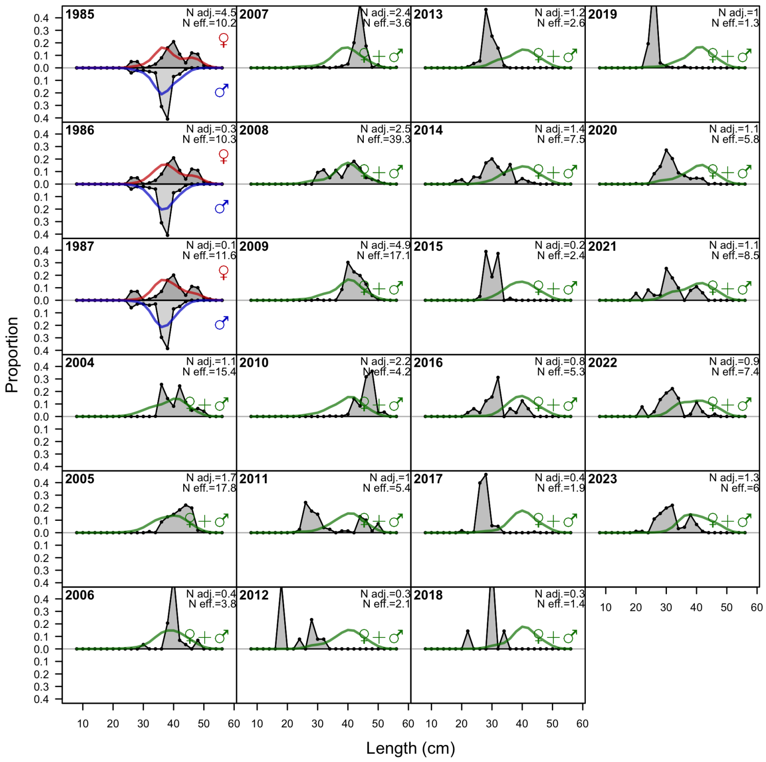


Figure A2: Fits to the discarded length compositions for the bottom trawl fleet.

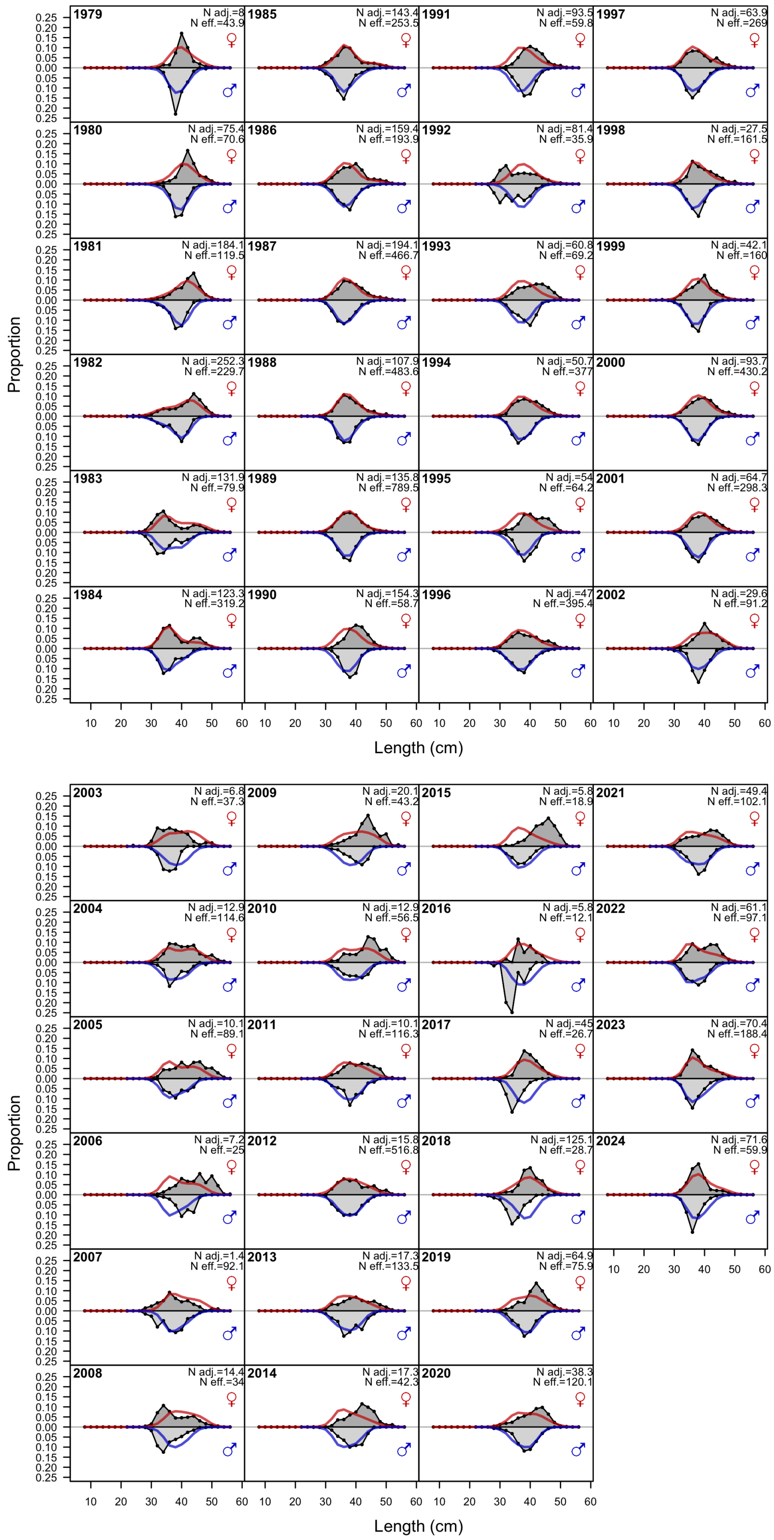


Figure A3: Fits to the retained length compositions for the midwater trawl fleet.

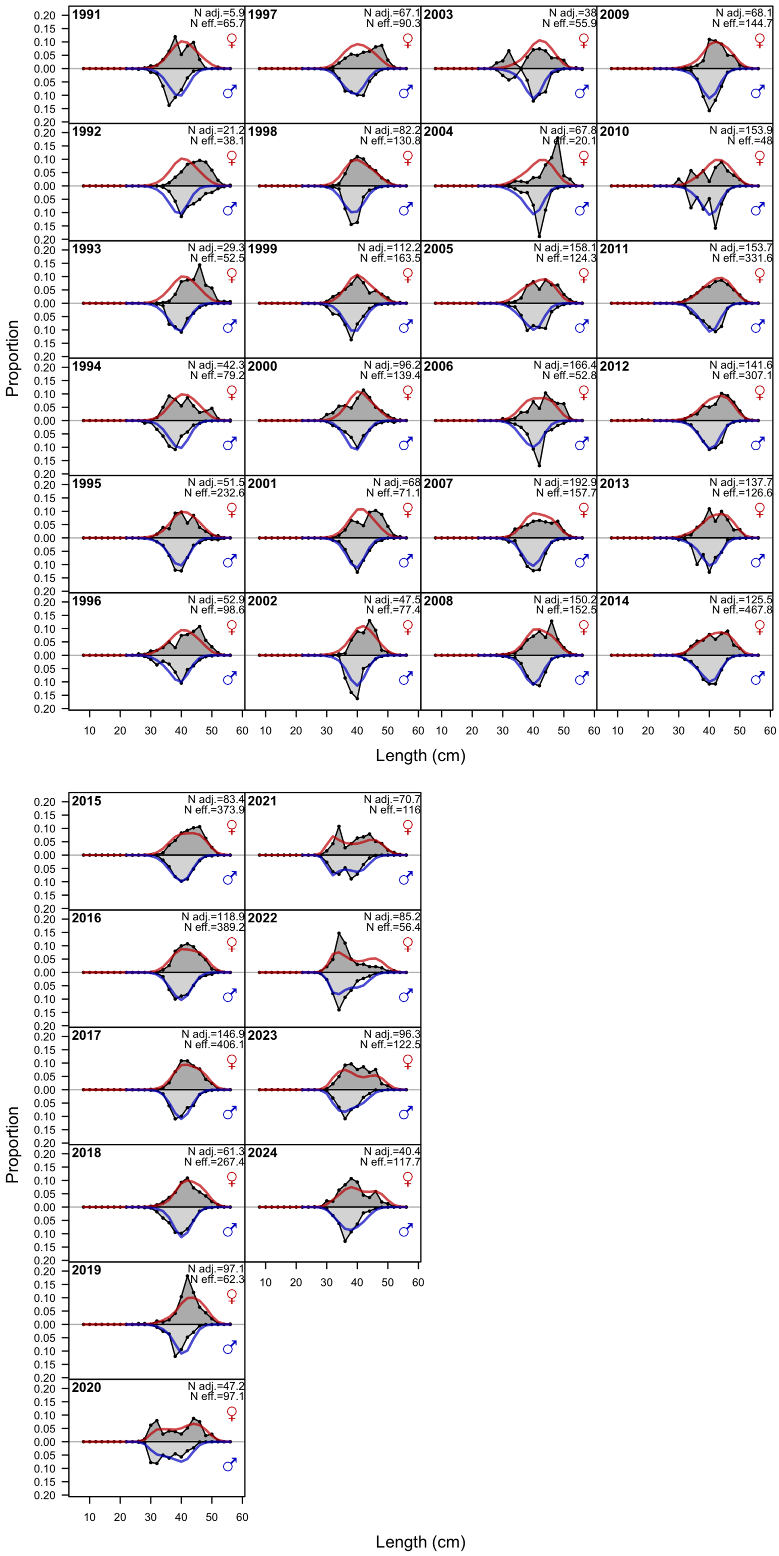


Figure A4: Fits to the retained length compositions for the hake fleet.

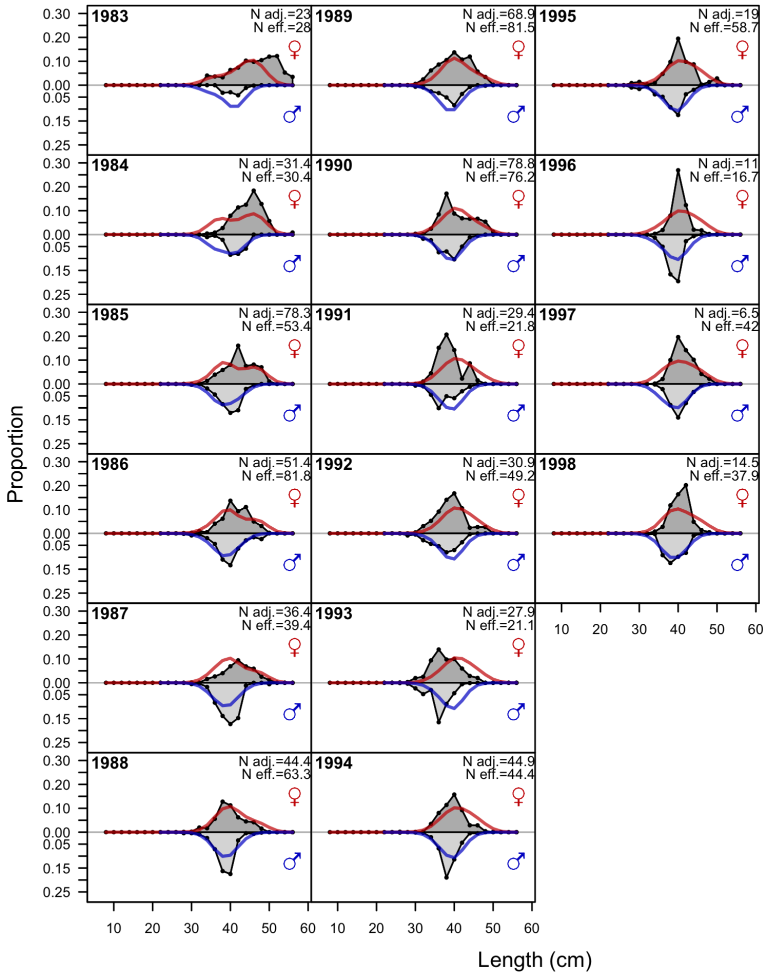


Figure A5: Fits to the retained length compositions for the net fleet.

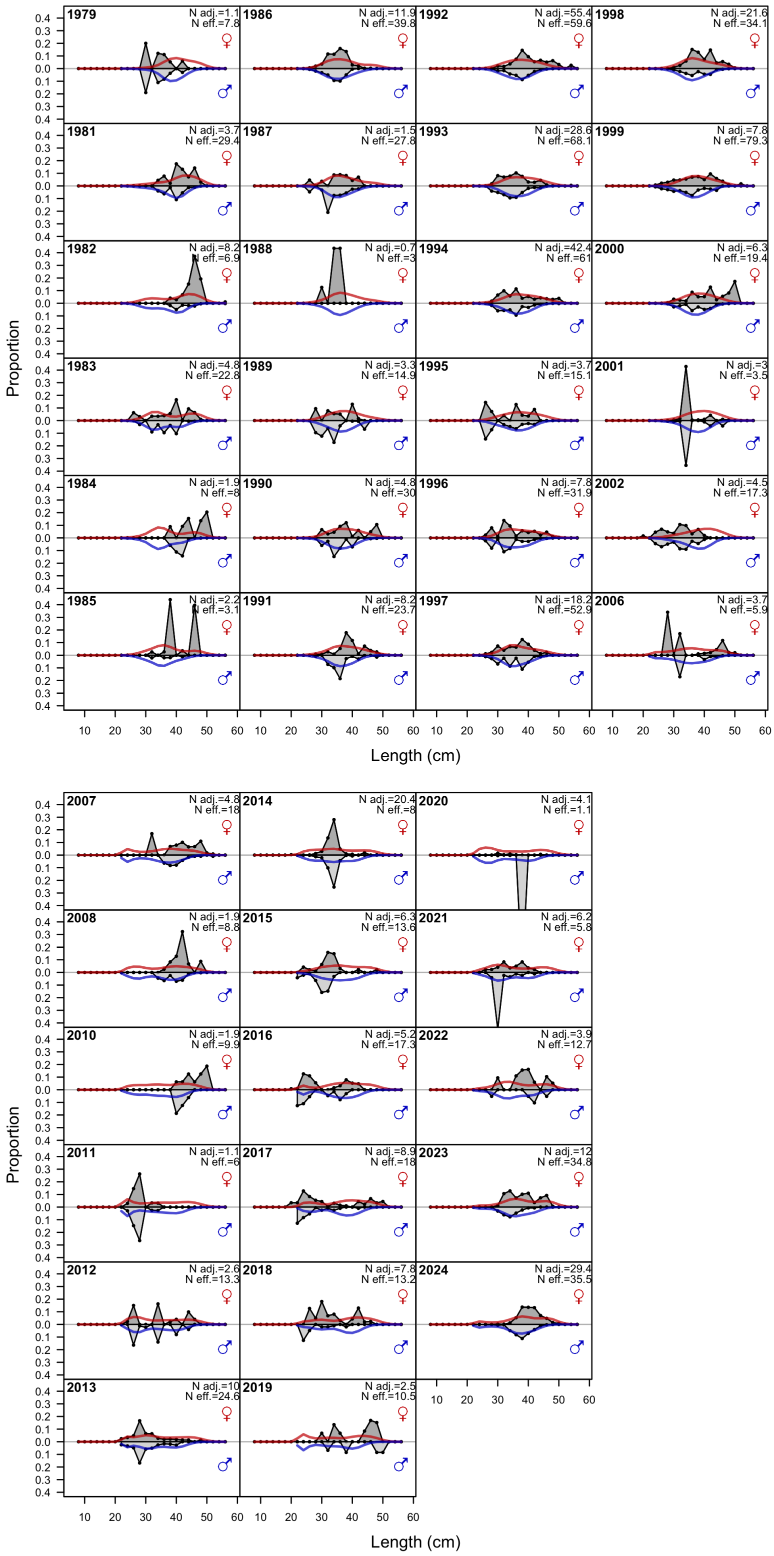


Figure A6: Fits to the retained length compositions for the hook-and-line fleet.

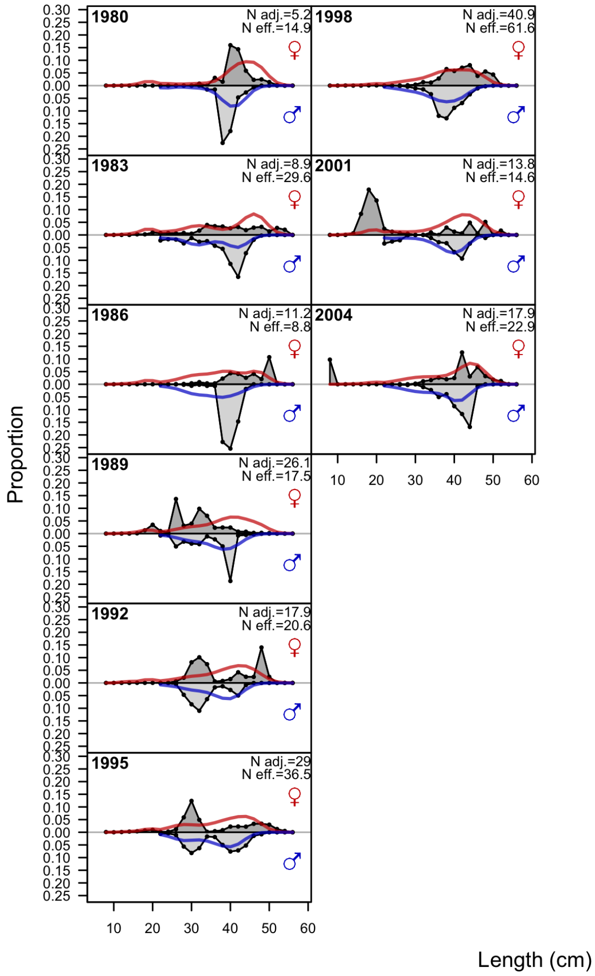


Figure A7: Fits to the length compositions for the triennial survey.

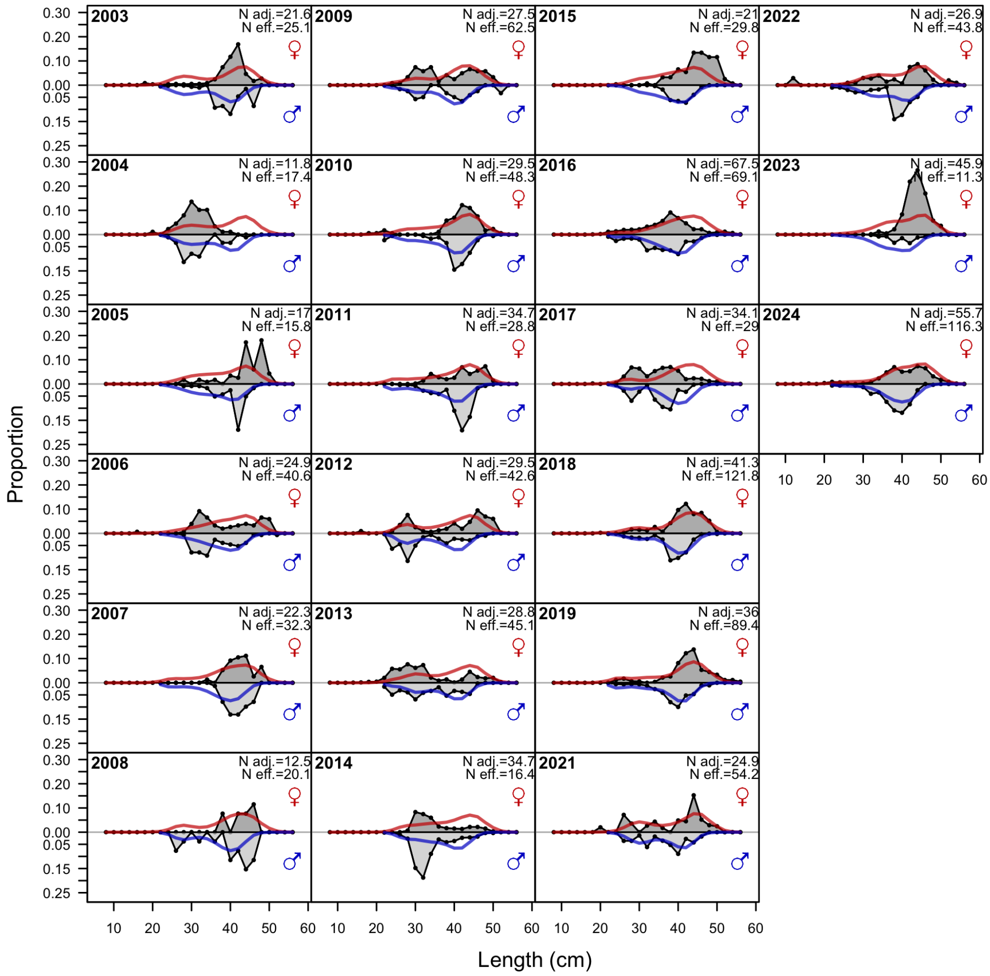


Figure A8: Fits to the length compositions for the WCGBTS.

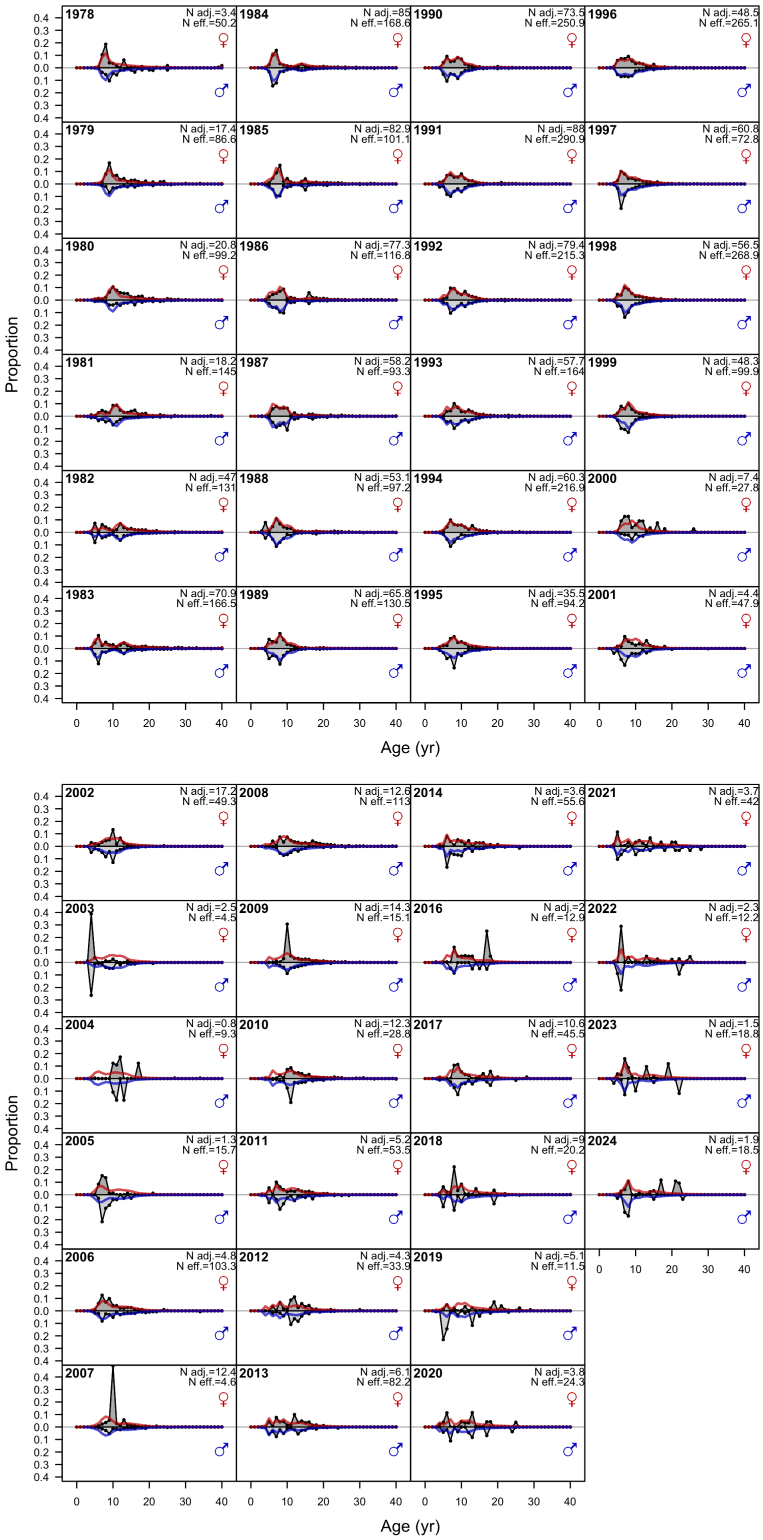
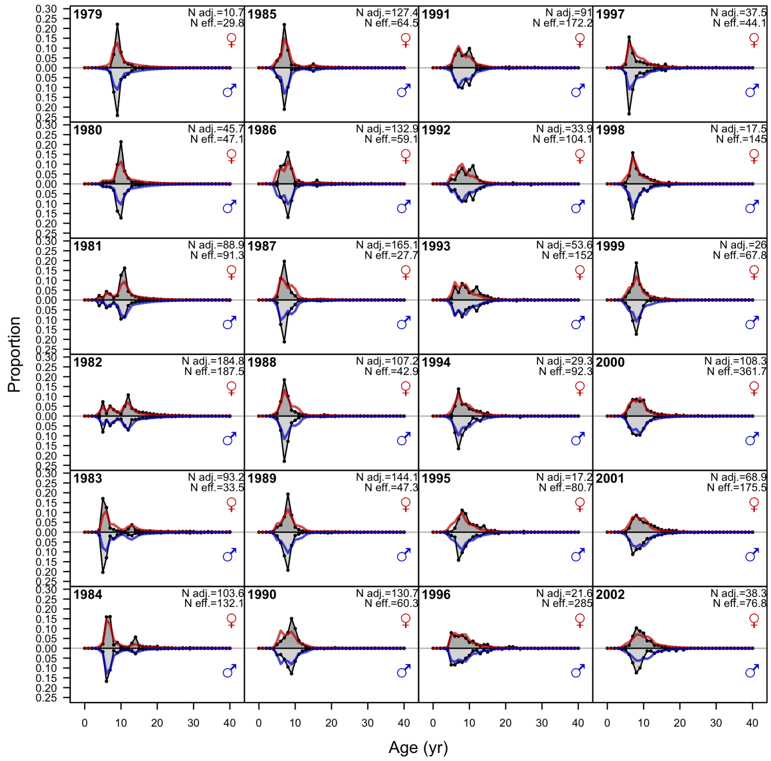


Figure A9: Fits to the retained age compositions for the bottom trawl fleet.



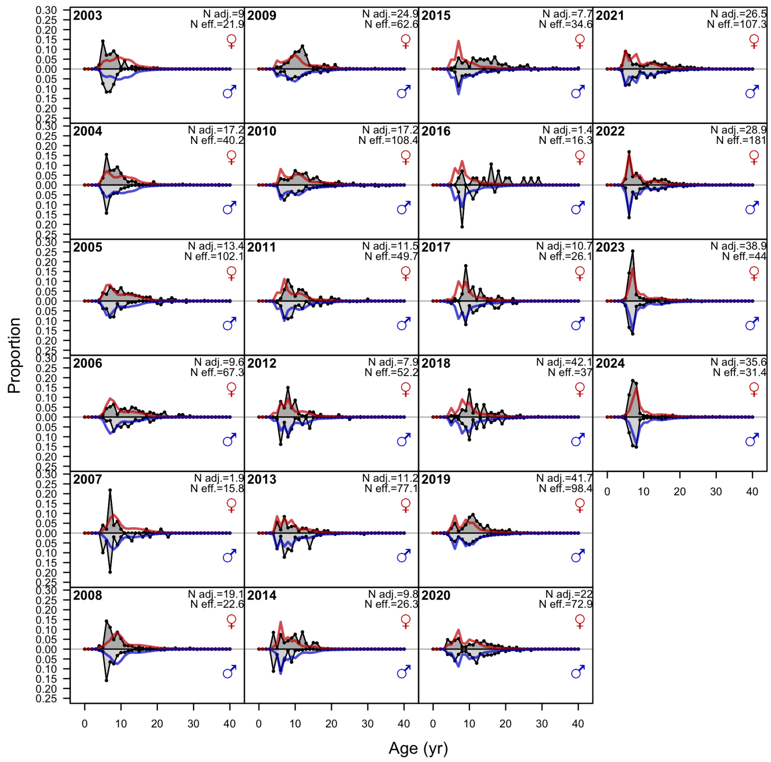


Figure A10: Fits to the retained age compositions for the midwater trawl fleet.

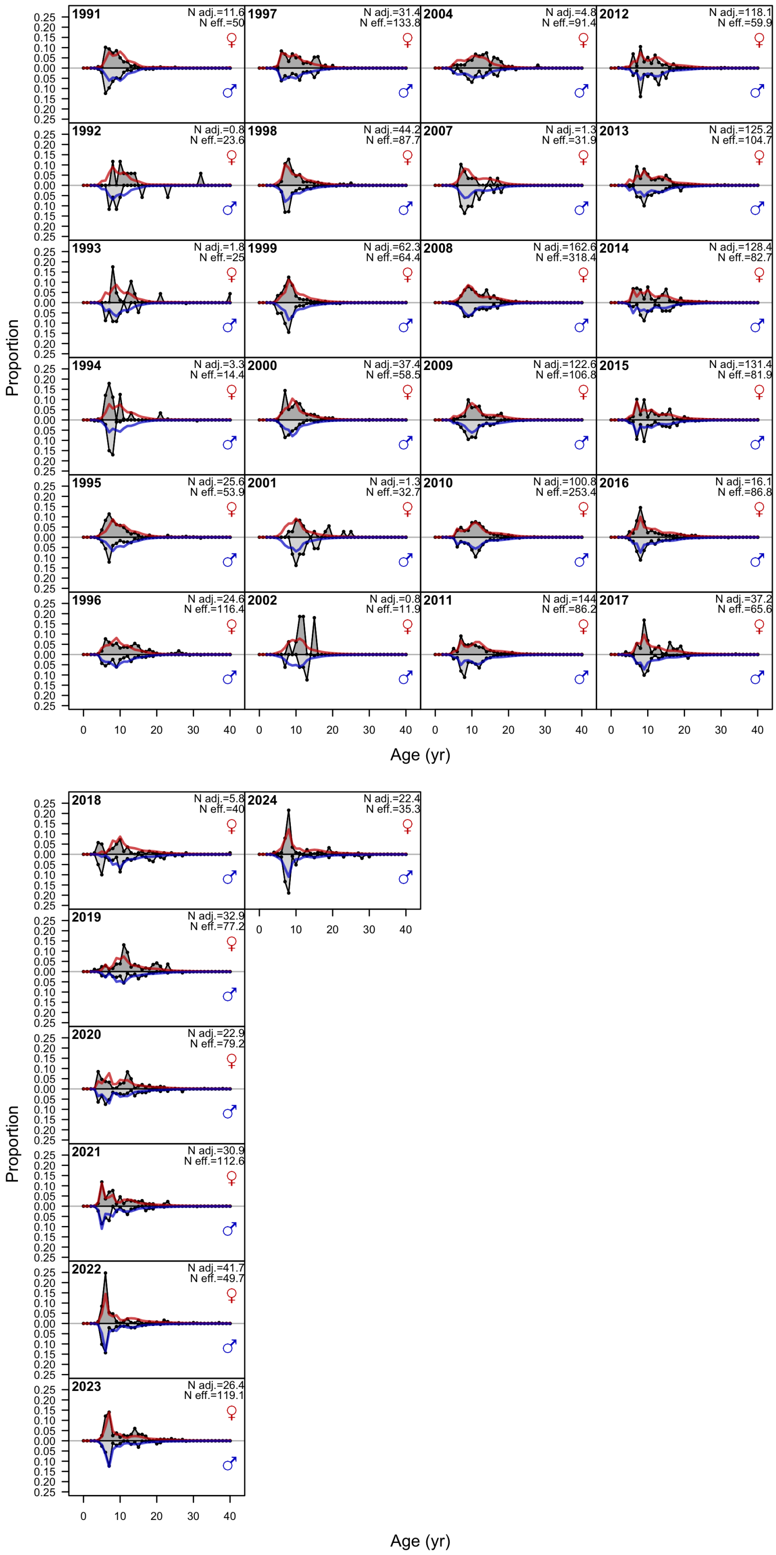


Figure A11: Fits to the retained age compositions for the hake fleet.

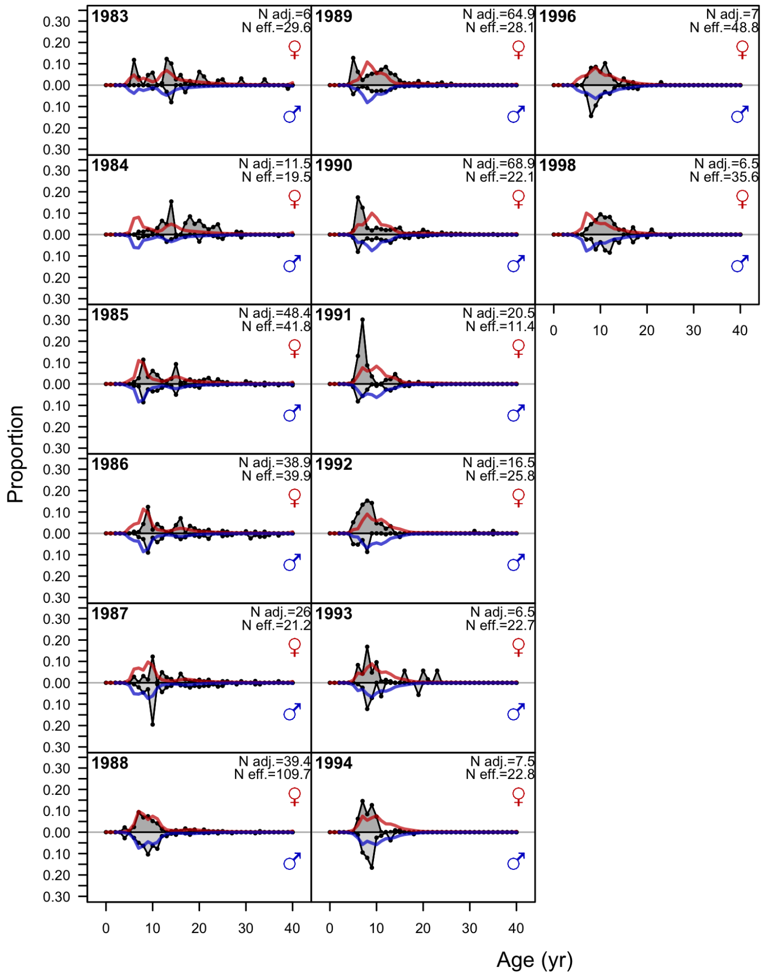


Figure A12: Fits to the retained age compositions for the net fleet.

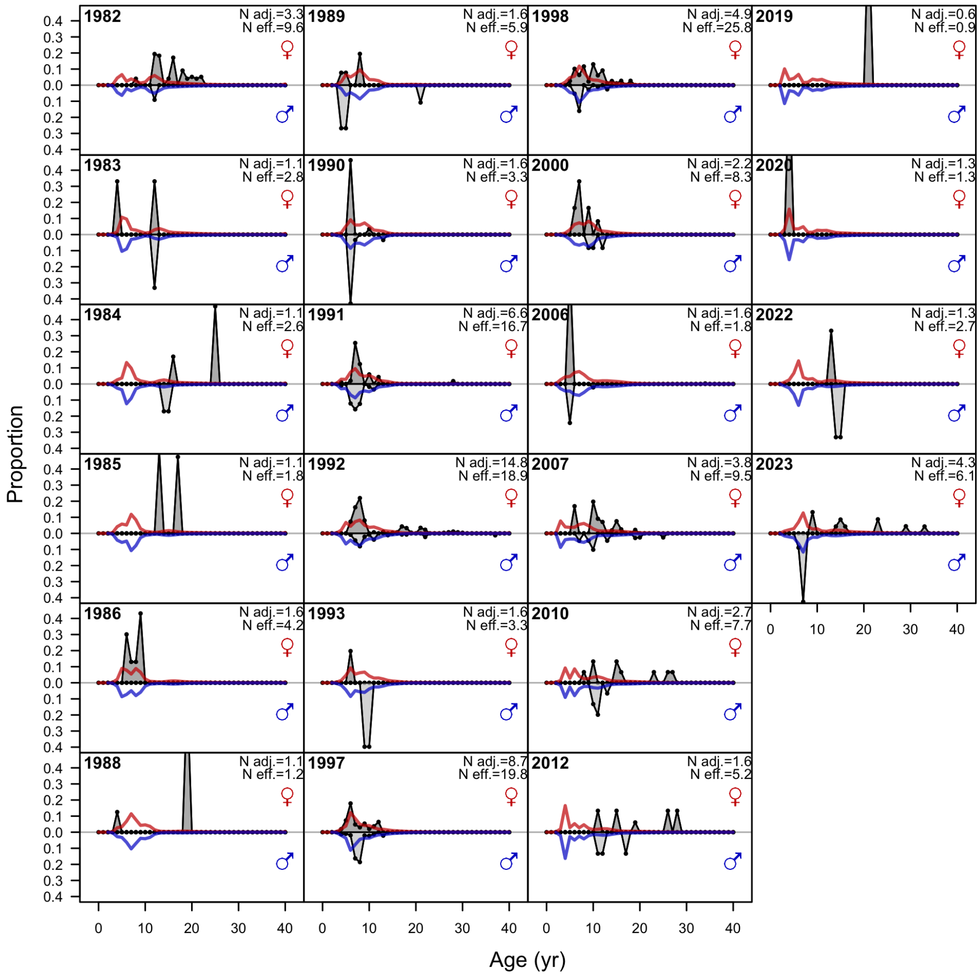


Figure A13: Fits to the retained age compositions for the hook-and-line fleet.