Status of SPECIES off the U.S. West Coast in 2025

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Refer to the most recent full assessment for additional information.

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Refer to the most recent full assessment for additional information.

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Refer to the most recent full assessment for additional information.

2 Data

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

2.1 Fishery-independent data

Data from three fishery-independent surveys were used in this assessment: 1) the SWFSC and NWFSC/PWCC Midwater Trawl Survey (hereafter, "juvenile survey"); 2) the Alaska Fisheries Science Center (AFSC)/NWFSC Triennial Shelf Trawl Survey (hereafter, "triennial survey"); and 3) the NWFSC West Coast Groundfish Bottom Trawl Survey (hereafter, "WCGBTS"). These surveys employed different designs and sampling methodologies, were conducted during different years and time periods within years, and included coverage over different areas of the coast. In some instances, the survey frequency, depths, and geographic areas covered were not internally consistent within surveys. A brief description of each survey is provided below. Strata were defined by latitude and depth to analyze the catch-rates, length compositions, and age compositions using stratified random sampling theory (Table 6 & Table 7). The latitude and depth breaks were chosen based on the design of the survey as well as by looking at biological patterns in relation to latitude and depth. Indices of abundance for all of the surveys were derived using model based approaches described below.

2.1.1 Alaska Fisheries Science Center/Northwest Fisheries Science Center West Coast Triennial Shelf Survey

The Triennial Survey was first conducted by the Alaska Fisheries Science Center (AFSC) in 1977, and the survey continued until 2004 (Weinberg et al. 2002). Its basic design was a series of equally-spaced east-to-west transects across the continential shelf from which searches for tows in a specific depth range were initiated. The survey design changed slightly over time. In general, all of the surveys were conducted in the mid summer through early fall. The 1977 survey was conducted from early July through late September. The surveys from 1980 through 1989 were conducted from the middle of July to late September. The 1992 survey was conducted from the middle of July through early October. The 1995 survey was conducted from early June through late August. The 1998 survey was conducted from early June through early August. Finally, the 2001 and 2004 surveys were conducted from May to July.

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

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

Widow Rockfish are not commonly caught in the WCGBTS. Higher catch rates occur north of 40° N latitude and catches are rare south of 36° N latitude (Figure 11). Few large fish are found shallower than 100 m and few small fish are found in the deeper water of the slope. There is no clear trend in length with latitude other than smaller fish tend to occur south of approximately 36° N latitude, and there appears to be some very small fish found near 39° N latitude.

An index was created using spatiotemporal species distribution modeling via the sdmTMB package (citation). This reflects an updated approach compared to the 2015 assessment (non-spatial delta-GLMM) and the 2019 update assessment (VAST delta-lognormal model). The sdmTMB index estimates spatial and spatiotemporal variation in encounter probability and positive catch weight across the survey range using a 200 knot grid. The positive catch weight model includes survey pass ('first' or 'second') to account for missing data, i.e., the incomplete second pass of the 2013 survey. Spatiotemporal estimates of weight are then converted into annual indices using XXX (something from sdmTMB??). Both gamma and lognormal error structures were tested for the positive catch model. Both models converged (positive, definite Hessian matrix) but predicted data from both models showed slightly right-heavy tails compared to null expectations, with the gamma model having stronger divergence.

The index estimate is relatively stable, with a slightly increasing trend in recent years and a moderate peak in 2016. Overall, the lognormal index estimates were more comparable to the 2019 spatiotemporal VAST-based index and seemed less influenced by potential extreme catch events, particularly in 2013 and 2016 [is there a more stats-y reason, e.g., AIC score]; for these reasons, the delta-lognormal sdmTMB-based index was used for the base model in this assessment. [The delta-lognormal mean value (XX) was slightly lower than the means of the index values used in the 2015 assessment (2701.12) and the 2019 update assessment (3301.765).] Comparisons of the different error structures, design-based estimate and the VAST index used in 2019 are in Figure XX.

2.2 Fishery-dependent data

Widow Rockfish have been caught in trawl and hook-and-line fisheries since the early part of the 20th century. Widow Rockfish are a desirable rockfish and are not likely to be discarded for market reasons. However, smaller Widow Rockfish are found at shallower depths and discarding practices in the early 1900s are uncertain. Few Widow Rockfish have been observed (relative to other gear types) in recreational, commercial pot, and commercial shrimp fisheries, thus only trawl, net, and hook-and-line landings were used in this assessment.

In data from the early 1980s, Widow Rockfish have had their own landing category. California began in 1982, Oregon in 1984, and Washington in 1988. Estimates of historical landings of Widow Rockfish rely upon species-composition sampling data from each period. The uncertainty in species composition is greater in past years, with less systematic and extensive sampling occurring prior to 1980. Consequently, the precision with which landings of Widow Rockfish can be estimated likely decreases for earlier years. A description of the methods used to determine the historical and current landings is provided below

2.2.1 Fishery length and age data

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

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

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

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

This is slightly different than the sample size of 2.43 per haul for rockfish that Stewart & Hamel (2014) report.

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

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

2.2.2 Discards

– TO DO!!! —

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

2.2.3 Biological data

2.2.3.1 Weight-length relationship

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

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

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

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

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

2.2.3.2 Maturity schedule

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

2.2.3.3 Fecundity

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

2.2.3.4 Natural Mortality

Natural mortality used in this update differed from the 2015 assessment. Natural mortality (M) is a parameter that is often highly uncertain in fish stocks. Past assessments of Widow Rockfish assumed constant natural mortality of 0.125 yr-1 or 0.15 yr-1. The 2011 assessment estimated M with a prior developed by Owen Hamel (NWFSC, pers. comm.) using methods described in Hamel (2014). This prior was based on a maximum age of 44 and 40 for females and males, respectively, a mean temperature of 8 degrees Celsius (about 150m deep off of Oregon), and a gonadosomatic index of 9.99% and 1.86% for females and males, respectively (Love et al 1990). The sex-specific lognormal priors for M have medians 11 of 0.124 yr-1 and 0.129 yr-1 for females and males, respectively, and a coefficient of variation (CV) of 30.7% for each sex. In 2015, discussions with Owen Hamel (NWFSC) led to the development of a new prior based solely on maximum age to use when estimating M. Using all of the available age data, a maximum age of 54 was determined for both females and males, although it has been rare to observe Widow Rockfish older than about 45 years old (Figure 33). This resulted in a prior with a much smaller median (0.0810 or -2.513284 in log space) and a larger standard deviation in log space (0.523694). For the update assessment, an updated meta-anaysis resulted in a prior with a slightly smaller median than the 2015 assessment (0.10 or -2.30 in log space) and a smaller standard deviation in log space (0.438). Figure 34 shows that these prior distributions are wide and not highly informative.

2.2.3.5 Length-at-age

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

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

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

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

2.2.3.6 Sex ratios

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

2.2.3.7 Ageing bias and imprecision

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

2.2.4 Abundance indices

2.3 Environmental and ecosystem data

3 Assessment model

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

3.1 History of modeling approaches

Refer to the most recent full assessment for additional information.

3.2 Responses to SSC Groundfish Subcommittee requests

To be completed after review.

3.3 Model Structure and Assumptions

3.3.1 Model Changes from the Last Assessment

3.3.2 Modeling Platform and Structure

3.3.3 Model Parameters

3.3.4 Key Assumptions and Structural Choices

Refer to the most recent full assessment for additional information.

3.4 Base Model Results

3.4.1 Parameter Estimates

3.4.2 Fits to the Data

3.4.3 Population Trajectory

3.5 Model Diagnostics

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

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

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

3.5.1 Convergence

3.5.2 Parameter Uncertainty

Parameter estimates are shown in Table 22, Table 23, and Table 28 along with approximate asymptotic standard errors. The only parameters with an absolute value of correlation greater than 0.95 were the female and male natural mortality parameters, which is expected. Estimates of key derived quantities are given in Table 26 along with approximate 95% asymptotic confidence intervals. There is a reasonable amount of uncertainty in the estimates of biomass. The confidence interval of the 2019 estimate of depletion is XX%–XX% and above the management target of 40% of the unfished spawning biomass.

3.5.3 Sensitivity Analyses

3.5.4 Retrospective Analysis

3.5.5 Likelihood Profiles and key parameters

Likelihood profiles were conducted for R0, steepness (even though it was not estimated in the base case) and over male and female natural mortality values simultaneously. These likelihood profiles were conducted by fixing the parameter at specific values and removing the prior on the parameter being profiled. Without the original prior distribution the MLE estimates from the base case will likely be different than the MLE in the likelihood profile, but this displays what information the data have. There was some difficulty in achieving model convergence for many parameterizations in the likelihood profile. In some cases jittering was required.

As R0 increased, natural mortality also increased and the relative spawning biomass in 2015 was less depleted (Table 31). There was variable support for each likelihood component across the range of R0 evaluated. The total likelihood supported the estimated value (Table 31). Profiles are illustrated in Figure 68.

3.6 Unresolved Problems and Major Uncertainties

4 Management

4.1 Reference Points

4.2 Harvest Projections and Decision Tables

4.3 Evaluation of Scientific Uncertainty

4.4 Regional management considerations

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

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

Widow Rockfish are managed on a coastwide basis and observed more often in the NWFSC WCGBT bottom trawl survey north of latitude 40° 10 N. Bottom trawl catches in California have historically been as large as in Oregon and larger than in Washington, but recently catches in California have been small. Rockfish Conservation Areas (RCAs) cover a significant proportion of Widow Rockfish habitat, but a midwater trawl fishery is beginning to re-develop that can fish in these areas. Future assessments and management of Widow Rockfish may want to monitor where catches are being taken to make sure that specific areas are not being overexploited. In addition, research on the connectivity along the coast as well as regional differences would help to inform the potential for overfishing specific areas.

4.5 Research and Data Needs

4.6 Acknowledgements

4.7 References

4.8 Tables

4.9 Figures

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