Agenda Item H.3
Attachment 10
September 2015

Disclaimer: This information is distributed solely for the purpose of pre-dissemination peer review under applicable information quality guidelines. It has not been formally disseminated by NOAA Fisheries. It does not represent and should not be construed to represent any agency determination or policy

DRAFT

The Status of Widow Rockfish (*Sebastes entomelas*) Along the U.S. West Coast in 2015

Allan C. Hicks
Chantel R. Wetzel

Northwest Fisheries Science Center
U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
2725 Montlake Boulevard East
Seattle, Washington 98112-2097

Allan.Hicks@noaa.gov
Chantel.Wetzel@noaa.gov

Briefing Book DRAFT
August 14, 2015

Table of Contents

Executive Summary ..... **i**
Stock ..... **i**
Landings ..... **i**
Data and assessment ..... **iii**
Stock biomass ..... **iv**
Recruitment ..... **v**
Exploitation status ..... **vii**
Ecosystem considerations ..... **ix**
Reference points ..... **ix**
Management performance ..... **x**
Unresolved problems and major uncertainties ..... **xi**
Decision table ..... **xi**
Research and data needs ..... **xiv**

1 Introduction ..... Error! Bookmark not defined.
1.1 Distribution and stock structure ..... Error! Bookmark not defined.
1.2 Life History and ecosystem interactions ..... Error! Bookmark not defined.
1.3 Historical and current fishery ..... Error! Bookmark not defined.
1.4 Management history and performance ..... Error! Bookmark not defined.
1.5 Fisheries and assessments in Canada and Alaska ..... Error! Bookmark not defined.

2 Data ..... Error! Bookmark not defined.
2.1 Fishery-independent data ..... Error! Bookmark not defined.
2.1.1 Juvenile survey ..... **Error! Bookmark not defined.**
2.1.2 AFSC/NWFSC triennial bottom trawl survey ..... **Error! Bookmark not defined.**
2.1.3 NWFSC shelf/slope survey ..... **Error! Bookmark not defined.**
2.1.4 Fishery-independent surveys not used in this analysis ..... **Error! Bookmark not defined.**
2.2 Fishery-dependent data ..... Error! Bookmark not defined.
2.2.1 Commercial catch reconstruction ..... **Error! Bookmark not defined.**
2.2.2 Fishery catch-per-unit-effort ..... **Error! Bookmark not defined.**
2.2.3 Fishery length and age data ..... **Error! Bookmark not defined.**
2.2.4 Discards ..... **Error! Bookmark not defined.**
2.3 Biological data ..... Error! Bookmark not defined.
2.3.1 Weight-length relationship ..... **Error! Bookmark not defined.**
2.3.2 Maturity schedule ..... **Error! Bookmark not defined.**
2.3.3 Fecundity ..... **Error! Bookmark not defined.**
2.3.4 Natural mortality ..... **Error! Bookmark not defined.**
2.3.5 Length-at-age ..... **Error! Bookmark not defined.**
2.3.6 Sex ratios ..... **Error! Bookmark not defined.**
2.3.7 Ageing bias and imprecision ..... **Error! Bookmark not defined.**
2.4 History of modeling approaches used for this stock ..... Error! Bookmark not defined.

3 Assessment ..... Error! Bookmark not defined.
3.1 General model specifications and assumptions ..... Error! Bookmark not defined.
3.1.1 Summary of fleets and areas ..... **Error! Bookmark not defined.**
3.1.2 Other specifications ..... **Error! Bookmark not defined.**
3.1.3 Priors ..... **Error! Bookmark not defined.**
3.1.4 Sample weights ..... **Error! Bookmark not defined.**

3.1.5 Estimated and fixed parameters............................ **Error! Bookmark not defined.**
3.2 Model selection and evaluation .... Error! Bookmark not defined.
3.2.1 Key assumptions and structural choices .... **Error! Bookmark not defined.**
3.2.2 Alternate models explored .... **Error! Bookmark not defined.**
3.2.3 Convergence status .... **Error! Bookmark not defined.**
3.3 Response to STAR panel review and recommendations........... Error! Bookmark not defined.
3.3.1 STAR panel in 2011.. **Error! Bookmark not defined.**
3.3.2 SSC recommendations in 2011............................. **Error! Bookmark not defined.**
3.3.3 STAR panel in 2015.. **Error! Bookmark not defined.**
3.4 Base-model results... Error! Bookmark not defined.
3.4.1 Parameter estimates... **Error! Bookmark not defined.**
3.4.2 Fits to the data .... **Error! Bookmark not defined.**
3.4.3 Population trajectory .... **Error! Bookmark not defined.**
3.5 Uncertainty and sensitivity analyses............................ Error! Bookmark not defined.
3.5.1 Parameter uncertainty... **Error! Bookmark not defined.**
3.5.2 Sensitivity analysis... **Error! Bookmark not defined.**
3.5.3 Retrospective analysis .... **Error! Bookmark not defined.**
3.5.4 Likelihood profiles over key parameters................ **Error! Bookmark not defined.**
3.5.5 Overall assessment uncertainty .... **Error! Bookmark not defined.**

4 Reference points... Error! Bookmark not defined.

5 Harvest projections and decision tables .... Error! Bookmark not defined.

6 Regional management considerations..................... Error! Bookmark not defined.

7 Research and data needs .... Error! Bookmark not defined.

8 Acknowledgments.. Error! Bookmark not defined.

9 Literature cited.. Error! Bookmark not defined.

10 Tables... Error! Bookmark not defined.

11 Figures .... Error! Bookmark not defined.

Appendix A. Year-specific fits to the length compositions........... Error! Bookmark not defined.

Appendix B. Predicted numbers-at-age .... Error! Bookmark not defined.

Appendix C. SS data file... Error! Bookmark not defined.

Appendix D. SS control file... Error! Bookmark not defined.

Appendix E. SS starter file .... Error! Bookmark not defined.

Appendix F. SS forecast file .... Error! Bookmark not defined.

Executive Summary

Stock

This is an assessment of Widow Rockfish (*Sebastes entomelas*) that reside in the waters off California, Oregon, and Washington from the U.S.-Canadian border in the north to the U.S.-Mexico border in the south. Widow Rockfish inhabit water depths of 25–370 m from northern Baja California, Mexico to Southeastern Alaska. Although catches north of the U.S.-Canada border and south of the U.S.-Mexico border were not included in this assessment, it is not certain if those populations contribute to the biomass of Widow Rockfish off of the U.S. West Coast, possibly through adult migration and/or larval dispersion.

There is little evidence of genetically separate stocks along the U.S. coast and past assessments have used a single area, coastwide model with multiple fisheries (He et al. 2011). In 2011, a two-area assessment model was brought forward for review, and was found to be similar to a coastwide model (He et al. 2011). There is some evidence of biological differences between areas. For example, Widow Rockfish collected off California tend to mature at a smaller length than Widow Rockfish collected off of Oregon (Barss and Echeverria 1987). This may be due to environmental or anthropogenic effects rather than genetic differences. It was decided to continue with a single area model for this assessment instead of potentially lose prediction power by splitting the data into two separate areas.

Landings

The historical reconstruction of landings for Widow Rockfish suggests that hook-and-line and bottom trawl fisheries have caught Widow Rockfish since the turn of the 20th century. Landings in the trawl fishery are estimated to have increased into the 1940s and remained relatively constant throughout the 1950s and into the 1960s before the foreign trawl fleet increased catches into the 1970s, peaking 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 a peak in landings exceeding 25,000 mt in 1981. After this sudden increase in catch, Widow Rockfish were given their own market category and often specifically identified in the landings. However, species composition sampling of market categories occurred before the mid-1980s when Widow Rockfish was not specifically identified. The uncertainty in species composition is greater in past years, thus landings of Widow Rockfish are not well known further back in history.

The large landings in the early 1980s were curtailed with trip limits beginning in 1982, which resulted in a decline in landings throughout the 1980s and 1990s following sequential reductions in the trip limits. From 2000 to 2003, landings of Widow Rockfish dropped from over 4,000 mt to about 40 mt and have been slowly increasing since, with a more rapid relative increase in 2013 and 2014 to above 700t. Bottom trawl and midwater trawl gears in groundfish and Pacific Whiting fisheries make up the majority of the catch.

Widow Rockfish are a desirable market species and it is believed that discarding was low historically. However, management restrictions (e.g., trip limits) resulted in a substantial amount of discarding beginning in 1982. Trawl rationalization was introduced in 2011, and since then very little discarding of Widow Rockfish has occurred. Discards were estimated in the model with the assistance of data from the West Coast Observer Program (WCGOP), and total catches (discards plus landings) are reported in addition to landings.

Table a: 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 estimated catch (discards + landings) (mt).

Year	Trawl	Midwater Trawl	At-Sea Hake	Net	Hook-and-line	Total Commercial Landings	Estimated Total Catch
2005	3.13	32.82	157.99	0.13	1.22	195.29	203.57
2006	6.01	12.86	193.19	0.00	0.88	212.94	220.68
2007	4.81	1.55	228.39	2.91	1.93	239.59	244.72
2008	2.15	42.15	217.96	0.00	1.25	263.51	272.37
2009	4.19	36.45	135.35	0.21	0.41	176.61	186.28
2010	4.73	54.67	106.35	0.00	0.15	165.90	178.87
2011	18.34	43.88	149.65	0.00	0.12	211.99	212.65
2012	41.23	47.36	181.43	0.00	0.33	270.35	271.34
2013	51.27	241.09	176.41	0.00	0.98	469.75	472.96
2014	71.28	306.62	342.16	0.03	1.84	721.93	726.17

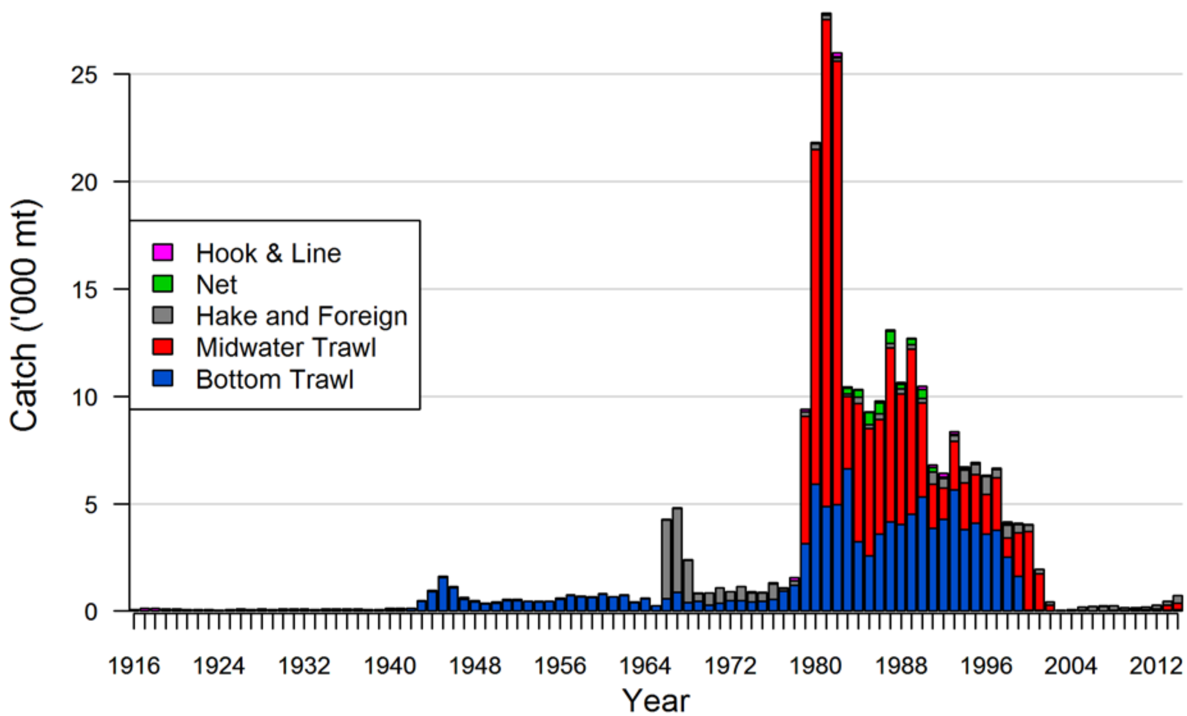

Figure a: Landings of Widow Rockfish from 1916 to 2014 for bottom trawl, midwater trawl, net, and hook-and-line fisheries, and catches of Widow Rockfish for the foreign (1966–1976), and Pacific Whiting (hake) fisheries.

Data and assessment

This is a new full assessment for Widow Rockfish which was last assessed in 2011. In this assessment, all aspects of the model including catches, data, and modelling assumptions were re-evaluated as much as possible. The assessment was conducted using the length- and age-structured modeling software Stock Synthesis (version 3.24U, pers. comm. Richard Methot, NMFS). The coastwide population was modeled assuming separate growth and mortality parameters for each sex (a two-sex model) from 1916 to 2015, and forecasted beyond 2015.

The definitions of fishing fleets have been changed from those in the 2011 assessment separating fisheries by strategy rather than space. Five fishing fleets were specified within the model: 1) a shorebased bottom trawl fleet with coastwide catches from 1916–2014, 2) a shorebased midwater trawl fleet with coastwide catches from 1979–2014, 3) a mostly midwater trawl fleet that targets Pacific Hake/Whiting (*Merluccius productus*) and includes a foreign and at-sea fleet with catches from 1975–2014, a domestic shorebased fleet that targeted Pacific Hake with catches from 1991–2014, and foreign vessels that targeted Pacific Hake and rockfish between 1966–1976, 4) a net fishery consisting of catches mostly from California from 1981–2014, and 5) a hook-and-line fishery (predominantly longline) with coastwide catches from 1916–2014.

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

The data used in the assessment model consisted of survey abundance indices, length compositions, discard data, and age compositions. Model-based biomass indices and length compositions were determined for the triennial and NWFSC surveys. Length and age compositions were also available from the five fisheries. Age data for all years of the NWFSC shelf/slope survey were input as age-at-length. Discard data for the bottom trawl, midwater trawl, and hook-and-line fisheries were available in various years in the form of discarded biomass and length compositions. A small amount of data was available to inform discarding practices of Widow Rockfish prior to 2002. The variances and sample sizes on all of the data were tuned to the expected variability in the model predictions.

The base model estimated parameters for length-based selectivity for all fleets and surveys, retention curves based on length for the bottom trawl, midwater trawl, and hook-and-line fishing fleets, a length-at-age relationship, natural mortality, and recruitment deviations starting in 1900. A Beverton-Holt stock-recruitment function was used to model productivity and the steepness parameter was fixed at 0.798 based on a steepness meta-analysis for west coast rockfishes (pers. comm. Jim Thorson, NWFSC).

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

Although there are many types of data available for Widow Rockfish since the late 1970s, which were used in this assessment, there is little information about steepness and natural mortality, and recent recruitment. Estimates of steepness are uncertain partly because of variable recruitment. Uncertainty in natural mortality is common in many fish stock assessments even when length and age data are available. Finally, there is little information about the strength of recent recruitment because the young fish are seen with a lower probability in the fisheries and surveys. These uncertainties were characterized as best as possible in the predictions and projections from this assessment.

Stock biomass

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. The 2015 spawning biomass relative to unfished equilibrium spawning biomass is above the target of 40% of unfished spawning biomass (75.1%), with a low of 37.3% in 1998.

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. The standard deviation of the log of the spawning biomass in 2015 is 0.18.

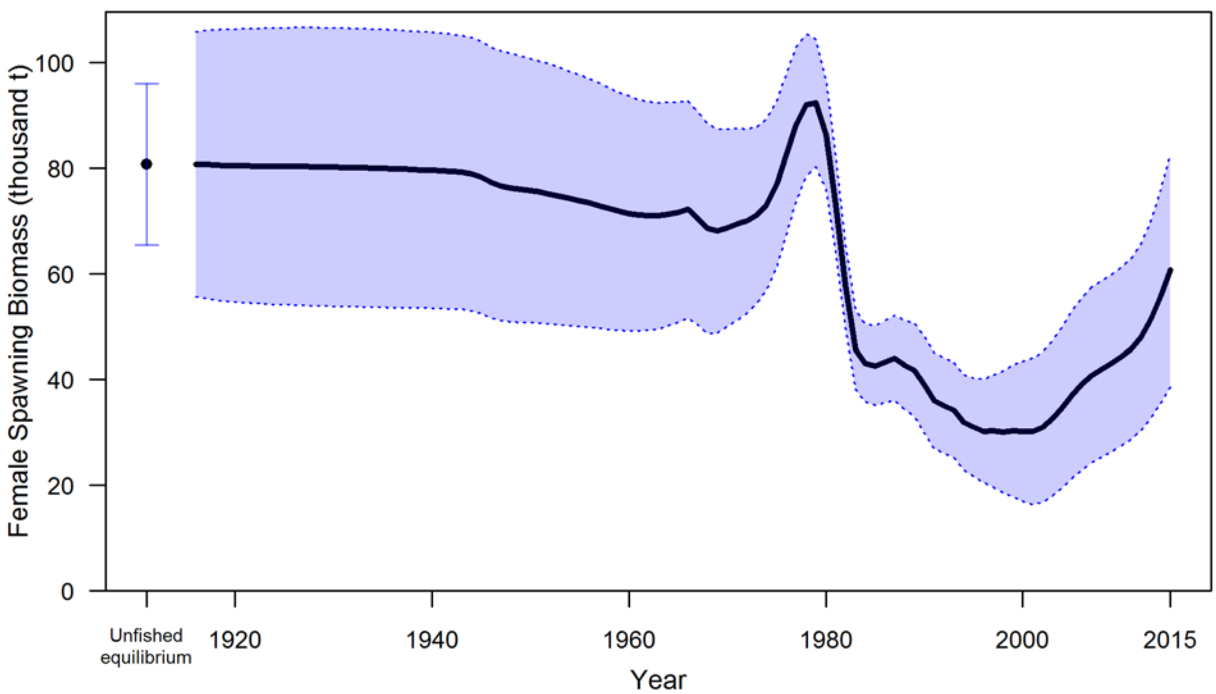

Figure b: Estimated female spawning biomass time-series from the base model (solid line) with an approximate asymptotic 95% confidence interval (shaded area).

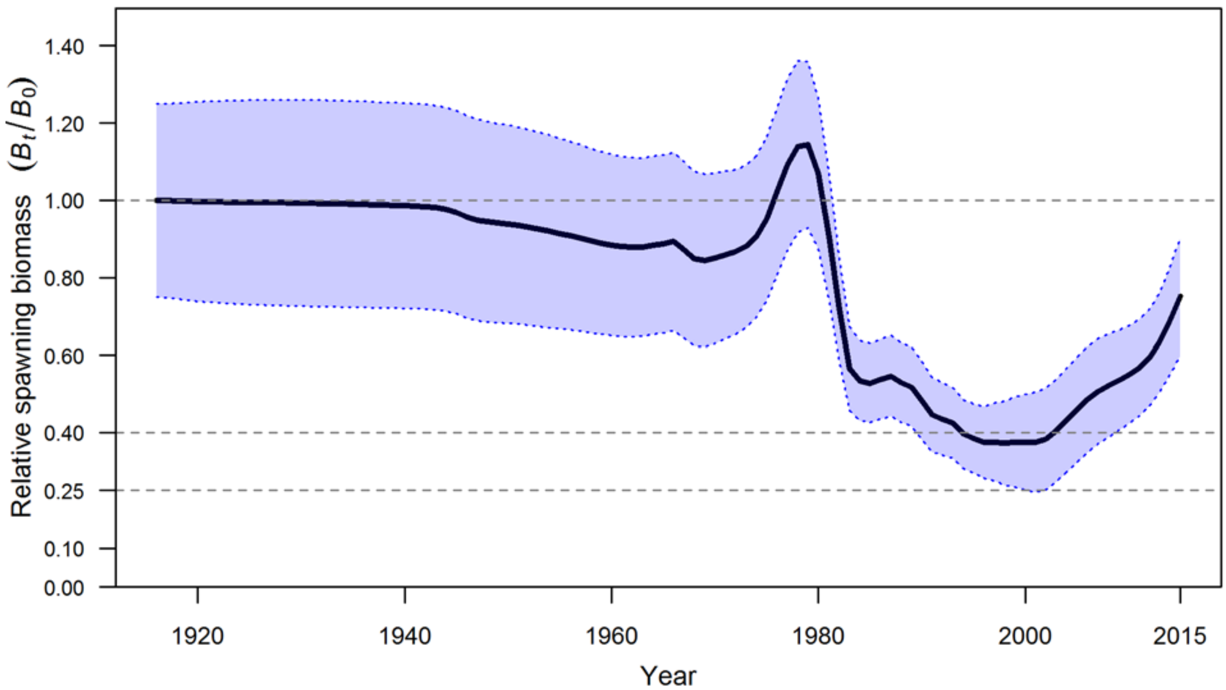

Figure c. Estimated relative spawning biomass (depletion) with approximate 95% asymptotic confidence intervals (filled area) for the base case assessment model.

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

Year	Spawning Biomass	~95% Confidence Interval	Estimated Depletion (%)	~95% Confidence Interval
2006	39,164	22,905–55,422	48.5	34.8–62.2
2007	40,825	24,272–57,377	50.6	37.0–64.2
2008	42,031	25,372–58,689	52.1	38.8–65.4
2009	43,110	26,388–59,832	53.4	40.5–66.4
2010	44,280	27,467–61,093	54.9	42.2–67.5
2011	45,813	28,751–62,874	56.8	44.3–69.2
2012	47,912	30,355–65,470	59.4	47.0–71.8
2013	51,215	32,650–69,779	63.5	50.6–76.3
2014	55,669	35,553–75,785	69.0	55.1–82.8
2015	60,608	38,622–82,594	75.1	59.8–90.4

Recruitment

Recruitment deviations were estimated for the entire time series modeled. There is little information regarding recruitment prior to 1965, and the uncertainty in these estimates is expressed in the model. There are very large, but uncertain, estimates of recruitment in 2008, 1970, and 1971. Other large recruitment events (in descending order of magnitude) occurred in 1978, 2010, 1981, 1991, and 1977. The five lowest recruitments (in ascending order) occurred in 1976, 2005, 1973, 1996, and 1972. Estimates of recruitment appear to be episodic and characterized by periods of low recruitment. Two of the five largest estimated recruitments happened in the last decade.

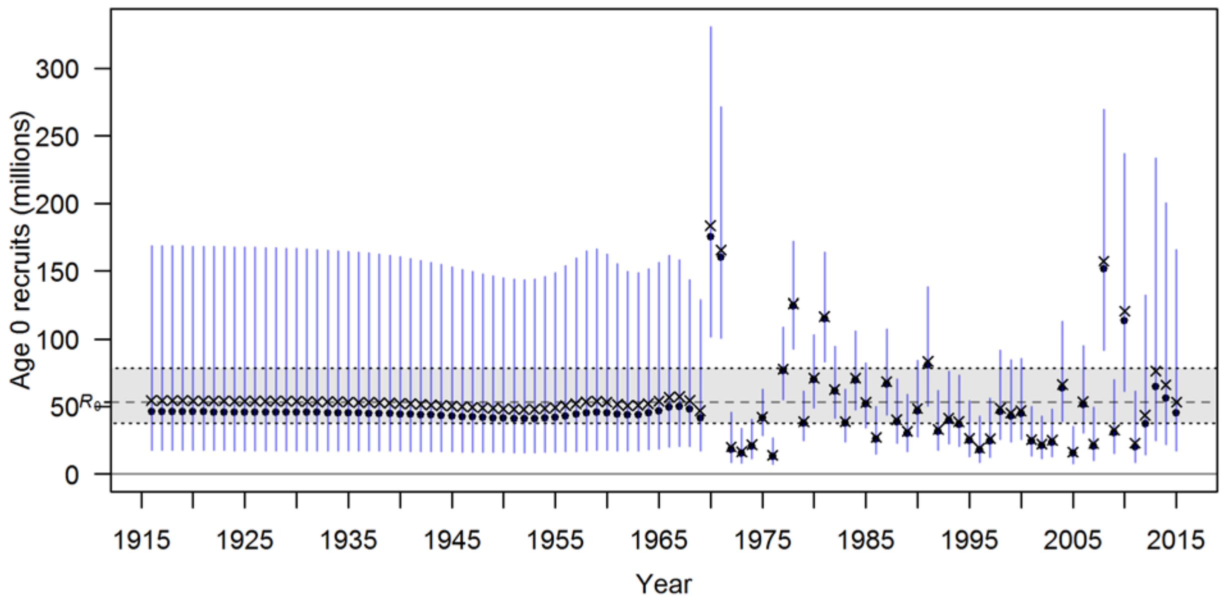

Figure d: Time-series of estimated recruitments (medians as solid circles and mean as an 'x') for the base case model with approximate asymptotic 95% confidence interval (vertical bars). Estimated mean unfished equilibrium recruitment (R_0) is shown as the horizontal dashed line with a 95% confidence interval shaded between the dotted lines.

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

Year	Estimated Recruitment (number in thousands)	~95% Confidence Interval	Estimated Recruitment Deviation	~95% Confidence Interval
2006	53,702	30,309–95,149	0.212	-0.181–0.606
2007	22,470	10,225–49,378	-0.664	-1.352–0.025
2008	157,219	91,670–269,639	1.278	0.921–1.635
2009	32,713	15,331–69,803	-0.295	-0.950–0.361
2010	120,622	61,356–237,136	1.007	0.453–1.561
2011	22,961	8,562–61,575	-0.709	-1.683–0.265
2012	43,443	14,268–132,274	-0.130	-1.276–1.015
2013	76,349	24,956–233,579	0.373	-0.780–1.526
2014	66,109	21,826–200,234	0.221	-0.918–1.361
2015	53,370	17,161–165,975	0.0	NA

Exploitation status

The spawning biomass of Widow Rockfish reached a low in 2001 before increasing due to low catches. The estimated depletion was possibly below the overfished level in the early 2000s, but has likely remained above that level otherwise, and currently is significantly greater than the 40% unfished spawning biomass target. Throughout the 1980s and 1990s the exploitation rate and (1-*SPR*) were mostly above target levels. Recent exploitation rates on Widow Rockfish were predicted to be significantly below target levels.

Table d. Recent trend in spawning potential ratio (entered as 1-SPR) and summary exploitation rate.

Year	Estimated 1-SPR (%)	~95% confidence interval	Harvest rate (proportion)	~95% confidence interval
2005	5.03	2.49–7.57	0.0026	0.0015–0.0037
2006	5.13	2.61–7.65	0.0027	0.0016–0.0039
2007	5.39	2.81–7.98	0.0030	0.0018–0.0042
2008	5.78	3.09–8.48	0.0032	0.0019–0.0044
2009	3.92	2.12–5.71	0.0021	0.0013–0.0030
2010	3.67	2.03–5.31	0.0020	0.0012–0.0027
2011	4.19	2.37–6.01	0.0023	0.0015–0.0032
2012	5.19	3.00–7.39	0.0026	0.0016–0.0035
2013	8.22	4.88–11.57	0.0042	0.0026–0.0058
2014	11.44	6.90–15.98	0.0057	0.0036–0.0079

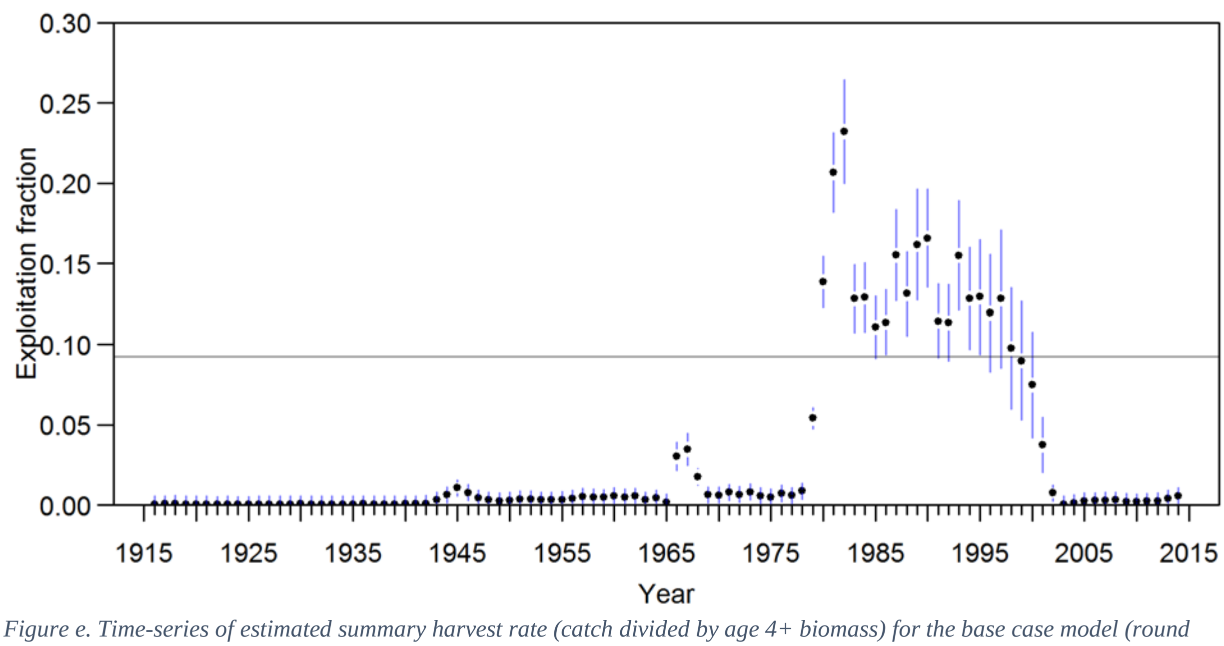

Figure e. Time-series of estimated summary harvest rate (catch divided by age 4+ biomass) for the base case model (round points) with approximate 95% asymptotic confidence intervals (gray lines). The horizontal line is the harvest rate at the overfishing F_{MSY} harvest rate proxy of $SPR_{50\%}$.

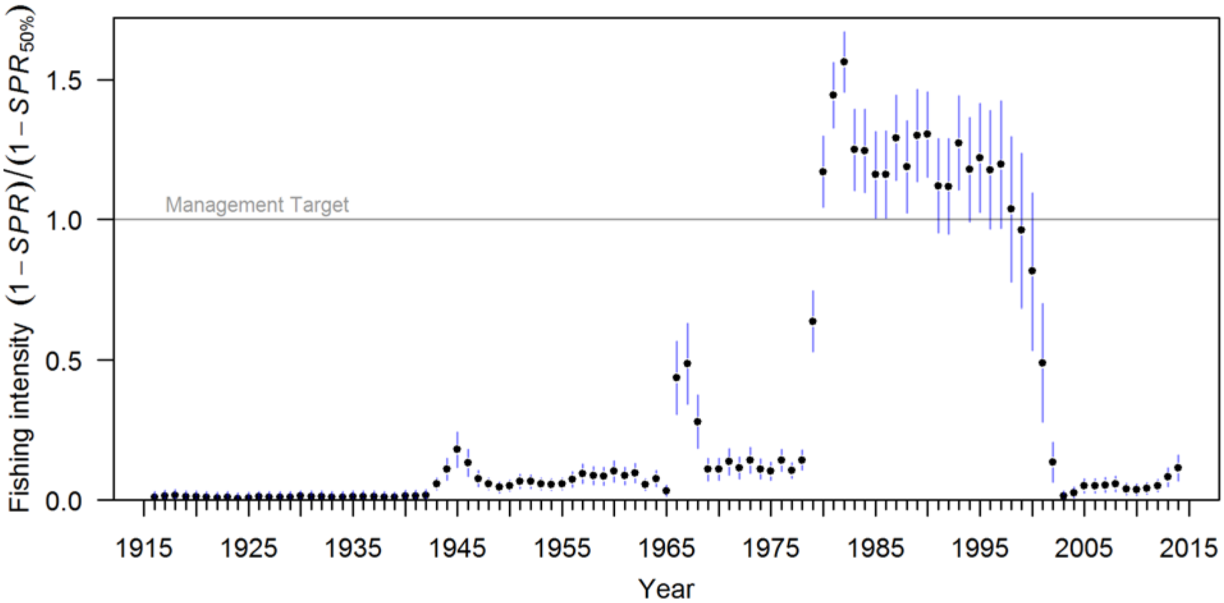

Figure f. Trend in estimated fishing intensity (relative to the SPR management target) through 2014 with 95% asymptotic confidence intervals. One minus SPR is used so that higher exploitation rates occur on the upper portion of the y-axis. The relative management target is plotted as a horizontal line and values above this reflect harvests in excess of the overfishing proxy based on $SPR_{50\%}$.

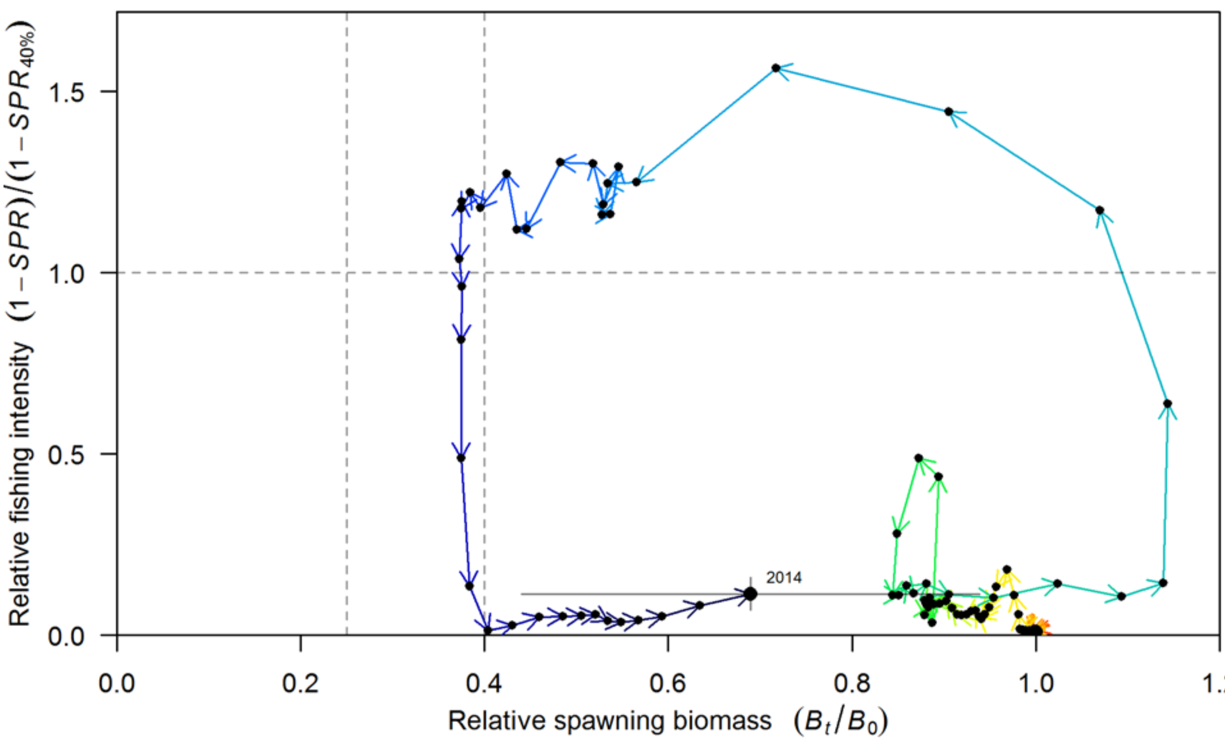

Figure g. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model. The relative (1-SPR) is (1-SPR) divided by 0.5 (one minus the SPR target). 2014 is noted with 95% asymptotic confidence intervals.

Ecosystem considerations

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

Recruitment is one mechanism by which the ecosystem may directly impact the population dynamics of Widow Rockfish. The 1999 cohort for many species of rockfish was large – sometimes significantly so – from these species' long-term averages suggesting that environmental conditions may influence the spawning success and survival of larvae and juvenile rockfish. Widow Rockfish showed an above average recruitment deviation in 1999, but absolute recruitment was not as large as other years. The specific pathways through which environmental conditions exert influence on Widow Rockfish dynamics are unclear; however, changes in water temperature and currents, distribution of prey and predators, and the amount and timing of upwelling are all possible linkages. Changes in the environment may also result in changes in age-at-maturity, fecundity, growth, and survival which can affect how the status of the stock and its susceptibility to fishing are determined. Unfortunately, there are few data available for Widow Rockfish that provide insights into these effects.

Fishing has effects on both the age structure of a population as well as the habitat with which the target species is associated. Fishing often targets larger, older fish, and years of fishing mortality results in a truncated age-structure when compared to unfished conditions. Rockfish are often associated with habitats containing living structure such as sponges and corals, and fishing may alter that habitat to a less desirable state. This assessment provides a look at the effects of fishing on age structure, and recent studies on essential fish habitat are beginning to characterize important locations for rockfish throughout their life history; however there is little current information available to evaluate the specific effects of fishing on the ecosystem issues specific to Widow Rockfish.

Reference points

Reference points were calculated using the estimated selectivities and catch distribution among fleets in the most recent year of the model (2014). Sustainable total yields (landings plus discards) were 7,776 mt when using an $SPR_{50\%}$ reference harvest rate and with a 95% confidence interval of 5,881 to 9,670 mt based on estimates of uncertainty. The spawning biomass equivalent to 40% of the unfished spawning output ($SB_{40\%}$) was 32,283 mt. The recent catches (landings plus discards) have been below the point estimate of potential long-term yields calculated using an $SPR_{50\%}$ reference point and the population has been increasing over the last decade.

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

Quantity	Estimate	~95% Confidence Interval
Unfished Spawning Biomass (mt)	80,708	65,427–95,989
Unfished age 4+ biomass (mt)	156,990	127,085–186,895
Unfished recruitment (R0)	60,608	38,622–82,594
Spawning Biomass (2015)	54,490	34,342–74,638
Depletion (2015)	75.1	59.82–90.37
Reference points based on $SB_{40\%}$		
Spawning biomass ($SB_{40\%}$, mt)	32,283	26,171–38,396
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.438	0.438–0.438
Exploitation rate resulting in $B_{40\%}$	0.113	0.102–0.124
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	8,468	6,397–10,540
Reference points based on SPR proxy for MSY		
Spawning Biomass ($SB_{SPR50\%}$, mt)	37,628	30,503–44,752
$SPR_{50\%}$	0.5	NA
Exploitation rate corresponding to $SPR_{50\%}$	0.092	0.083–0.101
Yield with $SPR_{50\%}$ at $SB_{SPR50\%}$ (mt)	7,776	5,881–9,670
Reference points based on estimated MSY values		
Spawning biomass at *MSY* (SB_{MSY}, mt)	18,247	14,812–21,681
SPR_{MSY}	0.275	0.269–0.281
Exploitation rate corresponding to SPR_{MSY}	0.197	0.175–0.218
MSY (mt)	9,464	7,111–11,817

Management performance

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

Table f. 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 discarded biomass.

Year	OFL (mt) (termed ABC prior to 2011)	ABC (mt)	ACL (mt) (termed OY prior to 2011)	Commercial Landings (mt)	Estimated Total Catch (mt)
2004	3,460	NA	284	87	99
2005	3,218	NA	285	195	204
2006	3,059	NA	289	213	221
2007	5,334	NA	368	240	245
2008	5,144	NA	368	264	272
2009	7,728	NA	522	177	186
2010	6,937	NA	509	166	179
2011	5,097	4,872	600	212	213
2012	4,923	4,705	600	270	271
2013	4,841	4,598	1,500	470	473
2014	4,435	4,212	1,500	722	726
2015	4,137	3,929	2,000	NA	NA

Unresolved problems and major uncertainties

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

Discards of Widow Rockfish are even more uncertain than landings, but because Widow Rockfish is a marketable species, historical discard rates were likely lower than less desirable or smaller species. In this assessment, we assumed that discarding was nearly negligible before management restrictions began in 1982. Once trip limits were introduced, discarding tended to be an all or none event, and detecting large, but rare, discard events with far less than 100% observer coverage has a low probability. For the years 2002–2010, 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. However, the open access fixed-gear fleet is not monitored by the full observer coverage required under trawl rationalization and data show that discarding of Widow Rockfish has occurred on fixed gear vessels in recent years (limited entry vessel fishing with fixed gear are subject to 100% observer coverage). Uncertainty in recent discards is greatly reduced because of observer coverage, but it is unknown what historical discarding may have been. The model assumes a discard rate of 1% pre-1982, which is arbitrary, but reasonable.

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 would be less than 0.10 yr^{-1}. However, even with length and age data available back to the late 1970s, natural mortality was estimated above 0.15 yr^{-1} with a small amount of uncertainty (7% coefficient of variation). This assessment attempts to capture that uncertainty by estimating natural mortality (M) and integrating that uncertainty into the derived biomass estimates, as well as additional uncertainty by including levels outside of the predicted interval in a decision table.

Model sensitivities and profiles over M showed that current stock status was highly sensitive to the assumption about natural mortality. 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 0.15 yr^{-1}. Profiles over natural mortality provide support for values above 0.13 yr^{-1}.

Steepness was fixed at 0.798 in the base model, but a likelihood profile showed that it would be estimated at a value less than that. Estimates of M increased slightly with lower steepness, while unfished equilibrium spawning biomass increased and current spawning biomass decreased. Equilibrium yield ranged from approximately 4,000 to 8,000 mt depending on the value of steepness.

Decision table

Model uncertainty has been described by the estimated uncertainty within the base model and by the sensitivities to different model structure. The estimated parameter that resulted in the most variability of predicted status and yield advice was natural mortality (M), which was estimated with much more certainty than the prior distribution implied. In fact, the 95% confidence interval for estimated M was entirely greater than and did not include the point estimate from the prior distribution. There is the possibility that the base model and the approximate uncertainty intervals based on maximum likelihood theory may not entirely convey the actual uncertainty of this assessment. However, preliminary (and non-converged) MCMC tests suggest that the uncertainty is similar to the results presented here for natural mortality, spawning biomass, and depletion.

Three categories of parameters that greatly contribute to uncertainty in the results were natural mortality (an important estimated parameter), steepness (not estimated in the model), and the strength of recent year classes (influential on projections). A combination of these three 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 (0.145 yr^{-1} and 0.170 yr^{-1} for females; 0.158 yr^{-1} and 0.183 yr^{-1} for males). The 12.5% and 87.5% quantile of t 2010 recruitment were also used (0.7340 and 1.3826). 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 (0.682 and 1.333). The low combination of these three factors defined the low state of nature and the high combination of these three factors defined the high state of nature. The predictions of spawning biomass in 2015 from the low and high states of nature are close to the 12.5% and 87.5% lognormal quantiles from the base model.

This assessment synthesizes many sources of data and estimates recruitment variability, thus it is classified as a Category 1 stock assessment. Therefore, the sigma for P* to determine the catch reduction to account for scientific uncertainty is 0.36, since the estimated sigma in the assessment is less than this for current spawning biomass.

Table g. Projection of potential OFL, landings, and catch, summary biomass (age-4 and older), spawning biomass, and depletion for the base case model projected with total catch equal to the default ACL of 2,000 mt annually. The predicted OFL is the calculated total catch determined by $F_{SPR=50\%}$.

Year	Predicted OFL (mt)	Projected Total Catch (mt)	Age 4+ biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2015	4,137*	2,000	132,031	60,608	75.1
2016	3,990*	2,000	135,187	64,599	80.0
2017	14,130	2,000	140,098	67,674	83.9
2018	14,511	2,000	144,029	69,856	86.6
2019	14,746	2,000	146,237	71,533	88.6
2020	14,966	2,000	147,574	72,892	90.3
2021	15,132	2,000	148,209	73,866	91.5
2022	15,200	2,000	148,328	74,413	92.2
2023	15,179	2,000	148,098	74,604	92.4
2024	15,108	2,000	147,654	74,556	92.4
2025	15,016	2,000	147,099	74,369	92.2
2026	14,924	2,000	146,502	74,110	91.8

*Value determined prior to the 2015 assessment as part of the harvest specifications

Table h. Summary table of 12-year projections beginning in 2017 for alternate states of nature based on the axis of uncertainty (a combination of M, h, and 2010 recruitment strength). Columns range over low, mid, and high state of nature, and rows range over different assumptions of total catch levels (discards + retained). Catches in 2015 and 2016 are determined from the percentage of landings for each fleet in 2014.

			State of nature					
			Low		Base case		High	
Relative probability of ln(SB_2013)			0.25		0.5		0.25	
Management decision	Year	Catch (mt)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)	Depletion (%)	Spawning biomass (mt)	Depletion (%)
1000K	2017	1,000	52,762	64%	67,674	84%	79,913	99%
	2018	1,000	54,446	66%	69,856	87%	83,026	102%
	2019	1,000	56,079	68%	71,533	89%	84,926	105%
	2020	1,000	57,729	70%	72,892	90%	85,972	106%
	2021	1,000	59,239	72%	73,866	92%	86,277	106%
	2022	1,000	60,490	73%	74,413	92%	85,944	106%
	2023	1,000	61,486	75%	74,604	92%	85,158	105%
	2024	1,000	62,287	76%	74,556	92%	84,116	104%
	2025	1,000	62,954	76%	74,369	92%	82,969	102%
	2026	1000	63,529	77%	74,110	92%	81,815	101%
Current ACL	2017	2,000	52,762	64%	67,674	84%	79,913	99%
	2018	2,000	54,446	66%	69,856	87%	83,026	102%
	2019	2,000	56,079	68%	71,533	89%	84,926	105%
	2020	2,000	57,729	70%	72,892	90%	85,972	106%
	2021	2,000	59,239	72%	73,866	92%	86,277	106%
	2022	2,000	60,490	73%	74,413	92%	85,944	106%
	2023	2,000	61,486	75%	74,604	92%	85,158	105%
	2024	2,000	62,287	76%	74,556	92%	84,116	104%
	2025	2,000	62,954	76%	74,369	92%	82,969	102%
	2026	2,000	63,529	77%	74,110	92%	81,815	101%
ACL (P* =0.45 and sigma=0.36)	2017	13,491	52,762	64%	67,674	84%	79,913	99%
	2018	12,641	48,317	59%	63,908	79%	77,179	95%
	2019	11,818	44,578	54%	60,327	75%	73,894	91%
	2020	11,188	41,738	51%	57,301	71%	70,629	87%
	2021	10,680	39,486	48%	54,680	68%	67,448	83%
	2022	10,212	37,565	46%	52,283	65%	64,331	79%
	2023	9,777	35,913	44%	50,105	62%	61,384	76%
	2024	9,395	34,519	42%	48,199	60%	58,730	72%
	2025	9,077	33,351	41%	46,588	58%	56,434	70%
	2026	8,820	32,363	39%	45,253	56%	54,498	67%

Research and data needs

There are many areas of research that could be improved to benefit the understanding and assessment of Widow Rockfish. Below, we specifically identify five topics that we believe are most important.

- **Historical landings and discards:** The historical landings and discards are uncertain for Widow Rockfish and improvements would increase the certainty that fishing removals are applied appropriately. Because landings are assumed to be known exactly in the assessment model, uncertainty in the predictions does not include uncertainty in the landings. A thorough look at historical landings, species compositions, and discarding practices would potentially account for and possibly reduce the uncertainty. More importantly, though, a measure of uncertainty on the estimated historical landings would allow for reasonable sensitivities to be investigated.

- **Natural mortality:** Uncertainty in natural mortality translates into uncertain estimates of status and sustainable fishing levels for Widow Rockfish. The collection of additional age data, re-reading of older age samples, reading old age samples that are unread, and improved understanding of the life-history of Widow Rockfish may reduce that uncertainty.

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

- **Age data and error:** There is a considerable amount of error in the age data and potential for bias. Investigating the ageing error and bias would help to understand the influences that the age data have on this assessment.

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

Table i. Summary table of results for the assessment of Widow Rockfish.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Commercial landings (mt)	213	240	264	177	166	212	270	470	722	NA
Total catch (mt)	221	245	272	186	179	213	271	473	726	NA
OFL (mt)	3059	5334	5144	7728	6937	5097	4923	4841	4435	4137
ACL (mt)	289	368	368	522	509	600	600	1500	1500	2000
1-SPR (%)	0.05	0.05	0.06	0.04	0.04	0.04	0.05	0.08	0.11	NA
Exploitation rate (catch/ age 4+ biomass)	0.0027	0.003	0.0032	0.0021	0.002	0.0023	0.0026	0.0042	0.0057	NA
Age 4+ biomass (mt)	80,300	81,347	86,157	86,889	90,515	91,387	106,032	112,532	126,652	132,031
Spawning Biomass	39,164	40,825	42,031	43,110	44,280	45,813	47,912	51,215	55,669	60,608
~95% Confidence Interval	22,905-55,422	24,272-57,377	25,372-58,689	26,388-59,832	27,467-61,093	28,751-62,874	30,355-65,470	32,650-69,779	35,553-75,785	38,622-82,594
Recruitment	53,702	22,470	157,219	32,713	120,622	22,961	43,443	76,349	66,109	53,370
~95% Confidence Interval	30,309-95,149	10,225-49,378	91,670-269,639	15,331-69,803	61,356-237,136	8,562-61,575	14,268-132,274	24,956-233,579	21,826-200,234	17,161-165,975
Depletion (%)	48.5	50.6	52.1	53.4	54.9	56.8	59.4	63.5	69	75.1
~95% Confidence Interval	34.8-62.2	37.0-64.2	38.8-65.4	40.5-66.4	42.2-67.5	44.3-69.2	47.0-71.8	50.6-76.3	55.1-82.8	59.8-90.4

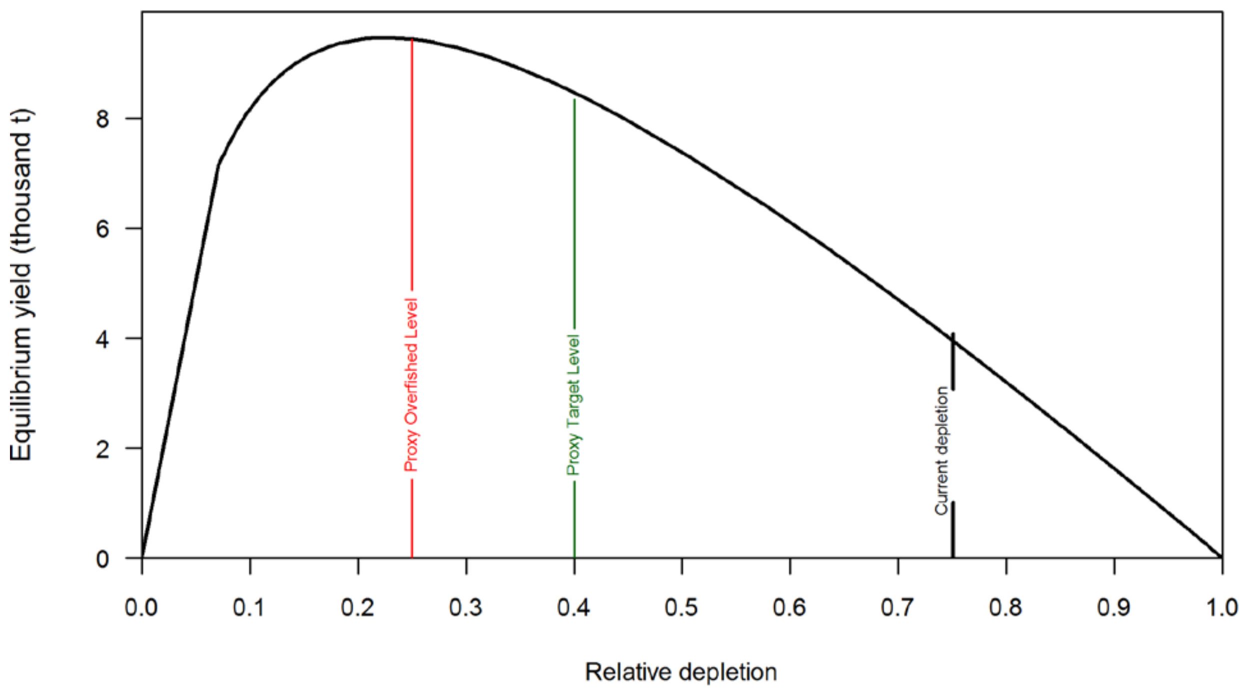

Figure h. Equilibrium yield curve (derived from reference point values reported in Table e) for the base case model. Values are based on 2015 fishery selectivity and distribution with steepness fixed at 0.798. The depletion is relative to unfished spawning biomass.