Fisheries and Oceans Canada
Pêches et Océans Canada

Ecosystems and Oceans Science
Sciences des écosystèmes et des océans

Pacific Region
Canadian Science Advisory Secretariat
Science Advisory Report 2019/044

WIDOW ROCKFISH (*SEBASTES ENTOMELAS*) STOCK ASSESSMENT FOR BRITISH COLUMBIA IN 2019

Widow Rockfish (Sebastes entomelas). Credit: Alaska Fisheries Science Center, National Oceanic and Atmospheric Administration.

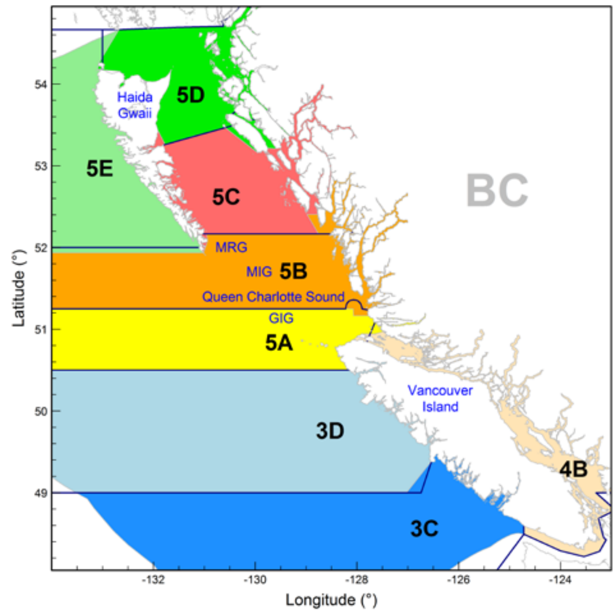

Figure 1. Widow Rockfish assessment areas comprising Pacific Marine Fisheries Commission (PMFC) major areas outlined with solid lines and used in this assessment. The Groundfish Management Unit area boundaries, based on Pacific Fisheries Management Areas, are superimposed as shaded polygons for comparison. This assessment is for all offshore areas combined (3CD5ABCDE, blue through green).

Context

Widow Rockfish (WWR, Sebastes entomelas) is a long-lived, commercially important species of rockfish found along the Pacific Rim of North America. Its commercial attractiveness stems from its propensity to aggregate in shoals at night, making it vulnerable to midwater trawl. Widow Rockfish supports the fourth largest rockfish fishery (based on the 2019 management harvest plan) in British Columbia (BC) with an annual coastwide total allowable catch (TAC) in 2019 of 2358 t and an average annual catch of 2001 t from 2014-2018. This quantitative age-structured stock assessment treats the BC population of WWR as a single coastwide stock based on the absence of regional or gear specific differences in biology. Harvest advice is provided showing that current harvest levels are sustainable and compliant with Fishery and Ocean's Canada (DFO) Decision-making Framework Incorporating the Precautionary Approach (DFO 2009).

This Science Advisory Report is from the June 18-19, 2019 regional peer review on Widow Rockfish (Sebastes entomelas) stock assessment for British Columbia in 2019. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- A single Widow Rockfish (WWR) stock was identified along the British Columbia (BC) coast based on no observable differences in mean weight, observed length, and growth models among three regional areas (BC North=PMFC 5E, BC Central=PMFC 5ABCD, BC South=PMFC 3CD). Also, there were no observable differences in WWR biology by fishing gear type.
- The WWR stock was assessed using a single fishery, annual two-sex catch-at-age model, implemented in a Bayesian framework to quantify uncertainty of estimated quantities. A composite base case that combined nine models across three fixed values for natural mortality (M) and three accumulator ages was used to evaluate this stock.
- The median (5 and 95 percentiles of the Bayesian results) female spawning biomass at the beginning of 2019 (B_{2019}) is estimated to be 0.37 (0.26, 0.54) of unfished female spawning biomass (B_0). Also, B_{2019} is estimated to be 1.51 (0.92, 2.61) of the equilibrium spawning biomass at maximum sustainable yield, B_{MSY}.
- At current catch levels, there is an estimated probability of >0.99 that $B_{2019} > 0.4B_{\text{MSY}}$ and a probability of 0.98 that $B_{2019} > 0.8B_{\text{MSY}}$ (i.e. of being in the healthy zone). The probability that the exploitation rate in 2018 was below that associated with MSY is 0.82.
- Advice to management is presented in the form of decision tables using the provisional reference points from the Fisheries and Oceans Canada (DFO) Sustainable Fisheries Framework (SFF) Precautionary Approach (DFO 2009). The decision tables provide five-year projections across a range of constant catches (Table 2).
- The appropriateness of the MSY based reference points for long-lived low productivity species is uncertain; consequently advice to management relative to reference points based on 0.2 and 0.4 of B_0 is also presented as alternative options (Appendix F, of the associated Research Document).
- It is recommended that the next assessment occur after 2024, with three new index values available from each of the three biennial synoptic trawl surveys relevant to WWR and five additional years of ageing and catch data. Intermediate progress before the next assessment year can be tracked using the commercial bottom trawl catch per unit effort (CPUE).
- Recommended future work includes the possible use of acoustic surveys to index WWR abundance, an increase in the level of biological sampling of commercial trawl catch of WWR, the use of geo-statistical methods for computing survey biomass indices and exploring improved biological sampling within the suite of groundfish.

INTRODUCTION

Widow Rockfish (*Sebastes entomelas*, WWR) is ubiquitous along the BC coast (Figure 1) (at ~100-500 m depth) and occurs in high densities along the west coast of Vancouver Island (WCVI) and off the shelf edge between the top of Vancouver Island and south of Cape St. James. Shoals of WWR have been studied near Triangle Island using acoustic surveys. This species exhibits diel migration from near bottom during the day to midwater at night, feeding on shrimps, euphausiids, salps, and fish. Night time aggregations make WWR very susceptible to the midwater trawl fishery. This species supports the fourth largest rockfish fishery in BC with an annual coastwide 'total allowable catch' (TAC) in 2017 of 2,358 t (98% allocated to the trawl fishery) and an average annual catch by all fisheries combined of 2001 t from 2014-2018. This stock assessment evaluates a BC coastwide population harvested by one fishery comprising combined bottom and midwater trawl tows. Analyses of demographic data did not support separate regional stocks for WWR, hence a single coastwide stock was assumed. Furthermore these data did not support considering separate selectivities for bottom and midwater trawl gear.

ASSESSMENT

The catch-at-age model used for the stock assessment was tuned to five fishery-independent trawl survey series (covering 1967-2018), a standardized commercial bottom trawl CPUE series (1996-2018), annual estimates of commercial catch, and age composition data from the commercial fishery and four of the five surveys. The model started from an assumed equilibrium state in 1940. Nine base runs using a two-sex model were implemented in a Bayesian framework (using the Markov Chain Monte Carlo procedure) under a range of scenarios that fixed natural mortality (M) to three levels (0.07, 0.08, 0.09) and set the accumulator age (A) to three values (40, 45, 50 y) while estimating steepness of the stock-recruit function (h), catchability (q) for surveys and CPUE, and selectivity (μ) for surveys and the commercial trawl fleet. These nine runs were combined into a composite base case which explored the major axes of uncertainty (M and A) in this stock assessment.

Each component run of the composite base case reconstructed the time series of vulnerable biomass (total of male and female biomass that is vulnerable to capture by the fishery) and spawning stock biomass (mature females only), given the model assumptions and parameter estimates. The estimated parameters were used to calculate maximum sustainable yield (MSY) and reference points. Five-year projections were performed over a range of constant catches to estimate probabilities of breaching reference points.

All calculations were made using the Bayesian Markov Chain Monte Carlo (MCMC) method to quantify parameter uncertainty. For each of the base runs, twelve million simulations were sampled to yield 1,000 MCMC samples (after dropping the first 200 samples as ‘burn-in’) from the posterior distributions for estimated parameters. Estimates of various quantities were calculated from nine pooled runs (9000 MCMC samples), and are presented as the median (with 5 and 95% quantiles to specify uncertainty). Calculated probabilities are also based on the MCMC posterior distributions.

Advice to managers is presented as sets of decision tables that provide probabilities of exceeding reference points (consistent with the DFO SFF Precautionary Approach [DFO 2009]): $0.4B_{MSY}$; $0.8B_{MSY}$) as well as remaining below u_{MSY} for 2019 through 2024 for a range of constant catch levels.

Figure 2 shows the composite base case posterior distribution of the estimated annual spawning biomass (mature females only) for the coastwide stock, together with the historical catches (males and females). The coastwide WWR stock was not greatly reduced by the early foreign fleet fishery (1965-76) but experienced a prolonged decline once the domestic fishery took over in 1977, which also coincided with a period of low recruitment. The decline ended when catch limits, implemented through Individual Vessel Quotas (IVQ), were imposed in 1997. A mandatory system of onboard observers was also implemented at the same time. A major recruitment event in 1961 likely ameliorated the effects of the foreign fleet activity, and a second major recruitment in 1990 likely stabilised the population in conjunction with management controls (Figure 3). Further, good recruitment years in 2006 and 2008 should sustain the population in coming years. The composite base case exploitation rate peaked at 0.16 in 1992, and is estimated to be 0.10 (0.06, 0.15) in 2018 (Figure 4).

The trend of spawning biomass and exploitation rate relative to MSY (Figure 5) suggests that the stock has been sustainably exploited in recent years, with a current position at B_{2019}/B_{MSY} = 1.51 (0.92, 2.61) and u_{2018}/u_{MSY} = 0.66 (0.29, 1.35).

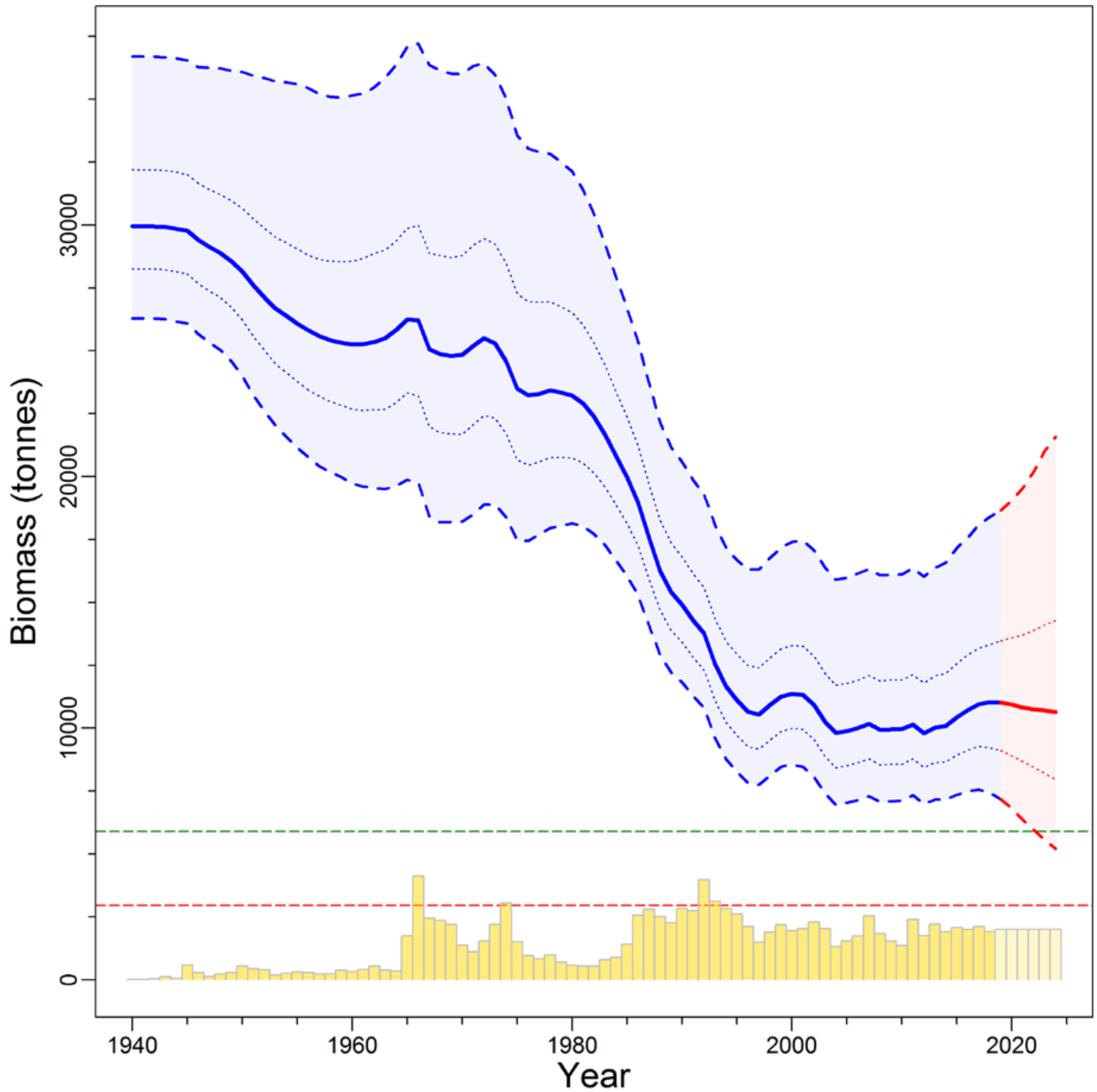

Figure 2. Estimates of spawning biomass B_t (tonnes) from the model posteriors of the composite base case. The median biomass trajectory appears as a solid curve surrounded by a 90% credibility envelope (quantiles: 0.05, 0.95) in light blue and delimited by dashed lines for years t=1940-2019; projected biomass appears in light red for years t=2020-2024. Also delimited is the 50% credibility interval (quantiles: 0.25-0.75) delimited by dotted lines. The horizontal dashed lines show the median limit reference point (LRP) and Upper Stock Reference (USR). Catch and assumed catch policy (2000 t/y) are represented as bars along the bottom axis.

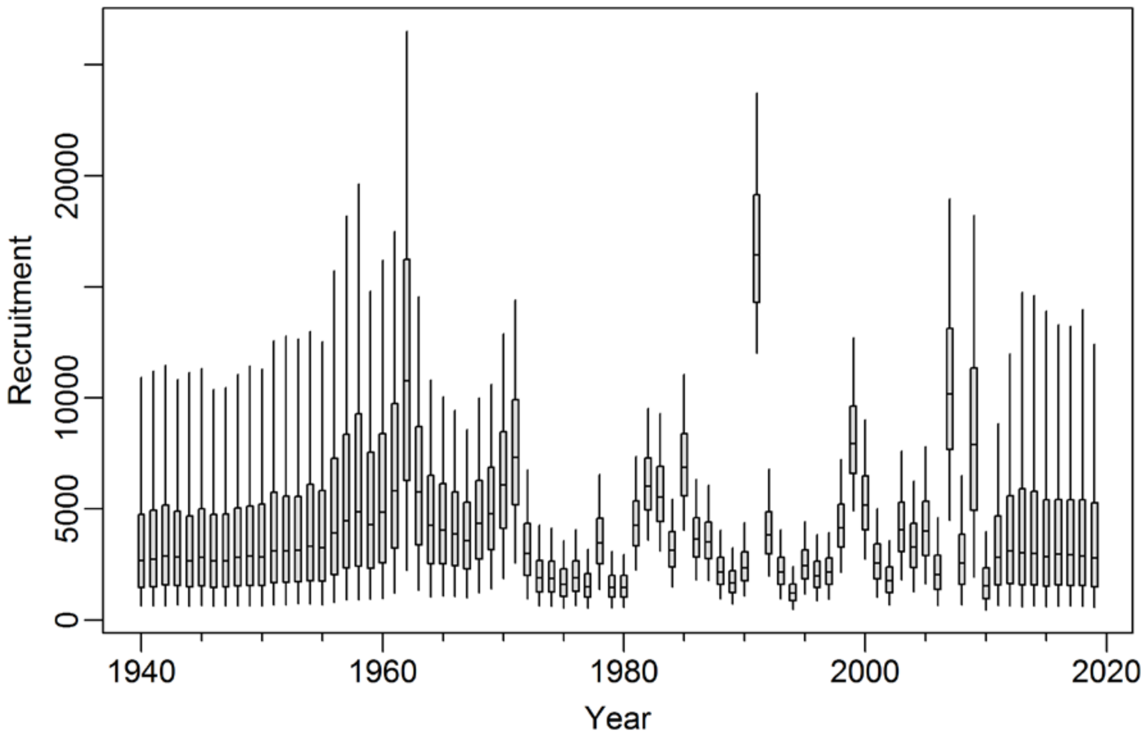

Figure 3. Composite base case: marginal posterior distribution of recruitment (in 1000s of age-1 fish) for each year. Boxplots give the 0.05, 0.25, 0.5, 0.75 and 0.95 quantiles from the MCMC results.

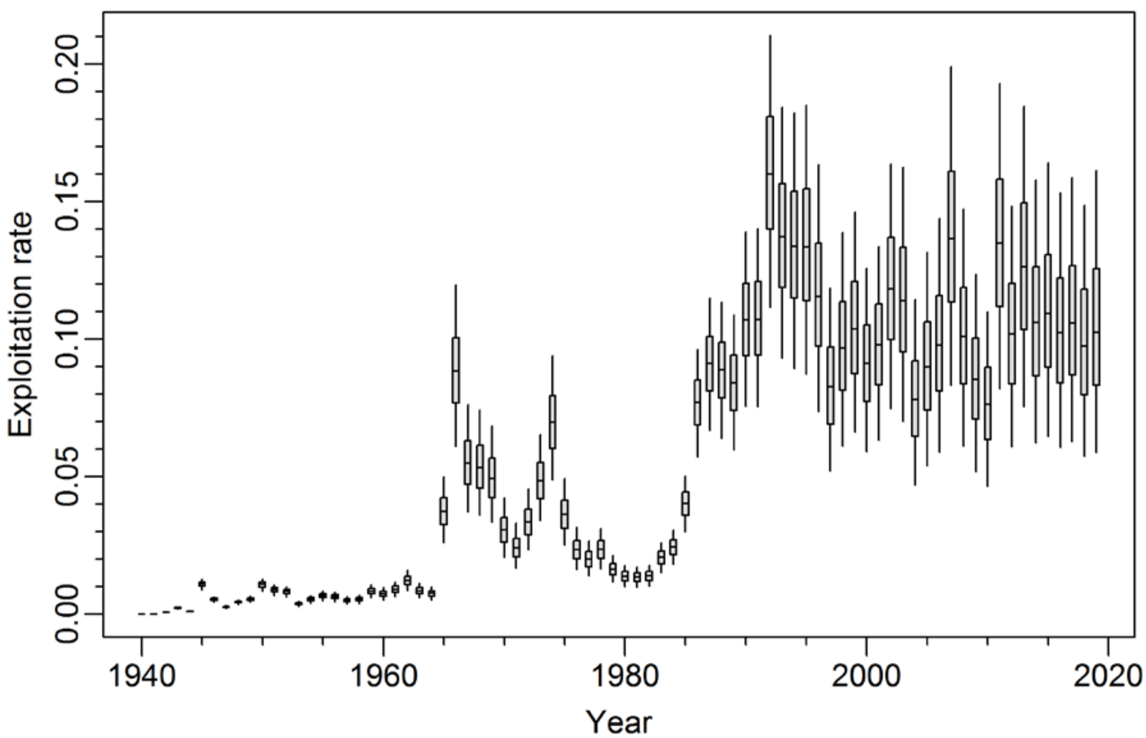

Figure 4. Composite base case: marginal posterior distributions of annual exploitation rate by year. Boxplots give the 0.05, 0.25, 0.5, 0.75 and 0.95 quantiles from the MCMC results.

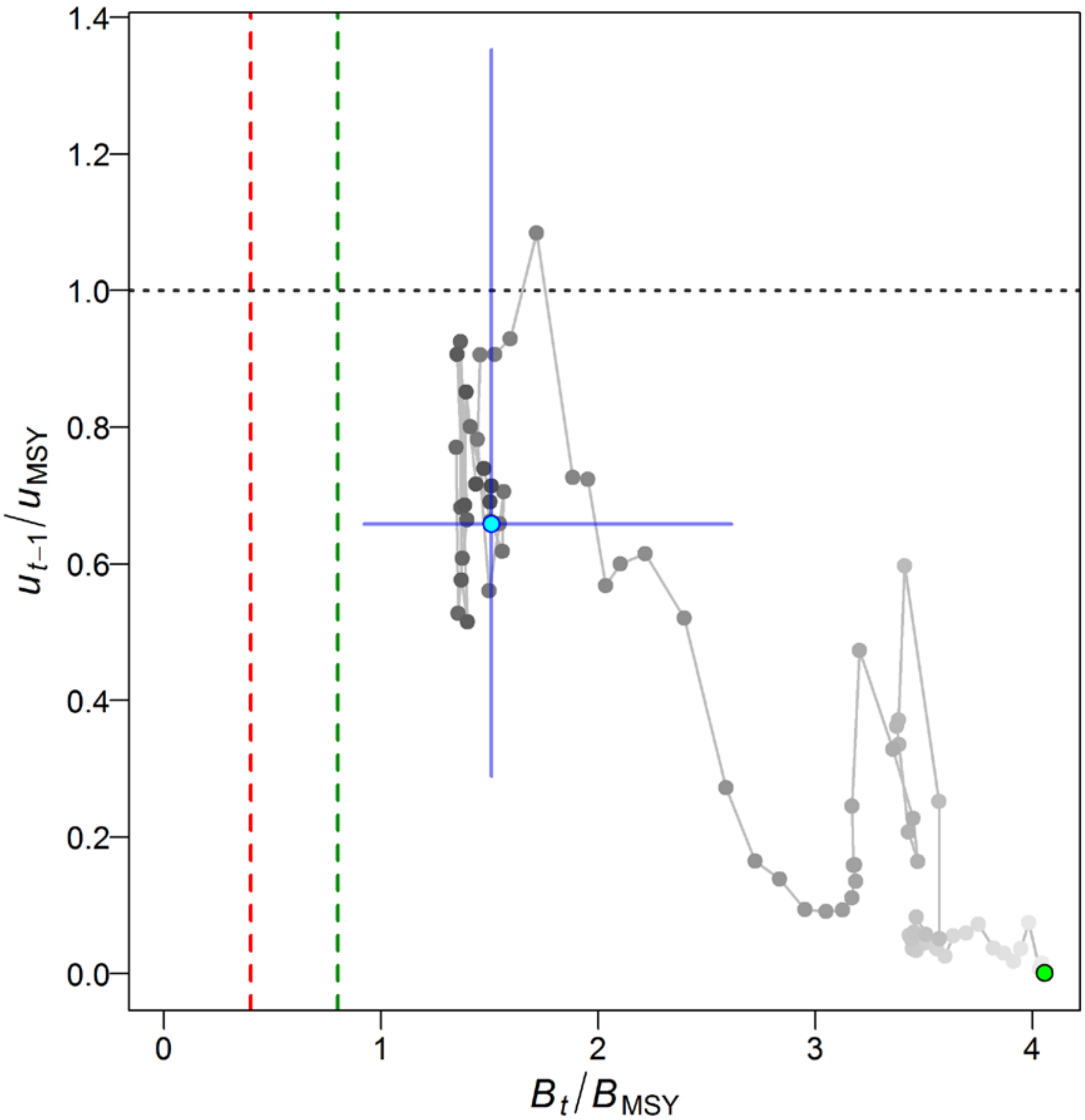

Figure 5. Composite base case: phase plot through time of the medians of the ratios B_t/B_{MSY} (the spawning biomass in year t relative to B_{MSY}) and u_{t-1}/u_{MSY} (the exploitation rate in year t - 1 relative to u_{MSY}). The filled green circle is the starting year (1941). Years then proceed from light grey through to dark grey with the final year (2019) as a filled cyan circle, and the blue lines represent the 0.05 and 0.95 quantiles of the posterior distributions for the final year. Red and green vertical dashed lines indicate the Precautionary Approach provisional limit and USR points (0.4, 0.8 B_{MSY}), and the horizontal grey dotted line indicates u at MSY.

Table 1. Quantiles of MCMC-derived quantities from the 9,000 samples of the MCMC posterior of the composite base case. Definitions: B_0 – unfished equilibrium spawning biomass (mature females), V_0 – unfished equilibrium vulnerable biomass (males and females), B_{2019} – spawning biomass at the start of 2019, V_{2019} – vulnerable biomass in the middle of 2018, u_{2018} – exploitation rate (ratio of total catch to vulnerable biomass) in the middle of 2018, u_{max} – maximum exploitation rate (calculated for each sample as the max. exploitation rate from 1940-2018), B_{MSY} – equilibrium spawning biomass at MSY (maximum sustainable yield), u_{MSY} – equilibrium exploitation rate at MSY, V_{MSY} – equilibrium vulnerable biomass at MSY. All biomass values (and MSY) are in tonnes. The average catch over the last 5 years (2014-18) was 2001 t.

	From model output		
Value	**5%**	**50%**	**95%**
B_0	26,282	29,951	36,692
V_0	46,361	53,380	66,080
B_{2019}	7,179	11,017	18,660
V_{2019}	12,396	19,526	34,035
B_{2019} / B_0	0.257	0.369	0.537
V_{2019} / V_0	0.252	0.366	0.54
u_{2018}	0.0574	0.0975	0.149
u_{max}	0.112	0.161	0.214

	MSY-based quantities		
Value	**5%**	**50%**	**95%**
MSY	1,460	1,909	2,685
B_{MSY}	4,815	7,373	11,307
$0.4B_{MSY}$	1,926	2,949	4,523
$0.8B_{MSY}$	3,852	5,898	9,045
B_{2019} / B_{MSY}	0.921	1.51	2.61
B_{MSY} / B_0	0.17	0.246	0.327
V_{MSY}	8,284	13,145	20,430
V_{MSY} / V_0	0.168	0.247	0.33
u_{MSY}	0.081	0.148	0.271
u_{2018} / u_{MSY}	0.289	0.658	1.35

The estimated ratio of current spawning biomass (B_{2019}) to equilibrium unfished biomass B_0, is 0.37 (0.26, 0.54). The estimated median MSY is 1909 t (1460, 2685) t, compared to the average catches over the last five years (2014-2018) of 2001 t. The estimated value of B_{2019}/B_{MSY}, where B_{MSY} is the equilibrium spawning biomass that would support the MSY, is 1.51 (0.92, 2.61).

Reference Points

Figure 6 shows the stock status relative to the provisional DFO (2009) limit and USR points of $0.4B_{MSY}$ and $0.8B_{MSY}$ respectively. These reference points define the critical, cautious and healthy zones. The composite base case spawning biomass at the beginning of 2019 is estimated to be above the limit reference point with probability $P(B_{2019} > 0.4B_{MSY}) > 0.99$, and above the upper stock reference point with probability $P(B_{2019} > 0.8B_{MSY}) = 0.98$. More precisely, the composite base case has a probability of < 0.01 of being in the critical zone, a 0.02 probability of being in the cautious zone, and a 0.98 probability of being in the healthy zone. All of the component runs of the base case lie in the healthy zone.

MSY-based reference points estimated within a stock assessment model can be highly sensitive to model assumptions about natural mortality and stock recruitment dynamics (Forrest et al.

2018). As a result, other jurisdictions use reference points that are expressed in terms of B_0 rather than B_{MSY} (e.g. New Zealand Ministry of Fisheries 2011) Therefore, the reference points of $0.2B_0$ and $0.4B_0$ are also presented in Appendix F of the Research Document. These are default values used in New Zealand respectively as a 'soft limit', below which management action needs to be taken, and a 'target' biomass for low productivity stocks, a mean around which the biomass is expected to vary. The "soft limit" is equivalent to the Upper Stock Reference (USR, $0.8B_{MSY}$) in the provisional DFO SFF while a 'target' biomass is not specified.

A second component of the provisional harvest rule of DFO (2009) concerns the relationship of the exploitation rate relative to that associated with MSY under equilibrium conditions (u_{MSY}). The rule specifies that the exploitation rate should not exceed u_{MSY} when the stock is in the healthy zone. Catches should be reduced when in the cautious zone, and be kept to the lowest level possible when in the critical zone. The estimated ratio of u_{2018}/u_{MSY}, which the harvest rule specifies should be ≤1, is 0.66 (0.29, 1.35) (Table 1). The probability that the current exploitation rate is below that associated with MSY is P(u_{2018} < u_{MSY}) = 0.82.

The stock is estimated to have been in the healthy zone (above $0.8B_{MSY}$) since the start of fishing in 1940 (based on median values) and the median exploitation rate is estimated to have been greater than u_{MSY} only once during this period (*Figure* 5).

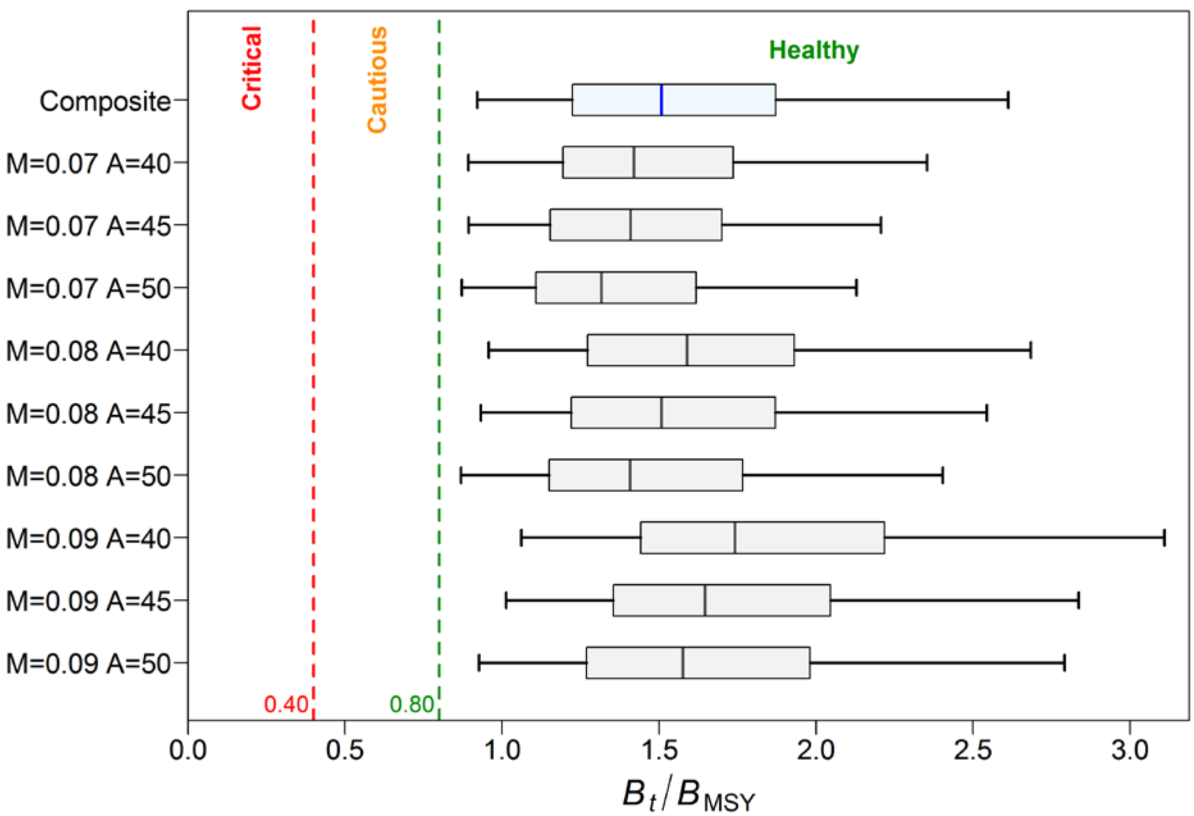

Figure 6. Status of the coastal WWR stock relative to the DFO Precautionary Approach provisional reference points of $0.4B_{MSY}$ and $0.8B_{MSY}$ for the t=2019 composite base case and the component base models. Boxplots show the 0.05, 0.25, 0.5, 0.75 and 0.95 quantiles from the MCMC posterior.

Projection Results and Decision Tables

Five-year projections, starting with the biomass at the beginning of 2019, were made over a range of constant catch levels (0-4,000 t in 250 t increments). This time frame was considered adequate for long-term advice and short enough for projections to be mainly based on individuals spawned before 2010 (and therefore explicitly estimated by the assessment model). The decision table (Table 2) gives the probabilities of the spawning biomass exceeding the biomass reference points and of being below u_{MSY} in each projected year for each catch level. Note that these tables assume that catches are held constant, so there is no consequent reduction of the exploitation rate in the projections if a stock reaches the cautious or critical zones.

Generally, it is up to managers to choose the preferred catch levels and the preferred risk levels. For example, it may be desirable to be 95% certain that B_t exceeds an LRP whereas exceeding a USR might only require a 50% probability in 2024. Assuming this risk profile, a catch policy of 2750 t/y would satisfy the LRP constraint and 3750 t/y would satisfy the USR constraint. Assuming that u_{MSY} is a target exploitation rate, a catch policy of 2250 t/y would mean that the harvest rate in 2024 would be less than u_{MSY} with a probability of at least 50%.

Table 2. Decision tables for the reference points 0.4B_{MSY}, 0.8B_{MSY}, and u_{MSY} for 1-5 year projections for a range of constant catch strategies (in tonnes) using the composite base case. Values are the probability (proportion of 9000 MCMC samples) of the female spawning biomass at the start of year t being greater than the B_{MSY} reference points, or the exploitation rate of vulnerable biomass in the middle of year t being less than the u_{MSY} reference point. For reference, the average catch over the last 5 years (2014-2018) was 2001 t. The use of "1" in the table does not necessarily represent perfect probability but rather a rounded value equivalent to >0.99.

	P(B_t >0.4B_{MSY})						P(B_t >0.8B_{MSY})						P(u_t <u_{MSY})					
Catch	2019	2020	2021	2022	2023	2024	2019	2020	2021	2022	2023	2024	2019	2020	2021	2022	2023	2024
0	1	1	1	1	1	1	0.98	0.99	1	1	1	1	1	1	1	1	1	1
250	1	1	1	1	1	1	0.98	0.99	0.99	1	1	1	1	1	1	1	1	1
500	1	1	1	1	1	1	0.98	0.99	0.99	0.99	1	1	1	1	1	1	1	1
750	1	1	1	1	1	1	0.98	0.99	0.99	0.99	0.99	0.99	1	1	1	1	1	1
1000	1	1	1	1	1	1	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
1250	1	1	1	1	1	1	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.96	0.96
1500	1	1	1	1	1	1	0.98	0.98	0.98	0.97	0.97	0.96	0.93	0.92	0.92	0.91	0.91	0.90
1750	1	1	1	1	1	1	0.98	0.98	0.97	0.96	0.95	0.94	0.86	0.85	0.84	0.83	0.82	0.81
2000	1	1	1	1	1	0.99	0.98	0.97	0.96	0.95	0.93	0.91	0.78	0.77	0.75	0.73	0.72	0.70
2250	1	1	1	1	0.99	0.99	0.98	0.97	0.95	0.93	0.90	0.87	0.70	0.67	0.65	0.63	0.61	0.59
2500	1	1	1	1	0.99	0.98	0.98	0.97	0.94	0.90	0.86	0.82	0.61	0.58	0.55	0.53	0.51	0.49
2750	1	1	1	0.99	0.98	0.97	0.98	0.96	0.93	0.87	0.82	0.77	0.54	0.50	0.47	0.44	0.42	0.40
3000	1	1	1	0.99	0.97	0.94	0.98	0.96	0.91	0.85	0.78	0.72	0.47	0.43	0.39	0.36	0.34	0.31
3250	1	1	1	0.99	0.96	0.91	0.98	0.95	0.89	0.81	0.73	0.66	0.40	0.36	0.33	0.30	0.27	0.25
3500	1	1	1	0.98	0.93	0.87	0.98	0.95	0.87	0.77	0.68	0.60	0.35	0.30	0.26	0.24	0.21	0.20
3750	1	1	0.99	0.97	0.90	0.82	0.98	0.94	0.85	0.74	0.63	0.55	0.30	0.25	0.21	0.19	0.17	0.15
4000	1	1	0.99	0.95	0.87	0.77	0.98	0.93	0.83	0.70	0.58	0.49	0.25	0.21	0.17	0.15	0.13	0.12

Sources of Uncertainty

Uncertainty in the estimated parameters is explicitly addressed using a Bayesian approach, with credibility intervals and probabilities provided for all quantities of interest. These intervals and probabilities are only valid for the specified model using the weights assigned to the various data components across the nine runs comprising the composite base case. The Bayesian approach also relies on the prior belief about each input parameter. In particular, the committee noted that natural mortality (*M*) was a key uncertainty for this species, especially as it could not be estimated. Using a range of *M* values and accumulator ages helped to capture this uncertainty in model results.

Other uncertainties were explored through sensitivity runs. These included:

- productivity assumptions – estimating/increasing *M*, changing standard deviation of recruitment residuals;
- abundance – decreasing/increasing historical catch, removing the CPUE signal, dropping added process error to CPUE, using an alternative CPUE model;
- composition – adding ageing error, removing survey ages.

All sensitivity runs remained primarily in the healthy zone. Explorations of alternative model runs which either estimated *M* or used *M*>0.09 improved perceived stock status relative to B_0; however, these runs had poor MCMC diagnostics.

Although the coastwide population of Widow Rockfish might comprise multiple stocks, these could not be separated given the data available at the time of the stock assessment. Future assessments might adopt spatially distinct stocks if additional data support subdivision.

Ecosystem Considerations and Climate Change

In 2012, measures were introduced to reduce and manage the bycatch of corals and sponges by the BC groundfish bottom trawl fishery. These measures were developed jointly by industry and environmental non-governmental organisations, and include: limiting the footprint of groundfish bottom trawl activities to manage the trawl fishery impacts on significant ecosystem components such as corals and sponges, establishing a combined bycatch conservation limit for corals and sponges, and establishing an encounter protocol for individual trawl tows when the combined coral and sponge catch exceeds 20 kg. These measures have been incorporated into DFO's Pacific Region Groundfish Integrated Fisheries Management Plan (Pacific Region Integrated Fisheries Management Plan, Groundfish, Effective February 21, 2017).

The fishery is also subject to the following management measures: 100% at-sea monitoring, 100% dockside monitoring, individual vessel accountability for all retained and released catch, individual transferable quotas and reallocation of these quotas between vessels and fisheries to cover catch of non-directed species (see aforementioned Management Plan).

While assessments and harvest options for groundfish species in the Pacific region are provided on a single species basis, the fishery is managed in a multi-species context wherein many single species quotas are managed simultaneously. Additionally, freezing the footprint of the trawl fishery reduces the likelihood of impacts from the activities of the commercial bottom trawl fleet expanding into new benthic habitats.

It is not known how climate change will affect this species and the conclusions made by this stock assessment. Although there is agreement that warmer temperature regimes and changes to other environmental variables such as dissolved oxygen will affect marine species, the exact nature of these effects is poorly understood. Previous attempts at incorporating climate variables into stock assessments such as this one have proved unsuccessful, largely because of low contrast in the introduced series, a too short time series, or overly simplistic (or unrealistic) functional models. Warmer temperatures may affect recruitment processes, natural mortality, and growth, any of which may affect stock resilience, productivity, and status relative to reference points which may in turn alter the perception of consequences associated with varying harvest levels relative to stock status. As well, reference points which rely on equilibrium conditions will shift because changing temperature regimes imply a change in productivity and consequently a different equilibrium level. Understanding the effect of climate change in a marine context will require additional monitoring and analyses.

CONCLUSIONS AND ADVICE

The assessment depicts a slow-growing, low-productivity stock which experienced commercial fishing by foreign and domestic fleets before the implementation of IVQs in 1997. Exploitation rates have since declined to moderate levels: median u_{2018}= 0.10 for the composite base case, which is similar to the assumed rates of natural mortality for the WWR stock.

It is recommended that the next assessment occur after 2024, once three new index values from each of the three synoptic surveys and five additional years of commercial fleet ageing and catch data become available. The estimated strong 2006 and 2008 year classes provide some confidence to the five year projections, making it unlikely that early intervention would be required. Intermediate progress before the next assessment year can be tracked using the commercial bottom trawl CPUE, given that this series shows the least inter-annual variation among the available biomass series. The relative errors associated with this species in the synoptic surveys are sufficiently large to exclude these series as reliable candidates for short term monitoring. Rapid intervention in the case of apparent stock decline is unlikely because there needs to be at least 6-12 months lead time to allow for the reading of new ageing structures necessary for any new assessment. However, advice for interim years is explicitly included in the decision tables and managers can select another line on the table if stock abundance appears to have declined and if greater certainty of staying above the reference point is desired.

Advice to management is provided in the form of decision tables. The tables assume the model to be valid and no future management interventions would occur if stock status changes for each level of constant catch.

LIST OF MEETING PARTICIPANTS

Last Name	First Name	Affiliation
Anderson	Sean	DFO Science, Groundfish Section
Candy	John	DFO Science, Centre for Science Advice Pacific
Dealy	Lindsay	DFO Science
Grandin	Chris	DFO Science, Groundfish Section
Haggarty	Dana	DFO Science, Groundfish Section
Haigh	Rowan	DFO Science, Groundfish Section
Hicks	Allan	International Pacific Halibut Commission
Holt	Kendra	DFO Science, Quantitative Assessment Methods
Keppel	Elise	DFO Science, Groundfish Section
Olmstead	Melissa	DFO Science
Rooper	Chris	DFO Science, Quantitative Assessment Methods
Starr	Paul	Canadian Groundfish Conservation Society
Surry	Maria	DFO Science, Fishery + Assessment Data
Tadey	Rob	DFO Resource Management, Groundfish
Wallace	Scott	David Suzuki Foundation
Workman	Greg	DFO Science, Groundfish Section

SOURCES OF INFORMATION

This Science Advisory Report is from the June 18-19, 2019 regional peer review on Widow Rockfish (*Sebastes entomelas*) stock assessment for British Columbia in 2019. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

DFO 2009. A fishery decision-making framework incorporating the Precautionary Approach, (last reportedly modified 23 May 2009, though figures have since changed). (Accessed June 18, 2019)

Forrest, R.E., Holt, K.R., Kronlund, A.R. 2018. Performance of alternative harvest control rules for two Pacific groundfish stocks with uncertain natural mortality: Bias, robustness and trade-offs. Fish. Res. 206, 259 – 286.

THIS REPORT IS AVAILABLE FROM THE:

Centre for Science Advice
Pacific Region
Fisheries and Oceans Canada
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

Telephone: (250) 756-7208
E-Mail: csap@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087

Correct Citation for this Publication:

DFO. 2019. Widow Rockfish (*Sebastes entomelas*) stock assessment for British Columbia in 2019. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/044.

Aussi disponible en français :

MPO. 2019. Évaluation des stocks de veuves (Sebastes entomelas) de la Colombie-Britannique en 2019. Secr. can. de consult. sci. du MPO, Avis sci. 2019/044.