Agenda Item H.5
Attachment 15
September 2019

A 2019 Catch-Only Projection from the 2015 Assessment of the Status of Black Rockfish (*Sebastes melanops*) along the U.S. West Coast

Andi Stephens

Northwest Fisheries Science Center
U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
2032 Marine Science Drive
Newport, Oregon 97365

Contents

1 Introduction

Stock and Assessments

The three catch-only update assessments described in this document apply to the Black Rockfish (*Sebastes melanops*) stocks that reside in the waters from Point Conception (34°27' N latitude) in the south to the U.S. boundary with Canada (approximately 48°30' N latitude). Following the consensus recommendations from a preliminary stock assessment workshop in April 2015 (PFMC 2015), the stock assessment team prepared three separate geographic stock assessments that are spatially stratified with boundaries at the CA/OR border (42°00' N latitude) and OR/WA border (46°16' N latitude).

As the three models differ considerably in input data and model structure, the subsequent sections of this document provide stand-alone assessment summaries for each state, performed using Stock Synthesis version 3.24, as in the original assessments. Table I-1 offers a comparison of the landings by sector in the three states.

Table I-1: Recent Black Rockfish removals by state (mt).

Year	CA Com	CA Rec	OR Com	OR Rec	WA Com	WA Rec
2009	94	243	136	310	0.003	251
2010	52	201	102	318	0.034	219
2011	27	178	98	221	0.997	231
2012	22	210	98	233	0.994	281
2013	35	363	108	328	0.009	325
2014	41	339	124	362	1.067	355
2015	103	227	123	477	1.751	349
2016	65	166	106	431	2.276	360
2017	54	97	125	422	0.449	226
2018	46	92	123	295	0.184	254

Data and Forecasts

For this catch-only update, catch data from 2015-2018 were added to each model, and the Pacific Council's Groundfish Management Team (GMT) provided catch estimates for 2019 and 2020. Forecasts begin in 2021 and assume full ACL/ABC removals, with annually increasing uncertainty buffers.

Temporally Increasing Uncertainty

Each update accounts for increasing uncertainty over time by annual adjustments to the buffer applied to the forecast for the following year. This was accomplished in the model by increasing the sigma value (σ) applied in each year (Table I-2). The ACLs projected in each forecast year were assumed to be fully attained, and each was proportioned among the fleets in the model according to the percentages seen in the catches in recent years. The Oregon buffers differ from those applied to Washington and California, as the Oregon stock is a Category II stock, with a sigma twice the size of the Category I sigma (Table I-2).

The algorithm for increasing sigma based on the elapsed time (t) since the stock was fully assessed is:

Sigma (years since assessment) = (baseline sigma) * (1.0 + (years since assessment – 1)*0.075)

$$\sigma_t = \sigma_{t=0} * (1.0 + (t - 1) * 0.075)$$

The buffer multiplier *b* (such that the ACL = *b* * OFL) is defined as the P* quantile of the lognormal distribution with median = 1 and sigma = sigma. The R code for this is:

$$b = \text{qlnorm}(P^*, 0, \sigma_t)$$

Finally, the size of the buffer as shown below is:

$$\text{Buffer} = 1\text{-}b$$

Table I-2: Buffers applied to the OFL forecasts for each year following the assumed catch in 2020, with the associated timeseries of increasing sigmas.

Year	Oregon		California and Washington	
	P*0.45; Category II Stock; σ = 1		P*0.45; Category I Stocks; σ = 0.5	
	Buffer	**σ**	**Buffer**	**σ**
2021	15.9%	1.075	8.3%	0.538
2022	16.7%	1.150	8.7%	0.575
2023	17.4%	1.225	9.1%	0.613
2024	18.2%	1.300	9.6%	0.650
2025	19.0%	1.375	10.0%	0.688
2026	19.7%	1.450	10.4%	0.725
2027	20.5%	1.525	10.8%	0.763
2028	21.2%	1.600	11.3%	0.800
2029	22.0%	1.675	11.7%	0.838
2030	22.7%	1.750	12.1%	0.875

2 California

Catch

Black Rockfish are caught by a wide variety of gear types and in recent decades have been a very important target species for recreational charter-boats and private sport anglers. In recent years the recreational fishery has accounted for most of the Black Rockfish catches (Figure CA-1). Black Rockfish can also be an important component of nearshore commercial fisheries, either as incidental catch by the troll fishery for salmon or as directed catch by jig fisheries for groundfish. California has a growing nearshore fishery that catches and sells fish live for the restaurant trade. There have been almost no trawl-caught landings of Black Rockfish in recent years (Table CA-1), but trawl landings in the past were substantial (Figure CA-1).

Detailed reports of commercial landings of Black Rockfish are generally unavailable prior to 1981, when the Pacific Fishery Information Network (PacFIN) database began. The catch series prior to 1981 for these assessments were derived by applying available estimates or assumed values for the proportion of Black Rockfish landings in reported landings of rockfish. Observer data, which are available only for the past decade, indicate low levels of discarding of Black Rockfish, generally less than 2% of the total catch.

Because of their nearshore distribution and low abundance compared to other rockfish species, Black Rockfish are unlikely to have ever comprised a large percentage of rockfish landings, but it seems quite certain that they have been more than a trivial component for many years. Black Rockfish were one of only six rockfish species mentioned by scientific name in reports of rockfish landings in California during the 1940s.

Table CA-1. Recent catch by fishery in California.

Year	Trawl	NonTrawl Dead	NonTrawl Live	Rec
2009	0.10	27	67	243
2010	0.00	12	40	201
2011	0.00	10	17	178
2012	0.00	10	12	210
2013	0.00	14	21	363
2014	0.00	17	24	339
2015	0.08	38	65	227
2016	0.27	31	33	166
2017	0.00	20	35	97
2018	0.01	19	27	92

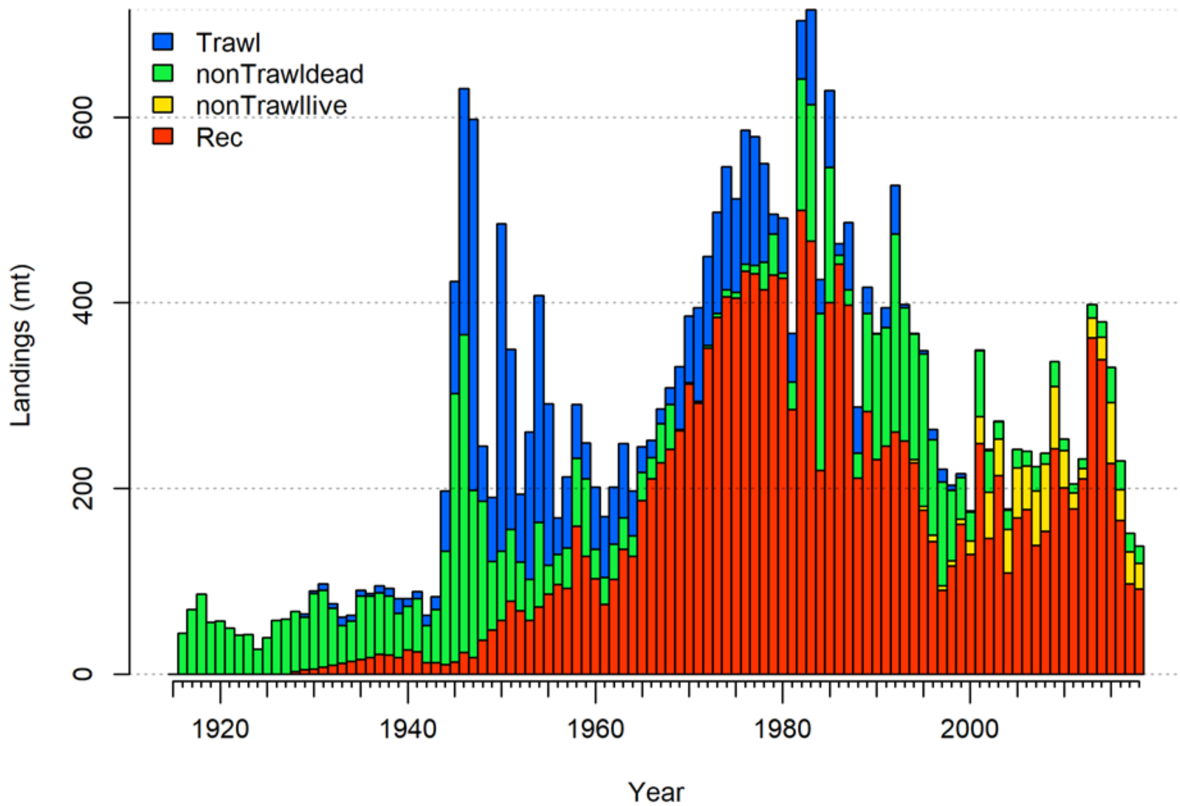

Figure CA-1 Landings history of Black Rockfish for California.

Data

California has three commercial fleets and 1 recreational fleet with three surveys of abundance, all based on recreational fisheries. The model includes age data as conditional age-at-length, as well as length data.

For this update, catch data from 2015-2018 were added to the model, and the Pacific Council's Groundfish Management Team (GMT) provided catch estimates for 2019 and 2020.

Spawning Stock Output

California stocks declined throughout the 20th Century, and are recovering from a low in the 1990's. The model estimates that the stock was recovered above the 40% target in 2017 (Table CA-2).

Table CA-2: Recent trend in beginning-of-year biomass and depletion in California.

Year	Spawning Output billion eggs	~ 95% confidence interval	Estimated depletion	~ 95% confidence interval
2010	268	(162-374)	0.25	(0.15-0.36)
2011	285	(170-401)	0.27	(0.16-0.38)
2012	305	(180-430)	0.29	(0.17-0.41)
2013	322	(189-454)	0.30	(0.17-0.43)
2014	329	(191-468)	0.31	(0.18-0.44)
2015	353	(204-503)	0.33	(0.19-0.48)
2016	403	(234-573)	0.38	(0.22-0.54)
2017	474	(278-670)	0.45	(0.26-0.64)
2018	549	(328-770)	0.52	(0.31-0.73)
2019	610	(370-849)	0.57	(0.35-0.8)

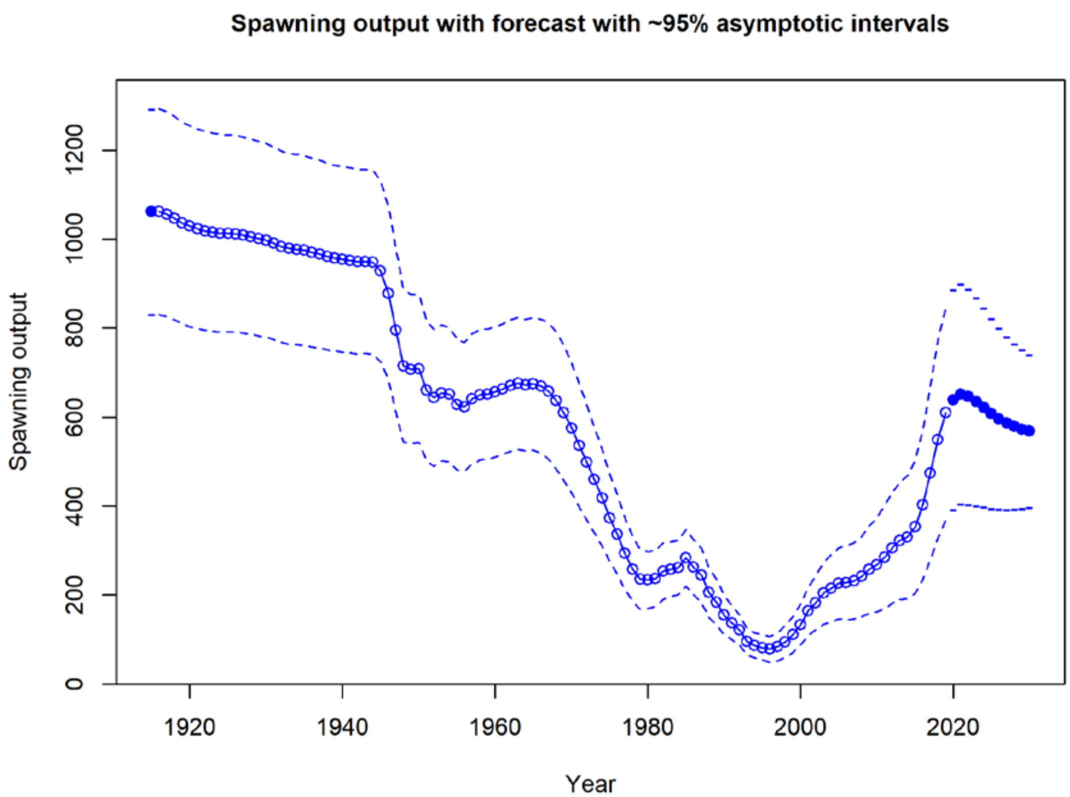

Figure CA-3: Timeseries of spawning output of Black Rockfish in California. Forecasts are shown as solid points. Forecasts begin in 2021 and assume full ABC/ACL removals.

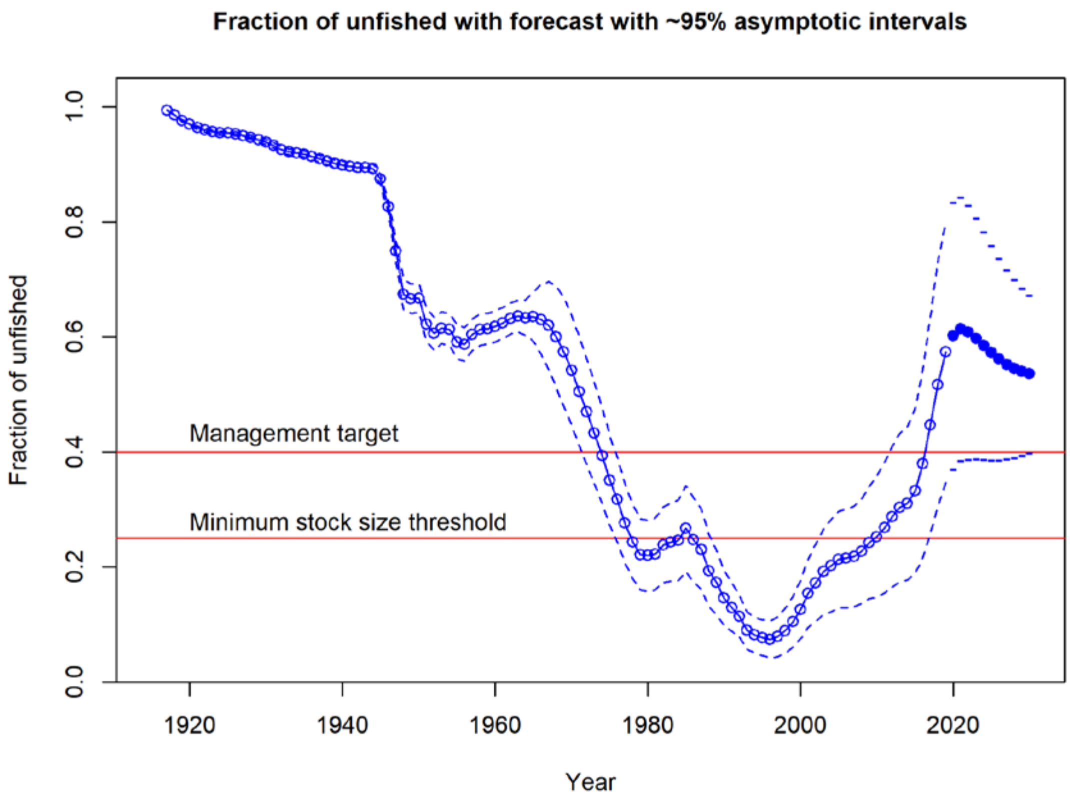

Figure CA-4. Timeseries of stock status (fraction unfished) of Black Rockfish in California. Forecasts are shown as solid points. Forecasts begin in 2021 and assume full ABC/ACL removals.

Recruitment

The California model shows a few extraordinarily high recruitment events that are supported by the length composition data, index data and on-the-water reports (Table CA-3; Figure CA-5). Oregon recruitment is highly uncertain (Table ES-3; Figure ES11). Washington recruitment is dynamic, but also shows the most informed recruitment time series, which is consistent with the extent of length and age compositions available to that assessment (Table ES-3; Figure ES12). Both California and Washington support elevated recruitment in the late 2000s.

Table CA-3. Recent trend in recruitment for Black Rockfish in California.

Year	Estimated Recruitment (1,000s)	~ 95% confidence interval
2010	2997	(1493-6015)
2011	1765	(798-3900)
2012	1701	(1274-2270)
2013	1719	(1292-2288)
2014	1728	(1299-2298)
2015	1752	(1323-2320)
2016	1795	(1366-2358)
2017	1842	(1415-2398)
2018	1881	(1456-2430)
2019	1906	(1483-2449)

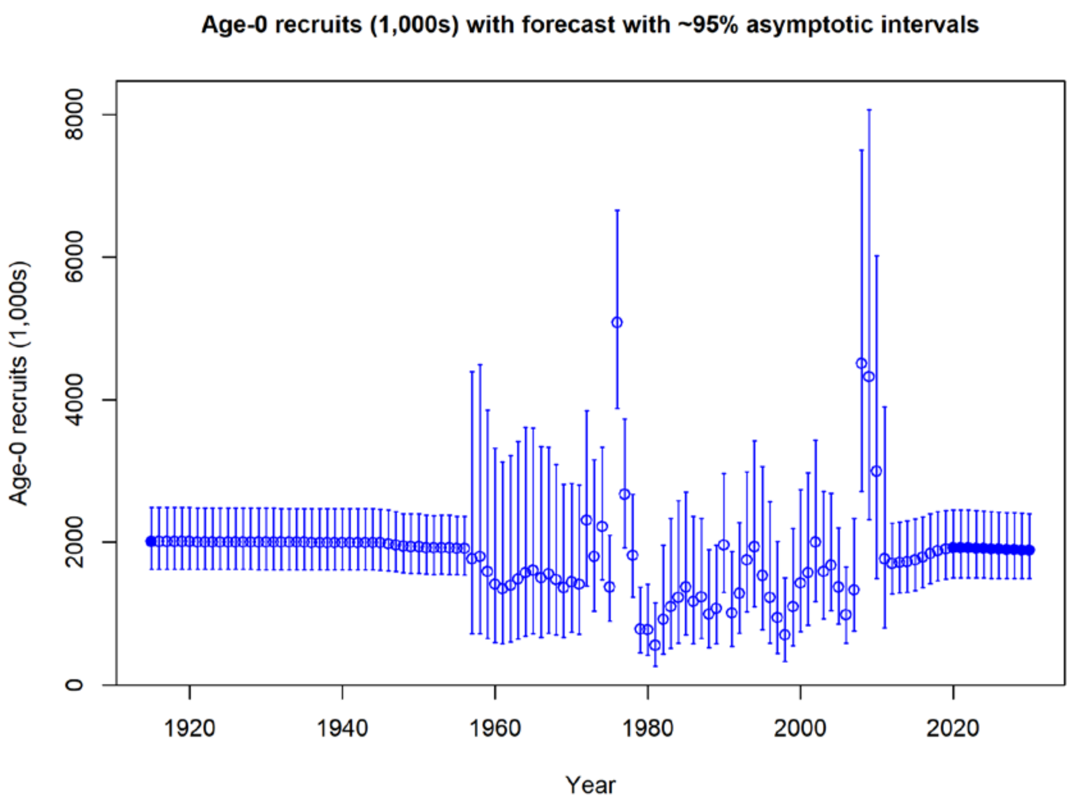

Figure CA-5. Timeseries of Black Rockfish recruitment in California. Forecasts are shown as solid points. Forecasts begin in 2021 and assume full ABC/ACL removals.

Exploitation Status

The California model indicates that current fishing practices are near or above the SPR rate fishing intensity target (Table CA-4 and Figure CA-6). Fishing rates have been above the target in California in nearly all years since the 1980s, but have dropped considerably in recent years.

Table CA-4. Recent trend in spawning potential ratio (1-SPR/1-SPR_{50}) and summary exploitation rate (catch divided by biomass of age 3+ fish) for Black Rockfish in California.

Year	Fishing intensity	~ 95% confidence interval	Exploitation rate	~ 95% confidence interval
2009	1.3	(1.04-1.55)	0.1	(0.07-0.14)
2010	1.12	(0.85-1.38)	0.08	(0.05-0.11)
2011	0.92	(0.67-1.18)	0.06	(0.04-0.08)
2012	0.89	(0.65-1.14)	0.05	(0.03-0.07)
2013	1.14	(0.88-1.41)	0.08	(0.05-0.11)
2014	1.07	(0.8-1.33)	0.07	(0.05-0.1)
2015	0.94	(0.68-1.2)	0.06	(0.04-0.08)
2016	0.72	(0.5-0.94)	0.04	(0.03-0.06)
2017	0.5	(0.33-0.66)	0.03	(0.02-0.04)
2018	0.45	(0.31-0.6)	0.02	(0.02-0.03)

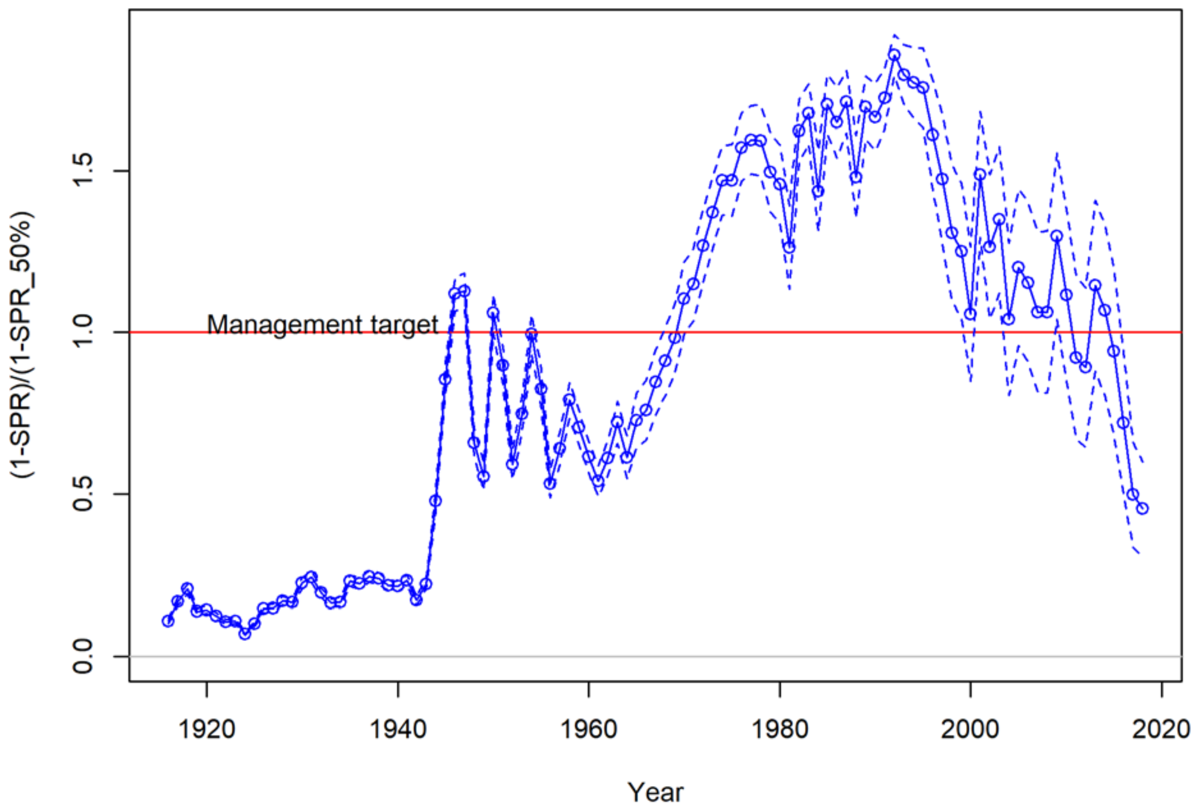

Figure CA-6. Estimated spawning potential ratio (SPR) for the California assessment. Relative SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{50\%}$ harvest rate. The last year in the time series is 2018.

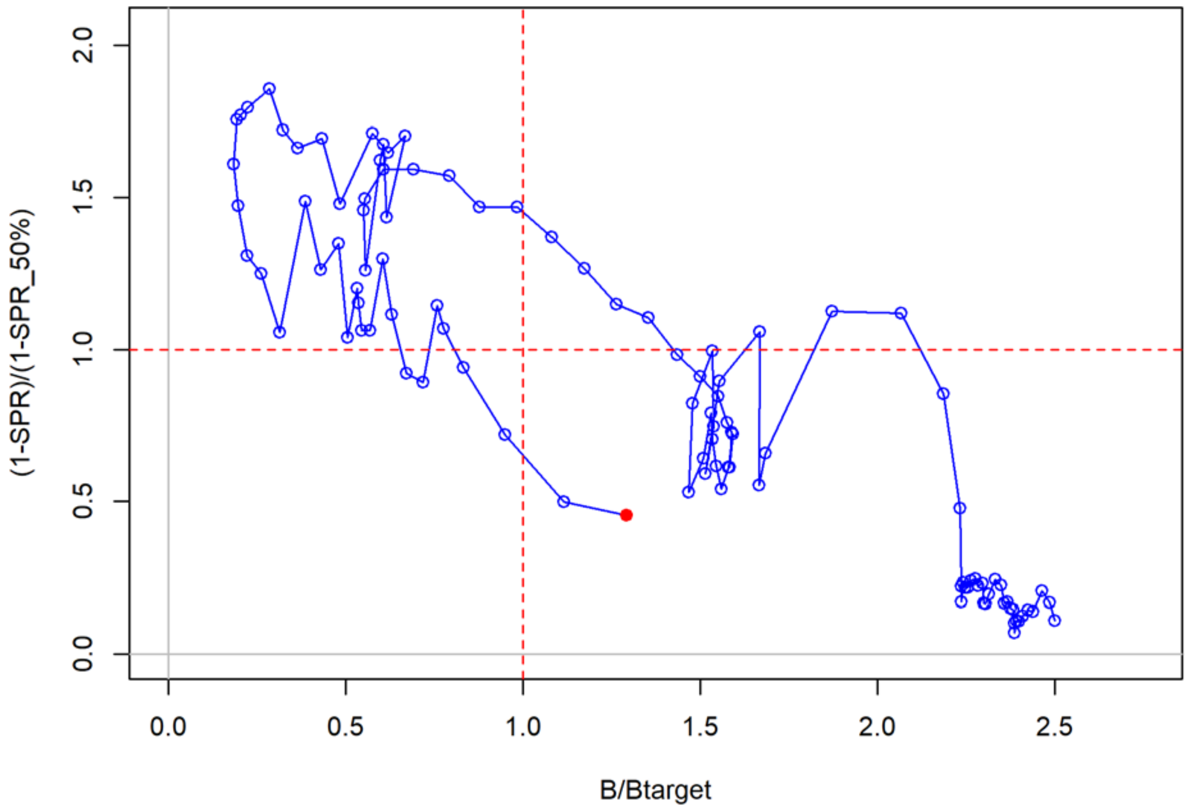

Figure CA-7. Phase plot of relative spawning biomass vs fishing intensity for the California model. The relative fishing intensity is (1-SPR) divided by 1-the SPR target. The vertical red line is the relative spawning biomass target defined as the annual spawning output divided by the spawning biomass corresponding to 40% of the unfished spawning biomass. The last year in the time series is 2018.

Ecosystem Considerations

Ecosystem considerations were not explicitly included in these models, though growth deviations were considered in the Washington model. While no mechanisms have been put forth for these time-varying changes in growth, an environmental component is possible. Limited data in Oregon and California also suggest the possibility that growth has changed over time.

Reference Points

Reference points were based on the rockfish F_{MSY} proxy ($SPR_{50\%}$), target relative biomass (40%) and model-estimated selectivity for each fleet. California is below the target biomass reference point, but above the limit reference biomass (25%). Yield values are lower than the previous assessment for similar reference points due to lower overall natural mortality values (Table CA-5). The proxy MSY values of management quantities are the most conservative compared to the estimated MSY and MSY relative to 40% biomass (Table CA-5). The equilibrium estimates of yield relative to biomass are provided in Figure CA-8.

Table CA-5. Summary of reference points for the California Black Rockfish base case model

Quantity	Estimate	~95% Confidence Interval
Unfished spawning output (billion eggs)	1061.5	(830.3-1292.7)
Unfished age 3+ biomass (mt)	9540.1	(8861.6-10218.6)
Unfished recruitment (R0, thousands)	2009.7	(1579.9-2439.5)
Spawning output(2019 billion eggs)	609.6	(370.4-848.9)
Depletion (2019)	0.5743	(0.347-0.8015)
Reference points based on $SB_{40\%}$		
Proxy spawning output ($B_{40\%}$)	424.6	(332.1-517.1)
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.444	(0.444-0.444)
Exploitation rate resulting in $B_{40\%}$	0.0753	(0.0695-0.0811)
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	342.9	(316.2-369.5)
Reference points based on SPR proxy for MSY		
Spawning output	488.7	(382.3-595.1)
SPR_{proxy}	0.5	
Exploitation rate corresponding to SPR_{proxy}	0.0637	(0.0587-0.0687)
Yield with SPR_{proxy} at SB_{SPR} (mt)	319.1	(294.7-343.6)
Reference points based on estimated MSY values		
Spawning output at MSY (SB_{MSY})	253.8	(198.7-308.8)
SPR_{MSY}	0.2949	(0.2869-0.3029)
Exploitation rate at MSY	0.1169	(0.1074-0.1264)
MSY (mt)	376.5	(345.4-407.6)

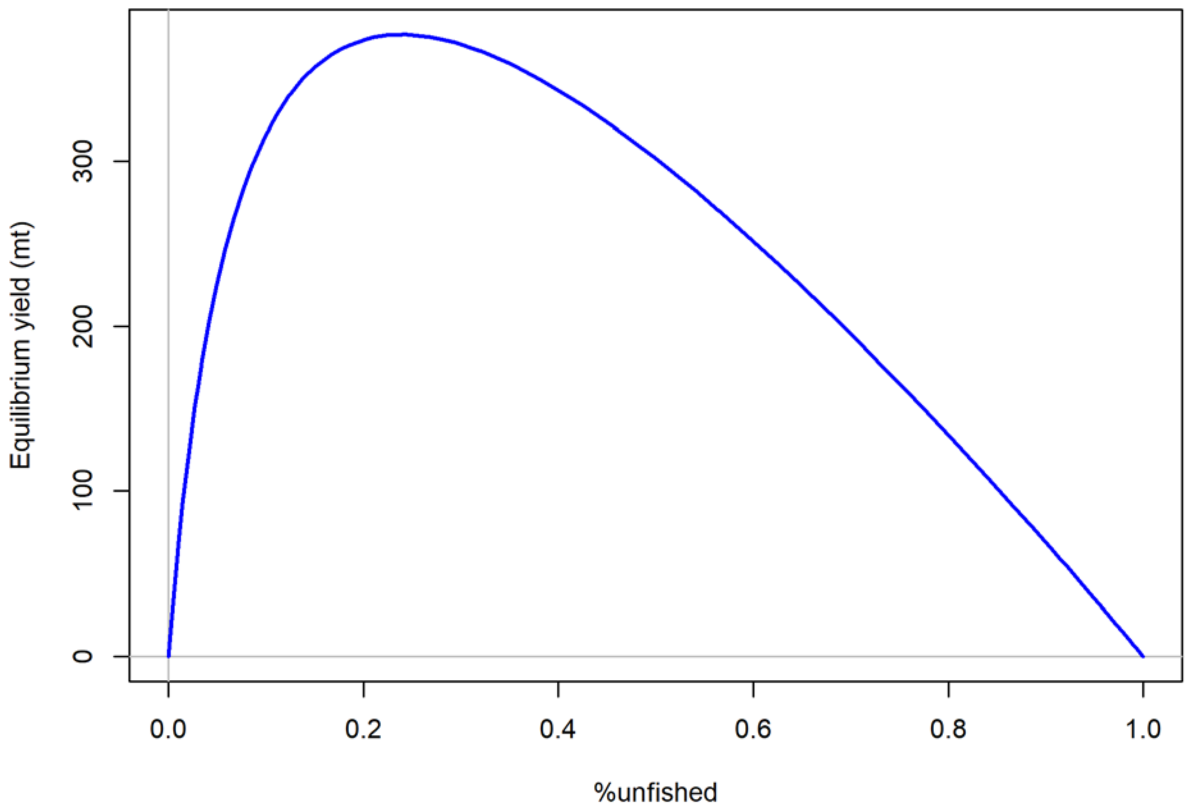

Figure CA-8. Equilibrium yield curve (derived from reference point values reported in Table CA-5) for the California base case model. Values are based on 2018 fishery selectivity and distribution with steepness fixed at 0.773. The depletion is relative to unfished spawning biomass.

Management Performance

Removals have been below the equivalent ABC-ACL since the prior assessment (Table ES-6), but those specified ABCs from the 2007 assessments are higher than those coming from the current assessment models. Removals over the last few years have or may have exceeded the newly estimated ABC-ACL values in some years. The differences in the treatment of natural mortality between the previous and current assessments are the biggest reason for this discrepancy.

Table CA-6. Recent trend in total catch and commercial landings (mt) relative to the management guidelines. Estimated total catch reflects the recreational and commercial landings plus estimated commercial discarded biomass. Until 2017, California and Oregon stocks were managed together,

with a single OFL and single ACL for the two states. Combined landings are shown below in addition to California landings.

Year	OFL	ACL	CA Catch	Combined OR/CA Catch
2009	1469	1000	337	783
2010	1317	1000	253	673
2011	1163	1000	205	525
2012	1117	1000	232	563
2013	1108	1000	398	834
2014	1115	1000	380	865
2015	1176	1000	330	930
2016	1183	1000	230	767
2017	577	527	152	
2018	570	520	138	

Unresolved Problems and Major Uncertainties

The most significant uncertainty for all models is the treatment and value of natural mortality and the form of fleet selectivity (e.g., length-based asymptotic vs. age-based dome-shaped selectivity). Data-driven selection between the extreme “kill” (using a ramping of M) or “hide” hypotheses are not currently resolvable. The California and Washington base models instead use a form of the “kill” hypothesis by not implementing the age-based selectivity (“hide” hypothesis) and estimating female and male natural mortality, thus avoiding a fixing natural mortality as was necessary in the Oregon model. The Oregon model also contained a step in female natural mortality, a specification not used in the California or Washington models.

Another important issue is the highly uncertain historical time-series of removals, which needs further consideration.

The development of fishery-dependent indices of abundance still requires further attention.

Steepness, while fixed, is still highly uncertain for rockfishes and currently is mismatched to the MSY proxy. And while the steepness profile shows low sensitivity in several derived quantities, steepness strongly defines the yield capacity of stocks, and therefore could cause major uncertainty in the recommended management quantities.

Stock structure and its relationship to the current political/management boundaries are also not fully understood, both within U.S. jurisdiction and between the U.S. and Canada. While this is a common challenge faced in most west coast stock assessments, further improvement on this topic will likely rely on Black Rockfish-specific data.

Harvest Projections and Decision Tables

The Black Rockfish assessment for California has a preliminary distinction as category 1 stock assessments, thus harvest projections and decision tables are based on using P*=0.45 with sigma increasing for each year of the harvest projections to produce the buffer sequence in Table I-2.

Uncertainty in management quantities for the California base model was characterized by exploring various model specifications in a decision table. Initial exploration included natural mortality and steepness values, and uncertainty in historical trawl catches. There was very little sensitivity to steepness and trawl catches, but natural mortality produced sensitive results of predicted population scale and status. Discussion with the STAR panel resulted in high and low states of nature +/- 0.03 from the base case natural mortality values for females and males. High and low catch streams (rows) were determined by the forecasts, as described above, for each state of nature. Thus the low catch stream is based on the forecast from the low state of nature.

The base case in the decision table provided in Table CA-8 reflects increasing buffers, as it is the base-case result, however the rest of the table was produced using the same buffer as in the original 2015 analysis. This is due to the fact that the model must be manually re-run with adjusted sigma values and the resultant catch entered manually for each year, which was thought to be unnecessary for the purposes of this update, which focuses on the impact of increasing buffers on the base model projections.

Table CA-7. Harvest projection of potential OFL and prescribed removals, summary biomass (age-3 and older), spawning output, and depletion for the California base case model projected with total projected catch equal to the 420 mt for 2015 and 2016. The predicted OFL is the calculated total catch determined by FSPR=50%.

Year	Predicted OFL	Projected removals	Age 3+ biomass	Spawning output	Depletion (%)
2019	382	265	6342	610	57%
2020	381	265	6338	639	60%
2021	379	348	6326	652	61%
2022	373	341	6233	646	61%
2023	368	334	6152	634	60%
2024	364	329	6084	621	58%
2025	360	324	6028	608	57%
2026	358	321	5982	596	56%
2027	356	317	5945	586	55%
2028	354	314	5915	579	55%
2029	353	311	5891	573	54%
2030	352	309	5871	568	54%

Table CA-8. Summary decision table of 12-year projections for the California model beginning in 2017 for alternate states of nature based on natural mortality. Columns range over low, mid, and high state of nature, and rows range over different assumptions of total catch levels corresponding to the forecast catches from each state of nature. Catches from 2019 on are allocated to each fleet based on the percentage of landings for each fleet in the years 2014-2018.

California			**State of nature**					
			Low M_{female} = 0.15 ; M_{male} = 0.10		Base case M_{female} = 0.18; M_{male} = 0.13		High M_{female} = 0.21 ; M_{male} = 0.16	
Relative probability of states of nature			0.25		0.5		0.25	
Management decision	Year	Catch (mt)	Spawning output	Stock status	Spawning output	Stock status	Spawning output	Stock status
Low catch	2021	275	600	44%	652	61%	705	79%
	2022	277	609	45%	654	62%	696	78%
	2023	278	614	45%	649	61%	681	77%
	2024	280	615	45%	642	61%	664	75%
	2025	281	616	45%	635	60%	648	73%
	2026	283	617	45%	628	59%	633	71%
	2027	285	619	45%	622	59%	620	70%
	2028	286	621	45%	617	58%	609	69%
	2029	287	624	46%	613	58%	599	67%
	2030	289	628	46%	610	57%	591	67%
Base catch	2021	348	600	44%	652	61%	705	79%
	2022	341	601	44%	646	61%	688	77%
	2023	334	596	44%	634	60%	667	75%
	2024	329	590	43%	621	58%	645	73%
	2025	324	584	43%	608	57%	624	70%
	2026	321	579	42%	596	56%	605	68%
	2027	317	576	42%	586	55%	589	66%
	2028	314	574	42%	579	55%	576	65%
	2029	311	574	42%	573	54%	566	64%
	2030	309	576	42%	568	54%	557	63%
High catch	2021	457	600	44%	652	61%	705	79%
	2022	440	587	43%	634	60%	678	76%
	2023	424	570	42%	611	58%	647	73%
	2024	412	552	40%	588	55%	615	69%
	2025	401	534	39%	565	53%	586	66%
	2026	392	519	38%	545	51%	561	63%
	2027	384	506	37%	528	50%	540	61%
	2028	378	497	36%	514	48%	522	59%
	2029	373	489	36%	503	47%	508	57%
	2030	368	484	35%	495	47%	496	56%

Research and Data Needs

Recommended avenues for research to help improve future Black Rockfish stock assessments:

1. Further investigation into the movement and behavior of older (> age 10) females to reconcile their absence in fisheries data. If the females are currently inaccessible to fishing gear, can we find where they are?
2. Appropriate natural mortality values for females and males. This will help resolve the extent to which dome-shaped age-based selectivity may be occurring for each.
3. All states need improved historical catch reconstructions. The trawl fishery catches in particular require particular attention. Given the huge historical removals of that fleet in each state, the assessment is very sensitive to the assumed functional form of selectivity. A synoptic catch reconstruction is recommended, where states work together to resolve cross-state catch issues as well as standardize the approach to catch recommendations.
4. Identifying stanzas or periods of uncertainty in the historical catch series will aid in the exploration of catch uncertainty in future assessment sensitivity runs.
5. An independent nearshore survey should be supported in all states to avoid the reliance on fishery-based CPUE indices.
6. Stock structure for Black Rockfish is a complicated topic that needs further analysis. How this is determined (e.g., exploitation history, genetics, life history variability, biogeography, etc.) and what this means for management units needs to be further refined. This is a general issue for all nearshore stocks that likely have significant and small scale stock structure among and within states, but limited data collections to support small-scale management.

Table CA-9. Summary tables of the result for the California assessment model for Black Rockfish. OFL and ACL values for California and Oregon were combined until 2017 (see Table CA-6).

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Landings (mt)	337	253	205	232	398	380	330	230	152	138
Total removals (mt)	337	253	205	232	398	380	330	230	152	138
OFL (mt)	1469	1317	1163	1117	1108	1115	1176	1183	577	570
ACL (mt)	1000	1000	1000	1000	1000	1000	1000	1000	527	520
1-SPR	1.3	1.12	0.92	0.89	1.14	1.07	0.94	0.72	0.5	0.45
Exploitation rate (catch/ age 3+ biomass)	0.1	0.08	0.06	0.05	0.08	0.07	0.06	0.04	0.03	0.02
Age 3+ biomass (mt)	3496	3447	3975	4714	5346	5610	5773	5890	6032	6198
Spawning Output	268	285	305	322	329	353	403	474	549	610
~95% CI	(162-374)	(170-401)	(180-430)	(189-454)	(191-468)	(204-503)	(234-573)	(278-670)	(328-770)	(370-849)
Recruitment	2997	1765	1701	1719	1728	1752	1795	1842	1881	1906
~95% CI	(1493-6015)	(798-3900)	(1274-2270)	(1292-2288)	(1299-2298)	(1323-2320)	(1366-2358)	(1415-2398)	(1456-2430)	(1483-2449)
Depletion (%)	0.25	0.27	0.29	0.3	0.31	0.33	0.38	0.45	0.52	0.57
~95% CI	(0.15-0.36)	(0.16-0.38)	(0.17-0.41)	(0.17-0.43)	(0.18-0.44)	(0.19-0.48)	(0.22-0.54)	(0.26-0.64)	(0.31-0.73)	(0.35-0.8)

3 Oregon

Catch

Black Rockfish are caught by a wide variety of gear types and in recent decades have been a very important target species for recreational charter-boats and private sport. In recent years the recreational fishery has accounted for most of the Black Rockfish catch (Figure OR-1). Black Rockfish can also be an important component of nearshore commercial fisheries, either as incidental catch by the troll fishery for salmon or as directed catch by jig fisheries for groundfish. In southern Oregon there are nearshore fisheries that catch and sell fish live for the restaurant trade. There have been almost no trawl-caught landings of Black Rockfish in recent years (Table OR-1), but trawl landings in the past were more substantial (Figure OR-1).

Detailed reports of commercial landings of Black Rockfish are generally unavailable prior to 1981, when the Pacific Fishery Information Network (PacFIN) database began. The catch series prior to 1981 for these assessments were derived by applying available estimates or assumed values for the proportion of Black Rockfish landings in reported landings of rockfish. Observer data, which are available only for the past decade, indicate low levels of discarding of Black Rockfish, generally less than 2% of the total catch.

Because of their nearshore distribution and low abundance compared to other rockfish species, Black Rockfish are unlikely to have ever comprised a large percentage of rockfish landings, but it seems quite certain that they have been more than a trivial component for many years. Black Rockfish were one of only four rockfish species mentioned by scientific name in reports of rockfish landings in Oregon during the 1940s.

Table OR-1. Recent catches in Oregon.

Year	Trawl	NonTrawl Dead	NonTrawl Live	Ocean Rec	Shoreside Rec
2009	0.00	42	93	295	15
2010	0.00	33	69	303	15
2011	0.03	28	71	206	15
2012	0.12	33	64	218	15
2013	0.00	40	69	313	15
2014	0.01	50	74	347	14
2015	0.01	51	72	463	14
2016	0.13	48	58	417	14
2017	0.00	59	66	409	14
2018	0.03	54	69	282	14

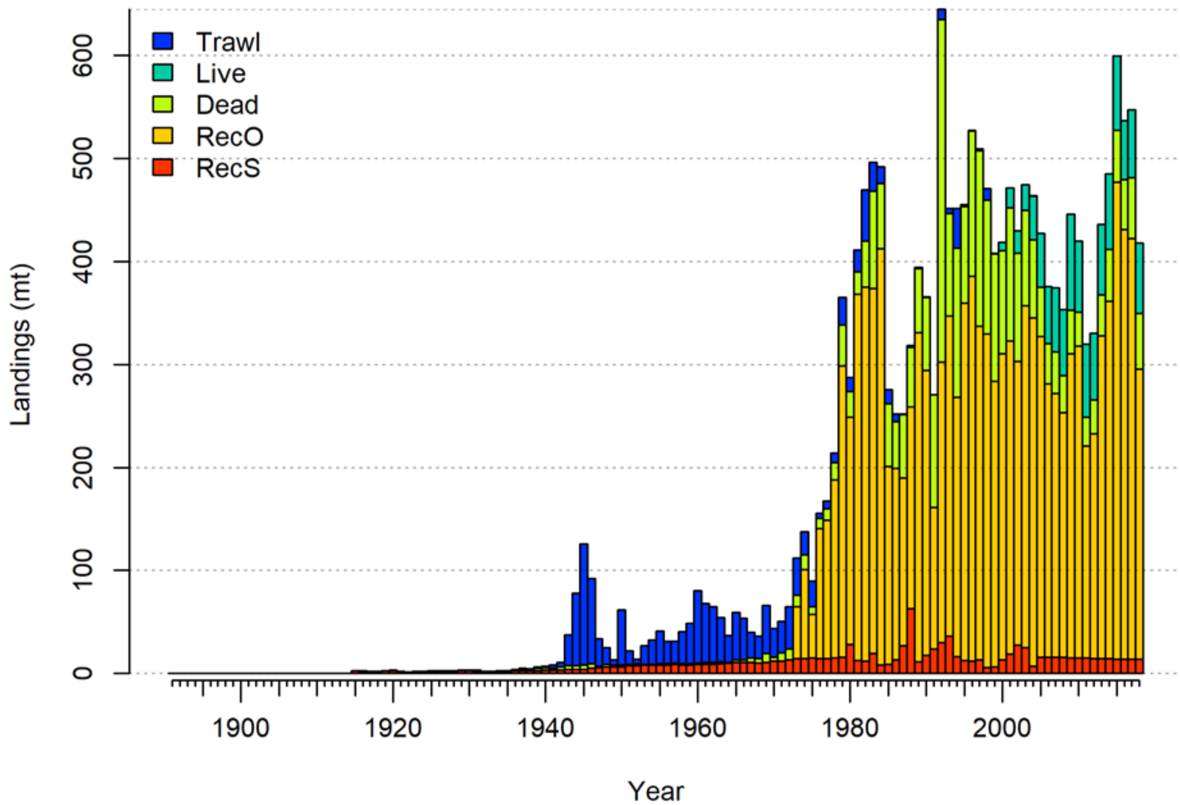

Figure OR-1 Landings history of Black Rockfish for Oregon.

Data

The Oregon assessment has three commercial fleets and two recreational fleets, while using five surveys and an additional research study for biological compositions. The model includes age data as conditional age-at-length, as well as length data.

For this update, catch data from 2015-2018 were added to the model, and the Pacific Council's Groundfish Management Team (GMT) provided catch estimates for 2019 and 2020.

Spawning Stock Output

Oregon spawning stock outputs are all at or above limit reference, with a decline in the most recent period. The Oregon stock dropped after the quick ramp up of catches in the late 1970s and continued a steady decline until around year 2000, settling in at a stock status around 60% of initial conditions (Table OR-2, Figures OR-3 and OR-4)

Table OR-2: Recent trend in beginning-of-year biomass and depletion in Oregon.

Year	Spawning Output (billion eggs)	~ 95% confidence interval	Estimated depletion	~ 95% confidence interval
2010	785	(685-885)	0.6	(0.58-0.61)
2011	786	(686-886)	0.6	(0.58-0.61)
2012	793	(693-894)	0.6	(0.59-0.62)
2013	801	(700-902)	0.61	(0.59-0.62)
2014	800	(699-902)	0.61	(0.59-0.62)
2015	795	(693-896)	0.6	(0.59-0.62)
2016	778	(677-879)	0.59	(0.58-0.61)
2017	765	(664-865)	0.58	(0.56-0.6)
2018	750	(650-849)	0.57	(0.55-0.59)
2019	745	(646-844)	0.56	(0.55-0.58)

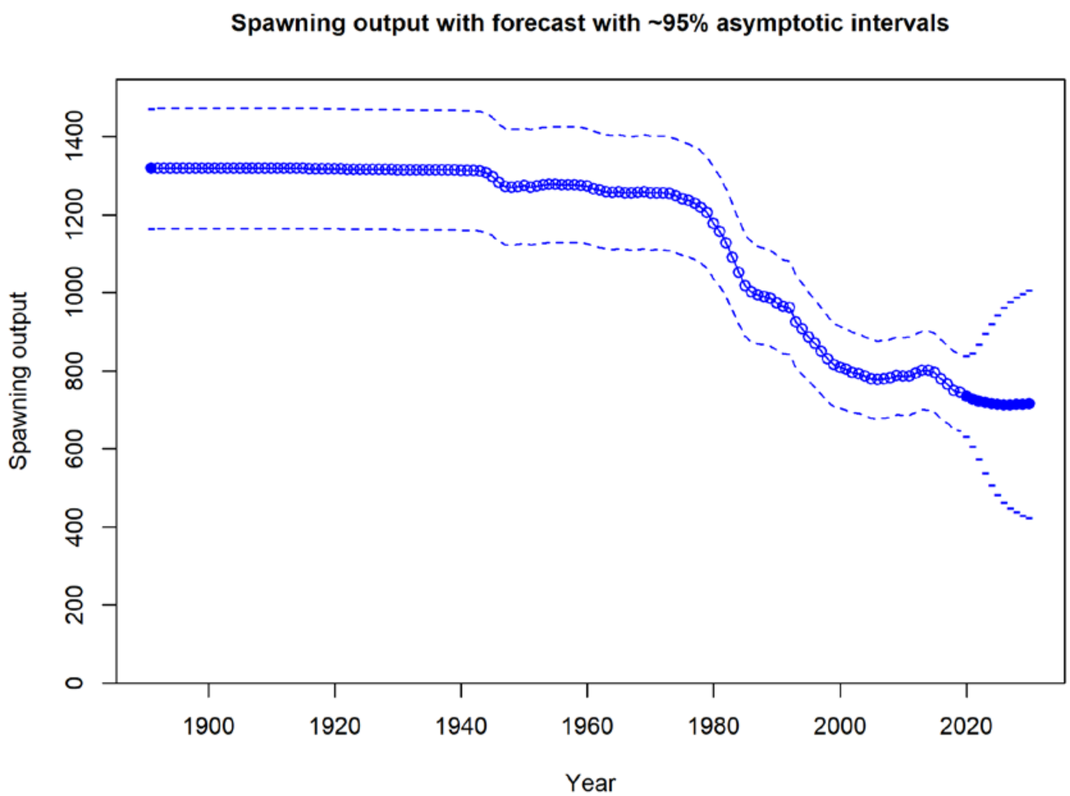

Figure OR-3: Timeseries of spawning output of Black Rockfish in Oregon. Forecasts are shown as solid points. Forecasts begin in 2021 and assume full ABC/ACL removals.

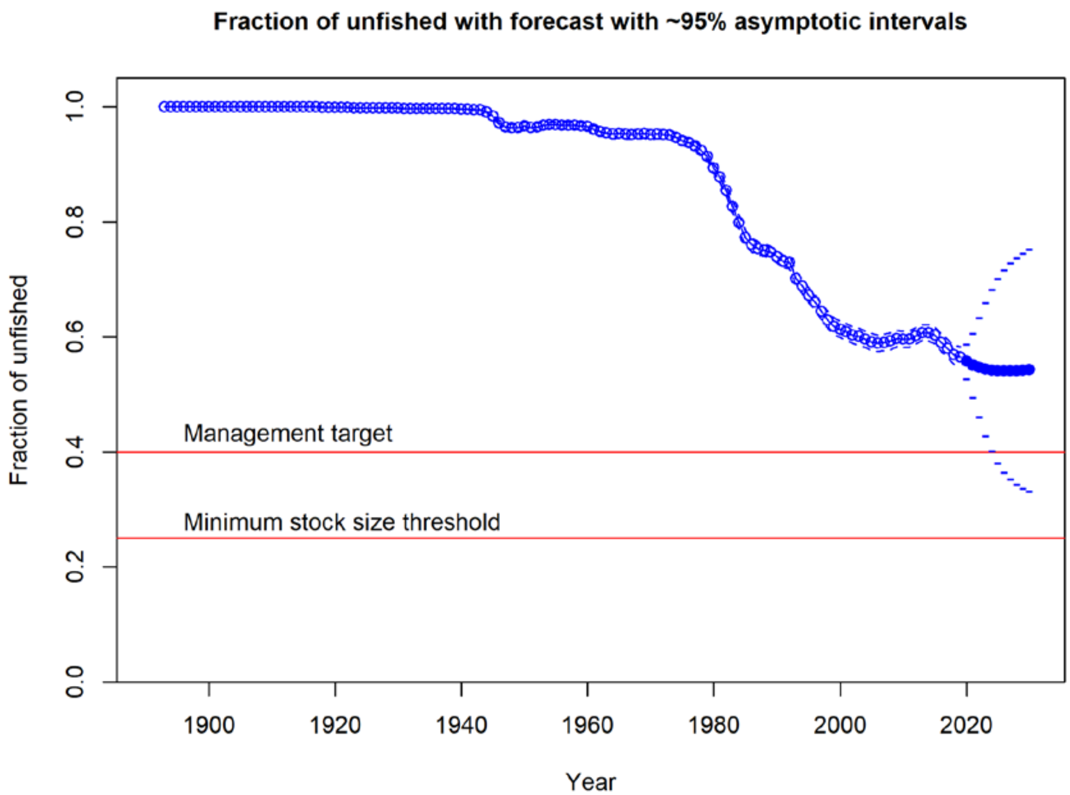

Figure OR-4. Timeseries of stock status (depletion) of Black Rockfish in Oregon. Forecasts are shown as solid points. Forecasts begin in 2021 and assume full ABC/ACL removals.

Recruitment

Oregon recruitment is highly uncertain (Table ES-3; Figure ES11); recruitment deviations could not be estimated in the model.

Table OR-3. Recent trend in recruitment for Black Rockfish in Oregon.

Year	Estimated Recruitment (1,000s)	~ 95% confidence interval
2010	3490	(3416-3565)
2011	3490	(3416-3565)
2012	3494	(3416-3565)
2013	3498	(3416-3565)
2014	3498	(3416-3565)
2015	3495	(3416-3565)
2016	3486	(3416-3565)
2017	3479	(3416-3565)
2018	3471	(3416-3565)
2019	3468	(3416-3565)

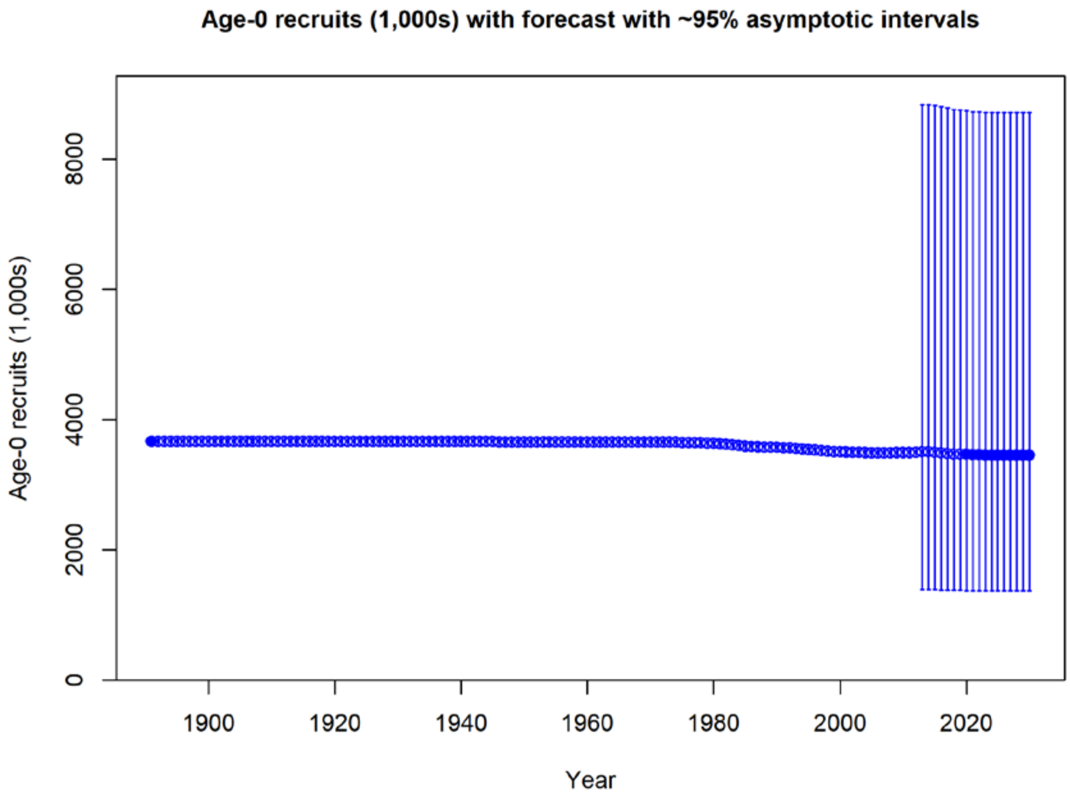

Figure OR-5. Timeseries of Black Rockfish recruitment in Oregon. Forecasts are shown as solid points. Forecasts begin in 2021 and assume full ABC/ACL removals.

Exploitation Status

The Oregon model indicates current fishing practices are quite a bit above the target SPR rate fishing intensity target (Table OR-4 and Figure OR-6). Oregon fishing rates have been consistently high in recent years.

Table OR-4. Recent trend in spawning potential ratio (1-SPR/1-SPR$_{50}$) and summary exploitation rate (catch divided by biomass of age 3+ fish) for Black Rockfish in Oregon.

Year	Fishing intensity	~ 95% confidence interval	Exploitation rate	~ 95% confidence interval
2009	0.795	(0.77-0.82)	0.084	(0.08-0.09)
2010	0.758	(0.73-0.79)	0.079	(0.08-0.08)
2011	0.615	(0.59-0.64)	0.061	(0.06-0.06)
2012	0.625	(0.6-0.65)	0.063	(0.06-0.07)
2013	0.770	(0.74-0.8)	0.081	(0.08-0.08)
2014	0.840	(0.81-0.87)	0.091	(0.09-0.09)
2015	0.984	(0.95-1.02)	0.112	(0.11-0.12)
2016	0.928	(0.9-0.96)	0.104	(0.1-0.11)
2017	0.954	(0.92-0.99)	0.108	(0.1-0.11)
2018	0.795	(0.73-0.86)	0.084	(0.07-0.09)

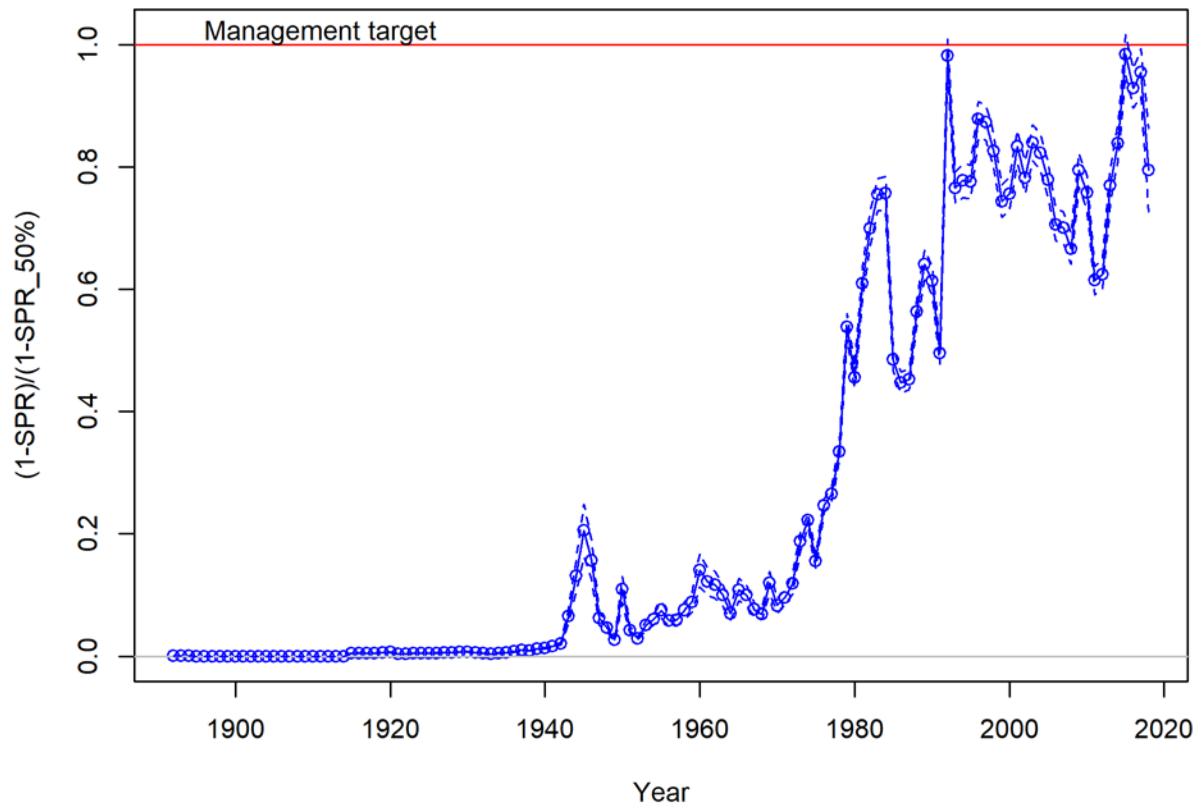

Figure OR-6. Estimated spawning potential ratio (SPR) for the Oregon assessment. Relative SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{50\%}$ harvest rate. The last year in the time series is 2018.

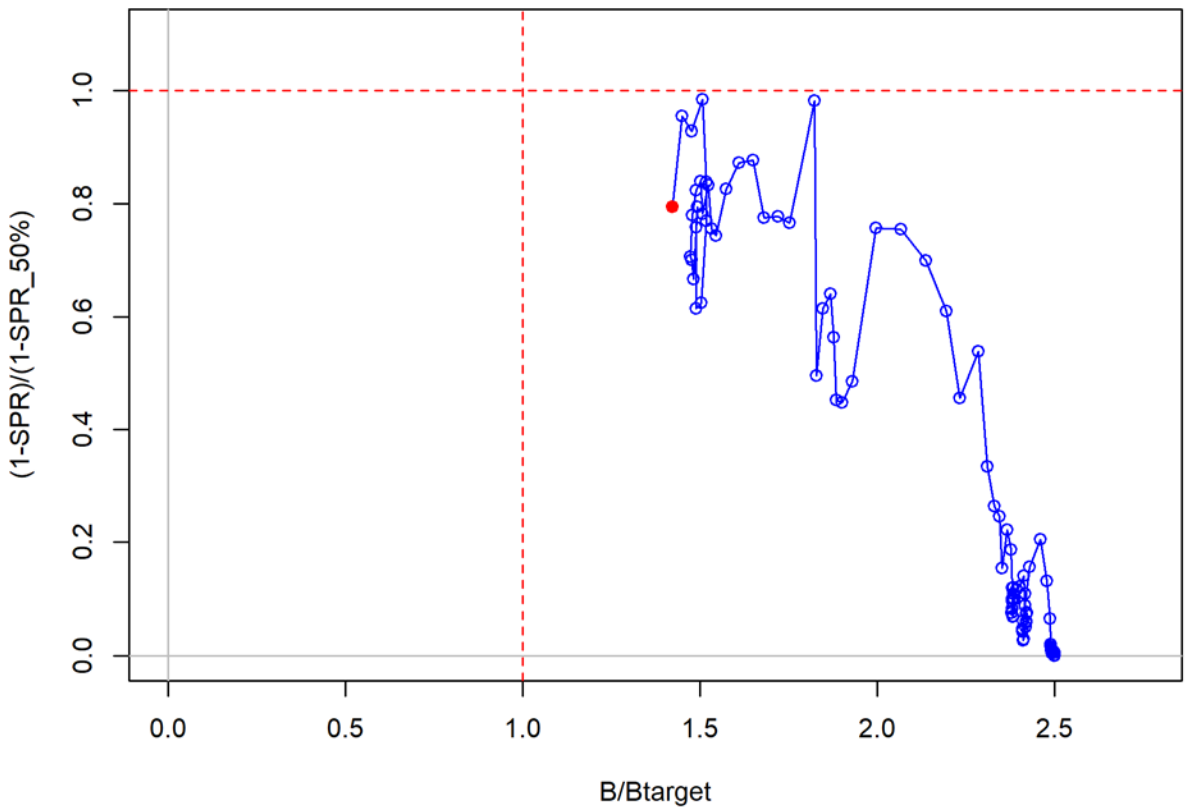

Figure OR-7. Phase plot of relative spawning biomass vs fishing intensity for the Oregon model. The relative fishing intensity is (1-SPR) divided by 1-the SPR target. The vertical red line is the relative spawning biomass target defined as the annual spawning output divided by the spawning biomass corresponding to 40% of the unfished spawning biomass. The last year in the time series is 2018.

Ecosystem Considerations

Ecosystem considerations were not explicitly included in these models, though growth deviations were considered in the Washington model. While no mechanisms have been put forth for these time-varying changes in growth, an environmental component is possible. Limited data in Oregon and California also suggest the possibility that growth has changed over time.

Reference Points

Reference points were based on the rockfish F_{MSY} proxy ($SPR_{50\%}$), target relative biomass (40%) and model-estimated selectivity for each fleet. Oregon is well above the target biomass (Table OR-5). The equilibrium estimates of yield relative to biomass are provided in Figure OR-8.

Table OR-5. Summary of reference points for the Oregon Black Rockfish base case model

Quantity	Estimate	~95% Confidence Interval
Unfished spawning output (billion eggs)	1318.5	(1164.5-1472.4)
Unfished age 3+ biomass (mt)	11641.9	(11354.4-11929.4)
Unfished recruitment (R_0, thousands)	3664	(3591.9-3736.2)
Spawning output(2019 billion eggs)	744.9	(646-843.8)
Depletion (2019)	0.565	(0.5472-0.5828)
Reference points based on $SB_{40\%}$		
Proxy spawning output (B40%)	527.4	(465.8-588.9)
SPR resulting in B40% (SPRB40%)	0.444	(0.444-0.444)
Exploitation rate resulting in B40%	0.1347	(0.1256-0.1438)
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	556.2	(541.6-570.9)
Reference points based on SPR proxy for MSY		
Spawning output	607	(536.1-677.9)
SPRproxy	0.5	
Exploitation rate corresponding to SPRproxy	0.1151	(0.1072-0.123)
Yield with SPR_{proxy} at SB_{SPR} (mt)	517.3	(502.9-531.6)
Reference points based on estimated MSY values		
Spawning output at MSY (SB_{MSY})	302.2	(264.6-339.8)
SPR_{MSY}	0.2858	(0.2828-0.2889)
Exploitation rate at MSY	0.2071	(0.1956-0.2186)
MSY (mt)	616.7	(602.5-630.9)

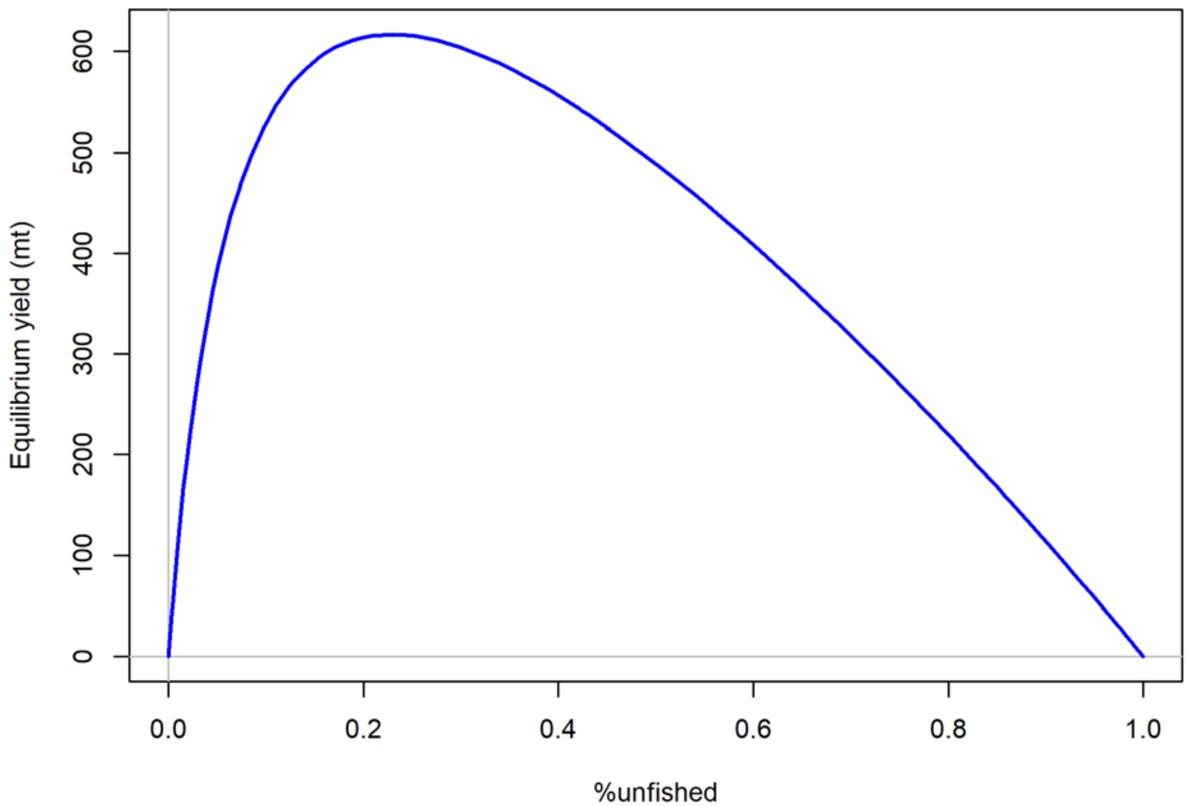

Figure OR-8. Equilibrium yield curve (derived from reference point values reported in Table CA-5) for the Oregon base case model. Values are based on 2018 fishery selectivity and distribution with steepness fixed at 0.773. The depletion is relative to unfished spawning biomass.

Management Performance

Table OR-6. Recent trend in total catch and commercial landings (mt) relative to the management guidelines. Estimated total catch reflects the recreational and commercial landings plus estimated commercial discarded biomass. Until 2017, California and Oregon stocks were managed together, with a single OFL and single ACL for the two states. Combined landings are shown below in addition to Oregon landings. Oregon Black Rockfish are managed in a complex with Oregon Blue and Deacon Rockfish in 2019 and 2020.

Year	OFL	ACL	OR Catch	Combined OR/CA Catch
2009	1469	1000	446	783
2010	1317	1000	420	673
2011	1163	1000	319	525
2012	1117	1000	330	563
2013	1108	1000	436	834
2014	1115	1000	485	865
2015	1176	1000	599	930
2016	1183	1000	537	767
2017	577	527	547	
2018	570	520	418	

Unresolved Problems and Major Uncertainties

The most significant uncertainty for all models is the treatment and value of natural mortality and the form of fleet selectivity (e.g., length-based asymptotic vs. age-based dome-shaped selectivity). Data-driven selection between the extreme "kill" (using a ramping of M) or "hide" hypotheses are not currently resolvable. The California and Washington base models instead use a form of the "kill" hypothesis by not implementing the age-based selectivity ("hide" hypothesis) and estimating female and male natural mortality, thus avoiding a fixing natural mortality as was necessary in the Oregon model. The Oregon model also contained a step in female natural mortality, a specification not used in the California or Washington models.

Another important issue is the highly uncertain historical time-series of removals, which needs further consideration.

The development of fishery-dependent indices of abundance still requires further attention.

Steepness, while fixed, is still highly uncertain for rockfishes and currently is mismatched to the MSY proxy. And while the steepness profile shows low sensitivity in several derived quantities, steepness strongly defines the yield capacity of stocks, and therefore could cause major uncertainty in the recommended management quantities.

Stock structure and its relationship to the current political/management boundaries are also not fully understood, both within U.S. jurisdiction and between the U.S. and Canada. While this is a common challenge faced in most west coast stock assessments, further improvement on this topic will likely rely on Black Rockfish-specific data.

Harvest Projections and Decision Tables

The Oregon Black Rockfish assessment is a category 2 assessment, with a P*=0.45 and sigma increasing each year to produce the buffer shown in Table I-2. These multipliers are combined with the rockfish MSY proxy of F_{SPR}=50% MSY and the 40-10 harvest control rule to calculate OFLs, ABCs and ACLs. Harvest projections are provided in Table OR-7.

Uncertainty in management quantities for the base model was characterized by exploring various model specifications in a decision table. Initial exploration included natural mortality and steepness values. The Oregon analysis also explored the scale factor coming from the value of the tagging catchability (Q) parameter. The OR model demonstrated little sensitivity to *M*, but high sensitivity to the tagging survey Q. High and low states of nature, respectively, were based on a fixed tag of Q = 0.125 and Q estimated by the model. Resultant decision tables are provided in Table OR-8.

The base case in the decision table provided in Table WA-8 reflects increasing buffers, as it is the base-case result, however the rest of the table was produced using the same buffer as in the original 2015 analysis. This is due to the fact that the model must be manually re-run with adjusted sigma values and the resultant catch entered manually for each year, which was thought to be unnecessary for the purposes of this update, which focuses on the impact of increasing buffers on the base model projections.

The constant high- and low-catch streams were produced in consultation with ODFW staff and the GMT.

Table OR-7. Harvest projection of potential OFL and prescribed removals, summary biomass (age-3 and older), spawning output, and depletion for the Oregon base case model projected with total projected catch equal to the 420 mt for 2015 and 2016. The predicted OFL is the calculated total catch determined by F_{SPR}=50%.

Year	Predicted OFL	Projected removals	Age 3+ biomass	Spawning output	Depletion (%)
2019	577	515	7614	745	56%
2020	573	511	7552	735	56%
2021	570	479	7499	727	55%
2022	569	474	7481	721	55%
2023	569	470	7470	718	54%
2024	569	466	7463	715	54%
2025	570	461	7461	714	54%
2026	570	458	7462	713	54%
2027	571	454	7465	713	54%
2028	571	450	7472	713	54%
2029	572	446	7481	714	54%
2030	573	443	7492	715	54%

Table OR-8. Summary decision table of 12-year projections for the Oregon model beginning in 2017 for alternate states of nature based on the value of catchability (Q) for the tagging study. Columns range over low, mid, and high state of nature, and rows range over different assumptions of total catch levels corresponding to the iteratively generated catch stream from the base model, and constant low and high catch values provided by the GMT.

Oregon			**State of nature**					
			Low *Tag Q =0.44*		Base case *Tag Q = 0.25*		High *Tag Q = 0.125*	
Relative probability of states of nature			0.25		0.5		0.25	
Management decision	Year	Catch (mt)	Spawning output	Stock status	Spawning output	Stock status	Spawning output	Stock status
Low Q Catch	2021	440	325	32%	727	55%	1560	75%
	2022	440	321	32%	725	55%	1559	75%
	2023	440	319	32%	724	55%	1559	75%
	2024	440	318	32%	725	55%	1561	75%
	2025	440	318	32%	726	55%	1563	75%
	2026	440	317	32%	727	55%	1565	75%
	2027	440	317	32%	729	55%	1567	75%
	2028	440	316	32%	730	55%	1569	75%
	2029	440	315	31%	732	55%	1571	75%
	2030	440	314	31%	733	56%	1573	75%
Base Catch	2021	479	325	32%	727	55%	1560	75%
	2022	474	318	32%	721	55%	1556	74%
	2023	470	313	31%	718	54%	1553	74%
	2024	466	309	31%	715	54%	1552	74%
	2025	461	305	30%	714	54%	1551	74%
	2026	458	302	30%	713	54%	1551	74%
	2027	454	300	30%	713	54%	1552	74%
	2028	450	298	30%	713	54%	1553	74%
	2029	446	296	30%	714	54%	1555	74%
	2030	443	295	29%	715	54%	1557	74%
High Q catch	2021	580	325	32%	727	55%	1560	75%
	2022	580	310	31%	713	54%	1548	74%
	2023	580	295	29%	700	53%	1536	73%
	2024	580	280	28%	686	52%	1524	73%
	2025	580	264	26%	673	51%	1512	72%
	2026	580	250	25%	661	50%	1502	72%
	2027	580	236	24%	649	49%	1492	71%
	2028	580	222	22%	638	48%	1483	71%
	2029	580	210	21%	628	48%	1475	71%
	2030	580	198	20%	619	47%	1467	70%

Research and Data Needs

Recommended avenues for research to help improve future Black Rockfish stock assessments:

7. Further investigation into the movement and behavior of older (> age 10) females to reconcile their absence in fisheries data. If the females are currently inaccessible to fishing gear, can we find where they are?
8. Appropriate natural mortality values for females and males. This will help resolve the extent to which dome-shaped age-based selectivity may be occurring for each.
9. All states need improved historical catch reconstructions. The trawl fishery catches in particular require particular attention. Given the huge historical removals of that fleet in each state, the assessment is very sensitive to the assumed functional form of selectivity. A synoptic catch reconstruction is recommended, where states work together to resolve cross-state catch issues as well as standardize the approach to catch recommendations.
10. Identifying stanzas or periods of uncertainty in the historical catch series will aid in the exploration of catch uncertainty in future assessment sensitivity runs.
11. The ODFW tagging study off Newport should be continued and expanded to other areas. To provide better prior information on the spatial distribution of the Black Rockfish stock, further work should be conducted to map the extent of Black Rockfish habitat and the densities of Black Rockfish residing there.
12. An independent nearshore survey should be supported in all states to avoid the reliance on fishery-based CPUE indices.
13. Stock structure for Black Rockfish is a complicated topic that needs further analysis. How this is determined (e.g., exploitation history, genetics, life history variability, biogeography, etc.) and what this means for management units needs to be further refined. This is a general issue for all nearshore stocks that likely have significant and small scale stock structure among and within states, but limited data collections to support small-scale management.

Table OR-9. Summary tables of the result for the Oregon assessment model for Black Rockfish. OFL and ACL values for California and Oregon are combined across both states (see Table OR-6).

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Landings (mt)	446	420	319	330	436	485	599	537	547	418
Total removals (mt)	446	420	319	330	436	485	599	537	547	418
OFL (mt)	1469	1317	1163	1117	1108	1115	1176	1183	577	570
ACL (mt)	1000	1000	1000	1000	1000	1000	1000	1000	527	520
1-SPR	0.795	0.758	0.615	0.625	0.77	0.84	0.984	0.928	0.954	0.795
Exploitation rate (catch/ age 3+ biomass)	0.084	0.079	0.061	0.063	0.081	0.091	0.112	0.104	0.108	0.084
Age 3+ biomass (mt)	8002	7966	7956	8041	8109	8071	7987	7803	7694	7587
Spawning Output	785	786	793	801	800	795	778	765	750	745
~95% CI	(685-885)	(686-886)	(693-894)	(700-902)	(699-902)	(693-896)	(677-879)	(664-865)	(650-849)	(646-844)
Recruitment	3490	3490	3494	3498	3498	3495	3486	3479	3471	3468
~95% CI	(3416-3565)	(3416-3565)	(3416-3565)	(3416-3565)	(3416-3565)	(3416-3565)	(3416-3565)	(3416-3565)	(3416-3565)	(3416-3565)
Depletion (%)	0.6	0.6	0.6	0.61	0.61	0.6	0.59	0.58	0.57	0.56
~95% CI	(0.58-0.61)	(0.58-0.61)	(0.59-0.62)	(0.59-0.62)	(0.59-0.62)	(0.59-0.62)	(0.58-0.61)	(0.56-0.6)	(0.55-0.59)	(0.55-0.58)

4 Washington

Catch

Black Rockfish are caught by a wide variety of gear types and in recent decades have been a very important target species for recreational charter-boats and private sport anglers. In recent years the recreational fishery has accounted for most of the Black Rockfish catches (Table WA-1) Black Rockfish can also be an important component of nearshore commercial fisheries, either as incidental catch by the troll fishery for salmon or as directed catch by jig fisheries for groundfish.

Washington managers closed nearshore commercial fisheries in state water in late 1990's, and never allowed the live-fish fishery to develop. There have been almost no trawl-caught landings of Black Rockfish in recent years (Table WA-1), but trawl landings in the past were substantial (Figure WA-1).

Detailed reports of commercial landings of Black Rockfish are generally unavailable prior to 1981, when the Pacific Fishery Information Network (PacFIN) database began. The catch series prior to 1981 for these assessments were derived by applying available estimates or assumed values for the proportion of Black Rockfish landings in reported landings of rockfish. Observer data, which are available only for the past decade, indicate low levels of discarding of Black Rockfish, generally less than 2% of the total catch.

Because of their nearshore distribution and low abundance compared to other rockfish species, Black Rockfish are unlikely to have ever comprised a large percentage of rockfish landings, but it seems quite certain that they have been more than a trivial component for many years. Mentions of Black Rockfish in landings data extend back before the year 1900 in Washington.

Table WA-1 Recent Landings inWashington.

Year	Trawl	NonTrawl	Rec
2009	0.003	0.000	251
2010	0.034	0.000	219
2011	0.997	0.000	231
2012	0.953	0.040	281
2013	0.009	0.000	325
2014	1.053	0.014	355
2015	0.964	0.787	349
2016	0.602	1.675	360
2017	0.239	0.210	226
2018	0.002	0.181	254

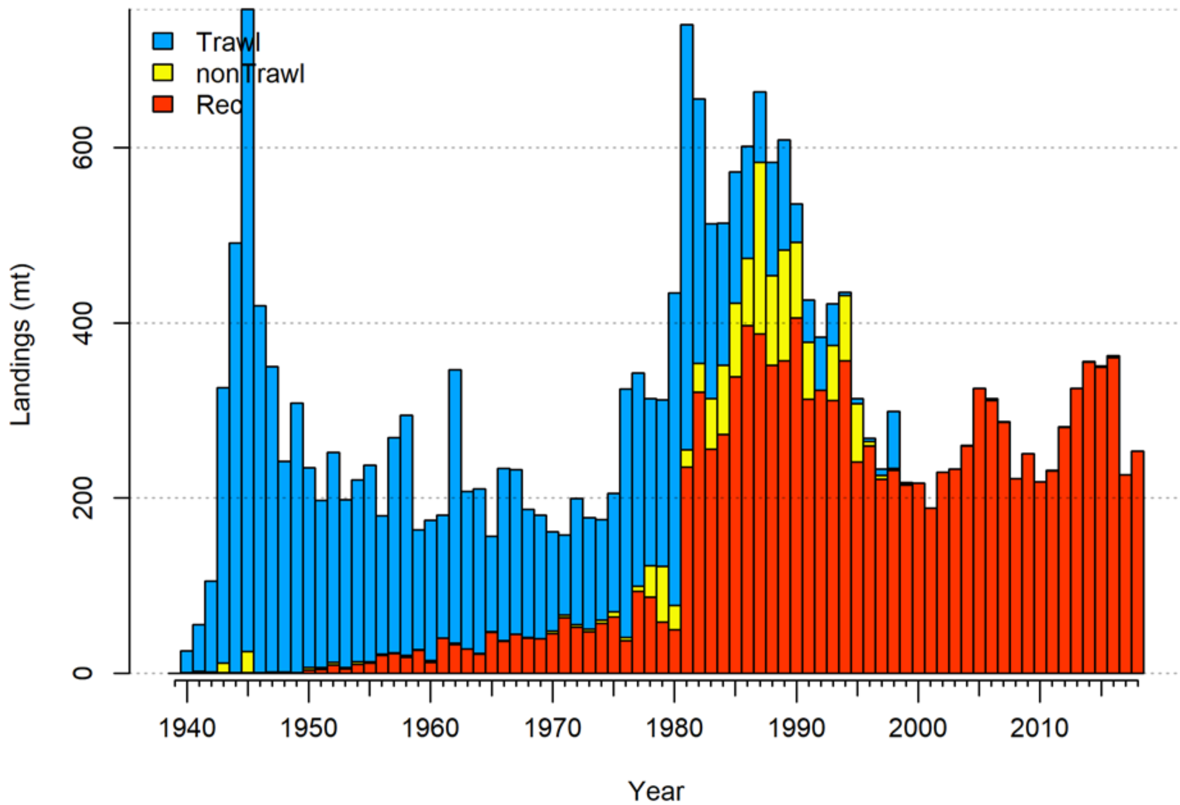

Figure WA-1 Landings history of Black Rockfish for Washington.

Data

The Washington base assessment includes a dockside and tag-based CPUE series, but does not include the abundance estimate time series from that same tagging study which was included in the last assessment due to too many violations in the assumptions of abundance estimation. The same two commercial and single recreational fleets are used as in the last assessment for Washington. The model includes age data as conditional age-at-length, as well as length data.

For this update, catch data from 2015-2018 were added to the model, and the Pacific Council's Groundfish Management Team (GMT) provided catch estimates for 2019 and 2020.

Spawning Stock Output

Spawning stock outputs are at or above limit reference points (Table WA-2). Washington stocks show a declining population through most of the 20th Century, with stronger declines in the 1980s, and recoveries beginning in the mid-1990s. The Washington stock, currently 47%, dropped below the target biomass in the early 1980s, then risen above since the late 1990s and has fluctuated above that point through 2014 (Figures WA-3 and WA-4).

Table WA-2: Recent trend in beginning-of-year biomass and depletion in Washington.

Year	Spawning Output (billion eggs)	~ 95% confidence interval	Estimated depletion	~ 95% confidence interval
2010	551	(444-657)	0.41	(0.34-0.47)
2011	550	(444-656)	0.41	(0.34-0.47)
2012	552	(446-658)	0.41	(0.34-0.47)
2013	557	(449-664)	0.41	(0.34-0.48)
2014	567	(456-678)	0.42	(0.35-0.49)
2015	582	(467-698)	0.43	(0.36-0.5)
2016	600	(478-722)	0.44	(0.37-0.52)
2017	611	(482-739)	0.45	(0.37-0.53)
2018	632	(498-767)	0.47	(0.38-0.55)
2019	643	(502-784)	0.47	(0.39-0.56)

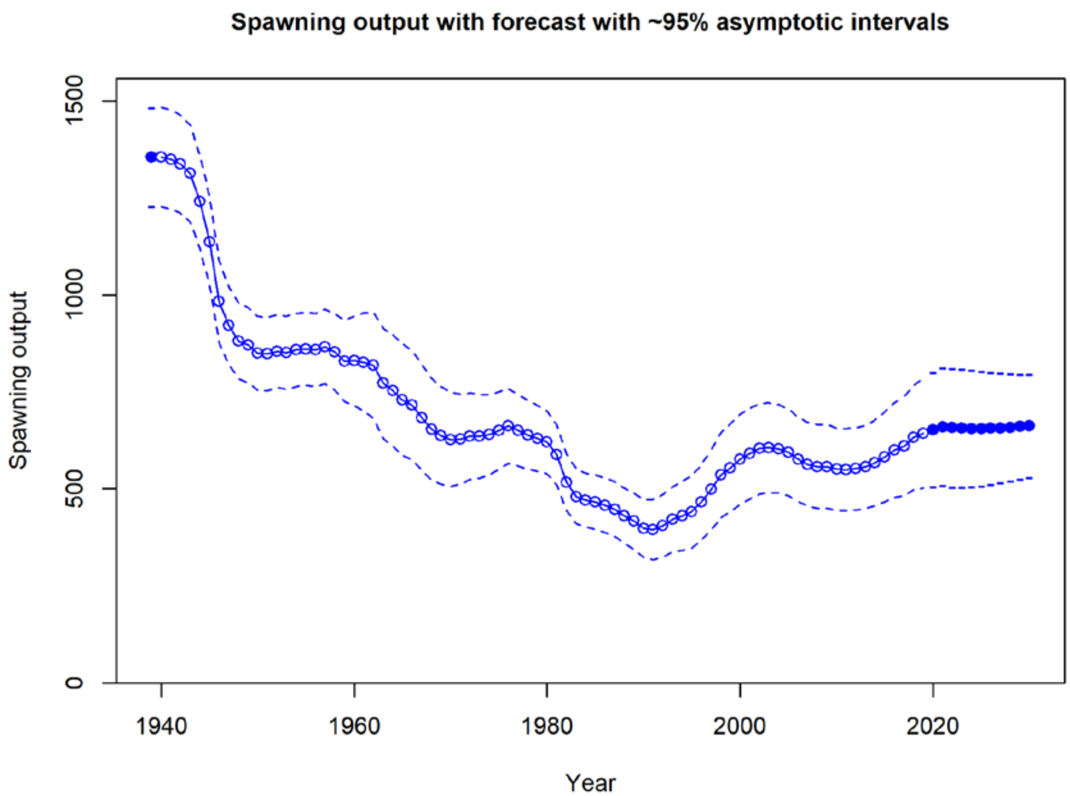

Figure WA-3: Timeseries of spawning output of Black Rockfish in Washington. Forecasts are shown as solid points. Forecasts begin in 2021 and assume full ABC/ACL removals.

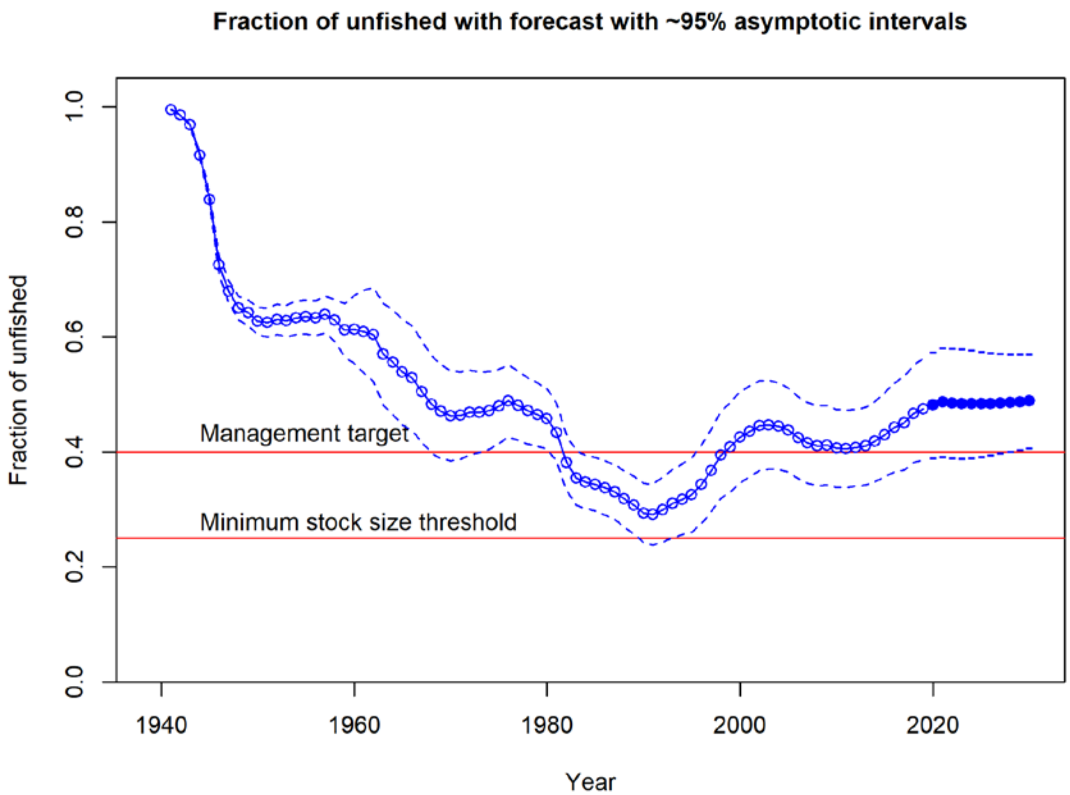

Figure WA-4. Timeseries of stock status (depletion) of Black Rockfish in Washington. Forecasts are shown as solid points. Forecasts begin in 2021 and assume full ABC/ACL removals.

Recruitment

Washington recruitment is dynamic, but well-informed, which is consistent with the extent of length and age compositions available to that assessment (Table WA-3; Figure WA-5).

Table WA-3. Recent trend in recruitment for Black Rockfish in Washington.

Year	Estimated Recruitment (1,000s)	~ 95% Confidence Interval
2010	2670	(1544-4617)
2011	1157	(508-2635)
2012	1899	(1459-2472)
2013	1901	(1461-2474)
2014	1907	(1466-2481)
2015	1915	(1472-2490)
2016	1924	(1480-2501)
2017	1929	(1484-2508)
2018	1939	(1493-2518)
2019	1943	(1497-2523)

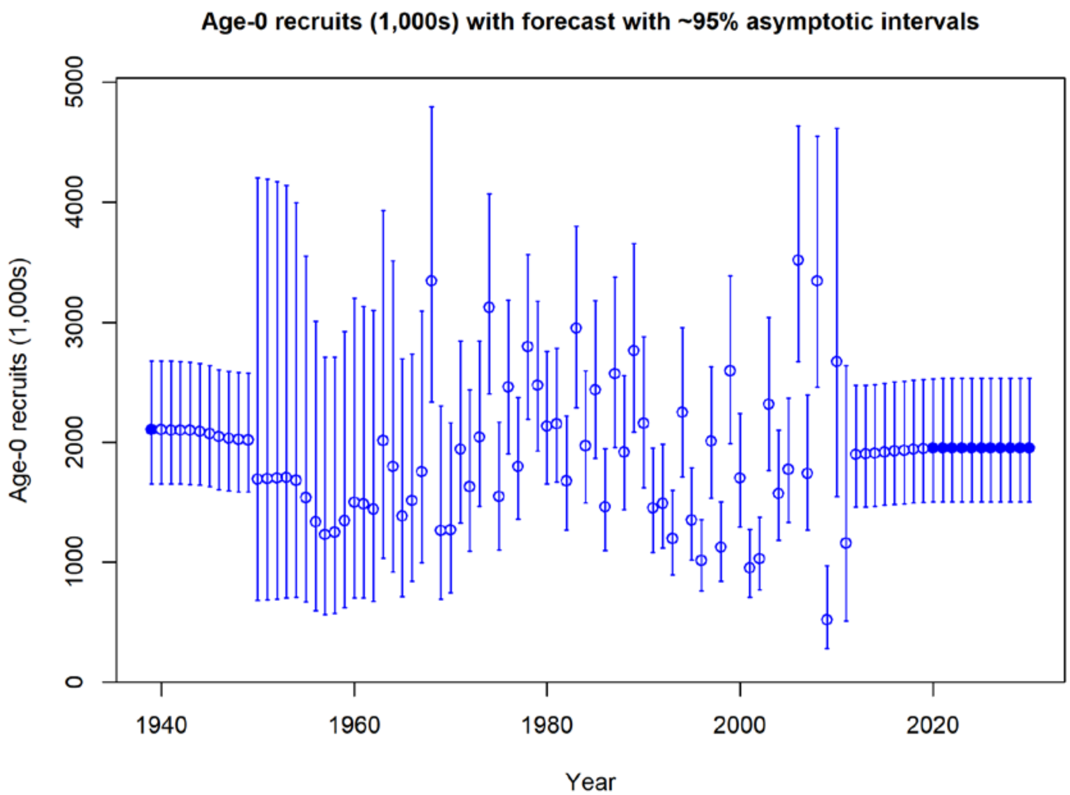

Figure WA-5. Timeseries of Black Rockfish recruitment in Washington. Forecasts are shown as solid points. Forecasts begin in 2021 and assume full ABC/ACL removals.

Exploitation Status

The Washington model indicates that current fishing practices are near or above the SPR rate fishing intensity target. Washington shows a dramatic decline in fishing intensity since the late 1990s and has fluctuated around the target since (Table WA-4, Figure WA-6).

Table WA-4. Recent trend in spawning potential ratio (1-SPR/1-SPR_{50}) and summary exploitation rate (catch divided by biomass of age 3+ fish) for Black Rockfish in Washington.

Year	Fishing intensity	~ 95% confidence interval	Exploitation rate	~ 95% confidence interval
2009	0.97	(0.83-1.1)	0.07	(0.06-0.08)
2010	0.88	(0.75-1.01)	0.06	(0.05-0.07)
2011	0.89	(0.76-1.02)	0.06	(0.05-0.07)
2012	0.98	(0.84-1.11)	0.07	(0.06-0.08)
2013	1.03	(0.89-1.17)	0.08	(0.06-0.09)
2014	1.07	(0.93-1.22)	0.08	(0.07-0.1)
2015	1.06	(0.92-1.21)	0.08	(0.06-0.09)
2016	1.09	(0.94-1.24)	0.08	(0.07-0.1)
2017	0.81	(0.67-0.96)	0.05	(0.04-0.06)
2018	0.88	(0.73-1.02)	0.06	(0.05-0.07)

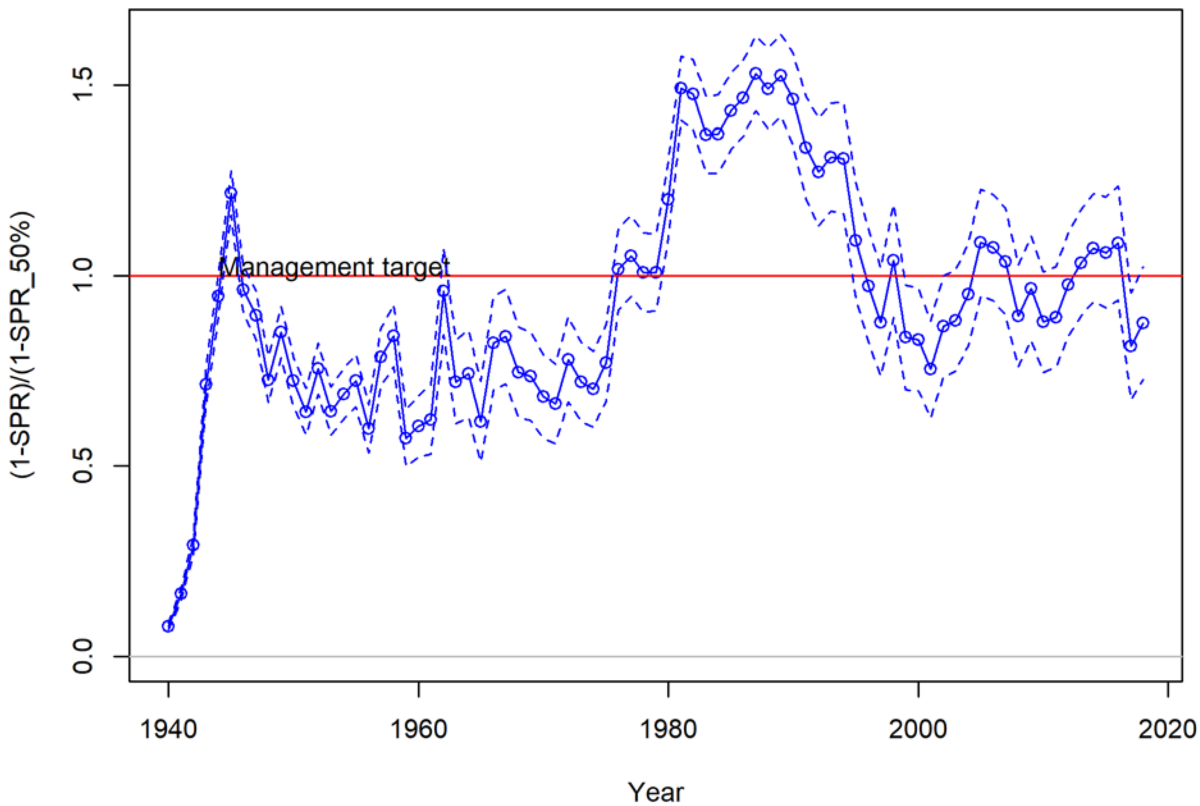

Figure WA-6. Estimated spawning potential ratio (SPR) for the Washington assessment. Relative SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{50\%}$ harvest rate. The last year in the time series is 2018.

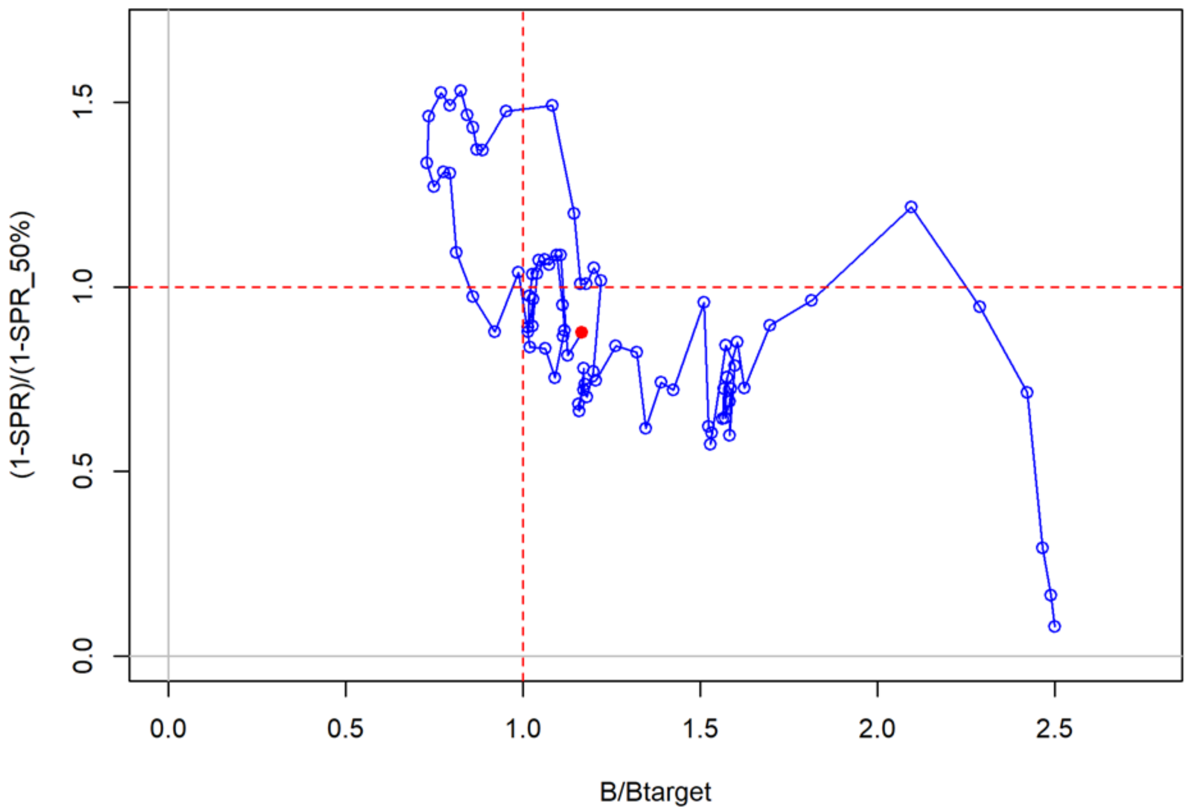

Figure WA-7. Phase plot of relative spawning biomass vs fishing intensity for the Washington model. The relative fishing intensity is (1-SPR) divided by 1-the SPR target. The vertical red line is the relative spawning biomass target defined as the annual spawning output divided by the spawning biomass corresponding to 40% of the unfished spawning biomass. The last year in the timeseries is 2018.

Ecosystem Considerations

Ecosystem considerations were not explicitly included in these models, though growth deviations were considered in the Washington model. While no mechanisms have been put forth for these time-varying changes in growth, an environmental component is possible. Limited data in Oregon and California also suggest the possibility that growth has changed over time.

Reference Points

Reference points were based on the rockfish F_{MSY} proxy ($SPR_{50\%}$), target relative biomass (40%) and model-estimated selectivity for each fleet. Washington relative biomass is above the target biomass. Yield values are lower than the previous assessment for similar reference points due to lower overall natural mortality values (Table WA-5). The proxy MSY values of management quantities are the most conservative compared to the estimated MSY and MSY relative to 40% biomass (Table WA-5). The equilibrium estimates of yield relative to biomass are provided in Figure WA-8.

Table WA-5. Summary of reference points for the Washington Black Rockfish base case model

Quantity	Estimate	~95% Confidence Interval
Unfished spawning output (billion eggs)	1355.8	(1228.2-1483.4)
Unfished age 3+ biomass (mt)	9119.2	(8466.7-9771.7)
Unfished recruitment (R_0, thousands)	2101.6	(1593.1-2610)
Spawning output (2019 billion eggs)	643.1	(502.1-784)
Depletion (2019)	0.4743	(0.3861-0.5625)
Reference points based on $SB_{40\%}$		
Proxy spawning output (B40%)	542.3	(491.3-593.4)
SPR resulting in B40% (SPRB40%)	0.444	(0.444-0.444)
Exploitation rate resulting in B40%	0.0863	(0.0801-0.0924)
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	337.1	(298.1-376.1)
Reference points based on SPR proxy for MSY		
Spawning output	624.2	(565.5-682.9)
SPRproxy	0.5	
Exploitation rate corresponding to SPRproxy	0.0722	(0.067-0.0774)
Yield with SPR_{proxy} at SB_{SPR} (mt)	310.5	(275-346)
Reference points based on estimated MSY values		
Spawning output at MSY (SB_{MSY})	294.1	(266.5-321.6)
SPR_{MSY}	0.2744	(0.2711-0.2777)
Exploitation rate at MSY	0.1486	(0.1368-0.1603)
MSY (mt)	383.4	(337.2-429.6)

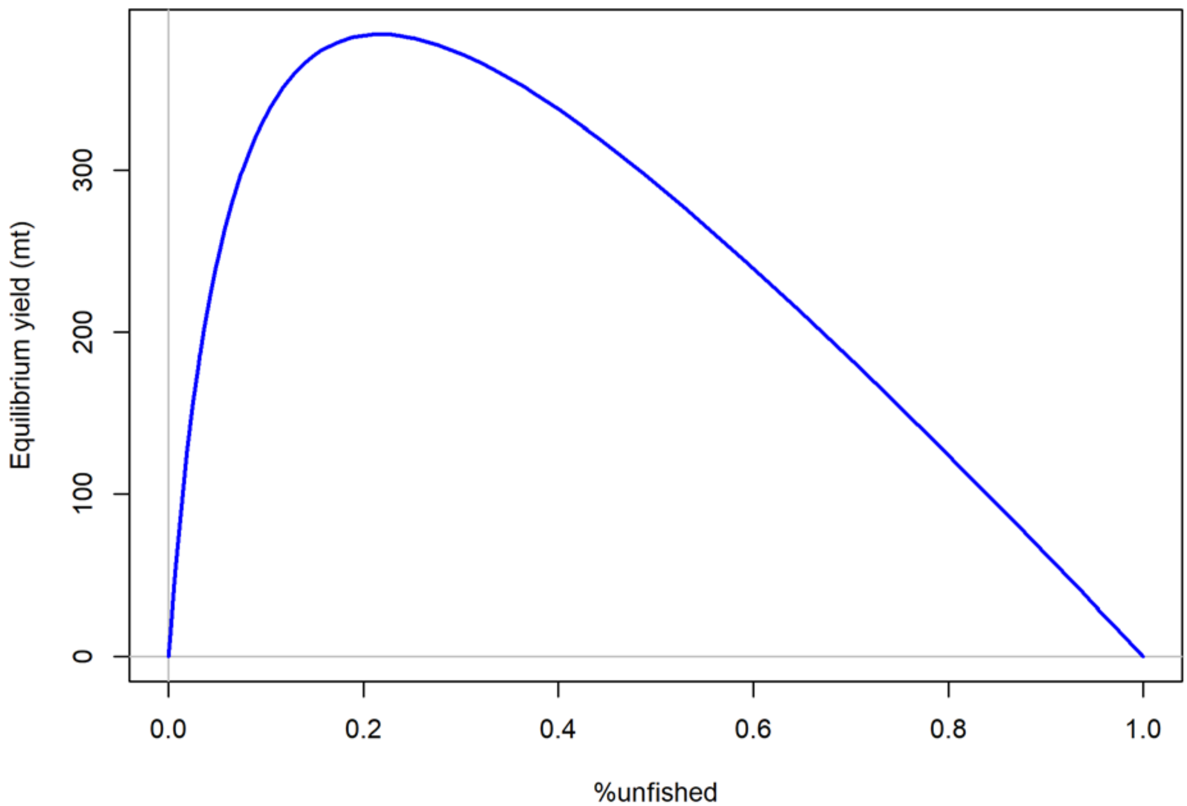

Figure WA-8. Equilibrium yield curve (derived from reference point values reported in Table WA-5) for the Washington base case model. Values are based on 2018 fishery selectivity and distribution with steepness fixed at 0.773. The depletion is relative to unfished spawning biomass.

Management Performance

Table WA-6. Recent trend in total catch and commercial landings (mt) relative to the management guidelines. Estimated total catch reflects the recreational and commercial landings plus estimated commercial discarded biomass.

Year	OFL	ACL	WA Catch
2009	490	490	251
2010	464	464	219
2011	426	426	232
2012	415	415	282
2013	411	411	325
2014	409	409	356
2015	421	402	351
2016	423	404	362
2017	319	305	227
2018	315	301	254

Unresolved Problems and Major Uncertainties

The most significant uncertainty for all models is the treatment and value of natural mortality and the form of fleet selectivity (e.g., length-based asymptotic vs. age-based dome-shaped selectivity). Data-driven selection between the extreme "kill" (using a ramping of M) or "hide" hypotheses are not currently resolvable. The California and Washington base models instead use a form of the "kill" hypothesis by not implementing the age-based selectivity ("hide" hypothesis) and estimating female and male natural mortality, thus avoiding a fixing natural mortality as was necessary in the Oregon model. The Oregon model also contained a step in female natural mortality, a specification not used in the California or Washington models.

Another important issue is the highly uncertain historical time-series of removals, which needs further consideration.

The development of fishery-dependent indices of abundance still requires further attention.

Steepness, while fixed, is still highly uncertain for rockfishes and currently is mismatched to the MSY proxy. And while the steepness profile shows low sensitivity in several derived quantities, steepness strongly defines the yield capacity of stocks, and therefore could cause major uncertainty in the recommended management quantities.

Stock structure and its relationship to the current political/management boundaries are also not fully understood, both within U.S. jurisdiction and between the U.S. and Canada. While this is a common challenge faced in most west coast stock assessments, further improvement on this topic will likely rely on Black Rockfish-specific data.

Harvest Projections and Decision Tables

Black Rockfish assessments for California and Washington have a preliminary distinction as category 1 stock assessments, thus harvest projections and decision tables are based on using P*=0.45 with sigma increasing for each year of the harvest projections to produce the buffer sequence in Table I-2.

Uncertainty in management quantities for the Washington base model was characterized by exploring various model specifications in a decision table. Initial exploration included natural mortality and steepness values, and uncertainty in historical trawl catches. There was very little sensitivity to steepness and trawl catches, but natural mortality produced sensitive results of predicted population scale and status. Discussion with the STAR panel resulted in high and low states of nature +/- 0.03 from the base case natural mortality values for females and males. High and low catch streams (rows) were determined by the forecasts, as described above, for each state of nature. Thus the low catch stream is based on the forecast from the low state of nature.

The base case in the decision table provided in Table WA-8 reflects increasing buffers, as it is the base-case result, however the rest of the table was produced using the same buffer as in the original 2015 analysis. This is due to the fact that the model must be manually re-run with adjusted sigma values and the resultant catch entered manually for each year, which was thought to be unnecessary for the purposes of this update, which focuses on the impact of increasing buffers on the base model projections.

Table WA-7. Harvest projection of potential OFL and prescribed removals, summary biomass (age-3 and older), spawning output, and depletion for the Washington base case model projected with total projected catch equal to the 420 mt for 2015 and 2016. The predicted OFL is the calculated total catch determined by F_{SPR}=50%.

Year	Predicted OFL	Projected removals	Age 3+ biomass	Spawning output	Depletion (%)
2019	312	228	5611	643	47%
2020	315	228	5673	653	48%
2021	319	293	5735	660	49%
2022	319	291	5735	658	49%
2023	319	290	5740	656	48%
2024	319	289	5747	656	48%
2025	320	288	5757	656	48%
2026	320	287	5768	656	48%
2027	321	287	5779	657	48%
2028	322	286	5791	659	49%
2029	323	285	5803	661	49%
2030	324	284	5814	663	49%

Table WA-8. Summary decision table of 12-year projections for the Washington model beginning in 2017 for alternate states of nature based on natural mortality. Columns range over low, mid, and high state of nature, and rows range over different assumptions of total catch levels corresponding to the forecast catches from each state of nature. Catches in 2019 and 2020 are allocated to each fleet based on the percentage of landings for each fleet in the previous five years

Washington			**State of nature**					
			Low		Base case		High	
			M_{female}= 0.133 ; M_{male} = 0.115		M_{female}= 0.163 ; M_{male} = 0.145		M_{female}= 0.193 ; M_{male} = 0.175	
Relative probability of states of nature			0.25		0.5		0.25	
Management decision	Year	Catch (mt)	Spawning output	Stock status	Spawning output	Stock status	Spawning output	Stock status
Low catch	2021	204	564	37%	660	49%	817	60%
	2022	210	576	38%	671	50%	826	61%
	2023	215	587	38%	682	50%	836	61%
	2024	220	598	39%	693	51%	847	62%
	2025	224	609	40%	704	52%	858	63%
	2026	227	619	41%	713	53%	868	64%
	2027	229	628	41%	722	53%	877	64%
	2028	231	637	42%	730	54%	886	65%
	2029	233	645	42%	737	54%	893	66%
	2030	235	652	43%	744	55%	899	66%
Base catch	2021	293	564	37%	660	49%	817	60%
	2022	291	561	37%	658	49%	814	60%
	2023	290	559	37%	656	48%	812	60%
	2024	289	556	36%	656	48%	813	60%
	2025	288	555	36%	656	48%	815	60%
	2026	287	554	36%	656	48%	817	60%
	2027	287	554	36%	657	48%	820	60%
	2028	286	554	36%	659	49%	823	61%
	2029	285	555	36%	661	49%	827	61%
	2030	284	556	36%	663	49%	830	61%
High catch	2021	453	564	37%	660	49%	817	60%
	2022	444	534	35%	633	47%	791	58%
	2023	436	506	33%	608	45%	768	56%
	2024	429	478	31%	585	43%	749	55%
	2025	424	453	30%	564	42%	732	54%
	2026	420	430	28%	546	40%	719	53%
	2027	417	410	27%	530	39%	708	52%
	2028	414	392	26%	517	38%	699	51%
	2029	412	375	25%	506	37%	692	51%
	2030	410	361	24%	496	37%	686	50%

Research and Data Needs

Recommended avenues for research to help improve future Black Rockfish stock assessments:

1. Further investigation into the movement and behavior of older (> age 10) females to reconcile their absence in fisheries data. If the females are currently inaccessible to fishing gear, can we find where they are?
2. Appropriate natural mortality values for females and males. This will help resolve the extent to which dome-shaped age-based selectivity may be occurring for each.
3. All states need improved historical catch reconstructions. The trawl fishery catches in particular require particular attention. Given the huge historical removals of that fleet in each state, the assessment is very sensitive to the assumed functional form of selectivity. A synoptic catch reconstruction is recommended, where states work together to resolve cross-state catch issues as well as standardize the approach to catch recommendations.
4. Identifying stanzas or periods of uncertainty in the historical catch series will aid in the exploration of catch uncertainty in future assessment sensitivity runs.
5. An independent nearshore survey should be supported in all states to avoid the reliance on fishery-based CPUE indices.
6. Stock structure for Black Rockfish is a complicated topic that needs further analysis. How this is determined (e.g., exploitation history, genetics, life history variability, biogeography, etc.) and what this means for management units needs to be further refined. This is a general issue for all nearshore stocks that likely have significant and small scale stock structure among and within states, but limited data collections to support small-scale management.

Table WA-9. Summary tables of the result for the Washington assessment model for Black Rockfish.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Landings (mt)	251	219	232	282	325	356	351	362	227	254
Total removals (mt)	251	219	232	282	325	356	351	362	227	254
OFL (mt)	490	464	426	415	411	409	421	423	319	315
ACL (mt)	490	464	426	415	411	409	402	404	305	301
1-SPR	0.97	0.88	0.89	0.98	1.03	1.07	1.06	1.09	0.81	0.88
Exploitation rate (catch/ age 3+ biomass)	0.07	0.06	0.06	0.07	0.08	0.08	0.08	0.08	0.05	0.06
Age 3+ biomass (mt)	4980	5119	5427	5550	5699	5690	5645	5588	5516	5576
Spawning Output	551	550	552	557	567	582	600	611	632	643
~95% CI	(444-657)	(444-656)	(446-658)	(449-664)	(456-678)	(467-698)	(478-722)	(482-739)	(498-767)	(502-784)
Recruitment	2670	1157	1899	1901	1907	1915	1924	1929	1939	1943
~95% CI	(1544-4617)	(508-2635)	(1459-2472)	(1461-2474)	(1466-2481)	(1472-2490)	(1480-2501)	(1484-2508)	(1493-2518)	(1497-2523)
Depletion (%)	0.41	0.41	0.41	0.41	0.42	0.43	0.44	0.45	0.47	0.47
~95% CI	(0.34-0.47)	(0.34-0.47)	(0.34-0.47)	(0.34-0.48)	(0.35-0.49)	(0.36-0.5)	(0.37-0.52)	(0.37-0.53)	(0.38-0.55)	(0.39-0.56)