Catch update for darkblotched rockfish (*Sebastes crameri*) off the U.S. West Coast.

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Contents

Executive Summary **1**

Stock . . . 1

Landings . . . 1

Data and Assessment . . . 3

Stock Output . . . 3

Recruitment . . . 6

Exploitation Status . . . 8

Ecosystem Considerations . . . 13

Reference Points . . . 13

Management Performance . . . 14

Unresolved Problems and Major Uncertainties . . . 14

Decision Table . . . 15

References **19**

Executive Summary

Stock

This catch update reports the status of darkblotched rockfish (*Sebastes crameri*) in U.S. waters off the West Coast. Darkblotched rockfish in the Northeast Pacific Ocean occur from the southeastern Bering Sea and Aleutian Islands to near Santa Catalina Island in southern California. This species is most abundant from off British Columbia to Central California. Commercially important concentrations are found from the Canadian border through Northern California. This update assessment focuses on the portion of the population that occurs in coastal waters of the western contiguous United States, off Washington, Oregon and California, the area bounded by the U.S.-Canada border on the north and U.S.-Mexico border on the south. The population within this area is treated as a single coast wide stock, due to the lack of biological and genetic data supporting the presence of multiple stocks.

Landings

Darkblotched rockfish is caught primarily with commercial trawl gear, as part of a complex of slope rockfish, which includes Pacific ocean perch (*Sebastes alutus*), splitnose rockfish (*Sebastes diploproa*), yellowmouth rockfish (*Sebastes reedi*), and sharpchin rockfish (*Sebastes zacentrus*). The species is managed with stock-specific harvest specifications (not within the current slope rockfish complexes). Catches taken with non-trawl gear over the years comprised 2% of the total coast wide shoreside catch. This species has not been taken recreationally.

Catch of darkblotched rockfish first became significant in the mid-1940s when balloon trawl nets (efficient in taking rockfish) were introduced, and due to increased demand during World War II. The largest removals of the species occurred in the 1960s, when foreign trawl fleets from the former Soviet Union, Japan, Poland, Bulgaria and East Germany came to the Northeast Pacific Ocean to target large aggregations of Pacific ocean perch, a species that co-occurs with darkblotched rockfish. In 1966 the removals of darkblotched rockfish reached 4,220 metric tons. By the late-1960s, the foreign fleet had more or less abandoned the fishery. Shoreside landings of darkblotched rockfish rose again between the late-1970s and the late-1980s, peaking in 1987 with landings of 2,415 mt. In 2000, the species was declared overfished, and landings substantially decreased due to management regulations. During the last decade the total removals of darkblotched rockfish has ranged from 106 - 338 mt (Table a and Figure a).

The total landings in Table a for 2017 and 2018 were fixed by fleet according to values provided by the Pacific Fishery Management Council (PFMC) Groundfish Management Team (GMT). The discard mortality was obtained from the Groundfish Mortality Report (Somers et al. 2018) and was based on recent average rate of 4% discarding for the shoreside fleet only.

Table a: Total removals (mt) for the past 10 years for darkblotched rockfish by source.

Year	Shoreside Hake	Bycatch At-Sea Hake	Total Landings	Total Removals
2010	176.2	8.2	184.3	337.9
2011	104.7	12.2	116.8	121.3
2012	96.3	2.7	99.0	102.5
2013	117.8	6.3	124.1	127.8
2014	92.6	10.6	103.2	106.5
2015	122.8	7.9	130.7	136.8
2016	124.0	5.1	129.1	136.6
2017	183.0	39.6	222.6	229.8
2018	267.8	65.1	332.9	343.5

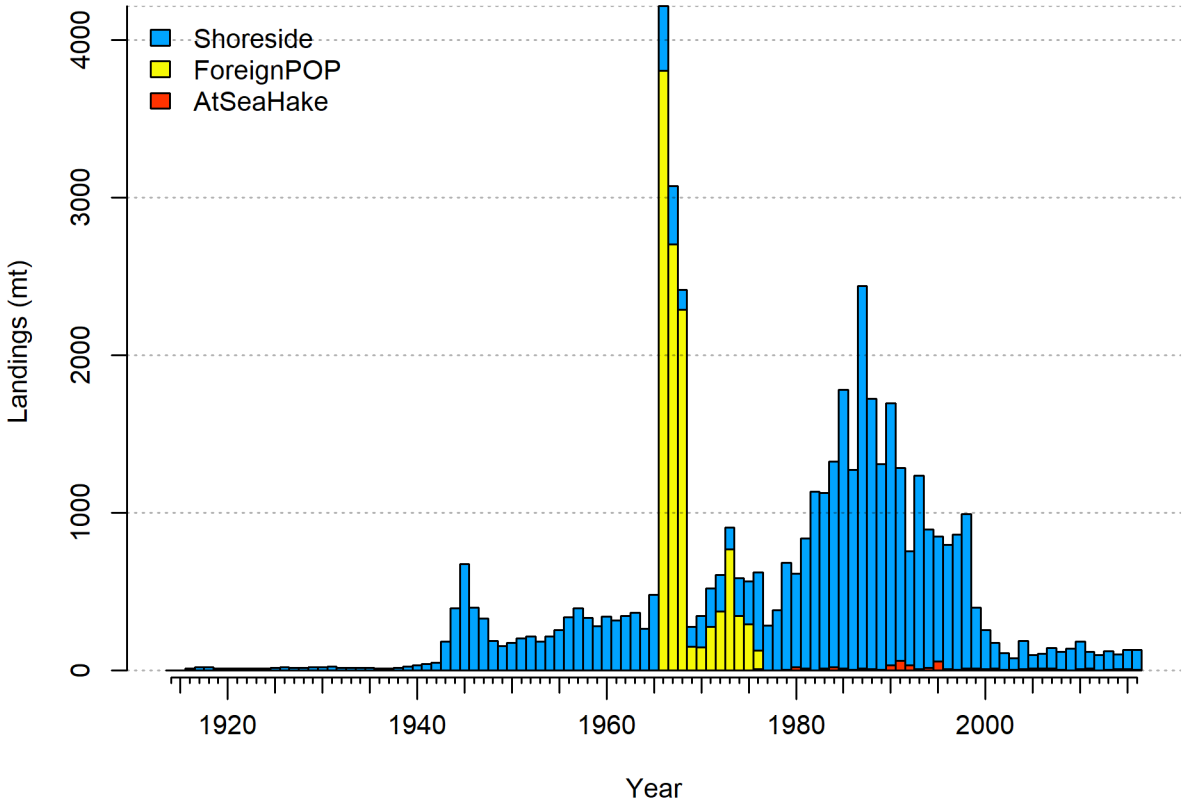

Figure a: 'Total landings by fleet and total removals off the U.S. West Coast.

Data and Assessment

Darkblotched rockfixh was last assessed in 2017, and estimated to be at 40% of unfished spawning output (Wallace and Gertseva 2018). The 2017 assessment of darkblotched rockfish used Stock Synthesis (version V3.30.01.12). The assessment was structured as a single, sex-disaggregated, unit population, spanning U.S. West Coast waters. The assessment model operated on an annual time step covering the period 1916 to 2017 (not including forecast years) and assumed an unfished population prior to 1915. Population dynamics were modeled for ages 0 through 45, with age-45 being the accumulator age. The model was conditioned on catch from three fleets (shoreside hake, foreign, and at-sea hake discards), and was informed by four fishery-independent abundance indices. Size composition data included lengths from multiple fleets spanning the period 1977-2016 and ages spanning the period 1980-2016. The assessment fixed female natural mortality, estimated male natural mortality, and fixed steepness of the Beverton-Holt stock-recruitment relationship, and estimated gender-specific growth parameters. The model estimated early recruitment deviations from the expected stock-recruitment relationship prior to the start of the model beginning in 1870, with the main period of estimated recruitment deviations, based on data, beginning in 1960 .

All assumptions from the 2017 assessment were retained here. Only landings and discards from 2017 and 2018 based on estimates of actual removals provided by the GMT were added and discarding rates based on Groundfish Mortality Report (Somers et al. 2018). Total removals in the projection years of 2019 and 2020 were based on projected removals provided by the GMT with discarding added. The removals from 2021-2030 were based on the estimated ABCs using an increasing σ for category 1 stocks (0.50) and a risk tolerance (P*) of 0.45.

Stock Output

Spawning output of darkblotched rockfish was estimated to be 1559 million eggs in 2019 ($\sim$ 95% asymptotic interval: $\pm$ 1559-1559 million eggs), or 44.0% of unfished spawning output ($\sim$ 95% asymptotic interval: $\pm$ 44.0%-44.0%; Table b). Relative spawning output (depletion) is a ratio of the estimated spawning output in a particular year relative to estimated unfished, equilibrium spawning output. The trend in spawning output in 2019 is above the management target (40% of unfished spawning output).

The spawning output of darkblotched rockfish started to decline in the 1940s, during World War II, but exhibited a sharp decline in the 1960s during the time of the intense foreign fishery targeting Pacific ocean perch (Figures b and c). Between 1965 and 1976, spawning output dropped from 90% to 64% of its unfished level. Spawning output continued to decline throughout the 1980s and 1990s and in 2000 reached its lowest estimated level of 17% of its unfished state. Since 2000, the spawning output has been slowly increasing, which corresponds to decreased removals due to management regulations.

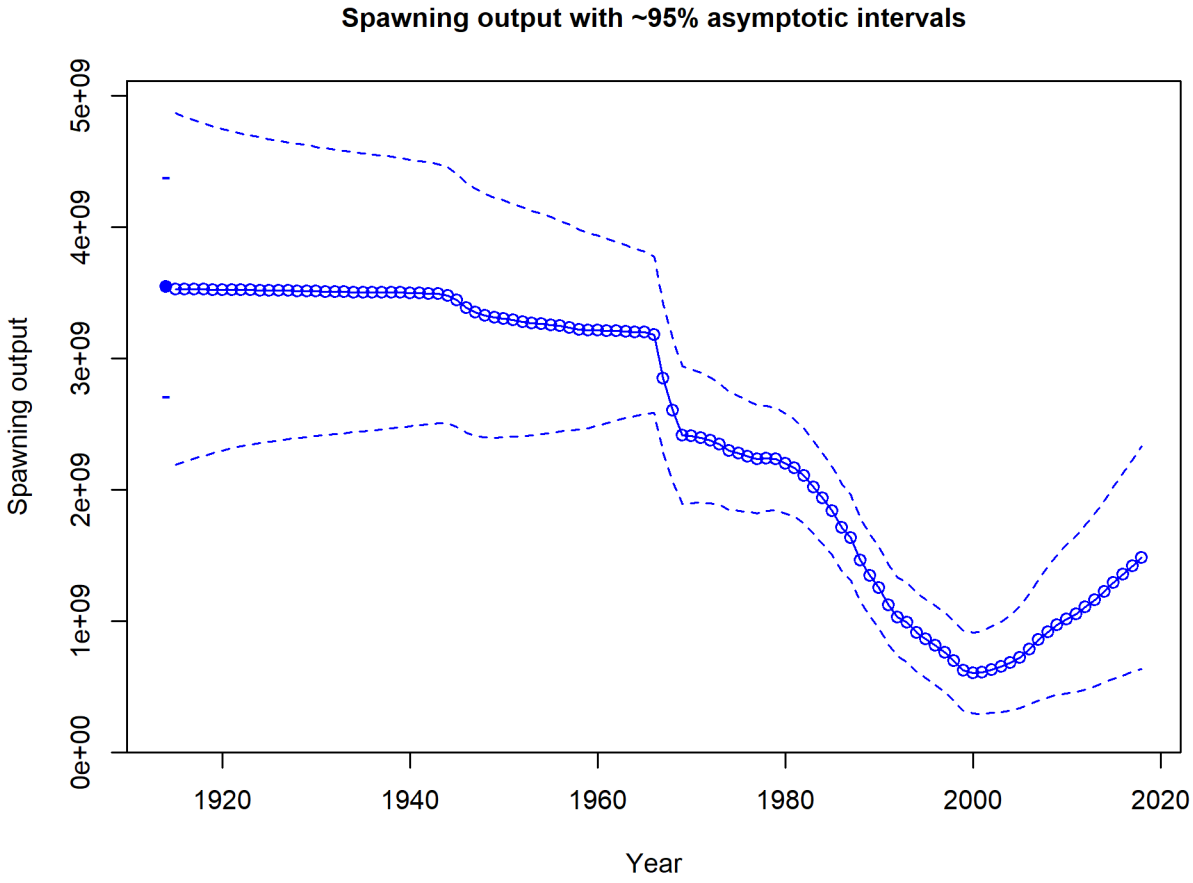

Figure b: Estimated time-series of spawning output trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the catch update model.

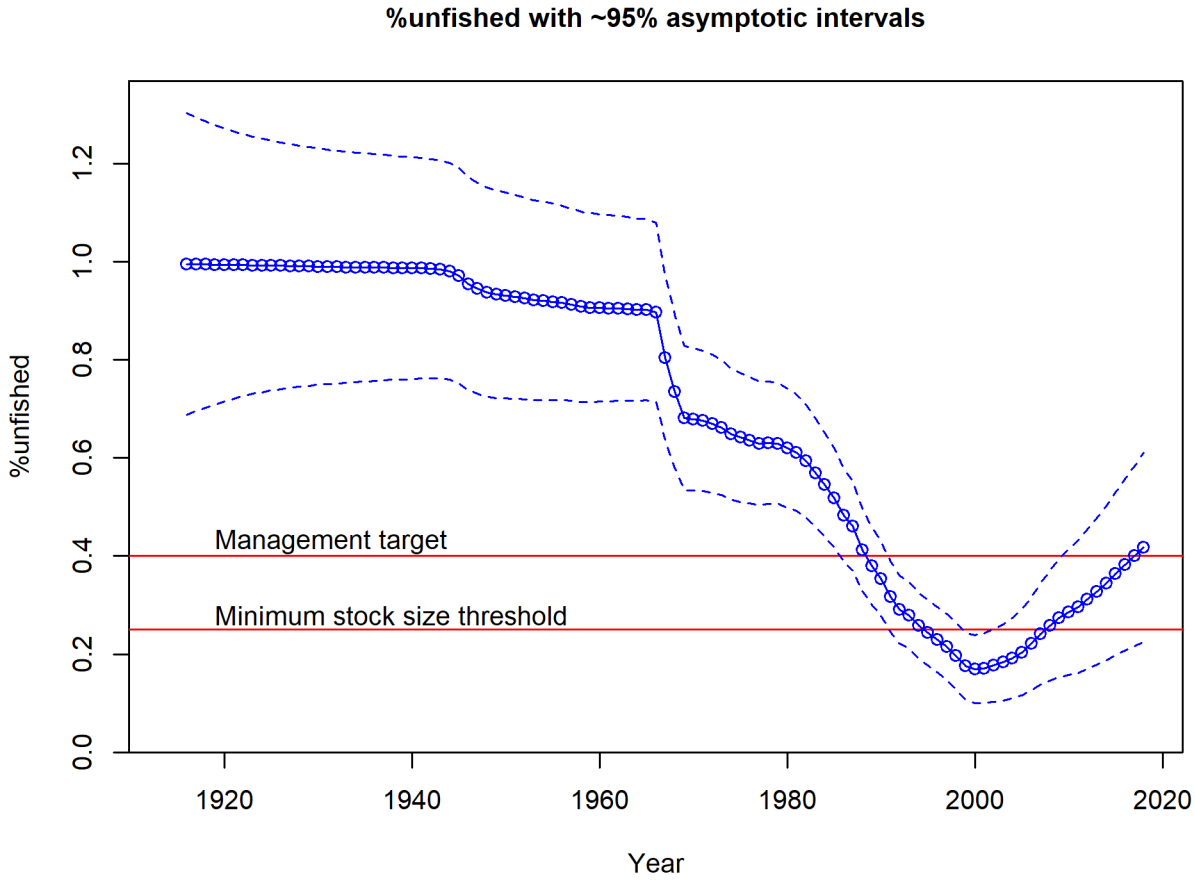

Figure c: Estimated time-series of relative spawning output (depletion) (circles and line: median; light broken lines: 95% credibility intervals) for the catch update model.

Table b: Recent trend in estimated spawning output (million eggs) and estimated relative spawning output.

Year	Spawning Output (million eggs)	~ 95% Confidence Interval	Relative Spawning Output	~ 95% Confidence Interval
2010	1014	1014 - 1014	0.286	0.286 - 0.286
2011	1051	1051 - 1051	0.297	0.297 - 0.297
2012	1105	1105 - 1105	0.312	0.312 - 0.312
2013	1161	1161 - 1161	0.328	0.328 - 0.328
2014	1222	1222 - 1222	0.345	0.345 - 0.345
2015	1289	1289 - 1289	0.364	0.364 - 0.364
2016	1355	1355 - 1355	0.382	0.382 - 0.382
2017	1419	1419 - 1419	0.400	0.400 - 0.400
2018	1482	1482 - 1482	0.418	0.418 - 0.418
2019	1559	1559 - 1559	0.440	0.440 - 0.440

Recruitment

Recruitment dynamics are assumed to follow a Beverton-Holt stock-recruit function. The level of virgin recruitment is estimated in order to assess the magnitude of the initial stock size. 'Main' recruitment deviations were estimated for modeled years that had information about recruitment, between 1960 and 2013 (as determined from the bias correction ramp in 2015). Early deviations were estimated between 1870 and 1959 so that age-structure in the initial modeled year (1915) could deviate from the stable age-structure. The Beverton-Holt recruitment compensation steepness parameter (h) was fixed in the assessment at the value of 0.72, the mean of steepness prior probability distribution, derived from 2017 meta-analysis of Category 1 rockfish assessments.

A recent, extremely strong recruitment was observed in 2013 for darkblotched rockfish (Table c; Figure d). Recruitment was estimated from the stock-recruitment curve with no deviations for the years of 2017 - 2019 for this catch update.

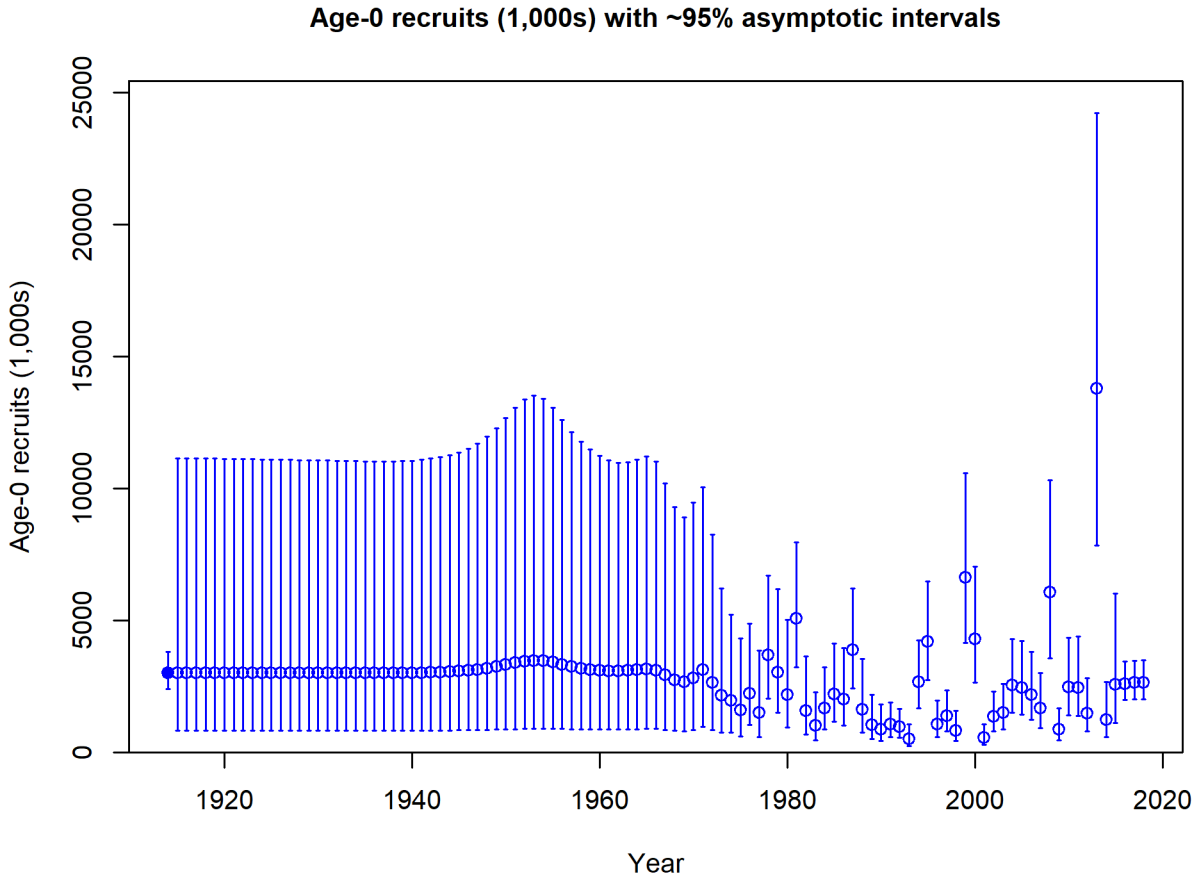

Figure d: Time-series of estimated darkblotched rockfish recruitments for the base model with 95% confidence or credibility intervals.

Table c: Recent estimated trend in recruitment and estimated recruitment deviations determined from the base model. The recruitment deviations for 2018 and 2019 were fixed at zero within the model.

Year	Estimated Recruitment	~ 95% Confidence Interval	Estimated Recruitment Devs.	~ 95% Confidence Interval
2010	2456	2456 - 2456	0.264	0.264 - 0.264
2011	2447	2447 - 2447	0.251	0.251 - 0.251
2012	1482	1482 - 1482	-0.264	-0.264 - -0.264
2013	13767	13767 - 13767	1.952	1.952 - 1.952
2014	1227	1227 - 1227	-0.504	-0.504 - -0.504
2015	2565	2565 - 2565	0.195	0.195 - 0.195
2016	2598	2598 - 2598	0.000	NA - NA
2017	2624	2624 - 2624	0.000	NA - NA
2018	2648	2648 - 2648	0.000	NA - NA
2019	2675	2675 - 2675	0.000	NA - NA

Exploitation Status

Recent exploitation, after 2000, has been well below the management target (Table d and Figures e). Historically, the darkblotched rockfish was fished underwent high exploitation rates between 1966 and 1968, during the peak years of the Pacific ocean perch fishery, in 1973, and for a prolonged period between from 1981 and 2000 (Figure g). Current, harvest rates are below target, and the stock is above the proxy target biomass (Figure f).

Table d: Recent trend in spawning potential ratio and summary exploitation rate for 1+ biomass for darkblotched rockfish.

Year	(1-SPR)/(1-SPR50)	~ 95% Confidence Interval	Exploitation Rate	~ 95% Confidence Interval
2009	0.728	0.728 - 0.728	0.021	0.021 - 0.021
2010	0.799	0.799 - 0.799	0.024	0.024 - 0.024
2011	0.312	0.312 - 0.312	0.008	0.008 - 0.008
2012	0.256	0.256 - 0.256	0.007	0.007 - 0.007
2013	0.300	0.300 - 0.300	0.008	0.008 - 0.008
2014	0.236	0.236 - 0.236	0.006	0.006 - 0.006
2015	0.280	0.280 - 0.280	0.008	0.008 - 0.008
2016	0.272	0.272 - 0.272	0.007	0.007 - 0.007
2017	0.427	0.427 - 0.427	0.011	0.011 - 0.011
2018	0.565	0.565 - 0.565	0.016	0.016 - 0.016
2019	0.487	0.487 - 0.487	0.015	0.015 - 0.015

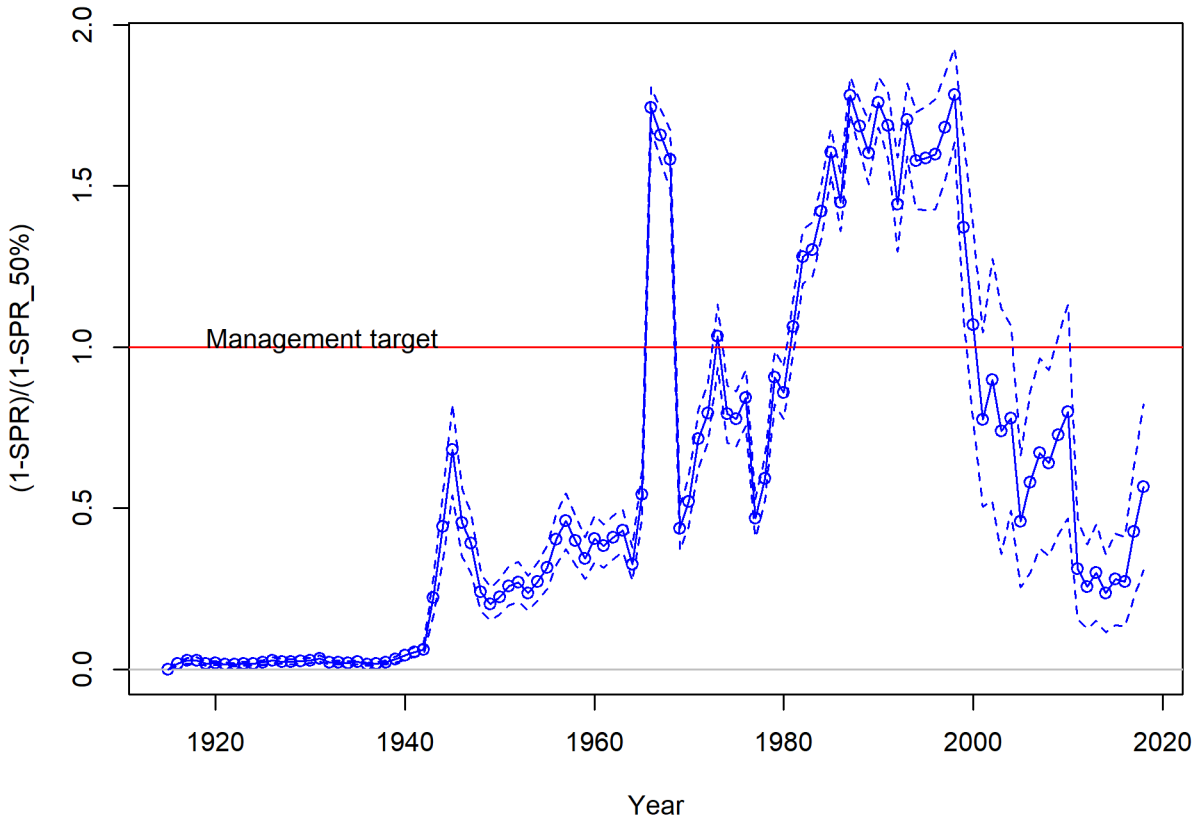

Figure e: Estimated relative spawning potential ratio (1-SPR)/(1-SPR50) for the catch update model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the SPR50% harvest rate. The last year in the time-series is 2018.

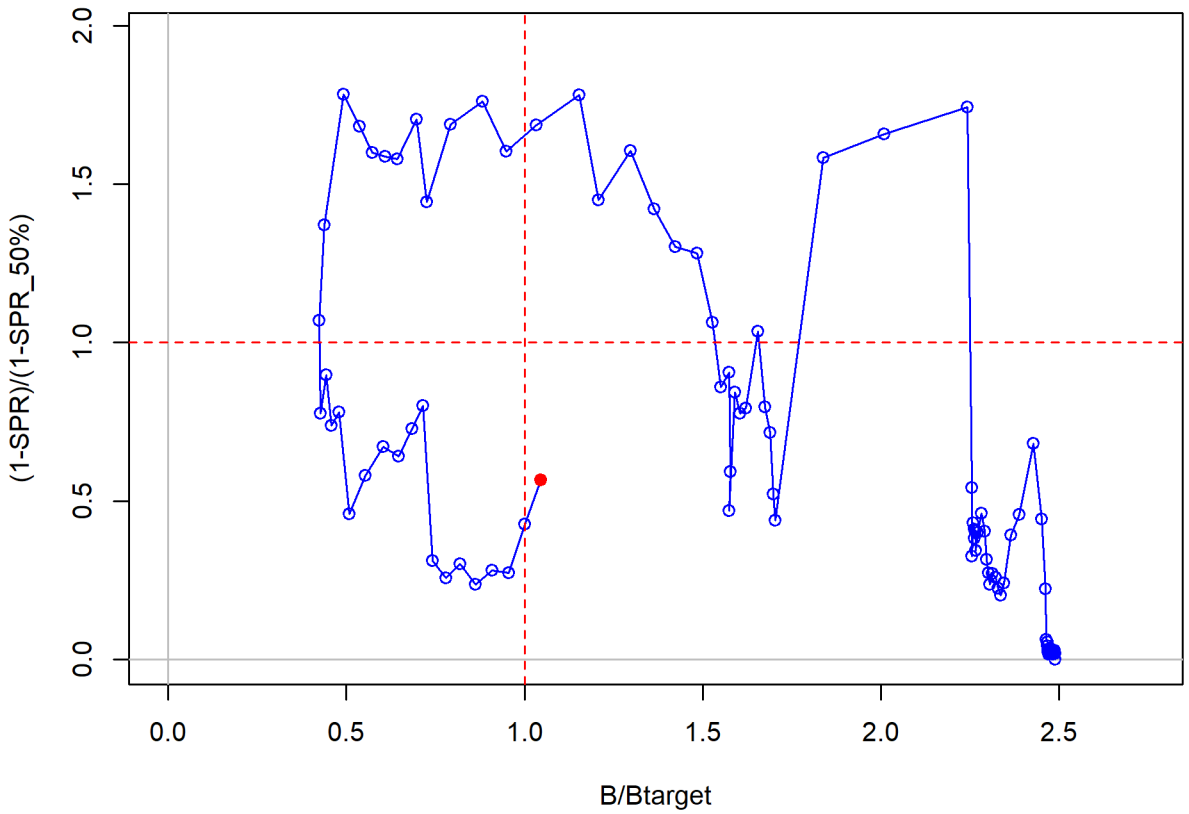

Figure f: Phase plot of estimated (1-SPR)/(1-SPR50) vs. relative spawning biomass (B/Btarget) for the catch update model. The red circle indicates 2018 estimated status and exploitation for darkblotched rockfish.

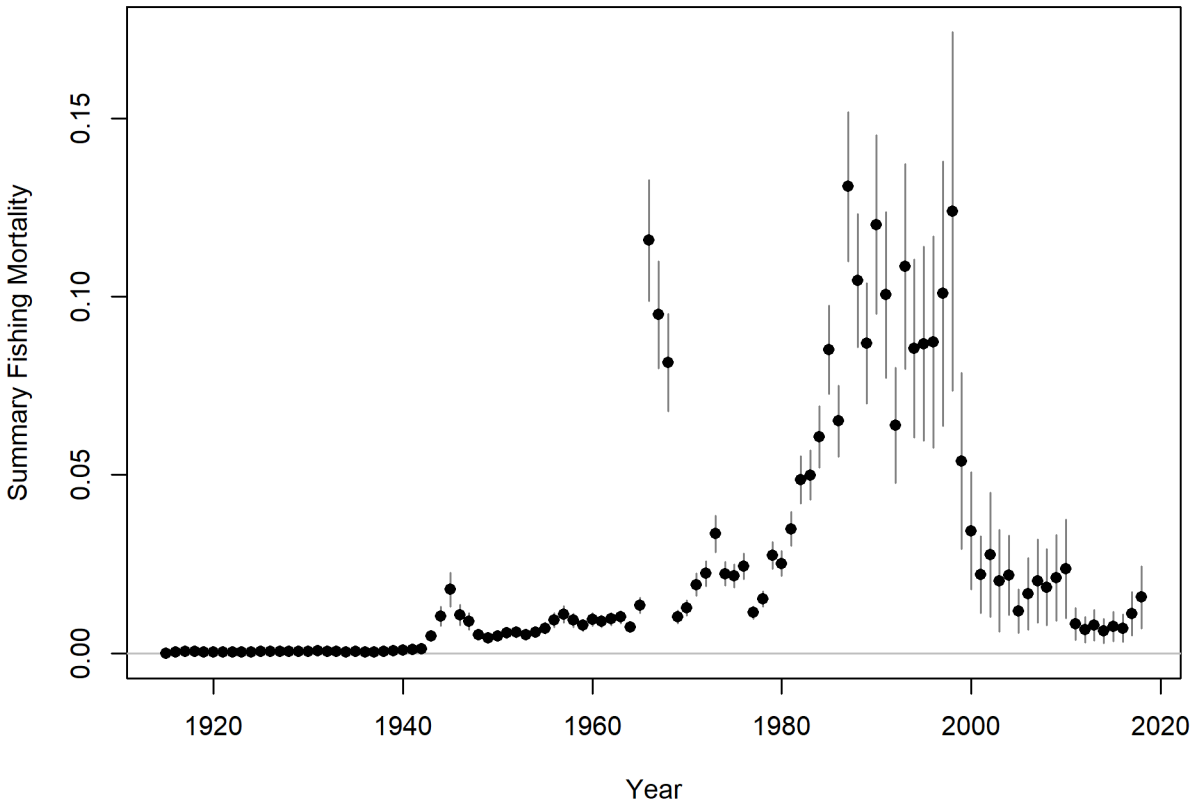

Figure g: Time-series of estimated summary harvest rate (total catch divided by age 1+ and older biomass) with approximate 95% asymptotic confidence intervals (grey lines).

Ecosystem Considerations

Ecosystem data were not explicitly included in this catch update. See the 2017 assessment for additional information (Wallace and Gertseva 2018).

Reference Points

Reference points and management quantities for darkblotched rockfish catch update are listed in Table e). In 2019, spawning output relative to unfished spawning output ("depletion") is estimated at 44.0% ($\sim$ 95% asymptotic interval: $\pm$ 44.0%-44.0%). The target spawning biomass based on the biomass target ($SB_{40\%}$) is 1,417.7 million eggs, with an equilibrium catch of 639.2 mt (Table e). Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 613 mt. Estimated MSY catch is 669.7 at a spawning output of 1,018.5 million eggs (28.7% relative spawning biomass).

Table e: Summary of reference points and management quantities for the catch update.

Quantity	**Estimate**	**$\sim$2.5% Confidence Interval**	**$\sim$97.5% Confidence Interval**
Unfished spawning output (million eggs)	3544.3	3544.3	3544.3
Unfished age 1+ output (mt)	39932.3	39932.3	39932.3
Unfished recruitment (R0, thousands)	3006.4	3006.4	3006.4
Spawning output(2019 million eggs)	1558.8	1558.8	1558.8
Relative spawning output (depletion) (2019)	0.44	0.44	0.44
Reference points based on $SB_{40\%}$			
Proxy spawning output ($B_{40\%}$)	1417.7	1417.7	1417.7
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.458	0.458	0.458
Exploitation rate resulting in $B_{40\%}$	0.037	0.037	0.037
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	639.2	639.2	639.2
Reference points based on SPR proxy for MSY			
Spawning output	1581.3	1581.3	1581.3
$SPR_{50\%}$			
Exploitation rate corresponding to $SPR_{50\%}$	0.032	0.032	0.032
Yield with $SPR_{50\%}$ at SB_{SPR} (mt)	613	613	613
Reference points based on estimated MSY values			
Spawning output at MSY (SB_{MSY})	1018.5	1018.5	1018.5
SPR_{MSY}	0.357	0.357	0.357
Exploitation rate at MSY	0.052	0.052	0.052
MSY (mt)	669.7	669.7	669.7

Management Performance

Darkblotched rockfish has been managed using species-specific harvest specifications since 2001. Over the last 10 years, the total estimated removals have not exceeded the Annual Catch Limit (ACL) (Table f).

Table f: Recent trend in total removals (mt) relative to the management guidelines.

Year	OFL (mt)	ACL (mt)	Total Removals (mt)
2011	508	298	121.3
2012	508	298	102.5
2013	541	317	127.8
2014	541	317	106.5
2015	574	338	136.8
2016	580	346	136.6
2017	671	641	330.7
2018	683	653	330.7

Unresolved Problems and Major Uncertainties

The 2017 darkblotched rockfish assessment cited the following items as the major uncertainties (Wallace and Gertseva 2018).

- Main life history parameters, such as natural mortality and stock-recruit curve steepness, continue to be a major source of uncertainty. These quantities, which the model is unable to estimate reliably, are essential for understanding the dynamics of the stock. In the model, female natural mortality is fixed at the value estimated outside the model using other life history characteristics of the species, while male natural mortality is estimated within the model, with a flat prior. Stock-recruit steepness is fixed at the value estimated outside the model using meta-analysis of species with similar life history characteristics.
- Historically, darkblotched rockfish landings have not been sorted at the discrete species level; therefore, the time series of catch remained a source of uncertainty. Although significant progress has been made in reconstructing historical landings in California, Oregon and Washington, the lack of early species composition data does not allow the reconstruction to account for a gradual shift of fishing effort towards deeper areas, which can cause the potential to overestimate the historical contribution of slope species (including darkblotched rockfish) to overall landings of the mixed-species market category (i.e. "unspecified rockfish"). Also, it is known that the shoreside fishery has discarded a portion of the catch at sea. Previous to 2002, when the West Coast Groundfish Observer Program was established, only the Pikitch et al. study exists (Wallace, in review) that informs pre-2002 discarding practices of darkblotched rockfish.

Decision Table

Projections of OFL (mt), ABC (mt), age 1+ biomass (mt), spawning output (millions of eggs), and relative spawning output (depletion), are shown for the default harvest control rule in Table g. The removals in 2017 and 2018 were set at the estimated total removals of 230 and 343 mt, respectively. The 2019 and 2020 removals were set equal to the projected values as provided by the GMT plus estimated discards for the shoreside hake fleet. The removals from 2021 onward assume full attainment of the ABC.

The decision table was based on uncertainty around female natural mortality as what was done in the 2017 assessment (Wallace and Gertseva 2018). The decision table explores three alternative catch streams: 1) assume full attainment of the estimated ABC, 2) fixed catches of 844 mt, and 3) fixed catches of 331 mt (Table h).

Table g: Projections of potential OFL (mt) and ABC (mt) and the estimated total removals, spawning output, and relative spawning output based on removals. The OFL and ABC values for 2021-2030 shown here are the model estimates.

Year	OFL (mt)	ABC (mt)	Total Removals (mt)	Spawning Output (million eggs)	Relative Output
2017	671	641	230	1419	0.400
2018	683	653	343	1482	0.418
2019	800	765	331	1559	0.440
2020	853	815	331	1659	0.468
2021	953	882	882	1762	0.497
2022	901	831	831	1821	0.514
2023	856	784	784	1863	0.526
2024	822	750	750	1891	0.533
2025	799	725	725	1908	0.538
2026	782	706	706	1918	0.541
2027	769	692	692	1922	0.542
2028	760	681	681	1921	0.542
2029	753	671	671	1917	0.541
2030	747	662	662	1911	0.539

Table h: Decision table summary of 12-year projections beginning in 2019 for alternate states of nature based on an axis of uncertainty about female natural mortality for the base model. Columns range over low, mid, and high states of nature, and rows range over different assumptions of catch levels. The ABC catch stream is based on the equilibrium yield applying the SPR50 harvest rate.

			States of nature					
			Female M = 0.0412		Female M = 0.054		Female M = 0.059	
	Year	Catch	Spawning Output	Depletion	Spawning Output	Depletion	Spawning Output	Depletion
ABC	2019	331	964	0.277	1559	0.440	1841	0.503
	2020	331	1031	0.296	1659	0.468	1953	0.534
	2021	882	1101	0.316	1762	0.497	2069	0.566
	2022	831	1130	0.325	1821	0.514	2138	0.585
	2023	784	1147	0.330	1863	0.526	2187	0.598
	2024	750	1156	0.332	1891	0.533	2220	0.607
	2025	725	1158	0.333	1908	0.538	2241	0.613
	2026	706	1156	0.332	1918	0.541	2253	0.616
	2027	692	1150	0.330	1922	0.542	2257	0.617
	2028	681	1141	0.328	1921	0.542	2257	0.617
	2029	671	1131	0.325	1917	0.541	2253	0.616
	2030	662	1119	0.322	1911	0.539	2246	0.614
Constant Catch 844 (mt)	2019	331	964	0.277	1559	0.440	1841	0.503
	2020	331	1031	0.296	1659	0.468	1953	0.534
	2021	884	1101	0.316	1762	0.497	2069	0.566
	2022	884	1130	0.325	1821	0.514	2138	0.585
	2023	884	1144	0.329	1859	0.525	2184	0.597
	2024	884	1145	0.329	1881	0.531	2210	0.604
	2025	884	1138	0.327	1889	0.533	2222	0.607
	2026	884	1123	0.323	1886	0.532	2221	0.607
	2027	884	1102	0.317	1876	0.529	2213	0.605
	2028	884	1077	0.310	1860	0.525	2197	0.601
	2029	884	1049	0.301	1840	0.519	2177	0.595
	2030	884	1018	0.293	1817	0.513	2154	0.589
Constant Catch 331 (mt)	2019	331	964	0.277	1559	0.440	1841	0.503
	2020	331	1031	0.296	1659	0.468	1953	0.534
	2021	331	1101	0.316	1762	0.497	2069	0.566
	2022	331	1164	0.335	1855	0.523	2172	0.594
	2023	331	1218	0.350	1933	0.545	2257	0.617
	2024	331	1264	0.363	1996	0.563	2325	0.636
	2025	331	1303	0.374	2048	0.578	2379	0.650
	2026	331	1336	0.384	2091	0.590	2423	0.663
	2027	331	1365	0.393	2127	0.600	2459	0.672
	2028	331	1392	0.400	2157	0.609	2488	0.680
	2029	331	1415	0.407	2183	0.616	2513	0.687
	2030	331	1437	0.413	2206	0.622	2534	0.693

Table i: Base model results summary.

Quantity	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
OFL (mt)	437	508	508	541	541	574	580	671	683	800
ACL (mt)	282	298	298	317	317	338	346	641	653	765
Removals (mt)	338	121	102	128	107	137	137	230	344	331
(1-SPR) (1-$SPR_{50\%}$)	0.799	0.312	0.256	0.300	0.236	0.280	0.272	0.427	0.565	0.487
Exploitation rate	0.024	0.008	0.007	0.008	0.006	0.008	0.007	0.011	0.016	0.015
Age 1+ biomass (mt)	14284	14826	15576	16313	17138	18190	19426	20713	21858	22779
Spawning Output	1014	1051	1105	1161	1222	1289	1355	1419	1482	1559
95% CI	1014 - 1014	1051 - 1051	1105 - 1105	1161 - 1161	1222 - 1222	1289 - 1289	1355 - 1355	1419 - 1419	1482 - 1482	1559 - 1559
Relative Depletion	0.286	0.297	0.312	0.328	0.345	0.364	0.382	0.400	0.418	0.440
95% CI	0.286 - 0.286	0.297 - 0.297	0.312 - 0.312	0.328 - 0.328	0.345 - 0.345	0.364 - 0.364	0.382 - 0.382	0.400 - 0.400	0.418 - 0.418	0.440 - 0.440
Recruits	2456	2447	1482	13767	1227	2565	2598	2624	2648	2675
95% CI	2456 - 2456	2447 - 2447	1482 - 1482	13767 - 13767	1227 - 1227	2565 - 2565	2598 - 2598	2624 - 2624	2648 - 2648	2675 - 2675

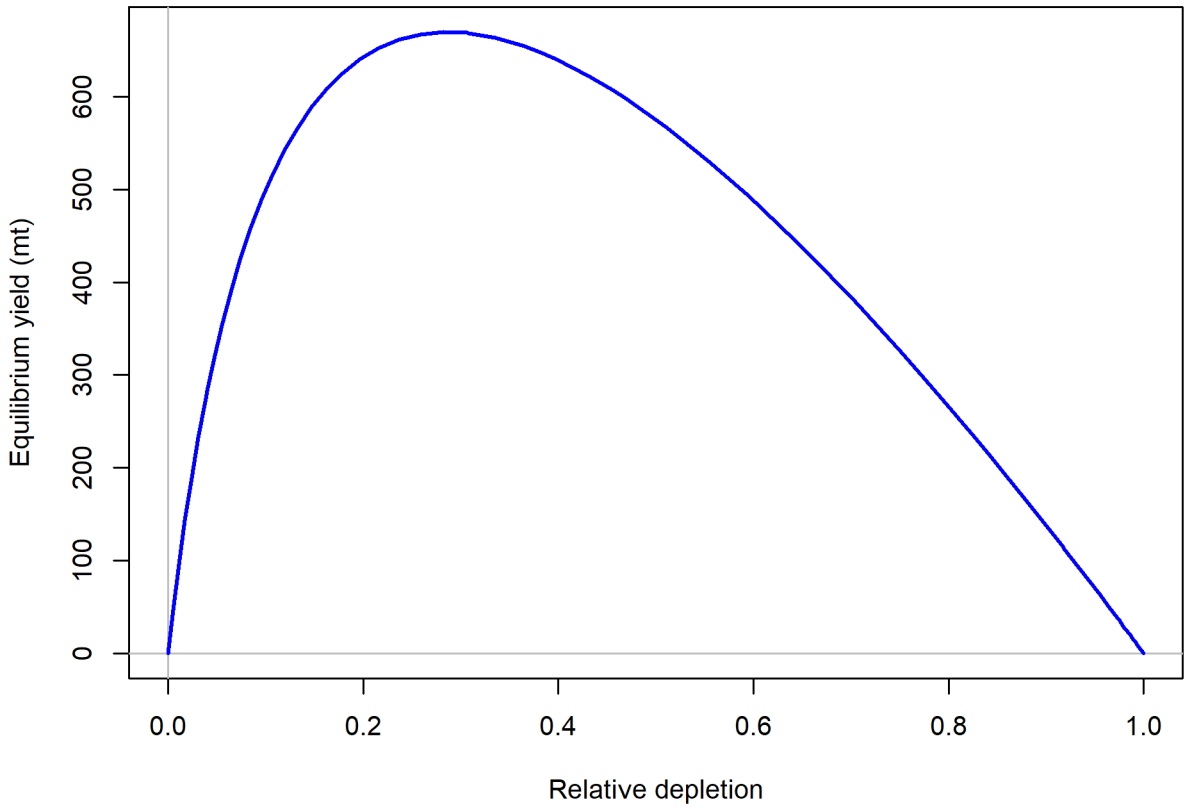

Figure h: Equilibrium yield curve for the catch update model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.72.

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