Catch update for blue/deacon rockfishes (*Sebastes mystinus* and *diaconus*) along the U.S. California coast.

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Contents

Executive Summary

Stock

This catch update reports the status of blue and deacon rockfish as a stock complex in U.S. waters off the coast of California. The California stock represents the stock complex in U.S. waters from Point Conception (34° 27' North latitude) to the California-Oregon border (42° N. lat.). Historical data streams did not separate the two species or estimate removals at a spatial scale small enough to evaluate assessment boundaries near Monterey Bay, but future assessments may wish to consider alternative spatial structures should long-term, species-specific data become available.

Landings

Over the past decade, blue and deacon rockfish off California have been caught primarily by the recreational fishery (Table a). Over this time period, the commercial passenger fishing vessel (CPFV) fleet accounted for over 50% of the total removals and the private boat fleet accounted for over 30%, with the remainder largely taken by commercial hook and line gears. Since 1900, recreational fisheries account for roughly 80% of cumulative removals in waters north of Point Conception. Blue and deacon rockfish landings from all sectors have historically been recorded as "Blue Rockfish" and recreational sampling in California currently does not differentiate between the two species.

Recreational removals in California prior to 2004 were only estimated at large spatial scales – north and south of Point Conception – following the design of the Marine Recreational Fisheries Statistics Survey (MRFSS). Recent sampling (2004 - present) by the California Recreational Fisheries Survey (CRFS) produces estimates of blue and deacon rockfish landings and discard at a finer spatial resolution. Total removals north of Point Conception increased steadily following World War II, peaking in the late 1970s and early 1980s with annual removals exceeding 600 mt per year (Figure a). This was followed by a decline in catch until about 2010. Recent years have seen a steady increase in landings, but total removals remain low relative to historical levels.

The catches 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).

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

Year	Rec. Charter	Rec. Private	Rec. Discard	Comm. HKL Gear	Comm. Other Gear	Comm. Discard	Total Removals
2010	28.9	21.6	1.0	4.9	0.0	2.5	58.9
2011	35.0	23.5	1.2	7.1	0.0	3.6	70.4
2012	30.1	18.5	1.0	6.6	0.0	3.4	59.6
2013	66.8	36.0	2.1	6.0	0.0	3.1	114.0
2014	64.4	49.4	2.3	5.9	0.0	3.0	124.9
2015	91.7	63.9	3.1	9.2	0.0	4.6	172.6
2016	81.2	41.8	2.5	7.1	0.1	3.6	136.3
2017	90.8	53.9	29.8	10.5	0.0	3.1	188.2
2018	107.7	46.8	59.5	11.5	0.1	3.1	228.7

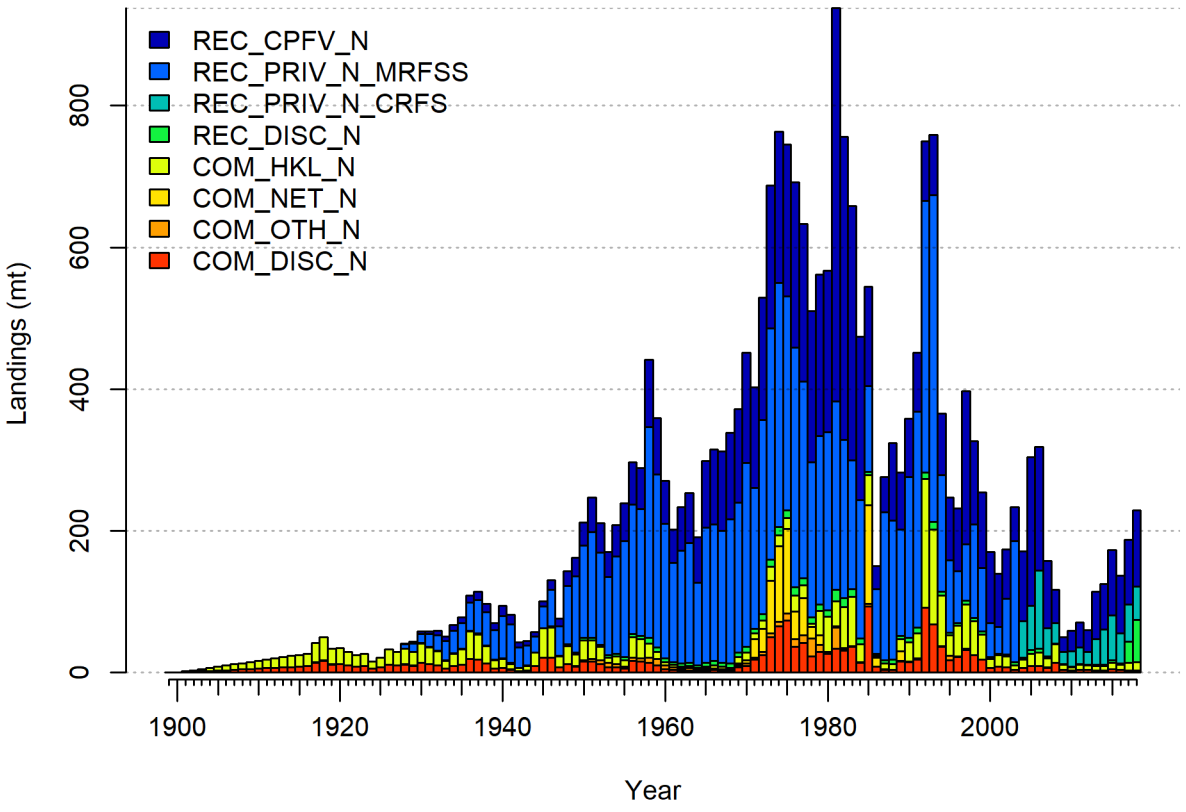

Figure a: Total removals by fleet off the U.S. California coast north of Pt. Conception.

Data and Assessment

Blue and deacon rockfish was last assessed in 2017, and estimated to be at 37% of unfished spawning output (Dick et al. 2018). The 2017 assessment of blue and deacon rockfish used Stock Synthesis (version V3.30.03.07). The assessment was structured as a single, sex-disaggregated, unit population, spanning U.S. waters from Point Conception to the California-Oregon border. The assessment model operated on an annual time step covering the period 1900 to 2017 (not including forecast years) and assumed an unfished population prior to 1900. Population dynamics were modeled for ages 0 through 35, with age-35 being the accumulator age. The model was conditioned on catch from two sectors (commercial and recreational) divided among eight fleets, and was informed by five abundance indices (one fishery-independent survey, two CPUE indices from shore-based sampling programs, and two CPUE indices from onboard observer programs). Size composition data included lengths from multiple fleets spanning the period 1959-2016, but a very limited number of age structures were available for California, specifically from the recreational fishery (1980-1984) and two research programs conducted in 2010-2011. The assessment estimated parameters for natural mortality of females and males, steepness of the Beverton-Holt stock-recruitment relationship, and gender-specific growth parameters. Year class strength was estimated as deviations from the expected stock-recruitment relationship beginning in 1950.

All assumptions from the 2017 assessment were retained here. Only catches from 2017 and 2018 based on estimates of actual removals provided by the GMT were added. Removals in the projection years of 2019 and 2020 were based on full attainment of the ACL values adopted by management. The removals from 2021-2030 were based on the estimated ACLs using an increasing σ for category 2 stocks (1.0) and a risk tolerance (P*) of 0.45.

Stock Output

Spawning output of blue and deacon rockfish in California was estimated to be 903 million eggs in 2019 ($\sim$ 95% asymptotic interval: $\pm$ 0-1867 million eggs), or 41.5% of unfished spawning output ($\sim$ 95% asymptotic interval: $\pm$ 0%-88.3%; 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. In California, spawning output declined rapidly in the 1970s and early 1980s, falling below the minimum stock size threshold in the early 1980s, followed by a steady recovery since the late 2000s (Figures b and c). The trend in spawning output in 2019 is above the management target (40% of unfished spawning output), but the precision of that estimate is low relative to other management reference points (e.g. the SPR50% proxies for target spawning output and maximum yield).

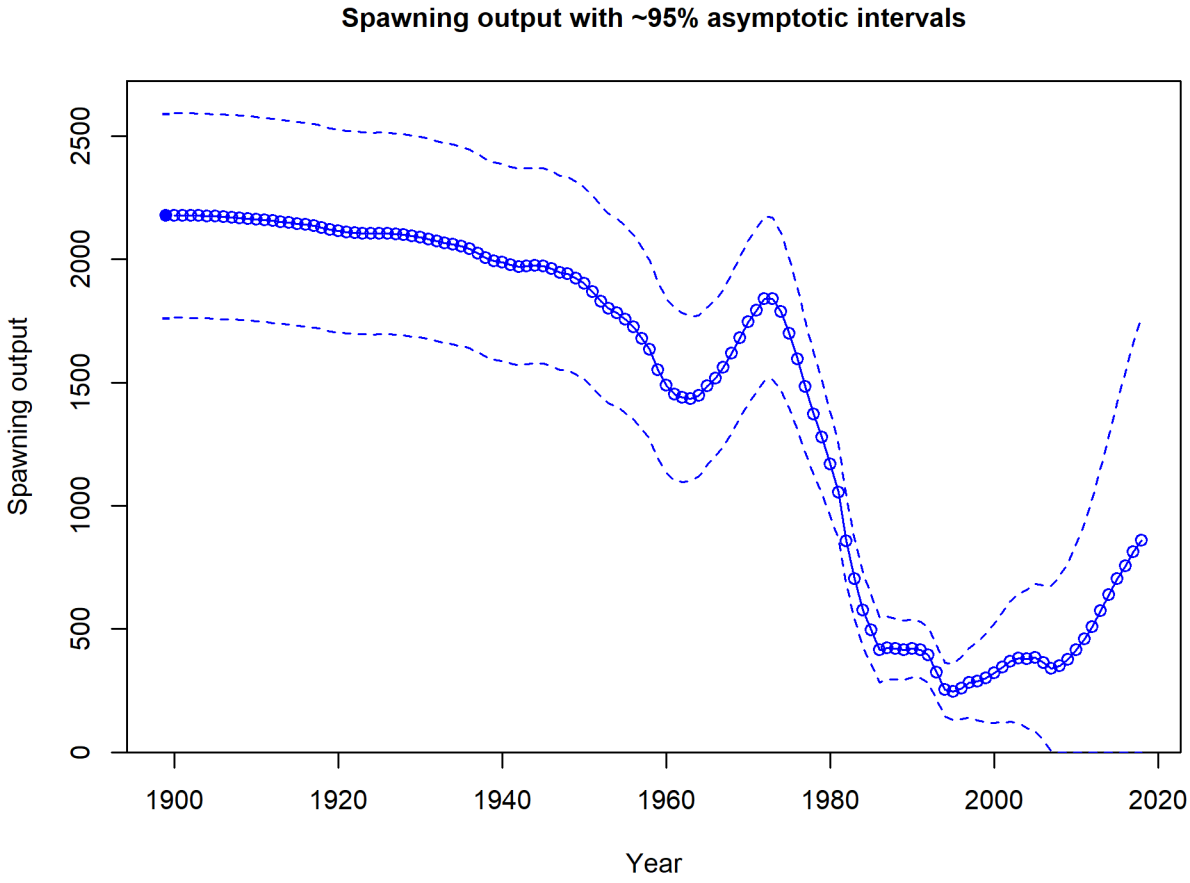

Figure b: Estimated time-series of spawning output trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the catch update model.

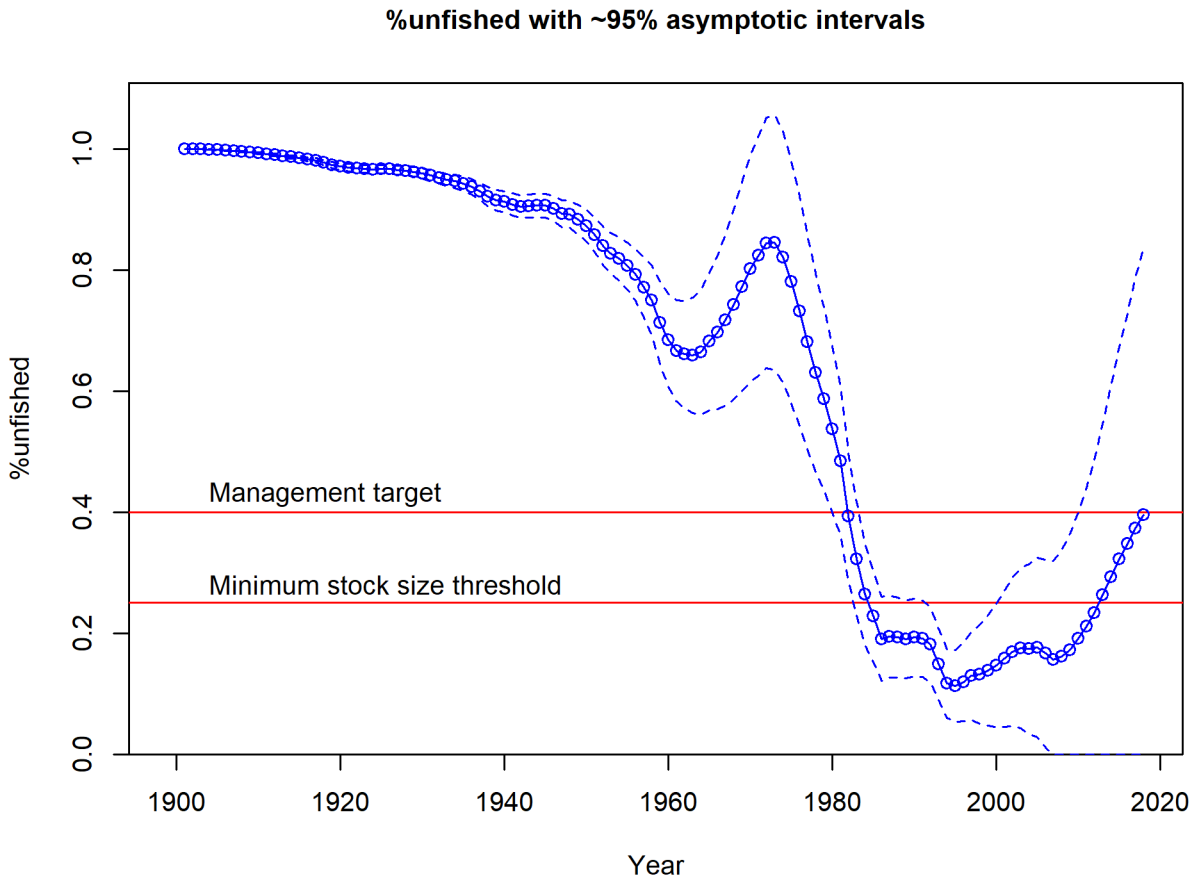

Figure c: Estimated time-series of relative spawning output (depletion) (circles and line: median; light broken lines: 95% credibility intervals) for the catch update model.

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	416	0 - 846	0.191	0.000 - 0.400
2011	459	0 - 930	0.211	0.000 - 0.440
2012	509	0 - 1028	0.234	0.000 - 0.487
2013	573	0 - 1152	0.263	0.000 - 0.545
2014	638	0 - 1285	0.293	0.000 - 0.608
2015	703	0 - 1421	0.323	0.000 - 0.673
2016	757	0 - 1542	0.347	0.000 - 0.730
2017	812	0 - 1660	0.373	0.000 - 0.786
2018	860	0 - 1767	0.395	0.000 - 0.836
2019	903	0 - 1867	0.415	0.000 - 0.883

Recruitment

A recent, strong recruitment in 2013 has contributed to the recent increase in blue and deacon rockfish biomass in California (Table c; Figure d). This recruitment is informed by several independent data sets, was observed by multiple juvenile rockfish surveys, and is also supported by length composition data in the model. Above-average recruitments in 2008 and 2009 are largely driven by recent age data covering the years 2010-2011, but the 2007 recruitment appears to be supported by multiple data sources, as well.

In this catch update the recruitment was estimated from the stock-recruitment curve with no deviations for the years of 2017 - 2019.

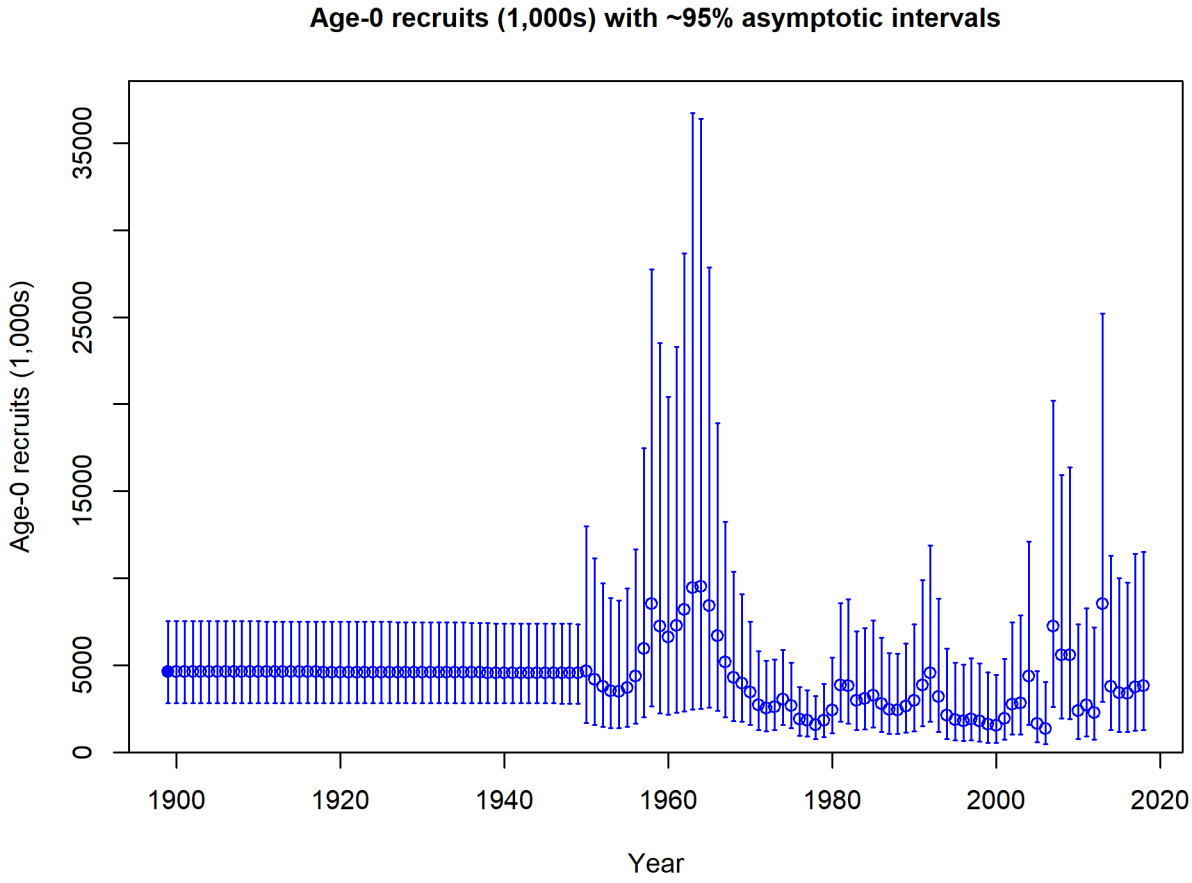

Figure d: Time-series of estimated blue and deacon rockfish recruitments for the base model with 95% confidence or credibility intervals.

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	2362	759 - 7349	-0.153	-0.869 - 0.564
2011	2722	895 - 8285	-0.055	-0.770 - 0.660
2012	2269	719 - 7159	-0.280	-1.108 - 0.547
2013	8510	2875 - 25190	0.995	0.323 - 1.667
2014	3791	1275 - 11269	0.144	-0.635 - 0.922
2015	3410	1163 - 9997	-0.010	-0.804 - 0.785
2016	3376	1170 - 9739	-0.058	-0.870 - 0.755
2017	3749	1234 - 11394	0.000	-0.980 - 0.980
2018	3813	1262 - 11521	0.000	-0.980 - 0.980
2019	3866	1285 - 11631	0.000	-0.980 - 0.980

Exploitation Status

The annual (equilibrium) SPR harvest rate for blue and deacon rockfish in California has been below target since 2008 (Table d and Figures e and f). Prior to 2008, the harvest rate exceeded the target for over 30 years, regularly reaching levels 50% above target in the 1980s and 1990s (Figure g). As with current estimates of spawning output, recent estimates of exploitation status are highly uncertain (Table d). As a percentage of total biomass (ages 0+), California harvest rates peaked at 15-20% in the 1980s and 1990s, but have since declined to levels below 3% for the past decade (Figure g). Harvest rates in California are currently below target, and the stock is approaching the proxy target biomass (Figure f).

Table d: Recent trend in spawning potential ratio and summary exploitation rate for all age biomass for blue and deacon rockfish.

Year	(1-SPR)/(1-SPR tgt)	~ 95% Confidence Interval	Exploitation Rate	~ 95% Confidence Interval
2009	0.521	0.061 - 0.982	0.013	0.000 - 0.026
2010	0.547	0.075 - 1.018	0.014	0.000 - 0.027
2011	0.580	0.093 - 1.067	0.015	0.000 - 0.029
2012	0.473	0.050 - 0.896	0.012	0.000 - 0.023
2013	0.701	0.162 - 1.239	0.021	0.001 - 0.042
2014	0.701	0.160 - 1.242	0.022	0.001 - 0.043
2015	0.818	0.235 - 1.401	0.029	0.001 - 0.056
2016	0.668	0.132 - 1.204	0.021	0.000 - 0.042
2017	0.779	0.197 - 1.360	0.028	0.001 - 0.055
2018	0.853	0.239 - 1.466	0.034	0.001 - 0.066
2019	0.789	0.195 - 1.383	0.030	0.001 - 0.059

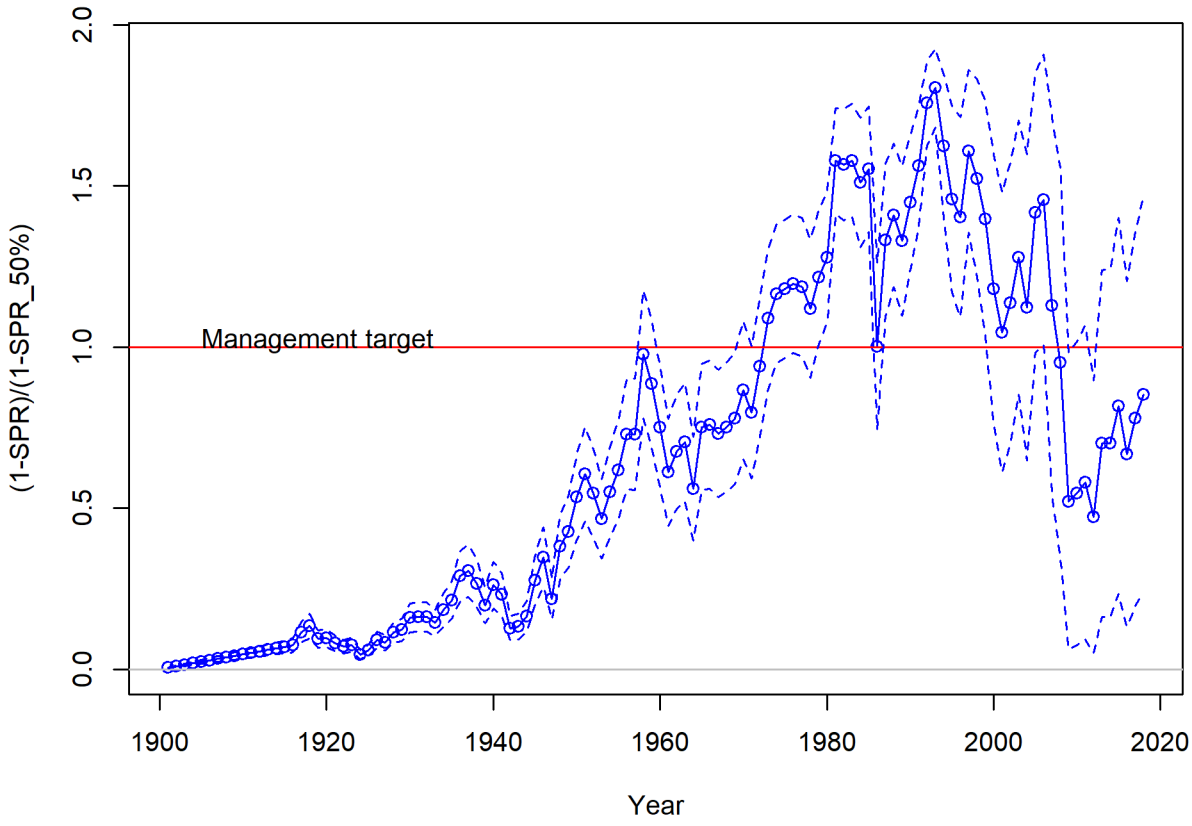

Figure e: Estimated relative spawning potential ratio (1-SPR)/(1-SPR_tgt) for the catch update model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in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

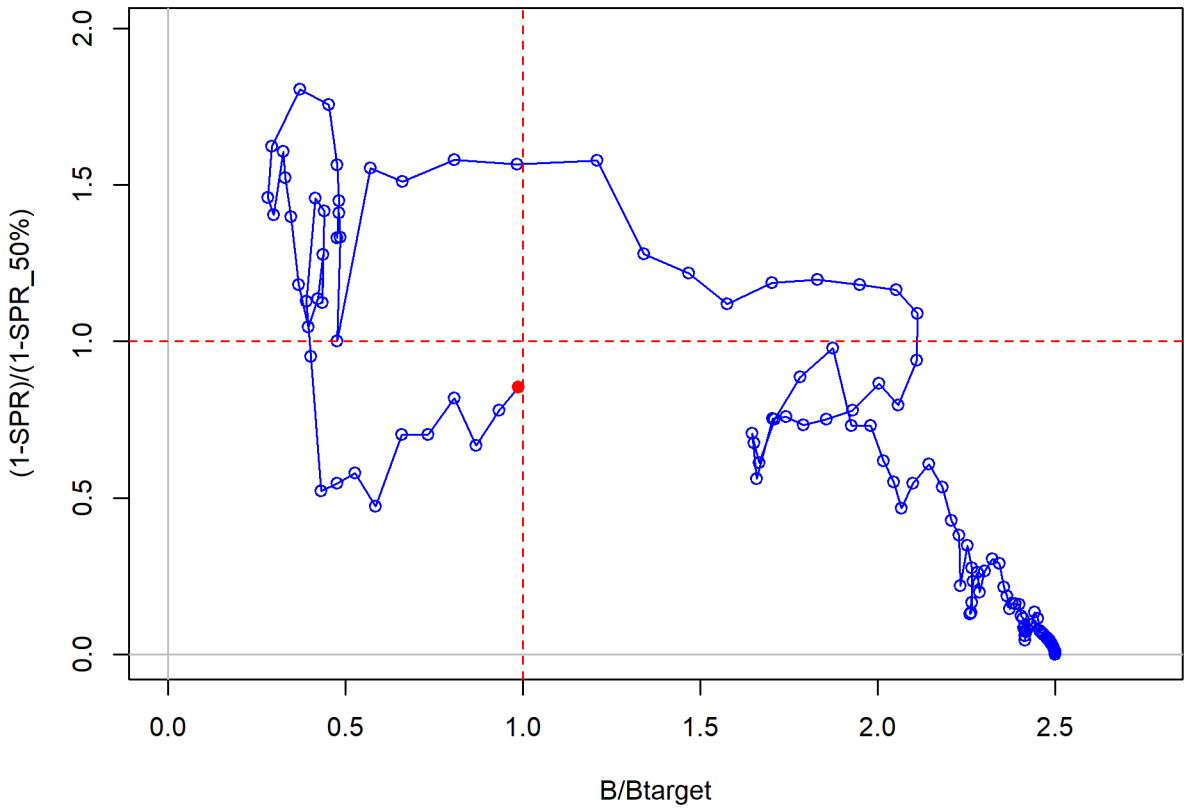

Figure f: Phase plot of estimated (1-SPR)/(1-SPR_tgt) vs. relative spawning biomass (B/Btarget) for the catch update model. The red circle indicates 2018 estimated status and exploitation for blue and deacon rockfish.

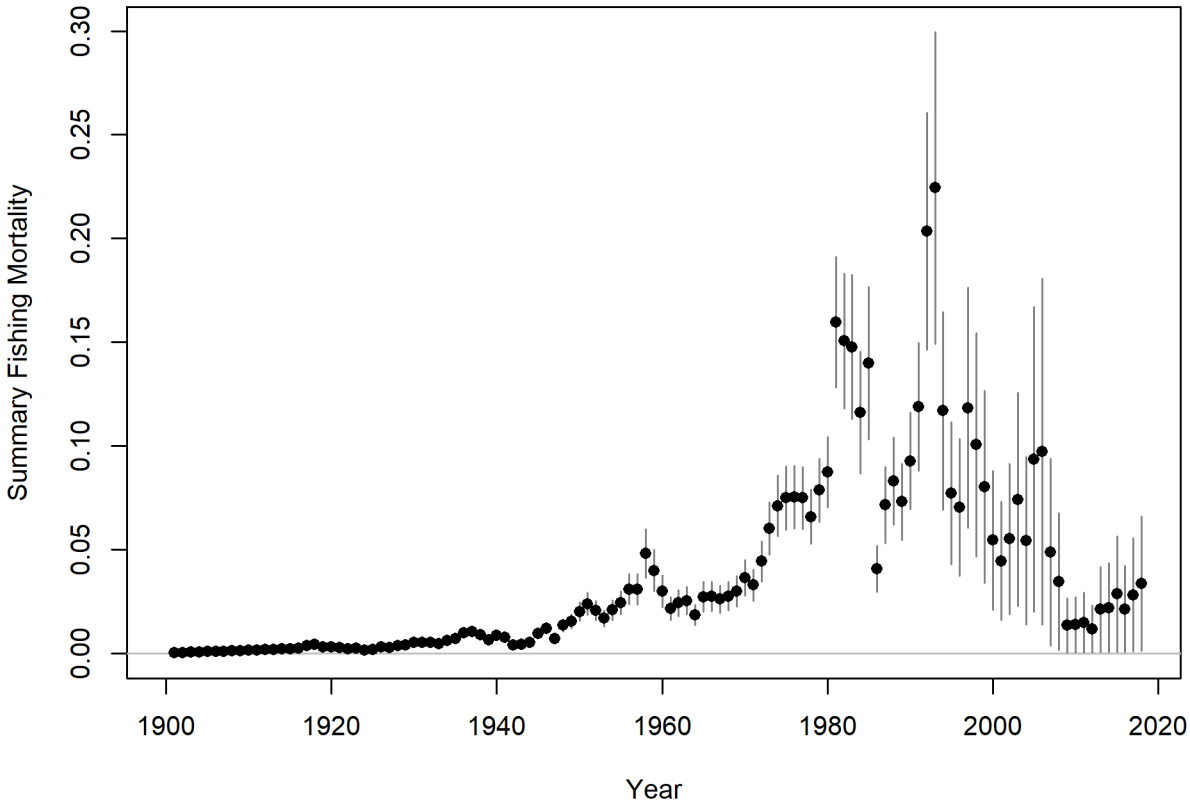

Figure g: Time-series of estimated summary harvest rate (total catch divided by age-0 and older biomass) with approximate 95% asymptotic confidence intervals (grey lines).

Ecosystem Considerations

Ecosystem data were not explicitly included in this catch update. See the 2017 assessment for additional information (Dick et al. 2018).

Reference Points

Reference points and management quantities for the California blue and deacon rockfish catch update are listed in Table e). In 2019, spawning output relative to unfished spawning output ("depletion") is estimated at 41.5% ($\sim$ 95% asymptotic interval: $\pm$ 0%-88.3%). The target spawning output based on the output target ($SB_{40\%}$) is 871.1 million eggs, with an equilibrium catch of 312.5 mt (Table e). Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 305.6 mt. Estimated MSY catch is 338.8 at a spawning output of 566.6 million eggs (26% relative spawning output).

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)	2177.7	1759.9	2595.5
Unfished age 0+ output (mt)	11535.9	9140.2	13931.6
Unfished recruitment (R0, thousands)	4617.5	2327.8	6907.2
Spawning output(2019 million eggs)	903.4	-59.659	1866.5
Relative spawning output (depletion) (2019)	0.415	-0.053	0.883
Reference points based on $SB_{40\%}$			
Proxy spawning output ($B_{40\%}$)	871.1	704	1038.2
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.483	0.402	0.563
Exploitation rate resulting in $B_{40\%}$	0.048	0.037	0.059
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	312.5	223.2	401.8
Reference points based on SPR proxy for MSY			
Spawning output	914.8	725.5	1104
$SPR_{50\%}$			
Exploitation rate corresponding to $SPR_{50\%}$	0.045	0.04	0.051
Yield with $SPR_{50\%}$ at SB_{SPR} (mt)	305.6	230.2	381.1
Reference points based on estimated MSY values			
Spawning output at MSY (SB_{MSY})	566.6	283.5	849.7
SPR_{MSY}	0.362	0.179	0.545
Exploitation rate at MSY	0.069	0.033	0.104
MSY (mt)	338.8	217.2	460.4

Management Performance

The contribution of blue and deacon rockfish to the Minor Nearshore Rockfish OFLs is currently derived from three sources: 1) forecasts from Key et al. (2008), allocated north and south of Cape Mendocino, 2) Depletion Corrected Average Catch (DCAC; (MacCall 2009)) for the area south of Point Conception, and 3) a DCAC estimate of yield for waters off Oregon and Washington. Since 2011, total mortality of blue and deacon rockfish has not exceeded the component OFL for "Blue Rockfish" and total mortality of Minor Nearshore Rockfishes has not exceeded the ACL or OFL in either the northern or southern areas (Table f).

Table f: Recent trend in total removals (mt) relative to the management guidelines. Blue and deacon rockfishes are managed as a part of the Minor Nearshore Rockfish Complex and the OFL and ABC values are based on the contribution of these species to the complex.

Year	OFL (mt)	ACL (mt)	Total Removals (mt)
2011	293.0	243.4	70.4
2012	291.0	241.4	59.6
2013	288.1	235.8	114.0
2014	288.1	235.8	124.9
2015	288.9	194.4	172.6
2016	290.9	198.3	136.3
2017	346.4	306.0	188.2
2018	347.1	311.2	228.7

Unresolved Problems and Major Uncertainties

The 2017 blue and deacon rockfish assessment cited the following items as the major uncertainties (Dick et al. 2018).

- The scale of the stock is similar, and proxy ($SPR50\%$) estimates of maximum sustainable yield are similar (275 mt per the 2007 assessment and 306 mt per the 2017 assessment). However, estimates of recent stock size based on the 2017 assessment are imprecise, which results in imprecise forecasts of yield. The 2017 assessment is sensitive to the removal of age data, because only seven years of age data (1980-1984 and 2010-2011) are currently available to inform the assessment.
- Since recreational fisheries account for the majority of removals, collection of age structures from California recreational fisheries is a priority for improving stock assessments of blue and deacon rockfish.
- Calibration and validation of age estimates is also needed, as there was some evidence of bias among agers.

- Collection of additional age data would assist with estimation of natural mortality rate, a major source of uncertainty in current stock status, and improve the precision of gender-specific estimates of the natural mortality rate.
- Similar to natural mortality, uncertainty in the Beverton-Holt steepness parameter contributes to the imprecision of recent blue and deacon rockfish output. However, population scale (unfished spawning output) in the California model is robust to changes in these parameters, relative to the Oregon model.
- Catches of blue and deacon rockfish are strongly skewed toward females. The current assessment accounts for this through gender-specific growth and natural mortality. An alternative (or parallel) hypothesis is that males are less vulnerable to the fishery (i.e. have a gender-specific selectivity). Although the STAT explored this possibility by profiling over the apical value of the male selectivity curve, the model was not able to estimate gender-specific selectivity curves given the available data.

Decision Table

Projections of OFL (mt), ABC (mt), age 0+ 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 removals as provided by the GMT of 187 and 229 mt, respectively. The 2019 and 2020 removals were set equal to the ABCs. The removals from 2021 onward assume full attainment of the ABC.

The decision table was based on uncertainty around female natural mortality and steepness same as what was done in the 2017 assessment (Dick et al. 2018). The decision table explores three alternative catch streams: 1) assume full attainment of the estimated ABC, 2) average catches of 154.4 mt (at the values assumed in the 2017 assessment), and 3) the MSY value based on SPR50 with an year specific σ for a category 2 stock and P* of 0.45 (Table h).

Table g: Projections of potential OFL (mt) and ABC (mt) and the estimated spawning output and relative spawning output based on removals. The OFL and ABC values for 2021-2030 shown here are the model estimates for the state of California north of Pt. Conception (e.g., management splits these values based on areas in CA).

Year	OFL	ABC	Removals (mt)	Spawning Output (million eggs)	Relative Output
2017	346.00	306.00	187.27	812	0.373
2018	347.00	311.20	228.74	860	0.395
2019	319.71	298.90	208.01	903	0.415
2020	327.71	311.60	208.01	946	0.434
2021	334.38	286.56	286.56	983	0.451
2022	335.79	285.09	285.09	1000	0.459
2023	336.24	282.78	282.78	1010	0.464
2024	336.07	279.95	279.95	1016	0.466
2025	335.61	277.21	277.21	1019	0.468
2026	335.08	274.10	274.10	1020	0.468
2027	334.66	271.07	271.07	1021	0.469
2028	334.42	268.54	268.54	1021	0.469
2029	334.38	265.83	265.83	1022	0.469
2030	334.55	263.63	263.63	1023	0.470

Table h: Decision table summary of 10-year projections beginning in 2021 for alternate states of nature based on an axis of uncertainty about female natural mortality and steepness for the base model. The removals in 2019 and 2020 were set at the defined management specification of 208 mt for each year, assuming full attainment. 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					
			h = 0.555 M = 0.113		h = 0.645 M = 0.119		h = 0.702 M = 0.131	
	Year	Catch	Spawning Output	Depletion	Spawning Output	Depletion	Spawning Output	Depletion
ABC	2021	287	367	0.159	983	0.451	1400	0.687
	2022	285	357	0.155	1000	0.459	1421	0.697
	2023	283	346	0.150	1010	0.464	1432	0.702
	2024	280	334	0.145	1016	0.466	1434	0.703
	2025	277	323	0.140	1019	0.468	1429	0.701
	2026	274	313	0.136	1020	0.468	1420	0.697
	2027	271	303	0.132	1021	0.469	1409	0.691
	2028	269	295	0.128	1021	0.469	1396	0.685
	2029	266	287	0.125	1022	0.469	1383	0.678
	2030	264	280	0.122	1023	0.470	1370	0.672
Average Catch = 154.4	2021	154	367	0.159	983	0.451	1400	0.687
	2022	154	379	0.165	1024	0.470	1446	0.709
	2023	154	390	0.170	1058	0.486	1481	0.726
	2024	154	401	0.174	1089	0.500	1507	0.739
	2025	154	412	0.179	1115	0.512	1525	0.748
	2026	154	423	0.184	1139	0.523	1538	0.755
	2027	154	434	0.188	1161	0.533	1547	0.759
	2028	154	445	0.193	1182	0.543	1552	0.761
	2029	154	456	0.198	1201	0.551	1555	0.763
	2030	154	468	0.203	1219	0.560	1557	0.764
Constant Catch MSY SPR50 P* = 0.45 Year Specific Sigma	2021	262	367	0.159	983	0.451	1400	0.687
	2022	260	361	0.157	1004	0.461	1426	0.699
	2023	257	354	0.154	1019	0.468	1441	0.707
	2024	255	347	0.151	1030	0.473	1448	0.710
	2025	253	340	0.148	1037	0.476	1448	0.710
	2026	250	334	0.145	1043	0.479	1443	0.708
	2027	248	328	0.142	1048	0.481	1436	0.704
	2028	246	323	0.140	1053	0.483	1427	0.700
	2029	243	319	0.139	1057	0.485	1417	0.695
	2030	241	316	0.137	1062	0.487	1406	0.690

Table i: Base model results summary.

Quantity	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
OFL (mt)		293	291	288	288	289	291	346	347	332
ACL (mt)		243	241	236	236	194	198	306	311	299
Removals (mt)	59	70	60	114	125	173	136	187	229	208
(1-SPR) (1-$SPR_{50\%}$)	0.547	0.580	0.473	0.701	0.701	0.818	0.668	0.779	0.853	0.789
Exploitation rate	0.014	0.015	0.012	0.021	0.022	0.029	0.021	0.028	0.034	0.030
Age 0+ biomass (mt)	4312	4789	5149	5490	5725	6093	6421	6655	6797	6876
Spawning Output	416	459	509	573	638	703	757	812	860	903
95% CI	0 - 846	0 - 930	0 - 1028	0 - 1152	0 - 1285	0 - 1421	0 - 1542	0 - 1660	0 - 1767	0 - 1867
Relative Depletion	0.191	0.211	0.234	0.263	0.293	0.323	0.347	0.373	0.395	0.415
95% CI	0.000 - 0.400	0.000 - 0.440	0.000 - 0.487	0.000 - 0.545	0.000 - 0.608	0.000 - 0.673	0.000 - 0.730	0.000 - 0.786	0.000 - 0.836	0.000 - 0.883
Recruits	2362	2722	2269	8510	3791	3410	3376	3749	3813	3866
95% CI	759 - 7349	895 - 8285	719 - 7159	2875 - 25190	1275 - 11269	1163 - 9997	1170 - 9739	1234 - 11394	1262 - 11521	1285 - 11631

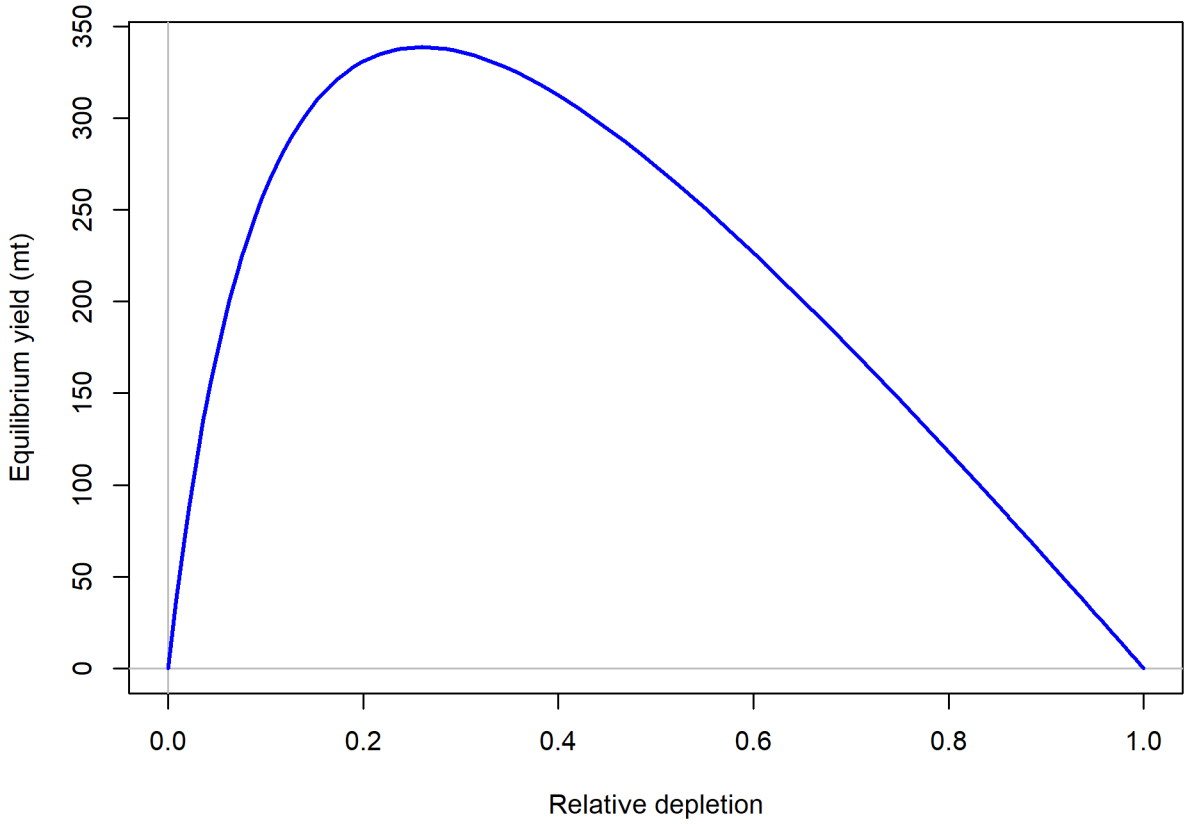

Figure h: Equilibrium yield curve for the catch update model. Values are based on the 2018 fishery selectivity and with steepness estimated at 0.64.

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