Agenda Item E.8
Attachment 9
September 2017

The Combined Status of Blue and Deacon Rockfishes in U.S. Waters off California and Oregon in 2017

Blue Rockfish (*Sebastes mystinus*)

Deacon Rockfish (*Sebastes diaconus*)

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Photos of Blue and Deacon rockfishes were downloaded from the RecFIN website (http://www.recfin.org/resources/fishid/) and taken by Vicky Okimura (WDFW).

Glossary of Acronyms:

ABC: Acceptable Biological Catch
ACL: Annual Catch Limit
BDR: Blue and Deacon Rockfish(es)
CAAL: Conditional age at length
CalCOFI: California Cooperative Oceanic Fisheries Investigations
CALCOM: California Cooperative Groundfish Survey
CDFW (CDFG): California Department of Fish and Wildlife (formerly Fish and Game)
CPFV: Commercial Passenger Fishing Vessel (aka “party” or “charter” boats)
CPAH: Catch-per-angler-hour
CPUE: Catch-per-unit-effort
CRFS: California Recreational Fisheries Survey
MRFSS: Marine Recreational Fisheries Statistics Survey
NMFS: National Marine Fisheries Service
NWFSC: Northwest Fisheries Science Center
ODFW: Oregon Department of Fish and Wildlife
OFL: Overfishing Limit
ORBS: Oregon Recreational Boat Survey
PacFIN: Pacific Fisheries Information Network
PFMC: Pacific Fishery Management Council
PISCO: Partnership for the Interdisciplinary Study of Coastal Oceans
PSMFC: Pacific States Marine Fisheries Commission
RecFIN: Recreational Fisheries Information Network
SEBS: Shore Estuary Boat Survey
SPR: Spawning Potential Ratio
STAR: Stock Assessment Review (Panel)
STAT: Stock Assessment Team
SWFSC: Southwest Fisheries Science Center
WCGOP: West Coast Groundfish Observer Program
WDFW: Washington Department of Fish and Wildlife
YOY: Young-of-the-year

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Executive Summary

Stock

This assessment reports the status of the Blue Rockfish (*Sebastes mystinus*) and the recently described Deacon Rockfish (*Sebastes diaconus*; Frabel et al. 2015) as a stock complex in U.S. waters off the coast of the California and Oregon. The complex is modelled with two independent stock assessments to approximate spatial variation in species composition, exploitation history, and other factors affecting stock dynamics. The California model represents the stock complex in U.S. waters from Point Conception (34° 27′ North latitude) to the California-Oregon border (42° N. lat.), and the Oregon model includes all U.S. waters off the coast of Oregon. Recent genetic analyses (see Appendix A) suggest that Blue Rockfish may be the dominant species south of Monterey Bay, CA, with an increasing fraction of Deacon Rockfish north of Monterey and into Oregon. Historical data streams did not separate the two species or estimate removals at a spatial scale small enough to evaluate assessment boundaries near Monterey, but future assessments may wish to consider alternative spatial structures should long-term, species-specific data become available.

Catches

California

Over the past decade, Blue and Deacon Rockfish (BDR) off California have been caught primarily by the recreational fishery (Table ES1). Over this time period, the commercial passenger fishing vessel 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. BDR landings from all sectors have historically been recorded as “blue rockfish” and recreational sampling in California currently does not differentiate between the two species.

Table ES1: Recent catches in California, north of Point Conception, by sector. Commercial landings are aggregated (see main text for disaggregated estimates) and minor removals by recreational shore modes are included with private boat landings.

Year	Recreational CPFV	Recreational Private	Recreational Discard	Commercial Landings	Commercial Discard	Total Removals
2005	209.25	62.44	5.43	17.77	9.00	303.89
2006	174.21	109.94	5.68	18.77	9.50	318.10
2007	95.03	39.88	2.70	13.40	6.78	157.79
2008	47.11	28.77	1.52	26.33	13.33	117.06
2009	21.49	16.89	0.77	7.35	3.72	50.22
2010	28.93	21.56	1.01	4.93	2.49	58.92
2011	34.97	23.53	1.17	7.12	3.60	70.39
2012	30.12	18.54	0.97	6.64	3.36	59.63
2013	66.84	35.95	2.06	6.10	3.09	114.04
2014	64.38	49.37	2.27	5.90	2.99	124.91
2015	91.73	63.91	3.11	9.18	4.65	172.58
2016	81.23	41.79	2.46	7.16	3.62	136.26

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 BDR 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 ES1). 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.

Oregon

BDR in Oregon is predominantly caught using hook-and-line gear by recreational fishermen and by hook-and-line or longline gear by commercial fishermen. Several other gear types harvest incidental amounts of BDR (including troll and trawl gear). Catch of BDR is almost all incidental as these species regularly school with Black Rockfish, the main target of Oregon nearshore fisheries. Only a small number of recreational and commercial fishermen target these fish regularly, generally in winter and spring months when catch rates tend to be higher.

Total landings have generally increased through time up until the late-1990s when landings returned to levels in the 2000s that more consistent with those observed in the 1980s (Figure ES2). Since the implementation of management limits on the commercial fishery in 2004 (fleet size limit, annual landing caps, and daily and period landing limits) and on the recreational fishery since 2001 (bag limit reductions), landings have reduced and have been generally stable. Recent landings continue to be dominated by the recreational landing fishery (Table ES2).

Table ES2: Recent catches (mt) for BDR in Oregon by fleet.

Year	Commercial Landings Fleet	Commercial Discards Fleet	Recreational Landings Ocean Fleet	Recreational Discards Ocean Fleet	Recreational Shore Fleet	Total Removals
2005	5.18	1.28	31.10	0.76	2.17	40.49
2006	4.68	1.16	11.52	0.30	1.06	18.72
2007	4.26	1.05	16.16	0.56	1.07	23.10
2008	2.74	0.68	15.14	0.68	1.08	20.32
2009	2.85	0.70	15.28	0.94	1.09	20.86
2010	4.04	1.00	21.17	0.79	1.09	28.09
2011	6.58	1.62	20.44	0.76	1.10	30.50
2012	6.84	1.69	25.12	0.71	1.11	35.47
2013	5.15	1.27	23.06	0.78	1.12	31.38
2014	3.97	0.98	18.11	0.62	1.12	24.80
2015	1.51	0.37	28.04	1.68	1.13	32.73
2016	2.06	0.51	19.95	0.71	1.14	24.37

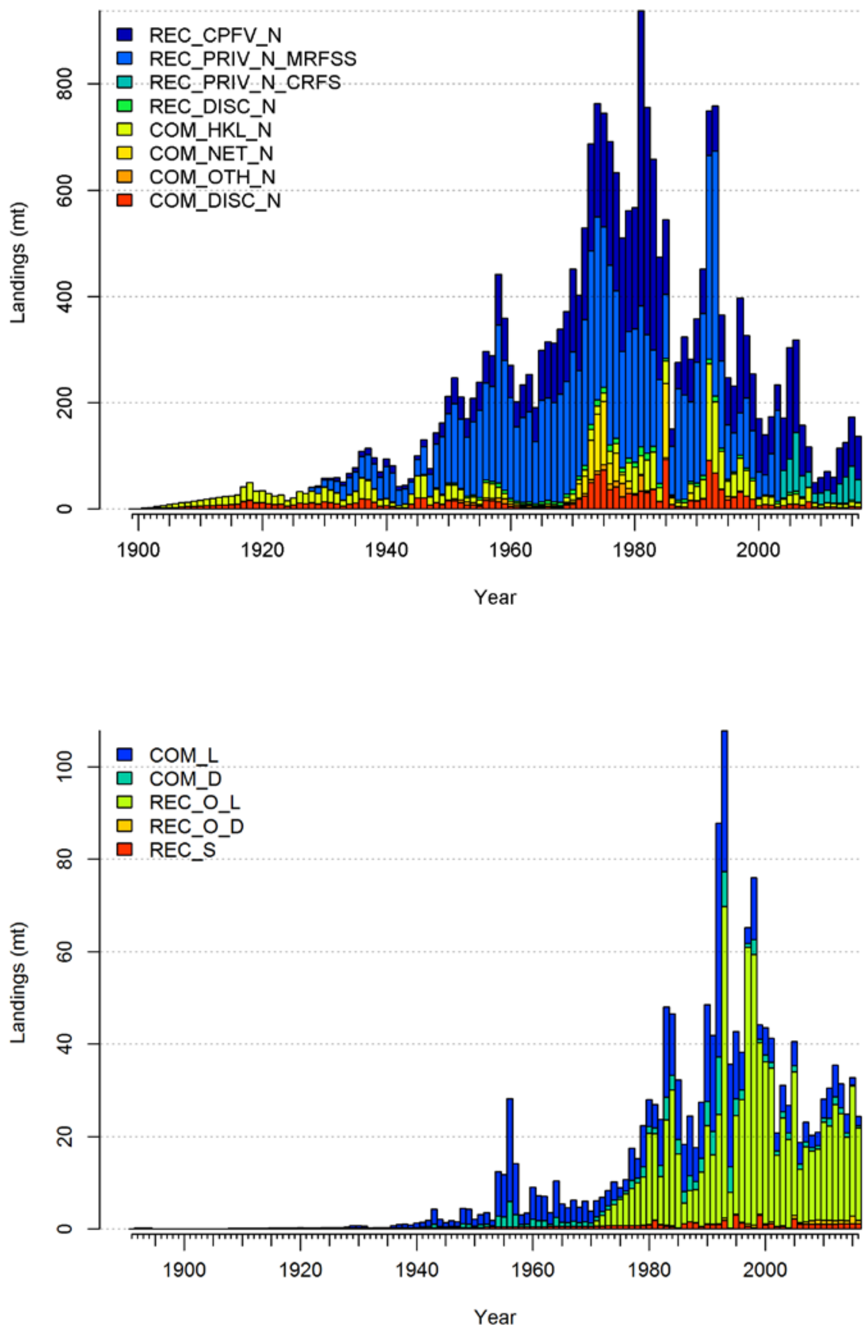


Figure ES1: Catch histories by fleet in the base models for California (upper panel) and Oregon (lower panel).

Data and assessment

California

“Blue Rockfish” (now known to include both Blue and Deacon Rockfishes) was last assessed in 2007, and estimated to be at 29% of unfished spawning output (Key et al. 2008). The 2017 assessment of BDR uses Stock Synthesis 3 (version V3.30.03.07). The assessment is structured as a single, sex-disaggregated, unit population, spanning U.S. waters from Point Conception to the California-Oregon border. The assessment model operates on an annual time step covering the period 1900 to 2017 (not including forecast years) and assumes an unfished population prior to 1900. Population dynamics are modeled for ages 0 through 35, with age-35 being the accumulator age. The maximum observed age was 39 for males and 43 for females. The model is conditioned on catch from two sectors (commercial and recreational) divided among eight fleets, and is 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 include 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 estimates parameters for natural mortality of females and males, steepness of the Beverton-Holt stock-recruitment relationship, and gender-specific growth parameters. Year class strength is estimated as deviations from the expected stock-recruitment relationship beginning in 1950.

Oregon

This is the first full assessment for BDR in Oregon waters so no direct transition from a previous assessment was possible. However, there was a transition from the 2007 Blue Rockfish assessment conducted in California waters (Key et al. 2008) to the current California BDR assessment. The base modeling assumptions used in the final transition step for the California model were used as a starting point for evaluating Oregon assessment models and building the Oregon BDR base case model.

The Oregon assessment uses the same recent version of Stock Synthesis 3 (version V3.30.03.07) as the California assessment. The Oregon assessment is structured as a single, sex-disaggregated, unit population, spanning Oregon coastal waters, and operates on an annual time step covering the period 1892 to 2017. Fleets were specified for recreational and commercial sectors. Three recreational fishing fleets are used in this assessment: 1) ocean-boats (Private Boat and Rental (PBR) and Commercial Passenger Fishing Vessel (CPFV) boat types) that landed BDR, 2) ocean-boats that discarded BDR, and 3) landings from shore (beach/bank and man-made structure types) and estuary-boats (PBR boat type). Two commercial fishing fleets are used in this assessment: 1) combined hook-and-line and longline gear type landed BDR, and 2) combined hook-and-line and longline gear type discarded BDR. Data used in the assessment includes time-series of commercial and recreational landings, four fishery-dependent abundance indices (catch-per-unit-effort or CPUE), length compositions for each fleet, and age compositions from the recreational ocean-boat landings fleet, the commercial landings fleet, and a collection of research survey ages.

Stock biomass

California

Spawning output of BDR in California was estimated to be 812 million eggs in 2017 (~95% asymptotic intervals: 0-1,661 million eggs), or 37% of unfished spawning output ("depletion," ~95% asymptotic intervals: 0-78.5%; Table ES3). Depletion is a ratio of the estimated spawning biomass in a particular year relative to estimated unfished, equilibrium spawning biomass. 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 ES2 and ES3). The trend in spawning output in 2017 is approaching 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 $SPR_{50\%}$ proxies for target spawning biomass and maximum yield).

Oregon

BDR spawning biomass was estimated to be 296 million eggs in 2017 (~95% asymptotic intervals: 64-527 million eggs), which when compared to unfished spawning biomass equates to a depletion level of 69% (~95% asymptotic intervals: 0.52-0.85; Table ES4) in 2017. In general, spawning biomass has been trending slightly downwards, with the exception of an increase in the 1990s due to several high recruitment years (Figure ES2). Stock size is estimated to be at the lowest level throughout the historic time series in 2017, but the stock is estimated to be well above the management target of $B_{40\%}$ (Figure ES3).

Table ES3: Recent trends in the beginning of the year biomass and depletion for BDR in California waters. Asymptotic confidence intervals truncated at zero.

Year	Spawning Output (eggs x 10^6)	~ 95% confidence intervals	Estimated depletion (%)	~ 95% confidence intervals
2005	383	85–682	17.6	2.8–32.4
2006	362	47–678	16.6	1.1–32.2
2007	340	5–675	15.6	0–32.0
2008	351	0–712	16.1	0–33.7
2009	375	0–768	17.2	0–36.3
2010	416	0–846	19.1	0–40.0
2011	459	0–930	21.1	0–44.0
2012	509	0–1,028	23.4	0–48.7
2013	573	0–1,152	26.3	0–54.5
2014	638	0–1,285	29.3	0–60.8
2015	703	0–1,421	32.3	0–67.3
2016	757	0–1,542	34.7	0–73.0
2017	812	0–1,661	37.3	0–78.5

Table ES4: Recent trends in the beginning of the year biomass and depletion for BDR in Oregon waters.

Year	Spawning Output (eggs x 10^6)	~ 95% confidence intervals	Estimated depletion	~ 95% confidence intervals
2005	386	107–665	89.6	72.3–106.9
2006	370	98–643	86.0	68.5–103.4
2007	358	94–621	83.0	66.0–99.9
2008	344	89–600	79.8	63.3–96.4
2009	337	86–587	78.1	61.9–94.4
2010	334	85–583	77.6	61.4–93.7
2011	330	82–578	76.5	60.3–92.7
2012	322	78–566	74.6	58.4–90.9
2013	312	72–553	72.5	56.1–88.9
2014	307	69–545	71.2	54.7–87.7
2015	304	68–540	70.5	54.2–86.8
2016	299	65–533	69.3	52.8–85.8
2017	296	64–527	68.6	52.2–84.9

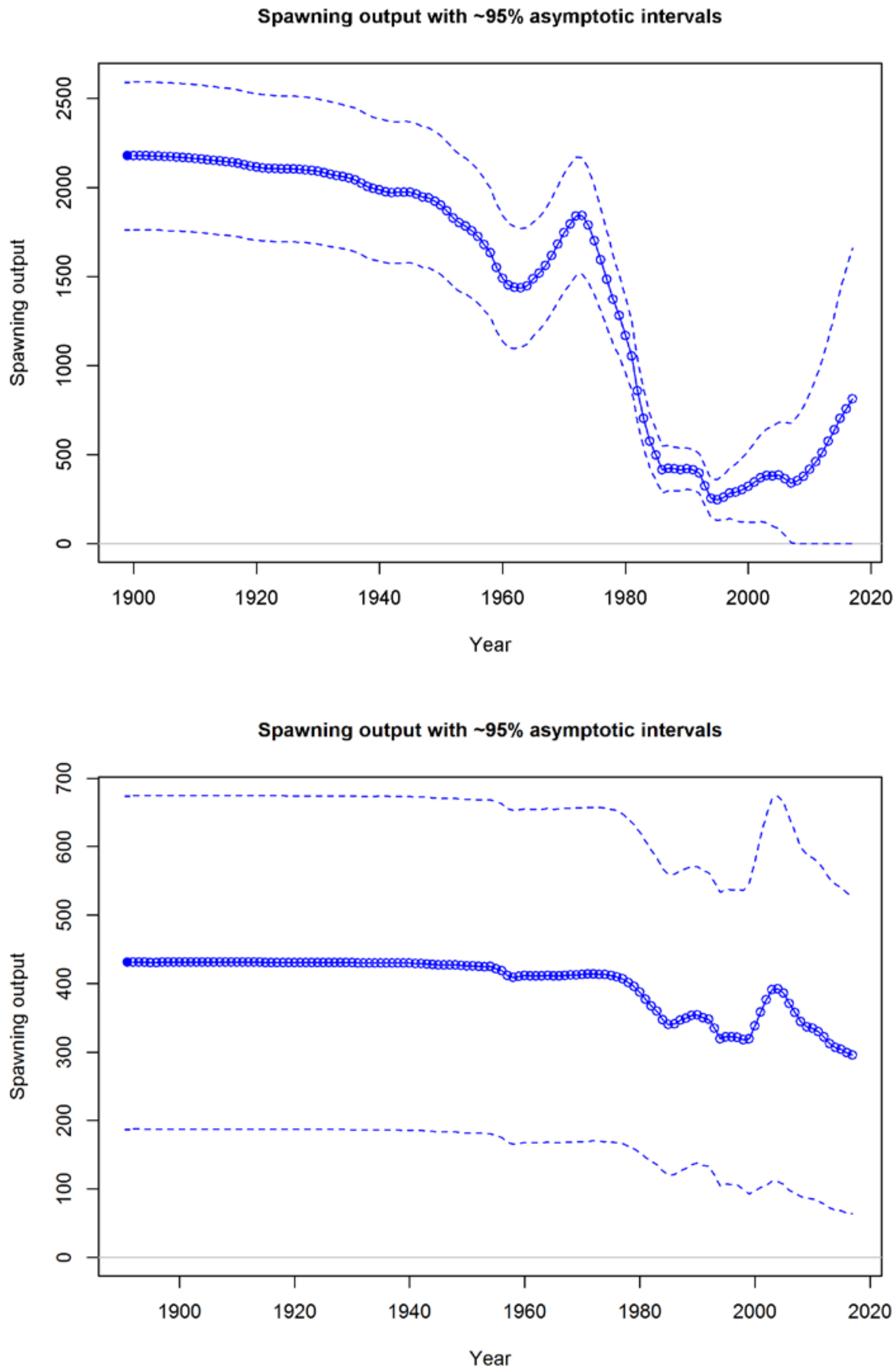


Figure ES2: Recent trends in the beginning of the year spawning output (millions of eggs) for BDR in California waters (upper panel) and Oregon waters (lower panel).

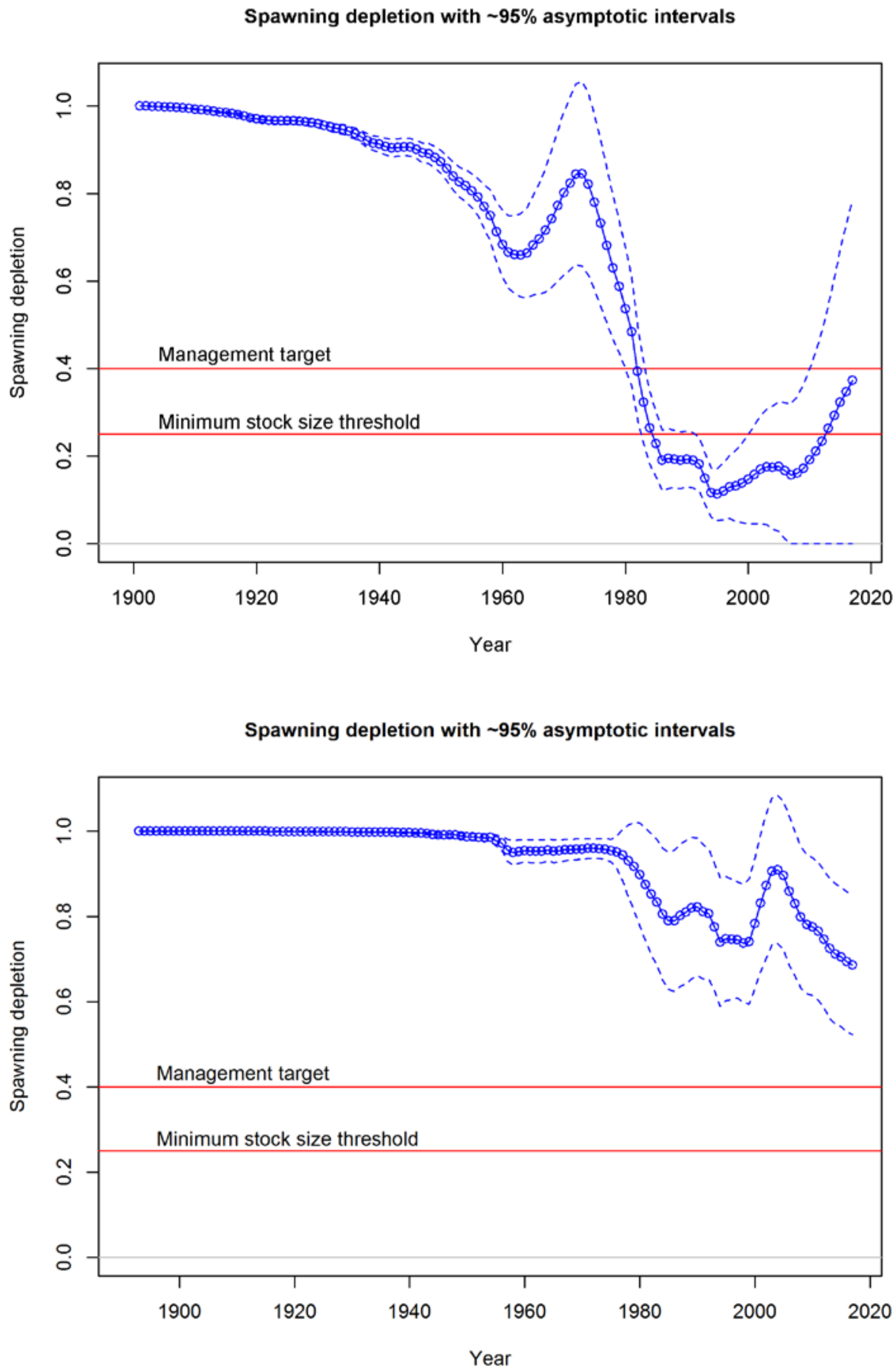


Figure ES3: Estimated relative depletion (spawning output relative to unfished spawning output) with approximate 95% asymptotic confidence intervals (dashed lines) for BDR in California (upper panel) and Oregon (lower panel).

Recruitment

California

A recent, strong recruitment in 2013 has contributed to the recent increase in BDR biomass in California (Table ES5; Figure ES4). 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. Overall, variability in recruitment is average (to low) relative to other rockfish species, with an RMSE of 0.47 for the main period of recruitment deviations.

Oregon

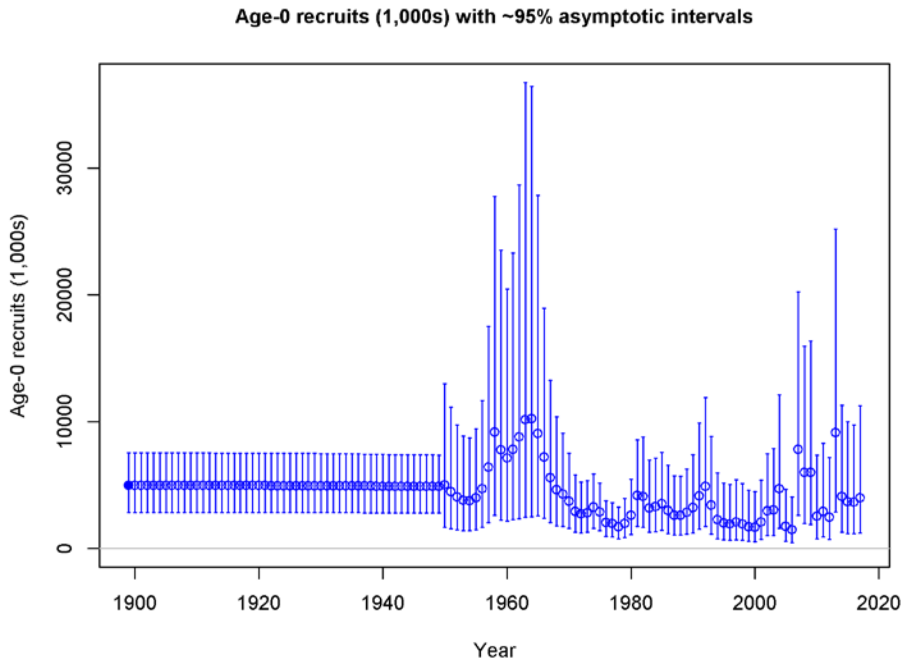
Recruitment variability was dynamic for BDR (Table ES6, Figure ES4) and indicated well above average recruitment in 2013. Other years with relatively high estimates of recruitment were 1993, 1994, and 1995. The BDR stock in Oregon has not been depleted to levels that would provide information on how recruitment changes with spawning biomass at low spawning biomass levels (i.e., inform the steepness parameter).

Table ES5: Recent trend in estimated recruitment for BDR in U.S. waters off California and north of Point Conception.

Year	Estimated Recruitment (1,000s)	~ 95% confidence intervals	Estimated Recruitment Deviations	~ 95% confidence intervals
2005	1,623	567–4,644	-0.49	-1.068–0.088
2006	1,364	462–4,028	-0.637	-1.256–-0.017
2007	7,249	2,601–20,201	1.065	0.695–1.436
2008	5,571	1,949–15,926	0.786	0.356–1.215
2009	5,568	1,896–16,351	0.753	0.263–1.243
2010	2,362	759–7,349	-0.153	-0.869–0.564
2011	2,722	895–8,285	-0.055	-0.770–0.660
2012	2,269	719–7,159	-0.28	-1.108–0.547
2013	8,510	2,875–25,190	0.995	0.323–1.667
2014	3,791	1,275–11,269	0.144	-0.635–0.922
2015	3,410	1,163–9,997	-0.01	-0.804–0.785
2016	3,376	1,170–9,739	-0.058	-0.870–0.755
2017	3,707	1,222–11,248	0	-0.980–0.980

Table ES6: Recent trend in estimated recruitment for BDR in Oregon waters.

Year	Estimated Recruitment (1,000s)	~ 95% confidence intervals	Estimated Recruitment Deviations	~ 95% confidence intervals
2005	1,039	525–2,057	0.017	-0.294–0.328
2006	369	172–792	-1.015	-1.506–-0.523
2007	959	483–1,903	-0.055	-0.383–0.272
2008	1,290	651–2,553	0.246	-0.078–0.570
2009	591	271–1,290	-0.531	-1.061–-0.001
2010	1,211	572–2,564	0.187	-0.276–0.649
2011	654	280–1,528	-0.433	-1.072–0.206
2012	738	304–1,797	-0.314	-1.021–0.393
2013	2,233	942–5,292	0.791	0.122–1.461
2014	1,054	387–2,871	0.037	-0.854–0.928
2015	960	339–2,718	-0.06	-1.009–0.888
2016	1,095	618–1,939	0	0.000–0.000
2017	1,093	617–1,937	0	0.000–0.000



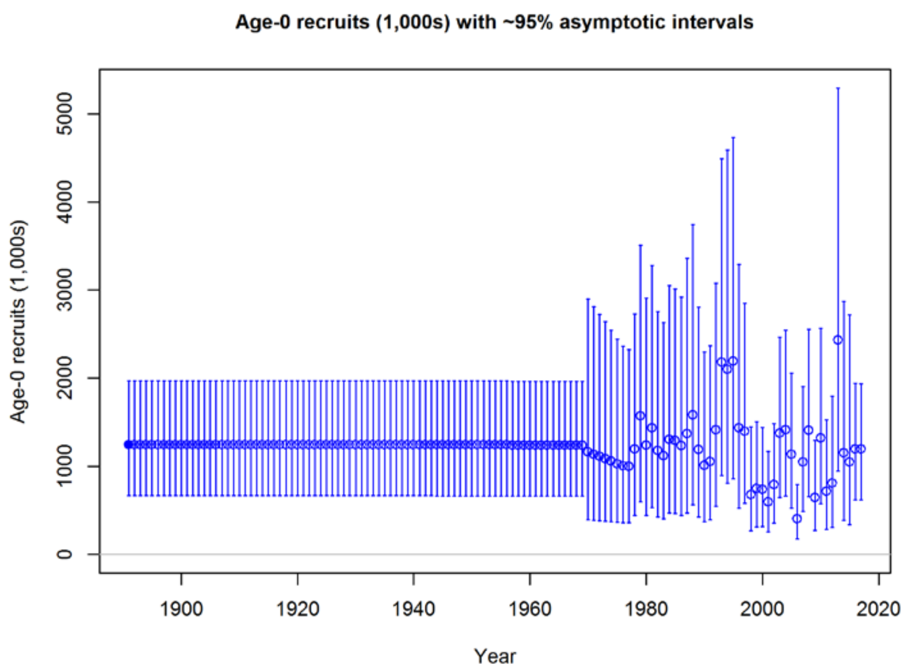


Figure ES4: Recent trend in estimated recruitment for BDR in U.S. waters off California (upper panel) and Oregon (lower panel).

Exploitation status

California

The annual (equilibrium) SPR harvest rate for BDR in California has been below target since 2008 (Table ES7, Figure ES5). 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 ES5). As with current estimates of spawning output, recent estimates of exploitation status are highly uncertain, ranging from 13% to 120% of target in 2016 (Table ES7). 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 ES6). Harvest rates in California are currently below target, and the stock is approaching the proxy target biomass (Figure ES7). Estimates of maximum sustainable yield for the California portion of the stock are 3 to 4 times larger than the Oregon stock (Figure ES8).

Oregon

Harvest rates in Oregon have generally increased through time until the mid-1990s when harvest was reduced to a relatively stable level beginning in the 2000s. The maximum harvest rate was 0.92 in 1993 (or 92% of the target level) before declining again to around 0.40 in recent years (Table ES8, Figure ES5). Summary fishing mortality rates have been around 0.02 in recent years (Figure ES6). Fishing intensity is estimated to have been below the target throughout the time series [(1-SPR) / (1-$SPR_{50\%}$) < 1]. In 2016, Oregon BDR biomass is estimated to have been 1.73 times higher than the target biomass level, while experiencing fishing intensity 2.86 times lower than the SPR fishing intensity target (Figure ES7). The equilibrium curve is shifted left, as expected from the high fixed steepness, showing a more productive stock than the SPR50% reference point would suggest (Figure ES8).

Table ES7. Recent trend in spawning potential ratio (entered as 1-SPR / 1-SPR50%) and exploitation for BDR in California waters.

Year	Estimated (1-SPR) / (1-$SPR50_{\%}$)	~ 95% confidence intervals	Harvest rate (ratio)	~ 95% confidence intervals
2005	141.69	98.22–185.16	0.09	0.020–0.167
2006	145.70	100.49–190.91	0.10	0.014–0.181
2007	112.86	54.07–171.65	0.05	0.004–0.094
2008	95.20	34.80–155.60	0.04	0.002–0.067
2009	52.14	6.09–98.20	0.01	0.000–0.026
2010	54.67	7.53–101.81	0.01	0.000–0.027
2011	57.99	9.29–106.70	0.02	0.000–0.029
2012	47.31	5.01–89.60	0.01	0.000–0.023
2013	70.08	16.23–123.93	0.02	0.001–0.042
2014	70.11	16.00–124.23	0.02	0.001–0.043
2015	81.77	23.49–140.05	0.03	0.001–0.056
2016	66.78	13.20–120.37	0.02	0.000–0.042
2017	93.96	72.84–115.08	0.04	0.015–0.060

Table ES8. Recent trend in spawning potential ratio (entered as 1-SPR / 1-SPR50%) and exploitation for BDR in Oregon waters.

Year	Estimated (1-SPR) / (1-SPR$_{50\%}$)	~ 95% confidence intervals	Harvest rate (ratio)	~ 95% confidence intervals
2005	43.34	18.51–68.16	0.02	0.007–0.036
2006	23.17	8.25–38.10	0.01	0.003–0.017
2007	28.78	10.71–46.85	0.01	0.004–0.021
2008	26.36	9.50–43.23	0.01	0.004–0.019
2009	27.37	9.87–44.87	0.01	0.004–0.020
2010	35.81	13.80–57.82	0.02	0.005–0.027
2011	38.95	15.27–62.63	0.02	0.005–0.030
2012	44.81	18.22–71.40	0.02	0.006–0.035
2013	41.26	16.00–66.53	0.02	0.006–0.032
2014	34.31	12.36–56.27	0.02	0.004–0.026
2015	43.66	17.18–70.13	0.02	0.006–0.033
2016	34.58	12.34–56.81	0.01	0.004–0.024
2017	95.3	95.12–95.48	0.06	0.049–0.064

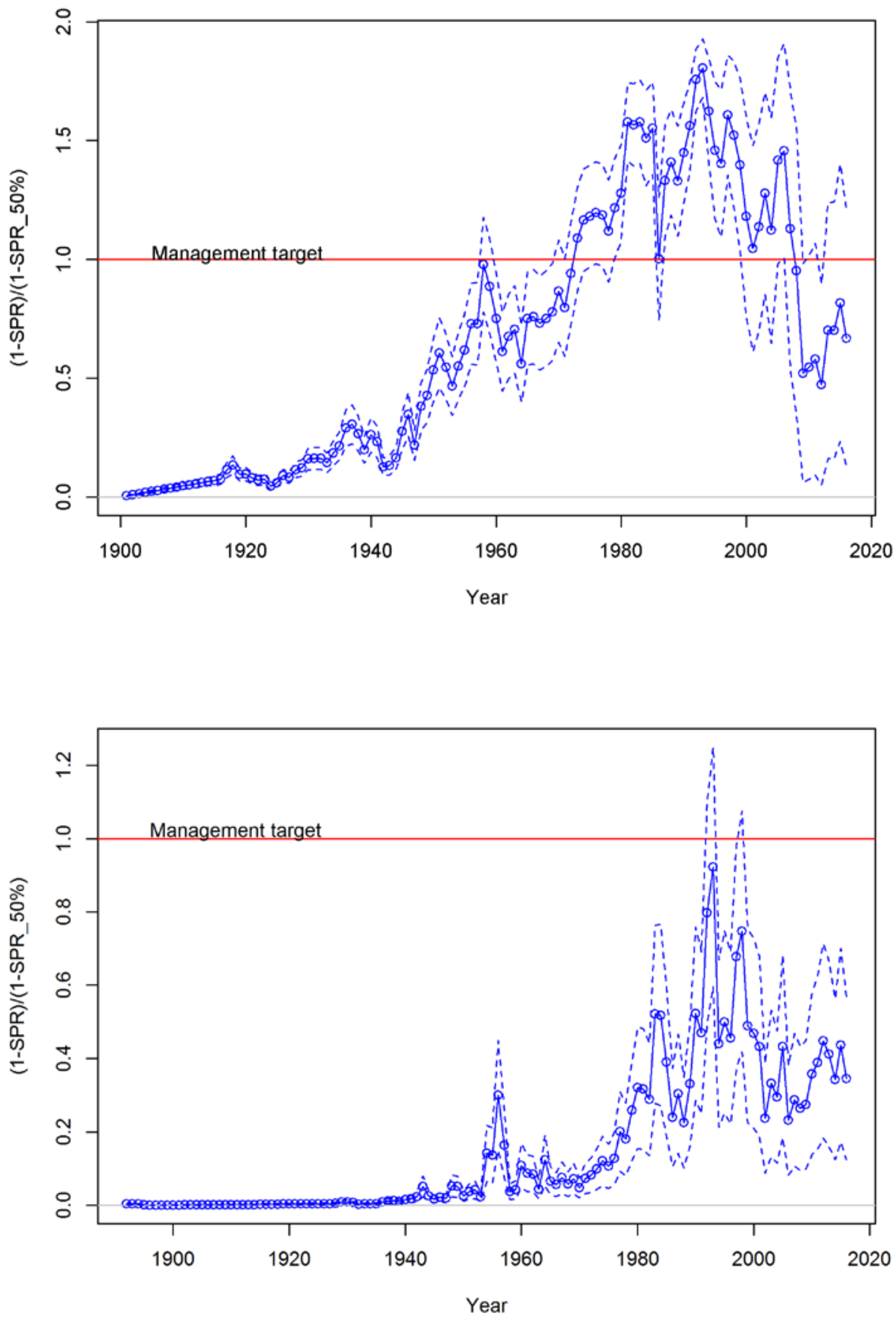


Figure ES5. Estimated spawning potential ratio (SPR) for the base case models with approximate 95% asymptotic confidence intervals (upper panel: California; lower panel: Oregon). One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{50\%}$.

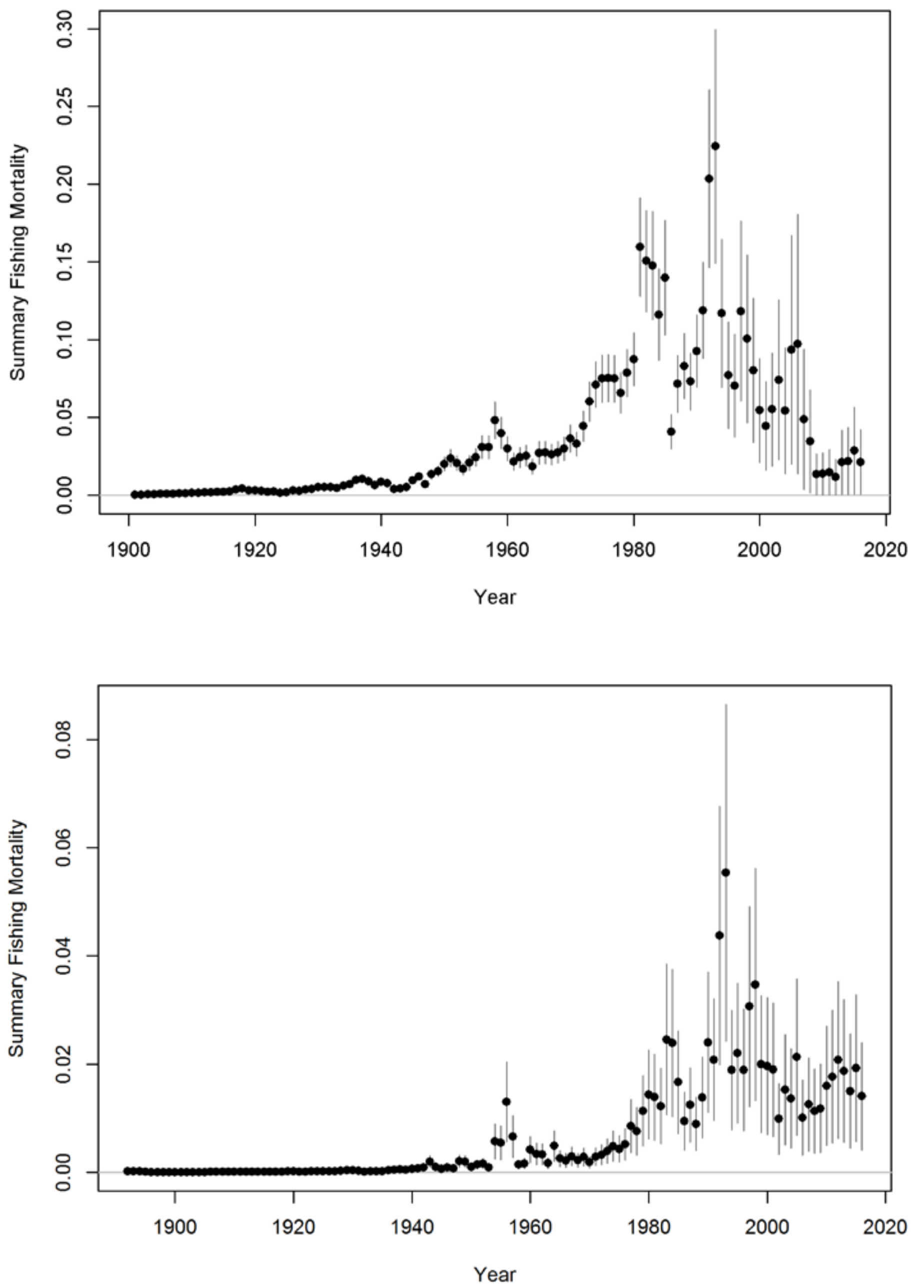


Figure ES6. Time-series of estimated summary harvest rate (total catch divided by age-0 and older biomass) for the base case models (California, upper panel; Oregon, lower panel) with approximate 95% asymptotic confidence intervals (grey lines).

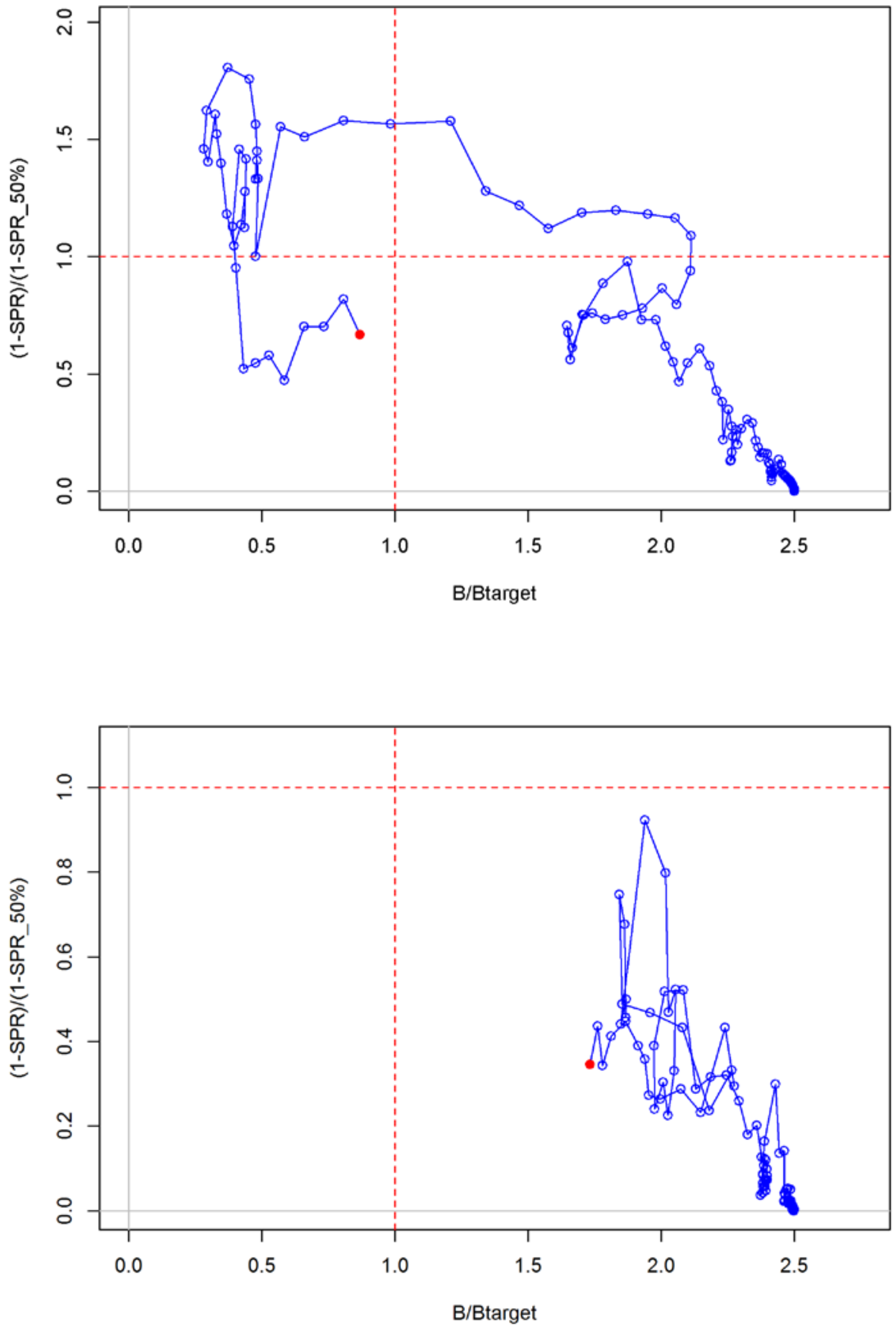


Figure ES7. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case models (California, upper panel; Oregon, lower panel). The relative (1-SPR) is (1-SPR) divided by 0.5 (the SPR target). Relative depletion is the annual spawning biomass divided by the spawning biomass corresponding to 40% of the unfished spawning biomass. The red point indicates the year 2016.

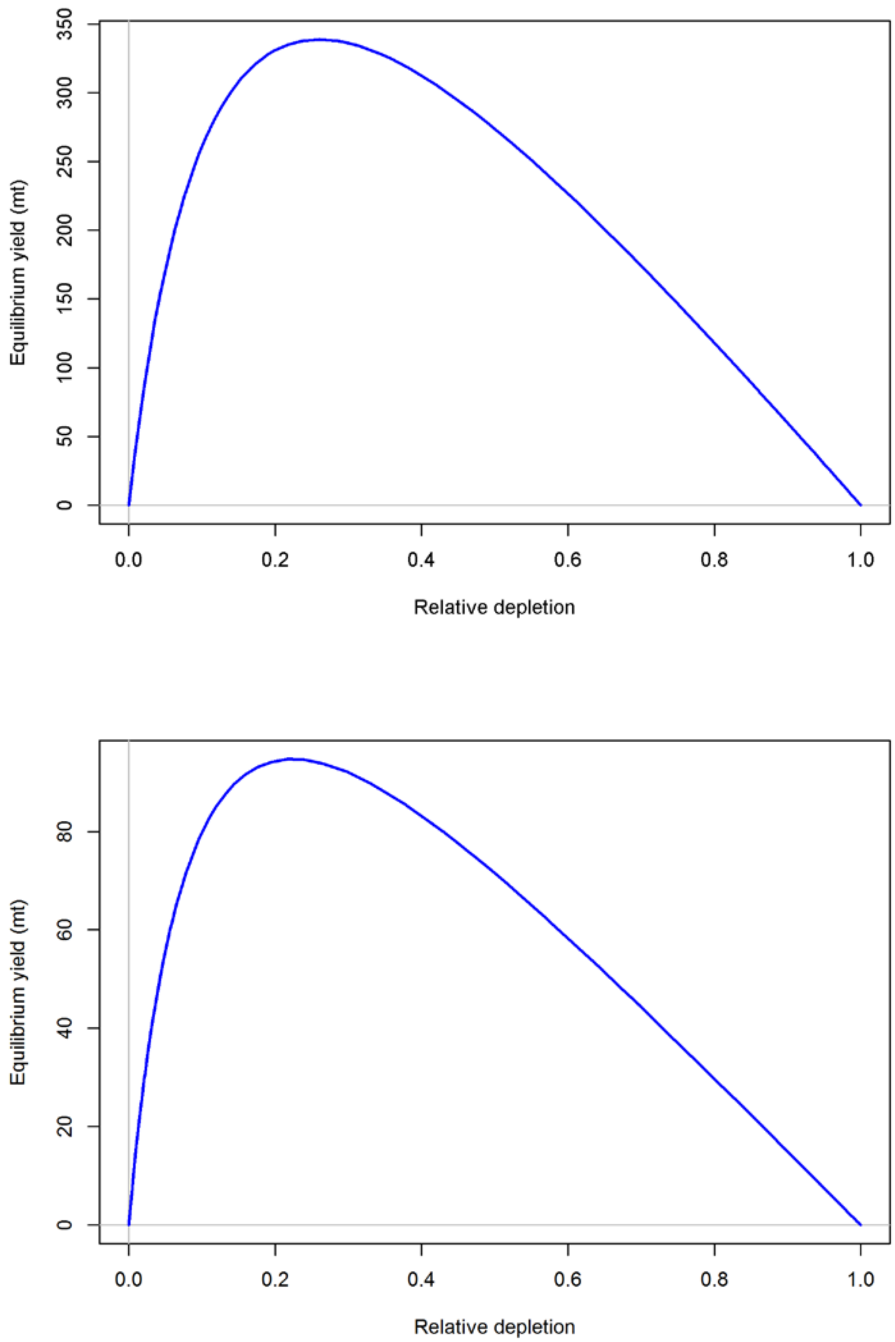


Figure ES8. Equilibrium yield curve (derived from reference point values reported in Table e) for the base case models (California, upper panel; Oregon, lower panel). The depletion is relative to unfished spawning biomass.

Ecosystem considerations

Ecosystem data were not explicitly included in either assessment model. Trophic relationships and habitat associations of Blue Rockfish are relatively well described among rockfishes; however, the recent discovery of a cryptic species (Deacon Rockfish) necessitates that historical information is considered for the Blue/Deacon Rockfish complex as a whole. Habitat associations vary ontogenetically for BDR but all post-larval stages occur in nearshore waters, often in association with kelp beds. Early juveniles are benthic, but BDR become more pelagic with ontogeny. Adult BDR do not typically move more than 100 m from their core home range, which is often centered on rock pinnacles and cliffs, but do commonly shift their home ranges, especially during the upwelling season. Large-scale climactic conditions (e.g., ENSO warming events) can influence adult reproductive condition. BDR is a largely planktivorous species that feed on midwater organisms. BDR is an important prey species for a variety of nearshore marine vertebrates.

Reference points

California

Reference points and management quantities for the California BDR base case model are listed in Table ES9. In 2017, spawning output relative to unfished spawning output ("depletion") is estimated at 37% (~95% asymptotic intervals = 0%-79%). Unfished spawning output was estimated at 2,178 million eggs (~95% asymptotic intervals = 1,763-2,593; Table ES9), and spawning output at the beginning of 2017 was estimated to be 812 million eggs (~95% asymptotic intervals = 0-1,661 mt). The target spawning output (*SB*40%) is 871 million eggs, compared to an equilibrium spawning output of 915 million eggs associated with the proxy $SPR_{50\%}$ harvest rate. Yield at the SPR proxy biomass and harvest rate is 306 mt per year (~95% asymptotic intervals = 230-381 mt). Estimates of MSY (and its proxies) for the California stock are considerably more precise than estimates of current OFL due to uncertainty in recent biomass levels.

Table ES9. Summary of reference points and management quantities for the California BDR base case model.

Quantity	Estimate	~95% Confidence Interval
Unfished Spawning biomass (millions of larvae)	2,178	1,763–2,593
Unfished Age 0+ Biomass (mt)	11,536	9,140–13,932
Spawning Biomass (2017, millions of larvae)	812	0–1,661
Unfished recruitment (R0, thousands of fish)	4,617	2,328–6,907
Depletion -- 100 x SB_{2017}/SB_0	37	0–78.54
Reference points based on SB $_{40\%}$		
Proxy spawning biomass ($B_{40\%}$)	871	705–1,037
SPR resulting in $B_{40\%}$	0.483	0.402–0.563
Exploitation rate resulting in $B_{40\%}$	0.048	0.036–0.059
Yield at $B_{40\%}$ (mt)	312	222–402
Reference points based on SPR proxy for MSY		
Proxy spawning biomass (SPR50)	915	722–1,108
SPR50	0.5	NA
Exploitation rate corresponding to SPR50	0.045	0.040–0.051
Yield with F(SPR50) at SB(SPR50) (mt)	306	230–381
Reference points based on estimated MSY values		
Spawning biomass at *MSY* (SB_{MSY})	567	286–847
SPR_{MSY}	0.362	0.180–0.544
Exploitation rate corresponding to SPR_{MSY}	0.069	0.032–0.105
MSY (mt)	339	216–461

Oregon

Reference points and management quantities for the Oregon BDR base case model are listed in Table ES10. Spawning output has generally declined throughout the time series, but there were increases in the early-1990s due to large recruitment events associated with increased catch levels and in the early 2000s. Stock status has remained above the biomass target reference point (40%), though is trending towards the target since the mid-2000s, and is estimated to be at 69% (~95% asymptotic intervals = 52%-85%) in 2017. Unfished spawning biomass was estimated at 431 mt (~95% asymptotic intervals = 187-675 mt; Table ES10), and spawning biomass at the beginning of 2017 was estimated to be 296 mt (~95% asymptotic intervals = 64-527 mt). The target stock size based on the biomass target (*SB*40%) is 172 mt, which corresponds to a catch of 83 mt. Equilibrium yield at the proxy *FMSY* harvest rate corresponding to *SPR50*% is 78 mt.

Table ES10. Summary of reference points and management quantities for the Oregon BDR base case model.

Quantity	Estimate	~95% Confidence Interval
Unfished Spawning biomass (mt)	431	187–675
Unfished Age 0+ Biomass (mt)	2,199	963–3,435
Spawning Biomass (2017)	296	64–527
Unfished recruitment (R0, thousands)	1142	508–1,777
Depletion (2017)	68.56	52.25–84.87
Reference points based on $SB_{40\%}$		
Proxy spawning biomass ($B_{40\%}$)	172	75–270
SPR resulting in $B_{40\%}$	0.459	0.459–0.459
Exploitation rate resulting in $B_{40\%}$	0.063	0.060–0.066
Yield at $B_{40\%}$ (mt)	83	36–130
Reference points based on SPR proxy for MSY		
Proxy spawning biomass (SPR50)	192	84–301
SPR50	0.50	NA
Exploitation rate corresponding to SPR50	0.056	0.053–0.058
Yield with SPR50 at SBSPR (mt)	78	34–123
Reference points based on estimated MSY values		
Spawning biomass at *MSY* (SB_{MSY})	97	41–152
SPR_{MSY}	0.3	0.296–0.305
Exploitation rate corresponding to SPR_{MSY}	0.1	0.097–0.104
MSY (mt)	95	41–148

Management performance

The contribution of BDR 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 BDR 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 ES11).

Table ES11. Evaluation of Management Performance for "Blue Rockfish" (Blue and Deacon Rockfishes, combined). Total Mortality estimates are based on annual reports from the NMFS NWFSC.

Area	Year	"Blue Rockfish" (BDR)			Minor Nearshore Rockfish		
		NWFSC Total Mortality	ABC/ACL Contribution [1] (CA + OR/WA)	OFL Contribution [1] (CA + OR/WA)	Total Mortality	ACL	OFL
North of 40° 10'	2011	44.0	*25.3 + 27.6 = 52.9*	*27.7 + 33.1 = 60.8*	99.0	99	116
	2012	43.6	*25.1 + 27.6 = 52.7*	*27.5 + 33.1 = 60.6*	96.0	99	116
	2013	36.5	*22.2 + 26.9 = 49.1*	*27.4 + 32.3 = 59.7*	75.0	94	110
	2014	29.4	*22.2 + 26.9 = 49.1*	*27.4 + 32.3 = 59.7*	59.0	94	110
	2015	41.6	*17.0 + 26.9 = 43.9*	*27.4 + 32.3 = 59.7*	64.3	69	88
	2016	TBD	*17.5 + 26.9 = 44.4*	*27.7 + 32.3 = 60.0*	TBD	69	88
South of 40° 10'			**(S + N of 34°27' N lat.)**	**(S + N of 34°27' N lat.)**			
	2011	58.3	*61.8 + 156.3 = 218.1*	*74.0 + 191.3 = 265.3*	436	1,001	1,156
	2012	50.7	*61.8 + 154.5 = 216.3*	*74.0 + 189.5 = 263.5*	445	1,001	1,145
	2013	107.6	*60.8 + 152.8 = 213.6*	*72.9 + 187.8 = 260.7*	495	990	1,164
	2014	138.8	*60.8 + 152.8 = 213.6*	*72.9 + 187.8 = 260.7*	596	990	1,160
	2015	181.9	*60.8 + 116.6 = 177.4*	*72.9 + 188.6 = 261.5*	676	1,114	1,313
	2016	TBD	*60.8 + 120.0 = 180.8*	*72.9 + 190.3 = 263.2*	TBD	1,006	1,288

1 - Harvest contributions to the Minor Nearshore Rockfish complexes are not management limits; management limits are specified at the complex level. ACL = ABC for these contributions with a 40-10 adjustment to the ACLs for those areas assessed in 2007 by Key et al. (off CA north of 34°27' N lat.).

The status of BDR off Oregon has never previously been fully assessed leaving only the DCAC (Depletion Corrected Adjusted Catch) data-poor method estimates to inform harvest limits. However, the harvest limit for the federally designated "northern nearshore rockfish" management complex, of which includes BDR, is calculated by summing the contributing component limits to a complex-level harvest control rule (Table ES12). While harvest levels for the northern nearshore rockfish have never exceeded the ACL, the complex attainment in 2011 was 100% and in recent years BDR harvest levels have exceeded the contributing ACL component of 29.6 mt for these species. At the state level, annual harvest limits for both the recreational and commercial fisheries have been in regulation since 2004 to maintain impacts within federal ACLs.

Table ES12. Summary of recent management history for the northern nearshore rockfish (40°10' N) complex relative to harvest limits (mt).

Year	Control Rule	Harvest Limit	Complex Impacts (mt)	Blue/Deacon Impacts (mt)	Blue/Deacon % of Complex Impacts	Complex Impacts % of Limit
2008	OY	142	97	30	31	68
2009	OY	155	63	30	47	41
2010	OY	155	75	40	54	48
2011	ACL	99	99	44	44	100
2012	ACL	99	96	44	45	97
2013	ACL	94	75	37	49	80
2014	ACL	94	59	29	50	63
2015	ACL	69	64	42	65	93
2016	ACL	69	*	*	*	*
2017	ACL	105	*	*	*	*

* - Totals not yet available from the West Coast Groundfish Observer Program

Unresolved problems and major uncertainties

California

The 2017 BDR assessment for California is generally consistent with the results of the 2007 assessment (see section 2.10.4). The scale of the stock is similar, and proxy ($SPR_{50\%}$) 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 (Table ES3, Figure ES2), 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 BDR. 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 BDR biomass. However, population scale (unfished spawning biomass) 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.

Oregon

The most significant uncertainty for the OR BDR model is the size of population scale, the treatment and value of natural mortality, and gender-specific selectivity. The development of a comprehensive fishery-independent index of abundance will help to resolve uncertainty in population scale. The treatment of selectivity and natural mortality was a major structural consideration that was explored in the development of the base case model. In particular, alternative approaches to estimating female and male natural mortality and gender specific selectivity were evaluated to account for differences in male selectivity (gear retention for the slower growing males) and availability (for sex-ratio reasons other than that attributed to natural mortality) relative to females in the catch. There was little information in the data to estimate gender-specific selectivity patterns, and most modeling attempts resulted in non-convergence or irrational results. The catch history for recreational fishing modes in years prior to 1979 and for the shore (and estuary) mode in recent years (2006-2014) is quite uncertain. In this assessment, historical catch reconstructions for these fleets included using a simple linear ramp, proportional fishing license sales ramp, and an extrapolation based on information available in the time series. Steepness, while fixed, is still highly uncertain for rockfishes and currently is mismatched to the MSY proxy. Stock structure and its relationship to the current political/management boundaries are also not fully understood.

Decision table and forecasts

California

Projections of OFL (mt), ABC (mt), age 0+ biomass (mt), spawning output (millions of eggs), and depletion (% of unfished spawning output), are shown for two catch scenarios: 1) the default harvest control rule (Table ES13), and 2) constant catch equal to average catch over the period 2015-2016 (Table ES14).

Table ES13. Projection of OFL, default harvest control rule catch (ABC = ACL above 40% SSB), biomass, and depletion using the California BDR base case model with 2017-2018 catches set equal to 2015-2016 average catch (154.4 mt).

Year	OFL	ABC Catch	Age 0+ Biomass	Spawning Output	Depletion (%)
2017	278.7	154.4	6654	812	37.3
2018	294.6	154.4	6830	864	39.7
2019	309.8	283.5	6984	917	42.1
2020	316.7	289.8	7014	943	43.3
2021	321.7	294.4	7029	963	44.2
2022	324.8	297.3	7034	975	44.8
2023	326.2	298.6	7033	982	45.1
2024	326.6	298.9	7028	985	45.2
2025	326.2	298.6	7023	985	45.2
2026	325.5	298.0	7018	984	45.2
2027	324.8	297.3	7014	982	45.1
2028	324.2	296.7	7011	981	45.0

Note: projection assumes a category 2 assessment as a result of assessing a complex, with a P=0.45 and sigma = 0.72 with a multiplier of 0.913 applied to the OFL.*

Table ES14. Projection of OFL, constant catch (2015-2016 average catch), biomass, and depletion using the California BDR base case model with 2017-2018 catches set equal to 2015-2016 average catch (154.4 mt).

Year	OFL	ABC Catch	Age 0+ Biomass	Spawning Output	Depletion (%)
2017	278.7	154.4	6654	812	37.3
2018	294.6	154.4	6830	864	39.7
2019	309.8	154.4	6984	917	42.1
2020	323.9	154.4	7124	968	44.5
2021	336.4	154.4	7250	1014	46.6
2022	347.1	154.4	7365	1055	48.4
2023	356.1	154.4	7470	1089	50.0
2024	363.6	154.4	7569	1119	51.4
2025	370.1	154.4	7663	1145	52.6
2026	375.8	154.4	7752	1168	53.6
2027	381.1	154.4	7838	1189	54.6
2028	386.1	154.4	7920	1209	55.5

Note: projection assumes a category 2 assessment as a result of assessing a complex, with a P=0.45 and sigma = 0.72 with a multiplier of 0.913 applied to the OFL.*

During the STAR Panel review, it was agreed that uncertainty in the BDR assessment for California would be represented by quantiles of spawning output (sometimes referred to as spawning stock biomass, or SSB). Specifically, the 12.5 and 87.5 percentiles of SSB were chose as "low" and "high" alternative states of nature. Catch streams based on the default harvest control rule were generated under each state of nature. Each of these catch streams (low, base, and high) were then applied to all three states of nature, bracketing the range of management decisions and uncertainty in current stock size in California (Table ES15). Forecasts based on two "constant" catch streams were also completed: one with catch equal to the $SPR_{50\%}$ proxy yield multiplied by 0.913 (the buffer resulting from $\sigma = 0.72$ and $P^* = 0.45$), and another set equal to average catch over the period 2015-2016.

Table ES15: Decision table summarizing 12-year projections (2017 – 2028) for California BDR based on three alternative states of nature spanning quantiles of spawning output in 2017. Columns range over low, medium, 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 2017 and 2018 are fixed at 2015-2016 average catch, and allocated to each fleet based on the percentage of landing for each fleet averaged over the same period.

[see next page]

		State of nature (percentiles of spawning output in 2017)								
		Low			Base case			High		
Percentile of Spawning Output		12.5%			50%			87.5%		
Estimated steepness and M_{fem}		h = 0.555, M = 0.113			h = 0.645, M = 0.119			h = 0.702, M = 0.131		
Management decision	Year	Catch (mt)	Spawning Output (eggs x 10^6)	Depletion (% of SB_0)	Catch (mt)	Spawning Output (eggs x 10^6)	Depletion (% of SB_0)	Catch (mt)	Spawning Output (eggs x 10^6)	Depletion (% of SB_0)
Catches from low SSB, Default Harvest Control Rule (40-10)	2017	154.4	330	14%	154.4	812	37%	154.4	1401	65%
	2018	154.4	342	15%	154.4	864	40%	154.4	1484	69%
	2019	51.5	355	15%	51.5	917	42%	51.5	1564	72%
	2020	63.9	388	17%	63.9	988	45%	63.9	1659	77%
	2021	75.1	418	18%	75.1	1053	48%	75.1	1739	80%
	2022	85.0	445	19%	85.0	1109	51%	85.0	1802	83%
	2023	93.7	469	20%	93.7	1156	53%	93.7	1849	85%
	2024	101.5	491	21%	101.5	1197	55%	101.5	1882	87%
	2025	108.6	510	22%	108.6	1232	57%	108.6	1903	88%
	2026	115.2	529	23%	115.2	1262	58%	115.2	1915	88%
	2027	121.5	546	24%	121.5	1288	59%	121.5	1919	89%
	2028	127.6	563	24%	127.6	1311	60%	127.6	1918	89%
Catches from median (base case) SSB, Default Harvest Control Rule (40-10)	2017	154.4	330	14%	154.4	812	37%	154.4	1401	65%
	2018	154.4	342	15%	154.4	864	40%	154.4	1484	69%
	2019	283.5	355	15%	283.5	917	42%	283.5	1564	72%
	2020	289.8	346	15%	289.8	943	43%	289.8	1613	75%
	2021	294.4	335	15%	294.4	963	44%	294.4	1648	76%
	2022	297.3	322	14%	297.3	975	45%	297.3	1668	77%
	2023	298.6	308	13%	298.6	982	45%	298.6	1675	77%
	2024	298.9	295	13%	298.9	985	45%	298.9	1671	77%
	2025	298.6	283	12%	298.6	985	45%	298.6	1659	77%
	2026	298.0	272	12%	298.0	984	45%	298.0	1641	76%
	2027	297.3	261	11%	297.3	982	45%	297.3	1621	75%
	2028	296.7	252	11%	296.7	981	45%	296.7	1599	74%
Catches from high SSB, Default Harvest Control Rule (40-10)	2017	154.4	330	14%	154.4	812	37%	154.4	1401	65%
	2018	154.4	342	15%	154.4	864	40%	154.4	1484	69%
	2019	526.3	355	15%	526.3	917	42%	526.3	1564	72%
	2020	524.4	303	13%	524.4	896	41%	524.4	1565	72%
	2021	518.9	253	11%	518.9	871	40%	518.9	1554	72%
	2022	510.2	207	9%	510.2	842	39%	510.2	1531	71%
	2023	498.9	165	7%	498.9	810	37%	498.9	1499	69%
	2024	486.0	131	6%	486.0	779	36%	486.0	1460	67%
	2025	472.6	103	4%	472.6	751	34%	472.6	1420	66%
	2026	459.3	80	3%	459.3	725	33%	459.3	1379	64%
	2027	446.9	59	3%	446.9	704	32%	446.9	1340	62%
	2028	435.5	40	2%	435.5	685	31%	435.5	1303	60%
Constant Catch, base model MSY ($F_{SPR50\%}$) proxy with buffer (σ=0.72, P*=0.45)	2017	154.4	330	14%	154.4	812	37%	154.4	1401	65%
	2018	154.4	342	15%	154.4	864	40%	154.4	1484	69%
	2019	279.0	355	15%	279.0	917	42%	279.0	1564	72%
	2020	279.0	347	15%	279.0	944	43%	279.0	1614	75%
	2021	279.0	337	15%	279.0	966	44%	279.0	1651	76%
	2022	279.0	327	14%	279.0	981	45%	279.0	1674	77%
	2023	279.0	317	14%	279.0	992	46%	279.0	1684	78%
	2024	279.0	307	13%	279.0	999	46%	279.0	1684	78%
	2025	279.0	297	13%	279.0	1002	46%	279.0	1676	77%
	2026	279.0	289	13%	279.0	1005	46%	279.0	1662	77%
	2027	279.0	281	12%	279.0	1006	46%	279.0	1645	76%
	2028	279.0	274	12%	279.0	1007	46%	279.0	1625	75%
Constant Catch, average catch from 2015-2016	2017	154.4	330	14%	154.4	812	37%	154.4	1401	65%
	2018	154.4	342	15%	154.4	864	40%	154.4	1484	69%
	2019	154.4	355	15%	154.4	917	42%	154.4	1564	72%
	2020	154.4	369	16%	154.4	968	44%	154.4	1638	76%
	2021	154.4	382	17%	154.4	1014	47%	154.4	1700	79%
	2022	154.4	394	17%	154.4	1055	48%	154.4	1748	81%
	2023	154.4	406	18%	154.4	1089	50%	154.4	1782	82%
	2024	154.4	416	18%	154.4	1119	51%	154.4	1804	83%
	2025	154.4	427	19%	154.4	1145	53%	154.4	1817	84%
	2026	154.4	438	19%	154.4	1168	54%	154.4	1823	84%
	2027	154.4	449	20%	154.4	1189	55%	154.4	1824	84%
	2028	154.4	461	20%	154.4	1209	56%	154.4	1822	84%

Oregon

The Oregon BDR assessment is automatically considered at least a category 2 stock assessment, because it is an assessment of a species complex. Therefore, projections and decision tables use a P* = 0.45 and a sigma = 0.72, resulting in a multiplier on the OFL of 0.9135. The OFL, ABC, and ACL for each forecast scenario is calculated following the rockfish MSY proxy of F_{SPR}=50% along with the 40-10 harvest control rule. Two harvest projections are provided based on alternative assumptions of catch during the forecast period (2019-2028), where catch during the current management cycle (2017-2018) was set to the average over the most recent two years (2015-2016). The first uses the catch specified by the F_{SPR}=50% MSY proxy following the 40:10 harvest control rule, where the ABC = ACL (Table ES16). The second uses a constant catch value specified by the STAR panel GMT representative. The constant catch was set at the average historical catch from 2005-2014, prior to newly implemented regulations in 2015 (Table ES17).

Uncertainty in management quantities for the Oregon model was characterized by exploring different values of $\ln(R_0)$. There was considerable discussion at the STAR panel about capturing the appropriate range of uncertainty relative to population scale. In response, the STAT and STAR panel agreed that the high and low states of nature should be based on ±1.15 * the asymptotic SE of $\ln(R_0)$ using the sensitivity model that estimated female natural mortality with a fixed male offset value (offset set to the average of the Hamel prior offset and the Then growth offset, see section 3.4.1). This model was chosen to develop the range of $\ln(R_0)$ because there were concerns that the base model did not capture the full range of uncertainty in $\ln(R_0)$ when natural mortality was fixed. This approach resulted in low ($\ln(R_0)$ = 6.453) and high ($\ln(R_0)$ = 7.641) states of nature relative to the base model ($\ln(R_0)$ = 7.047) that were used to characterize uncertainty in the decision table (Table ES18).

Table ES16. Projection of BDR OFL, catch, biomass, and depletion using the Oregon BDR base case model projected with total projected catch equal to 28.6 mt for 2017 and 2018. The predicted OFL is the calculated total catch determined by FSPR=50% (ABC=ACL). Total catch in 2017 and 2018 were set to the average over the most recent two years (2015 – 2016).

Year	Predicted OFL (mt)	ABC Catch (mt)	Age 0+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2017	109.1	28.6	1773	295.51	0.686
2018	110.1	28.6	1801	294.04	0.682
2019	112.3	103.0	1824	300.59	0.697
2020	108.8	99.8	1776	289.61	0.672
2021	105.7	96.9	1734	278.67	0.647
2022	102.6	94.1	1696	267.80	0.621
2023	99.7	91.4	1664	257.97	0.598
2024	97.2	89.1	1637	249.51	0.579
2025	95.0	87.1	1614	242.46	0.563
2026	93.2	85.5	1594	236.65	0.549
2027	91.7	84.1	1577	231.88	0.538
2028	90.4	82.9	1562	227.93	0.529

Note: projection assumes a category 2 assessment as a result of assessing a complex, with a P=0.45 and sigma = 0.72 with a multiplier of 0.9135 applied to the OFL.*

Table ES17. Projection of BDR OFL, catch, biomass, and depletion using the Oregon BDR base case model projected with total projected catch equal to 28.6 mt for 2017 and 2018. The predicted OFL is the calculated total catch determined by the catch levels specified by the STAR panel GMT representative (i.e., 2019-2028 catches set to average historical, 2005-2014, catch level). Total catch in 2017 and 2018 were set to the average over the most recent two years (2015 – 2016).

Year	Predicted OFL (mt)	ABC Catch (mt)	Age 0+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2017	109.1	28.6	1773	295.51	0.686
2018	110.1	28.6	1801	294.04	0.682
2019	112.3	27.4	1824	300.59	0.697
2020	115.1	27.4	1842	309.95	0.719
2021	117.5	27.4	1857	317.07	0.736
2022	119.3	27.4	1869	322.07	0.747
2023	120.6	27.4	1879	325.87	0.756
2024	121.6	27.4	1887	328.89	0.763
2025	122.3	27.4	1895	331.35	0.769
2026	122.9	27.4	1901	333.41	0.774
2027	123.5	27.4	1907	335.19	0.778
2028	123.9	27.4	1912	336.75	0.781

Note: projection assumes a category 2 assessment as a result of assessing a complex, with a P=0.45 and sigma = 0.72 with a multiplier of 0.9135 applied to the OFL.*

Table ES18. Decision table summarizing 12-year projections (2017 – 2028) for Oregon BDR according to three alternative states of nature based on equilibrium unfished recruitment. Columns range over low, medium, 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 2017 and 2018 are allocated to each fleet based on the percentage of landing for each fleet averaged over the period 2015-2016.

			State of nature					
			Low		Base case		High	
			$\ln(R_0) = 6.453$		$\ln(R_0) = 7.047$		$\ln(R_0) = 7.641$	
Relative probability of states of nature:			0.25		0.5		0.25	
Management decision	Year	Catch (mt)	Spawning Biomass (mt)	Depletion	Spawning Biomass (mt)	Depletion	Spawning Biomass (mt)	Depletion
	2017	28.6	117	0.49	298	0.69	636	0.80
	2018	28.6	115	0.48	297	0.68	633	0.80
	2019	41.7	116	0.49	303	0.70	645	0.82
Catches from low SSB, Default Harvest Control Rule (40-10)	2020	41.4	115	0.48	309	0.71	657	0.83
	2021	41.2	114	0.48	312	0.72	665	0.84
	2022	41.0	113	0.47	314	0.72	669	0.85
	2023	40.9	112	0.47	315	0.73	672	0.85
	2024	40.9	112	0.47	315	0.73	673	0.85
	2025	40.9	112	0.47	316	0.73	674	0.85
	2026	41.0	112	0.47	316	0.73	674	0.85
	2027	41.1	112	0.47	315	0.73	674	0.85
	2028	41.1	112	0.47	315	0.73	674	0.85
	2017	28.6	117	0.49	296	0.69	636	0.80
	2018	28.6	115	0.48	294	0.68	633	0.80
	2019	103.0	116	0.49	301	0.70	645	0.82
Catches from median (base case) SSB, Default Harvest Control Rule (40-10)	2020	99.8	100	0.42	290	0.67	640	0.81
	2021	96.9	86	0.36	279	0.65	633	0.80
	2022	94.1	74	0.31	268	0.62	624	0.79
	2023	91.4	64	0.27	258	0.60	615	0.78
	2024	89.1	57	0.24	250	0.58	608	0.77
	2025	87.1	52	0.22	242	0.56	601	0.76
	2026	85.5	48	0.20	237	0.55	595	0.75
	2027	84.1	44	0.19	232	0.54	590	0.75
	2028	82.9	41	0.17	228	0.53	586	0.74
	2017	28.6	117	0.49	298	0.69	636	0.80
	2018	28.6	115	0.48	297	0.68	633	0.80
	2019	214.6	116	0.49	303	0.70	645	0.82
Catches from high SSB, Default Harvest Control Rule (40-10)	2020	204.8	73	0.31	263	0.61	610	0.77
	2021	196.0	42	0.17	227	0.52	576	0.73
	2022	187.7	21	0.09	196	0.45	545	0.69
	2023	180.4	10	0.04	170	0.39	518	0.65
	2024	174.1	4	0.02	149	0.34	494	0.62
	2025	168.8	1	0.01	133	0.31	475	0.60
	2026	164.5	0	0.00	120	0.28	460	0.58
	2027	160.9	0	0.00	109	0.25	447	0.57
	2028	157.9	0	0.00	101	0.23	437	0.55
	2017	28.6	117	0.49	296	0.69	636	0.80
	2018	28.6	115	0.48	294	0.68	633	0.80
	2019	27.4	116	0.49	301	0.70	645	0.82
	2020	27.4	119	0.50	310	0.72	661	0.84
Constant Catch, average catch from 2005-2014	2021	27.4	121	0.51	317	0.74	673	0.85
	2022	27.4	123	0.52	322	0.75	680	0.86
	2023	27.4	125	0.52	326	0.76	685	0.87
	2024	27.4	127	0.53	329	0.76	690	0.87
	2025	27.4	129	0.54	331	0.77	693	0.88
	2026	27.4	131	0.55	333	0.77	695	0.88
	2027	27.4	133	0.56	335	0.78	697	0.88
	2028	27.4	135	0.57	337	0.78	699	0.88

Research and data needs

There are several areas for further research that were identified while conducting this assessment that could result in information useful to future Blue and/or Deacon Rockfish assessments. The list below is believed to represent strategic pieces of information that would likely help to resolve key uncertainties associated with assessing BDR. Many would provide the necessary information to evaluate basic life history parameters and spatiotemporal population and fleet dynamics.

1. Nearshore survey. A fisheries-independent nearshore survey should be supported to improve estimates of abundance trends (not having to rely on fisheries data for such trends) and, if possible, absolute abundance. Population scale has proven difficult to estimate for many nearshore species without informative data.

2. Collection of gender- and species-specific data. Gender- and species-specific information from the recreational fishery should be collected for BDR given differences in growth and natural mortality by gender and the importance of this fishery to overall catches. This information should continue to be collected for commercial fisheries. For California, collection of age data (particularly from the recreational fishery) is a priority for stock assessment of BDR and other species important to recreational fisheries.

3. A study of the stock structure of Blue and Deacon Rockfish. Stock structure for Blue Rockfish and Deacon Rockfish needs further study and the results accounted for in future assessments. In particular, ontogenetic and gender-related movement according to offshore depth and spawning seems plausible, and data to inform tests of that hypothesis would be beneficial for future assessments given the lack of larger/older males in the fisheries data. Given that the vast majority of catches for BDR are in the nearshore waters, the intersection of seasonal movements to offshore habitat coupled with fleet dynamics could play an important role determining vulnerability. Alternative sub-stock boundaries, those that do not lie on political borders, should also be explored.

4. Further analyses on natural mortality values for females and males. This will help resolve the extent to which gender-based selectivity (e.g., dome-shaped or relative male-to-female scales) may be occurring, and whether natural mortality and such complex selectivity patterns can be estimated (and when they cannot).

5. Historical catch reconstructions for recreational fleets in Oregon. Ocean-boat landings comprise the vast majority of landings for BDR, but there has been no rigorous attempt at a catch reconstruction beyond linking catch to license sales (as was done for this assessment).

6. Accurate accounting of removals for recreational shore fleet (estuary-boat and shore fishing modes). Fisheries exploited by the recreational sector are traditionally hard to monitor. Since 2005, there has been no comprehensive information collected about catch or effort or biological information from estuary-boat and shore fishing modes. Although these modes do not represent major fisheries for BDR in terms of landed catch, they do tend to catch smaller individuals. Biological data on smaller individual is a data-gap for this and many other nearshore rockfish species.

7. Calibration and validation of BDR ages. Formal ageing criteria for BDR should be developed and standardized and ages validated.

Table ES19. Summary of base case model results for BDR in California waters.

Quantity	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total landings (mt)	289.46	302.92	148.31	102.21	45.73	55.42	65.62	55.30	108.89	119.65	164.82	130.18	
Total removals (mt)	303.89	318.10	157.79	117.06	50.22	58.92	70.39	59.63	114.04	124.91	172.58	136.26	
(1-SPR) / (1-$SPR_{50\%}$)	1.42	1.46	1.13	0.95	0.52	0.55	0.58	0.47	0.70	0.70	0.82	0.67	NA
Exploitation rate	0.09	0.10	0.05	0.03	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.02	NA
Age 0+ biomass (mt)	3,273	3,287	3,326	3,457	3,810	4,312	4,789	5,149	5,490	5,725	6,093	6,421	6654
Spawning Output	383	362	340	351	375	416	459	509	573	638	703	757	812
~95% CI	85–682	47–678	5–675	0–712	0–768	0–846	0–930	0–1028	0–1152	0–1285	0–1421	0–1542	0–1661
Recruitment (1000s)	1,623	1,364	7,249	5,571	5,568	2,362	2,722	2,269	8,510	3,791	3,410	3,376	3,707
~95% CI	567–4644	462–4028	2601–20201	1949–15926	1896–16351	759–7349	895–8285	719–7159	2875–25190	1275–11269	1163–9997	1170–9739	1222–11248
Depletion (%)	17.60	16.60	15.60	16.10	17.20	19.10	21.10	23.40	26.30	29.30	32.30	34.70	37.30
~95% CI	2.8–32.4	1.1–32.2	0–32.0	0–33.7	0–36.3	0–40.0	0–44.0	0–48.7	0–54.5	0–60.8	0–67.3	0–73.0	0–78.5

Table ES20. Summary of base case model results for BDR in Oregon waters.

Quantity	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total landings (mt)	38.44	17.26	21.49	18.96	19.21	26.30	28.12	33.06	29.33	23.21	30.68	23.15	
Total removals (mt)	40.48	18.71	23.10	20.31	20.86	28.08	30.51	35.46	31.38	24.81	32.74	24.37	
(1-SPR)/(1-$SPR_{50\%}$)	0.43	0.23	0.29	0.26	0.27	0.36	0.39	0.45	0.41	0.34	0.44	0.35	NA
Exploitation rate	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.01	NA
Age 0+ biomass (mt)	1,898	1,856	1,841	1,799	1,770	1,758	1,726	1,711	1,677	1,654	1,702	1,737	1773
Spawning Output	386	370	358	344	337	334	330	322	312	307	304	299	296
~95% CI	107–665	98–643	94–621	89–600	86–587	85–583	82–578	78–566	72–553	69–545	68–540	65–533	64–527
Recruitment (1,000s)	1,039	369	959	1,290	591	1,211	654	738	2,233	1,054	960	1,095	1,093
~95% CI	525–2,057	172–792	483–1,903	651–2,553	271–1,290	572–2,564	280–1,528	304–1,797	942–5,292	387–2,871	339–2,718	618–1,939	617–1,937
Depletion (%)	89.60	86.00	83.00	79.80	78.10	77.60	76.50	74.60	72.50	71.20	70.50	69.30	68.60
~95% CI	72.3–106.9	68.5–103.4	66.0–99.9	63.3–96.4	61.9–94.4	61.4–93.7	60.3–92.7	58.4–90.9	56.1–88.9	54.7–87.7	54.2–86.8	52.8–85.8	52.2–84.9