The Status of Black Rockfish (*Sebastes melanops*) in U.S. Waters off California in 2023

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Cover photo credit:
Photo of Black Rockfish was downloaded from the RecFIN website and taken by Vicky Okimura (WDFW).

Acronym Definitions:
ABC: Acceptable Biological Catch
ACL: Annual Catch Limit
CAAL: Conditional age-at-length
CalCOFI: California Cooperative Oceanic Fisheries Investigations
CALCOM: California Cooperative Groundfish Survey Database
CCFRP: California Collaborative Fisheries Research Program
CDFW (formerly CDFG): California Department of Fish and Wildlife (formerly Fish and Game)
CPAH: Catch-per-angler-hour
CPFV: Commercial Passenger Fishing Vessel (aka "party" or "charter" boats, or "PC mode")
CPUE: Catch-per-unit-effort
CRFS: California Recreational Fisheries Survey
GMT: Groundfish Management Team of the PFMC
MRFSS: Marine Recreational Fisheries Statistics Survey
MSY: Maximum Sustainable Yield
NMFS: National Marine Fisheries Service
NWFSC: Northwest Fisheries Science Center
ODFW: Oregon Department of Fish and Wildlife
OFL: Overfishing Limit
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
RREAS: The NMFS SWFSC's Rockfish Recruitment and Ecosystem Assessment Survey
SPR: Spawning Potential Ratio
SSC: Scientific and Statistical Committee of the PFMC
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

Executive Summary

Stock

This assessment reports the status of the black rockfish (*Sebastes melanops*) in U.S. waters off the coast of California. The stock dynamics are modeled with two independent assessments to approximate spatial and temporal variation in size composition, exploitation history, recruitment, and other factors affecting stock dynamics. The northern California model represents the portion of the stock in U.S. waters from Point Arena (38° 57.5´ North latitude) to the California-Oregon border (42° N. lat.), and the central California model includes U.S. waters off from Point Arena to the U.S./Mexico border. Recent genetic analyses and tagging studies provide seemingly contradictory evidence about barriers to gene flow in waters off California (see “Research and data needs” section, below). Future assessments could consider alternative model structures (e.g. multi-area models) if sufficient data become available to parameterize adult movement and/or larval dispersal.

Catches

Over the past decade, black rockfish off California have been caught primarily by the recreational fishery, both north and south of Point Arena, although commercial landings are a significant fraction of total mortality in the northern part of the state (Table ES1). The private/rental boat fleet has accounted for the majority of recreational landings, and hook and line gear types account for the majority of recent commercial landings. Only a small fraction of commercial catches were landed in the central region over the past decade, although historical catch estimates suggest that the commercial fishery developed earlier in the central region (Figure ES1). Commercial landings recorded as live fish have been of similar magnitude to dead fish landings in recent years. A peak in estimated landings in the central region around 2013 was driven by increased catch rates observed in both fishery-dependent and fishery-independent data sources (see also the Recruitment section, below). Landings in the north peaked in response to wartime demand in the 1940s, and peaked again in the late 1970s to early 1990s, with annual removals typically in the range of 100-200 mt since the year 2000 (Figure ES2).

Table ES1. Estimated commercial and recreational mortality (mt) of California black rockfish by region and year.

Year	Commercial North	Recreational North	Commercial Central	Recreational Central	Grand Total
2013	30.7	142.6	5.1	220.3	398.7
2014	37.5	180.5	3.9	101.8	323.7
2015	100.1	159.5	4.5	65.8	329.9
2016	62.8	103.6	2.0	61.5	229.8
2017	55.4	74.3	1.0	23.6	154.3
2018	45.0	75.3	1.1	20.4	141.8
2019	49.3	91.3	0.7	18.9	160.2
2020	41.2	74.4	1.2	28.6	145.4
2021	38.1	162.1	1.3	37.1	238.6
2022	56.0	180.5	1.2	31.7	269.4

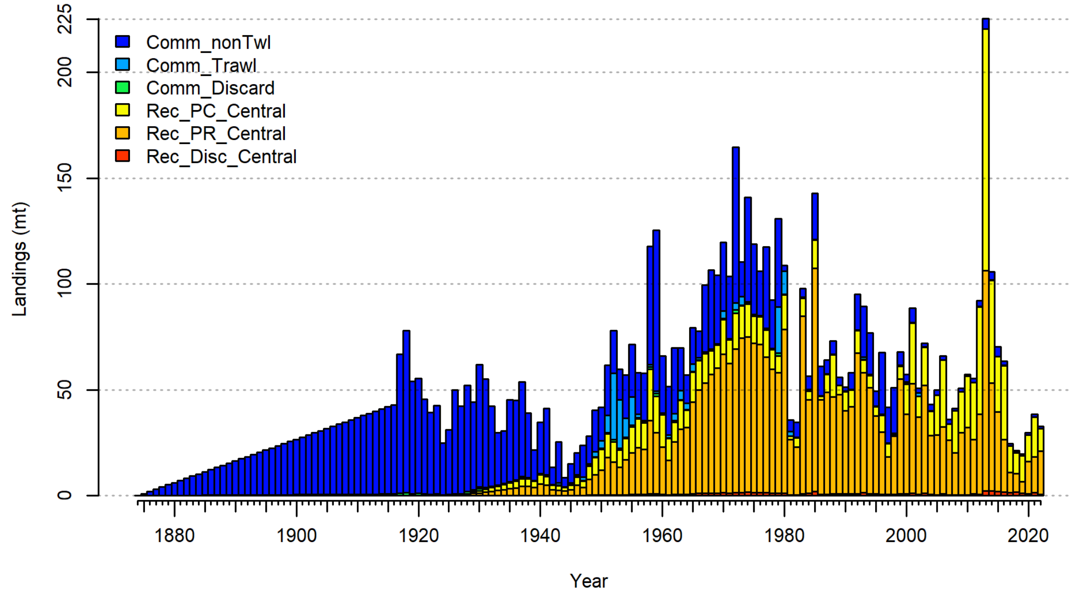

Figure ES1. Estimated landings (mt) of black rockfish in central California, 1875-2022, by fleet. Discarded dead catch is modeled as separate fleets, one commercial and one recreational, to account for differences in size composition between discarded and retained catch.

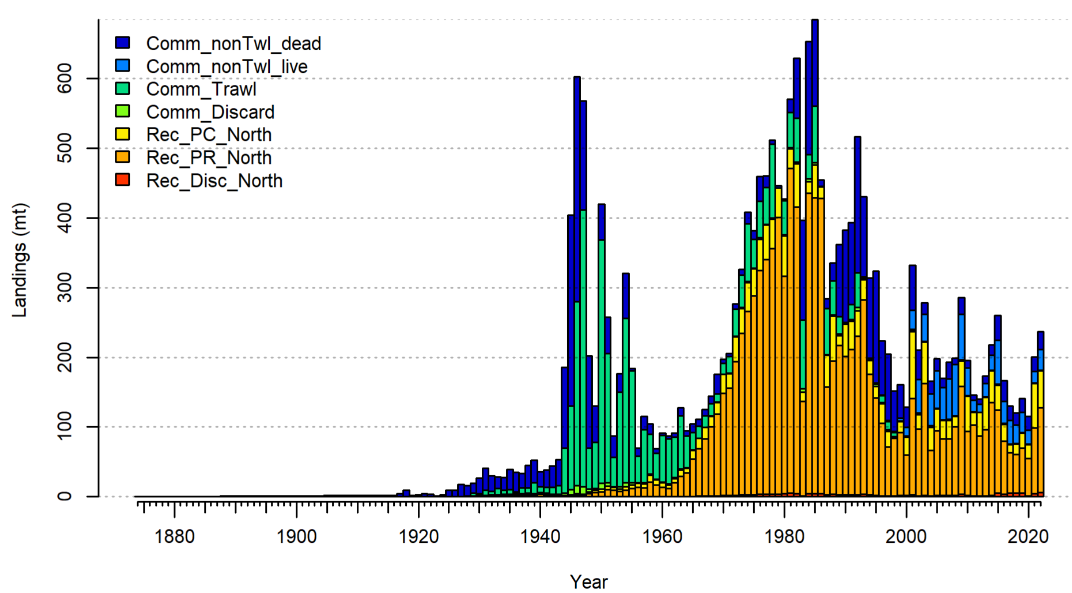

Figure ES2. Estimated landings (mt) of black rockfish in northern California, 1875-2022, by fleet. Discarded dead catch is modeled as separate fleets, one commercial and one recreational, to account for differences in size composition between discarded and retained catch. Note the difference in scale relative to landings in the central region.

Data and assessment

Northern California Model

The assessment is structured as a single, sex-disaggregated population model, spanning U.S. waters from Point Arena to the California-Oregon border. The model operates on an annual time step covering the period 1875 to 2022 (not including forecast years) and assumes an unfished equilibrium population prior to 1875. Population dynamics are modeled for ages 0 through 50, with age-50 being the accumulator age. The maximum observed age was 33 for males and 35 for females. Population bins were set every 1 cm from 5 to 70 cm, and data bins were set every 2 cm from 8 to 60 cm. The model is conditioned on catch from two sectors (commercial and recreational) divided among seven fleets, and is informed by three time series of relative abundance (one fishery-independent survey, one CPUE index from a shore-based recreational sampling program, and one CPUE index from an onboard CPFV observer program). Size and age composition data include lengths from 1978-2022 and ages from 1980-2022, with intermittent gaps in each data type. Recruitment is assumed to be related to spawning output via the Beverton-Holt stock recruitment relationship with log-normally distributed, bias corrected process error. Growth was modeled across a range of ages from 0 through 50. All catch was assumed to be known with high precision (log-scale standard error of 0.05).

Fleets were specified for recreational and commercial sectors. While the previous assessment combined all recreational fishing modes and catch types (retained or discarded) into a single fleet, we split the recreational sector into two main fleets according to fishing type (CPFV or private boat) and catch type (retained or discarded). All recreational shore modes were combined with the private boat fleet due to their small contribution to overall catch. Discarded catch (CPFV and private boats combined) was modeled as separate fleet due to differences in size composition relative to retained catch, and a lack of sufficient data in an appropriate format to explicitly model retention. The commercial sector was represented by four fleets. Two “non-trawl” fleets representing primarily hook-and-line and longline gear types, but including other minor gears, were differentiated by the condition of landed fish (landed dead or alive), as fish in each group often have different size compositions. Other commercial fleets include a trawl fleet, and a fleet for discarded catch which represents the aggregated, dead discards from all commercial fleets. Fleet selectivity was assumed to be asymptotic for all retained commercial fleets, and dome-shaped for the recreational and commercial discard fleets. Sensitivity to these selectivity assumptions were explored during model development and relative to the base model.

Central California Model

The model for the central region is very similar in structure to the northern model. Black rockfish are rare south of Point Conception, so data informing the central California model are primarily from the region between Point Conception (34° 27′ North latitude) and Point Arena. All catches south of Point Arena are included in the model, so results reflect the area spanning U.S. waters from the US/Mexico border to Point Arena. Model dimensions for year, age bins, and length bins are identical to the northern model. The central model is conditioned on catch from two sectors (commercial and recreational) divided among six fleets, and is informed by four time series of relative abundance (one fishery-independent survey, one CPUE index from a shore-based recreational sampling program, and two CPUE indices from onboard CPFV observer programs operating over different time periods). Size and age composition data include lengths from 1959-2022 and ages from 1980-2022, with intermittent gaps in each data type. Recruitment is assumed to be related to spawning output via the Beverton-Holt stock recruitment relationship with log-normally distributed, bias corrected process error. Growth was modeled across a range of ages from 0 through 50. All catch was assumed to be known with high precision (log-scale standard error of 0.05).

Fleets were identical to the northern model, except that the commercial sector was represented by three fleets rather than four. A single “non-trawl” fleets representing primarily hook-and-line and longline gear types, but including other minor gears, included both ‘live’ and ‘dead’ conditions, as samples of live fish were too small to warrant a separate fleet. Other commercial fleets include a trawl fleet, and a fleet for discarded catch which represented discarded dead catch from both non-trawl and trawl fleets. Fleet selectivity was allowed to be domed for all commercial fleets. Sensitivity to these selectivity assumptions were explored during model development and relative to the base model.

Stock biomass and dynamics

The last assessment of black rockfish in California estimated spawning output to be at 33% of unfished levels in 2015 (Cope et al., 2016). The two models in the current assessment estimate 2023 spawning output to be 410 billion eggs (~95% asymptotic interval: 175-645) in the northern area and 136 billion eggs (~95% asymptotic interval: 35-238) in the central area (Tables ES2 and ES3). Statewide, this suggests the stock is near target biomass, at roughly 38% of unfished spawning output, in 2023 (Table ES4). The ratio of estimated spawning output in a particular year relative to estimated unfished, equilibrium spawning output is sometimes referred to as “depletion” or the “fraction unfished.” In northern California, estimates of spawning output declined rapidly in the 1940s due to wartime demand, recovered briefly, and then declined from the 1970s to late 1990s (Figure ES3). Declines in spawning output began earlier in central California but have been more gradual. Models for both areas estimate consistent increases in spawning output since the late 2000s.

Combining spawning output estimates from both areas, time series for the California stock primarily reflect patterns in the northern model, as the majority of spawning output comes from this area, but declines prior to the 1940s in the central area also become apparent (Figure ES4). Relative to unfished levels, the combined spawning output for the California stock is estimated to have declined below the minimum stock size threshold (25% of unfished spawning output) from 1978-2009 (Figure ES5). However, estimated trends in statewide spawning output have shown a consistent increase since the late 1990s and are currently near target levels.

Table ES2. Recent trends in spawning output (billions of eggs) from the northern area base model. Uncertainty intervals are 95% asymptotic estimates.

Year	Spawning Output	Interval	Fraction Unfished	Interval
2013	339	142 - 536	0.301	0.13 - 0.47
2014	352	149 - 556	0.313	0.13 - 0.49
2015	366	154 - 579	0.325	0.14 - 0.51
2016	375	153 - 597	0.333	0.14 - 0.53
2017	393	162 - 624	0.349	0.15 - 0.55
2018	411	174 - 648	0.365	0.16 - 0.57
2019	423	183 - 663	0.376	0.17 - 0.59
2020	427	187 - 667	0.379	0.17 - 0.59
2021	431	193 - 670	0.383	0.18 - 0.59
2022	423	186 - 659	0.376	0.17 - 0.58
2023	410	175 - 645	0.364	0.16 - 0.57

Table ES3. Recent trends in spawning output (billions of eggs) from the central area base model. Uncertainty intervals are 95% asymptotic estimates.

Year	Spawning Output	Interval	Fraction Unfished	Interval
2013	63	10 - 115	0.193	0.04 - 0.34
2014	63	8 - 118	0.194	0.04 - 0.35
2015	70	9 - 131	0.215	0.04 - 0.39
2016	81	11 - 151	0.249	0.05 - 0.45
2017	93	13 - 173	0.287	0.06 - 0.51
2018	107	18 - 195	0.329	0.08 - 0.58
2019	118	23 - 213	0.364	0.1 - 0.63
2020	126	27 - 226	0.390	0.11 - 0.67
2021	131	30 - 232	0.404	0.12 - 0.69
2022	134	32 - 235	0.412	0.13 - 0.69
2023	136	35 - 238	0.421	0.14 - 0.7

Table ES4. Recent trends in statewide spawning output (billions of eggs) derived from the northern and central area base models.

Year	Spawning Output	Fraction Unfished
2013	401	0.277
2014	415	0.286
2015	436	0.301
2016	456	0.315
2017	486	0.335
2018	518	0.357
2019	542	0.373
2020	554	0.382
2021	562	0.388
2022	557	0.384
2023	547	0.377

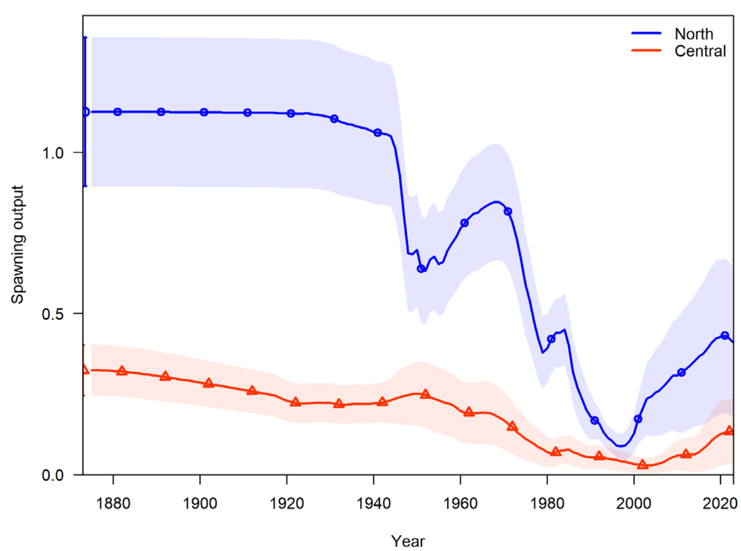

Figure ES3. Estimated spawning output (trillions of eggs) time series for the northern and central area models. Shaded areas represent 95% asymptotic confidence intervals.

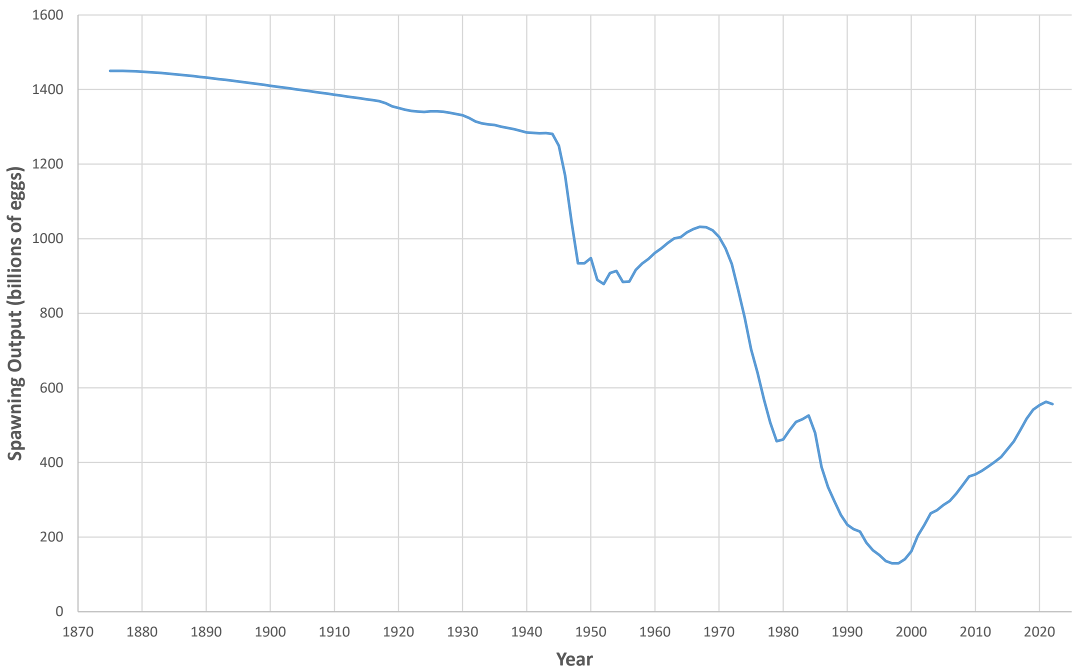

Figure ES4. Combined spawning output (billions of eggs) for the California stock of black rockfish, 1875-2023.

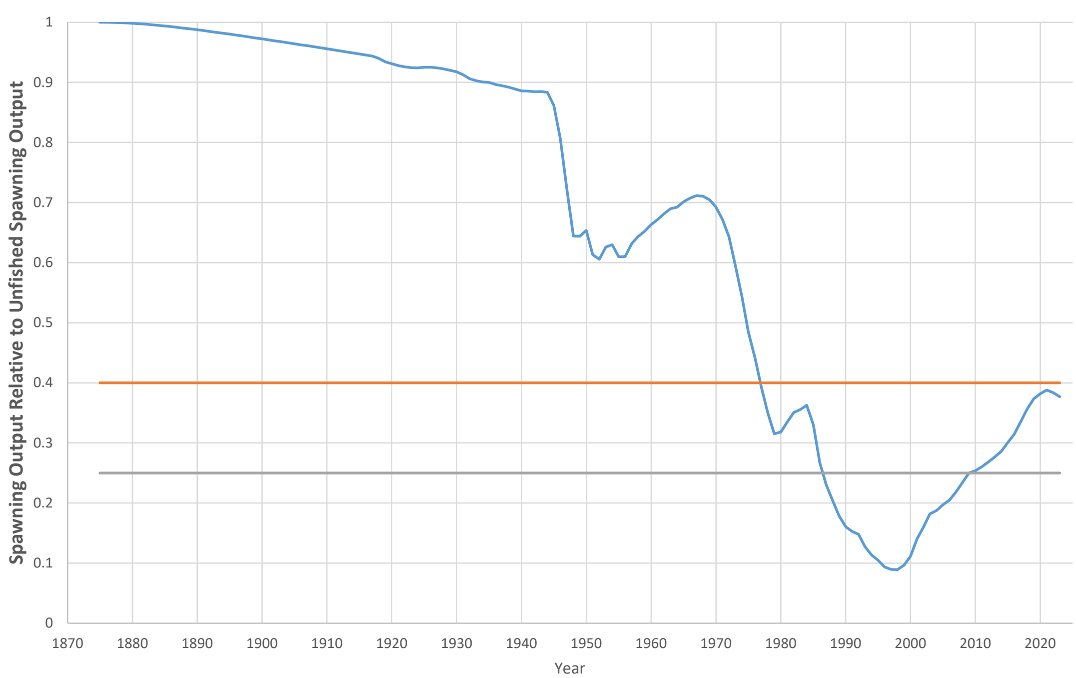

Figure ES5. Spawning output relative to unfished spawning output for the California stock of black rockfish, 1875-2023. The target level of spawning output (40% of unfished) and minimum stock size threshold (25% of unfished) are shown as horizontal lines for reference.

Recruitment

Recruitment patterns in the two sub-area models show a weak but significant correlation (see responses to STAR panel requests). Strong estimated recruitments in 2008 and 2010 in the central area model were positive, but weak in the northern model (Figures ES6 and ES7). In the central area, the previously mentioned spike in landings around 2013 was preceded by sudden decreases in mean length, suggesting entry of a large year class into the fishery in that region and these patterns were not observed in the north. Large deviations in the 1970s and mid-1990s were estimated in the northern model, but were estimated closer to mean levels in the central area model. Beverton-Holt steepness is fixed at 0.72 in both models.

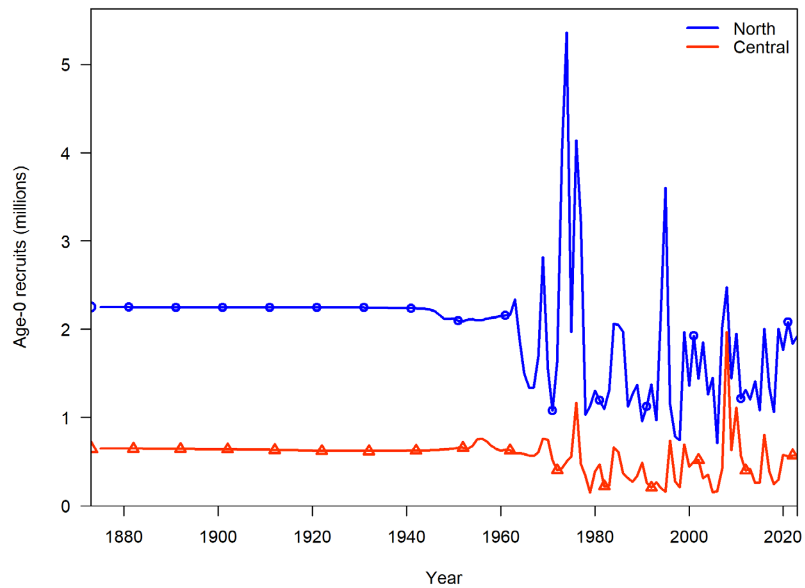

Figure ES6. Time series of estimated recruitment (millions of age-0 fish) in the northern and central area models.

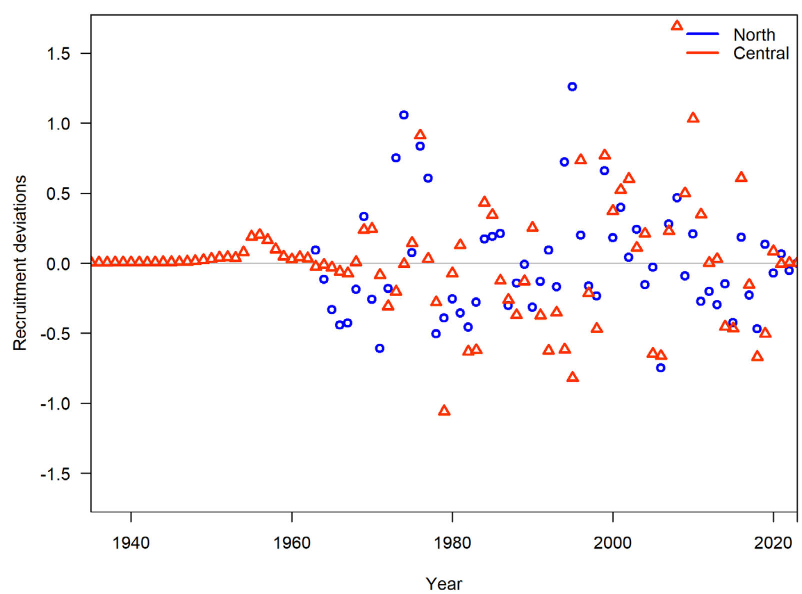

Figure ES7. Comparison of estimated annual recruitment deviations in the northern and central area models.

Exploitation status

Based on the best available historical catch reconstructions, exploitation rates of black rockfish in California increased earlier in the central area (Figure ES8). This is consistent with spatial patterns of population growth and development of infrastructure to support large-scale fisheries in the state. Exploitation rates exceeded target levels in both areas from 1970s through the 1990s. More recent exploitation rates have been variable, but closer to target levels.

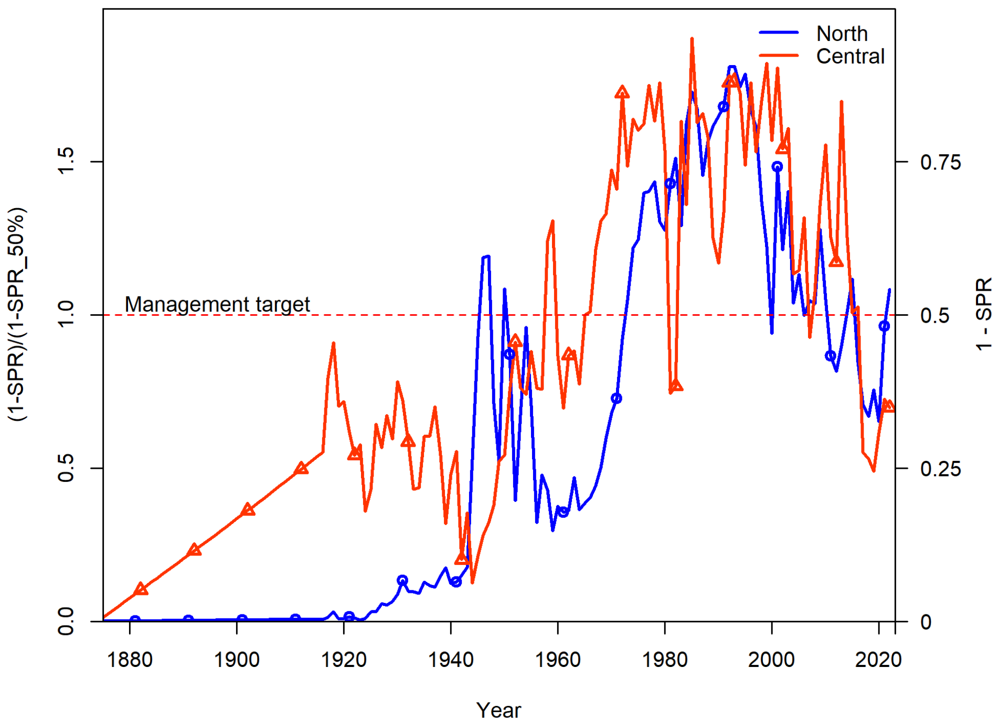

Figure ES8. Fishing intensity (1-SPR) relative to target levels, 1875-2022, by sub-area.

Ecosystem considerations

Ecological information was not explicitly represented in the stock assessment model. This is due to a complicated mechanistic relationship between black rockfish population dynamics and the California Current ecosystem. Some data on predators and prey are available but lack sufficient coverage to inform spatiotemporal dynamics of black rockfish (e.g., natural mortality). A number of studies have investigated potential environmental drivers of black rockfish recruitment (e.g., Caselle et al. 2010; Ralston et al. 2013; Schroeder et al. 2019; Field et al. 2021). Black rockfish have also been identified as a candidate for multispecies indicators of recruitment (along with blue, deacon, darkblotched, widow, and yellowtail rockfishes; Field et al. 2021).

Reference points

Management reference points for the California stock (Table ES5) were derived from the two sub-area models (Tables ES6 and ES7). At the statewide level, stock status is near target (38% of unfished spawning output). Long-term equilibrium yield based on SPR proxy harvest rates is 330 mt statewide, compared to 348 mt based on the SB40% proxy and 382 mt based on the assumed stock-recruitment relationship with steepness fixed at 0.72 in both models.

Unfished spawning output in the northern area is roughly three times larger than the central area, i.e. this assessment estimates that about 75% of statewide spawning output is generated north of Point Arena in the absence of fishing (Tables ES6 and ES7). Current spawning output levels show a similar ratio.

Table ES5. Reference points for the California stock, derived from the sub-area models.

a	Estimate
Unfished Spawning Output (billions of eggs)	1,471
Unfished Age 8+ Biomass (mt)	5,491
Unfished Recruitment (R0, 1000s)	2,900
Spawning Output (2023, billions of eggs)	555
Fraction Unfished (2023)	0.377
Reference Points Based SB40%	
Proxy Spawning Output SB40%	588
Yield with SPR Based On SB40% (mt)	348
Reference Points Based on SPR Proxy for MSY	
Proxy Spawning Output (SPR50)	656
Yield with SPR50 at SB SPR (mt)	330
Reference Points Based on Estimated MSY Values	
Spawning Output at MSY (SB MSY)	361
MSY (mt)	382

Table ES6. Northern model reference points and 95% asymptotic intervals.

Reference Point	Estimate	Interval
Unfished Spawning Output (billions of eggs)	1,126	926 - 1,326
Unfished Age 8+ Biomass (mt)	4,219	3,651 - 4,787
Unfished Recruitment (R0, 1000s)	2,249	1,493 - 3,005
Spawning Output (2023, billions of eggs)	410	175 - 645
Fraction Unfished (2023)	0.36	0.16 - 0.57
Reference Points Based SB40%		
Proxy Spawning Output SB40%	450	370 - 531
SPR Resulting in SB40%	0.458	0.458 - 0.458
Exploitation Rate Resulting in SB40%	0.16	0.131 - 0.190
Yield with SPR Based On SB40% (mt)	280	239 - 321
Reference Points Based on SPR Proxy for MSY		
Proxy Spawning Output (SPR50)	502	413 - 592
SPR50	0.5	-
Exploitation Rate Corresponding to SPR50	0.137	0.112 - 0.162
Yield with SPR50 at SB SPR (mt)	265	227 - 304
Reference Points Based on Estimated MSY Values		
Spawning Output at MSY (SB MSY)	276	223 - 330
SPR MSY	0.319	0.313 - 0.325
Exploitation Rate Corresponding to SPR MSY	0.281	0.220 - 0.342
MSY (mt)	307	261 - 353

Table ES7. Central model reference points and 95% asymptotic intervals.

Reference Point	Estimate	Interval
Unfished Spawning Output (billions of eggs)	345	311 - 379
Unfished Age 8+ Biomass (mt)	1,272	1,125 - 1,419
Unfished Recruitment (R0, 1000s)	651	587 - 715
Spawning Output (2023, billions of eggs)	145	36 - 253
Fraction Unfished (2023)	0.42	0.14 - 0.70
Reference Points Based SB40%		
Proxy Spawning Output SB40%	138	124 - 151
SPR Resulting in SB40%	0.458	0.458 - 0.458
Exploitation Rate Resulting in SB40%	0.135	0.128 - 0.142
Yield with SPR Based On SB40% (mt)	68	62 - 75
Reference Points Based on SPR Proxy for MSY		
Proxy Spawning Output (SPR50)	154	139 - 169
SPR50	0.5	-
Exploitation Rate Corresponding to SPR50	0.115	0.109 - 0.121
Yield with SPR50 at SB SPR (mt)	65	59 - 71
Reference Points Based on Estimated MSY Values		
Spawning Output at MSY (SB MSY)	85	77 - 93
SPR MSY	0.32	0.316 - 0.324
Exploitation Rate Corresponding to SPR MSY	0.241	0.227 - 0.256
MSY (mt)	75	68 - 82

Management performance

Total mortality estimates for the the California stock of black rockfish have not exceeded the ACL since the last assessment (Table ES8).

Table ES8. Evaluation of Management Performance for Black Rockfish. Total Mortality estimates are based on the Groundfish Expanded Mortality Multiyear (GEMM) report. Catch values prior to 2017 are not reported here because black rockfish catch limits were defined across state lines and are not comparable to the California-only estimates used in this assessment. The GEMM report estimate for 2022 was not yet released when this assessment was prepared.

Year	Assessed Area	OFL (mt)	ABC (mt)	ACL (mt)	Total Mortality (mt)
2013	OR - CA	1159	1108	1000	--
2014	OR - CA	1166	1115	1000	--
2015	OR - CA	1176	1124	1000	--
2016	OR - CA	1183	1131	1000	--
2017	CA	349	334	334	171
2018	CA	347	332	332	142
2019	CA	344	329	329	159
2020	CA	341	326	326	117
2021	CA	379	348	348	236
2022	CA	373	341	341	--

Unresolved problems and major uncertainties

- There is conflicting evidence and limited information with which to evaluate black rockfish stock structure, especially off California.
- Productivity of the stock is poorly understood. The current models assume a value of 0.72 for the Beverton-Holt steepness parameter. Additional age data are needed, particularly for the central region, to better inform estimates of natural mortality.
- Much of what we know about the habitat associations and ecological role of black rockfish come from Oregon, Washington, and Alaska.
- Attempts to investigate recruitment indices (RREAS, SWFSC SCUBA) for the fleets-as-areas model configuration were not successful, and there was not enough time to evaluate area-specific indices prior to the STAR panel document deadline (although they have been developed).
- In the northern assessment, the fishery-independent abundance indices are of short duration and insufficient precision to provide much information on recent trends in abundance. Thus, the indices such as CCFRP need to mature to provide better catchability estimates as the abundance in the northern area increases.
- Further research is needed to explain skewed sex ratios among older individuals in the population.

Decision table and projections

Alternative states of nature identified during the STAR panel were used to forecast population dynamics for the California stock assuming low, medium, and high catch projections (Table ES9). Catch projections for 2023-2024 and fleet allocations for 2025-2034 were provided for each area and fleet by state representatives on the GMT. Harvest control rules were applied iteratively, at the state level, based on output from both models. An allocation of the ACL based on the proportion of the OFL from each area was requested by the GMT, and is provided as Table ES10.

Table ES9. 12-year projections (2023 – 2034) for California black rockfish (statewide) according to three alternative states of nature based on the annual rate of natural mortality. Columns represent low, medium (base case), and high states of nature, and rows range over different assumed catch levels corresponding to the forecast catches from each state of nature. Spawning output units are billions of eggs. Catches in 2023-2024 assume full attainment of the ACL as forecast by the 2015 assessment.

P* = 0.45, sigma = 0.5			**State of nature**					
			Low		**Base case**		**High**	
			Female M = 0.147		Female M = 0.210		Female M = 0.300	
Management decision	Year	Catch (mt)	Spawning Output	Fraction Unfished	Spawning Output	Fraction Unfished	Spawning Output	Fraction Unfished
Low Catch	2023	334	494	0.222	547	0.377	872	0.736
	2024	329	477	0.215	530	0.365	847	0.716
	2025	86	457	0.205	513	0.354	824	0.696
	2026	96	471	0.212	532	0.367	837	0.707
	2027	109	487	0.219	558	0.384	858	0.725
	2028	122	506	0.227	590	0.407	885	0.748
	2029	135	528	0.237	627	0.432	912	0.770
	2030	148	555	0.249	664	0.458	933	0.788
	2031	160	586	0.263	700	0.483	948	0.801
	2032	171	618	0.278	731	0.504	957	0.808
	2033	181	651	0.293	758	0.523	960	0.811
	2034	189	683	0.307	781	0.539	960	0.811
Base Catch	2023	334	494	0.222	547	0.377	872	0.736
	2024	329	477	0.215	530	0.365	847	0.716
	2025	224	457	0.205	513	0.354	824	0.696
	2026	236	447	0.201	511	0.353	819	0.692
	2027	249	437	0.196	516	0.356	822	0.694
	2028	261	428	0.192	526	0.363	832	0.702
	2029	270	421	0.189	539	0.372	841	0.711
	2030	277	420	0.189	554	0.382	848	0.716
	2031	282	423	0.190	569	0.392	851	0.719
	2032	285	428	0.193	583	0.402	850	0.718
	2033	286	436	0.196	595	0.410	848	0.716
	2034	287	443	0.199	606	0.418	844	0.713
High Catch	2023	334	494	0.222	547	0.377	872	0.736
	2024	329	477	0.215	530	0.365	847	0.716
	2025	580	457	0.205	513	0.354	824	0.696
	2026	566	384	0.173	458	0.316	771	0.652
	2027	555	313	0.141	412	0.284	732	0.618
	2028	543	249	0.112	374	0.258	704	0.594
	2029	529	204	0.092	344	0.237	682	0.576
	2030	518	181	0.081	321	0.221	664	0.561
	2031	507	174	0.078	303	0.209	649	0.548
	2032	498	172	0.077	290	0.200	637	0.538
	2033	491	173	0.078	278	0.192	627	0.530
	2034	485	174	0.078	268	0.185	619	0.523

Table ES10. Base model estimates of the OFL (mt), ABC (mt), ACL (mt), buffer, spawning output in billions of eggs across California, and relative spawning output by year along with the sub-area allocations of the ACL for the northern and central regions. Buffers are based on the default category 1 uncertainty level (sigma=0.5) and a P-star of 0.45.

Year	OFL (mt)	ABC (mt)	ACL (mt)	Buffer	Spawning Output	Fraction Unfished	Sub-ACL North	Sub-ACL Central
2025	250.1	233.8	223.6	0.935	513.0	0.354	182.0	41.6
2026	265.3	246.8	235.7	0.93	511.5	0.353	190.3	45.5
2027	280.6	259.9	249.1	0.926	516.0	0.356	199.4	49.7
2028	293.2	270.3	261.0	0.922	526.0	0.363	208.1	53.0
2029	302.2	277.1	270.2	0.917	539.4	0.372	215.2	55.0
2030	308.4	281.6	277.2	0.913	554.2	0.382	221.1	56.1
2031	312.6	284.2	282.3	0.909	569.0	0.392	225.6	56.7
2032	315.6	285.3	285.3	0.904	582.8	0.402	228.4	56.9
2033	318.1	286.3	286.3	0.9	595.1	0.410	229.5	56.8
2034	320.5	287.2	287.2	0.896	606.1	0.418	230.5	56.7

Research and data needs

1. There is conflicting evidence and limited information with which to evaluate black rockfish stock structure, especially off California. Future research on larval dispersal, life history traits, adult movement, and genetics south of the California-Oregon border would improve inputs for stock assessments and provide support for the spatiotemporal scale that is most appropriate for modeling black rockfish. Specifically, information about growth, maturity, and mortality north and south of Point Arena would further justify the separation of black rockfish at this location. Further genetic evaluation regarding the extent to which Point Arena may serve as a barrier to gene flow would also be valuable for this stock.
2. Specific estimates of larval dispersal and movement rates at various life stages would further our understanding about connectivity among the three West Coast stocks of black rockfish. Although most black rockfish show moderate to high site fidelity and some degree of homing, a notable proportion of fish appear to cross stock boundaries. Additional research on the directions and distances that black rockfish move in northern California and southern Oregon would help elucidate the degree of intergenerational exchange across this particular stock boundary.
3. Finally, much of what we know about the habitat associations and ecological role of black rockfish come from Oregon, Washington, and Alaska. Research that is specific to central and northern California is needed to fully understand variation in black rockfish life history, population structure, and trophic positioning.
4. Exploration of multiple-area models for the stock is recommended when sufficient data are available to parameterize movement within the model. Directional movement between areas (south to north, as observed in the CCFRP movement data) may partially explain sustained differences in size and age composition throughout the state.
5. Attempts to investigate recruitment indices (RREAS, SWFSC SCUBA) for the fleets-as-areas model configuration were not successful, and there was not enough time to evaluate area-specific indices prior to the STAR panel document deadline (although they have been developed). Future assessments may benefit from an analysis of these recruitment indices representing sub-areas defined in this assessment.
6. Further research is also needed to explain skewed sex ratios among older individuals in the population. This assessment assumes that size-dependent selectivity is equal for both sexes, and does not consider alternative hypotheses such as sex- or age-specific selectivity or age-dependent natural mortality, both of which could also explain, in whole or in part, the reduced fraction of older females in the data.