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Status of the darkblotched rockfish resource off the continental U.S. Pacific Coast in 2015

by

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Executive Summary

Stock

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

Catches

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

Catch of darkblotched rockfish first became significant in the mid-1940s when balloon trawl nets (efficient in taking rockfish) were introduced, and due to increased demand during World War II. The largest removals of the species occurred in the 1960s, when foreign trawl fleets from the former Soviet Union, Japan, Poland, Bulgaria and East Germany came to the Northeast Pacific Ocean to target large aggregations of Pacific ocean perch, a species that co-occurs with darkblotched rockfish. In 1966 the removals of darkblotched rockfish reached 4,220 metric tons. By the late-1960s, the foreign fleet had more or less abandoned the fishery. Shoreside landings of darkblotched rockfish rose again between the late-1970s and the late-1980s, peaking in 1987 with landings of 2,415 metric tons. In 2000, the species was declared overfished, and landings substantially decreased due to management regulations. During the last decade the average landings of darkblotched rockfish made by the shoreside fishery was around 120 metric tons. Since the mid-1970s, a small amount of darkblotched rockfish has been also taken as bycatch in the at-sea Pacific hake fishery, with a maximum annual removal of 49 metric tons that occurred in 1995.

In this assessment, removals are divided between three fleets, which include the shoreside commercial fishery (that included removals by all gear types), bycatch removals in foreign Pacific ocean perch and bycatch removals in at-sea Pacific hake fisheries. Reconstructed removals of darkblotched rockfish bycatch in the Pacific ocean perch and at-sea hake fisheries represent total catch that includes both retained and discarded catch. Discards in the shoreside fishery were explicitly modeled in the assessment; total catches were estimated simultaneously with other model parameters and derived quantities of management interest.

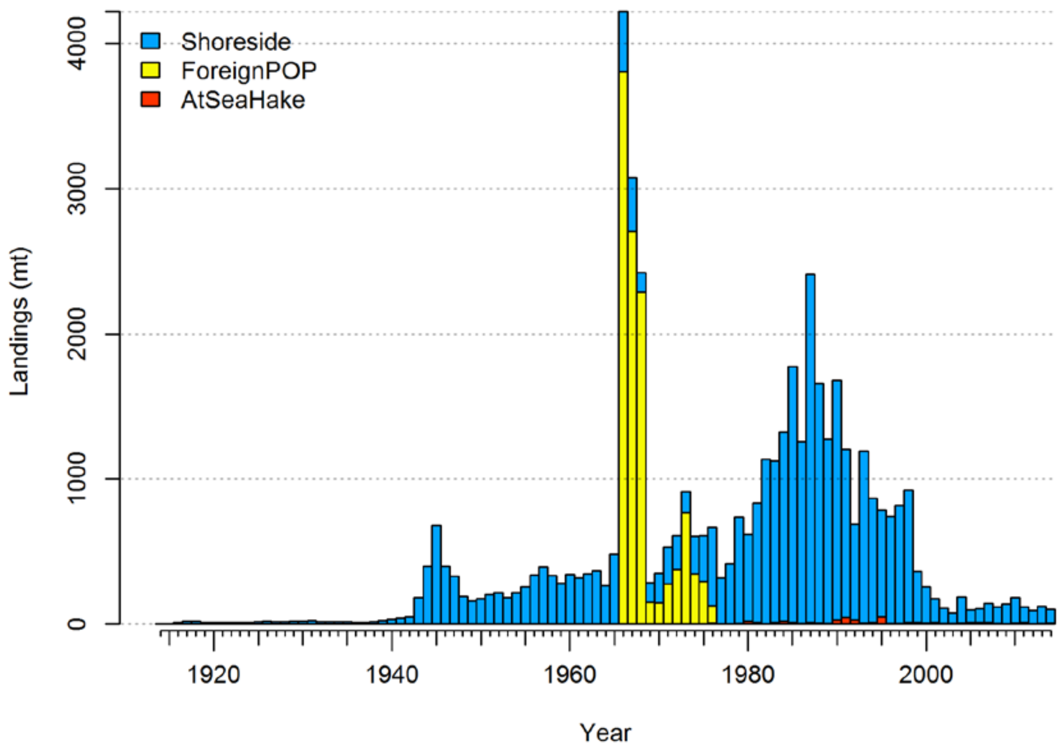

Figure ES-1: Darkblotched rockfish landings history between 1915 and 2014 by fleet.

Table ES-1: Recent darkblotched rockfish landings (mt) by component that comprised three fleets used in the assessment (removals by California, Oregon and Washington were combined into Shoreside fleet).

Year	California landings	Oregon landings	Washington landings	Bycatch in at-sea hake fishery	Total
2005	18	68	1	11	98
2006	23	71	2	11	107
2007	41	87	3	12	144
2008	34	74	3	6	117
2009	47	89	2	0	138
2010	17	152	7	8	184
2011	3	87	14	12	117
2012	7	70	15	2	94
2013	4	103	11	6	124
2014	4	77	11	11	103

Data and assessment

The last full assessment of darkblotched rockfish was conducted in 2013. This assessment uses the Stock Synthesis modeling framework developed by Dr. Richard Methot at the NWFSC. The most recent version (SSv3.24U, distributed on January 24, 2013) was used, since it included improvements in the output statistics for producing assessment results and several corrections to older versions.

The data used in the assessment include landings, length and age compositions of the retained commercial catch from Pacific Fisheries Information Network (PacFIN) and, for the first time since 2005, includes historical age data from 1980 forward. It includes discard ratios, length and age compositions of the discards from West Coast Groundfish Observer Program (WCGOP). The assessment also includes bycatch data within the at-sea hake fishery and, for the first time, length and age compositions of darkblotched bycatch from the At-Sea Hake Observer Program (ASHOP). Data from four National Marine Fisheries Service (NMFS) bottom trawl surveys are used to estimate indices of stock abundance and generate length and age frequency distributions for each survey. The Northwest Fisheries Science Center (NWFSC) shelf-slope survey covers the period between 2003 and 2014 and provides information on the current trend of the stock. Three other surveys (which are discontinued) include the NWFSC slope survey (1999- 2002), the AFSC slope survey (1997-2001), and the AFSC shelf triennial survey (1980-2004).

The modeling period in the assessment begins in 1916, assuming that in 1915 the stock was in an unfished equilibrium condition. Females and males are treated separately to account for sexual dimorphism in growth exhibited by the species. Growth is assumed to follow the von Bertalanffy growth model, and the assessment explicitly estimates most parameters describing growth for both sexes. Externally estimated life history parameters, included those defining the weight-length relationship, female fecundity and maturity schedule. Recruitment dynamics are assumed to follow the Beverton-Holt stock-recruit function. Natural mortality is fixed at the value of 0.054 yr^{-1} for females and estimated for males.

Stock spawning output

The darkblotched rockfish assessment uses a non-proportional egg-to-weight relationship, and the spawning output is reported in the number of eggs. The unexploited level of spawning stock output is estimated to be 3,203 million eggs (95% confidence interval: 2,370-4,036 million eggs). At the beginning of 2015, the spawning stock output is estimated to be 1,261 million eggs (95% confidence interval: 340-2,181 million eggs), which represents 39% of the unfished spawning output level.

The spawning output of darkblotched rockfish started to decline in the 1940s, during World War II, but exhibited a sharp decline in in the 1960s during the time of the intense foreign fishery targeting Pacific ocean perch. Between 1965 and 1976, spawning output dropped from 94% to 65% of its unfished level. Spawning output continued to decline throughout the 1980s and 1990s and in 2000 reached its lowest estimated level of 16% of its unfished state. Since 2000, the spawning output has been slowly increasing, which corresponds to decreased removals due to management regulations.

Table ES-2: Recent trends in estimated darkblotched rockfish spawning biomass, recruitment and relative depletion.

Year	Spawning stock output (million eggs)	~95% confidence interval	Estimated recruitment (1000s)	~95% confidence interval	Estimated depletion	~95% confidence interval
2006	716	237-1,196	2,168	598-3,738	22%	11-34%
2007	790	256-1,324	1,644	409-2,879	25%	12-38%
2008	856	269-1,443	6,240	1,784-10,695	27%	12-41%
2009	913	277-1,550	950	199-1,702	29%	13-44%
2010	961	279-1,643	2,243	619-3,867	30%	13-47%
2011	1,002	276-1,729	2,025	501-3,550	31%	13-49%
2012	1,061	289-1,832	956	132-1,779	33%	14-52%
2013	1,123	305-1,940	9,616	1,323-17,909	35%	15-55%
2014	1,189	321-2,056	2,466	1,679-3,253	37%	16-58%
2015	1,261	340-2,181	2,491	1,704-3,278	39%	17-62%

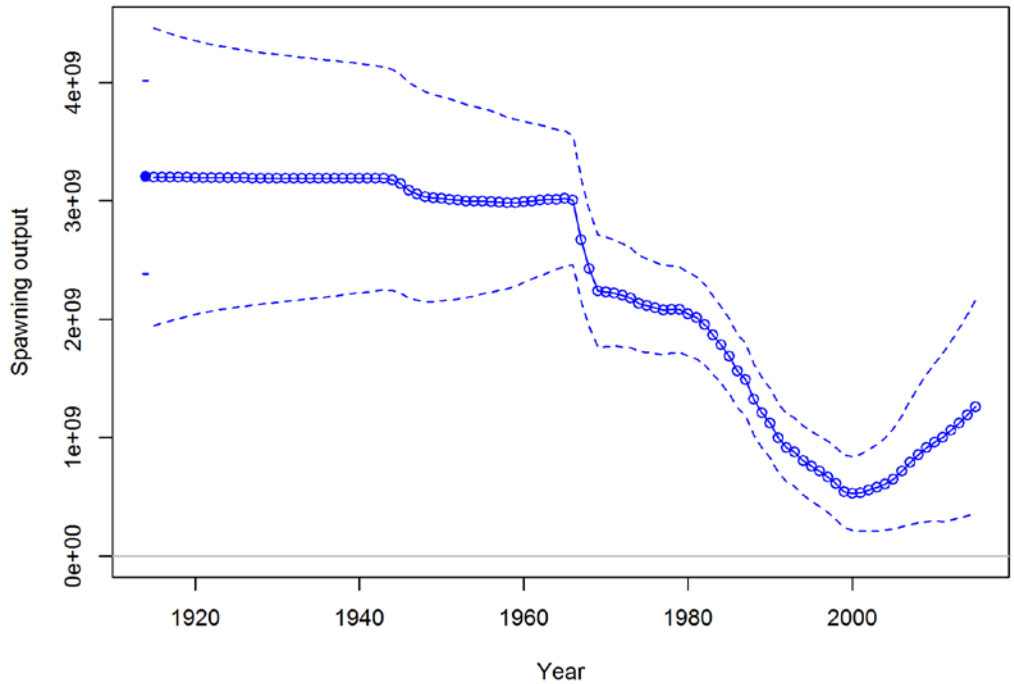

Figure ES-2: Estimated spawning biomass time-series (1915-2015) for the base-case model (circles) with ~ 95% interval (dashed lines). Spawning output is expressed in the number of eggs.

Recruitment

Recruitment dynamics are assumed to follow a Beverton-Holt stock-recruit function. The level of virgin recruitment is estimated in order to assess the magnitude of the initial stock size. 'Main' recruitment deviations were estimated for modeled years that had information about recruitment, between 1960 and 2011 (as determined from the bias-correction ramp). We additionally estimated 'early' deviations between 1870 and 1959 so that age-structure in the initial modeled year (1915) would deviate from the stable age-structure. The Beverton-Holt steepness parameter (*h*) is fixed in the assessment at the value of 0.773, which is the mean of steepness prior probability distribution, derived from this year's meta-analysis of Tier 1 rockfish assessments.

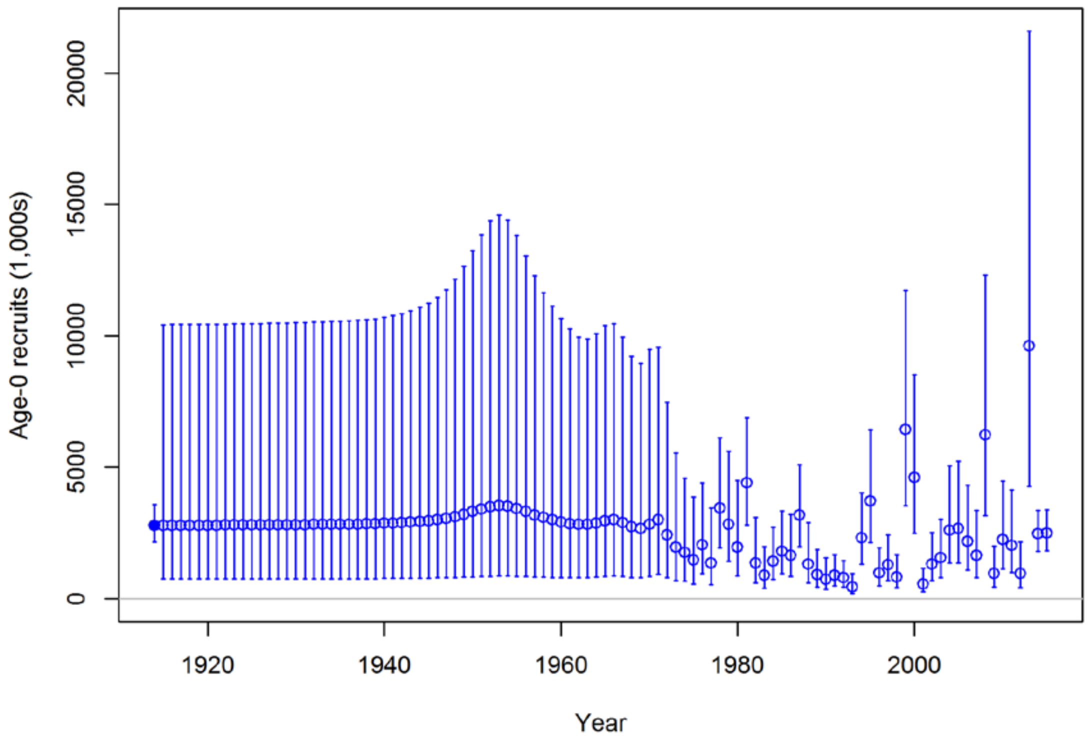

Figure ES-3: Time series of estimated darkblotched rockfish recruitments for the base-case model (solid line) with ~95% intervals (vertical lines).

Reference points

Unfished spawning stock output for darkblotched rockfish was estimated to be 3,203 million eggs (95% confidence interval: 2,370-4,036 million eggs). The stock is declared overfished if the current spawning output is estimated to be below 25% of unfished level. The management target for darkblotched rockfish is defined as 40% of the unfished spawning output ($SB_{40\%}$), which is estimated by the model to be 1,281 million eggs (95% confidence interval: 948-1,614), which corresponds to an exploitation rate of 0.041. This harvest rate provides an equilibrium yield of 674 mt at $SB_{40\%}$ (95% confidence interval: 504-844 mt). The model estimate of maximum sustainable yield (MSY) is 728 mt (95% confidence interval: 544-912 mt). The estimated spawning stock output at MSY is 815 million eggs (95% confidence interval: 603-1,026 million of eggs). The exploitation rate corresponding to the estimated SPR_{MSY} of $F_{31\%}$ is 0.0655.

Table ES-3. Summary of reference points for the base case model.

Quantity	Estimate	~95% Confidence Interval
Unfished Spawning output (million eggs)	3,203	2,370-4,036
Unfished age 1+ biomass (mt)	36,459	27,360-45,557
Unfished recruitment (R0)	2,773	2,051-3,494
Depletion (2015)	39%	17-62%
Reference points based on $SB_{40\%}$		
Proxy spawning output ($B_{40\%}$)(million eggs)	1,281	948-1,614
SPR resulting in $B40_{\%}$ ($SPR_{B40\%}$)	44%	NA
Exploitation rate resulting in $B_{40\%}$	4.1%	3.98-4.29%
Yield with *SPR* at $B_{40\%}$ (mt)	674	504-844
Reference points based on SPR proxy for MSY		
Spawning output (million eggs)	1,474	1,091-1,858
SPR_{proxy}	50%	NA
Exploitation rate corresponding to SPR_{proxy}	3.4%	3.3-3.5%
Yield with SPR_{proxy} at SB_{SPR} (mt)	630	472-789
Reference points based on estimated MSY values		
Spawning output at *MSY* (SB_{MSY}) (million eggs)	815	603-1,026
SPR_{MSY}	31%	30-32%
Exploitation rate corresponding to SPR_{MSY}	6.55%	6.24-6.74%
MSY (mt)	728	544-912

Exploitation status

The assessment shows that the stock of darkblotched rockfish off the continental U.S. Pacific Coast is currently at 39% of its unexploited level. This is above the overfished threshold of $SB_{25\%}$, but below the management target of $SB_{40\%}$ of unfished spawning biomass. Historically, the spawning output of darkblotched rockfish dropped below the $SB_{40\%}$ target for the first time in 1989, as a result of intense fishing by foreign and domestic fleets. It continued to decline and reached the level of 16% of its unfished output in 2000. The same year, the stock was declared overfished. Since then, the spawning output was slowly increasing primarily due to management regulations instituted for the species.

This assessment estimates that the 2014 SPR is 89%. The SPR used for setting the OFL is 50%, while the SPR-based management fishing mortality target, specified in the current rebuilding plan and is used to determine the ACL, is 64.9%. Historically, the darkblotched rockfish has been fished beyond the relative SPR ratio (calculated as 1-SPR/1-$SPR_{Target=0.5}$) between 1966 and 1968, during the peak years of the Pacific ocean perch fishery, in 1973 and for a prolonged period between from 1981 and 2000.

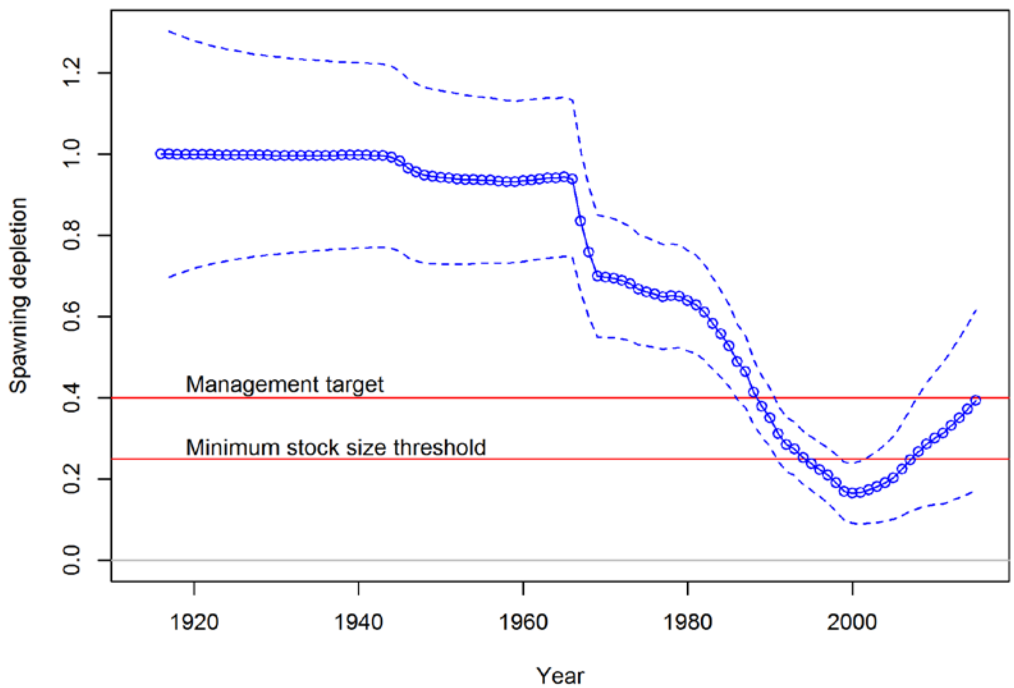

Figure ES-4. Estimated relative depletion with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model.

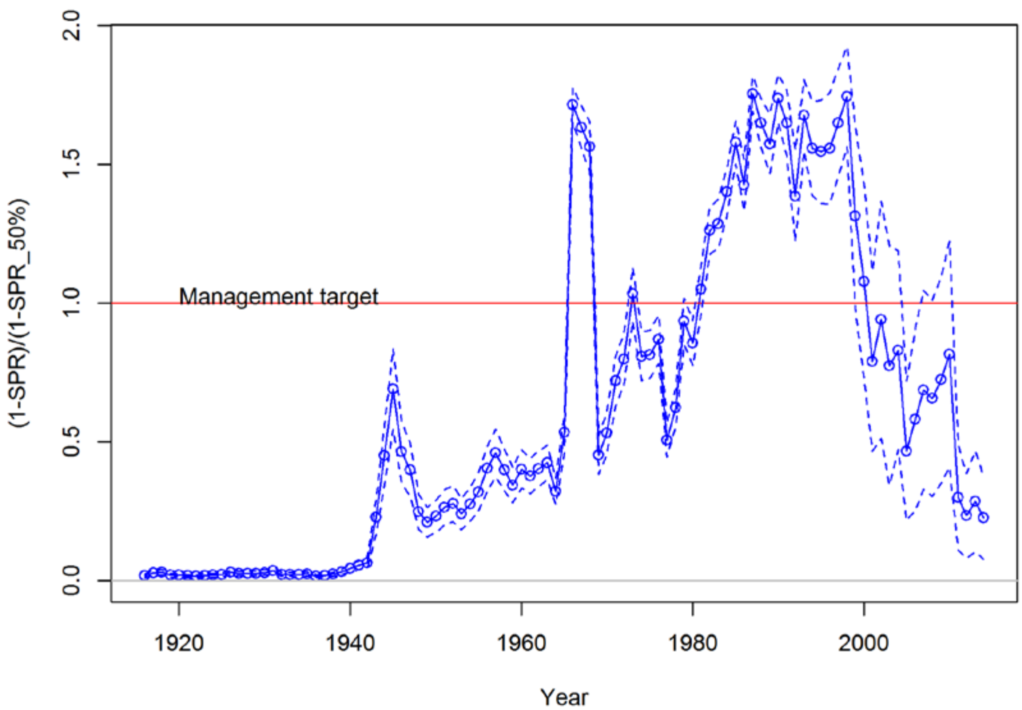

Figure ES-5. Time series of estimated relative spawning potential ratio (1-SPR/1-$SPR_{Target=0.5}$) for the base-case model (round points) with ~95% intervals (dashed lines). Values of relative SPR above 1.0 (100% in the table above) reflect harvests in excess of the current overfishing proxy.

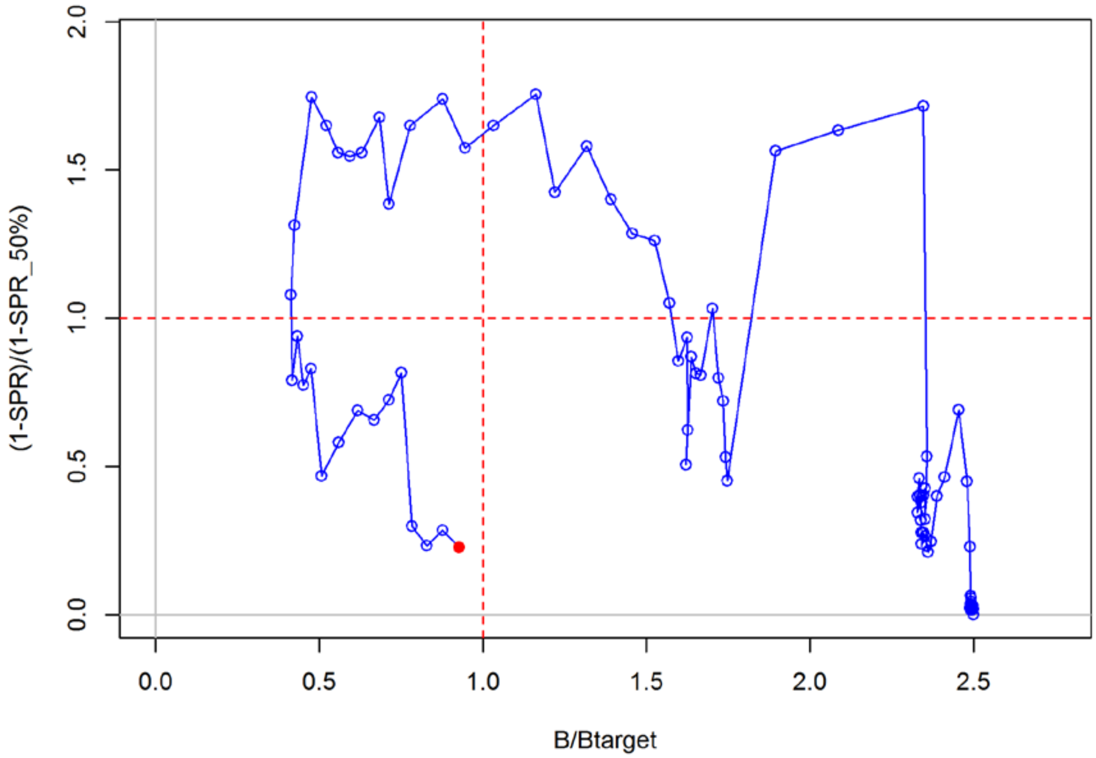

Figure ES-6. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model. The relative (1-SPR) is (1-SPR) divided by 0.5 (the SPR target). Relative depletion is the annual spawning biomass divided by the spawning biomass corresponding to 40% of the unfished spawning biomass. The red point indicates the year 2014.

Table ES-4. Recent trend in spawning potential ratio (SPR) and harvest rate.

Year	SPR (%)	Harvest rate (proportion)	~95% confidence interval
2005	77%	0.012	0.004-0.020
2006	71%	0.017	0.004-0.029
2007	66%	0.021	0.006-0.036
2008	67%	0.019	0.005-0.033
2009	64%	0.021	0.006-0.037
2010	59%	0.025	0.007-0.043
2011	85%	0.008	0.002-0.014
2012	88%	0.006	0.002-0.010
2013	86%	0.008	0.002-0.013
2014	89%	0.006	0.002-0.010

Ecosystem considerations

Darkblotched rockfish is most abundant from off British Columbia to Central California. This is a slope species that occurs at depths between 25 and 600m, with the majority of fish inhabiting at depths between 100 and 400 meters. Darkblotched rockfish co-occurs with an assemblage of slope rockfish, including Pacific ocean perch (*Sebastes alutus*), splitnose rockfish (*Sebastes diploproa*), yellowmouth rockfish (*Sebastes reedi*), and sharpchin rockfish (*Sebastes zacentrus*). Pacific ocean perch and darkblotched rockfish are the most abundant members of that assemblage off the coasts of Oregon and Washington, but splitnose rockfish and darkblotched rockfish dominate off the northern coast of California. Adults typically are observed resting on mud near cobble or boulders. They feed primarily in the midwater on large planktonic organisms such as krill, gammarid amphipods, copepods and salps, and less frequently on fishes and octopi. Young darkblotched are eaten by king salmon and albacore.

In this assessment, ecosystem considerations were not explicitly included in the analysis. This is primarily due to a lack of relevant data and results of analyses (conducted elsewhere) that could contribute ecosystem-related quantitative information for the assessment. However, we used the recently developed geostatistical delta-GLMM approach to estimate an abundance index from NWFSC shelf-slope survey data. This method uses information on the location of samples (i.e., whether located in high- or low-density habitats) to explain a portion of the variability in catch rates, and thus indirectly incorporates information on habitat quality that, in many respects, shapes spatial distribution of organisms and determines density of their occurrence.

Management performance

The stock has historically been managed with bimonthly cumulative landings limit (a.k.a. “trip limits”) as most of the catch came from the limited entry bottom trawl fishery. However, since 2011, that allocation has been managed as a catch share fishery, using Individual Fishing Quotas (IFQ), where each permit holder has an annual quota. Darkblotched rockfish has been managed using species-specific harvest specifications since 2001. Over the last 10 years, the total dead catch (as estimated in this assessment) exceeded the Annual Catch Limit (ACL) in two years: 2009 and 2010. The total dead catch has not exceeded the Overfishing Limit (OFL) during the last decade.

Table ES-5. Recent trend in total catch and commercial landings (mt) relative to the management guidelines. Estimated total catch consists of commercial landings, plus the model-estimated discarded biomass.

Year	OFL (mt)	ACL (mt)	Landings (mt)	Estimated Total Catch (mt)
2005	269	122	98	129
2006	269	122	107	194
2007	456	260	144	261
2008	456	260	117	250
2009	437	282	138	289
2010	437	282	184	351
2011	508	298	117	118
2012	508	298	94	95
2013	541	317	124	125
2014	541	317	103	104

Unresolved problems and major uncertainties

Uncertainty in the model was explored though asymptotic variance and sensitivity analyses. Asymptotic confidence intervals were estimated within the model and reported throughout the assessment for key model parameters and management quantities. To explore uncertainty associated with alternative model configurations and evaluate the responsiveness of model outputs to changes in key model assumptions, a variety of sensitivity runs were performed, including an increase and decrease of fishery removals, runs with different assumptions regarding life-history parameters, shape of selectivity curves, stock-recruitment parameters, and many others. The uncertainty regarding natural mortality, stock-recruit steepness and the unfished recruitment level was also explored through likelihood profile analysis. Additionally, a retrospective analysis was conducted where the model was re-run after successively removing data from recent years, one year at a time.

Main life history parameters, such as natural mortality and stock-recruit curve steepness, continue to be a major source of uncertainty. These quantities, which the model is unable to estimate reliably, are essential for understanding the dynamics of the stock. In the model, female natural mortality is fixed at the value estimated outside the model using other life history characteristics of the species, while male natural mortality is estimated within the model. Stock-recruit steepness is fixed at the value estimated outside the model using meta-analysis of species with similar life history characteristics.

Historically, darkblotched rockfish landings have not been sampled at the discrete species level; therefore, the time series of catch remained a source of uncertainty. Although significant progress has been made in reconstructing historical California and Oregon landings, the lack of early species composition data does not allow to account for a gradual shift of fishing effort towards deeper areas, which can cause the potential to overestimate the historical contribution of slope species (including darkblotched rockfish) to overall landings of the mixed-species market category (i.e. “unspecified rockfish”). Also, it is known that the shoreside fishery has discarded a portion of the catch at sea. Previous to 2002, when the West Coast Groundfish Observer Program was established, only one study exists (limited in time and space) that informs pre-2002 discarding practices of darkblotched rockfish.

Decision table

The base model estimate for 2015 spawning depletion is 39%. The primary axis of uncertainty about this estimate used in the decision table was based on female natural mortality. To identify female natural mortality values that correspond to low and high states of nature, we followed a multi-step algorithm. First, we selected alternative values of stock-recruit steepness. For this, we used a normal approximation to the prior distribution for steepness with an identical mean and standard deviation to the prior distribution from that analysis (mean=0.773, SD=0.147). We then identified two values from that normal distribution which are half as likely as the mode. Those values are:

$$h = 0.773 \pm 0.147(1.18) = (0.600, 0.946)$$

where 0.600 represents the low and 0.946 the high steepness alternatives.

We then determined depletion levels associated with alternative steepness values; depletion under low steepness was 9%, and it was 49% under high steepness. Finally, we identified female natural mortality values associated with these low and high depletion levels; they were 0.0412 and 0.059 respectively. We used these values to define low and high states of nature and construct the decision table.

Twelve-year forecasts for each state of nature were calculated based on average catch for the period between 2011 and 2014. They were also produced with future catches fixed at the 2016 darkblotched rockfish ACL. Finally, forecasts for each state of nature were calculated based on removals at a current rebuilding SPR of 64.9% for the base model.

Under the middle state of nature (which corresponds to the base model), the spawning output and depletion are projected to increase under all three considered catch streams, and reach the $SB_{40\%}$ target in 2015. Under the low state of nature, spawning depletion will stay below the $SB_{40\%}$ target within the next 12 years. Under the high state of nature, the spawning output remains above the 40% target level throughout the 12-year projection period.

Research and data needs

The following research could improve the ability of future stock assessments to determine the current status and productivity of the darkblotched rockfish population:

1) Additional population genetics research to elucidate potential spatial stock structure would be valuable for assessment and management, to ensure prevention of local depletion and preserve genetic diversity.

2) Additional research on darkblotched movement including migration patterns by latitude and depth, diurnal migration patterns through the water column, relative time spent off-bottom versus midwater, relating movements to size, age and sex would be valuable for further understanding this rockfish's ecological niche, stock structure, and lend insight to catchability and gear selectivity patterns.

3) Given that the population range extends north to the border with Canada, it is important that future research would evaluate the impact of not accounting for any Canadian portion of population abundance. Such an analysis would require evaluation of movement of darkblotched along the coast; such information is currently lacking.

4) Continuing collection of maturity and fecundity data on darkblotched rockfish would allow further research into latitudinal variability in life history parameters that again would advance understanding this species stock structure. Multi-year data would also allow evaluation of temporal changes in darkblotched maturity and fecundity.

5) Additional research into natural mortality, as it relates to length and age would be valuable to enable more realistic and accurate modeling of this parameter, which is a common source of uncertainty in assessment of this, and other rockfish species. Councill and Harford method is an example of one approach; it models natural mortality as a decaying function of size, with assumptions that mortality rates should be constrained by lifetime mortality rate.

6) Future research could also improve existing meta-analyses for natural mortality and steepness, which both contribute to the implied yield curve. Directions for improvements could include (1) weighting methods in natural mortality prior estimates included in the Hamel meta-analysis, and (2) developing a larger database of species for estimating steepness, perhaps by including species from other regions, e.g., Canada and Alaska.

7) Research into establishing optimum methods for more precise modeling of selectivity patterns is needed. Either asymptotic or dome-shaped selectivity assumptions are frequently used in stock assessments, when neither may be the best available representation of selectivity. Assumptions of a dome shape can suggest a "cryptic" biomass, or create confounding with natural mortality assumptions, potentially inflating abundance indices (Crone et al.

2013). Assumptions of asymptotic shape may also not be realistic. Simulation studies could be performed to empirically evaluate varying degrees of intermediate selectivity shapes, and how best to effectively implement them in existing stock assessment software platforms.

8) Research assessing the effects of the unprecedented warm ocean conditions off the West Coast of the U.S. during 2014 and 2015, on rockfish populations is needed. Specifically, investigations are needed that focus on how temperature and other water conditions at depth, in rockfish habitat correspond to high sea-surface temperatures recorded throughout those years, and how the fish respond to those changing conditions. Research is needed that examines whether fish move in response to changing temperatures, where, and how they move, as well as whether the conditions influence life history parameters and aspects such as mortality, feeding, fecundity and other reproductive considerations. What oceanographic and climatic forces are responsible and how long these conditions are expected to persist are also critical pieces of knowledge.

Table ES-6. 12-year projections for alternate states of nature defined based on female natural mortality. Columns range over low, mid, and high state of nature, and rows range over different assumptions of catch levels.

			State of nature					
			Low *Female M=0.0412*		Base case Female M=0.054		High *Female M=0.059*	
Management decision	Year	Catch (mt)	Spawning output (million eggs)	Depletion	Spawning output (million eggs)	Depletion	Spawning output (million eggs)	Depletion
Average catch for the period between 2011 and 2014	2015	110	263	9%	1,261	39%	1,660	49%
	2016	110	278	10%	1,331	42%	1,744	51%
	2017	110	291	10%	1,396	44%	1,820	53%
	2018	110	305	11%	1,459	46%	1,893	56%
	2019	110	324	12%	1,531	48%	1,976	58%
	2020	110	349	12%	1,618	51%	2,077	61%
	2021	110	379	13%	1,711	53%	2,183	64%
	2022	110	410	15%	1,799	56%	2,283	67%
	2023	110	442	16%	1,878	59%	2,369	69%
	2024	110	474	17%	1,948	61%	2,442	72%
	2025	110	507	18%	2,008	63%	2,503	73%
	2026	110	539	19%	2,062	64%	2,555	75%
2016 ACL catch assumed for years between 2015 and 2026	2015	338	263	9%	1,261	39%	1,660	49%
	2016	346	264	9%	1,317	41%	1,730	51%
	2017	346	260	9%	1,365	43%	1,790	53%
	2018	346	256	9%	1,411	44%	1,845	54%
	2019	346	256	9%	1,465	46%	1,911	56%
	2020	346	262	9%	1,534	48%	1,994	58%
	2021	346	271	10%	1,609	50%	2,082	61%
	2022	346	280	10%	1,677	52%	2,162	63%
	2023	346	288	10%	1,736	54%	2,229	65%
	2024	346	295	11%	1,786	56%	2,283	67%
	2025	346	302	11%	1,827	57%	2,327	68%
	2026	346	308	11%	1,863	58%	2,362	69%
Catch calculated using current rebuilding SPR of 64.9% applied to the base model (40-10 rule and buffer applied)	2015	388	263	9%	1,261	39%	1,660	49%
	2016	389	260	9%	1,314	41%	1,727	51%
	2017	386	253	9%	1,359	42%	1,783	52%
	2018	399	246	9%	1,400	44%	1,835	54%
	2019	438	241	9%	1,451	45%	1,897	56%
	2020	467	241	9%	1,513	47%	1,973	58%
	2021	474	241	9%	1,579	49%	2,053	60%
	2022	469	239	9%	1,637	51%	2,123	62%
	2023	461	236	8%	1,686	53%	2,180	64%
	2024	454	231	8%	1,725	54%	2,224	65%
	2025	450	226	8%	1,758	55%	2,259	66%
	2026	448	221	8%	1,784	56%	2,285	67%

Table ES-7. Summary of recent trends in estimated darkblotched rockfish exploitation and stock level from the assessment model.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Landings (mt)	98	107	144	117	138	184	117	94	124	103	NA
Estimated Total catch (mt)	129	194	261	250	289	351	118	95	125	104	NA
OFL (mt)	269	269	456	456	437	437	508	508	541	541	574
ACL (mt)	122	122	260	260	282	282	298	298	317	317	338
SPR	77%	71%	66%	67%	64%	59%	85%	88%	86%	89%	NA
Exploitation rate (catch/ age 1+ biomass)	0.012	0.017	0.021	0.019	0.021	0.025	0.008	0.006	0.008	0.006	NA
Age 1+ biomass (mt)	10,850	11,631	12,319	12,906	13,519	14,129	14,721	15,524	16,288	17,038	17,897
Spawning output (million eggs)	649	716	790	856	913	961	1,002	1,061	1,123	1,189	1,261
~95% Confidence Interval	216-1,082	237-1,196	256-1,324	269-1,443	277-1,550	279-1,643	276-1,729	289-1,832	305-1,940	321-2,056	340-2,181
Recruitment	2,671	2,168	1,644	6,240	950	2,243	2,025	956	9,616	2,466	2,491
~95% Confidence Interval	785-4,557	598-3,738	409-2,879	1,784-10,695	199-1,702	619-3,867	501-3,550	132-1,779	1,323-17,909	1,679-3,253	1,704-3,278
Depletion (%)	20%	22%	25%	27%	29%	30%	31%	33%	35%	37%	39%
~95% Confidence Interval	10-30%	11-34%	12-38%	12-41%	13-44%	13-47%	13-49%	14-52%	15-55%	16-58%	17-62%

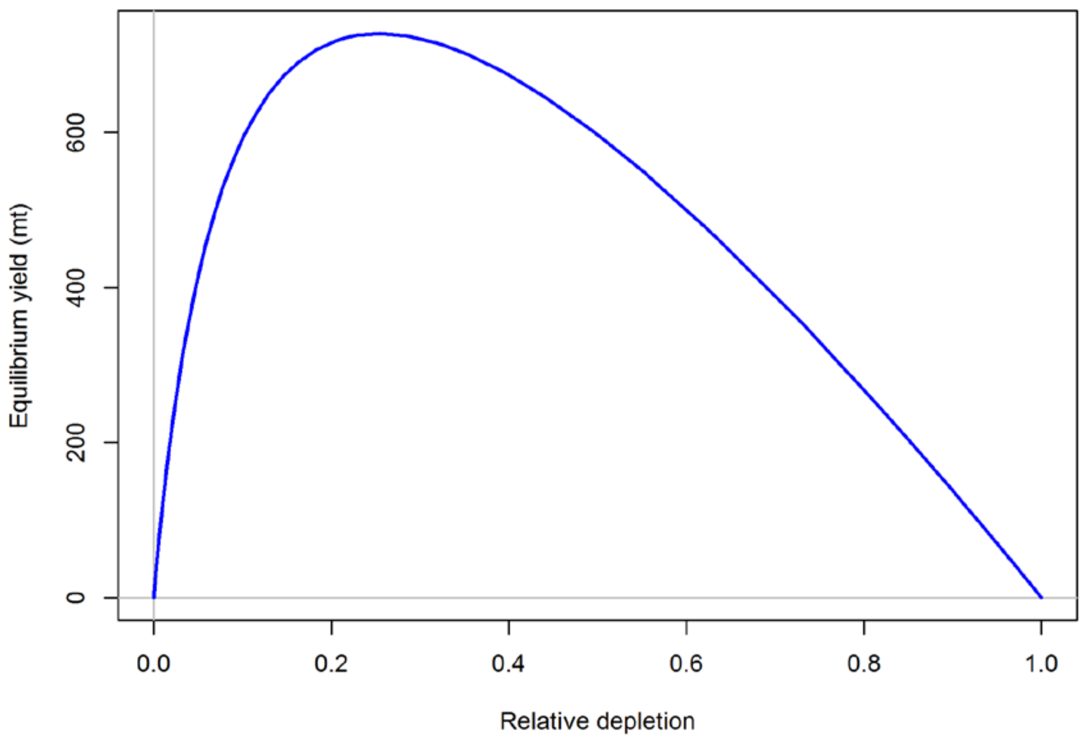

Figure ES-7. Equilibrium yield curve (derived from reference point values reported in Table ES-5) for the base case model. Values are based on 2014 fishery selectivity and distribution with steepness fixed at 0.773. The depletion is relative to unfished spawning biomass.