Agenda Item F.4
Attachment 4
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Status of the darkblotched rockfish resource off the continental U.S. Pacific Coast in 2017
(Update of 2015 assessment model)

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 contiguous United States, off Washington, Oregon and California, the area bounded by the U.S.-Canada border on the north and U.S.-Mexico border on the south. The population within this area is treated as a single 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 annual 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.

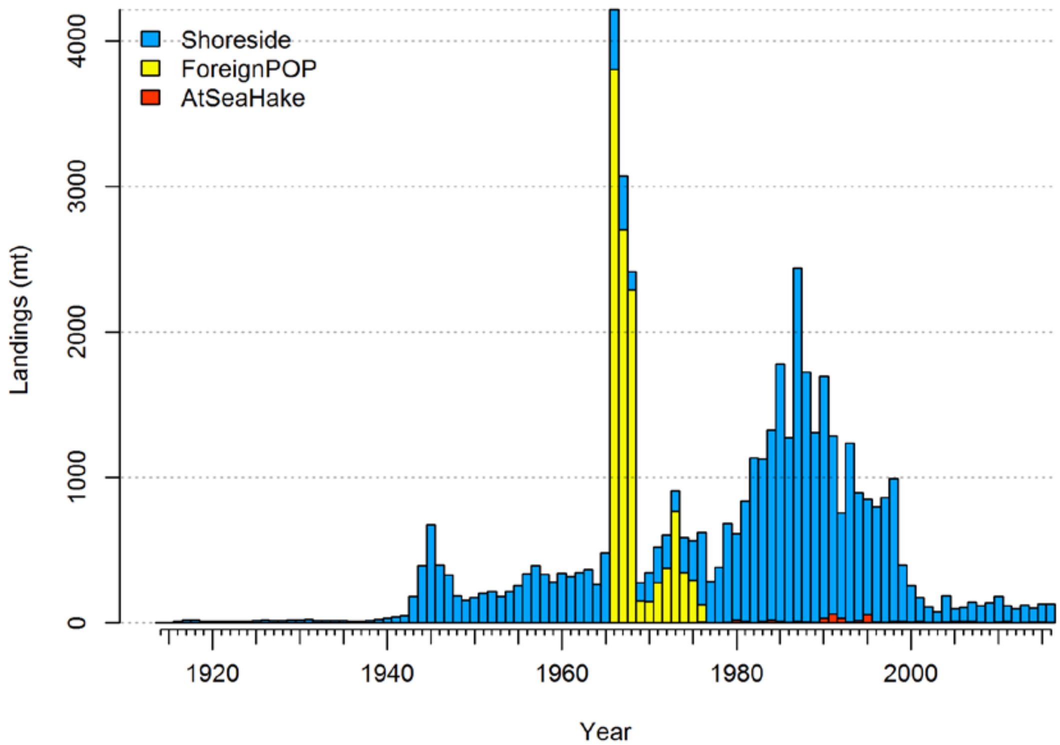

Figure ES-1: Darkblotched rockfish landings history between 1915 and 2016 by fleet.

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 a Shoreside fleet).

Year	California landings	Oregon landings	Washington landings	Bycatch in at-sea hake fishery	Total
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	20	3	99
2013	4	103	11	6	124
2014	4	77	11	11	103
2015	8	103	11	8	131
2016	10	108	6	5	129

Data and assessment

The last full assessment of darkblotched rockfish was conducted in 2015. The assessment here uses the Stock Synthesis modeling framework developed by Dr. Richard Methot at the NWFSC. The most recent version (SSv3.30.01.12) available at the time this assessment was undertaken was used, since it included improvements in the output statistics for producing assessment results and several corrections to older versions. Relative spawning biomass of the models to move from the 2015 base (using SSv3.24U) to the current 2017 base model, including a fit with the new base using the old steepness (0.773) is shown in Figure 99.

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 2016 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 3,548 million eggs (95% confidence interval: 2,714-4,382 million eggs). At the beginning of 2017, the spawning stock output is estimated to be 1,423 million eggs (95% confidence interval: 615-2,230 million eggs), which represents 40.11% 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 the 1960s during the time of the intense foreign fishery targeting Pacific ocean perch. Between 1965 and 1976, spawning output dropped from 90% to 64% of its unfished level. Spawning output continued to decline throughout the 1980s and 1990s and in 2000 reached its lowest estimated level of 17% of its unfished state. Since 2000, the spawning output has been slowly increasing, which corresponds to decreased removals due to management regulations.

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

Year	Spawning stock output (millions of eggs)	~95% confidence interval	Estimated depletion	~95% confidence interval
2008	920	421–1,418	25.9%	14.7–37.1%
2009	973	440–1,507	27.4%	15.4–39.5%
2010	1,017	452–1,582	28.7%	15.9–41.4%
2011	1,055	458–1,651	29.7%	16.2–43.2%
2012	1,109	481–1,736	31.2%	17.0–45.5%
2013	1,165	506–1,825	32.8%	17.9–47.8%
2014	1,226	532–1,921	34.6%	18.8–50.3%
2015	1,294	561–2,026	36.5%	19.8–53.1%
2016	1,359	589–2,130	38.3%	20.8–55.8%
2017	1,423	616–2,231	40.1%	21.8–58.4%

Table ES-3: Recent trends in estimated darkblotched rockfish recruitment and recruitment deviations.

Year	Estimated recruitment (1000s)	~95% confidence interval	Recruitment Deviations	95% Asymptotic Interval
2008	6,064	3,561–10,327	1.195	0.853–1.537
2009	875	457–1,675	-0.757	-1.283–-0.231
2010	2,463	1,394–4,350	0.265	-0.139–0.669
2011	2,457	1,373–4,397	0.253	-0.170–0.676
2012	1,494	786–2,839	-0.258	-0.774–0.259
2013	13,912	7,911–24,465	1.961	1.560–2.362
2014	1,239	573–2,680	-0.496	-1.197–0.205
2015	2,588	1,105–6,065	0.202	-0.607–1.011
2016	2,602	1,974–3,431	0.000	0.000–0.000
2017	2,628	1,997–3,458	0.000	0.000–0.000

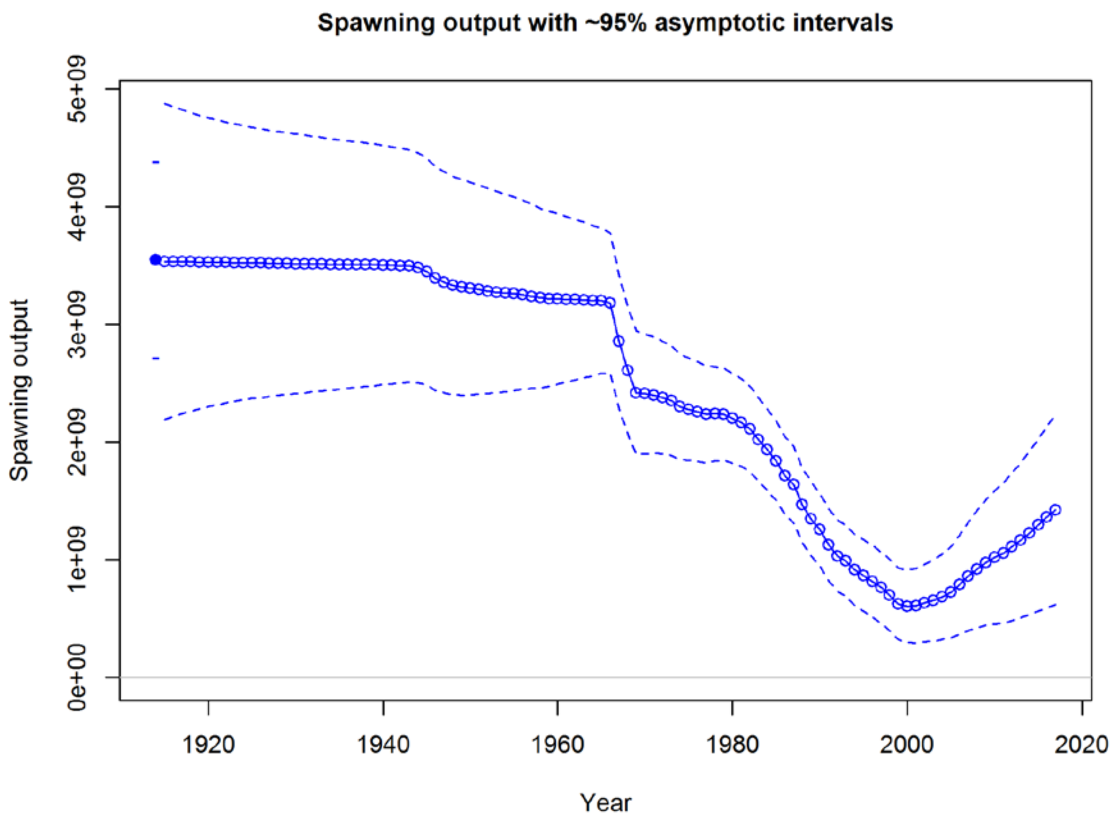

Figure ES-2: Estimated spawning biomass time-series (1915-2017) for the base-case model (circles) with ~ 95% interval (dashed lines). Spawning output is expressed in the number of eggs.

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 2013 (as determined from the bias-correction ramp in 2015). We additionally estimated ‘early’ deviations between 1870 and 1959 so that age-structure in the initial modeled year (1915) could deviate from the stable age-structure. The Beverton-Holt steepness parameter (*h*) is fixed in the assessment at the value of 0.72 (down from 0.773 in 2015), which is the mean of steepness prior probability distribution, derived from this year’s meta-analysis of Tier 1 rockfish assessments.

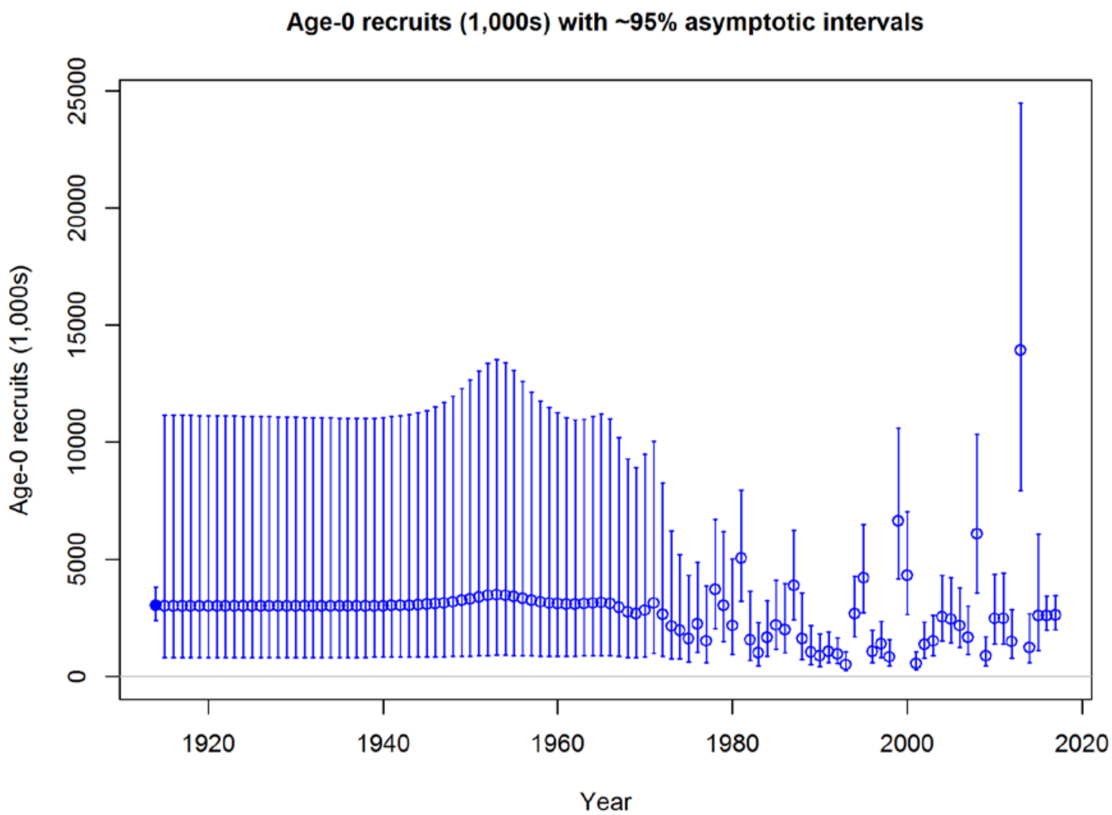

Figure ES-3: Time series of estimated darkblotched rockfish recruitments for the base-case model (solid line) with ~95% intervals (vertical lines).

Reference points

Unfished spawning stock output for darkblotched rockfish was estimated to be 3,548 million eggs (95% confidence interval: 2,714-4,382 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 1,419 million eggs (95% confidence interval: 1,086-1,753), which corresponds to an exploitation rate of 0.037. This harvest rate provides an equilibrium yield of 641 mt at $SB_{40\%}$ (95% confidence interval: 496-785 mt). The model estimate of maximum sustainable yield (MSY) is 641 mt (95% confidence interval: 496-785 mt). The estimated spawning stock output at MSY is 1,019 million eggs (95% confidence interval: 779-1,259 million of eggs). The exploitation rate corresponding to the estimated SPR_{MSY} of $F_{36\%}$ is 0.052.

Table ES-4. Summary of reference points for the base case model.

Quantity	**Estimate**	**~95% Confidence Interval**
Unfished Spawning output (million eggs)	3,548	2,714–4,382
Unfished Age 1+ Biomass (mt)	39,969	30,999–48,938
Spawning output (million eggs, 2017)	1,423	615–2,230
Unfished Recruitment (R0)	3,010	2,306–3,713
Depletion (2017)	40.11	21.78–58.45
Reference Points Based SB40%		
Proxy spawning output ($B_{40\%}$, million eggs)	1,419	1,086–1,753
SPR resulting in $B40_{\%}$ ($SPR_{B40\%}$)	0.458	0.458–0.458
Exploitation rate resulting in $B_{40\%}$	0.037	0.036–0.038
Yield with *SPR* at $B_{40\%}$ (mt)	641	496–785
Reference Points based on SPR proxy for MSY		
Proxy spawning biomass (SPR_{50}, million eggs)	1,583	1,211–1,955
SPR_{50}	50%	NA
Exploitation rate corresponding to SPR_{50}	0.032	0.031–0.033
Yield with SPR_{50} at SB_{SPR} (mt)	614	476–753
Reference points based on estimated MSY values		
Spawning biomass at MSY (SB_{MSY})	1,019	779–1,259
SPR_{MSY}	35.6%	0.351–0.362
Exploitation rate corresponding to SPR_{MSY}	0.052	0.050–0.054
MSY (mt)	671	520–823

Exploitation status

The assessment shows that the stock of darkblotched rockfish off the continental U.S. Pacific Coast is currently at 40% of its unexploited level. This is above the overfished threshold of $SB_{25\%}$, but just at 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 2016 SPR is 86%. The SPR used for setting the OFL is 50%, while the SPR-based management fishing mortality target, specified in the current rebuilding plan and used to determine the ACL, is 64.9%. Historically, the darkblotched rockfish was 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.

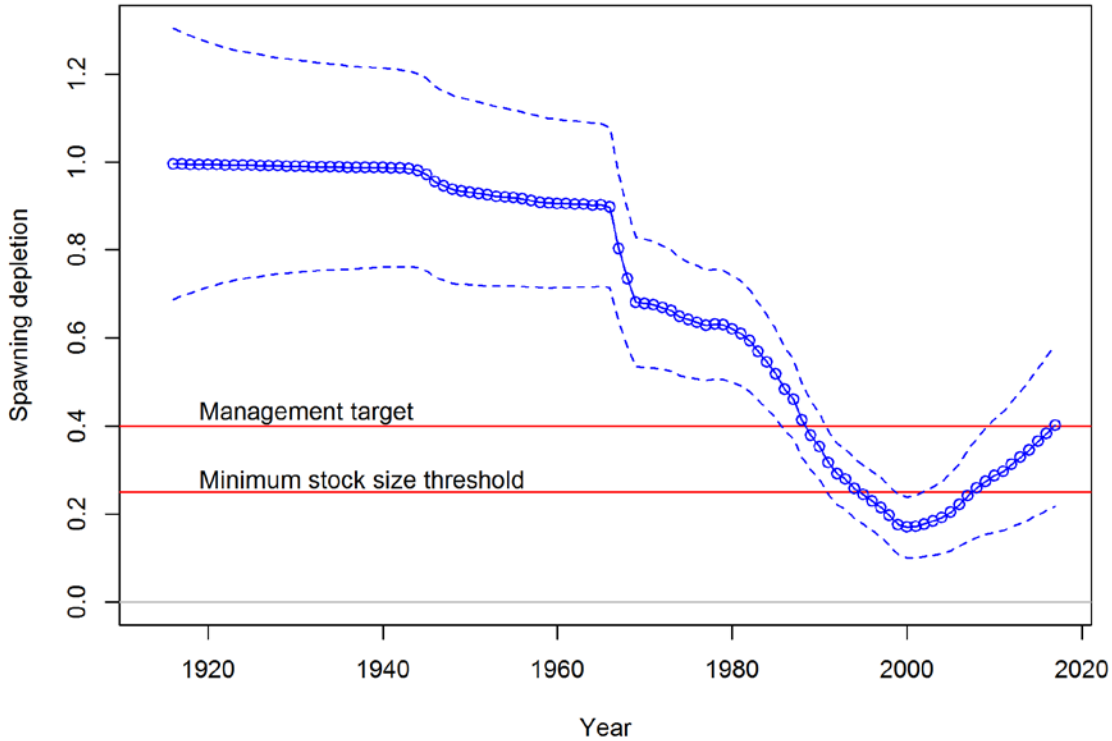

Figure ES-4. Estimated relative depletion with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model.

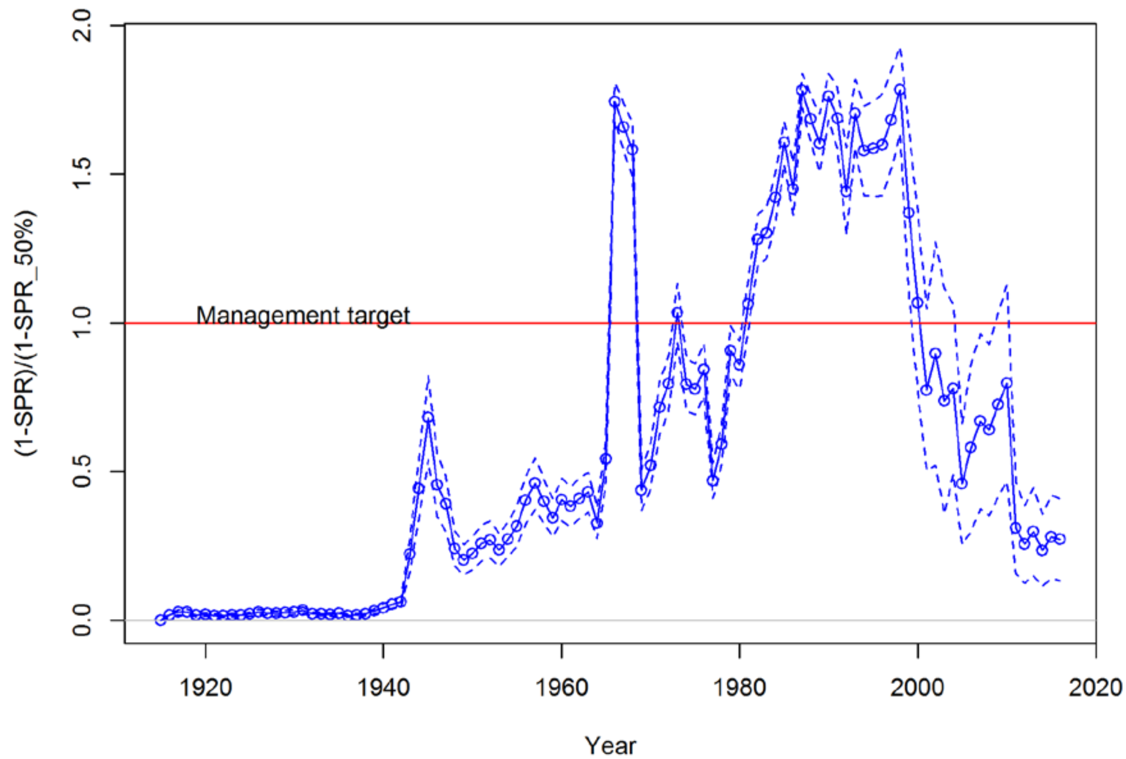

Figure ES-5. Time series of estimated relative spawning potential ratio (1-SPR/1-$SPR_{Target=0.5}$) for the base-case model (round points) with ~95% intervals (dashed lines). Values of relative SPR above 1.0 reflect harvests in excess of the current overfishing proxy.

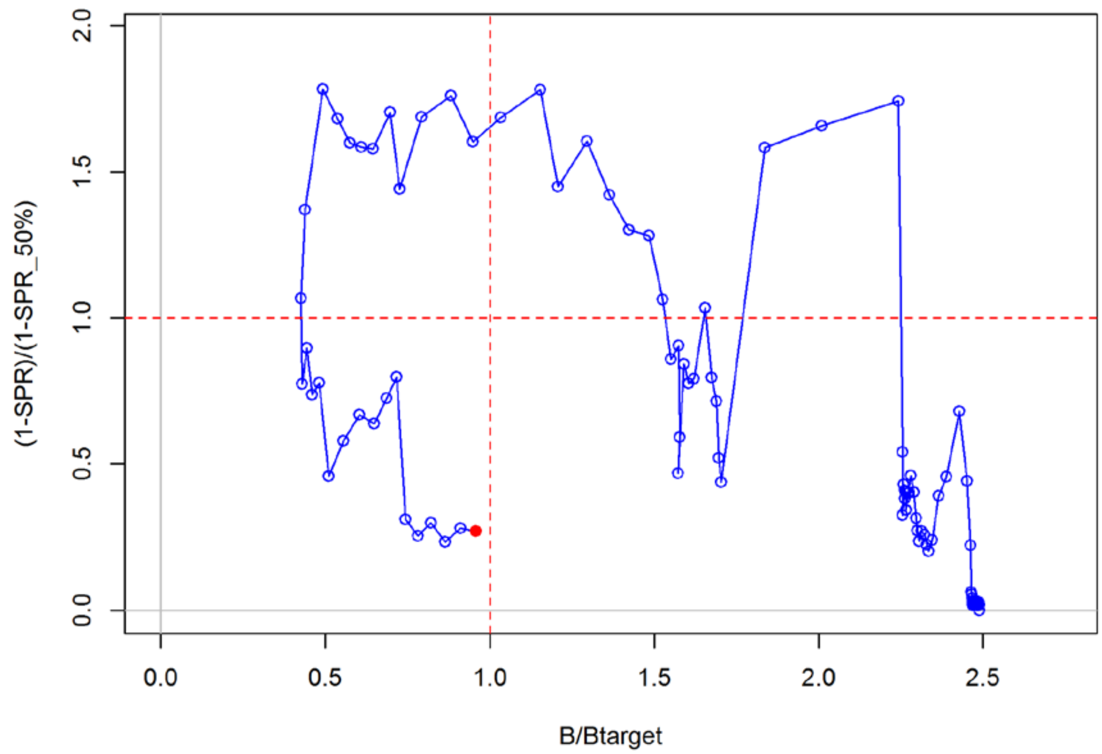

Figure ES-6. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model. The relative (1-SPR) is (1-SPR) divided by 0.5 (the SPR target). Relative depletion is the annual spawning biomass divided by the spawning biomass corresponding to 40% of the unfished spawning biomass. The red point indicates the year 2016.

Table ES-5. Recent trend in spawning potential ratio (SPR) and harvest rate.

Year	(1-SPR)/ (1-SPR_50%)	95% Asymptotic Interval	Harvest rate (proportion)	95% Asymptotic Interval
2007	66.92%	37.57–96.28%	0.020	0.009–0.032
2008	63.89%	35.16–92.63%	0.018	0.008–0.029
2009	72.55%	41.80–103.31%	0.021	0.009–0.033
2010	79.72%	46.70–112.73%	0.024	0.010–0.037
2011	31.02%	15.62–46.41%	0.008	0.004–0.013
2012	25.51%	12.56–38.45%	0.007	0.003–0.010
2013	29.78%	14.87–44.69%	0.008	0.004–0.012
2014	23.48%	11.43–35.54%	0.006	0.003–0.010
2015	27.95%	13.79–42.11%	0.007	0.003–0.012
2016	27.11%	13.28–40.93%	0.007	0.003–0.011

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 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 VAST 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 their density of 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 AnnualCatch 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-6. 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)
2007	456	260	143.6	256.1
2008	456	260	117.4	243.8
2009	437	282	138.4	290.7
2010	437	282	184.3	337.8
2011	508	298	116.9	121.2
2012	508	298	99.0	102.4
2013	541	317	124.1	127.8
2014	541	317	103.2	106.5
2015	574	549	130.7	136.7
2016	580	554	129.1	136.5

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

Decision table

The base model estimate for 2017 spawning depletion is 40.11%. 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, a multi-step algorithm was followed in 2015 (Gertseva, et al., 2016). Those same natural mortality levels are used in this update.

Twelve-year forecasts for each state of nature were calculated based on average catch for the period between 2013 and 2016 using a SPR of 0.50. They were also produced with future catches fixed at the 2018 darkblotched rockfish ACL. Also, forecasts for each state of nature were calculated based on removals at a current rebuilding SPR of 64.9% for the base model. Finally, a mixture of approach was used with the average 2013-2016 catch assumed for 2017-2020 and 2018 ACL catch for 2021-2028 at an SPR of 0.50.

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. Under the low state of nature, spawning depletion mostly stays below the $SB_{40\%}$ target during 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. The 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.

8) Research assessing the effects of the unprecedented warm ocean conditions off the West Coast of the U.S., first detected in late 2013 and persisting into 2016, 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-7. 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. Decision

			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 2013 and 2016 with SPR = 0.50	2017	122	868	25%	1,423	40%	1,687	46%
	2018	122	919	26%	1,493	42%	1,762	48%
	2019	122	985	28%	1,584	45%	1,861	51%
	2020	122	1,066	31%	1,699	48%	1,987	54%
	2021	122	1,153	33%	1,821	51%	2,120	58%
	2022	122	1,236	36%	1,933	54%	2,240	61%
	2023	122	1,310	38%	2,030	57%	2,343	64%
	2024	122	1,376	40%	2,113	60%	2,430	66%
	2025	122	1,435	41%	2,184	62%	2,502	68%
	2026	122	1,488	43%	2,245	63%	2,563	70%
	2027	122	1,537	44%	2,299	65%	2,616	72%
	2028	122	1,583	45%	2,346	66%	2,662	73%
2018 ACL catch assumed for years between 2018 and 2028 with SPR = 0.50	2017	641	868	25%	1,423	40%	1,687	46%
	2018	653	889	26%	1,463	41%	1,732	47%
	2019	653	920	26%	1,522	43%	1,798	49%
	2020	653	964	28%	1,600	45%	1,888	52%
	2021	653	1,008	29%	1,679	47%	1,979	54%
	2022	653	1,041	30%	1,745	49%	2,054	56%
	2023	653	1,063	31%	1,793	51%	2,110	58%
	2024	653	1,076	31%	1,828	52%	2,150	59%
	2025	653	1,082	31%	1,851	52%	2,176	59%
	2026	653	1,083	31%	1,866	53%	2,193	60%
	2027	653	1,081	31%	1,875	53%	2,203	60%
	2028	653	1,075	31%	1,878	53%	2,206	60%
Projections based on current rebuilding SPR of 64.9% applied to the base model For 2017 and 2018, adopted ACLs are used.	2017	641	868	25%	1,423	40%	1,687	46%
	2018	653	889	26%	1,463	41%	1,732	47%
	2019	496	920	26%	1,522	43%	1,798	49%
	2020	532	973	28%	1,609	45%	1,897	52%
	2021	528	1,025	29%	1,696	48%	1,996	55%
	2022	507	1,068	31%	1,772	50%	2,081	57%
	2023	488	1,103	32%	1,832	52%	2,149	59%
	2024	474	1,131	32%	1,880	53%	2,201	60%
	2025	465	1,153	33%	1,918	54%	2,242	61%
	2026	460	1,171	34%	1,949	55%	2,274	62%
	2027	457	1,185	34%	1,973	56%	2,299	63%
	2028	456	1,198	34%	1,993	56%	2,318	63%

Table ES-7 (continued). 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 2013-2016 catch assumed for 2017-2020 and 2018 ACL catch for 2021-2028 with SPR = 0.50	2017	122	868	25%	1,423	40%	1,687	46%
	2018	122	919	26%	1,493	42%	1,762	48%
	2019	122	985	28%	1,584	45%	1,861	51%
	2020	122	1,066	31%	1,699	48%	1,987	54%
	2021	653	1,153	33%	1,821	51%	2,120	58%
	2022	653	1,204	35%	1,901	54%	2,209	60%
	2023	653	1,240	36%	1,962	55%	2,275	62%
	2024	653	1,265	36%	2,005	57%	2,323	63%
	2025	653	1,281	37%	2,035	57%	2,355	64%
	2026	653	1,290	37%	2,054	58%	2,374	65%
	2027	653	1,292	37%	2,064	58%	2,385	65%
	2028	653	1,290	37%	2,068	58%	2,389	65%

Table ES-8. Summary of recent trends in estimated darkblotched rockfish exploitation and stock level from the assessment model.

	2007	2008	2009	2010	20011	2012	2013	2014	2015	2016	2017
Landings (mt)	144	117	138	184	117	94	124	103	131	129	NA
Estimated Total catch (mt)	261	250	289	351	118	95	125	104	137	137	NA
OFL (mt)	456	456	437	437	508	508	541	541	574	580	671
ACL (mt)	260	260	282	282	298	298	317	317	338	346	641
1-SPR	0.67	0.64	0.73	0.80	0.31	0.26	0.30	0.23	0.28	0.27	NA
Exploitation_Rate (catch/ age 1+ biomass)	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	NA
Age 1+ Biomass (mt)	12,688	13,220	13,780	14,331	14,874	15,625	16,363	17,191	18,252	19,498	20,799
Spawning output (million eggs)	857	920	973	1,017	1,055	1,109	1,165	1,226	1,294	1,359	1,423
~95% Confidence Interval	397–1,318	421–1,418	440–1,507	452–1,582	458–1,651	481–1,736	506–1,825	532–1,921	561–2,026	589–2,130	616–2,231
Recruitment	1,654	6,064	875	2,463	2,457	1,494	13,912	1,239	2,588	2,602	2,628
~95% Confidence Interval	916–2,985	3,561–10,327	457–1,675	1,394–4,350	1,373–4,397	786–2,839	7,911–24,465	573–2,680	1,105–6,065	1,974–3,431	1,997–3,458
Depletion (%)	24.2	25.9	27.4	28.7	29.7	31.2	32.8	34.6	36.5	38.3	40.1
~95% Confidence Interval	13.8–34.5	14.7–37.1	15.4–39.5	15.9–41.4	16.2–43.2	17.0–45.5	17.9–47.8	18.8–50.3	19.8–53.1	20.8–55.8	21.8–58.4

Table ES-9. 10-year projections of predicted OFL, maximum potential ACL, estimated summary biomass (age-1 and older), spawning output, and depletion based on current rebuilding SPR of 64.9%. Projections assume total catch of 641 and 653 mt (the Council's adopted ACLs) for 2017 and 2018, respectively.

Year	Predicted OFL (mt)	Potential ACL (mt)	Summary biomass (mt)	Spawning output (million eggs)	Depletion (%)
2019	810	496	22,117	1,522	43%
2020	869	532	22,730	1,609	45%
2021	861	528	23,162	1,696	48%
2022	828	507	23,474	1,772	50%
2023	797	488	23,710	1,832	52%
2024	774	474	23,894	1,880	53%
2025	760	465	24,040	1,918	54%
2026	751	460	24,156	1,949	55%
2027	747	457	24,250	1,973	56%
2028	744	456	24,327	1,993	56%

Table ES-10. 10-year projections of predicted OFL, maximum potential ACL, estimated summary biomass (age-1 and older), spawning output, and depletion based on target SPR of 50%, under the ACL = ABC (P*=0.45) harvest control rule. Projections assume total catch of 641 and 653 mt (the Council's adopted ACLs) for 2017 and 2018, respectively.

Year	Predicted OFL (mt)	Potential ACL (mt)	Summary biomass (mt)	Spawning output (million eggs)	Depletion (%)
2019	810	775	22,117	1,522	43%
2020	855	819	22,442	1,593	45%
2021	834	798	22,565	1,662	47%
2022	791	757	22,577	1,715	48%
2023	752	720	22,536	1,754	49%
2024	723	692	22,465	1,781	50%
2025	704	673	22,378	1,800	51%
2026	691	661	22,279	1,811	51%
2027	682	652	22,174	1,817	51%
2028	675	646	22,065	1,819	51%

Table ES-11. 10-year projections of predicted OFL, estimated summary biomass (age-1 and older), spawning output, and depletion under a constant ACL catch of 653 mt. Projections assume total catch of 641 and 653 mt (the Council's adopted ACLs) for 2017 and 2018, respectively.

Year	Predicted OFL (mt)	ACL (mt)	Summary biomass (mt)	Spawning output (million eggs)	Depletion (%)
2019	810	653	22,117	1,522	43%
2020	861	653	22,568	1,600	45%
2021	848	653	22,868	1,679	47%
2022	810	653	23,039	1,745	49%
2023	774	653	23,114	1,793	51%
2024	746	653	23,118	1,828	52%
2025	726	653	23,071	1,851	52%
2026	712	653	22,989	1,866	53%
2027	702	653	22,884	1,875	53%
2028	695	653	22,762	1,878	53%

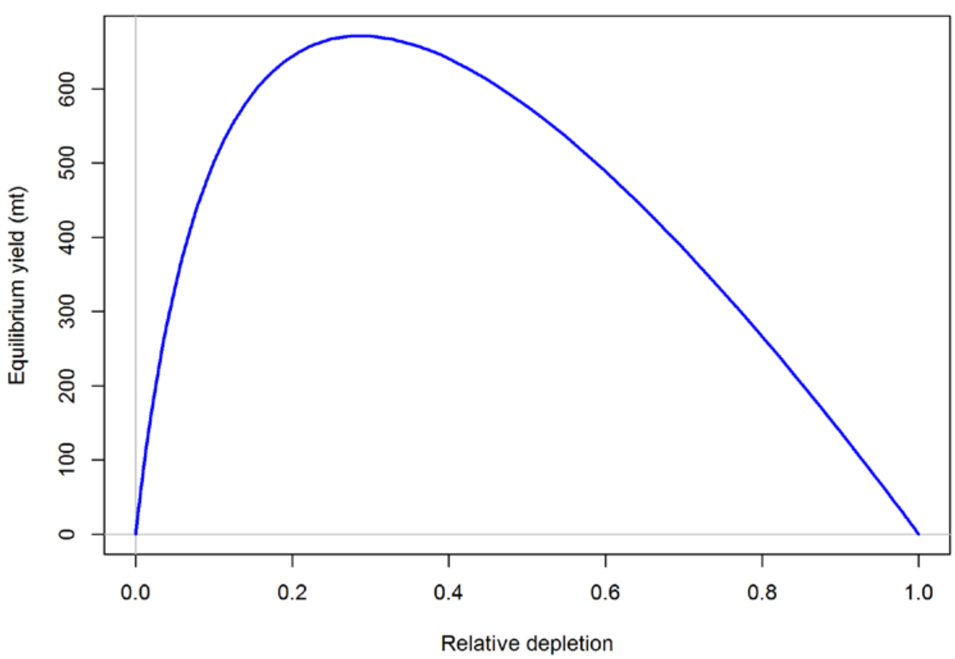

Figure ES-7. Equilibrium yield curve (derived from reference point values reported in Table ES-5) for the base case model. Values are based on 2014 fishery selectivity and distribution with steepness fixed at 0.773. The depletion is relative to unfished spawning biomass.