A 2019 catch-only projection from the 2013 assessment of the status of rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*S. melanostictus*) as a complex along the U.S. West Coast

Owen Hamel

DRAFT2

August 22, 2019

Northwest Fisheries Science Center
U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
2725 Montlake Boulevard East
Seattle, Washington 98112-2097

owen.hamel@noaa.gov

Executive Summary

Stock

This is a catch-only projection of an assessment of rougheye rockfish (*Sebastes aleutianus*) that reside in the waters off California, Oregon, and Washington from the U.S.-Canadian border in the north to the U.S.-Mexico border in the south. Rougheye rockfish are more common north of the California-Oregon border and are also harvested in waters off British Columbia and the Gulf of Alaska. Although catches north of the U.S.-Canada border were not included in this assessment, it is not certain if those populations contribute to the biomass of rougheye rockfish off the U.S. West Coast possibly through adult migration and/or larval dispersion.

The depth and geographic distribution of blackspotted rockfish (*S. melanostictus*) overlaps with rougheye rockfish and it is very difficult to visually distinguish between the two species. It has only been from recent genetic studies in the early 2000's that two separate species have been identified and described. Consequently, the vast majority of data that are available include pooled contributions from both rougheye rockfish and blackspotted rockfish. Due to the difficulty in distinguishing these two species and the lack of historical separation of the species in all of the data, this assessment combines any data for blackspotted rockfish with rougheye rockfish and provides management advice for the two species combined. In this assessment, the term "rougheye rockfish" refers to rougheye and blackspotted rockfishes unless specified.

Catches

Rougheye rockfish are landed as part of the minor slope rockfish species complex. Because landings from the complex need not be sorted into component species for purposes of fish-ticket reporting, species composition sampling of this 'market' category is required to determine the amount of landed catch. The uncertainty in species composition is greater in past years, thus landings of rougheye rockfish are not well known further back in history.

The historical reconstruction of landings for rougheye rockfish suggests that fixed gear fisheries have caught rougheye rockfish since the turn of the 20th century and landings in the trawl fishery are estimated to have increased into the 1940's. Landings remained relatively constant throughout the 1950's and into the 1960's before the foreign trawl fleet increased catches into the 1970's. The declaration of the exclusive economic zone resulted in the buildup of a domestic fleet and landings increased rapidly into the late 1980's and early 1990's. Subsequently, landings declined in the late 1990's and have been between 100 and 200 metric tons in recent years. Trawl, long-line, and Pacific whiting at-sea trawl fisheries make up the majority of the catch.

Rougheye rockfish are a desirable market species and discarding has been low, historically. However, management restrictions (e.g., trip limits) have resulted in increased discarding since 2000. Trawl rationalization was introduced in 2011, and since then very little discarding of rougheye rockfish has occurred. Discards were estimated in the model with the assistance of observer data.

Recent total removals (catches) from 2013 – 2018 were taken from the Groundfish Expanded Mortality Multi-year (GEMM) report published on August 22nd, 2019, while 2019 and 2020 removals are assumed to be the average of removals for 2016-2018 (181.82 mt). Distribution of removals among the fleets for those years is based on advice from the Pacific Fishery Management Council's Groundfish Management Team (GMT).

Table a: Recent catch (landings + discard) for trawl and hook & line (mt) used in the catch-only projection. Catches (mt) from the Pacific whiting at-sea fishery as determined by onboard observers are also shown.

Year	Trawl	Hook & Line	At-sea	Total
2009	*109.96*	*109.46*	*9.30*	*228.72*
2010	*134.03*	*73.79*	*21.57*	*229.39*
2011	*57.34*	*64.12*	*80.95*	*202.42*
2012	*79.87*	*51.64*	*54.00*	*185.51*
2013	68.17	67.66	18.26	154.08
2014	39.61	44.13	5.85	89.59
2015	53.82	54.16	23.44	131.42
2016	49.16	66.05	31.35	146.57
2017	34.17	78.20	46.90	159.27
2018	21.23	49.83	168.55	239.61

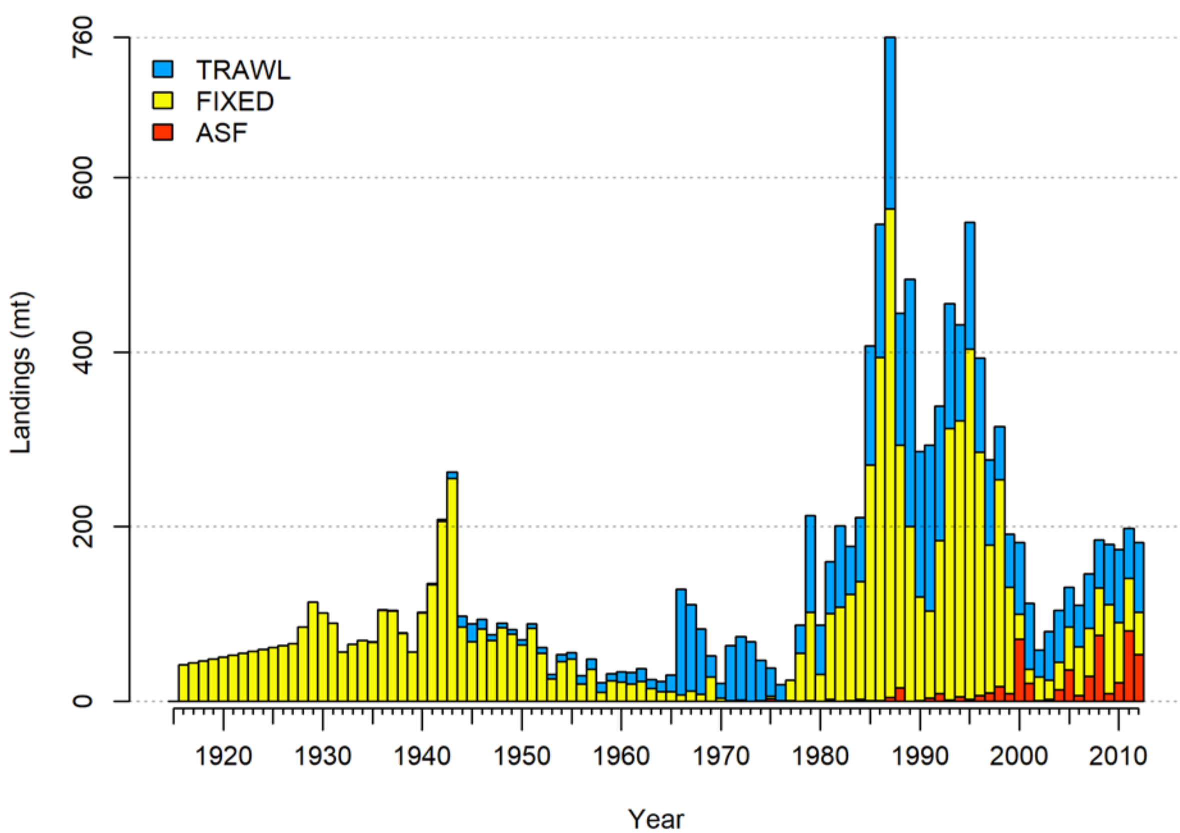

Figure a: Landings (without discards) of rougheye rockfish from 1916 to 2018 for the trawl and hook & line fisheries, and catches of rougheye rockfish for the foreign (1966–1976) and Pacific whiting at-sea fisheries

Data and assessment

The 2013 assessment was the first formal assessment model for rougheye rockfish on the U.S. West Coast and was conducted using the length- and age-structured model called Stock Synthesis (version 3.24o, pers. comm. Richard Methot, NMFS). The coastwide population was modeled assuming parameters for combined sexes (a single sex model) from 1916 to 2013, and forecasted beyond 2013. Three fishing fleets were specified within the model: 1) a shore-based trawl fleet with foreign catches between 1966–1976 added to the domestic trawl catches, 2) a hook & line fleet, and 3) a foreign and at-sea fleet that targets Pacific whiting. Data from four fishery-independent surveys were also included in the model: 1) the triennial survey which was conducted from 1980–2004 in depths less than 500 meters, 2) a slope survey executed by the Alaska Fishery Science Center in 1996, 1997, and 1999-2001 which took place in waters north of 43° N latitude and between 183 and 1,280 meters in depth, 3) a Northwest Fishery Science Center (NWFSC) slope survey which occurred from 1999–2002 and included nearly the entire coastline in depths from 183 to 1280 meters, and 4) the NWFSC shelf/slope survey which has been surveying the entire U.S. West Coast in depths between 55 and 1,280 meters since 2003.

The data used in the assessment model consisted of survey abundance indices, length compositions, discard data, and ages. Model-based biomass indices and length compositions were determined for each survey, except for the NWFSC slope survey, which did not record rockfish lengths. Length data were also available from the fisheries in recent years. Age data for all years of the NWFSC shelf/slope survey and the years 2008 and 2011 from the trawl and at-sea fisheries were input as age-at-length. Discard data for the trawl and hook & line fisheries were available for 2002–2011 in the form of discarded biomass, length compositions, and average weights. No data were available to inform discarding practices of rougheye rockfish prior to 2002, although anecdotal information suggests little discarding occurred before trip limits were implemented in the 1990s. The variances and sample sizes on all of the data were tuned to the expected variability in the model predictions.

The base model estimated parameters for selectivity and retention curves based on length for the trawl and hook & line fishing fleets, selectivity curves for the at-sea fleet and the four surveys, a length-at-age relationship, natural mortality, and recruitment deviations starting in 1900. A steepness parameter was fixed at 0.779 based on a steepness meta-analysis for west coast rockfishes (pers. comm. Jim Thorson, NWFSC) and was not estimated.

Although there are many types of recent data available for rougheye rockfish, which were used in this assessment, there is little information about steepness, natural mortality, and historical recruitment. Estimates of steepness are uncertain partly because the stock has not been fished to low levels. Uncertainty in natural mortality is common in many fish stock assessments and because length and age data are available only for recent years, there is little information to accurately estimate natural mortality, thus estimated spawning biomass is also uncertain. Finally, there is little information about the levels of historical recruitment mostly due to a lack of historical length or age data. This uncertainty was included in the predictions from this assessment.

Stock biomass

The predicted spawning biomass from the base model generally showed a slight decline over the entire time series with a period of steeper decline during the 1980’s and 1990’s. Since 2000, the spawning biomass has stabilized and possibly increased because of reduced catches and above average recruitment in 1999. The 2019 spawning biomass relative to unfished equilibrium spawning biomass is above the target of 40% of unfished spawning biomass.

Approximate confidence intervals based on the asymptotic variance estimates show that the uncertainty in the estimated spawning biomass is high. The standard deviation of the log of the spawning biomass in 2019 is 0.30.

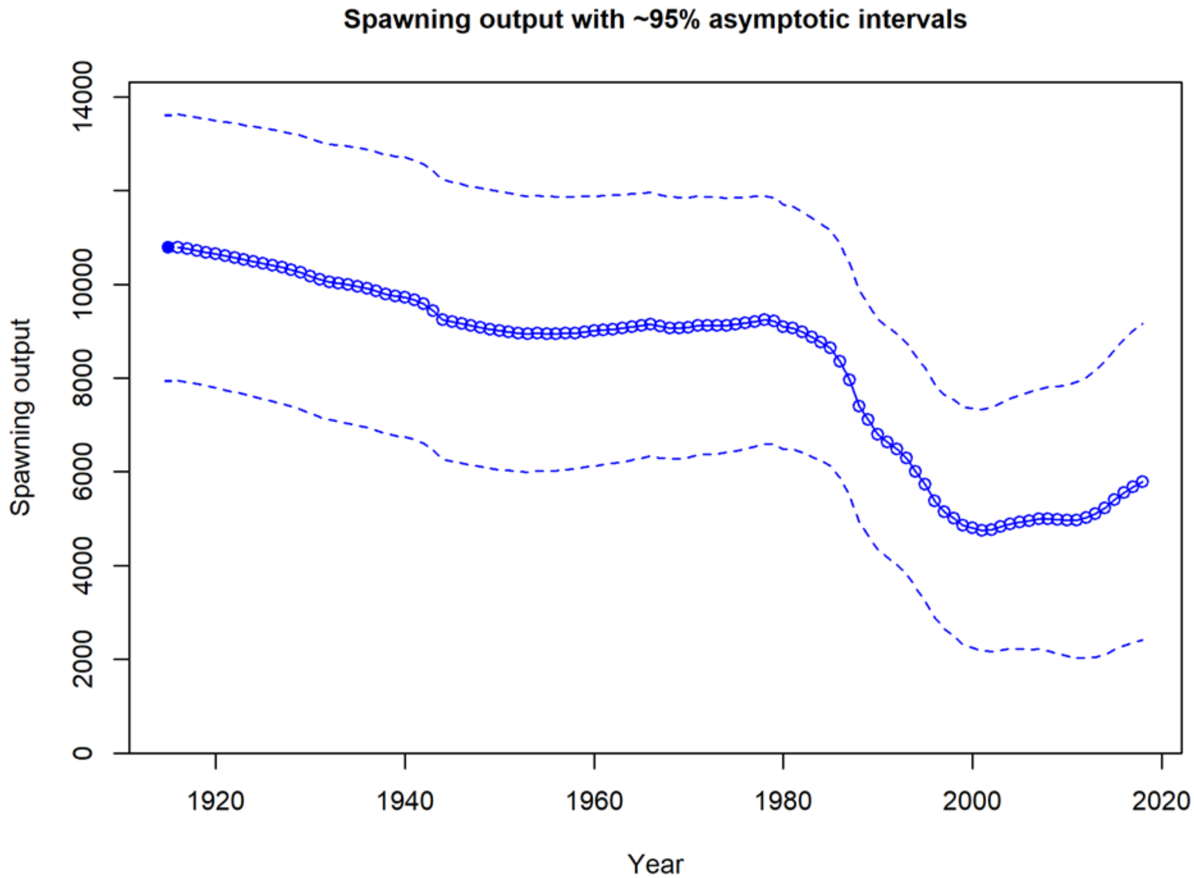

Figure b: Estimated female spawning biomass time-series from the base model (solid line) with an approximate asymptotic 95% confidence interval (thick dashed lines).

Table b: Recent trend in estimated female spawning biomass and relative depletion of the spawning biomass.

Year	Spawning Biomass (mt)	~95% confidence interval	Estimated depletion	~95% confidence interval
2010	*2,483*	*1,038 – 3,929*	*46.04*	*30.4 – 61.7*
2011	*2,487*	*1,017 – 3,956*	*46.10*	*30.0 – 62.2*
2012	*2,511*	*1,014 – 4,008*	*46.56*	*30.1 – 63.0*
2013	*2,552*	*1,024 – 4,081*	*47.32*	*30.5 – 64.2*
2014	2,613	1,051 – 4,176	48.45	31.3 – 65.6
2015	2,703	1,105 – 4,300	50.11	32.7 – 67.5
2016	2,777	1,146 – 4,408	51.49	33.8 – 69.2
2017	2,842	1,181 – 4,503	52.70	34.7 – 70.7
2018	2,897	1,210 – 4,684	53.71	35.5 – 71.9
2019	2,914	1,205 – 4,622	54.02	35.5 – 72.5

Recruitment

Recruitment deviations were estimated for the entire time series modeled. There is little information regarding recruitment prior to 1980, and the uncertainty in these estimates is expressed in the model. Estimates of recruitment appear to oscillate between periods of low and high recruitment. The four largest recruitments were estimated in 1999, 1998, 2001, and 1988, and the four smallest recruitments were estimated in 2002, 2006, 2005, and 1995. Recruitment predictions since 2002 are all below the unfished average of 485,000 fish.

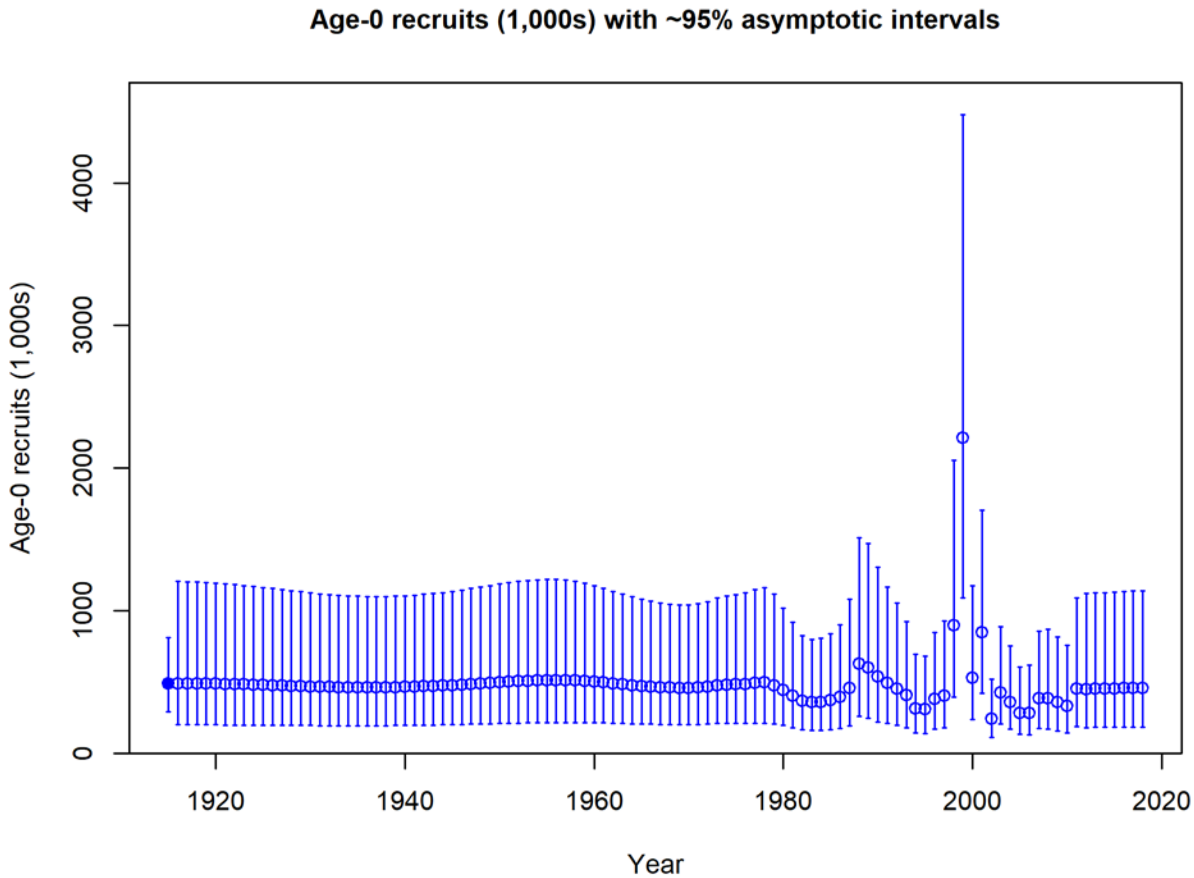

Figure c: Time-series of estimated recruitments for the base case model (round points) with approximate asymptotic 95% confidence interval (vertical bars).

Table c: Recent estimated trend in rougheye rockfish recruitment with approximate 95% confidence intervals determined from the base model.

Year	Estimated recruitment (1,000's)	~95% confidence interval
2010	328.2	142–757
2011	452.3	188–1,090
2012	448.9	180–1,121
2013	449.9	180–1,123
2014	451.4	181–1,126
2015	453.4	182–1,130
2016	455.0	183–1,133
2017	456.4	183–1,136

2018	457.5	184–1,139
2019	457.8	184–1,140

Exploitation status

The spawning biomass of rougheye rockfish reached a low in the late 1990's before stabilizing in the early 2000's and then slightly increasing during the last decade. The estimated depletion has remained above the 40% of unfished spawning biomass target and there is a small probability that the stock has fallen below this threshold in the last decade. Throughout the 1980's and 1990's the exploitation rate and (1-*SPR*) were mostly above target levels. Recent exploitation rates on rougheye rockfish were estimaed to be near or below target levels.

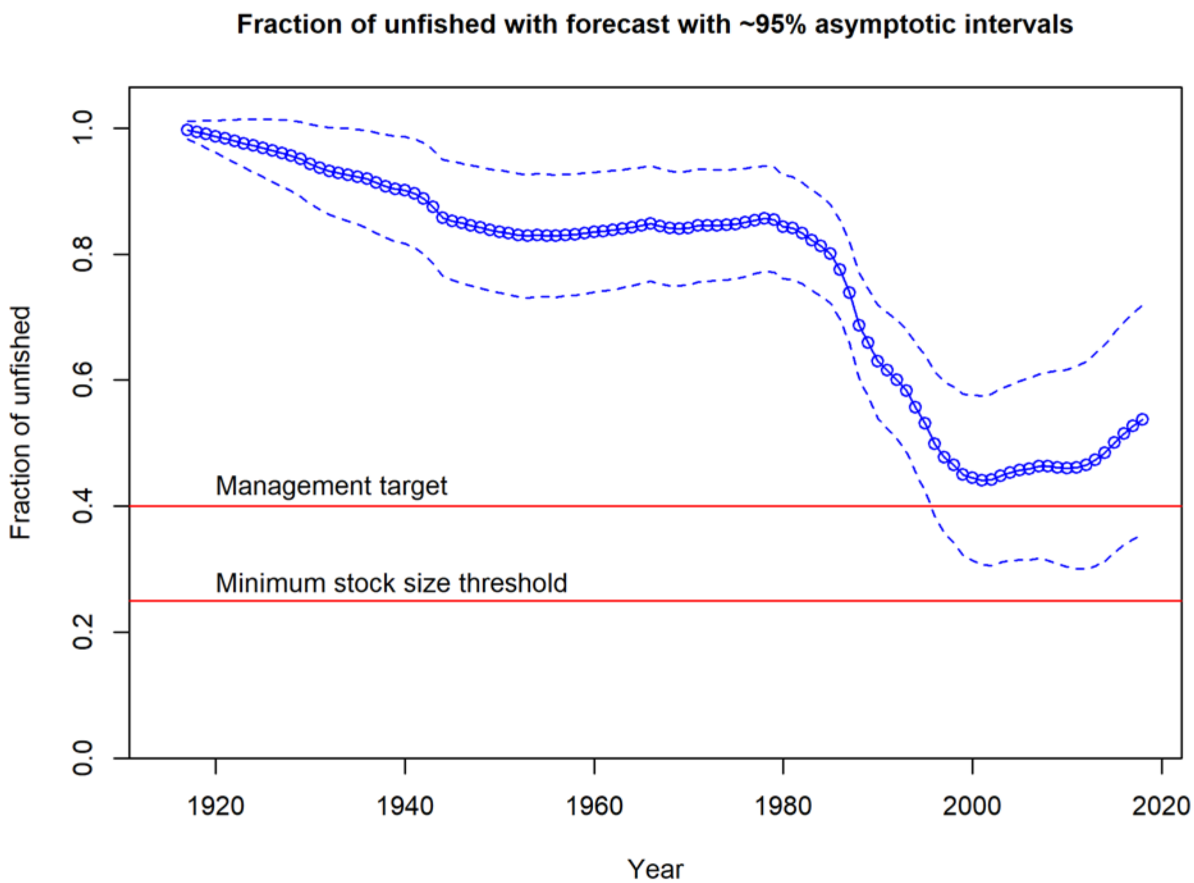

Figure d. Estimated relative depletion with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model.

Table d. Recent trend in spawning potential ratio (entered as 1-SPR) and summary exploitation rate.

Year	Estimated 1-SPR (%)	~95% confidence interval	Harvest rate	~95% confidence interval
2009	55.00	36.7–73.3	0.02923	0.013–0.045
2010	55.12	36.4–73.8	0.02904	0.013–0.045
2011	51.00	32.5–69.5	0.02506	0.011–0.039
2012	48.99	30.2–67.8	0.02291	0.010–0.036
2013	44.22	25.0–62.7	0.01885	0.008–0.029
2014	30.69	14.7-46.7	0.01086	0.005–0.017
2015	38.68	20.9-56.4	0.01574	0.007–0.024
2016	40.55	22.6-58.5	0.01747	0.008–0.027
2017	41.81	23.8-59.8	0.01889	0.009–0.029
2018	50.81	32.9-69.1	0.02833	0.013–0.044

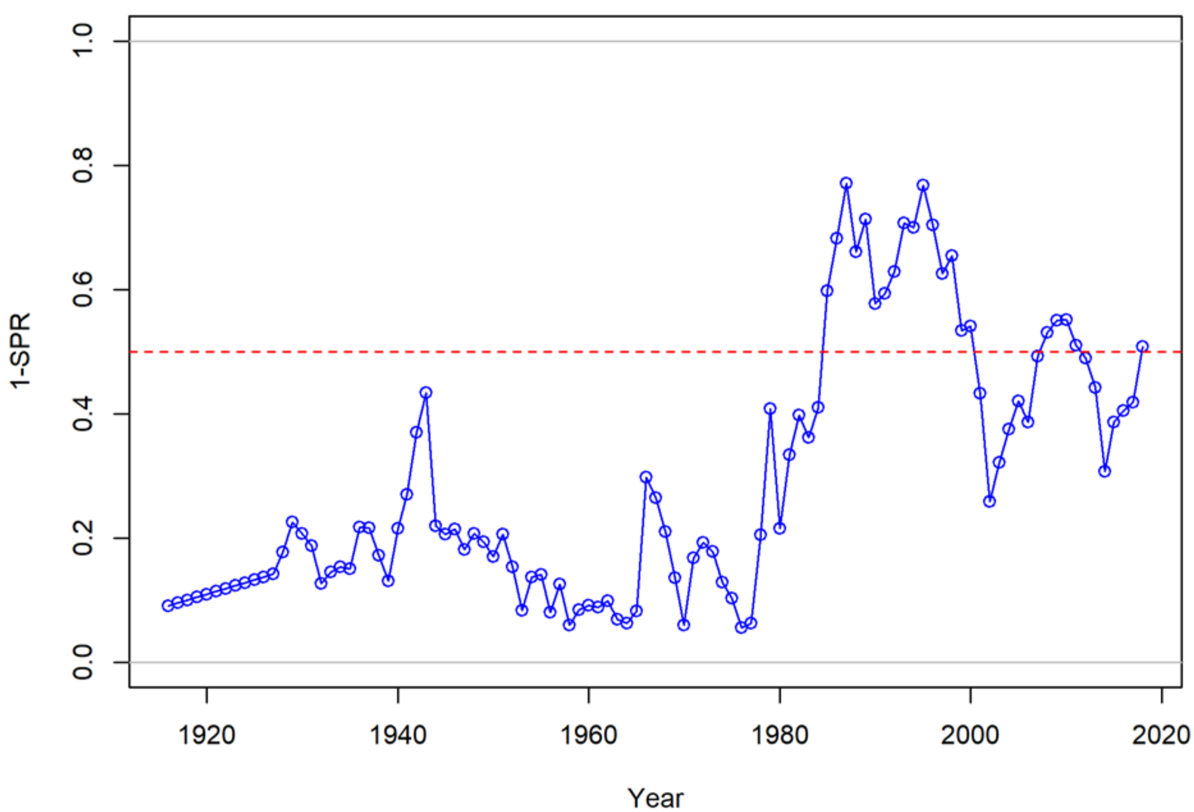

Figure e. Time-series of estimated relative harvest rate (1-SPR)/(1-SPR50%) for the base case model (round points) with approximate 95% asymptotic confidence intervals. The red line is the harvest rate at the overfishing proxy using $SPR_{50\%}$.

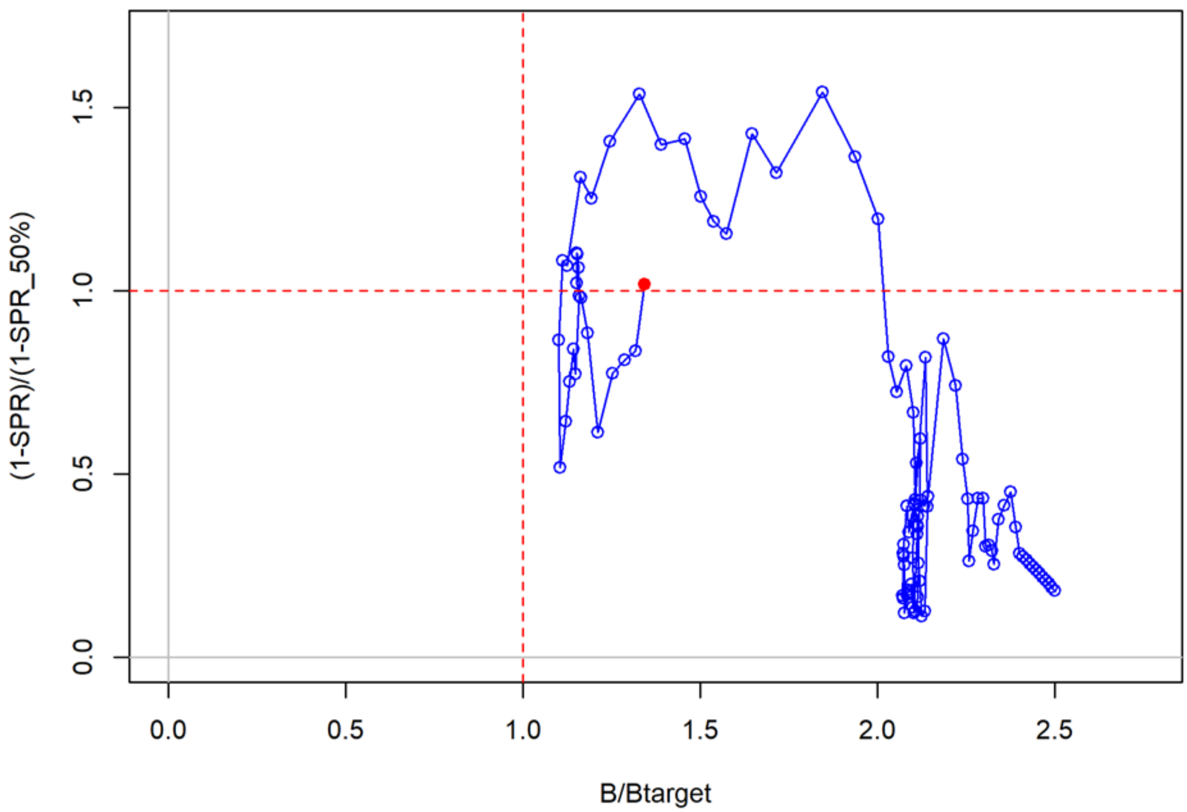

Figure f. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model. The relative (1-SPR) is (1-SPR) divided by 0.5 (one minus the SPR target). Relative depletion is the annual spawning biomass divided by the spawning biomass corresponding to 40% of the unfished spawning biomass. The red point indicates the year 2018.

Ecosystem considerations

Rockfish are an important component of the California Current ecosystem along the U.S. West Coast, with its many dozens of species filling various niches in both soft and hard bottom habitats from the nearshore to the continental slope. Rougheye rockfish are one of the larger species of rockfishes and occupy shelf areas when they are young and move into deeper slope waters with age. As they age, they tend to become more solitary, but may form aggregations during the spawning season. Due to a paucity of life-history data for rougheye rockfish, most ecosystem considerations are implied from the understanding of rockfishes in general.

Recruitment is one mechanism by which the ecosystem may directly impact the population dynamics of rougheye rockfish. The 1999 cohort for many species of rockfish was larger – sometimes significantly so – from these species' long-term averages suggesting that environmental conditions may influence the spawning success and survival of larvae and juvenile rockfish, including rougheye rockfish. The specific pathways through which environmental conditions exert influence on rougheye rockfish dynamics are unclear; however, changes in water temperature and currents, distribution of prey and predators, and the amount and timing of upwelling are all possible linkages. Changes in the environment may also result in changes in age-at-maturity, fecundity, growth, and survival, which can affect how the status of the stock and its susceptibility to fishing are determined. Unfortunately, there are no data for rougheye rockfish that provide insights into these effects.

Fishing has effects on both the age structure of a population as well as the habitat with which the target species is associated. Fishing often targets larger, older fish, and years of fishing mortality results in a truncated age-structure when compared to unfished conditions. Rockfish are often associated with habitats containing living structure such as sponges and corals, and fishing may alter that habitat to a less desirable state. This assessment provides a look at the effects of fishing on age structure, and recent studies on essential fish habitat are beginning to characterize important locations for rockfish throughout their life history, however there is little current information available to evaluate the specific effects of fishing on the population and ecosystem issues specific to rougheye rockfish.

Reference points

Reference points were calculated using the estimated selectivities and catch distribution among fleets averaged across the last five years of the model (2008–2012). Sustainable total yields (landings plus discards) were 194 mt when using an $SPR_{50\%}$ reference harvest rate and ranged from 120 to 269 mt based on estimates of uncertainty. The spawning biomass equivalent to 40% of the unfished spawning output ($SB_{40\%}$) was 2,158 metric tons. The recent catches (landings plus discards) have been slightly below the point estimate of potential long-term yields calculated using an $SPR_{50\%}$ reference point. However, due to high predicted recruitment in 1999, the spawning biomass of the stock has been stable and slightly increasing over the last decade.

Table e. Summary of reference points and management quantities for the base case model.

Quantity	Estimate	~95% Confidence Interval
Unfished Spawning biomass (mt)	5,394	3,976–6,812
Unfished age 10+ biomass (mt)	13,756	9,883–17,629
Unfished recruitment (R0, thousands)	485	291–810
Spawning biomass (2019)	2,914	1,205 – 4,622
SD of log Spawning Biomass (2019)	0.30	–
Depletion (2019)	54.47	36.1 – 72.9
Reference points based on $SB_{40\%}$		
Proxy spawning biomass ($SB_{40\%}$)	2,158	1,590–2,725
SPR resulting in $SB_{40\%}$	44.3%	–
Exploitation rate resulting in $SB_{40\%}$	3.2%	2.9–3.6%
Yield with *SPR* based on $SB_{40\%}$ (mt)	210	129–290
Reference points based on SPR proxy for MSY		
Spawning biomass	2,491	1,836–3,146
SPR_{proxy}	50%	
Exploitation rate corresponding to SPR_{proxy}	2.7%	2.4–3.0%
Yield with SPR_{proxy} at SB_{SPR} (mt)	194	120–269
Reference points based on estimated MSY values		
Spawning biomass at *MSY* (SB_{MSY})	1,305	965–1,644
SPR_{MSY}	29.6%	29.2–30.0%
Exploitation rate corresponding to SPR_{MSY}	5.3%	4.7–5.8%
MSY (mt)	230	142–319

Management performance

Exploitation rates on rougheye rockfish have exceeded *MSY* proxy target harvest rates during the 1980's and 1990's, and only slightly in the mid-2000's. Spawning biomass is predicted to have never fallen below the proxy management target of 40%. Exploitation rates decreased in the late 1990's due to management restrictions, and have increased in recent years. Rougheye rockfish are managed as part of the minor slope rockfish complex, and there were species specific contributions to the OFL catch levels set for the complex in 2011 and 2012. However, catch is measured on the complex as a whole and rougheye landings exceeded the rougheye contributions to the ABC's for the complex in 2011 and 2012. In retrospect, those landings are predicted to have been only slightly above proxy harvest target levels in 2011 and just below them in 2012. The estimated 2018 harvest rate was also just below the proxy harvest level target.

Unresolved problems and major uncertainties

This is the first full stock assessment for rougheye rockfish on the U.S. West Coast and although scientifically credible advice is provided by synthesizing many sources of data, there are still some data and structural assumptions that contribute to uncertainty in the estimates. Major sources of uncertainty include fishing mortality, natural mortality, and growth and are discussed below.

There is little information to accurately determine the catch history for rougheye rockfish. Historically, there are few observations to determine species compositions of landings and often little information to even determine if landings came from trawl or hook & line fisheries. It is uncertain if the landings used in the assessment are likely biased high or low. Recent landings are better determined than historical landings, but there still is uncertainty in the values used in this assessment. The landings of rougheye are not determined exactly, but are predicted by applying an estimated species composition to the landed catch. Furthermore, rougheye rockfish are often difficult to distinguish from blackspotted rockfish and sometimes shortraker rockfish (*S. borealis*). We combined blackspotted and rougheye rockfish catches, but did not make any assumptions about which fish labeled as rougheye may be shortraker and vice versa.

Discards of rougheye rockfish are even more uncertain than landings, but because rougheye rockfish is a marketable species commonly above average size, discard rates are likely lower than less desirable or smaller species. This assessment assumed that discarding was nearly negligible before management restrictions began in 2000. The few observations of rougheye in discarding studies corroborates that discarding was rare before 2000. For the years 2002–2010, the West Coast Groundfish Observer Program (WCGOP) has provided data on discards from vessels that were randomly selected for observer coverage, thus some uncertainty is present in the total amount discarded. The implementation of trawl rationalization in 2011 resulted in almost 100% observer coverage for the trawl fleet and very little incentive to discard rougheye rockfish. However, the fixed-gear fleet is not encompassed by the full observer coverage required under trawl rationalization and data show that discarding of rougheye rockfish occurred on fixed gear vessels in recent years. Uncertainty in recent discards is greatly reduced because of observer coverage, but it is unknown what historical discarding may have been.

Rougheye rockfish are one of the longest lived species of rockfish on the West Coast and therefore natural mortality is likely to be lower than for other rockfish species. With length and age data available only for years after 1994, there are few observations available to monitor the long-term changes of aging cohorts. Therefore, estimates of natural mortality are uncertain. This assessment attempts to capture that uncertainty by estimating natural mortality and integrating that uncertainty into the derived biomass estimates.

Model sensitivities and profiles over M showed that current stock status was highly sensitive to the assumption about natural mortality.

Decision table

Model uncertainty has been described by the estimated uncertainty within the base model and by the sensitivities to different model structure. The parameter that resulted in the most variability of predicted status and yield advice was natural mortality (*M*), which was also estimated with much more certainty than the prior distribution implied. In fact, the 95% confidence interval for *M* was entirely greater than and did not include the point estimate from McDermott (1994), which was used in the assessment of rougheye and blackspotted rockfishes in the Gulf of Alaska assessment (Shotwell et al. 2011), and was greater than and did not include the value assumed in the analysis by Dick and MacCall (2010). It is possible that the base model and the approximate uncertainty intervals based on maximum likelihood theory may not entirely convey the actual uncertainty of this assessment. Preliminary (and non-converged) MCMC tests in 2013 suggested that the uncertainty is greater than depicted by these results.

Therefore, to characterize uncertainty in the assessments, the 2013 STAT used low and high values of natural mortality (0.037 and 0.047). These values closely corresponded to the 95% confidence interval from the likelihood profile, the 95% confidence interval of *M* estimated from the asymptotic variance estimate (0.035–0.049), and the *M* values of 0.037 and 0.047 respectively resulted in 2013 spawning biomass estimates that were near the 12.5% and 87.5% quantiles of spawning biomass from the base model when assuming a lognormal distribution. The 12.5% and 87.5% quantiles were chosen based on the groundfish terms of reference to give the base model a probability that is twice as likely as each alternative state of nature (12.5% and 87.5 are the central quantiles in the tails containing 25% probability).

Due to the unknown differences in life-history between rougheye rockfish and blackspotted rockfish, the Scientific and Statistical Committee (SSC) of the Pacific Fishery Management Council (PFMC) deemed this a Category 2 stock assessment. Therefore, the base sigma to determine the catch reduction (when combined with P*) to account for scientific uncertainty is 1.0.

Table f. Projection of potential OFL, landings, and catch, summary biomass (age-10 and older), spawning biomass, and depletion for the base case model projected with total catch 2019 and 2020 (*in italics*) based on the GMT spreadsheet and recent discard rates, and equal to the predicted ABC afterwards. The predicted OFL is the calculated total catch determined by $F_{SPR=50\%}$.

Year	Predicted OFL (mt)	ABC/ Catch (mt)	Landings (mt)	Age 10+ biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2019		*182*	177	8,393	2,914	54.0%
2020		*182*	177	8,358	2,944	54.6%
2021	237	195	190	8,354	2,965	55.0%
2022	238	195	189	8,333	2,973	55.1%
2023	238	193	188	8,309	2,974	55.1%
2024	238	191	186	8,286	2,971	55.1%
2025	238	189	184	8,263	2,964	54.9%
2026	237	187	182	8,242	2,955	54.8%
2027	236	184	179	8,223	2,944	54.6%
2028	235	182	177	8,207	2,934	54.4%
2029	234	180	175	8,194	2,925	54.2%
2030	234	177	172	8,183	2,916	54.1%

Table g. Summary table of 10-year projections beginning in 2021 for alternate states of nature based on the axis of uncertainty. Columns range over low, mid, and high state of nature, and rows range over different assumptions of total catch levels (discards + retained).

			State of nature					
			Low *M* = 0.037		Base case *M* estimated at 0.042		High *M* = 0.047	
Relative probability of ln(SB_2013)			0.25		0.5		0.25	
Management decision	Year	Catch (mt)	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion
Similar to 2015-2016 catches	2021	142.5	2,087	43.5%	2,965	55.0%	4,191	66.3%
	2022	142.5	2,107	43.9%	2,993	55.5%	4,226	66.8%
	2023	142.5	2,122	44.2%	3,014	55.9%	4,251	67.2%
	2024	142.5	2,133	44.4%	3,030	56.2%	4,269	67.5%
	2025	142.5	2,140	44.6%	3,042	56.4%	4,281	67.7%
	2026	142.5	2,145	44.7%	3,050	56.5%	4,289	67.8%
	2027	142.5	2,149	44.8%	3,056	56.7%	4,294	67.9%
	2028	142.5	2,151	44.8%	3,061	56.7%	4,297	67.9%
	2029	142.5	2,153	44.8%	3,065	56.8%	4,300	68.0%
	2030	142.5	2,155	44.9%	3,068	56.9%	4,302	68.0%
ABC	2021	195.5	2,087	43.5%	2,965	55.0%	4,191	66.3%
	2022	194.6	2,087	43.5%	2,973	55.1%	4,206	66.5%
	2023	193.1	2,082	43.4%	2,974	55.1%	4,211	66.6%
	2024	191.4	2,074	43.2%	2,971	55.1%	4,210	66.6%
	2025	189.1	2,062	43.0%	2,964	54.9%	4,204	66.5%
	2026	186.8	2,050	42.7%	2,955	54.8%	4,195	66.3%
	2027	184.2	2,037	42.4%	2,944	54.6%	4,184	66.1%
	2028	181.8	2,024	42.1%	2,934	54.4%	4,173	66.0%
	2029	179.5	2,011	41.9%	2,925	54.2%	4,162	65.8%
	2030	177.0	2,000	41.7%	2,916	54.1%	4,153	65.7%
Near average catch from 2013 high catch stream.	2021	265	2,087	43.5%	2,965	55.0%	4,191	66.3%
	2022	265	2,061	42.9%	2,947	54.6%	4,179	66.1%
	2023	265	2,030	42.3%	2,921	54.2%	4,158	65.7%
	2024	265	1,993	41.5%	2,890	53.6%	4,130	65.3%
	2025	265	1,954	40.7%	2,855	52.9%	4,096	64.8%
	2026	265	1,912	39.8%	2,818	52.2%	4,059	64.2%
	2027	265	1,870	38.9%	2,779	51.5%	4,020	63.6%
	2028	265	1,827	38.0%	2,739	50.8%	3,980	62.9%
	2029	265	1,784	37.2%	2,700	50.0%	3,941	62.3%
	2030	265	1,742	36.3%	2,661	49.3%	3,902	61.7%

Research and data needs

There are many areas of research that could be improved to benefit the understanding and assessment of rougheye and blackspotted rockfishes. Below, we specifically identify five topics that we believe are most important.

- **Historical landings and discards:** The historical landings and discards are uncertain for rougheye rockfish and improvements would increase the certainty that fishing removals are applied appropriately. Because landings are assumed to be known exactly in the assessment model, uncertainty in the predictions does not include uncertainty in the landings. A thorough look at historical landings, species compositions, and discarding practices would reduce the potential uncertainty that is not entirely accounted for.

- **Natural mortality:** Uncertainty in natural mortality translates into uncertain estimates of status and sustainable fishing levels for rougheye rockfish. The collection of additional age data and improved understanding of the life-history of rougheye rockfish may reduce that uncertainty.

- **Maturity and fecundity:** There are few studies on the maturity of rougheye rockfish and only one has reported the results of a histological analysis. Further research on the maturity and fecundity of rougheye rockfish, the potential differences between areas, the possibility of changes over time, and differences between rougheye rockfish and blackspotted rockfish would greatly improve the assessment of these species.

- **Age data and error:** There is a considerable amount of error in the age data and the ageing of rougheye rockfish has not been validated. Investigating the ageing error and bias would help to understand the influences that the age data have on this assessment.

- **Understanding the stock structure and biology of rougheye and blackspotted rockfishes:** This assessment reports the status of rougheye and blackspotted rockfish as a pooled complex because it is extremely difficult to separate the catches of each species even in recent data, and attempting to do so would greatly increase the uncertainty in the predictions. Because little is known about the respective biology and catch histories of the two species, it is unclear whether managing them as a complex may place one species at disproportionate risk of overfishing relative to the other. We recommend additional research that will provide insight into the distribution, life history, biological characteristics, and catch and discard profiles of the two species. Such an endeavor would like require the efforts of at sea observers in all fleets, biologists aboard fishery-independent surveys, and port samplers along the entire West Coast requiring broad, inter-agency collaboration.

- **Basin-wide understanding of stock structure, connectivity, and distribution:** This is a stock assessment for rougheye rockfish off of the west coast of the U.S. and does not consider data from British Columbia or Alaska. Further investigating and comparing the data and predictions from British Columbia and Alaska to determine if there are similarities with the U.S. West Coast observations would help to define the connectivity between rougheye rockfish north of the U.S.-Canada border.

Table h. Summary table of results for the assessment of rougheye rockfish. OFL values are for 2011 and 2012 were for rougheye specifically. Rougheye and blackspotted rockfish are managed within the minor slope rockfish complex, the OFL and ABC split between north and south of 40° 10'.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Commercial landings (mt)	179.90	173.89	197.83	181.79	149.24	86.43	127.54	141.85	153.71	236.07	NA
Estimated Total catch (mt)	228.72	229.39	202.42	185.51	154.09	89.59	131.42	146.56	159.27	239.61	NA
OFL (mt)	—	—	78.8	78.8	—	—	—	—	215	219	222
ACL (mt)	—	—	—	—	—	—	—	—	196.3	199.9	202.7
1-SPR	0.55	0.55	0.51	0.49	0.44	0.31	0.39	0.41	0.51	0.44	—
Exploitation rate	2.9%	2.9%	2.5%	2.3%	1.9%	1.1%	1.6%	1.7%	1.9%	2.8%	—
Age 10+ biomass (mt)	7,825	7,899	8,077	8,097	8,176	8,251	8,347	8,388	8,433	8,456	8,393
Spawning Biomass	2,489	2,483	2,487	2,511	2,552	2,613	2,703	2,777	2,842	2,897	2,914
~95% Confidence Interval	1,064–3,913	1,038–3,929	1,017–3,956	1,014–4,008	1,124–4,081	1,051–4,176	1,105–4,300	1,146–4,408	1,181–4,503	1,210–4,584	1,205–4,622
Recruitment	358	328	452	449	450	451	453	455	456	458	458
~95% Confidence Interval	157–816	142–757	188–1090	180–1121	180–1123	181–1126	182–1130	183–1133	183–1136	184–1139	184–1140
Depletion (%)	46.1%	46.0%	46.1%	46.6%	47.3%	48.5%	50.1%	51.5%	52.7%	53.7%	54.0%
~95% Confidence Interval	31–61%	30–62%	30–62%	30–63%	30–64%	31–66%	33–68%	34–69%	35–71%	36–72%	36–73%

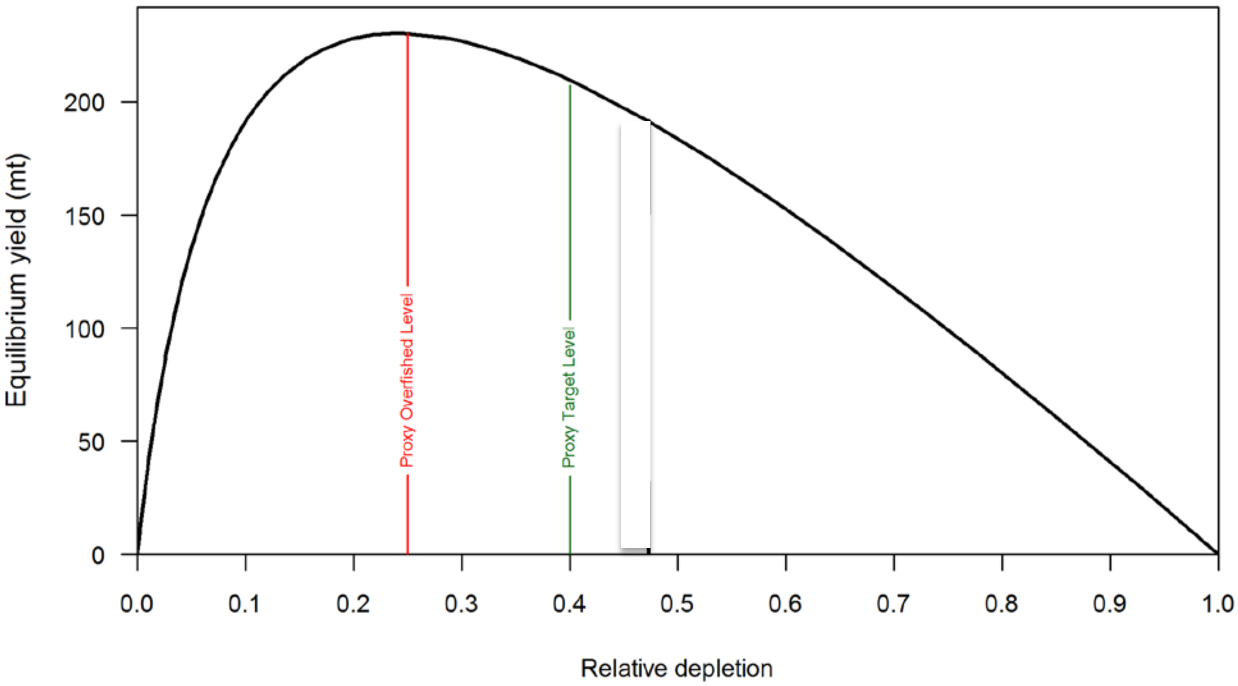

Figure g. Equilibrium yield curve (derived from reference point values reported in Table i) for the base case model. Values are based on 2012 fishery selectivity and distribution with steepness fixed at 0.779.