Agenda Item H.5
Attachment 18
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The status of canary rockfish (*Sebastes pinniger*) in the California Current in 2019: A catch-only update

by

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Executive Summary

This is a catch only update of the 2017 assessment that updated/corrected the 2015 benchmark assessment of the canary rockfish (*Sebastes pinniger*) resource status off the coast of the United States from southern California to the U.S.-Canadian border. The 2017 update used corrected data through 2014 and updated catches in 2015. This catch only update uses catches through 2018 and introduces yearly buffer reductions based on time since last update.

Stock

This assessment uses a three-area model, corresponding approximately to state boundaries (32-42°, 42-46°, 46-49°N) to account for spatial variation in exploitation history among strata.

Catches

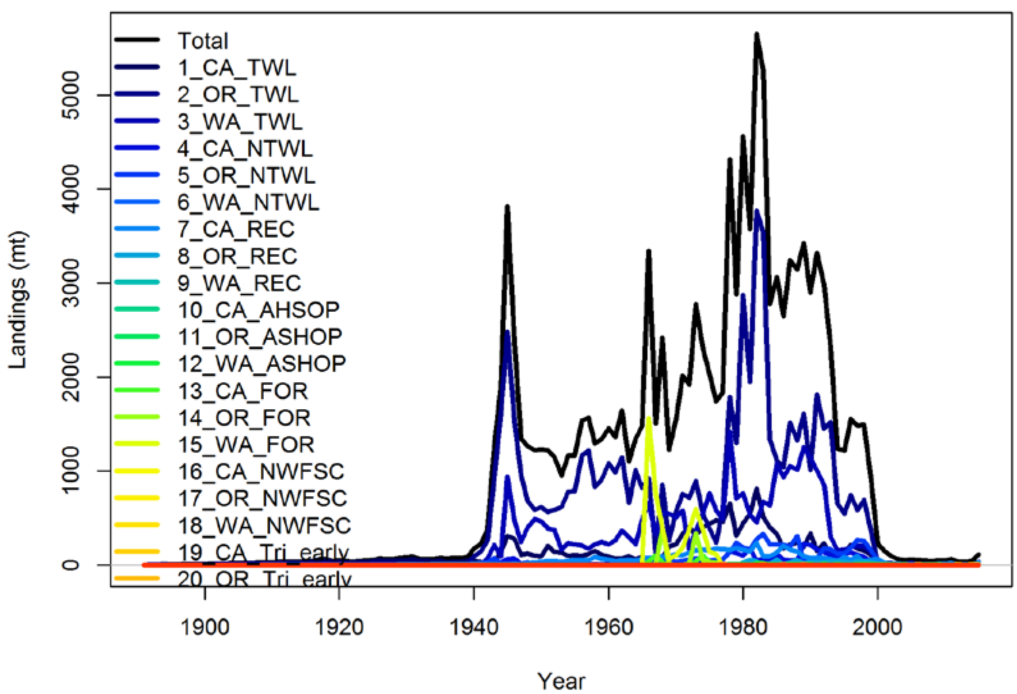
Recent catches have been at historical lows (Table a), with 2012 and 2013 having the lowest catches in nearly one-hundred years (since fishing increased in 1916). Our current (2017) catch reconstruction shows that the first recorded catches commenced in the Oregon non-trawl fishery in 1892, and annual catches reached two peaks, in 1945 (4,187 mt) and again in 1982 (5,652 mt). Catches since 1892 have totaled nearly 127,000 mt. This total is slightly lower (1,000 mt) than the total catch included in the 2015 assessment. Both of these amounts are considerably less than the catch total in the 2007 assessment (148,000 mt), and somewhat higher than amounts included in update assessments in 2009 and 2011 (112,000 mt and 120,000 mt, respectively). These changes are attributable to ongoing updates in the catch reconstruction for California Current groundfishes, the introduction of errant pre-1951 catches in 2015, and the correction of those amounts in the current assessment. Historically, the greatest catches of this stock have come from the domestic and foreign trawl fisheries, although the non-trawl fishery has increased its relative proportion (from 20% in the mid-1990s) to a larger share (25-40% since 2010) of the much smaller recent totals. Similarly, the recreational fishery first exceeded 10% of total catch in 1995, and has ranged widely in annual catch since then. Catch limits and total realized catches were reduced by an order of magnitude starting in 2000 to promote stock rebuilding.

For the 2017 update, WCGOP's estimates for 2016 were not available for inclusion prior to the submission deadline for SSC review, so the ACL value of 125 mt continued to be assumed in that update. This updates adds the catch from 2016-2018 and assumes catch of ~700 mt for 2019 and 2020. While some recruitment values are noticeably different from estimates from 2015 and 2017, biomass and depletion levels at the end of the time series are similar.

Table a: Recent Catches with *2019 & 2020 ACL assumed (and in the forecast)

Year	Catch (mt)
2010	44.4
2011	60.1
2012	34.1
2013	35.8
2014	41.6
2015	112.2
2016	53.6
2017	397.6
2018	592.3
2019	699.2*
2020	695.0*

Figure a: Historical canary rockfish catch for all fleets.



Data and assessment

This update assessment uses Stock Synthesis version 3.24v, which was used in the 2015 and 2017 benchmark assessment. The model includes three spatial strata, uses Pope's approximation to the catch equation, and assumes that expected recruitment is a function of stock-wide spawning output. The model includes abundance indices, and length and conditional age-at-length compositions from the West Coast Groundfish Bottom Trawl Survey (WCGBTS) 2003-2014, and the Alaska Fisheries Science Center triennial sampling program (1980-2004). The model also includes catch and biological data from trawl and non-trawl fisheries, as well as the recreational, foreign, and at-sea hake fisheries, where each fishery's catch is apportioned among 3 spatial strata. Fishery data include total catch (landings plus estimated dead discards) as well as length and age composition data where available. The Southwest Fisheries Science Center (SWFSC)/NWFSC/Pacific Whiting Conservation Cooperative (PWCC) coast-wide pre-recruit survey provides an updated indicator of recent recruitment strength. We include time blocks in trawl and non-trawl fishery selectivity which change between 1999/2000 (to account for changes in fisher behavior following the overfished declaration in 2000), and again for the trawl fishery in 2010/2011 (to account for changes in fishery behavior following the introduction of ITQs).

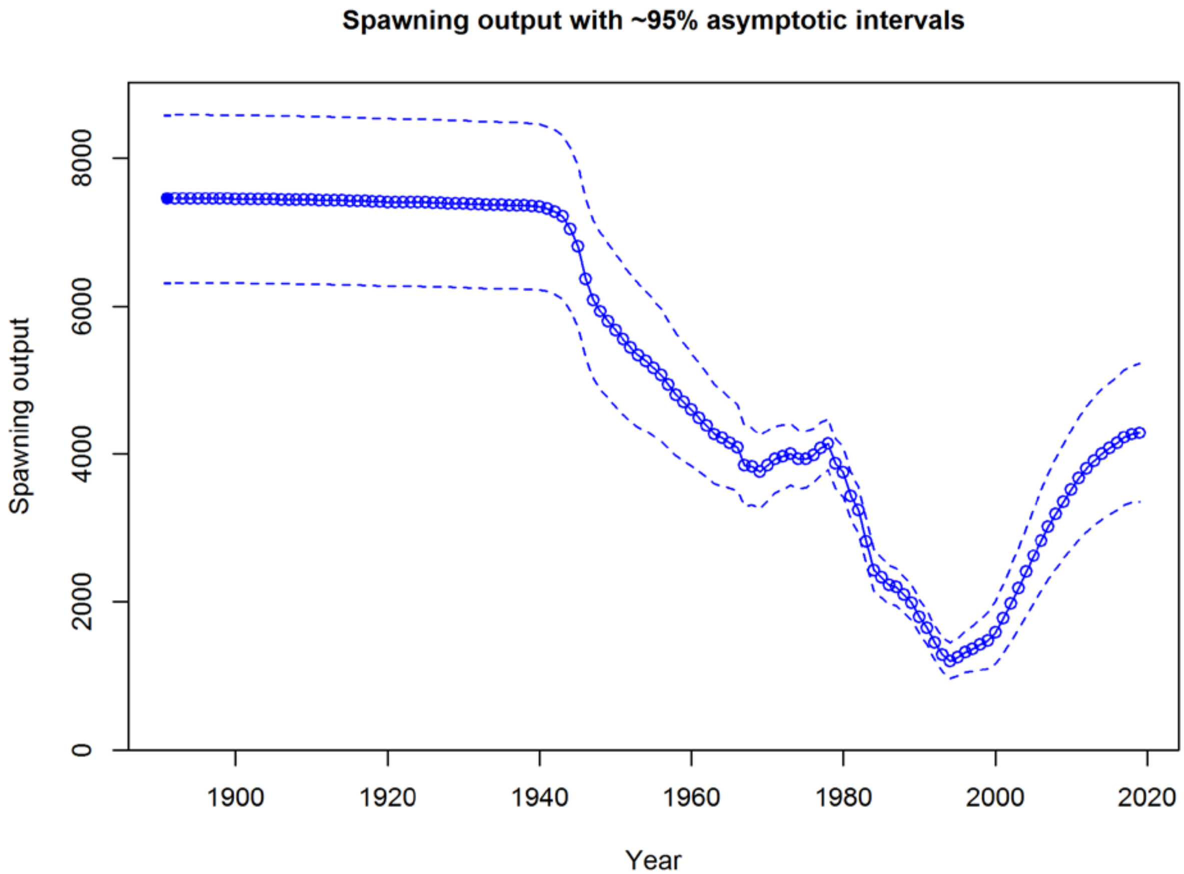
Stock biomass

The canary rockfish stock was relatively lightly exploited until the early 1940s, when catches increased and a decline in biomass began. The rate of decline in spawning biomass accelerated during the early 1980s, and finally stabilized in the late 1990s in response to management measures drastically reducing total catch. The canary rockfish spawning output reached an estimated low 16% in 1994, but has been steadily increasing since that time. The relative depletion level in 2018 is 57.3% (~95% interval: 49-66%), compared to 54.6% estimated in the 2017 update. The 95% confidence interval is based upon the model's analytical estimate of the estimation variance of estimated parameters near their maximum likelihood estimates in the base model configuration.

Table b: Recent trend in beginning of the year spawning output and depletion

Year	Spawning Output (millions eggs)	~95% Confidence Interval	Estimated Depletion (%)	~95% Confidence Interval
2011	3,669	2,842–4,497	49.2	40.0–58.4
2012	3,800	2,951–4,649	51	41.7–60.2
2013	3,907	3,041–4,773	52.4	43.2–61.7
2014	3,995	3,116–4,874	53.6	44.5–62.8
2015	4,074	3,184–4,963	54.7	45.6–63.7
2016	4,144	3,245–5,043	55.6	46.7–64.5
2017	4,223	3,313–5,132	56.7	47.9–65.4
2018	4,270	3,349–5,190	57.3	48.6–66.0
2019	4,285	3,352–5,218	57.5	48.8–66.2
2011	3,669	2,842–4,497	49.2	40.0–58.4

Figure b: Spawning output trajectory (in units millions of eggs) with 95% confidence interval indicated by dashed lines



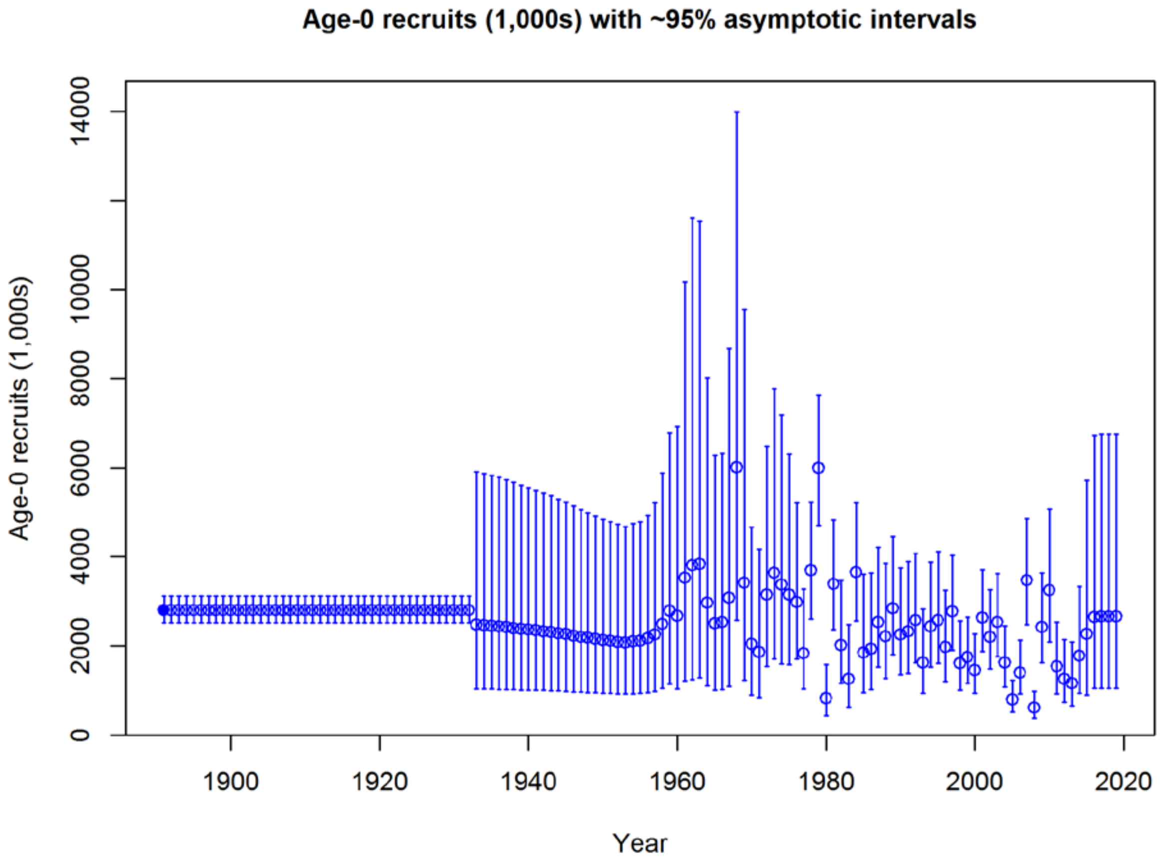
Recruitment

In this 2019 catch-only update, the same prior for recruitment compensation ("steepness") was used as in the prior 2015 stock assessment and 2017 update (i.e., a steepness of 0.773). Given this high level of recruitment compensation, recruitment is not estimated to have substantially declined for canary during the decreased spawning output in the 1980s-2000s (Fig. d), such that 1984 and 1997 both have estimated recruitment near the estimated average level for the unfished population. Recovery after the decrease in fishing during the 2000s has been particularly aided by strong recruitment in 2001-2003, and again by strong cohorts in 2007 and 2009-2010.

Table c: Recent recruitment (95% confidence intervals are calculated assuming a lognormal distribution for recruitment estimates)

Year	Estimated Recruitment (1,000s)	~95% Confidence Interval
2010	3,251	2,083–5,075
2011	1,529	926–2,527
2012	1,255	736–2,141
2013	1,161	646–2,086
2014	1,769	940–3,330
2015	2,261	894–5,716
2016	2,649	1,043–6,728
2017	2,655	1,046–6,744
2018	2,659	1,047–6,753
2019	2,660	1,047–6,756

Figure c: Recruitment estimates (blue circles) and 95% confidence intervals (whiskers) for 1892 – 2019.



Exploitation status

Rockfishes in the California Current are managed to have target spawning potential ratios (SPR) of 50% of their equilibrium values, given recent fleet selectivity patterns and the distribution of catch among sectors. Now that canary has recovered, the fishing intensity for canary rockfish for 2017-2019 is nearer the target level then during the recovery period (Table d). Harvest rates (i.e., total catch divided by biomass of all fishes aged 5 and older) in recent years are now near the highs of 20% in the 1980s and early 1990s. Large decreases in harvest rate were accomplished between 1993/1994 (1993: 16.7%, 1994: 9.2%) and 1999/2000 (1999: 5.8%, 2000: 1.4%).

The extremely low harvest rate of the recent past (when interpreted in conjunction with the higher magnitude of recruitment compensation estimated by recent meta-analyses for rockfishes in the California Current) is estimated to have resulted in a rapid rebuilding of spawning output. In retrospect, spawning output dropped below the target of 40% in 1983, and dropped below the limit of 25% in 1990. During subsequent rebuilding, the population is estimated to have increased above the limit again in 2002 and above the target stock size in 2007.

Table d. Recent trend in spawning potential ratio [entered as (1-SPR)/(1-SPR_50%)] and summary exploitation rate (catch divided by biomass of age-5+ and older fish)

Year	Estimated 1-SPR/(1-SPR_50%)	~95% confidence interval	Harvest rate (proportion)
2010	7.54%	4.65–10.42	0.0164
2011	4.34%	2.62–6.06	0.0215
2012	4.58%	3.19–5.97	0.0115
2013	4.90%	3.37–6.43	0.0118
2014	5.14%	3.53–6.75	0.0129
2015	13.77%	9.79–17.74	0.0323
2016	7.65%	4.21–11.09	0.0151
2017	40.92%	27.70–54.14	0.1084
2018	54.66%	40.77–68.54	0.1614
2019	65.60%	49.14–82.05	0.1879

Figure d. Estimated relative depletion with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model 1892 - 2016.

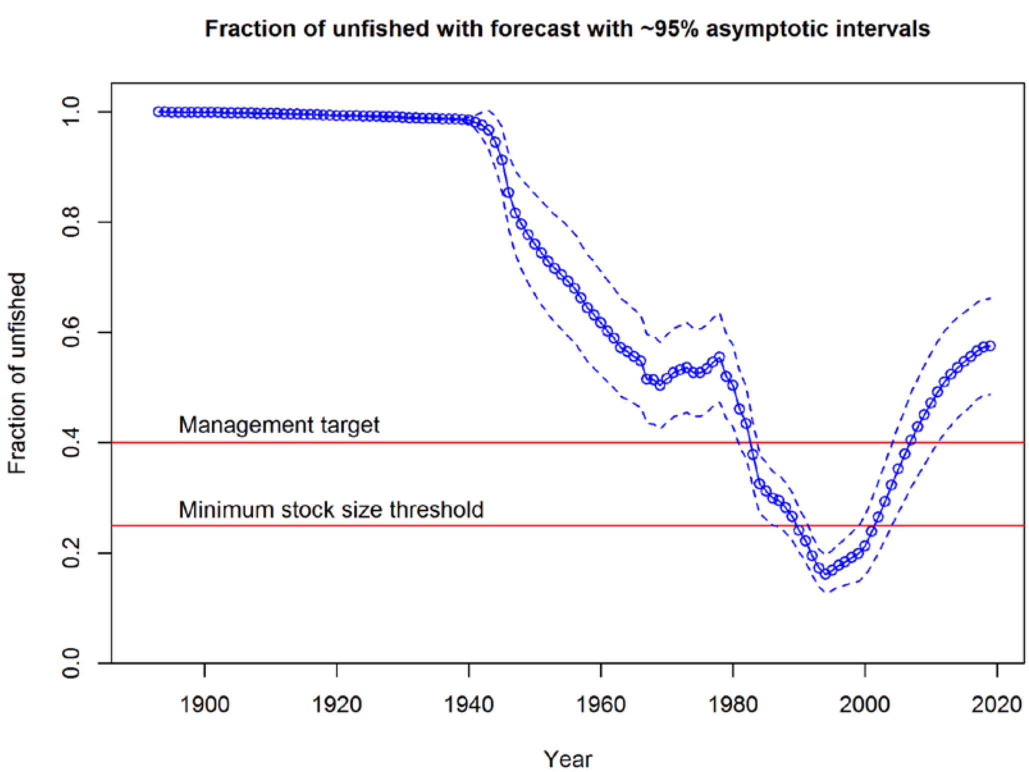


Figure e. Time-series of estimated summary harvest rate (total catch divided by age-5 and older biomass) for the base case model (round points) with approximate 95% asymptotic confidence intervals (grey lines), 1892-2015.

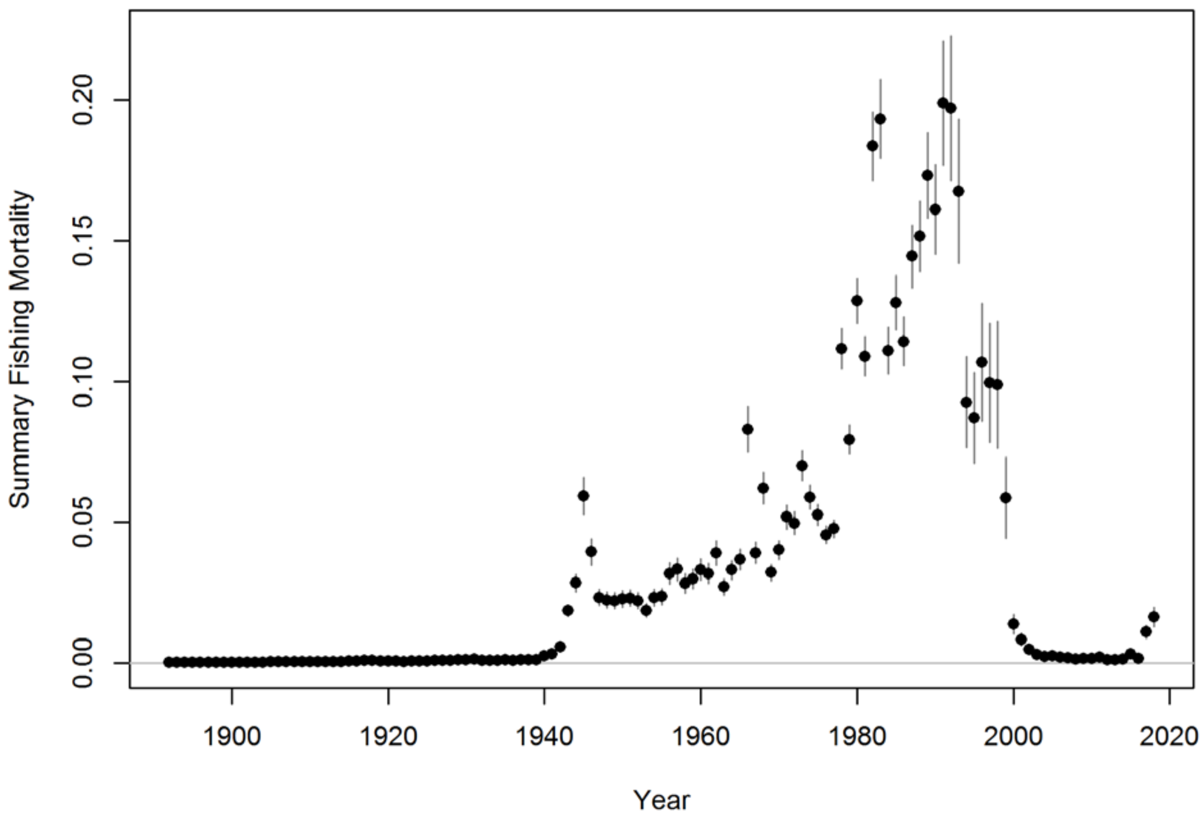


Figure f. Estimated spawning potential ratio (SPR) for the base case model with approximate 95% asymptotic confidence intervals, 1892-2015. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{50\%}$.

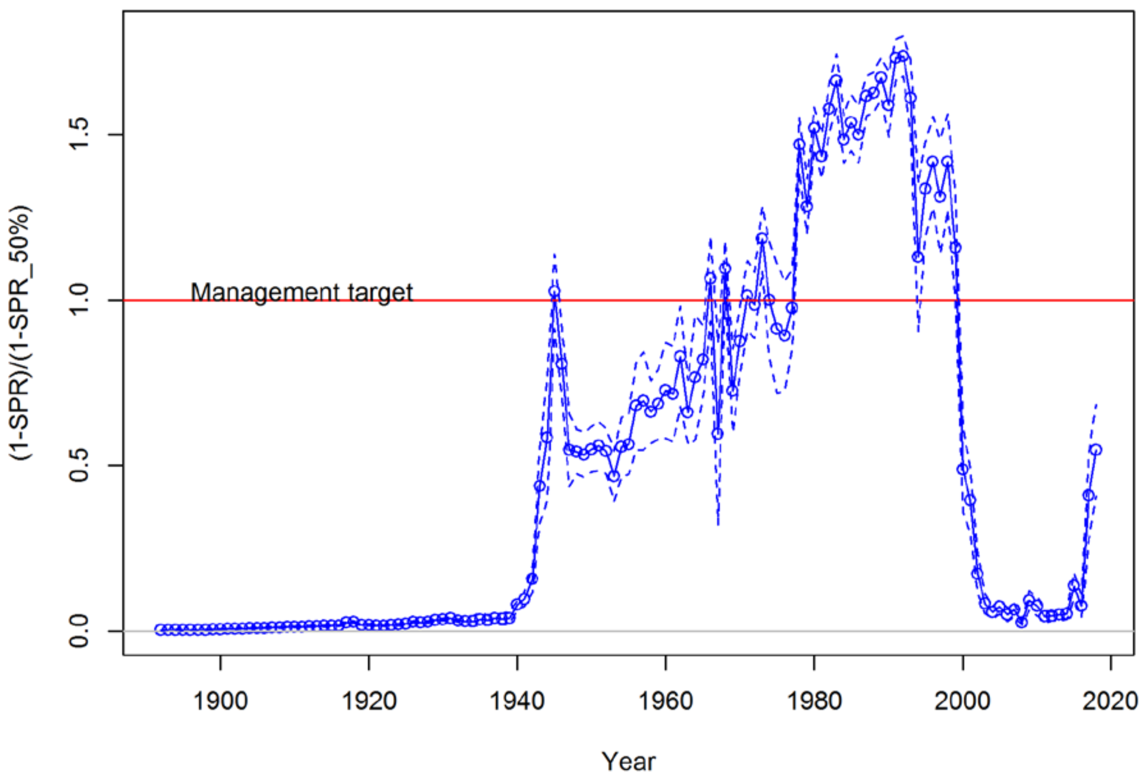
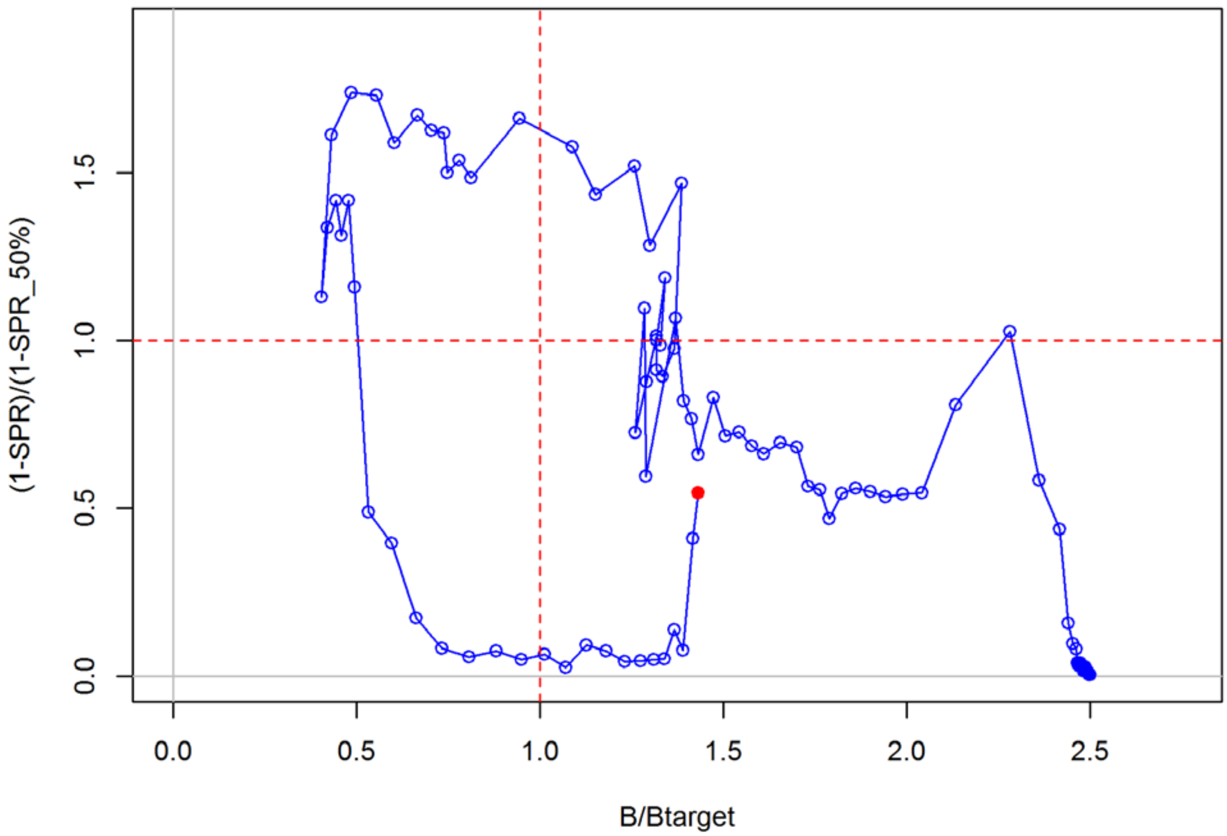


Figure g. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model, 1892-2015. The relative (1-SPR) is (1-SPR) divided by 0.50 (the SPR target). Relative depletion is the annual spawning biomass divided by the spawning biomass corresponding to 40% of the unfished spawning biomass.



Ecosystem considerations

In this assessment, ecosystem considerations were not explicitly included in the analysis. This is primarily due to lack of relevant data and results of analyses (conducted elsewhere) that could contribute ecosystem-related quantitative information for the assessment.

Reference points

Due to time constraints and the similarity of results between the corrected and original models, a revised table of reference point estimates was not generated.

Management performance

Following the overfished declaration in 2000, the canary rockfish optimum yield (OY, currently termed the ACL) was reduced by over 70% in 2000 and by the same margin again over the next three years. Managers employed several tools in an effort to constrain catches to these dramatically lower targets. These included: reductions in trip/bag limits for canary and co-occurring species, the institution of spatial closures, and new gear restrictions intended to reduce trawling in rocky shelf habitats and the coincident catch of rockfish in shelf flatfish trawls. From 2004-2007 (Table e), the total mortality was somewhat above the allowable biological catch but well below the overfishing limit, and from 2008-2014 the total mortality was below the ABC/OFL and ACL/OY. The highest mortality in these 7 years (2011: 60 mt) was approximately 1% of the peak catch that occurred in the early 1980s.

Table e. Recent trend in estimated total catches relative to the management guidelines. Total catch reflect the commercial landings plus the discarded biomass from commercial trawl and non-trawl, recreational, at-sea hake, and research catches from 2004-2016. *2019 & 2020 catches assumed to be ACL.

Year	OFL (mt) (termed ABC prior to 2011)	ABC (mt)	ACL (mt) (termed OY prior to 2011)	Estimated Total Catch (mt)
2008	179	NA	44	36.8
2009	937	NA	105	47.3
2010	940	NA	105	44.4
2011	614	586	102	60.1
2012	622	594	107	34.1
2013	752	719	116	35.8
2014	741	709	119	41.6
2015	733	701	122	112.2
2016	729	697	125	53.1
2017				397.6
2018				592.3
2019				699.2*
2020				695.0*

Unresolved problems and major uncertainties (unchanged from 2015)

We note several important sources of uncertainty regarding our base model:

1. We have adopted a spatially stratified assessment model to account for spatial variation in exploitation history, which would otherwise invalidate the assumption of a single well-mixed population. However, we note that portside estimates of strata-specific landings are likely to represent an imperfect estimate of spatial variation in the distribution of catch at sea. We therefore present estimates from a non-spatial model as a sensitivity analysis, in addition to alternative treatments of selectivity.

2. Another consequence of using a spatial model is that we must implicitly or explicitly account for movement of adults, as well as the degree to which recruitment in each stratum is a

function of local or stock-wide spawning output. Adult movement rates among spatial strata are largely unknown, although previous tagging work and anecdotal information support a localized movement for adults (i.e. low movement among large spatial areas). We have explored the impact of different levels of movement as a sensitivity analysis, but recommend future localized tagging studies (using pop-off tags to avoid the necessity of recovering tagged individuals). While localized tagging studies will never give a clear estimate of coast-wide average movement rates, they can still provide an upper bound on plausible movement rates (which generally will not exceed the rate of emigration seen at fine spatial scales). The relative importance of local vs. stock-wide spawning output on recruitment in each stratum is also unknown. We have therefore taken the common approach of assuming that expected recruitment is a function of stock-wide spawning output. However, we encourage further research regarding the topic.

3. We have fixed the magnitude of recruitment compensation (termed "steepness") and the natural mortality rate for juvenile female and male individuals at the median of the prior distribution estimated for rockfishes in general. However, we note that considerable uncertainty remains regarding these life history parameters for canary rockfish (and for many other species nation-wide and globally). We have explored the impact of different values of steepness as alternative states of nature.

Projections and Decision Tables

The canary rockfish stock assessments are Category 1 stock assessments, thus projections and decision tables are based on using P*=0.45 and the yearly buffer reductions. The yearly buffer reductions are combined with the 40-10 harvest control rule to calculate OFLs, ABCs and ACLs. The total catches in 2019 and 2020 were set at the PFMC groundfish management team (GMT) requested values of ~700 mt. In subsequent years, the projections reflect full catch of the projected ABC/ACL amounts (Table f).

Table f. Summary table of 10-year projections beginning in 2021 for the base case model.

Year	Buffer	OFL Predicted	ACL Predicted	Age 5+ Biomass (mt)	Spawning biomass (mt)	Depletion
2021	0.917	1,450	1,338	36,264	4,226	56.71%
2022	0.913	1,424	1,308	35,696	4,110	55.15%
2023	0.909	1,407	1,285	35,204	4,000	53.67%
2024	0.904	1,395	1,266	34,784	3,903	52.37%
2025	0.900	1,387	1,253	34,432	3,824	51.31%
2026	0.896	1,378	1,239	34,140	3,762	50.48%
2027	0.892	1,368	1,225	33,901	3,715	49.85%
2028	0.887	1,357	1,209	33,706	3,680	49.38%
2029	0.883	1,345	1,193	33,552	3,655	49.04%
2030	0.879	1,333	1,172	33,430	3,637	48.80%

Decision tables forecasting spawning biomass given two alternative harvest control rules (i.e., harvest at the annual catch limit, ACL, and a fixed catch of 700 mt), are shown using states-of-nature involving either alternative values for steepness or natural mortality rate (Tables h.1 and h.2). In each table, we again set total catch in 2019/2020 equal to the GMT preferred values of ~700 mt. Projecting catches for 2021- 2030 using the estimated ACL given the lower state-of-nature for either natural mortality (Table h.1) or steepness (Table h.2) results in declining spawning biomass over these 10 years. By contrast, projecting catches using a fixed catch of 700 mt, given the lower natural mortality or steepness values results in a small increase in spawning output over time. Projecting catches using the estimated ACL and either the base-model values or the upper states of nature for steepness and natural mortality rate results in a steady decline in spawning output towards the target level of 40%. Finally, projecting catches using a fixed catch of 700 mt, given either the base values or upper state-of-nature for steepness or natural mortality, results in a gradual increase or decrease in spawning output over the ten years.

Research and data needs (from 2015 assessment)

We recommend the following research be conducted before the next benchmark assessment model:

1. The canary rockfish stock has high density near the US-Canadian border, so previous assessment authors and STAR panel reports have recommended an assessment model that incorporates landings, abundance index, and compositional data from both US and southern British Columbia regions. However, we do not believe that incorporating heterogeneous data from different sampling programs and management jurisdictions is feasible without using a spatial model (e.g., our base model), both because different jurisdictions are likely to have different exploitation histories, and because different regions are likely to have different data sources (invalidating the second-stage expansion used in coast-wide models). Given the use of a spatial model, we recommend that efforts proceed to gather, document, analyze, and evaluate Canadian data sources for a joint assessment.

2. Direct observation of canary rockfish suggests that individuals are often associated with rocky habitat, and therefore may not be available to the bottom trawl gear used to obtain coast-wide fishery-independent data in the California Current. Recent research suggests that, when (1) a portion of the population is unavailable to survey sampling gear, and (2) the proportion of the population that is unavailable varies among years (e.g., due to density-dependent habitat selection), then survey indices are likely not representative of stock-wide trends in abundance. Therefore, we highly encourage a coast-wide pilot study for an alternative sampling method (e.g., hook-and-line sampling), as well as its calibration against the existing bottom trawl survey via paired sampling methods (J. T. Thorson et al., 2013).

3. A spatial model replaces problematic assumptions in a coast-wide model (i.e., an equally mixed stock in which every individual fish and fishing operation has equal probability of encounter, no spatial variation in density or exploitation history) with other difficult assumptions (Punt et al., 2015). In particular, our base model represents the assumption that

movement is negligible among strata. We therefore recommend that tag-resighting studies be initiated to estimate interannual movement rates.

4. We also note that this assessment, like many other rockfish assessments in the California Current (e.g., darkblotched rockfish) is highly sensitive to assumptions regarding life history characteristics including natural mortality rate and the steepness of the stock-recruit relationship. We therefore recommend ongoing research for these and other life history parameters that form the primary axis of uncertainty for many rockfishes. In particular, research regarding steepness could involve exploration of the impact of autocorrelation within a species, cross-correlation among species, and model mis-specification leading to bias in the reconstruction of spawning output for species included in the prior. Steepness research could also involve a management strategy evaluation to evaluate the potential impact of rapid changes in the assumed value of steepness on management performance (i.e., false positives in detecting overfished or rebuilt stocks). Research regarding natural mortality could involve continued investigations of the relationship between natural mortality and the Brody growth coefficient, as well as how to incorporate prior information regarding this relationship into Stock Synthesis.

Table g. Summary table of the results.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1-SPR (%)	7.54	4.34	4.58	4.90	5.14	13.77	7.65	40.92	54.66	65.60
Exploitation rate (catch/ age 5+ biomass)	0.016	0.022	0.012	0.012	0.013	0.032	0.015	0.108	0.161	0.188
Age 5+ biomass (mt)	30,361	31,156	32,524	33,043	33,986	35,224	35,901	36,443	36,464	36,352
Spawning Output (millions eggs)	3,517	3,669	3,800	3,907	3,995	4,074	4,144	4,223	4,270	4,285
~95% Confidence Interval	2,715–4,319	2,842–4,497	2,951–4,649	3,041–4,773	3,116–4,874	3,184–4,963	3,245–5,043	3,313–5,132	3,349–5,190	3,352–5,218
Recruitment	3,251	1,529	1,255	1,161	1,769	2,261	2,649	2,655	2,659	2,660
~95% Confidence Interval	2,083–5,075	926–2,527	736–2,141	646–2,086	940–3,330	894–5,716	1,043–6,728	1,046–6,744	1,047–6,753	1,047–6,756
Depletion (%)	47	49.2	51	52.4	53.6	54.7	55.6	56.7	57.3	57.5
~95% Confidence Interval	38.1–56.3	40.0–58.4	41.7–60.2	43.2–61.7	44.5–62.8	45.6–63.7	46.7–64.5	47.9–65.4	48.6–66.0	48.8–66.2

Table h.1. Summary table of 10-year projections beginning in 2021 for alternate states of nature based on natural mortality for males and young females. Columns range over low, mid, and high state of nature based on natural mortality for males and young females, and rows range over the ACL catch level and a fixed catch 700 mt. Years in italics and indicated with light blue (i.e., 2023-2030 for the low M state of nature) represent years where the fishery is not able to attain the full ACL catch due to the stock having too low values of biomass.

			State of nature					
			Low $M_{BASE} = 0.025$		Base case $M_{BASE} = 0.0521$		High $M_{BASE} = 0.06$	
Relative probability of ln(SB_2015)			0.25		0.5		0.25	
Management decision	Year	Catch (mt)	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion
ACL	2021	1,338	2,554	34.94%	4,226	56.71%	4,789	62.52%
	2022	1,308	2,412	33.01%	4,110	55.15%	4,666	60.91%
	2023	1,285	*2,272*	*31.08%*	4,000	53.67%	4,550	59.40%
	2024	1,266	*2,139*	*29.26%*	3,903	52.37%	4,450	58.09%
	2025	1,253	*2,018*	*27.61%*	3,824	51.31%	4,368	57.02%
	2026	1,239	*1,908*	*26.11%*	3,762	50.48%	4,305	56.19%
	2027	1,225	*1,810*	*24.77%*	3,715	49.85%	4,257	55.56%
	2028	1,209	*1,721*	*23.55%*	3,680	49.38%	4,221	55.09%
	2029	1,193	*1,643*	*22.48%*	3,655	49.04%	4,194	54.75%
	2030	1,178	*1,574*	*21.53%*	3,637	48.80%	4,175	54.50%
Constant Catch of 700mt	2021	700	2,554	34.94%	4,226	56.71%	4,789	62.52%
	2022	700	2,480	33.93%	4,174	56.01%	4,730	61.74%
	2023	700	2,409	32.96%	4,127	55.38%	4,678	61.07%
	2024	700	2,347	32.11%	4,097	54.98%	4,644	60.63%
	2025	700	2,297	31.43%	4,087	54.85%	4,632	60.47%
	2026	700	2,259	30.91%	4,098	54.99%	4,640	60.57%
	2027	700	2,231	30.53%	4,124	55.34%	4,663	60.87%
	2028	700	2,212	30.27%	4,161	55.84%	4,697	61.32%
	2029	700	2,200	30.10%	4,206	56.43%	4,738	61.85%
	2030	700	2,192	30.00%	4,254	57.09%	4,783	62.43%

Table h.2. Summary table of 10-year projections beginning in 2021 for alternate states of nature based on steepness. Columns range over low, mid, and high state of nature based on steepness, and rows range over the ACL catch and a fixed catch 700 mt.

			State of nature					
			Low h = 0.60		Base case h=0.773		High h=0.946	
Relative probability of ln(SB_2015)			0.25		0.5		0.25	
Management decision	Year	Catch (mt)	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion
ABC	2021	1,338	3,217	42.38%	4,226	56.71%	4,932	67.08%
	2022	1,308	3,107	40.94%	4,110	55.15%	4,802	65.32%
	2023	1,285	3,005	39.59%	4,000	53.67%	4,674	63.58%
	2024	1,266	2,919	38.46%	3,903	52.37%	4,559	62.01%
	2025	1,253	2,851	37.56%	3,824	51.31%	4,459	60.65%
	2026	1,239	2,800	36.90%	3,762	50.48%	4,375	59.51%
	2027	1,225	2,764	36.42%	3,715	49.85%	4,305	58.56%
	2028	1,209	2,739	36.09%	3,680	49.38%	4,247	57.77%
	2029	1,193	2,723	35.87%	3,655	49.04%	4,198	57.11%
	2030	1,178	2,712	35.73%	3,637	48.80%	4,158	56.56%
Constant Catch of 700mt	2021	700	3,217	42.38%	4,226	56.71%	4,932	67.08%
	2022	700	3,167	41.73%	4,174	56.01%	4,866	66.20%
	2023	700	3,127	41.20%	4,127	55.38%	4,804	65.35%
	2024	700	3,105	40.91%	4,097	54.98%	4,756	64.69%
	2025	700	3,105	40.92%	4,087	54.85%	4,725	64.28%
	2026	700	3,126	41.19%	4,098	54.99%	4,713	64.11%
	2027	700	3,164	41.68%	4,124	55.34%	4,716	64.15%
	2028	700	3,212	42.32%	4,161	55.84%	4,729	64.33%
	2029	700	3,267	43.05%	4,206	56.43%	4,749	64.61%
	2030	700	3,326	43.82%	4,254	57.09%	4,774	64.95%