Agenda Item D.8
Attachment 1
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The status of canary rockfish (*Sebastes pinniger*) in the California Current in 2015

by

James T. Thorson and Chantel Wetzel

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

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Executive Summary

Stock

This benchmark assessment reports the status of the canary rockfish (*Sebastes pinniger*) resource off the coast of the United States from southern California to the U.S.-Canadian border using data through 2014. 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 (2015) 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 128,800 mt. This is lower than the total catch reported in the 2007 assessment (148,000 mt), although update assessments in 2009 and 2011 reported a lower total catch (2009: 112,000 mt, 2011: 120,000 mt) due to ongoing updates in the catch reconstruction for California Current groundfishes. The stock has historically had greatest catches from the domestic and foreign trawl fishery, 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 a much smaller total. 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.

Table a: Recent Catches

Year	Catch (mt)
2005	57.6
2006	53.7
2007	47.0
2008	36.8
2009	47.3
2010	44.3
2011	60.1
2012	34.1
2013	35.8
2014	41.6

Figure a: Historical canary rockfish catch for all fleets (left column: by fishing gear where TWL is trawl, NONTWL is non-trawl, REC is recreational, ASHOP is at-sea-hake, FOR is foreign, and SURVEY is West Coast groundfish and triennial bottom trawl surveys; right

column: apportioned by stratum where CA is 32-42°N, OR is 42-46°N, and WA is 46-49°N).**

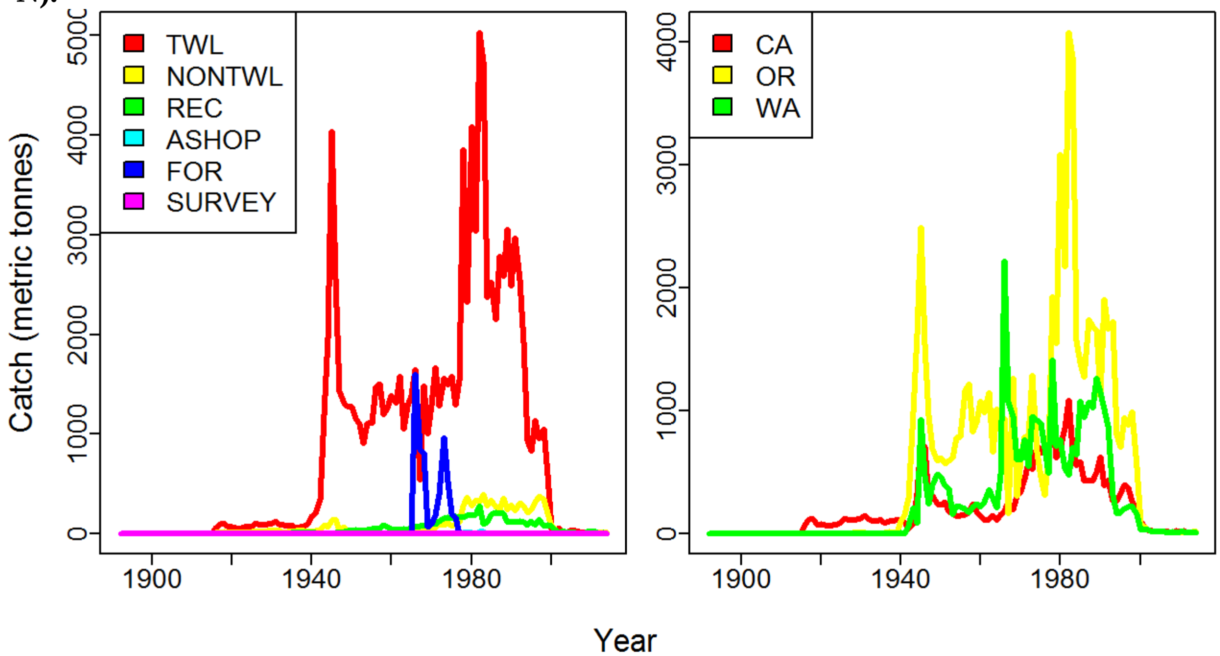
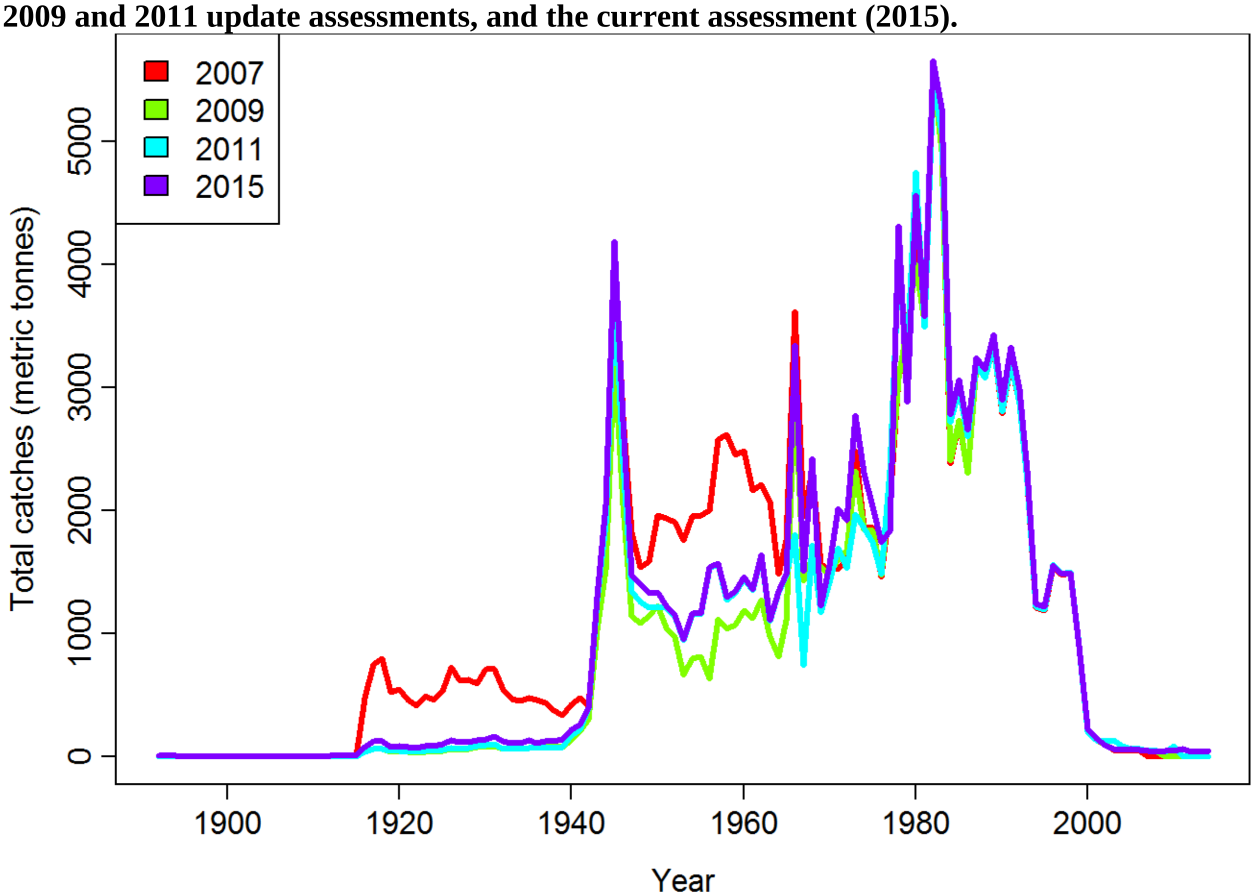


Figure b: Comparison of total canary rockfish catch included in the 2007 assessment, the 2009 and 2011 update assessments, and the current assessment (2015).



Data and assessment

This benchmark assessment uses the newest version of Stock Synthesis available (3.24v), which differs from v3.24u by including an additional feature regarding mirroring of movement parameters (as explored in a subsequent sensitivity analysis). 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. Change in assessment results from 2011 due to software updates was negligible. The model includes abundance index, length, and conditional age-at-length samples 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 fishery data from the trawl and non-trawl fisheries, as well as the recreational, foreign, and at-sea hake fisheries, where each fishery is apportioned among strata. Fishery data include total catch (landings plus estimated dead discards) as well as length and age composition samples 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).

As in previous benchmark and update assessments, the base-case assessment model includes parameter uncertainty from a variety of sources. However, parameter uncertainty does not account for uncertainty about model structure or the value of parameters that are fixed at values that are established externally to the model (MacCall 2013). For this reason, in addition to asymptotic confidence intervals (based upon the model's analytical estimate of the variance of estimated parameters near their maximum likelihood estimates), we also include a comparison of the base model with two alternative states of nature, which reflect different assumptions regarding the strength of recruitment compensation for the population. Specifically these states of nature involve fixing steepness at values that represent the upper and lower 25% of the prior estimated in 2015 for California Current rockfishes (i.e., h=0.600, or h=0.946).

Stock biomass

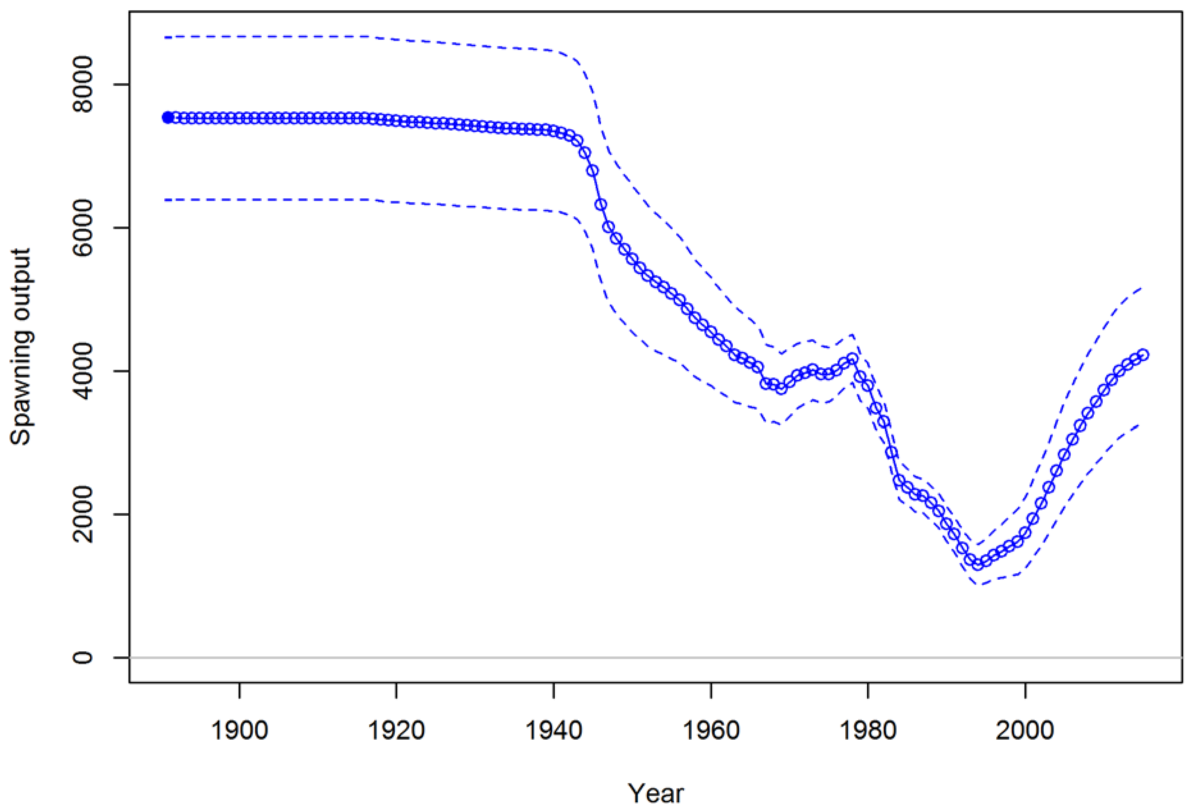
The canary rockfish stock was relatively lightly exploited until the early 1940's, when catches increased and a decline in biomass began. The rate of decline in spawning biomass accelerated during the early 1980s, and finally stabilized in the late 1990s in response to management measures drastically reducing total catch. The canary rockfish spawning output reached an estimated low in 1994, but has been steadily increasing since that time. The estimated relative depletion level in 2015 is 56.0% (~95% interval: 51-61%). 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	~95% Confidence Interval	Estimated Depletion	~95% Confidence Interval

	(millions eggs)			
2006	3,044	2,661-3,427	40.4%	35.9-44.8%
2007	3,234	2,834-3,635	42.9%	38.3-47.5%
2008	3,407	2,992-3,822	45.2%	40.5-49.9%
2009	3,570	3,142-3,999	47.4%	42.6-52.2%
2010	3,727	3,286-4,168	49.5%	44.7-54.3%
2011	3,873	3,421-4,325	51.4%	46.6-56.2%
2012	3,994	3,533-4,455	53.0%	48.2-57.8%
2013	4,089	3,622-4,557	54.3%	49.5-59.1%
2014	4,161	3,689-4,632	55.2%	50.5-59.9%
2015	4,218	3,744-4,693	56.0%	51.4-60.6%

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



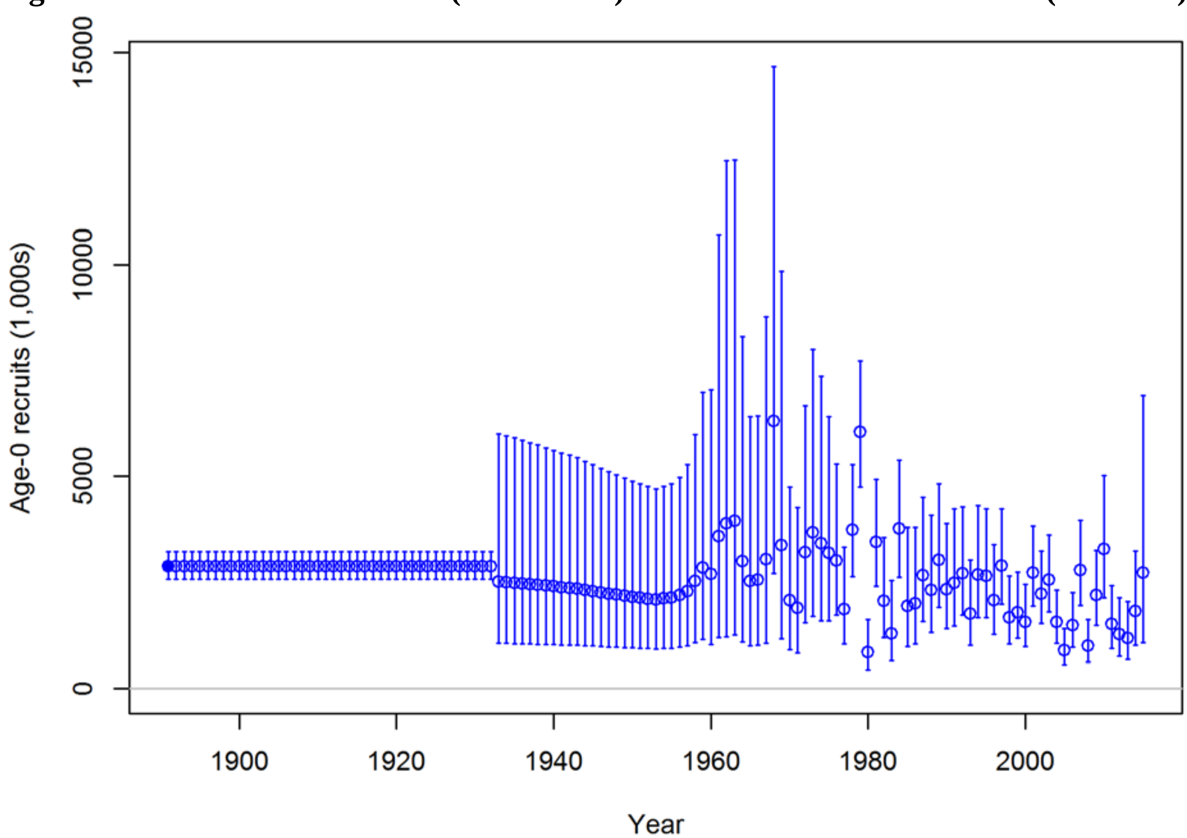
Recruitment

The estimate of rebuilding rate for canary rockfish in this assessment is informed by prior information regarding the strength of recruitment compensation in other rockfishes. In 2015, this prior information indicates that recruitment compensation for rockfishes is in-line with other taxa worldwide (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 2001-2003, and again by strong cohorts in 2007 and 2010 (which are projected to impact spawning output in the coming years).

Table c: Recent recruitment

Year	Estimated Recruitment (1,000's)	~95% Confidence Interval
2006	1,477	969-2,253
2007	2,778	1,949-3,959
2008	1,001	620-1,615
2009	2,193	1,482-3,244
2010	3,274	2,137-5,014
2011	1,509	941-2,421
2012	1,261	747-2,130
2013	1,176	677-2,042
2014	1,809	1,011-3,239
2015	2,719	1,070-6,910

Figure d: Recruitment estimates (blue circles) and 95% confidence intervals (whiskers)



Exploitation status

Rockfishes in the California Current are managed to have a target spawning potential ratio (SPR) of 50% of its equilibrium value in a population given current fishing. By contrast, the fishing intensity for canary rockfish for all recent years (2005-2014) would result in an equilibrium SPR of >96% (Table d). Current fishing corresponds to a harvest rate (i.e., total catch divided by biomass of all fishes aged 5 and older) of 0.09-0.2% for all recent years. Harvest rates were previously as high as 20% in the 1980s and early 1990s, and fishing rates were above the level that would result in 50% equilibrium spawning potential ratio for the majority of years from 1966-1999. Large decreases in harvest rate were accomplished between 1993/1994 (1993: 17.1%, 1994: 9.4%) and 1999/2000 (1999: 4.8%, 2000: 0.8%).

This extremely low harvest rate (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 1982, and dropped below the limit of 25% in 1988. During subsequent rebuilding, the population is estimated to have increased above the limit again in 2001 and above the target stock size in 2006.

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

Year	Estimated 1-SPR (%)	~95% confidence interval	Harvest rate (proportion)	~95% confidence interval
2005	0.032	0.026-0.037	0.0022	0.0020-0.0025
2006	0.027	0.023-0.031	0.0020	0.0017-0.0022
2007	0.032	0.027-0.038	0.0016	0.0014-0.0018
2008	0.020	0.017-0.024	0.0012	0.0011-0.0014
2009	0.044	0.037-0.050	0.0015	0.0013-0.0017
2010	0.034	0.027-0.040	0.0014	0.0012-0.0015
2011	0.022	0.018-0.025	0.0018	0.0016-0.0020
2012	0.022	0.019-0.025	0.0010	0.0009-0.0012
2013	0.023	0.019-0.027	0.0010	0.0009-0.0012
2014	0.025	0.022-0.029	0.0012	0.0010-0.0013

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

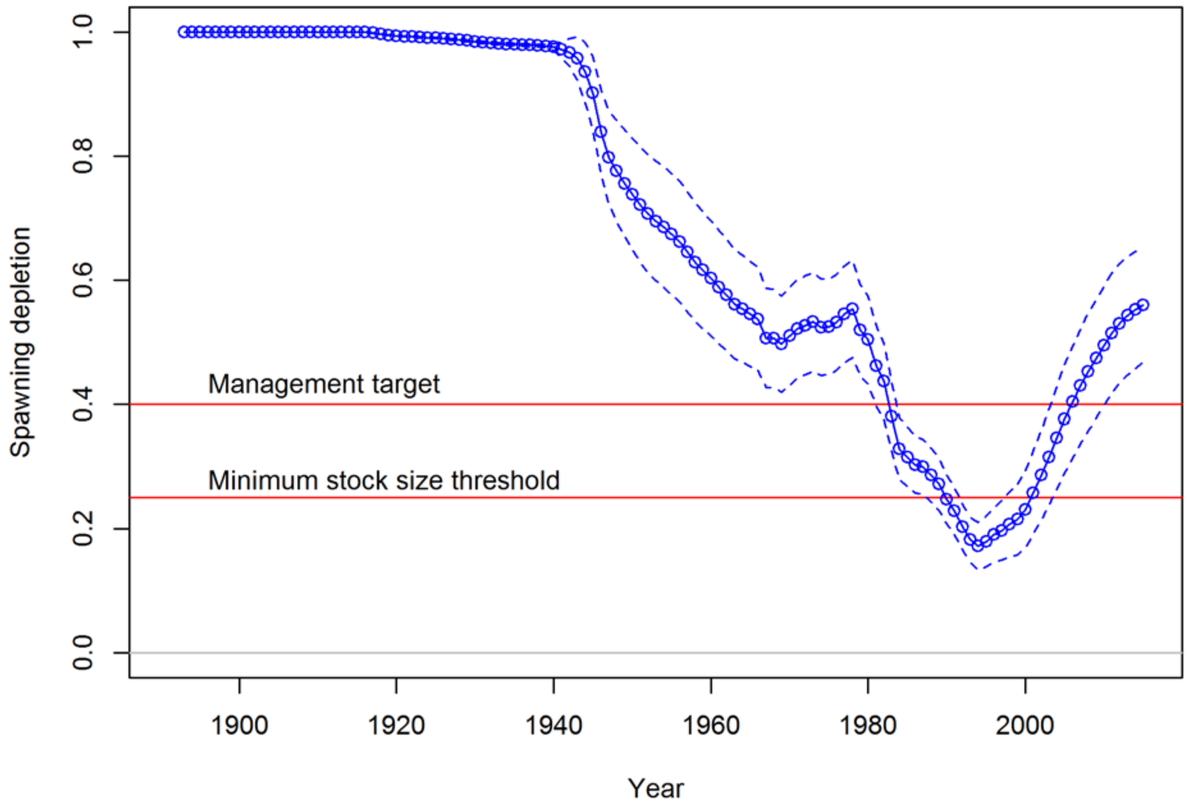


Figure f. Time-series of estimated summary harvest rate (total catch divided by age-5 and older biomass) for the base case model (round points) with approximate 95% asymptotic confidence intervals (grey lines).

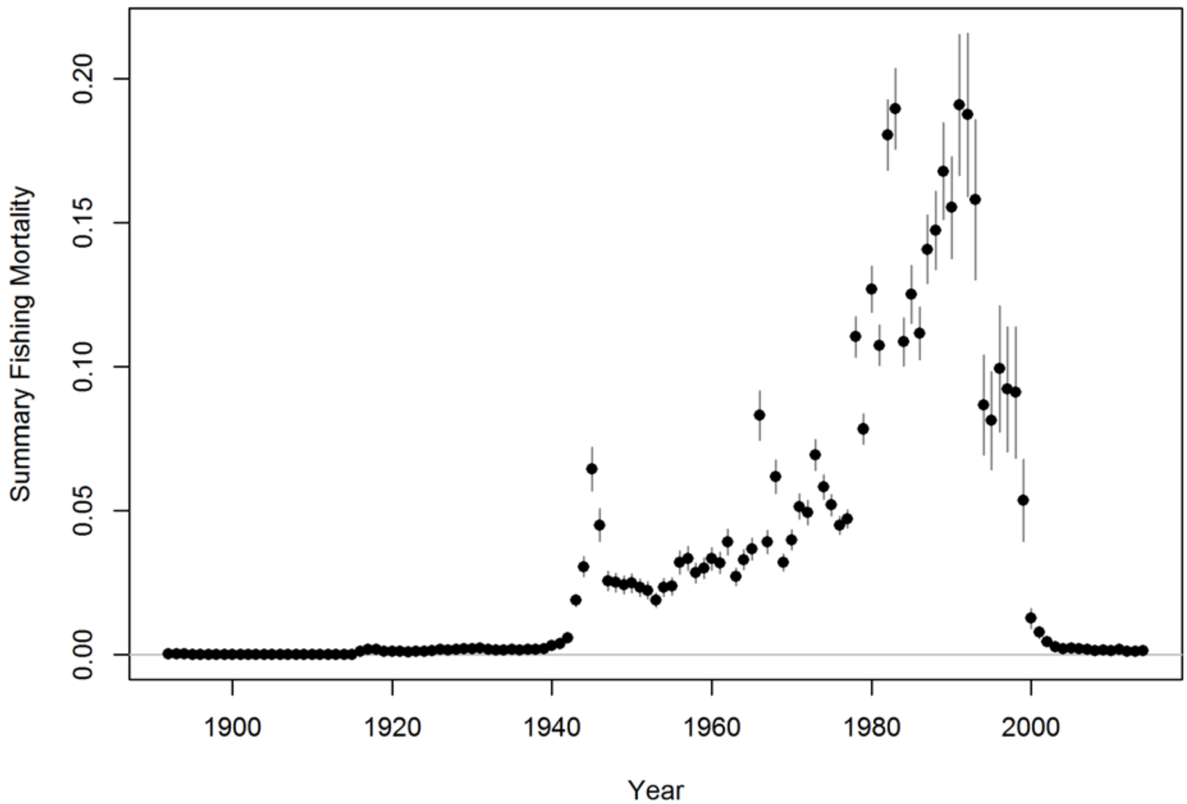


Figure g. Estimated spawning potential ratio (SPR) for the base case model with approximate 95% asymptotic confidence intervals. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is

plotted as red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the SPR50%.

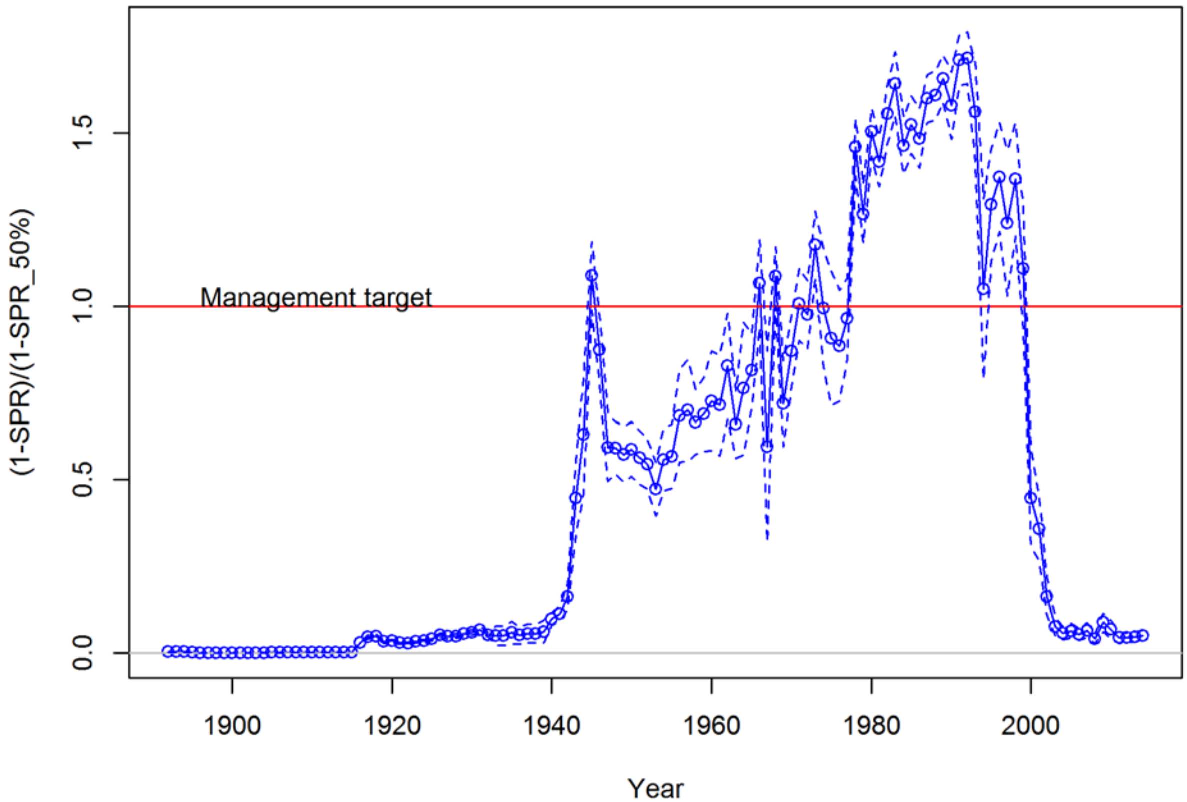
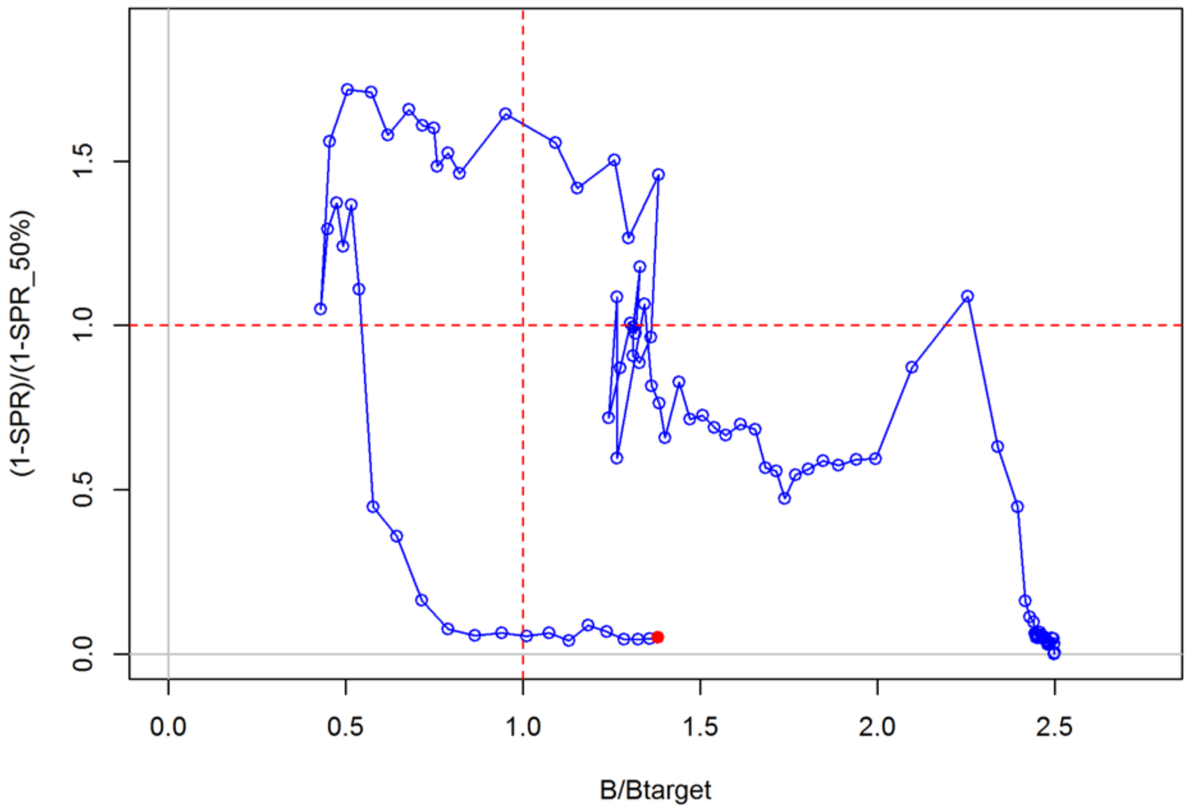


Figure h. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model. The relative (1-SPR) is (1-SPR) divided by 0.50 (the SPR target). Relative

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

Average unfished spawning biomass is estimated to be 26,610 mt. This is directly comparable to previous assessments, despite our use of an updated maturity-at-length schedule, and is slightly lower than the estimate of 27,846 mt in the 2011 update assessment. Average unfished spawning output is estimated to be 7,534 million eggs, and relative spawning output (often termed "depletion" in West Coast assessments) is estimated to be 0.559 in 2015. A comparison among historical assessments shows that this rate of rebuilding is faster than previously estimated due to our updated prior for the strength of recruitment compensation (termed "steepness"). Our base model estimates a target spawning output of 3,014 million eggs using a biological reference point proxy of $SB_{40\%}$ and 3,468 million eggs using a proxy targeting a 50% reduction in spawning potential relative to average unfished levels. Maximum sustainable yield is estimated to be 1,165 mt, and this estimate is considerably higher than the value (803 mt) estimated in the 2011 update assessment.

Table e. Summary of reference points for the base case model (please note that reference points based on MSY and SPR proxy values are identical because the SPR_{MSY} value was estimated to be 50%, which is identical to the SPR_{MSY} proxy).

Quantity	Estimate	~95% Confidence Interval
Unfished Spawning output (millions eggs)	7,534	6,964-8,104
Unfished age 5+ biomass (mt)	72,539	68,627-76,450
Unfished recruitment (R0)	2,876	2,572-3,216
Depletion (2015)	56.0%	51.4-60.6%
Reference points based on $SB_{40\%}$		
Proxy spawning output ($B_{40\%}$ millions eggs)	3,014	2,786-3,242
SPR resulting in $B_{40\%}$ ($SPR_{50\%}$)	0.444	0.444-0.444
Exploitation rate resulting in $B_{40\%}$	0.044	0.042-0.046
Yield with $SPR_{50\%}$ at $B_{40\%}$ (mt)	1,232	1,157-1,307
Reference points based on SPR proxy for MSY		
Spawning output (millions eggs)	3,468	3,206-3,730
SPR_{50}	0.50	
Exploitation rate corresponding to SPR_{50}	0.036	0.035-0.038
Yield with SPR_{50} at SB_{SPR} (mt)	1,165	10,941,237
Reference points based on estimated MSY values		
Spawning output at *MSY* ($SB_{MSY,}$ millions eggs)	3,468	3,206-3,731
SPR_{MSY}	0.50	0.50-0.50
Exploitation rate corresponding to SPR_{MSY}	0.036	0.035-0.038
MSY (mt)	1,165	1,094-1,237

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 f), the total mortality was somewhat above the allowable biological catch but well below the overfishing limit, and from 2008-2014 the total mortality has been below the ABC/OFL and ACL/OY. The highest mortality in these past 10 years (2011: 60 mt) is approximately 1% of the peak catch that occurred in the early 1980's.

Table f. 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 2004-2014.

Year	OFL (mt) (termed ABC prior to 2011)	ABC (mt)	ACL (mt) (termed OY prior to 2011)	Estimated Total Catch (mt)

2004	256	NA	47.3	50.0
2005	270	NA	46.8	57.6
2006	279	NA	47	53.7
2007	172	NA	44	47.0
2008	179	NA	44	36.8
2009	937	NA	105	47.3
2010	940	NA	105	44.3
2011	614	586	102	60.1
2012	622	594	107	34.1
2013	752	719	116	35.8
2014	741	709	119	41.6

Unresolved problems and major uncertainties

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.

Decision table (groundfish only)*

As indicated above, the status and allowable catch for canary rockfish depends strongly on the magnitude of recruitment compensation (steepness), and the rate of natural mortality for juvenile females and males of all ages. In this assessment, both of these parameters have been fixed at values predicted from meta-analysis. We therefore seek to provide information regarding predicted trends in spawning output arising from different potential harvest strategies given uncertainty in the values of these important life history parameters.

As alternative states of nature for steepness, we use values that represent the upper and lower 25% of the prior probability for this parameter (i.e., lower: $h=0.600$, upper: $h=0.946$). As alternative states of nature for natural mortality rate, we use values that result in a similar level of spawning output relative to unfished levels as the states of nature for steepness (i.e., lower: $M=0.025$, upper: $M=0.060$). Projecting catches 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 from 2017-2026 (i.e., a 2026 spawning biomass relative to average unfished levels of 20.8% for the lower natural mortality rate, or 32.5% for the lower steepness level). By contrast, projecting catches using a target SPR of 88.7% results in a small increase in spawning output over time (i.e., a 2026 relative spawning biomass of 37.4% and 47.6% respectively). Similarly, 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 target SPR of 88.7%, given either the base values or upper state-of-nature for steepness or natural mortality results in a gradual increase in spawning output over ten years.

Table h.1. Summary table of 10-year projections beginning in 2017 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 the catch predicted based on the rebuilding SPR harvest rate of 88.7%.

			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	2017	1699	2637	35.3%	4310	57.2%	5297	66.3%
	2018	1525	2487	33.3%	4197	55.7%	5158	64.6%
	2019	1420	2334	31.3%	4082	54.2%	5024	62.9%
	2020	1354	2177	29.2%	3957	52.5%	4880	61.1%
	2021	1308	2023	27.1%	3823	50.7%	4726	59.2%

	2022	1272	1877	25.1%	3693	49.0%	4579	57.4%
	2023	1245	1753	23.5%	3583	47.6%	4456	55.8%
	2024	1224	1671	22.4%	3499	46.4%	4365	54.7%
	2025	1208	1605	21.5%	3440	45.7%	4305	53.9%
	2026	1194	1550	20.8%	3404	45.2%	4271	53.5%
SPR = 88.7% Catches	2017	220	2637	35.3%	4310	57.2%	5297	66.3%
	2018	219	2657	35.6%	4353	57.8%	5316	66.6%
	2019	221	2671	35.8%	4391	58.3%	5332	66.8%
	2020	226	2674	35.8%	4412	58.6%	5330	66.8%
	2021	232	2670	35.8%	4415	58.6%	5310	66.5%
	2022	239	2666	35.7%	4414	58.6%	5287	66.2%
	2023	245	2672	35.8%	4427	58.8%	5280	66.1%
	2024	250	2695	36.1%	4462	59.2%	5300	66.4%
	2025	256	2735	36.6%	4522	60.0%	5347	67.0%
	2026	261	2791	37.4%	4601	61.1%	5417	67.9%

Table h.2. Summary table of 10-year projections beginning in 2017 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 level and the catch predicted based on the rebuilding SPR harvest rate of 88.7%.

			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
ACL	2017	1699	3326	43.4%	4310	57.2%	5030	67.7%
	2018	1525	3199	41.8%	4197	55.7%	4911	66.1%
	2019	1420	3078	40.2%	4082	54.2%	4794	64.5%
	2020	1354	2953	38.5%	3957	52.5%	4662	62.7%

	2021	1308	2826	36.9%	3823	50.7%	4518	60.8%
	2022	1272	2708	35.4%	3693	49.0%	4375	58.9%
	2023	1245	2614	34.1%	3583	47.6%	4249	57.2%
	2024	1224	2548	33.3%	3499	46.4%	4149	55.8%
	2025	1208	2508	32.7%	3440	45.7%	4075	54.8%
	2026	1194	2489	32.5%	3404	45.2%	4024	54.1%
	2017	220	3326	43.4%	4310	57.2%	5030	67.7%
	2018	219	3354	43.8%	4353	57.8%	5074	68.3%
	2019	221	3382	44.1%	4391	58.3%	5110	68.8%
	2020	226	3398	44.4%	4412	58.6%	5125	69.0%
SPR = 88.7% Catches	2021	232	3403	44.4%	4415	58.6%	5118	68.9%
	2022	239	3409	44.5%	4414	58.6%	5103	68.7%
	2023	245	3432	44.8%	4427	58.8%	5097	68.6%
	2024	250	3479	45.4%	4462	59.2%	5112	68.8%
	2025	256	3553	46.4%	4522	60.0%	5148	69.3%
	2026	261	3647	47.6%	4601	61.1%	5203	70.0%

Research and data needs

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 (Thorson et al. 2013b).

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 the 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.

Rebuilding projections

The assessment estimates that the canary stock is fully rebuilt, and has been since 2006. As stated previously (and demonstrated in subsequent sensitivity analyses), the increased rate of rebuilding estimated in this assessment relative to previous assessments is informed in large part by changes in the meta-analytic prior on steepness since the last full canary assessment in 2007. Given that we estimate the stock to have rebuilt, we do not provide any rebuilding projections.

Table i. Summary table of the results.

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Commercial landings (mt)	7.76	12.02	8.16	11.7	14.3	14.82	15.6	14.66	16.72	NA
Total catch (mt)	54.82	47.7	38.06	47.68	45.62	60.48	36.53	35.58	43.29	NA
OFL (mt)	279	172	179	937	940	614	622	752	741	733
ACL (mt)	47	44	44	105	105	102	107	116	119	122
1-SPR	0.027	0.032	0.020	0.044	0.034	0.022	0.022	0.023	0.025	NA
Exploitation rate (catch/ age 5+ biomass)	0.002	0.002	0.001	0.002	0.001	0.002	0.001	0.001	0.001	NA
Age 5+ biomass (mt)	27,246	28,693	30,211	31,376	32,156	32,929	34,006	34,521	35,287	36,411
Spawning Output (millions eggs)	3,044	3,234	3,407	3,570	3,727	3,873	3,994	4,089	4,161	4,218
~95% Confidence Interval	2,661-3,427	2,834-3,635	2,992-3,822	3,142-3,999	3,286-4,168	3,421-4,325	3,533-4,455	3,622-4,557	3,689-4,632	3,744-4,693
Recruitment	1,477	2,778	1,001	2,193	3,274	1,509	1,261	1,176	1,809	2,719
~95% Confidence Interval	969-2,253	1,949-3,959	620-1,615	1,482-3,244	2,137-5,014	941-2,421	747-2,130	677-2,042	1,011-3,239	1,070-6,910
Depletion (%)	40.4%	42.9%	45.2%	47.4%	49.5%	51.4%	53.0%	54.3%	55.2%	56.0%
~95% Confidence Interval	35.9-44.8%	38.3-47.5%	40.5-49.9%	42.6-52.2%	44.7-54.3%	46.6-56.2%	48.2-57.8%	49.5-59.1%	50.5-59.9%	51.4-60.6%

Figure h. Equilibrium yield curve (derived from reference point values reported in Table i) for the base case model.