Agenda Item E.9
Attachment 2
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The status of canary rockfish (*Sebastes pinniger*) in the California Current in 2017: A catch-only update

by

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Executive Summary

This assessment updates/corrects 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, using corrected data through 2014 and updated catches in 2015. During the process of developing other assessments for review during 2017, an error that affected historical commercial landings in California was discovered in the CalCOM database. A review of data series used in earlier assessment cycles indicated that the 2015 canary assessment was one of two assessments conducted in 2015 that included errant California landings prior to 1951. This update was conducted to provide corrected forecasts of canary OFLs and ABCs for 2019-20, and beyond. As part of this update, previously assumed catches for 2015 were replaced with actual fishing mortality estimates.

Additionally, in the process of exploring the best fit (through jittering and alternative phasing) of the 2015 model with updated/corrected catches, a slightly better MLE solution was identified (an improvement of 1 log-likelihood unit), relative to the 2015 base model. This slightly better-fitting model was used as the base model for the 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.

This update includes corrections to catch attributed to California trawl and nontrawl sectors, following discovered of the errors in the CalCom database during the 2017 assessment cycle. Corrected catches for California trawl and nontrawl sectors for years 1916-1950, which were roughly half of the amounts included in the 2015 assessment, are included, along with a linear ramp in catches from 1892-1916. Additionally, fleet catch amounts in 2015, which were assumed to total 122 mt (the ACL) in the prior assessment, were replaced with mortality estimates (totaling 112.2 mt) generated by the West Coast Groundfish Observer Program. 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 continues to be assumed in the update. While some recruitment values are noticeably different from estimates from 2015, biomass and depletion levels at the end of the time series are very similar.

Table a: Recent Catches with *2016 ACL assumed (and in forecast)

Year	Catch (mt)
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
2015	112.2
2016	125*

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).

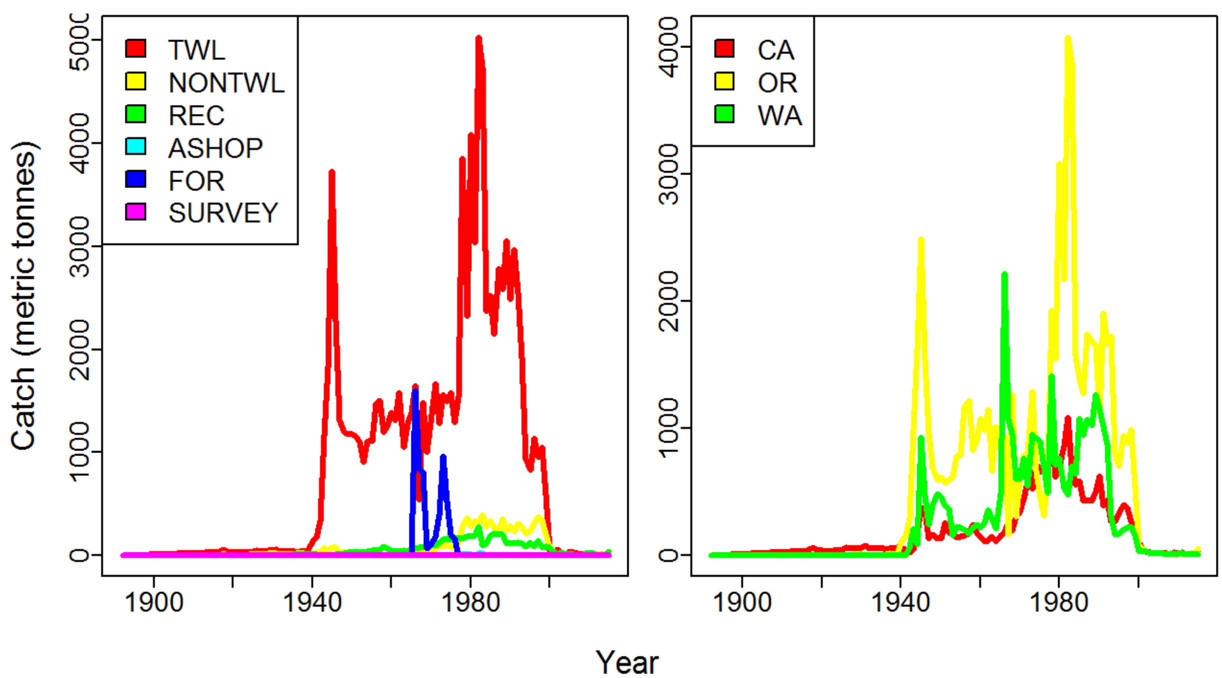
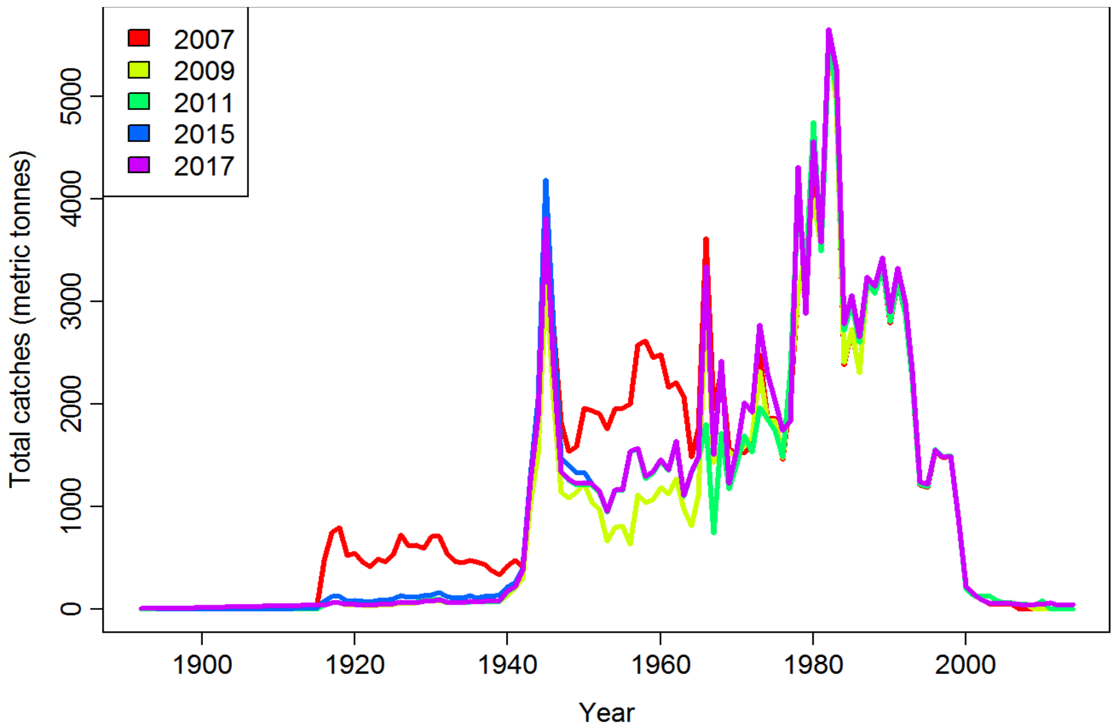


Figure b: Comparison of total canary rockfish catch included in the 2007 assessment, the 2009 and 2011 update assessments, and the last full assessment (2015), and the current catch-only update (2017).



Data and assessment

This update assessment uses Stock Synthesis version 3.24v, which was used in the 2015 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).

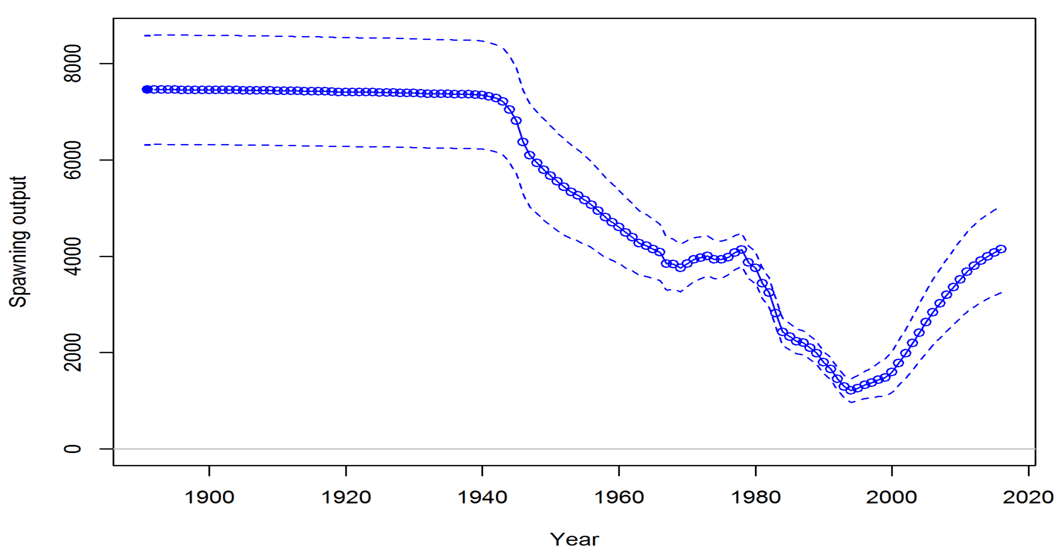
Stock biomass

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 corrected relative depletion level in 2015 is 54.6% (~95% interval: 46-64%), compared to 55.5% estimated in the 2015 stock assessment. 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. A comparison of biomass and depletion estimates from this and the 2015 assessments is provided in Figure 1.

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
2007	3025	2388-3833	40.5	32.0-49.1
2008	3197	2531-4039	42.9	34.0-51.7
2009	3362	2669-4234	45.1	36.1-54.0
2010	3521	2804-4422	47.2	38.1-56.3
2011	3673	2932-4601	49.2	40.0-58.5
2012	3803	3042-4754	51	41.7-60.2
2013	3910	3133-4878	52.4	43.2-61.6
2014	3997	3209-4978	53.6	44.4-62.7
2015	4075	3277-5067	54.6	45.6-63.7
2016	4145	3338-5147	55.6	46.6-64.5

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



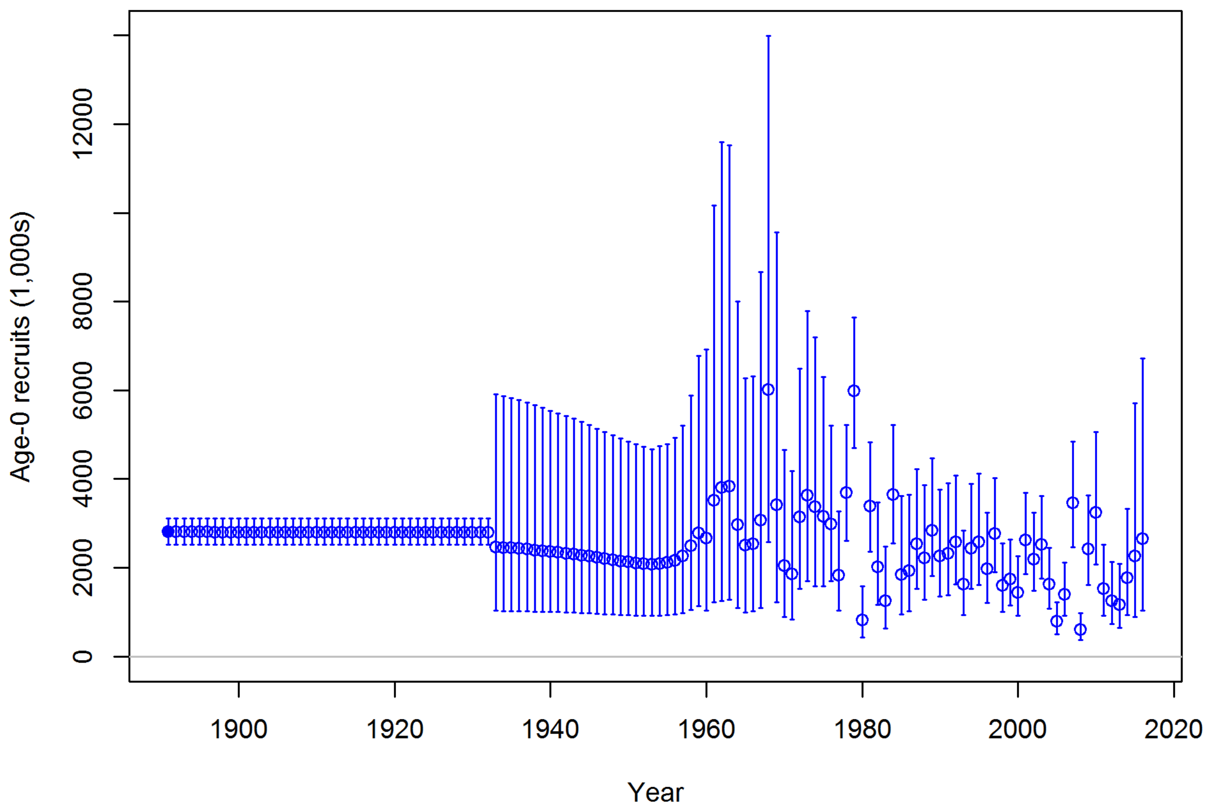
Recruitment

In this 2017 catch-only update, we use the same prior for recruitment compensation ("steepness") as the prior 2015 stock assessment (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 (which are projected to impact spawning output in the coming years).

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

Year	Estimated Recruitment (1,000s)	~95% Confidence Interval
2007	3459	2468-4846
2008	606	375-980
2009	2418	1609-3633
2010	3242	2076-5062
2011	1528	925-2524
2012	1254	735-2139
2013	1160	645-2083
2014	1768	940-3327
2015	2260	894-5713
2016	2647	1042-6723

Figure d: Recruitment estimates (blue circles) and 95% confidence intervals (whiskers) for 1892 – 2016.



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. By contrast, the fishing intensity for canary rockfish 2005-2014 would result in an equilibrium SPR of >96% (Table d). Fishing 2006-2014 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: 16.7%, 1994: 9.2%) and 1999/2000 (1999: 5.8%, 2000: 1.4%).

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 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) 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
2006	2.45%	1.42-3.48%	0.0211	0.0161-0.0261
2007	3.23%	2.17-4.29%	0.0175	0.0134-0.0216
2008	1.28%	0.89-1.68%	0.013	0.0100-0.0160
2009	4.63%	3.16-6.11%	0.016	0.0124-0.0196
2010	3.78%	2.33-5.23%	0.0146	0.0113-0.0179
2011	2.17%	1.31-3.03%	0.0193	0.0150-0.0236
2012	2.29%	1.60-2.99%	0.0105	0.0082-0.0128
2013	2.45%	1.69-3.22%	0.0108	0.0085-0.0132
2014	2.57%	1.76-3.38%	0.0122	0.0096-0.0149
2015	6.89%	4.89-8.88%	0.0319	0.0251-0.0386
2016	7.49%	5.32-9.66%	0.0348	0.0275-0.0421

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

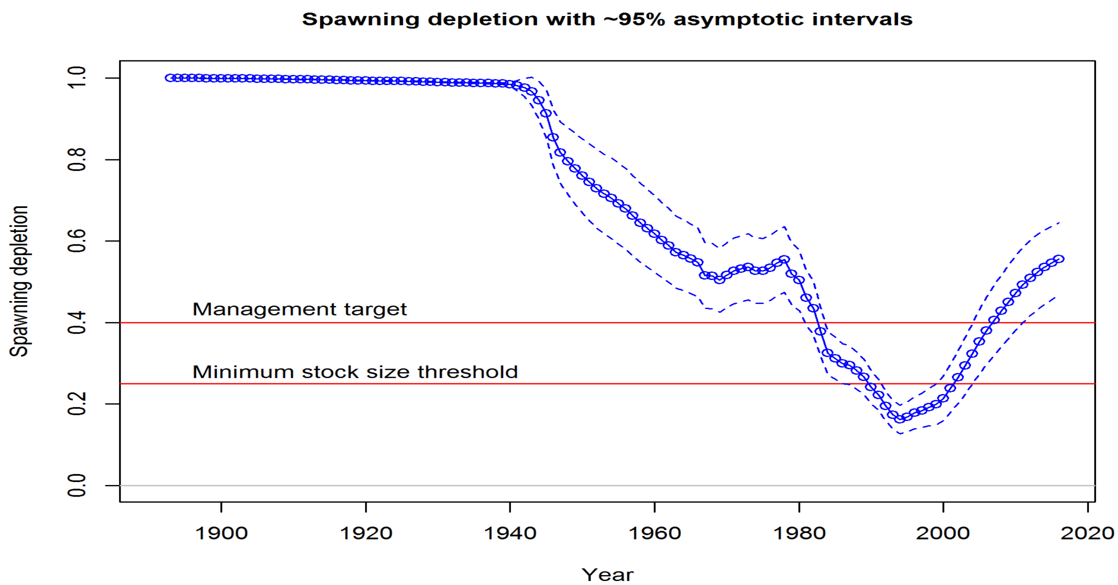


Figure f. Time-series of estimated summary harvest rate (total catch divided by age-5 and older biomass) for the base case model (round points) with approximate 95% asymptotic confidence intervals (grey lines), 1892-2015.

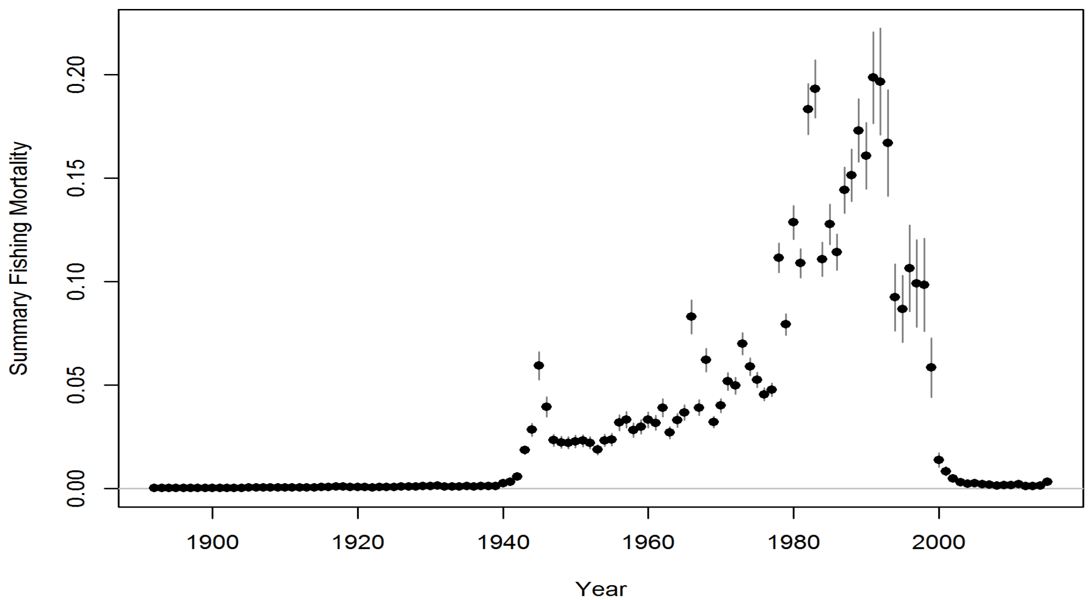


Figure g. Estimated spawning potential ratio (SPR) for the base case model with approximate 95% asymptotic confidence intervals, 1892-2015. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as red horizontal line and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

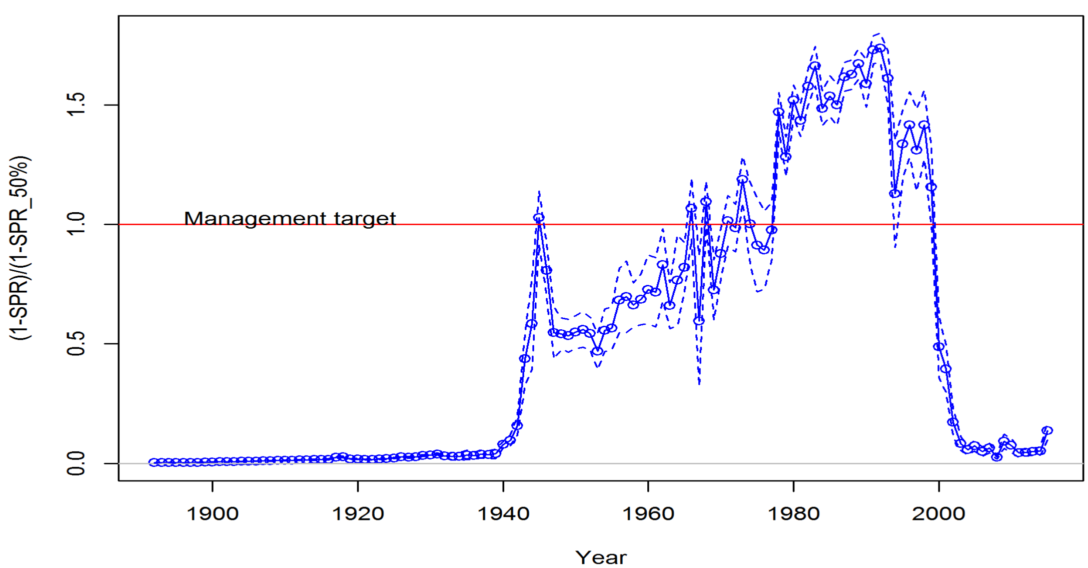
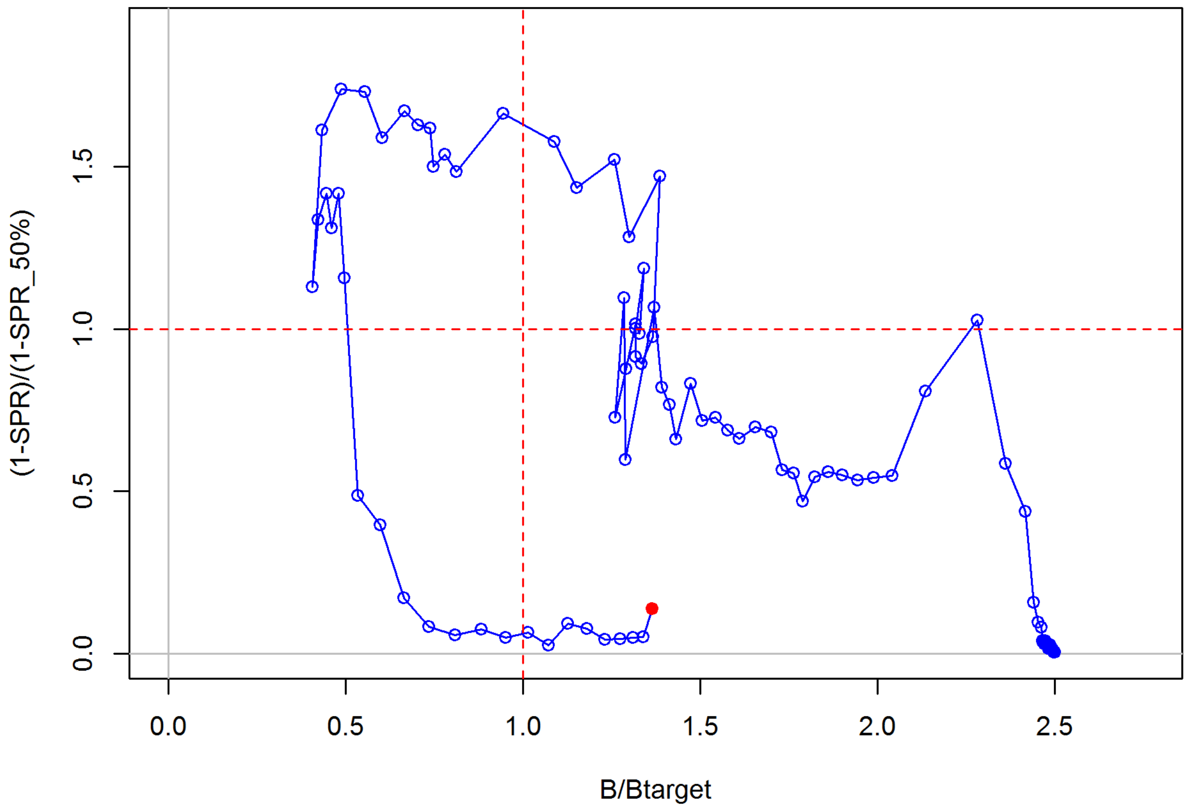


Figure h. Phase plot of estimated relative (1-SPR) vs. relative spawning biomass for the base case model, 1892-2015. The relative (1-SPR) is (1-SPR) divided by 0.50 (the SPR target). Relative depletion is the annual spawning biomass divided by the spawning biomass corresponding to 40% of the unfished 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 f), 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 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 2004-2016. *2016 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)
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
2015	733	701	122	112.2
2016	729	697	125	125*

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

For purposes of projecting management specifications for 2019-20 and beyond, total catch in 2016 was set equal to the ACL (125 mt), and catches in 2017 and 2018 were set at 700 mt and 800 mt, respectively. In subsequent years, the projections reflect full catch of the projected ABC/ACL amounts.

Table h.3. Summary table of 10-year projections beginning in 2017 for the base case model 700 tons in 2017 and 800 tons in 2018, and ACL=ABC for 2019 and beyond.

Year	OFL	ACL	Projected Catch (mt)	Spawning biomass (mt)	Depletion
2017	1793	1714	700*	4217	56.5%
2018	1596	1526	800*	4231	56.7%
2019	1517	1450	1450	4221	56.6%
2020	1431	1368	1368	4110	55.2%
2021	1369	1309	1309	3983	53.6%
2022	1326	1268	1268	3851	51.9%
2023	1296	1239	1239	3729	50.3%
2024	1275	1219	1219	3627	49.0%
2025	1259	1203	1203	3548	48.0%
2026	1245	1190	1190	3491	47.3%

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 i. Summary table of the results.

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total catch (mt)	47.05	36.81	47.3	44.36	60.06	34.15	35.79	41.61	112.2	125
OFL (mt)	172	179	937	940	614	622	752	741	733	729
ACL (mt)	44	44	105	105	102	107	116	119	122	125
1-SPR	3.23%	1.28%	4.63%	3.78%	2.17%	2.29%	2.45%	2.57%	6.89%	7.49%
Exploitation rate (catch/ age 5+ biomass)	0.0175	0.013	0.016	0.0146	0.0193	0.0105	0.0108	0.0122	0.0319	0.0348
Age 5+ biomass (mt)	26848	28368	29581	30373	31163	32525	33040	33978	35210	35883
Spawning Output (millions eggs)	3025	3197	3362	3521	3673	3803	3910	3997	4075	4145
~95% Confidence Interval	2388-3833	2531-4039	2669-4234	2804-4422	2932-4601	3042-4754	3133-4878	3209-4978	3277-5067	3338-5147
Recruitment	3459	606	2418	3242	1528	1254	1160	1768	2260	2647
~95% Confidence Interval	2468-4846	375-980	1609-3633	2076-5062	925-2524	735-2139	645-2083	940-3327	894-5713	1042-6723
Depletion (%)	40.5	42.9	45.1	47.2	49.2	51	52.4	53.6	54.6	55.6
~95% Confidence Interval	32.0-49.1	34.0-51.7	36.1-54.0	38.1-56.3	40.0-58.5	41.7-60.2	43.2-61.6	44.4-62.7	45.6-63.7	46.6-64.5

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

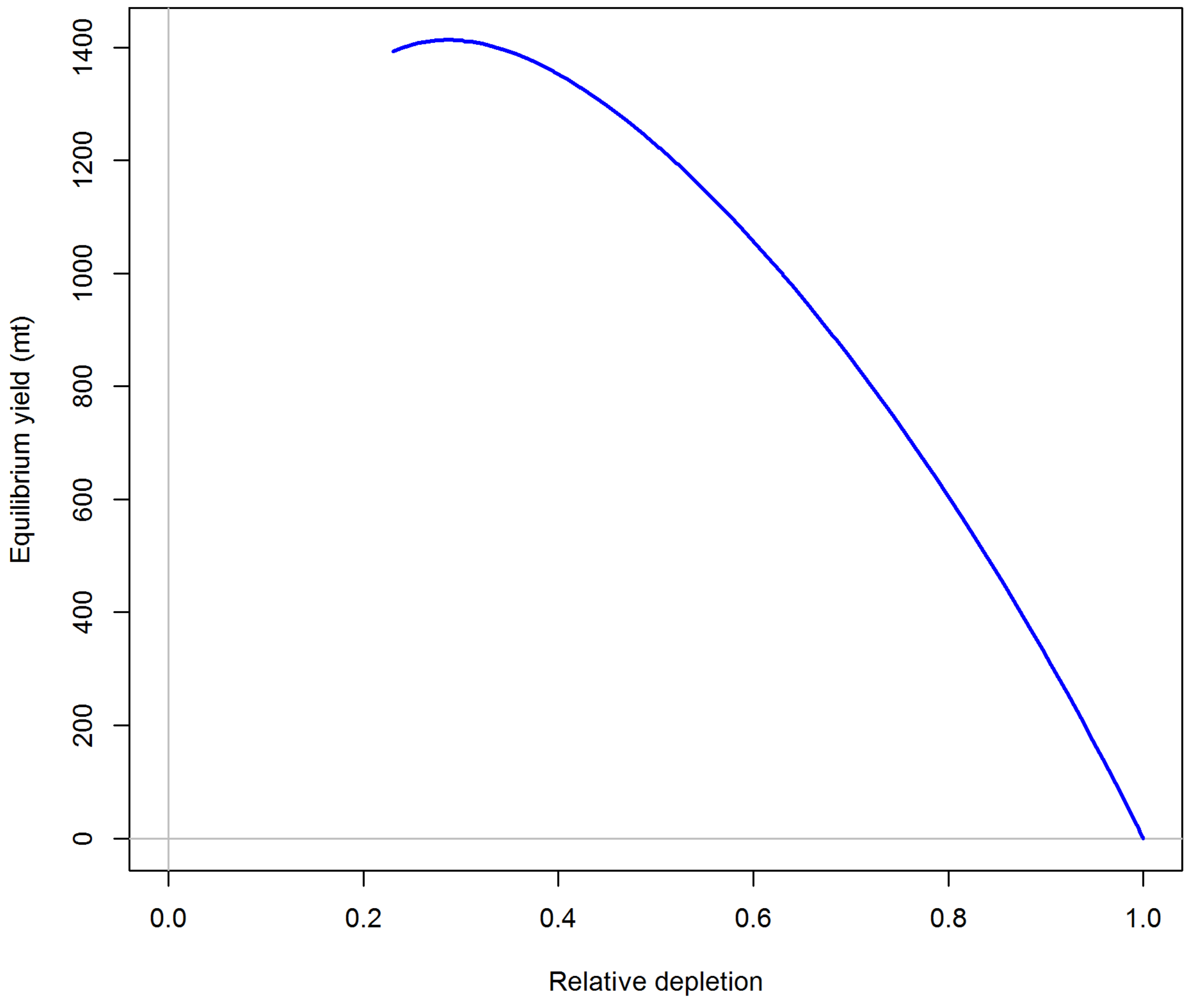


Table 1 – Summary time series for base model

Year	Age 5+ biomass (mt)	Spawning output (millions eggs)	Spawning Depletion	Age-0 recruits (1000s)	Total Catch (mt)	1-SPR (%)	Relative exploitation rate
1892	70994	7461	NA	2803	5.8	0.14	0.00%
1893	70988	7460	1	2803	7.3	0.17	0.00%
1894	70981	7459	1	2803	8.9	0.2	0.00%
1895	70973	7459	1	2803	6.1	0.13	0.00%
1896	70967	7458	1	2803	6.5	0.14	0.00%
1897	70962	7457	1	2803	8.1	0.17	0.00%
1898	70955	7457	1	2803	9.4	0.2	0.00%
1899	70947	7456	1	2803	11.1	0.24	0.00%
1900	70938	7455	1	2803	12.8	0.27	0.00%
1901	70928	7454	1	2803	14.5	0.31	0.00%
1902	70916	7452	1	2802	16.1	0.34	0.00%
1903	70904	7451	1	2802	17.8	0.38	0.00%
1904	70890	7449	1	2802	19.5	0.42	0.00%
1905	70875	7448	1	2802	21.2	0.45	0.00%
1906	70859	7446	1	2802	22.8	0.49	0.00%
1907	70842	7444	1	2802	24.5	0.52	0.00%
1908	70825	7443	1	2802	26.2	0.56	0.00%
1909	70806	7441	1	2802	27.9	0.59	0.00%
1910	70787	7439	1	2802	29.6	0.63	0.00%
1911	70767	7437	1	2802	31.3	0.67	0.00%
1912	70746	7435	1	2802	32.9	0.7	0.00%
1913	70725	7432	1	2802	34.6	0.74	0.00%
1914	70702	7430	1	2802	36.3	0.77	0.10%
1915	70680	7428	1	2802	38	0.81	0.10%
1916	70656	7425	1	2802	39.6	0.85	0.10%
1917	70632	7423	0.99	2802	61.6	1.29	0.10%
1918	70588	7418	0.99	2802	64.2	1.35	0.10%
1919	70543	7414	0.99	2801	41.7	0.9	0.10%
1920	70521	7412	0.99	2801	44	0.95	0.10%
1921	70499	7409	0.99	2801	38.5	0.84	0.10%
1922	70484	7408	0.99	2801	35.8	0.78	0.10%
1923	70472	7407	0.99	2801	42.3	0.92	0.10%
1924	70454	7406	0.99	2801	44.2	0.96	0.10%
1925	70436	7404	0.99	2801	50.7	1.1	0.10%
1926	70412	7402	0.99	2801	66.5	1.42	0.10%
1927	70373	7398	0.99	2801	60.2	1.3	0.10%
1928	70342	7395	0.99	2801	62.8	1.38	0.10%
1929	70310	7392	0.99	2801	73.8	1.65	0.10%
1930	70269	7388	0.99	2801	78.7	1.76	0.10%
1931	70223	7383	0.99	2801	88.3	1.96	0.10%
1932	70171	7378	0.99	2800	65.4	1.52	0.10%
1933	70142	7375	0.99	2468	61.9	1.48	0.10%
1934	70118	7373	0.99	2456	62.1	1.51	0.10%
1935	70094	7371	0.99	2443	73.8	1.78	0.10%
1936	70060	7368	0.99	2429	67.4	1.69	0.10%
1937	70033	7365	0.99	2414	75.5	1.89	0.10%
1938	69882	7362	0.99	2397	74.5	1.88	0.10%
1939	69687	7357	0.99	2378	81	1.98	0.10%
1940	69443	7348	0.98	2359	175.6	4.01	0.30%
1941	69063	7322	0.98	2342	219	4.85	0.30%

Table 1 cont. – Summary time series for base model

Year	Age 5+ biomass (mt)	Spawning output (millions eggs)	Spawning Depletion	Age-0 recruits (1000s)	Total Catch (mt)	1-SPR (%)	Relative exploitation rate
1942	68606	7282	0.98	2325	382.8	7.87	0.60%
1943	67959	7215	0.97	2307	1254.5	21.88	1.80%
1944	66437	7049	0.94	2282	1887.1	29.23	2.80%
1945	64309	6812	0.91	2257	3813.7	51.38	5.90%
1946	60334	6371	0.85	2226	2377.6	40.4	3.90%
1947	57891	6094	0.82	2199	1345.8	27.35	2.30%
1948	56543	5938	0.8	2174	1261.2	27.12	2.20%
1949	55325	5800	0.78	2149	1221.6	26.69	2.20%
1950	54188	5673	0.76	2126	1230.2	27.48	2.30%
1951	53077	5553	0.74	2103	1221.7	28.01	2.30%
1952	52006	5440	0.73	2085	1149.2	27.17	2.20%
1953	51035	5339	0.72	2068	952.8	23.43	1.90%
1954	50282	5262	0.71	2092	1164.5	27.82	2.30%
1955	49336	5166	0.69	2111	1163	28.26	2.40%
1956	48411	5073	0.68	2161	1537.2	34.1	3.20%
1957	47136	4941	0.66	2255	1565.5	34.85	3.30%
1958	45864	4808	0.64	2486	1293.1	33.12	2.80%
1959	44904	4708	0.63	2777	1340.7	34.36	3.00%
1960	43939	4606	0.62	2672	1455.7	36.37	3.30%
1961	42918	4493	0.6	3522	1361.3	35.82	3.20%
1962	42076	4395	0.59	3802	1640.9	41.53	3.90%
1963	41102	4273	0.57	3841	1108.4	33.03	2.70%
1964	40850	4219	0.57	2965	1345.1	38.31	3.30%
1965	40442	4151	0.56	2500	1482	41.01	3.70%
1966	40293	4088	0.55	2533	3343.1	53.32	8.30%
1967	38601	3845	0.52	3073	1508.1	29.8	3.90%
1968	38983	3834	0.51	6007	2420.2	54.79	6.20%
1969	38354	3759	0.5	3417	1228.5	36.31	3.20%
1970	38803	3850	0.52	2039	1553.4	43.86	4.00%
1971	38907	3931	0.53	1863	2013.8	50.72	5.20%
1972	38699	3966	0.53	3148	1921.2	49.27	5.00%
1973	39622	4002	0.54	3635	2773.6	59.35	7.00%
1974	39153	3933	0.53	3378	2303.3	50.07	5.90%
1975	38704	3930	0.53	3155	2030.4	45.69	5.20%
1976	38312	3982	0.53	2976	1741.8	44.66	4.50%
1977	38470	4076	0.55	1835	1833.2	48.82	4.80%
1978	38678	4139	0.55	3691	4314.8	73.49	11.20%
1979	36386	3876	0.52	5990	2885	64.16	7.90%
1980	35464	3757	0.5	825	4560.4	76.03	12.90%
1981	32839	3437	0.46	3383	3575.4	71.78	10.90%
1982	30818	3246	0.44	2010	5652.2	78.86	18.30%
1983	27282	2819	0.38	1252	5268.6	83.13	19.30%
1984	25073	2425	0.33	3652	2777.4	74.24	11.10%
1985	23967	2329	0.31	1849	3062	76.84	12.80%
1986	23248	2231	0.3	1934	2653.5	74.97	11.40%
1987	22498	2203	0.3	2534	3244.7	80.88	14.40%
1988	20790	2103	0.28	2218	3147.1	81.35	15.10%
1989	19806	1987	0.27	2846	3427.4	83.6	17.30%
1990	18030	1801	0.24	2261	2900	79.4	16.10%
1991	16729	1655	0.22	2325	3323.3	86.54	19.90%
1992	15167	1452	0.19	2578	2983.8	86.9	19.70%
1993	13869	1292	0.17	1627	2317.3	80.59	16.70%
1994	13456	1210	0.16	2431	1242.8	56.44	9.20%
1995	13999	1259	0.17	2577	1214.9	66.78	8.70%
1996	14615	1330	0.18	1976	1555.1	70.84	10.60%
1997	14991	1373	0.18	2762	1485.7	65.56	9.90%

Table 1 cont. – Summary time series for base model

Year	Age 5+ biomass (mt)	Spawning output (millions eggs)	Spawning Depletion	Age-0 recruits (1000s)	Total Catch (mt)	1-SPR (%)	Relative exploitation rate
1998	15120	1433	0.19	1598	1488.6	70.84	9.80%
1999	15429	1483	0.2	1740	900.6	57.82	5.80%
2000	16378	1595	0.21	1447	223.7	24.37	1.40%
2001	17824	1783	0.24	2617	148.1	19.78	0.80%
2002	19597	1982	0.27	2189	94.3	8.6	0.50%
2003	21078	2193	0.29	2520	61.2	4.12	0.30%
2004	22550	2413	0.32	1620	50	2.83	0.20%
2005	23843	2632	0.35	786	57.6	3.73	0.20%
2006	25412	2837	0.38	1394	53.6	2.45	0.20%
2007	26848	3025	0.41	3459	47	3.23	0.20%
2008	28368	3197	0.43	606	36.8	1.28	0.10%
2009	29581	3362	0.45	2418	47.3	4.63	0.20%
2010	30373	3521	0.47	3242	44.4	3.78	0.10%
2011	31163	3673	0.49	1528	60.1	2.17	0.20%
2012	32525	3803	0.51	1254	34.1	2.29	0.10%
2013	33040	3910	0.52	1160	35.8	2.45	0.10%
2014	33978	3997	0.54	1768	41.6	2.57	0.10%
2015	35210	4075	0.55	2260	112.2	6.89	0.30%
2016	35883	4145	0.56	2647	125	7.49	0.30%

Figure 1. A comparison of spawning biomass and depletion estimates from the 2015 and 2017 canary rockfish assessments, 1980-2015.

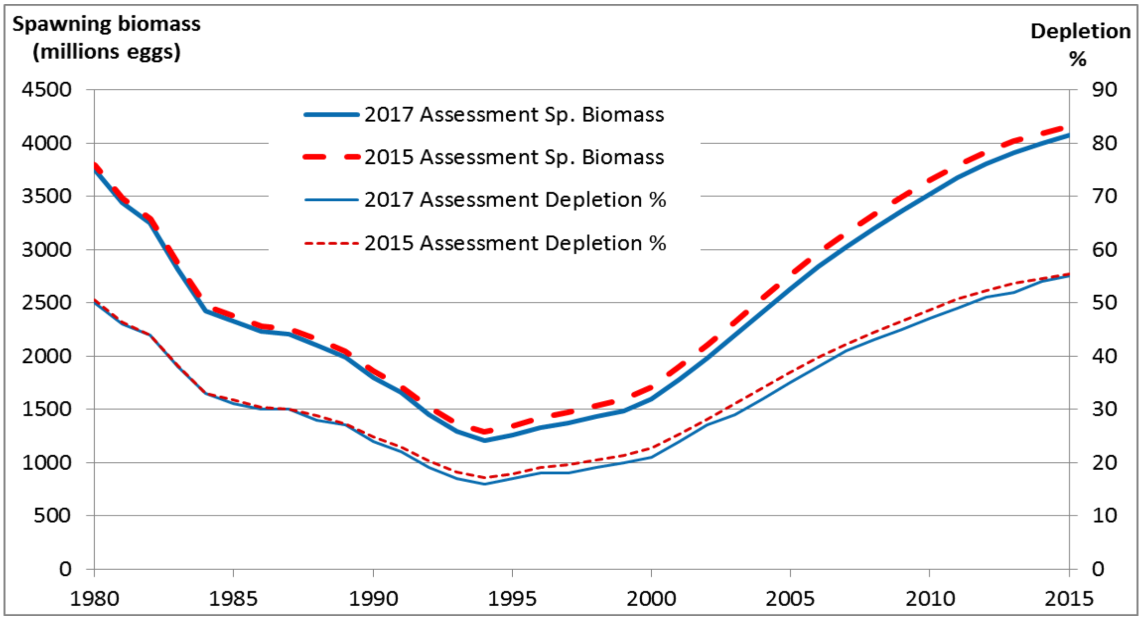


Figure 2. A comparison of recruitment estimates from the 2015 and 2017 canary rockfish assessments, 1990-2015.