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Stock Assessment Update: Status of Bocaccio, *Sebastes paucispinis*, in the Conception, Monterey and Eureka INPFC areas for 2017

by
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Table of Contents

Executive Summary

Stock

This assessment reports the status of the Bocaccio rockfish (*Sebastes paucispinis*) off of the West Coast of the United States, from the U.S.-Mexico border to Cape Blanco, Oregon (representing the Conception, Monterey and Eureka INPFC areas), and it is an update of the 2015 benchmark assessment (He et al. 2015). Although the range of Bocaccio extends considerably further north, there is some evidence that there are two demographic clusters centered around southern/central California and the West Coast of British Columbia, with a relative rarity of Bocaccio (particularly smaller fish) in the region between Cape Mendocino and the mouth of the Columbia River. This is supported by apparent differences in growth, maturity and longevity, although genetic evidence seems to indicate a single West Coast population. Within the stock area, there is also evidence of limited demographic separation, which is treated through some separation of fleets and data. These and other issues related to stock identification and relative levels of demographic mixing and isolation remain important research questions for future assessments.

Catches

Bocaccio rockfish have long been one of the most important targets of both commercial and recreational fisheries in California waters, accounting for between 25 and 30% of the commercial rockfish (*Sebastes*) historical catch over the past century. However, this percentage has declined in recent years as a result of stock declines, management actions and the development of alternative fisheries (particularly the widow rockfish fishery in the early 1980s). The catch history for this assessment begins in 1892, and relies heavily on the catch reconstruction efforts and products recently developed for historical California groundfish landings. Total catches, including both commercial and recreational fisheries, have been low in recent years as compared to those in the late period of the last century (Figure 1 and Table 1).

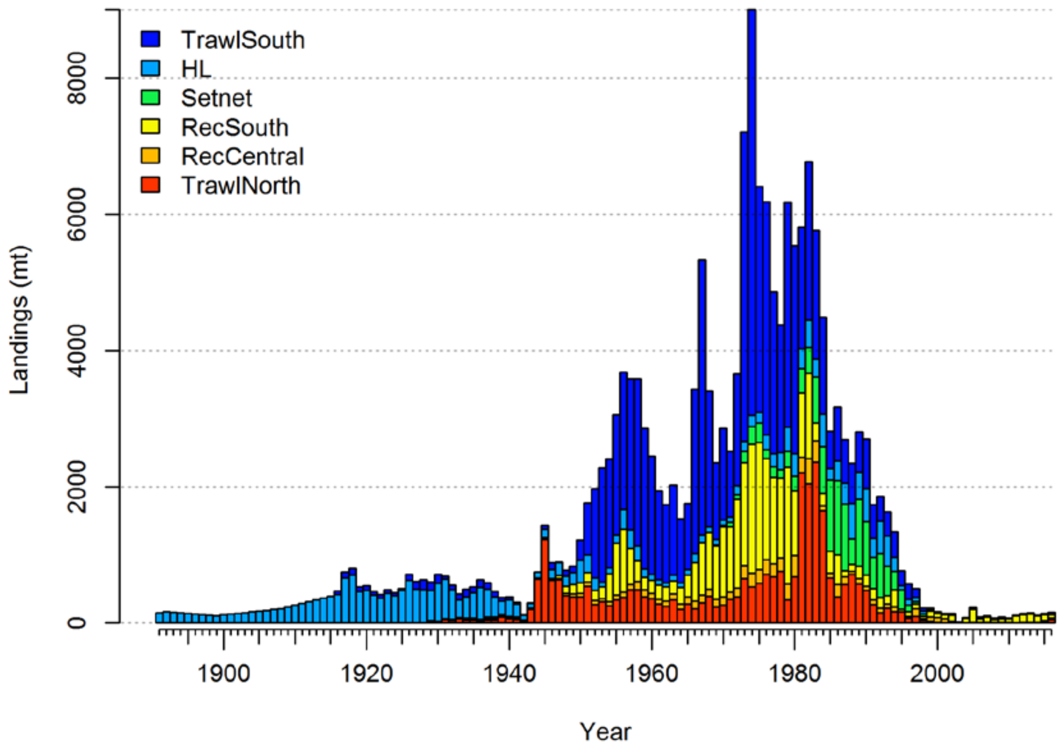

Figure 1. Time series of total catches of Bocaccio (in metric tons) and catches by six fisheries from 1892 to 2016 (HL = hook-and-line fishery).

Table 1: Estimated recent catches (mt) of Bocaccio from six fisheries and sum of annual total catches.

Year	Trawl south	Hook-and-line	Setnet	Recreational south	Recreational central	Trawl north	Total
2007	5.2	10.9	0	80.2	9.3	1.5	107.1
2008	7.5	3.8	0	49.3	3.7	4.4	68.7
2009	19.8	2.7	0	52	8.8	1.4	84.6
2010	12.9	1.8	0	50.1	6.5	2.1	73.4
2011	7.9	2.5	0	99.3	4.1	1.9	115.7
2012	11.4	3.5	0	119.1	5.7	2	141.7
2013	14.3	3.9	0	125.9	5	1.3	150.4
2014	6.4	6.6	0	93.4	6.1	6.5	119
2015	11	7.9	0	82.9	7.5	30	139.4
2016	31.6	0.7	0	57.9	10.1	56.9	157.2

Data and assessment

The last benchmark assessment of Bocaccio rockfish was done in 2015 in Stock Synthesis 3 (version 3.24U; He et al. 2015), and this update assessment uses the same version of the Stock Synthesis 3. This assessment update uses the same modeling framework, including the fleet and survey structures, data inputs and analysis, and sensitivity analysis and data-weighting schemes, as in the 2015 assessment. The model includes catch and length-frequency from six fisheries, two trawl fisheries (north and south of 38° N, labelled as "TrawlSouth" and "TrawlNorth", respectively), a hook-and-line fishery (labelled as "HL"), a set net (gillnet, labelled as "Setnet") fishery and recreational fisheries south and north of Point Conception, CA (labelled as "RecSouth" and "RecCentral"). Age data are unchanged from the 2015 assessment. Fisheries-dependent relative abundance (CPUE) indices from both trawl fisheries (one index) and recreational fisheries (five indices) are included. Fisheries-independent data used in the past assessments and continued here include the CalCOFI larval abundance time series and the triennial trawl survey index; the NWFSC trawl survey (also referred to as combo trawl survey); the NWFSC Southern California Bight hook-and-line survey; and the coast wide pelagic juvenile index. The growth and natural mortality rates are estimated in the base model, while steepness is fixed at an updated prior value of 0.718 (Thorson, NWFSC, personal communication), which is less than the value (0.773) used in the 2015 assessment.

Stock biomass and spawning output

The spawning output was estimated to be very slightly below the estimated unfished levels in the beginning of the modeled period, due to very moderate fishing pressure that began no later than the 1850s. The spawning output trajectory continues to show a very moderate decline until about 1950, but is estimated to have declined steeply from the early 1950s through the early 1960s as catches rose from several hundred to several thousand tons. The biomass increased sharply thereafter, as a result of one or several very strong recruitment events in the early 1960s, exceeding the mean unfished biomass level through the early 1970s. During that time, catches climbed rapidly to their peak levels, which was associated with high fishing mortality rates and a subsequent rapid drop in spawning output. Fishing mortality remained high throughout the 1980s and 1990s, even as catches, biomass and spawning output declined rapidly. Fishing mortality declined towards the end of the 1990s, in response to severe management restrictions and coincident with a series of several strong year classes (following a decade of very poor recruitment) that began in 1999. Since the early 2000s, spawning output has been increasing steadily. The base model estimates increasing trends of total biomass and spawning outputs, and a current (2017) depletion level of 48.6% (Figures 2-4 and Table 2).

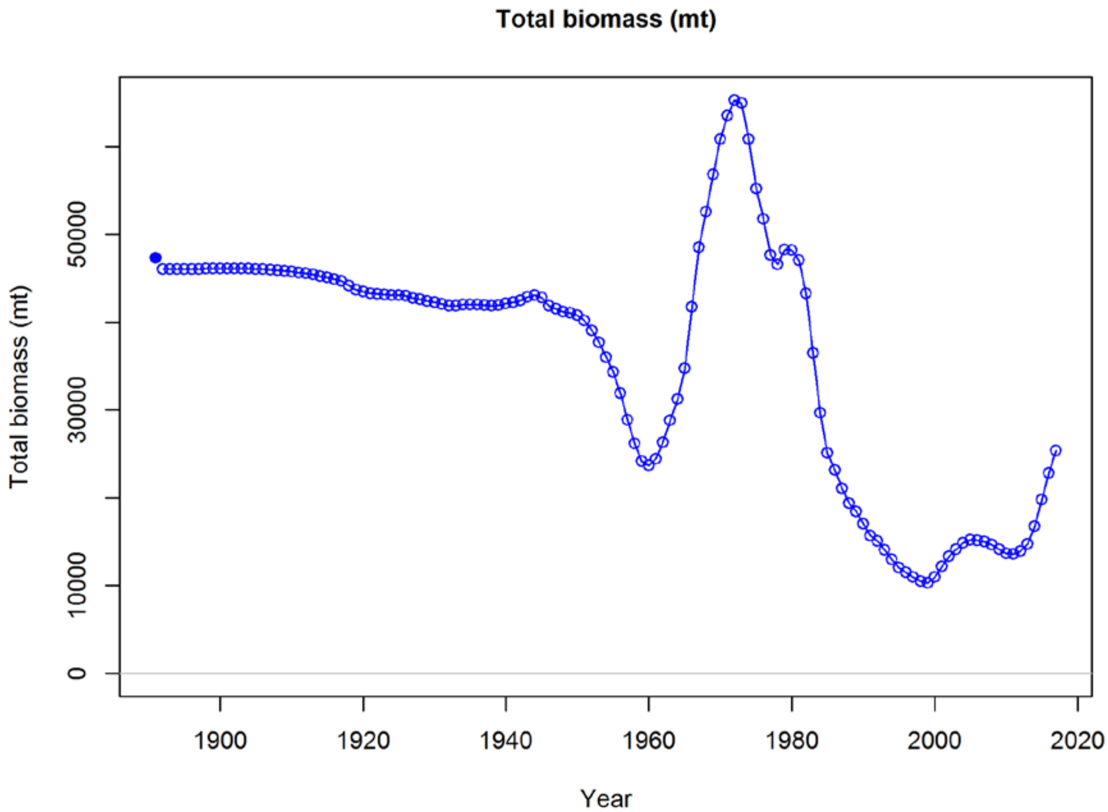

Figure 2. Estimated total biomass (defined as biomass for all fish age 1 and older).

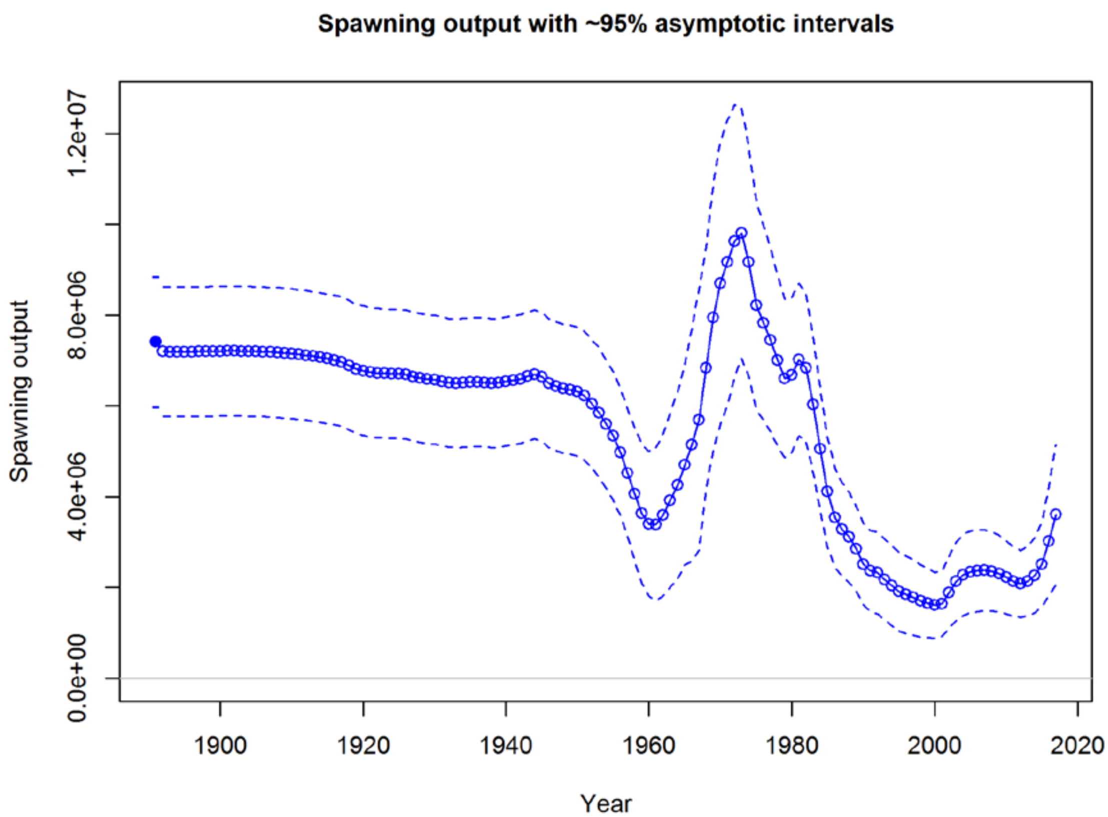

Figure 3. Estimated spawning output (10^6 larvae) with 95% confident intervals.

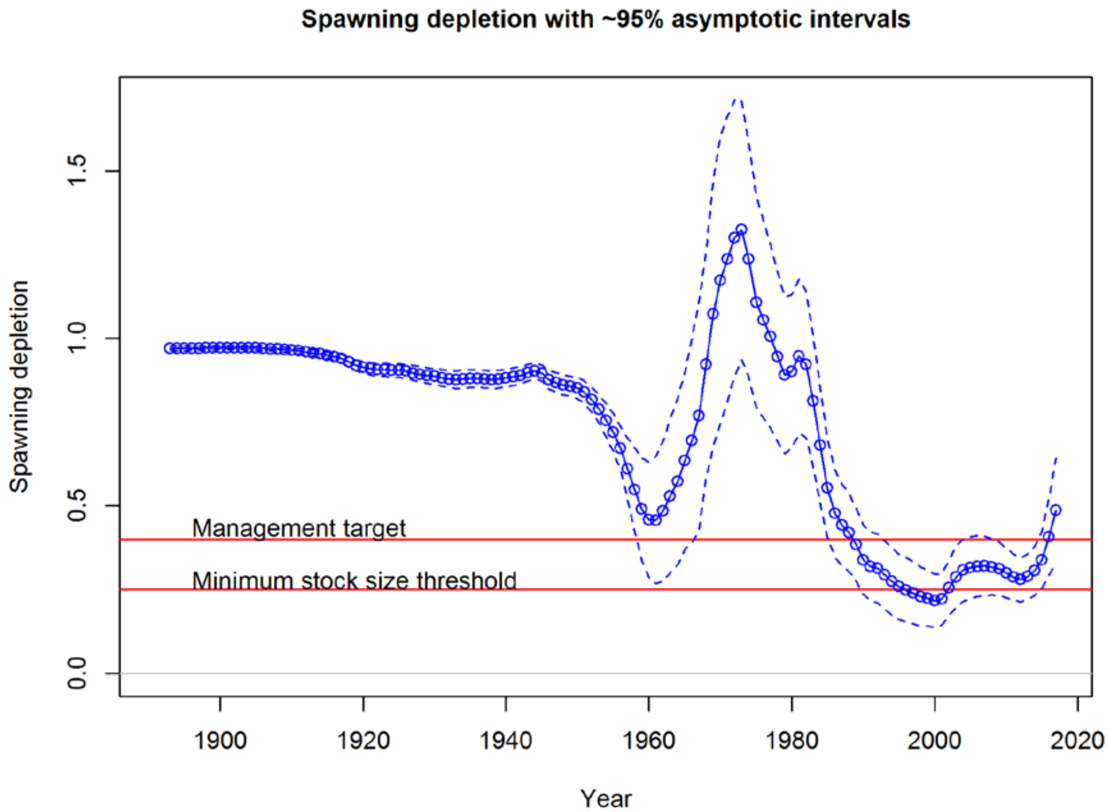

Figure 4. Estimated stock depletion with 95% asymptotic intervals.

Table 2: Estimated recent trends in estimated spawning outputs, recruitment, and stock depletion.

Year	Spawning output (10^6 larvae)	~95% confident interval	Recruitment (10^6)	~95% confident interval	Stock depletion (%)	~95% confident interval
2007	2379	1489 - 3270	1193	635 - 2239	32.1	23.3 - 40.9
2008	2356	1487 - 3226	978	500 - 1913	31.8	23.4 - 40.2
2009	2306	1465 - 3146	1949	1092 - 3480	31.1	23.1 - 39.1
2010	2223	1420 - 3025	5459	3214 - 9273	30.0	22.5 - 37.4
2011	2128	1366 - 2890	4594	2532 - 8332	28.7	21.8 - 35.7
2012	2075	1336 - 2814	2831	1454 - 5509	28.0	21.4 - 34.6
2013	2137	1374 - 2899	15582	8561 - 28358	28.8	22.1 - 35.6
2014	2270	1447 - 3093	7744	3606 - 16630	30.6	23.3 – 38.0
2015	2505	1570 - 3439	4223	1715 - 10400	33.8	25.3 - 42.3
2016	3022	1821 - 4224	2430	843 - 7004	40.8	29.2 - 52.3
2017	3603	2066 - 5139	6220	1194 - 32412	48.6	33.1 - 64.1

Recruitment

Recruitment for Bocaccio is highly variable, with a small number of year classes tending to dominate the catch in any given fishery or region. Recruitment appears to have been at very low levels throughout most of the 1990s, but several recent year classes (1999, 2010, and 2013) have been strong, particularly relative to spawner abundance, and have resulted in sharp increases in abundance and spawning output. The 2013 recruitment was estimated to be high in the 2015 assessment, and recent length composition and index data are consistent with this year class being among the strongest in the past two decades. Thus, this and other strong year classes (such as 2010) are expected to lead to continued increasing biomass levels over the next few years (Figure 5 and Table 2).

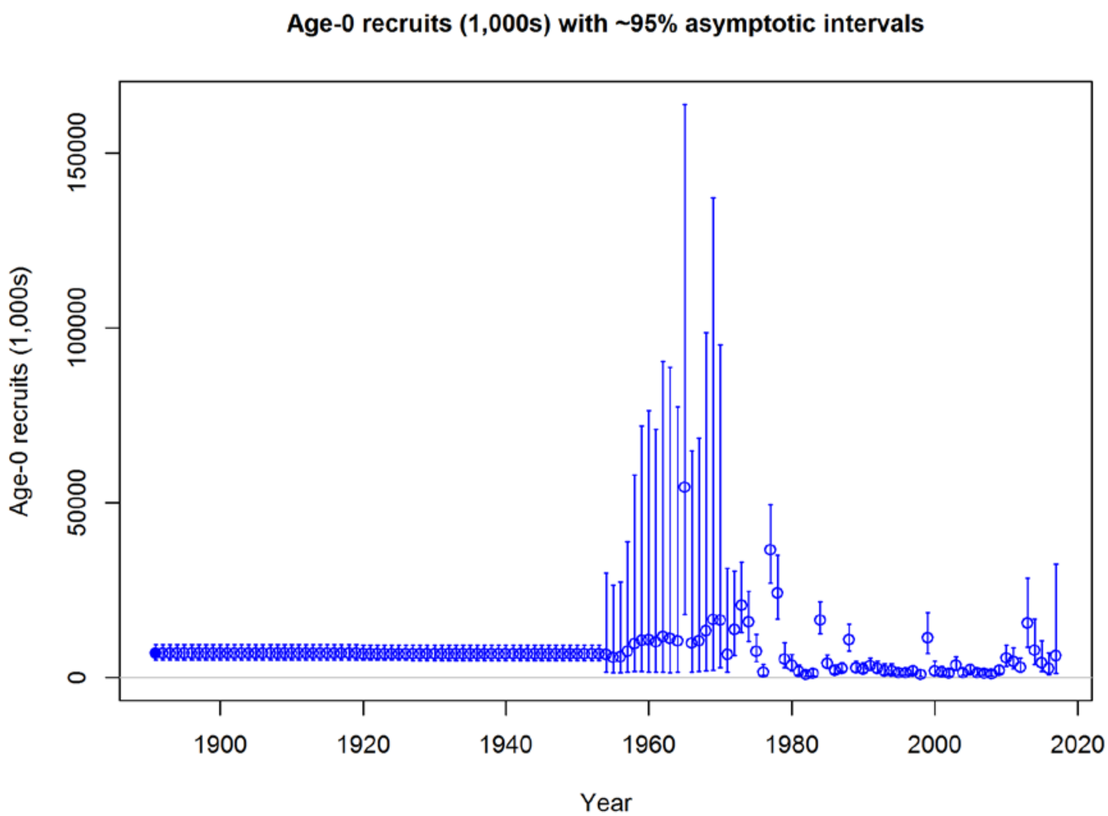

Figure 5. Estimated annual recruits with 95% asymptotic intervals.

Exploitation status

The 2017 spawning output is estimated to be at 48.6% of the unfished spawning output (Table 2). The base model indicates that the exploitation rates for Bocaccio rockfish has remained at low levels since the turn of the millennia, and the population has been increasing accordingly (Figure 6 to Figure 8, and Table 1).

Table 3: Recent trend in harvest rate and spawning potential ratio (SPR).

Year	Harvest rate	SPR (%)
2007	0.0071	91.2
2008	0.0047	93.8
2009	0.0060	92.1
2010	0.0054	92.2
2011	0.0086	88.0
2012	0.0102	89.0
2013	0.0103	90.4
2014	0.0071	93.7
2015	0.0071	94.5
2016	0.0069	94.5

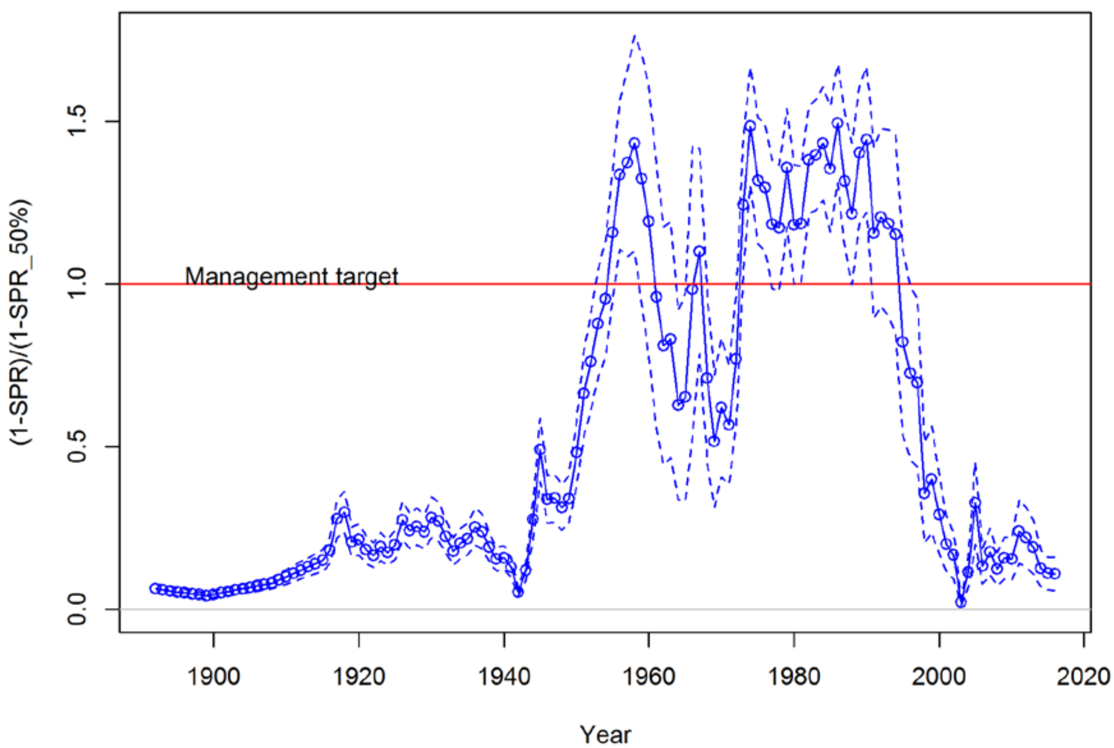

Figure 6. Time series of relative SPR with the target level of 50% for the base model. Values of relative SPR about 1.0 (red line, management target) indicate harvests in excess of the current overfishing proxy.

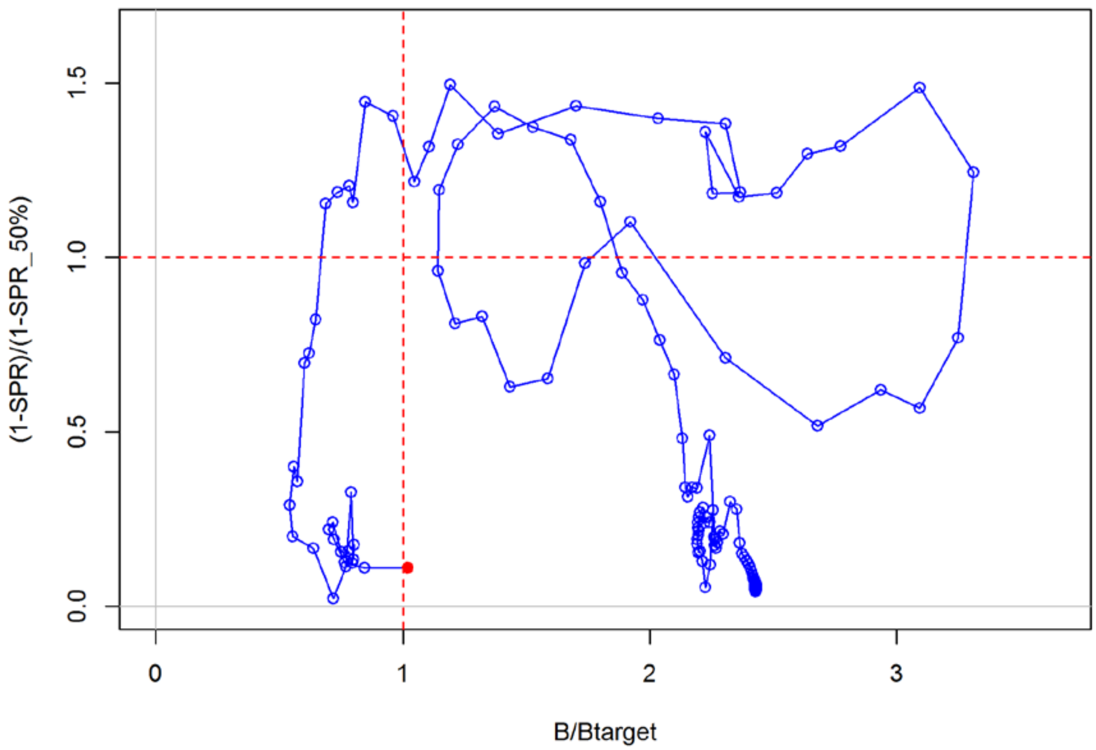

Figure 7. Phase plot of relative SPR with the target level of 50% versus relative stock depletion (labelled as B/Btarget) for the base model. Relative stock depletion is the spawning outputs divided by the spawning output corresponding to 40% of the unfished spawning output. The red end point indicates the year 2016.

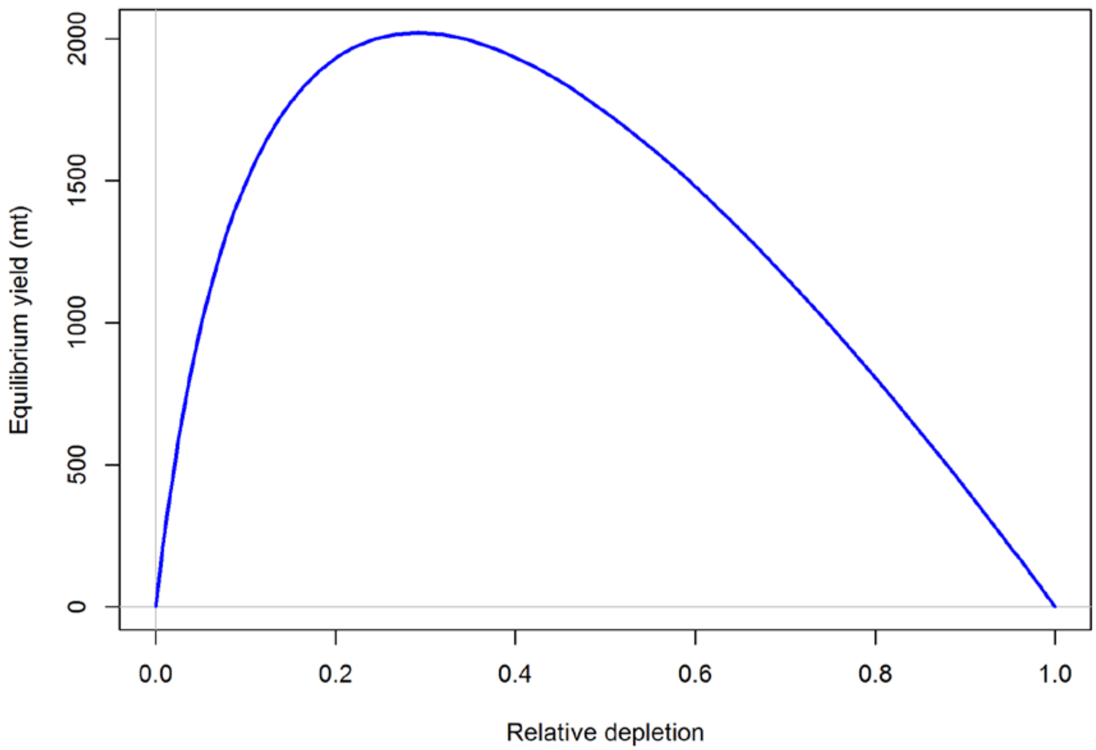

Figure 8. Equilibrium yield curve for the base model.

Ecosystem considerations

Bocaccio are an important component of coastal food webs by virtue of being both fairly abundant (historically more so) and very piscivorous. Although there are no published quantitative food habits studies of this species, they have long been described as primarily piscivorous, and young Bocaccio are known to prey on other young-of-year (YOY) rockfish, surfperch, jack mackerel and other small inshore fish species (Phillips 1964, Nelson 2001). The high recruitment variability exhibited by this species may serve to constrain or limit recruitment of co-occurring species at times, and the dynamics of this interaction could be revealing with respect to patterns of recruitment variability observed in other species. Adults in deeper waters feed on small rockfish, Pacific hake, sablefish, anchovies, mesopelagic fishes, and squids, particularly California market squids.

Reference points

Summary of reference points for the base model is presented in Table 4, including the unfished summary biomass, unfished spawning output, mean unfished recruitment and the proxy estimates for MSY based on the $SPR_{50\%}$ rate as well as the fishing mortality rate associated with a spawning stock output of 40% of the unfished level and with MSY estimated based on the spawner/recruit relationship and yield curve. The corresponding yields for these three estimates vary between 1,857 mt based on the SPR target and 2,158 mt based on the MSY estimate. The unfished total biomass is estimated to be 47,268 mt, which was similar to that estimated in the 2015 assessment (45,476 mt). Unfished spawning output and virgin recruitment are also comparable with those in the 2013 assessment update.

Table 4: Summary of reference points for the base model.

Quantity	Estimate	Low 2.5% limit	High 97.5% limit
Unfished Spawning output (10^6 larvae)	7411	5977	8845
Unfished age 1+ biomass (mt)	47268	38348	56188
Unfished recruitment (R_0)	6865	5011	9405
Depletion (2017)	48.6%	33.1%	64.1%
Reference points based on $SB_{40\%}$			
Proxy spawning biomass ($B_{40\%}$)	2964	2391	3538
SPR resulting in $B_{40\%}$ ($SPR_{50\%}$)	0.459	0.459	0.459
Exploitation rate resulting in $B_{40\%}$	0.093	0.081	0.106
Yield with *SPR* at $B_{40\%}$ (mt)	1934	1462	2406
Reference points based on SPR proxy for MSY			
Spawning biomass	3302	2663	3941
SPR_{proxy}	50%		
Exploitation rate corresponding to SPR_{proxy}	0.082	0.071	0.092
Yield with SPR_{proxy} at SB_{SPR} (mt)	1857	1406	2309
Reference points based on estimated MSY values			
Spawning biomass at *MSY* (SB_{MSY})	2158	1736	2579
SPR_{MSY}	0.361	0.357	0.365
Exploitation rate corresponding to SPR_{MSY}	0.129	0.112	0.146
MSY (mt)	2021	1525	2517

Management performance

Bocaccio rockfish were formally designated as overfished in March of 1999, after the groundfish FMP was amended to incorporate the mandates of the Sustainable Fisheries Act reauthorization to the MSFCMA. The rebuilding policy adopted by the PFMC held the rebuilding optimum (OY) constant at 100 MT for the years 2000-2002, with the intention of switching to a constant fishing rate policy beginning in 2003. However, due to an extremely pessimistic 2002 assessment, the 2003 OY was set to 20 tons. A more optimistic assessment in 2003 led to a 2004 OY of 199 tons. The OY or more recently ACL values have been set at a range of values between 218 and 362 tons since then (Table 5), with estimated catches (including discards) typically observed to be less than half of the adopted values in most years since 2005. A summary of recent catches, regulations, and stock status between 2005 and 2017 is presented in Table 5. A summary of catch distribution data as the basis for the apportionment of Bocaccio ACL and OFL estimates North and South of 40°10’ N latitude is listed in Appendix C.

Unresolved problems and major uncertainties

For this assessment, steepness (*h*) is treated as fixed, with natural mortality (M) estimated, as in the 2015 base model. Sensitivity analyses conducted for the 2015 base model (and elsewhere) demonstrate considerable covariance among these two parameters, such that there is rarely adequate data to reliably estimate both simultaneously. Moreover, because Bocaccio exhibit very large recruitment variability, estimations of the stock-recruitment relationship for this species are highly uncertain.

Abundance trends in this population are driven to a large extent by strong year classes, for which the relative magnitude may not be apparent for several years. The 2015 assessment indicated a very strong 2013 year class, although the magnitude of that year class was difficult to evaluate at that time. Length composition data in this update are consistent with a very large 2013 year class, although the true magnitude of the year class may not be obvious until more data is available. Similarly, an abundance of pelagic YOY rockfish has been noted in several surveys and in anecdotal accounts in the 2014-2016 period, although it remains to be seen whether strong recruitment will materialize in the populations.

Decision table

The decision table in the 2015 assessment was based on two major sources of uncertainties and four forecast catch streams (Table 6 in He et al. 2016). The basis for the alternative states of nature were a combination of steepness values and relative strength of the 2013 year class. As this year class is better resolved in this assessment, the updated decision table states of nature are limited to the steepness values associated with the 2015 assessment.

Three catch streams, which are similarly defined in the 2015 assessment, were included for each scenario, with the adopted ACL values used for 2017-2018 used for each one. The low catch stream was represented by status quo catches (average of total catch in 2012-2016 period), the catches associated with the adopted rebuilding SPR rate (0.777) in the low productivity scenario, the catches associated with the rebuilding SPR rate in the base model scenario, and the base model estimate of ACL catches under the SPR=0.50 harvest rate policy. Table 6 shows time series of spawning outputs and stock depletion for all nine scenarios for three states of natures and three catch streams. Under the most pessimistic scenario (high catches and low *h* value, lower left column in the Table), the stock is estimated to fall below the management target in 2023. For all other scenarios, the stock is estimated to be above the management target level for all years.

Research and data needs

Stock structure and stock boundaries for Bocaccio rockfish on the West Coast remains an important issue to consider with respect to both future assessments and future management actions.

Since large scale area closures and other management actions were initiated in 2001, the spatial distributions of fishing effort (fishing mortality) have changed over both large and small spatial scales. This confounds the interpretation of survey indices for surveys that do not sample in the Cowcod Conservation Areas (CCAs), although the decision to begin sampling for the NWFSC hook and line survey within the CCAs should begin to address this issue with time.

Recently updated reproductive biology data (maturity and fecundity) show some differences in length and weight specific fecundity in Bocaccio from those used in the past assessments. Regional differences (southern and northern California, as well as southern Oregon), and multiple brood spawning, are poorly understood.

Information regarding diet and movement patterns associated with habitat and prey abundance are key in order to further understand its roles in the ecosystem of the California waters. Northward migratory behaviors of juvenile and young adults are indicated by length frequency data, but such behaviors are also poorly understood.

Table 5: Summary table of recent catches, regulations, and stock status between 2007 and 2017.

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Commercial landings (mt)	18	16	24	17	12	17	20	20	49	89	
Estimated total catch (mt)	107	69	85	73	116	142	150	119	139	157	
OFL (mt)	602	618	793	793	737	732	884	881	1444	1351	2139
ACL (mt)	218	218	288	288	263	274	320	337	349	362	790
1-SPR (%)	91.2	93.8	92.1	92.2	88.0	89.0	90.4	93.7	94.5	94.5	
Exploitation rate	0.007	0.005	0.006	0.005	0.009	0.010	0.010	0.007	0.007	0.007	
Age 0+ biomass (mt)	14983	14623	14122	13583	13520	13915	14533	16669	19701	22816	25293
Spawning output (10^6 larvae)	2379	2356	2306	2223	2128	2075	2137	2270	2505	3022	3603
Spawning output (low 2.5%)	1489	1487	1465	1420	1366	1336	1374	1447	1570	1821	2066
Spawning output (high 97.5%)	3270	3226	3146	3025	2890	2814	2899	3093	3439	4224	5139
Recruitment	1193	978	1949	5459	4594	2831	15582	7744	4223	2430	6220
Recruitment (low 2.5%)	635	500	1092	3214	2532	1454	8561	3606	1715	843	1194
Recruitment (high 97.5%)	2239	1913	3480	9273	8332	5509	28358	16630	10400	7004	32412
Depletion (%)	32.1	31.8	31.1	30.0	28.7	28.0	28.8	30.6	33.8	40.8	48.6
Depletion (low 2.5%)	23.3	23.4	23.1	22.5	21.8	21.4	22.1	23.3	25.3	29.2	33.1
Depletion (high 97.5%)	40.9	40.2	39.1	37.4	35.7	34.6	35.6	38.0	42.3	52.3	64.1

Table 6: Decision table based on three states of nature and three alternative future catch streams. States of nature are defined as low recruitment potential (*h*=0.545) and high recruitment potential (h=0.845). Both *h* values are offsets by -0.055 from those used in the 2015 settings of the state of nature, due to that the *h* prior (0.718) used in this assessment is 0.055 less than that used in the 2015 assessment (0.773). Also, the low/high 2013 recruitment was used as factor in the settings of state of nature in the 2015 assessment, but it is not considered here because the 2013 recruitment has been estimated to be high in this assessment. Spawning output has unit of billions of larvae.

			State of nature					
			Low state of nature (h = 0.545)		Base (h=0.718)		High state of nature (h = 0.845)	
Management decision	Year	Catch (mt)	Spawning output	Depletion (%)	Spawning output	Depletion (%)	Spawning output	Depletion (%)
Average catch (2012-2016)	2017	790	3.27	40.1	3.60	48.6	3.82	53.6
	2018	741	3.54	43.3	3.93	53.1	4.19	58.8
	2019	142	3.65	44.7	4.10	55.3	4.38	61.4
	2020	142	3.83	46.9	4.31	58.1	4.60	64.5
	2021	142	4.04	49.5	4.53	61.1	4.82	67.5
	2022	142	4.26	52.2	4.75	64.1	5.03	70.5
	2023	142	4.49	55.0	4.97	67.1	5.23	73.3
	2024	142	4.71	57.8	5.18	69.9	5.41	75.9
	2025	142	4.94	60.5	5.37	72.5	5.59	78.3
	2026	142	5.15	63.2	5.56	75.0	5.74	80.5
Base model rebuilding SPR (0.777) catches	2017	790	3.27	40.1	3.60	48.6	3.82	53.6
	2018	741	3.54	43.3	3.93	53.1	4.19	58.8
	2019	764	3.65	44.7	4.10	55.3	4.38	61.4
	2020	781	3.74	45.8	4.22	56.9	4.50	63.2
	2021	803	3.84	47.1	4.33	58.5	4.62	64.8
	2022	824	3.95	48.4	4.44	60.0	4.72	66.2
	2023	843	4.06	49.7	4.54	61.3	4.80	67.3
	2024	860	4.16	51.0	4.63	62.5	4.87	68.3
	2025	875	4.26	52.2	4.71	63.5	4.93	69.1
	2026	888	4.36	53.4	4.78	64.5	4.97	69.7
Base model ACL catch (SPR=0.5 with P*=0.45 and sigma=0.36)	2017	790	3.27	40.1	3.60	48.6	3.82	53.6
	2018	741	3.54	43.3	3.93	53.1	4.19	58.8
	2019	2102	3.65	44.7	4.10	55.3	4.38	61.4
	2020	2043	3.54	43.4	4.02	54.3	4.31	60.4
	2021	2011	3.44	42.2	3.93	53.0	4.22	59.1
	2022	1986	3.34	40.9	3.83	51.7	4.10	57.6
	2023	1964	3.24	39.7	3.72	50.2	3.98	55.9
	2024	1945	3.14	38.4	3.61	48.7	3.86	54.1
	2025	1928	3.04	37.3	3.51	47.3	3.74	52.5
	2026	1914	2.95	36.2	3.41	46.0	3.63	50.9