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Status of Bocaccio, *Sebastes paucispinis*, in the Conception, Monterey and Eureka INPFC areas for 2015

by
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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). Although the range extends considerably further north, there is some evidence that there are two demographic clusters of Bocaccio, 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 1and Table 1).

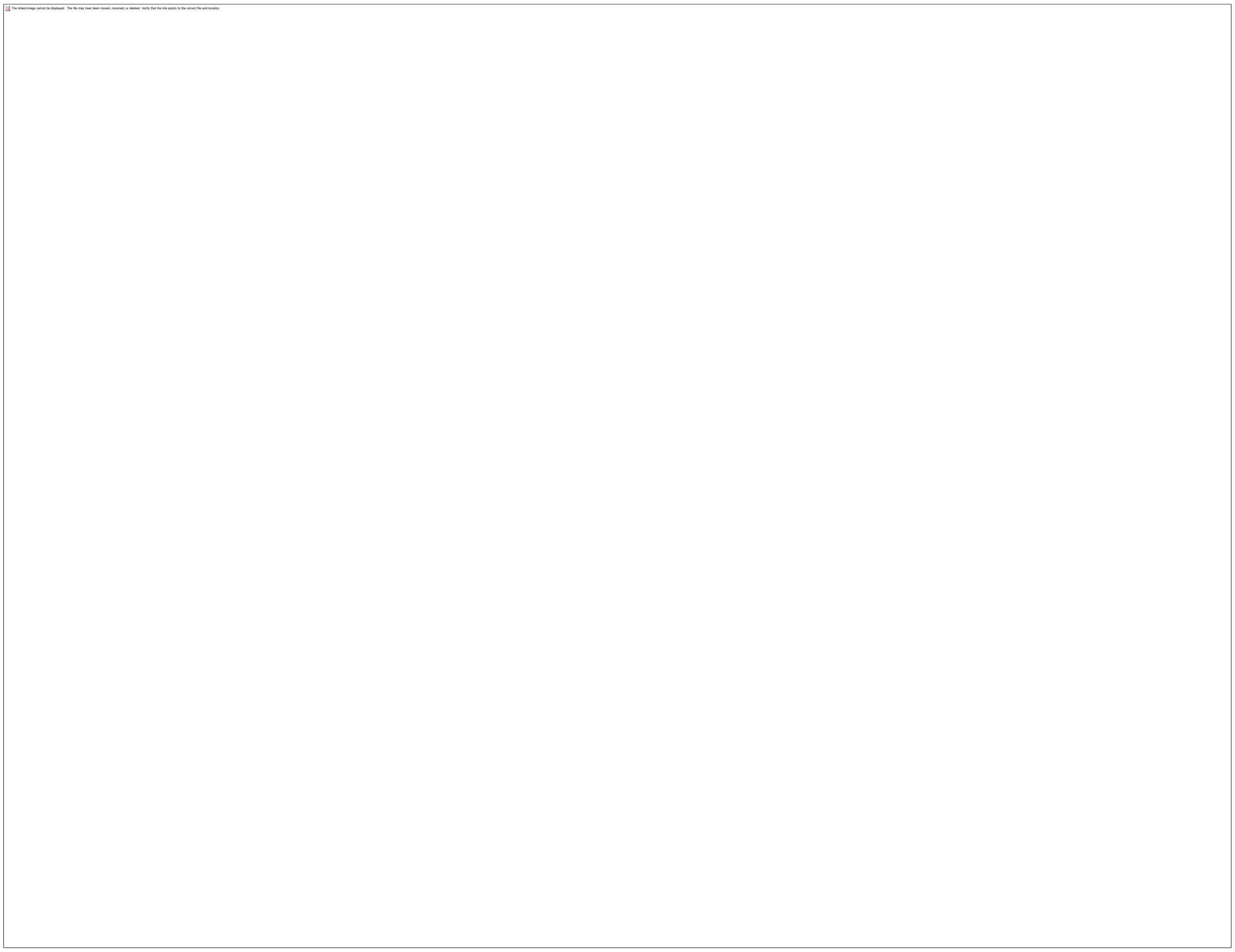

Figure 1. Time series of total catches of Bocaccio (in metric tons) and catches by six fisheries from 1892 to 2014 (HL = hook-and-line fishery).

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
2005	24.6	1.5	0.2	191.9	11.1	0.4	229.7
2006	15.8	10.0	0.0	52.1	12.2	1.0	91.1
2007	5.2	10.9	0.0	80.2	9.3	1.5	107.1
2008	7.5	3.6	0.0	49.3	3.7	4.2	68.3
2009	19.8	2.6	0.0	52.0	8.8	1.3	84.5
2010	12.9	1.8	0.0	50.1	6.5	2.1	73.4
2011	7.9	2.5	0.0	99.3	4.1	1.9	115.7
2012	11.4	3.5	0.0	119.1	5.7	2.0	141.7
2013	14.3	3.9	0.0	125.9	5.0	1.3	150.4
2014	4.1	6.1	0.0	93.4	6.1	4.2	113.9

Data and assessment

The last full assessment of Bocaccio rockfish was done in 2009 in Stock Synthesis 3 (version 3.03a), and subsequently updated (with the same software) in 2011 and 2013. This assessment uses a recent version of the Stock Synthesis 3 (version 3.24U, August 28, 2014). This assessment uses the same assessment boundaries from the U.S./Mexico border to Cape Blanco, OR, and the same starting year (1892) as in the 2009 assessment. This 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"). This assessment includes age data, recently obtained from the Bocaccio ageing project in the Southwest Fisheries Science Center. This is a significant addition to the assessment, as age data had not been included in assessments of this species since 1995 due to difficulties associated with age determination. 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. A recruitment index based on power plant impingement data is also included in the base model. The growth and the natural mortality rates are estimated in the base model, while one of stock-recruitment parameters (steepness) is fixed at a prior value of 0.773.

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 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, when catches again began to climb 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 (2015) depletion level of 36.8% (Figure 2 to Figure 4 and Table 2).

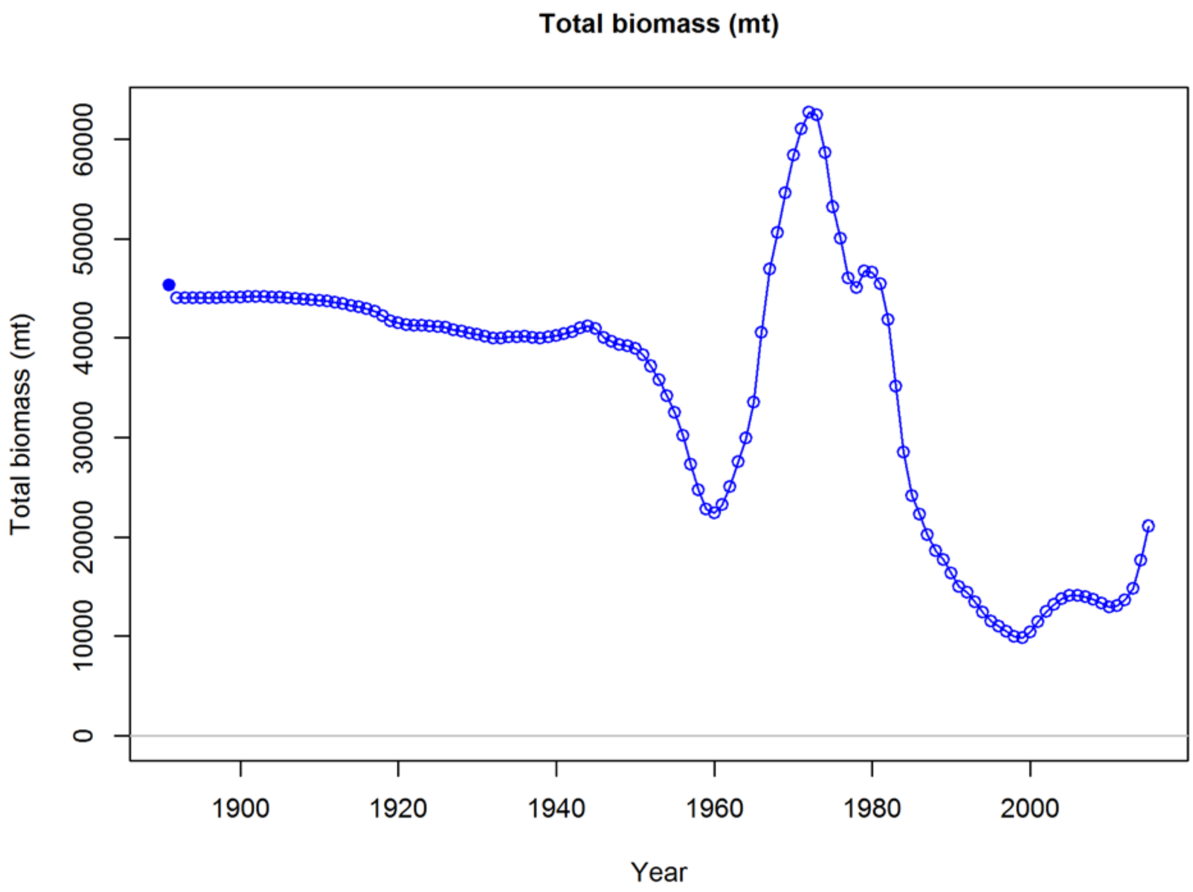

Figure 2. Estimated total biomass (defined as biomass for all fish age 1 and older).

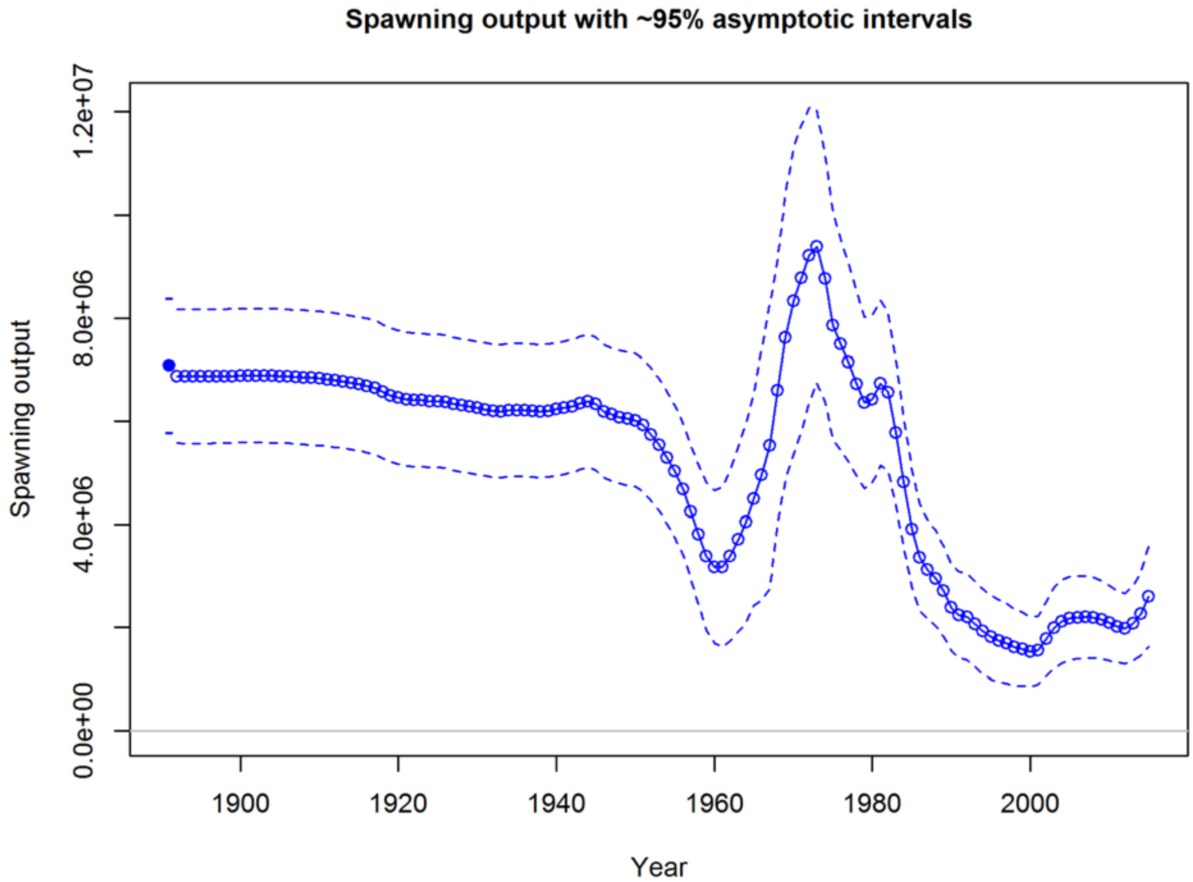

Figure 3. Estimated spawning output with 95% confident intervals.

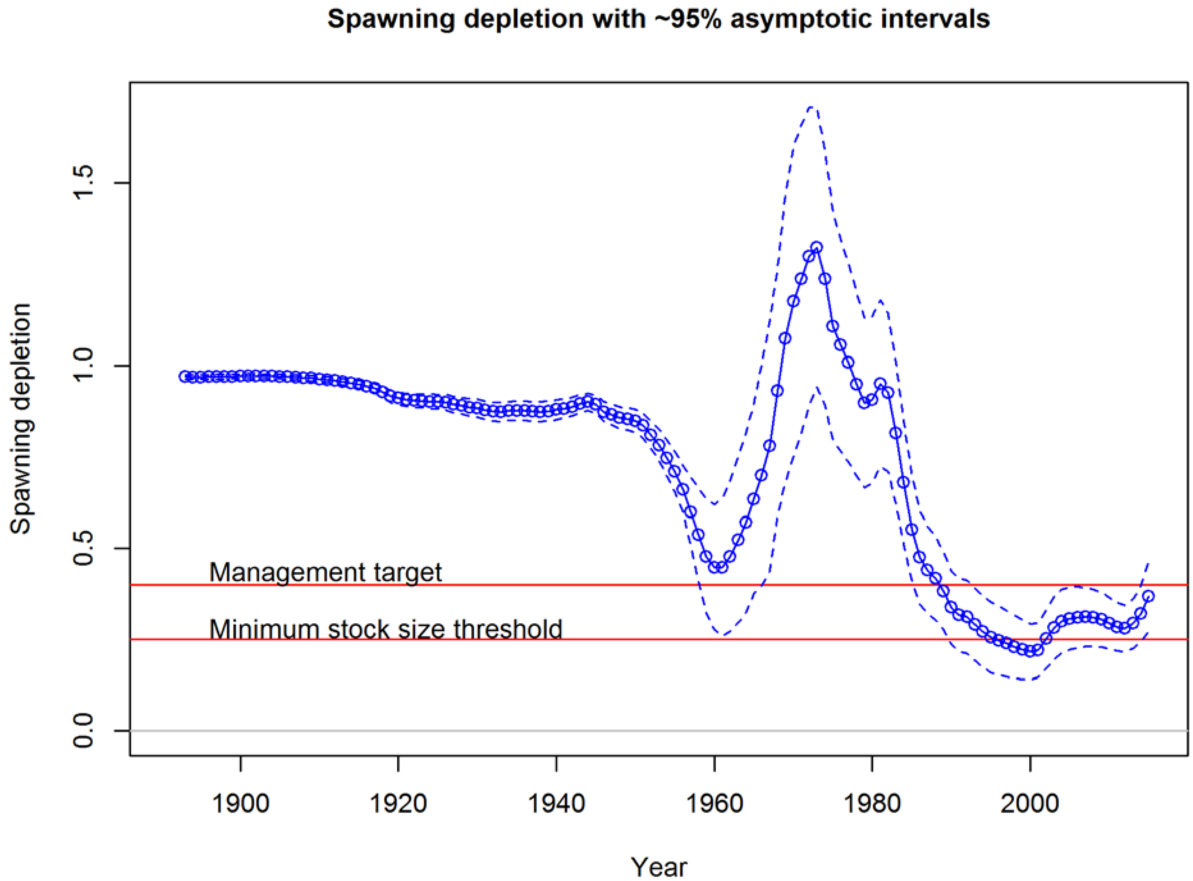

Figure 4. Estimated stock depletion with 95% asymptotic intervals.

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

Year	Spawning output (10^6 eggs)	~95% confident interval	Recruitment (10^6)	~95% confident interval	Stock depletion (%)	~95% confident interval
2005	2171	1362 - 2981	2031	1175 - 3511	30.6	22.1 - 39.2
2006	2194	1386 - 3002	1259	672 - 2361	31.0	22.6 - 39.4
2007	2206	1407 - 3005	1191	653 - 2174	31.1	23.0 - 39.3
2008	2191	1408 - 2974	980	516 - 1862	30.9	23.1 - 38.7
2009	2153	1394 - 2912	2053	1169 - 3605	30.4	22.9 - 37.8
2010	2085	1356 - 2814	5605	3313 - 9482	29.4	22.4 - 36.4
2011	2009	1312 - 2707	5341	2956 - 9649	28.4	21.8 - 34.9
2012	1982	1296 - 2667	3364	1696 - 6672	28.0	21.6 - 34.4
2013	2078	1354 - 2803	20483	10614 - 39528	29.3	22.5 - 36.1
2014	2265	1456 - 3073	2497	989 - 6304	32.0	24.2 - 39.7
2015	2607	1634 - 3579	5709	1096 - 29743	36.8	27.0 - 46.5

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 relatively strong given the decline in spawner abundance, and have resulted in an increase in abundance and spawning output. The 2013 recruitment appears to be high, which is expected to lead to high biomass levels over the next few years (Figure 5 and Table 2).

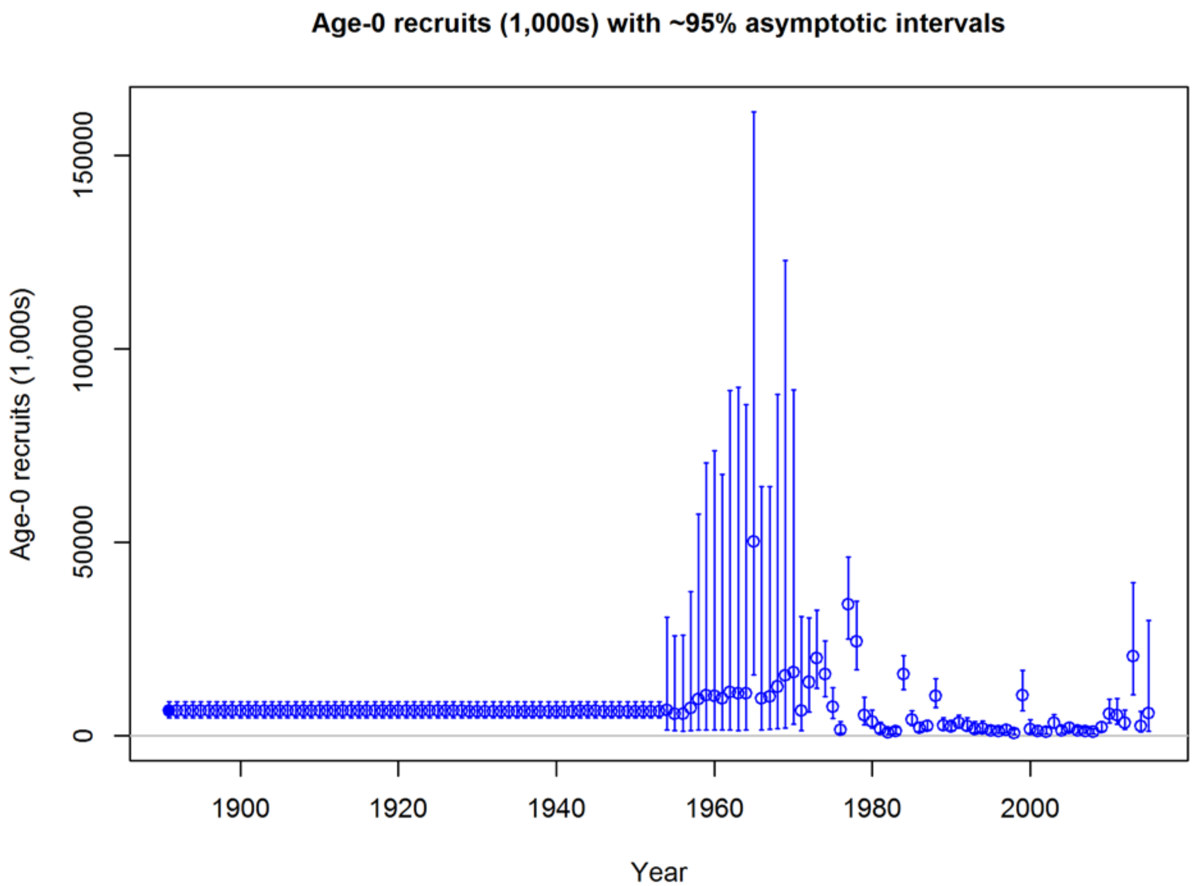

Figure 5. Estimated annual recruits with 95% asymptotic intervals.

Exploitation status

The 2015 spawning output is estimated to be at 36.8% 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 3).

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

Year	Harvest rate	SPR (%)
2005	0.0163	82.7
2006	0.0065	93.0
2007	0.0077	90.8
2008	0.0050	93.7
2009	0.0064	92.0
2010	0.0057	92.2
2011	0.0089	88.1
2012	0.0104	89.3
2013	0.0103	91.1
2014	0.0065	94.6

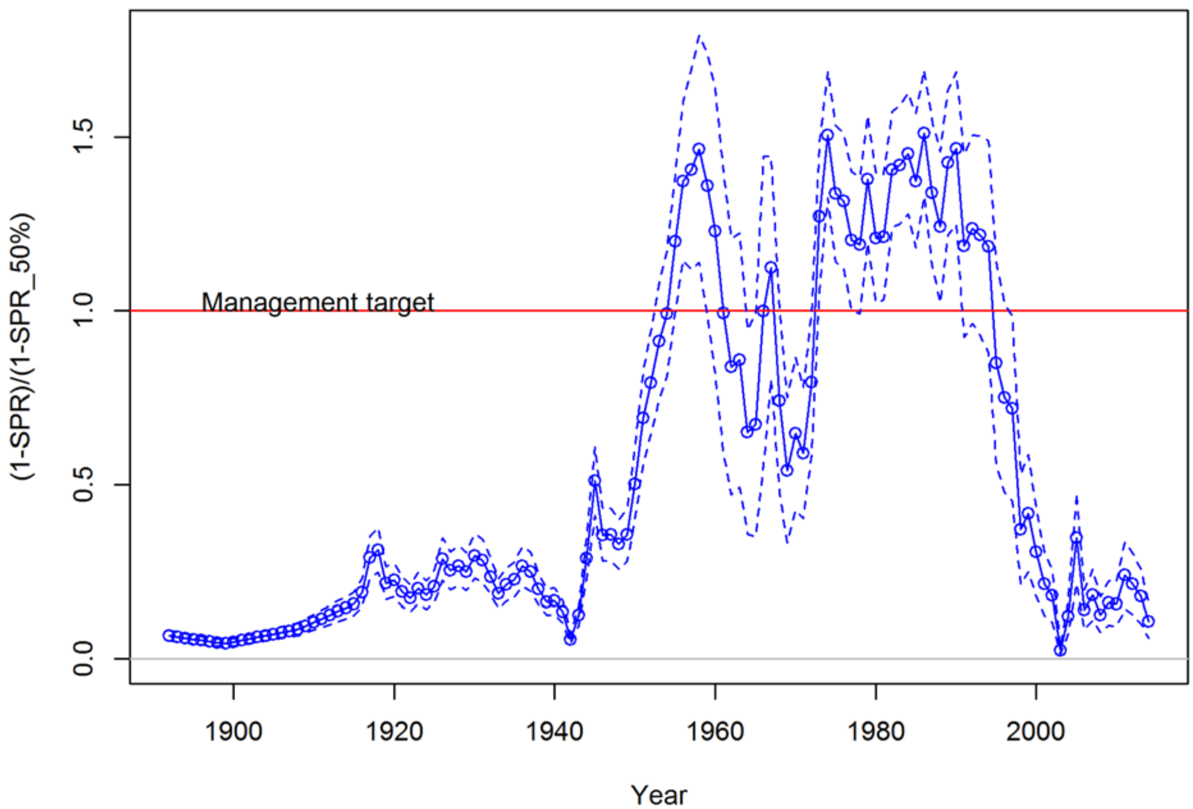

Figure 6. Time series of relative SPR with the target level of 50% for the base model. Values of relative SPR about 1.0 (red line, management target) indicate harvests in excess of the current overfishing proxy.

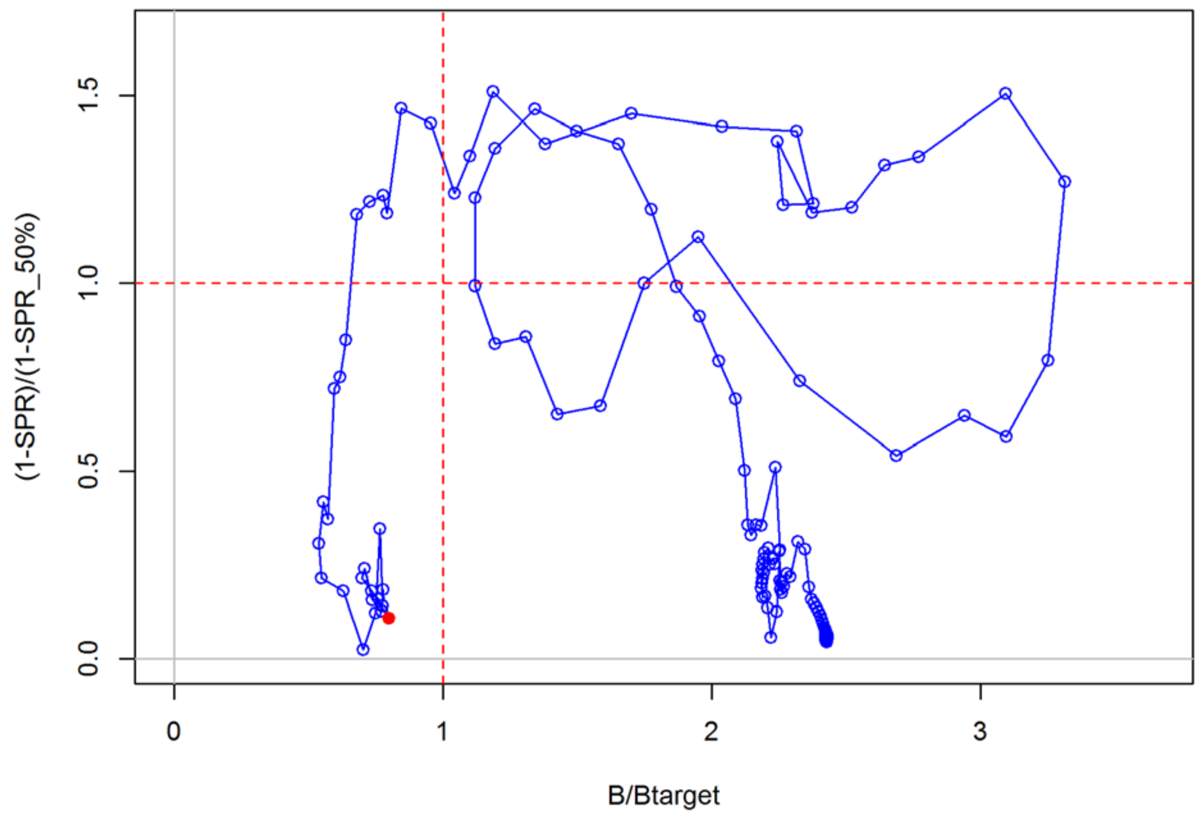

Figure 7. Phase plot of relative SPR with the target level of 50% versus relative stock depletion (labelled as B/Btarget) for the base model. Relative stock depletion is the spawning outputs divided by the spawning output corresponding to 40% of the unfished spawning output. The red end point indicates the year 2014.

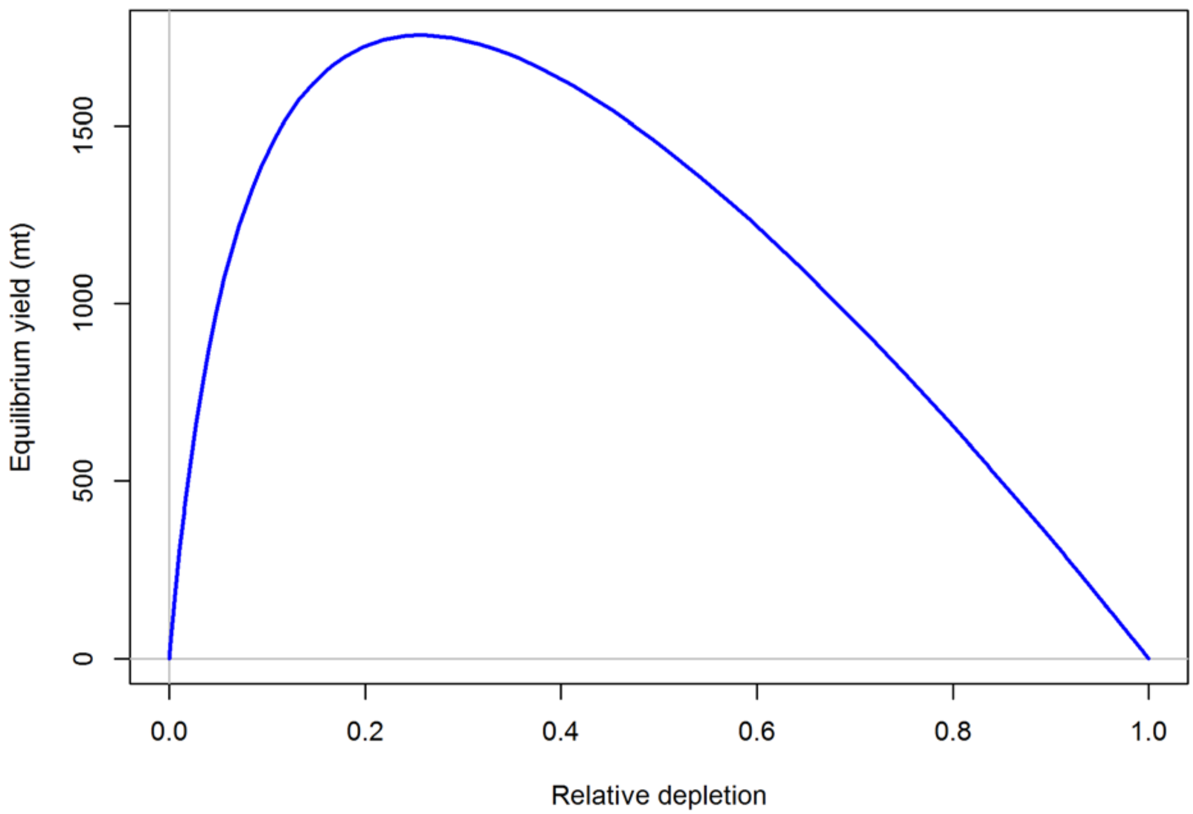

Figure 8. Equilibrium yield curve for the base model.

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-occuring 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 squid*s*.

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 1,528 mt based on the SPR target and 1,755 mt based on the MSY estimate. The unfished total biomass is estimated to be 45,254 mt, which was similar to that estimated in the 2013 assessment update (45,476 mt). Unfished spawning output and virgin recruitment are also comparable with those in the 2013 assessment.

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

Quantity	Estimate	Low 2.5% limit	High 97.5% limit
Unfished Spawning biomass (mt)	7088	5784	8392
Unfished age 1+ biomass (mt)	45254	37139	53369
Unfished recruitment (R_0)	6429	4669	8854
Depletion (2015)	36.8%	27.0%	46.5%
Reference points based on $SB_{40\%}$			
Proxy spawning biomass ($B_{40\%}$)	2835	2313	3357
SPR resulting in $B_{40\%}$ ($SPR_{50\%}$)	0.444	0.444	0.444
Exploitation rate resulting in $B_{40\%}$	0.086	0.073	0.099
Yield with *SPR* at $B_{40\%}$ (mt)	1632	1222	2042
Reference points based on SPR proxy for MSY			
Spawning biomass	3263	2663	3864
SPR_{proxy}	50%		
Exploitation rate corresponding to SPR_{proxy}	0.070	0.060	0.081
Yield with SPR_{proxy} at SB_{SPR} (mt)	1528	1145	1911
Reference points based on estimated MSY values			
Spawning biomass at *MSY* (SB_{MSY})	1824	1484	2164
SPR_{MSY}	0.312	0.308	0.316
Exploitation rate corresponding to SPR_{MSY}	0.137	0.116	0.158
MSY (mt)	1755	1310	2200

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 (**Error! Reference source not found.**), 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 2015 is presented in Table 5.

Unresolved problems and major uncertainties

For this assessment, steepness (*h*) is treated as fixed, with natural mortality (M) estimated for this assessments. This is a reversal from past practices of estimating steepness and fixing natural mortality, however likelihood profiles indicated that there was more information available to the model to estimate natural mortality than there was steepness. Sensitivity analyses conducted here and for other models demonstrate the 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

As identified in the 2009 assessment, there is clear tension in the model between several key indices, particularly the CalCOFI index and the southern recreational CPUE index, which tend to reflect a more optimistic view of stock status, and the trawl CPUE and triennial survey index, which tend to reflect a more pessimistic view of stock status. This tension still exists in this assessment.

The 2013 assessment update identified the 2010 recruitment as a major uncertainty as the year class may not have fully recruited to the fisheries or may not been sampled adequately by the surveys. Data from the latest years confirm that it was a relatively strong year class. However, the latest data indicate there may be an even stronger year class in 2013, as informed by composition data from some fisheries and surveys suggested (particularly the NWFSC survey). The strength of this year class is also a major uncertainty for this assessment, and will also have large influences on the stock projections for the next few years.

Decision table

A decision table was constructed during the STAR Panel review that was based on two major sources of uncertainties and four forecast catch streams (Table 6). The basis for the alternative states of nature were based on the observation that a key uncertainty for this stock is the magnitude of both recent and future recruitment, which is highly variable for this stock. Given the high uncertainty associated with the magnitude of the 2013 year class, and the observation that some recent year classes (such as 2010) were initially estimated to be higher than subsequently realized, two forms of uncertainty in recruitment were combined in this decision table. The low productivity (pessimistic) state of nature was defined by low steepness (h = 0.6) and low 2013 recruitment (~12.5 percentile of the uncertainty of the 2013 recruitment estimate), while the high productivity state of nature was defined by high steepness (h = 0.9) and high 2013 recruitment (~87.5 percentile of the uncertainty of the 2013 recruitment estimate). The 2013 recruitments were scaled by adding a faux survey with a q=1 and a very small CV for the numbers of age 0 fish in 2013; the recruitment deviation value was still included in the model estimation (as were all other parameters, including natural mortality).

This approach had the effect of accounting for both near term and longer term uncertainty in recruitment with respect to stock productivity, which is a key uncertainty in the estimation of stock status. Four catch streams were included for each scenario, with the adopted ACL values used for 2015-2016 used for each one. The low catch stream was represted by status quo catches (average of total catch in 2010-2014 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. Note that the 2015 model estimated depletion levels were more pessimistic under the low productivity scenario (27.5%), and more optimistic (43.3%) in the high productivity scenario; yet in all scenarios except the low productivity scenario with the base model ACL catches, the spawning output was forecast to increase. Under the base model, the stock is expected to rebuild by 2016 (assuming adopted ACL catches), under the low productivity scenario the stock is not expected to rebuild until 2018 with status quo catches and 2019 with rebuilding SPR associated catches. Under the high productivity scenario the stock is estimated to be rebuilt and to stay at high levels in the foreseeable future. However, it should be recognized that all of the projections include deterministic recruitment, and the actual future stock trajectories should be expected to be considerably more variable.

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.

As Bocaccio is one of the most abundant and important piscivorous rockfish species, and its interactions with other predator and prey species are poorly known, 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. Studies on these behaviors and their associations with oceanographic or other ecological factors can help future assessments in defining stock structure as well as explaining high variability in stock recruitments.

Table 5: Summary table of recent catches, regulations, and stock status between 2005 and 2015.

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Commercial landings (mt)	27	27	18	15	24	17	12	17	20	14	
Estimated total catch (mt)	230	91	107	68	85	73	116	142	150	114	
OFL (mt)	566	549	602	618	793	793	737	732	884	881	1444
ACL (mt)	307	308	218	218	288	288	263	274	320	337	349
1-SPR (%)	82.7	93.0	90.8	93.7	92.0	92.2	88.1	89.3	91.1	94.6	
Exploitation rate	0.016	0.006	0.008	0.005	0.006	0.006	0.009	0.010	0.010	0.006	
Age 0+ biomass (mt)	14075	14041	13954	13672	13267	12850	12951	13600	14536	17622	21032
Spawning output (10^6 eggs)	2171	2194	2206	2191	2153	2085	2009	1982	2078	2265	2607
Spawning output (low 2.5%)	1362	1386	1407	1408	1394	1356	1312	1296	1354	1456	1634
Spawning output (high 97.5%)	2981	3002	3005	2974	2912	2814	2707	2667	2803	3073	3579
Recruitment	2031	1259	1191	980	2053	5605	5341	3364	20483	2497	5709
Recruitment (low 2.5%)	1175	672	653	516	1169	3313	2956	1696	10614	989	1096
Recruitment (high 97.5%)	3511	2361	2174	1862	3605	9482	9649	6672	39528	6304	29743
Depletion (%)	30.6	31.0	31.1	30.9	30.4	29.4	28.4	28.0	29.3	32.0	36.8
Depletion (low 2.5%)	22.1	22.6	23.0	23.1	22.9	22.4	21.8	21.6	22.5	24.2	27.0
Depletion (high 97.5%)	39.2	39.4	39.3	38.7	37.8	36.4	34.9	34.4	36.1	39.7	46.5

Table 6. (next page) Decision table based on three states of nature and four alternative future catch streams. States of nature are defined as low recruitment potential (*h*=0.6) and pessimistic estimate of the 2013 recruit, and high recruitment potential (h=0.9) and optimistic estimate of the 2013 recruit. Spawning output has unit of billions of eggs.

			State of nature					
			Low state of nature (*h* = 0.60, low 2013 recruitment)		Base (*h*=0.773, estimated 2013 recruitment)		High state of nature (*h* = 0.90, high 2013 recruitment)	
Management decision	Year	Catch (mt)	Spawning output	Depletion (%)	Spawning output	Depletion (%)	Spawning output	Depletion (%)
Average catch (2010-14)	2015	349	2.03	27.5	2.61	36.8	3.07	43.3
	2016	362	2.39	32.3	3.25	45.8	3.97	56.0
	2017	119	2.70	36.5	3.81	53.8	4.76	67.0
	2018	119	2.99	40.4	4.26	60.1	5.33	75.1
	2019	119	3.26	44.0	4.63	65.3	5.76	81.2
	2020	119	3.52	47.6	4.94	69.7	6.08	85.7
	2021	119	3.78	51.1	5.21	73.5	6.31	88.9
	2022	119	4.02	54.4	5.43	76.6	6.48	91.3
	2023	119	4.26	57.6	5.62	79.3	6.60	92.9
	2024	119	4.49	60.7	5.78	81.5	6.68	94.1
Low state of nature model rebuilding SPR (0.777) catches	2015	349	2.03	27.5	2.61	36.8	3.07	43.3
	2016	362	2.39	32.3	3.25	45.8	3.97	56.0
	2017	587	2.70	36.5	3.81	53.8	4.76	67.0
	2018	581	2.92	39.5	4.19	59.2	5.27	74.2
	2019	586	3.12	42.2	4.49	63.4	5.62	79.2
	2020	596	3.31	44.7	4.73	66.7	5.87	82.7
	2021	607	3.48	47.0	4.91	69.3	6.02	84.9
	2022	617	3.63	49.1	5.05	71.3	6.11	86.1
	2023	626	3.78	51.2	5.16	72.8	6.16	86.8
	2024	634	3.92	53.0	5.25	74.0	6.17	86.9
Base model rebuilding SPR (0.777) catches	2015	349	2.03	27.5	2.61	36.8	3.07	43.3
	2016	362	2.39	32.3	3.25	45.8	3.97	56.0
	2017	853	2.70	36.5	3.81	53.8	4.76	67.0
	2018	800	2.88	38.9	4.15	58.5	5.22	73.6
	2019	770	3.03	41.0	4.40	62.1	5.54	78.0
	2020	758	3.18	43.0	4.60	64.9	5.74	80.9
	2021	755	3.31	44.8	4.75	67.1	5.87	82.7
	2022	755	3.44	46.5	4.87	68.7	5.94	83.6
	2023	757	3.56	48.2	4.96	70.0	5.96	84.0
	2024	758	3.68	49.7	5.03	71.0	5.96	84.0
Base model ACL catch	2015	349	2.03	27.5	2.61	36.8	3.07	43.3
	2016	362	2.39	32.3	3.25	45.8	3.97	56.0
	2017	2213	2.70	36.5	3.81	53.8	4.76	67.0
	2018	1951	2.68	36.2	3.95	55.7	5.02	70.7
	2019	1793	2.63	35.6	4.00	56.5	5.14	72.4
	2020	1705	2.59	35.0	4.02	56.7	5.17	72.8
	2021	1654	2.54	34.3	4.00	56.4	5.13	72.3
	2022	1622	2.49	33.6	3.96	55.9	5.05	71.2
	2023	1601	2.44	32.9	3.92	55.2	4.96	69.8
	2024	1585	2.39	32.3	3.86	54.5	4.85	68.3