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Bocaccio Rebuilding Analysis for 2009

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Introduction

In 1998, the PFMC adopted Amendment 11 of the Groundfish Management Plan, which established a minimum stock size threshold of 25% of unfished biomass. Based on the stock assessment by Ralston et al. (1996), bocaccio rockfish (*Sebastes paucispinis*) was declared formally to be overfished, thereby requiring development of a rebuilding plan for consideration by the Council in the fall of 1999. Rebuilding was initiated by catch restrictions beginning in 2000. A number of bocaccio stock assessments (MacCall et al. 1999, MacCall 2002, MacCall 2003a, MacCall 2005a, MacCall 2007, Field et al. 2009) and rebuilding analyses (MacCall 1999, MacCall and He 2002, MacCall 2003b, MacCall 2005b, MacCall 2007b) have been conducted since that time. In 2004, a formal rebuilding plan for bocaccio was enacted by the Pacific Fishery Management Council (PFMC) as part of Amendment 16-3 to the Pacific Coast Groundfish Fishery Management Plan (PFMC 2004). That plan was revised by Amendment 16-4, which was based on the 2005 rebuilding analysis (MacCall 2005b).

The most recent bocaccio assessment was adopted by the PFMC in September 2009. Although that assessment reports the status of bocaccio rockfish from the U.S.-Mexico border to Cape Blanco, Oregon (representing the Conception, Monterey and Eureka INPFC areas), an extension of the area modeled from recent assessments, past assessments (e.g., Ralston 1996) had used a similar spatial structure. While the range of bocaccio extends considerably further north, into the Queen Charlotte area of Canada, there is some evidence that there are two demographic clusters of bocaccio, centered around southern/central California and the west coast of British Columbia respectively. As the stock structure is very unclear in the region between Cape Mendocino and the Columbia rivermouth, and both historical and contemporary landings are relatively modest in this region, management measures from both the stock assessment and the rebuilding analysis are likely to be applied only to the region south of Cape Mendocino. The results of this rebuilding analysis should likely be scaled accordingly as well.

The results of the 2008 assessment indicated that spawning output declined rapidly through the 1980s and 1990s due primarily to high fishing mortality. Fishing mortality declined towards the end of the 1990s, in response to severe management restrictions, and also coincident with a series of several year classes (1999, 2003, 2005), that were strong relative to the very poor recruitment observed from 1990 to 1998. Even greater declines in fishing mortality took place following the overfished declaration of 1999; since 2001 the most recent assessment indicates that the SPR rate has been above 90%. In response to both of these factors, spawning output appears to have been increasing steadily since the early 2000s. The base model estimates a current (2009) depletion level of 28%, up from an estimated low of 14% in 1999, with the forecast under constant harvest rates indicating a continued increase in spawning output.

Since 2002 both commercial and recreational fisheries have been subject to very restrictive management measures that have brought catches down to very low levels. Recent catches by sector are provided in Table 1, these numbers include regulatory discards, which represent a significant fraction of the total catch for most centers. Estimates for the 2002-2007 period are based on the total mortality reports produced by the Pacific States Marine Fisheries Commission and the Northwest Fisheries Science Center (Bellman et al. 2008; provided by E. Heery), while the 2008 estimates are based on the PFMC's Groundfish Management Team scorecard (J. DeVore, PFMC) and recreational estimates from California Department of Fish and Game (J. Budrick, CDFG). For the purposes of the model, catches by the various open access fleets and research catches (the latter of which are principally trawl-caught) are pooled with the southern trawl fishery (note that due to reporting constraints the northern trawl landings in this period only reflect those north of 40°10' N latitude). Discards represented approximately 75% of total trawl landings during this period, and for commercial fisheries discards have been centered around the central California region (Monterey Bay to San Francisco) region.

Although the rebuilding OY is estimated to have been exceeded during two of the early years of rebuilding, since 2004 the total estimated catch (landings plus discards) has averaged approximately 80 tons. This represents less than 50% of the adopted OY values, and has been associated with low SPR harvest rates, such that SPR has been greater than 0.9 since 2004.

Simulation Model

This analysis uses the SSC Default Rebuilding Analysis (version 3.12a, Punt 2009). All data and parameters use as input to this analysis were taken from base model in the 2009 assessment, or from the results of the sensitivity analysis in the stock assessment, and the input file is given in Appendix A. Recruitments are pre-specified from 2000 through 2009 for the re-estimation of reference parameters, and future recruitments were simulated by drawing off of the spawner-recruit relationship, estimated in the base model (using the Dorn prior) with a steepness of 0.57. Probability distributions are based on 5000 simulations. The key model parameters are given in Table 2. Estimates of unfished biomass and recruitment are taken directly from the base model results, and the rebuilding target is based on the PFMC proxy value for MSY of 40% of estimated unfished spawning output. The mean generation time of bocaccio is estimated from the net maternity function, and is currently estimated at 13 years, a slight change from the 2003 (and subsequently updated) assessment (14 years) due to a re-estimation of the maturity function in the 2009 model.

Eleven scenarios are examined (Table 3). The scenarios include cases of no fishing, of fishing at the current Council adopted SPR rate of 0.777, fishing at the SPR rate associated with catches of 288 tons south of Point Conception in 2011 (assuming 6% of catches take place north of Mendocino), of fishing at a rate comparable to recent catches (SPR of 0.95), of fishing at a rate that achieves a 50% probability of rebuilding by T_{target}, a 40-10 harvest policy scenario, an F_{msy} scenario, and several alternative SPR rate scenarios to explore the full range of results. Included among the harvest rate scenarios are the expected median times to rebuild and associated statistics for the two alternative states of nature from the stock assessment. These states of nature represent a scenario in which the pessimistic indices (State 1) and optimistic indices (State 2) are sequentially emphasized (by varying the emphasis, or λ, on each index). Consequent estimates of depletion in 2009 and steepness were 14% depletion and 0.54 for steepness for state 1, and 38% depletion with a steepness of 0.72 for state 2. Catches for these scenarios were fixed at the projected catches from the SPR=0.777 scenario in the base model for the first 10 years of the simulation. However, projecting with fixed catches beyond ten years was not possible, as a small number of simulations with fixed catches led to population crashes, causing the model to stop. Consequently, the projection was continued with an SPR=0.50 thereafter, as this value best approximated the catch stream associated with the base model projection (mean catches were within 5% of the base model projection through 2035, becoming increasingly greater than the base model SPR=0.777 thereafter, although these catches varied from simulation to simulation due to the application of a rate rather than absolute catch). While this simulation was slightly less than optimal, the results provide a valid approximation of the potential population trajectory if State 1 is actually the true state of nature and management is based on the base model and default SPR rate into the foreseeable future.

Results

The individual rebuilding trajectories from these simulations are erratic due to rare large recruitments (Figure 1), which lead to a wide range of variability in future population trajectories that is not necessarily captured by the estimates of median rebuilding times under alternative harvest rates. This is a consequence of the high observed recruitment variability in bocaccio, and indicates a wide spread of probable outcomes around the median point estimates for any given harvest rate or scenario. This range is captured in Figure 2, which shows the estimated 5th, 25th, 50th, 75th and 95th percentiles of estimated spawning output (relative to target) under continuation of the SPR 0.777 strategy into the future. Both the probability that the stock will not be rebuilt within 50 years, as well as the probability that the stock will be above (mean) unfished abundance levels, are non-trivial (approximately 5% each) due to the magnitude of recruitment variability observed for this species.

Table 3, and Figure 3 shows the median probabilities of recovery under a range of adopted harvest rate strategies, from no harvest (SPR 1) to the ABC rule (SPR 0.5). Note that under the SPR rate adopted in the most recent rebuilding plan (0.777), the population would be expected to be rebuilt by 2021, two years earlier than the median time to rebuild (2023) under the last rebuilding analysis (MacCall 2007b). Much of the difference is thought to be due to differences in the nature of the estimation procedures for the stock recruit relationship between SS1 and SS3, as well as significant changes in catch estimates and the time period in the base model. Alternatively, if the rebuilding policy were to seek a policy of maintaining a 50% probability of rebuilding by T_{target} (2026), a greater optimal yield could be sustained. Figure 4 shows the trade-off between higher harvest rates and the probabilities of recovery by 2026, as well as the associated median rebuilding times. Figure 5 shows the projected median catches for the alternative harvest rate strategies, and Figure 6 shows the projected median spawning output (relative to the target of 40% of the unfished spawning output) under those strategies.

Table 4 shows the median probability of rebuilding by year for each of these scenarios as well. With moderate harvest rates (SPR 0.65 to 0.8), the probability of recovery by 2026 is still generally high, however catches remain well below the ABC for several decades. However, as harvest rates approach the MSY proxy, the probability of recovery by T_{target} declines sharply and the estimated median rebuilding time climbs by several decades as the median biomass trajectory remains relatively flat. With respect to the scenarios relating to the alternative states of nature, the pessimistic scenario projects only a 3% probability of rebuilding by at T_{target} (2026), and a 6% chance of rebuilding by T_{max}. Importantly, these results assume that catches are based on the default SPR estimated catches from base model for the first ten years, and an SPR of 0.50 to best approximate these catches thereafter; one might presume that if this state of nature were the true one, it would be recognized well before that and harvest rates reduced accordingly. By contrast, the optimistic scenario projects a 94% probability of rebuilding by the base model T_{target} and a 98% probability of rebuilding by T_{max} (in both state of nature models, T_{target} and T_{max} are based on the base model results, rather than the re-estimated results). By contrast the base scenario (with the same catch stream) projects a 73% probability of rebuilding by T_{target}., and an 87% probability of rebuilding by T_{max}. Note that the 5^{th}, 50^{th} and 95^{th} percentiles for the spawning output relative to target values in Table 3 for the state 1 and state 2 scenarios correspond to the base model T_{max} (2031) rather than the T_{max} values re-estimated by these models.

The value of the Acceptable Biological Catch (ABC) for 2011 is 784 tons, the associated value for 2012 is slightly dependent on the 2011 OY, assuming a 2011 OY based on the current rebuilding SPR rate, the ABC would be 815 tons.

Under the fishing rates that are consistent with recent OY values and catches, the probability of further long-term decline in bocaccio abundance is negligible in the near term and rebuilding is projected to continue at a rate somewhat greater than previously estimated. However, with respect to an analysis of long-term sustainability, the greatest factor determining future abundance (assuming harvest rates comparable to current adopted rates) is likely to be recruitment variability. Similarly, upon rebuilding, the probability of declining below the target biomass, as well as below the minimum stock size threshold, is not insignificant if future harvests are derived from the 40:10 harvest strategy, based on the life history and in particular the highly variable recruitment observed for this species. For example, Table 3 also includes an estimate of the probability of being below the current depletion level (28% of unfished spawning output) in 100 years, representing really any random point in the future after the stock has been rebuilt. Given the dynamic nature of the stock, the depletion level might be expected to be at or below 28% of unfished (nearly at the overfished threshold) 16.8% of the time with the 40:10 policy, and 26.9% of the time with the target fishing mortality rate (SPR of 0.5) without the 40:10 adjustment. Comparable results have been described for Pacific hake, another species with highly variable recruitment and population trajectories (Haltuch et al. 2008).

References

Field, J.C., E.J. Dick, D. Pearsons and A.D. MacCall. 2009. Status of bocaccio, *Sebastes paucispinis*, in the Conception, Monterey and Eureka INPFC areas for 2009. Pacific Fishery ManagementCouncil.

Haltuch, M.A., A.E. Punt and M.W. Dorn. 2008. Evaluating alternative estimators of fishery management reference points. Fisheries Research 94: 290-303.

MacCall, A. 2007. Status of bocaccio off California in 2007. Pacific Fishery Management Council.

MacCall, A. 2005a. Status of bocaccio off California in 2005. Pacific Fishery Management Council.

MacCall, A. 2005b. Bocaccio rebuilding analysis for 2005. Pacific Fishery Management Council.

MacCall, A. 2003a. Status of bocaccio off California in 2003. Pacific Fishery Management Council.

MacCall, A. 2003b. Bocaccio rebuilding analysis for 2003. Pacific Fishery Management Council.

MacCall, A. 2002. Status of bocaccio off California in 2002. Pacific Fishery Management Council.

MacCall, A., and X. He. 2002a. Bocaccio rebuilding analysis for 2002 (revised version, August 2002). Pacific Fishery Management Council.

MacCall, A., and X. He. 2002b. Status review of the southern stock of bocaccio (*Sebastes paucispinis*). NMFS Santa Cruz Laboratory Document 366 (Document prepared for NMFS Southwest Region).

MacCall, A. 1999. Bocaccio Rebuilding (revised 10/7/99). Pacific Fishery Management Council.

MacCall, A., S. Ralston, D. Pearson and E. Williams. 1999. Status of bocaccio off California in 1999, and outlook for the next millennium. Pacific Fishery Management Council.

Punt, A. 2009. SSC default rebuilding analysis (Version 3.12a, September 2009). University of Washington, Seattle.

Ralston, S., J. Ianelli, R. Miller, D. Pearson, D. Thomas, and M. Wilkins. 1996. Status of bocaccio in the Conception/Monterey/Eureka INPFC areas in 1996 and recommendations for management in 1997. Pacific Fishery Management Council.

Table 1. Recent catches (landed only through 2001, landings plus discards for 2002-2008) of bocaccio rockfish south of Cape Blanco (in metric tons). Estimates for 2008 are preliminary.

	trawl south	trawl north	hook and line	setnet	rec south	rec north	total	ABC	OY	% of OY
1999	19	26	20.7	7.2	80.1	60.2	213.2	230	230	0.93
2000	13.2	6,6	7,0	0,7	58.2	74.4	145.8	164	100	1.46
2001	9.2	4.4	7.8	0.8	62.7	53.8	138.7	122	100	1.39
2002	28	20.7	0.1	0	35.9	4.9	89.6	122	100	0.90
2003	5.1	0.3	0	0	5.5	1.9	12.8	244	20	0.64
2004	13.9	3.5	1.8	0.2	63.4	2.3	85.1	400	199	0.43
2005	24.6	0.4	1.5	0.2	69.9	10.7	107.3	566	307	0.35
2006	16.1	0.3	2.3	0.3	29	11.8	59.8	549	306	0.20
2007	4.1	1.6	3.4	0.4	44.2	8.9	62.6	602	218	0.29
2008	28.7	1.6	13.4	0.5	30.3	3.6	78.1	618	218	0.36

Table 2. Parameters and re-estimated reference points for rebuilding from this analysis

Parameter	2009	2007 (Stat c)
Year declared overfished	2000	2000
Current year	2009	"2007"
First OY year	2011	(2009?)
T_{MIN}	2018	2019
Mean generation time	13	14
T_{MAX} (estimated)	2031	2033
$T_{F=0}$ (beginning in 2011)	2018	2020
Bunfished (billion eggs)	7946	13554
Rebuilding target ($B_{40\%}$)	3178	5421
Current SPR (2008)	0.950	0.939 (06)
Target SPR	0.777	0.777
Current T_{TARGET}	2026	2026
Spawning output $_{2009}$	2249	1727

Table 3: Results of the suite of rebuilding alternatives considered for this analysis.

	SPR= 0.600	SPR= 0.700	SPR= 0.777	SPR= 0.900	SPR= 0.950	50% T_{target}	50% Tmax	2011 OY= 288	F=0	40-10 rule	ABC Rule	State 1	State 2
Rationale	range	range	target	range	current	min	range	target	F=0	40:10	ABC	uncert	uncert
SPR (target)	0.600	0.700	0.777	0.900	0.950	0.632	0.564	0.760	1.000	0.550	0.500	n/a	n/a
OY (2011)	573	397	280	116	56	513	644	288	0	674	784	n/a	n/a
ABC (2011)	784	784	784	784	784	784	784	784	784	784	784	n/a	n/a
OY (2012)	580	409	291	122	60	522	648	299	0	663	779	n/a	n/a
ABC (2012)	794	806	815	826	830	798	789	813	834	787	779	n/a	n/a
50% Prob Yr	2028	2024	2022	2020	2019	2026	2031	2022	2019	2035	2041	2073	2015
P > SSB_{2009} in 100 years	94.1	99.2	99.9	100	100	96.8	89.9	99.9	100	83.2	73.1	99.7	99.5
<5th %tile, sp.output/tar in T_{max}	0.59	0.71	0.81	0.96	1.02	0.63	0.54	0.77	1.08	0.55	0.46	0.22	0.98
Median, sp.output/tar in T_{max}	0.99	1.19	1.34	1.58	1.68	1.05	0.92	1.31	1.77	0.86	0.79	0.47	1.63
>95th %tile, sp.output/tar in T_{max}	1.77	2.12	2.37	2.77	2.93	1.89	1.65	2.33	3.10	1.47	1.43	0.99	2.75
Percent probability of recovery by pre-specified years													
2010	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	1	1	2	2	3	1	1	2	3	1	0	0	39
2018	13	20	27	38	43	16	10	26	48	9	7	0	76
2022	29	44	55	71	77	34	24	54	81	21	16	1	87
2026	44	62	73	87	91	50	37	71	93	31	25	3	94
2030	56	75	85	94	96	62	48	82	98	41	33	6	97
2034	65	82	91	97	98	71	57	89	99	48	40	9	99
2038	73	88	95	99	99	78	64	94	100	56	46	13	100

Table 4: Year specific probabilities of rebuilding to target levels for Table 3 scenarios.

	SPR= .600	SPR= .700	SPR= .777	SPR= .900	SPR= .950	50% Ttarget	50% Tmax	2011 OY 288	F=0	40-10 rule	ABC Rule	State 1	State 2
2009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2013	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.118
2014	0.009	0.014	0.018	0.025	0.028	0.010	0.007	0.020	0.028	0.006	0.005	0.000	0.385
2015	0.031	0.043	0.054	0.077	0.089	0.035	0.027	0.050	0.102	0.023	0.020	0.001	0.541
2016	0.059	0.090	0.118	0.171	0.194	0.068	0.049	0.119	0.220	0.043	0.037	0.001	0.640
2017	0.092	0.143	0.191	0.271	0.309	0.109	0.077	0.184	0.349	0.065	0.054	0.004	0.709
2018	0.129	0.205	0.268	0.383	0.433	0.155	0.103	0.259	0.481	0.087	0.073	0.005	0.762
2019	0.170	0.267	0.350	0.484	0.540	0.196	0.140	0.333	0.594	0.116	0.093	0.009	0.802
2020	0.210	0.328	0.425	0.574	0.629	0.249	0.173	0.409	0.686	0.145	0.117	0.012	0.832
2021	0.255	0.384	0.492	0.650	0.701	0.294	0.210	0.477	0.758	0.175	0.141	0.013	0.851
2022	0.295	0.435	0.553	0.709	0.767	0.340	0.243	0.542	0.813	0.205	0.164	0.015	0.872
2023	0.333	0.489	0.604	0.762	0.810	0.382	0.276	0.586	0.855	0.233	0.186	0.019	0.897
2024	0.369	0.534	0.650	0.806	0.850	0.420	0.311	0.632	0.888	0.260	0.208	0.022	0.912
2025	0.405	0.578	0.696	0.840	0.882	0.460	0.339	0.675	0.916	0.286	0.230	0.026	0.930
2026	0.438	0.616	0.731	0.870	0.905	0.500	0.366	0.708	0.933	0.310	0.253	0.031	0.941
2027	0.473	0.651	0.768	0.893	0.923	0.533	0.396	0.741	0.949	0.334	0.272	0.038	0.948
2028	0.503	0.688	0.797	0.912	0.940	0.562	0.426	0.775	0.962	0.360	0.293	0.045	0.961
2029	0.530	0.716	0.822	0.929	0.952	0.594	0.452	0.796	0.970	0.383	0.315	0.053	0.968
2030	0.556	0.747	0.847	0.943	0.962	0.622	0.476	0.822	0.978	0.408	0.333	0.059	0.971
2031	0.582	0.768	0.868	0.952	0.970	0.648	0.500	0.848	0.983	0.428	0.354	0.064	0.977
2032	0.606	0.790	0.883	0.960	0.975	0.671	0.521	0.865	0.986	0.449	0.371	0.072	0.981
2033	0.630	0.806	0.898	0.966	0.980	0.694	0.543	0.880	0.988	0.466	0.387	0.082	0.985
2034	0.652	0.824	0.911	0.972	0.983	0.713	0.569	0.894	0.990	0.484	0.403	0.091	0.988
2035	0.670	0.840	0.920	0.977	0.985	0.732	0.586	0.910	0.991	0.505	0.418	0.098	0.989
2036	0.690	0.854	0.930	0.980	0.988	0.751	0.606	0.920	0.994	0.523	0.432	0.108	0.992
2037	0.709	0.868	0.939	0.983	0.992	0.769	0.623	0.930	0.996	0.539	0.444	0.118	0.994
2038	0.726	0.881	0.946	0.987	0.994	0.784	0.639	0.938	0.997	0.558	0.459	0.126	0.995
2039	0.743	0.891	0.952	0.990	0.996	0.802	0.657	0.943	0.998	0.574	0.474	0.134	0.998
2040	0.759	0.900	0.958	0.991	0.997	0.814	0.674	0.950	0.998	0.593	0.491	0.146	0.999
2041	0.771	0.908	0.965	0.993	0.998	0.827	0.688	0.957	0.999	0.607	0.505	0.157	0.999
2042	0.785	0.916	0.968	0.995	0.998	0.837	0.699	0.963	0.999	0.622	0.520	0.170	0.999
2043	0.795	0.922	0.972	0.996	0.999	0.847	0.714	0.967	1.000	0.635	0.535	0.183	0.999
2044	0.807	0.929	0.976	0.996	0.999	0.857	0.726	0.970	1.000	0.649	0.548	0.191	0.999
2045	0.817	0.935	0.979	0.997	0.999	0.867	0.739	0.975	1.000	0.660	0.560	0.203	0.999
2046	0.829	0.941	0.981	0.997	0.999	0.876	0.751	0.977	1.000	0.671	0.571	0.215	1.000
2047	0.838	0.946	0.983	0.998	1.000	0.884	0.760	0.979	1.000	0.682	0.583	0.230	1.000
2048	0.847	0.949	0.985	0.998	1.000	0.890	0.772	0.982	1.000	0.694	0.591	0.239	1.000
2049	0.857	0.956	0.987	0.998	1.000	0.899	0.780	0.985	1.000	0.704	0.602	0.247	1.000
2050	0.866	0.959	0.988	0.999	1.000	0.905	0.788	0.986	1.000	0.716	0.611	0.253	1.000
2051	0.873	0.962	0.989	0.999	1.000	0.911	0.798	0.988	1.000	0.724	0.622	0.269	1.000
2052	0.879	0.966	0.990	0.999	1.000	0.917	0.807	0.988	1.000	0.734	0.632	0.279	1.000
2053	0.886	0.968	0.991	0.999	1.000	0.920	0.815	0.989	1.000	0.744	0.641	0.291	1.000
2054	0.891	0.971	0.992	0.999	1.000	0.926	0.823	0.989	1.000	0.754	0.650	0.302	1.000
2055	0.897	0.974	0.992	0.999	1.000	0.931	0.830	0.989	1.000	0.760	0.659	0.316	1.000
2056	0.903	0.975	0.993	0.999	1.000	0.936	0.839	0.991	1.000	0.770	0.665	0.325	1.000
2057	0.907	0.978	0.995	1.000	1.000	0.941	0.845	0.993	1.000	0.779	0.676	0.334	1.000
2058	0.913	0.981	0.996	1.000	1.000	0.945	0.853	0.993	1.000	0.788	0.683	0.346	1.000

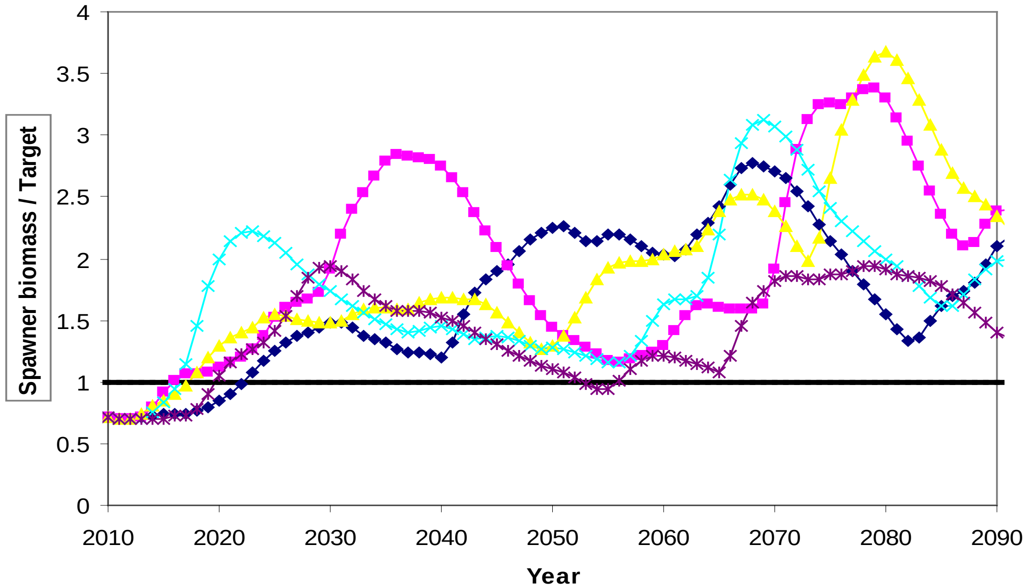

Figure 1. Examples of individual rebuilding trajectories for bocaccio (based on the rebuilding plan SPR rate of 0.777)

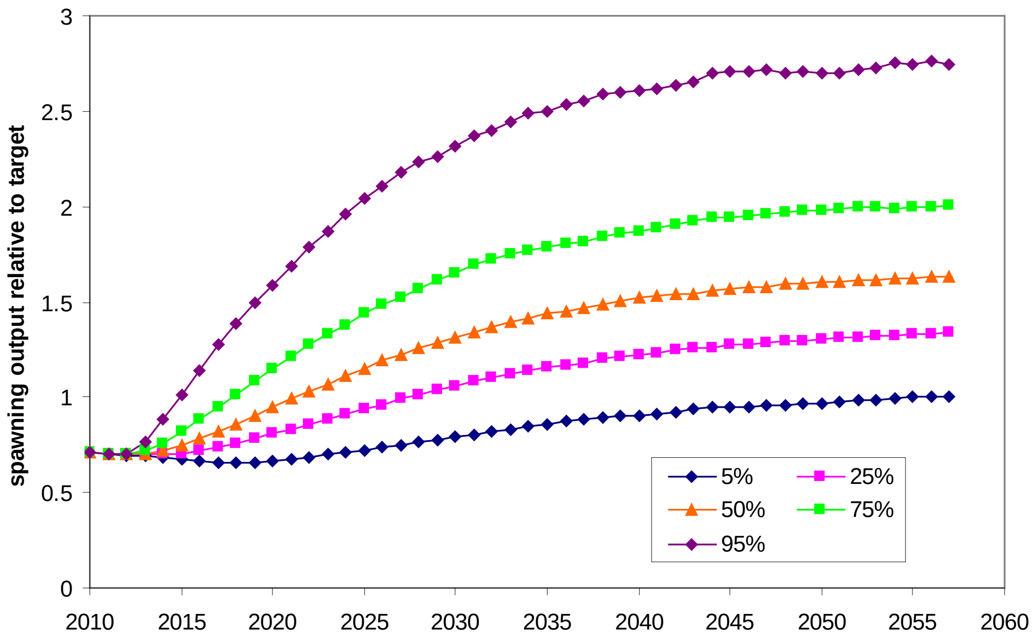

Figure 2. Estimated 5th, 25th, 50th, 75th and 95th percentiles of spawning output (relative to target) under continuation of the SPR 0.777 strategy into the future.

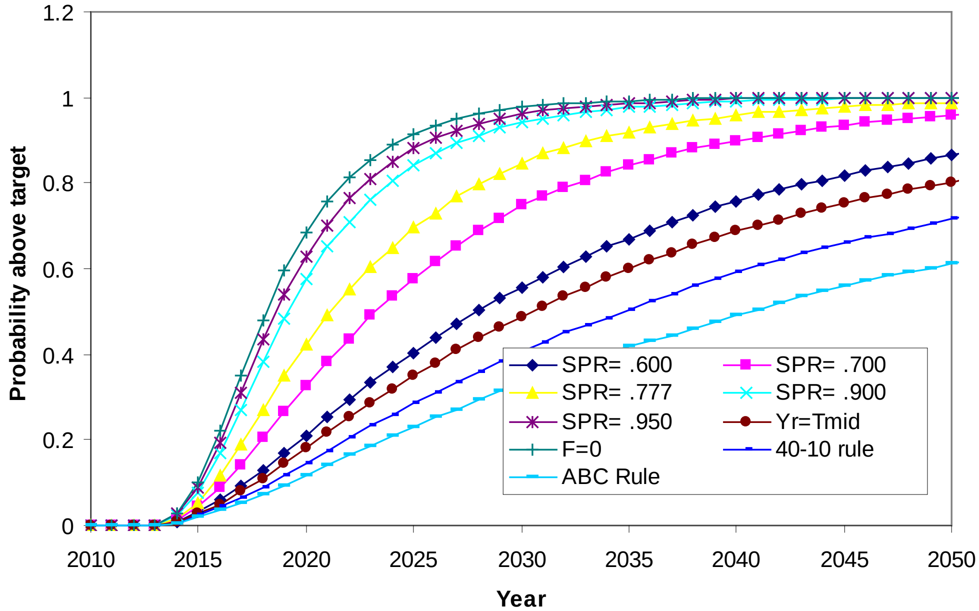

Figure 3: Probability of recovery for a suite of the rebuilding alternatives described in Table 3.

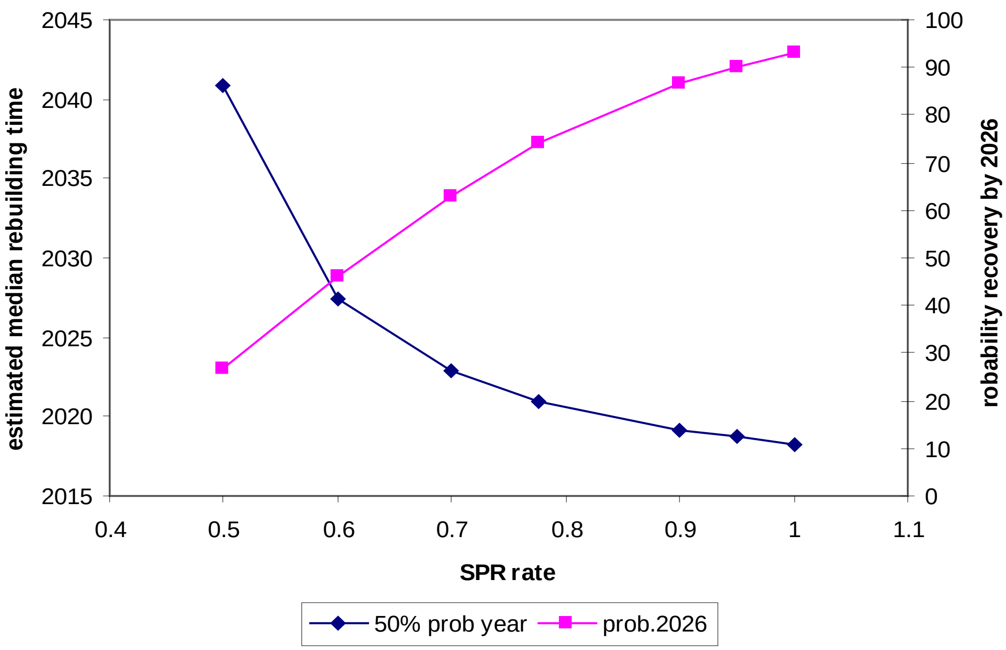

Figure 4: Probability of recovery by the target year (2026, left y axis) and estimated median year of rebuilding (right y axis) under alternative SPR harvest rates.

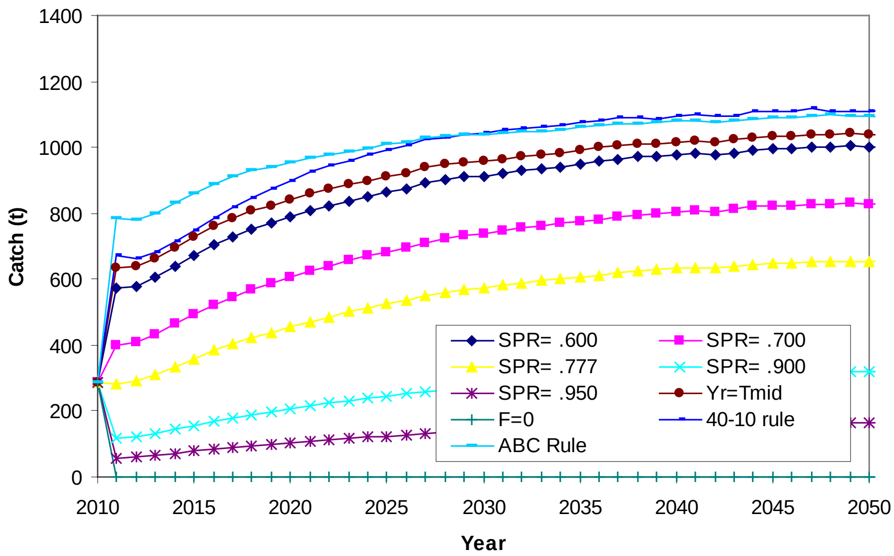

Figure 5: Projected median catches (mt) for a suite of the rebuilding alternatives from Table 3.

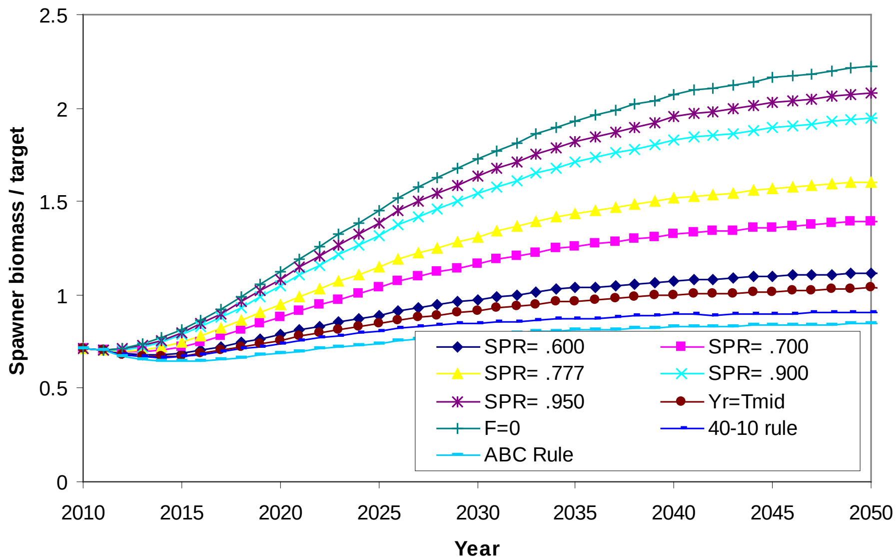

Figure 6: Projected median spawning output (relative to target) for a suite of the rebuilding alternatives described in Table 3

Appendix A. Projection data file for base run.

#Title, #runnumber: 25 bocstar85.dat bocstar85.ctl 3103.32 7.94425e+006 2.24911e+006 StartTime: Tue Sep 15 10:43:28 2009
SSv3_default_rebuild.dat
Number of sexes
2
Age range to consider (minimum age; maximum age)
0 21
Number of fleets
6
First year of projection (Yinit)
2009
First Year of rebuilding period (Ydecl)
2000
Number of simulations
5000
Maximum number of years
500
Conduct projections with multiple starting values (0=No;else yes)
0
Number of parameter vectors
1000
Is the maximum age a plus-group (1=Yes;2=No)
1
Generate future recruitments using historical recruitments (1) historical recruits/spawner (2) or a stock-recruitment (3)
3
Constant fishing mortality (1) or constant Catch (2) projections
1
Fishing mortality based on SPR (1) or actual rate (2)
1
Pre-specify the year of recovery (or -1) to ignore
-1
Fecundity-at-age
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 #runnumber: 25 bocstar85.dat bocstar85.ctl 3103.32 7.94425e+006 2.24911e+006
0 0.0320825 4.51517 61.0387 189.808 331.861 469.763 602.673 728.431 844.301 948.357 1039.78 1118.68 1185.79 1242.23 1289.25 1328.14 1360.12 1386.28 1407.62 1424.96 1439.02 #female fecundity; weighted by N in year Y_init across morphs and areas
Age specific selectivity and weight adjusted for discard and discard mortality
#wt and selex for gender,fleet: 1 1
0.0501803 0.264118 0.545662 0.839903 1.14585 1.44703 1.73454 2.00846 2.2654 2.49948 2.70622 2.88411 3.03424 3.15922 3.26225 3.34661 3.41537 3.4712 3.51642 3.55298 3.5825 3.60629
3.23902e-005 0.0285912 0.365894 0.818067 0.921228 0.829802 0.701441 0.594938 0.519326 0.468354 0.434276 0.411244 0.395384 0.384233 0.376231 0.370382 0.366037 0.362764 0.36027 0.358351 0.356862 0.3557
#wt and selex for gender,fleet: 1 2
0.0397553 0.287589 0.617773 0.949916 1.25838 1.54437 1.80314 2.03779 2.25506 2.45704 2.64172 2.80635 2.94949 3.0714 3.17363 3.25838 3.32807 3.38503 3.43139 3.46899 3.49943 3.52402
6.62111e-005 0.00140511 0.0653984 0.372372 0.729027 0.877567 0.856989 0.770602 0.679544 0.605164 0.549809 0.509954 0.481435 0.4609 0.445945 0.43491 0.426663 0.420427 0.415663

0.411992 0.409141 0.406914
#wt and selex for gender,fleet: 1 3
0.0397053 0.194686 0.703841 1.0213 1.27559 1.51655 1.74018 1.94768 2.14429 2.33186 2.5081
2.6692 2.81221 2.936 3.04107 3.12894 3.20165 3.26135 3.3101 3.34974 3.38189 3.40789
0.00187389 0.00231872 0.0195081 0.279654 0.688494 0.822311 0.747029 0.618512 0.505581
0.422189 0.364087 0.324124 0.29645 0.276998 0.263084 0.252957 0.245468 0.239851 0.235587
0.232317 0.229787 0.227817
#wt and selex for gender,fleet: 1 4
0.0419526 0.228217 0.485398 0.78507 1.09768 1.39255 1.65977 1.89739 2.10653 2.2893 2.44789
2.5844 2.70087 2.79935 2.88194 2.95067 3.0075 3.05424 3.0925 3.12371 3.14908 3.16966
0.00985281 0.261401 0.801342 0.947591 0.829444 0.651501 0.496154 0.381275 0.301199 0.246176
0.208148 0.181482 0.162456 0.148641 0.138446 0.130815 0.125031 0.120602 0.11718 0.114517
0.112433 0.110793
#wt and selex for gender,fleet: 1 5
0.0427124 0.229124 0.506932 0.827727 1.17819 1.5345 1.87429 2.18396 2.45745 2.69364 2.8943
3.06268 3.20264 3.31815 3.41293 3.49036 3.55339 3.60456 3.64601 3.67952 3.70659 3.72841
0.00875859 0.122917 0.490837 0.799549 0.926291 0.970074 0.986016 0.992519 0.995502 0.997019
0.997861 0.998363 0.998679 0.998889 0.999033 0.999136 0.99921 0.999265 0.999306 0.999338
0.999362 0.999381
#wt and selex for gender,fleet: 1 6
0.0475569 0.277291 0.616714 0.909558 1.2159 1.54771 1.87789 2.18432 2.45681 2.69275 2.89339
3.06182 3.20184 3.3174 3.41223 3.4897 3.55276 3.60396 3.64542 3.67895 3.70603 3.72787
1.22315e-005 0.00273196 0.113914 0.543559 0.852534 0.956899 0.986197 0.994845 0.99774
0.998854 0.999342 0.99958 0.999708 0.999783 0.999829 0.999858 0.999878 0.999893 0.999903
0.99991 0.999916 0.99992
#wt and selex for gender,fleet: 2 1
0.0501803 0.264118 0.520282 0.770289 1.00918 1.22931 1.42136 1.58475 1.7218 1.83523 1.92785
2.00254 2.06212 2.10924 2.14624 2.17515 2.19763 2.21506 2.22855 2.23896 2.24698 2.25316
3.23902e-005 0.0285912 0.322726 0.746783 0.917839 0.910852 0.844492 0.77163 0.709574 0.661211
0.624795 0.597693 0.577556 0.562554 0.551333 0.542903 0.536545 0.531732 0.528079 0.5253
0.523181 0.521564
#wt and selex for gender,fleet: 2 2
0.0397553 0.287589 0.587262 0.871894 1.12011 1.33385 1.51534 1.66554 1.7879 1.88684 1.96642
2.03006 2.08065 2.12061 2.15201 2.17655 2.19567 2.21051 2.222 2.23088 2.23773 2.24301
6.62111e-005 0.00140511 0.0521353 0.282806 0.592814 0.797627 0.880289 0.890552 0.869012
0.837861 0.807081 0.780317 0.758362 0.740878 0.727175 0.716531 0.708305 0.701967 0.697091
0.693344 0.690466 0.688257
#wt and selex for gender,fleet: 2 3
0.0397053 0.194686 0.661045 0.954253 1.15995 1.33788 1.49218 1.62208 1.72938 1.81713 1.88834
1.9457 1.99157 2.02797 2.05669 2.07921 2.0968 2.11047 2.12108 2.12929 2.13562 2.14051
0.00187389 0.00231872 0.0138088 0.185556 0.531408 0.76394 0.832038 0.812093 0.762446 0.710064
0.664411 0.627473 0.598562 0.576275 0.559211 0.54618 0.536236 0.528645 0.522847 0.518415
0.515025 0.512431
#wt and selex for gender,fleet: 2 4
0.0419526 0.228217 0.462011 0.714123 0.962288 1.18354 1.37169 1.52765 1.65473 1.75699 1.83848
1.90291 1.95354 1.99312 2.02394 2.04787 2.06639 2.0807 2.09174 2.10025 2.1068 2.11183
0.00985281 0.261401 0.769194 0.95053 0.899222 0.783066 0.668274 0.574668 0.503567 0.45094
0.412243 0.383741 0.362646 0.346942 0.335188 0.326346 0.319668 0.314607 0.310761 0.307832
0.305598 0.303891
#wt and selex for gender,fleet: 2 5
0.0427124 0.229124 0.481408 0.750287 1.01989 1.27348 1.4988 1.69088 1.85001 1.9792 2.08258
2.16445 2.22878 2.27904 2.31813 2.34845 2.37189 2.38999 2.40395 2.41469 2.42296 2.42931
0.00875859 0.122917 0.457578 0.749974 0.888087 0.944582 0.968778 0.980185 0.986111 0.989458

0.99148 0.992771 0.99363 0.99422 0.994636 0.994935 0.995154 0.995315 0.995435 0.995526 0.995594 0.995645
#wt and selex for gender,fleet: 2 6
0.0475569 0.277291 0.588299 0.840528 1.07272 1.30022 1.51174 1.69712 1.853 1.98055 2.08307 2.16446 2.22851 2.2786 2.31759 2.34783 2.37123 2.3893 2.40323 2.41395 2.42221 2.42855
1.22315e-005 0.00273196 0.0908083 0.439746 0.753861 0.898935 0.955034 0.977279 0.986942 0.991592 0.99405 0.995455 0.996313 0.996863 0.997231 0.997485 0.997664 0.997793 0.997888 0.997957 0.99801 0.998049
M and current age-structure in year Yinit: 2009
gender = 1
0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15
1747.17 369.728 314.502 138.855 998.583 132.021 785.128 212.143 46.1802 33.3943 852.425 109.453 16.7064 66.4504 30.5838 45.999 48.8795 15.7466 40.4059 32.65 3.89216 94.8533
gender = 2
0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15
1747.17 369.728 314.502 138.905 999.303 132.064 784.816 211.745 45.9703 33.1624 845.406 108.447 16.5348 65.6137 30.2028 45.5004 48.2894 15.582 39.8907 31.9384 3.75416 79.4612
Age-structure at Ydeclare= 2000
136.02 3526.71 461.149 70.7112 279.622 127.585 190.407 201.135 64.5213 165.067 133.101 15.8428 216.557 48.4227 9.55928 7.43326 57.7925 5.51867 0.322745 1.17761 1.61981 36.949
136.02 3526.71 461.149 70.8329 280.524 128.435 192.395 203.205 65.3217 166.743 133.211 15.6325 208.81 45.3488 8.56095 6.14798 43.7151 3.86541 0.207421 0.675208 0.810805 12.0988
Year for Tmin Age-structure (set to Ydecl by SS)
2000
recruitment and biomass
Number of historical assessment years
119
Historical data
year recruitment spawner in B0 in R project in R/S project
1891 1892 1893 1894 1895 1896 1897 1898 1899 1900 1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945 1946 1947 1948 1949 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 #years (with first value representing R0)
5107.96 5074.14 5073.88 5073.8 5073.85 5073.95 5074.11 5074.34 5074.66 5075.09 5075.23 5075.1 5074.7 5074.05 5073.18 5072.09 5070.82 5069.36 5067.74 5065.65 5063.11 5060.12 5056.72 5052.91 5048.74 5044.2 5038.19 5026.24 5013.26 5006.9 5000.65 4997.02 4994.96 4991.56 4989.57 4986.32 4978.33 4972.99 4967.22 4962.64 4955.44 4949.01 4946.5 4947.63 4947.44 4946.3 4942.78 4940.36 4941.31 4944.53 4947.63 4952.58 4962.09 4966.63 4958.63 4931.67 4920.82 4910.25 4904.73 4897.79 4880.19 4845.8 4804.69 5017.36 1605.57 5330.72 1617.28 2761.35 4445.59 3845.57 75194 3942.44 4240.25 5514.25 6024.26 25691.9 4436.11 4150.37 4467.5 6175.13 6341.26 10404.3 24803.4 8376.92 1254.48 2511.23 37607 2462.83 7637.43 1996.3 1042.07 189.786 2096.94 14212.4 1215.15 1034.4 3328.7 9530.45 466.682 2725.71 2414.35 684.632 1582.9 1161.25 616.331 1095.67 230.031 1256.9 8198.11 272.041 322.29 1272.2 4016.44 574.15 3701.64 438.966 850.402 859.172 3494.34 #recruits; first value is R0 (virgin)
7.94425e+006 7.66413e+006 7.66199e+006 7.66136e+006 7.66174e+006 7.66261e+006 7.66386e+006 7.6657e+006 7.6683e+006 7.67176e+006 7.67291e+006 7.67182e+006 7.6686e+006 7.66341e+006 7.65638e+006 7.64768e+006 7.63745e+006 7.62583e+006 7.61293e+006 7.59634e+006 7.5762e+006 7.55268e+006 7.52601e+006 7.49641e+006 7.4641e+006 7.42928e+006 7.38353e+006

7.29394e+006 7.19854e+006 7.15255e+006 7.10786e+006 7.08203e+006 7.06749e+006 7.04358e+006
7.02961e+006 7.00695e+006 6.95164e+006 6.91507e+006 6.87593e+006 6.84506e+006 6.79709e+006
6.75459e+006 6.73815e+006 6.74554e+006 6.74433e+006 6.73687e+006 6.71388e+006 6.69817e+006
6.70433e+006 6.72529e+006 6.74554e+006 6.77813e+006 6.84138e+006 6.87191e+006 6.81826e+006
6.64222e+006 6.5734e+006 6.50742e+006 6.47338e+006 6.43099e+006 6.32539e+006 6.12667e+006
5.90158e+006 5.626e+006 5.33651e+006 4.94646e+006 4.4526e+006 3.90382e+006 3.32808e+006
2.88334e+006 2.49311e+006 2.24419e+006 2.23537e+006 3.4399e+006 5.67356e+006 7.39776e+006
8.26494e+006 8.41826e+006 8.87532e+006 9.51229e+006 9.71524e+006 9.63895e+006 9.19172e+006
8.06177e+006 6.70827e+006 6.16198e+006 5.83867e+006 5.4615e+006 4.96643e+006 4.74408e+006
4.88852e+006 4.65254e+006 4.02471e+006 3.25259e+006 2.46094e+006 1.96429e+006 1.67847e+006
1.62455e+006 1.50107e+006 1.25039e+006 1.13966e+006 1.2231e+006 1.19907e+006 1.15923e+006
1.11951e+006 1.09941e+006 1.10596e+006 1.09333e+006 1.10762e+006 1.10464e+006 1.11224e+006
1.24582e+006 1.47816e+006 1.65556e+006 1.76355e+006 1.88074e+006 2.01465e+006 2.14025e+006
2.24911e+006 #spbio; first value is S0 (virgin)
1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 # in Bzero
0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 0 0 0 # in R project
0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 0 0 0 # in R/S project

Number of years with pre-specified catches
2
catches for years with pre-specified catches go next
2009 288
2010 288
Number of future recruitments to override
9
Process for overiding (-1 for average otherwise index in data list)
2001 1 2001
2002 1 2002
2003 1 2003
2004 1 2004
2005 1 2005
2006 1 2006
2007 1 2007
2008 1 2008
2009 1 2009
Which probability to product detailed results for (1=0.5; 2=0.6; etc.)
3
Steepness sigma-R Auto-correlation
0.578214 1 0
Target SPR rate (FMSY Proxy); manually change to SPR_MSY if not using SPR_target
0.5
Discount rate (for cumulative catch)
0.1
Truncate the series when 0.4B0 is reached (1=Yes)
0
Set F to FMSY once 0.4B0 is reached (1=Yes)
0

```
# Maximum possible F for projection (-1 to set to FMSY)
-1
# Defintion of recovery (1=now only;2=now or before)
2
# Projection type
4
# Definition of the 40-10 rule
10 40
# Calculate coefficients of variation (1=Yes)
0
# Number of replicates to use
10
# Random number seed
-99004
# File with multiple parameter vectors
rebuild.SSO
# User-specific projection (1=Yes); Output replaced (1->9)
0  5
# Catches and Fs (Year; 1/2/3 (F or C or SPR); value); Final row is -1
2011 2 0
2040 2 0
-1 -1 -1
# Fixed catch project (1=Yes); Output replaced (1->9); Approach (-1=Read in else 1-9)
0 2 -1
# Split of Fs
2009  0.00362301 0.00161635 7.58146e-005 0.00515832 0.000289909 0.000133024
-1 0.00362301 0.00161635 7.58146e-005 0.00515832 0.000289909 0.000133024
# Yrs to define T_target for projection type 4 (a.k.a. 5 pre-specified inputs)
2016 2026 2029 2032 2033
# Year for probability of recovery
2010 2014 2018 2022 2026 2030 2034 2038
# Time varying weight-at-age (1=Yes;0=No)
0
# File with time series of weight-at-age data
none
# Use bisection (0) or linear interpolation (1)
1
# Target Depletion
0.4
# CV of implementation error
0
```