Supplemental Attachment G.x.x
November 1999

Bocaccio Rebuilding

Alec D. MacCall revised 10/7/99
NMFS Santa Cruz/Tiburon Laboratory
3150 Paradise Dr.
Tiburon, CA 94920
email: alecm@tib.nmfs.gov

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 existing abundance estimates (Ralston et al. 1996), bocaccio was declared formally to be overfished, thereby requiring development of a rebuilding plan for consideration by the Council in the fall of 1999. This timing was complicated by the stock assessment schedule, which called for a new bocaccio stock assessment to be prepared in the summer of 1999.

Development of alternative management options for bocaccio rebuilding began before the new assessment was available, and required interim use of the results of the 1996 stock assessment. MacCall (1999) developed a simple production model to project bocaccio rebuilding trajectories. Assuming the 1999 stock to be at 50% of the 1996 abundance, that preliminary model indicated that the total catch (plus discards) would have to be reduced to about 100 tons.

The new stock assessment (MacCall et al. 1999) established that the stock off California is genetically distinct from bocaccio found to the north, and that the groundfish management line at Cape Mendocino can be considered as the northern boundary of the stock for management purposes. The new assessment found that under continuing recruitment failure, the index of bocaccio spawning output had fallen from Ralston et al's estimate of 568 units in 1996 to 259 units in 1999. Estimated total biomass fell from 3,857 mt in 1996 to 1,271 mt in 1999. A portion of this change was due to a change in estimation methodology. The decline shown by the 1999 assessment was more severe than the 50% decline assumed in MacCall's (1999) preliminary rebuilding analysis.

Management Reference Points

Bmsy: The rebuilding target is the spawning abundance level that produces MSY. This cannot be determined directly, but experience in other fisheries has shown that Bmsy is often near 40% of the initial unfished spawning abundance (Binit). This is the rebuilding target endorsed by the SSC's Rebuilding Workshop (Conser 1999). Binit can be estimated by simulating an unfished resource with recruitment levels sampled from an appropriate historical

time period. The STAR Panel proposed that the entire history of recruitment be used, but the Rebuilding Workshop favored using an early period when biomasses were large (in this case, the 1970 to 1979 year classes. The two approaches generate simulated distributions of initial abundance that can be compared with the 1969 abundance estimated in the stock assessment (Figure 1). A biomass as large as that in 1969 would be unlikely given the frequency distribution based on samples taken from the entire series of recruitments, but would be commonplace based on use of recruitments sampled from the early period. Estimated unfished abundance is a linear function of recruitments, so the mean recruitment from 1970 to 1979 (9.7896 million fish) can be expanded by the SPR ratio at F=0 (1.286 units of spawning output per recruit) to give estimated Binit= 12587 units of spawning output. The corresponding estimate of Bmsy is 40% of this amount, or 5035 units of spawning output. For comparison, the estimated 1999 spawning output of 259 is 5.1% of the rebuilding target, and is only 2.1% of Binit.

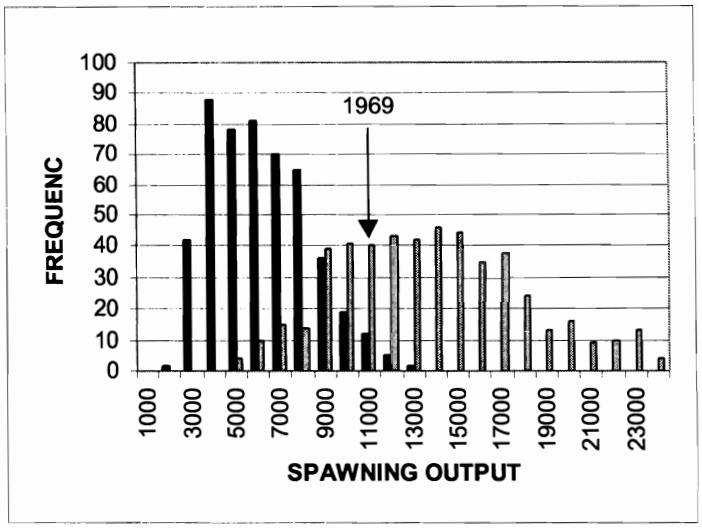

Figure 1. Simulated distribution of unfished abundances based on resampling recruitments. Dark bars utilize entire series; light bars utilize 1970 to 1979 values. Spawning output in 1969 is shown for comparison.

Mean generation time: If the stock cannot be rebuilt in ten years, then the maximum time allowed for rebuilding is the length of time required to rebuild at F=0 plus one generation time. Mean generation time can be estimated from the net maternity function (product of survivorship and fecundity at age, Figure 2), and for bocaccio is estimated to be 12.06 years, which is rounded to an integer value of 12 years.

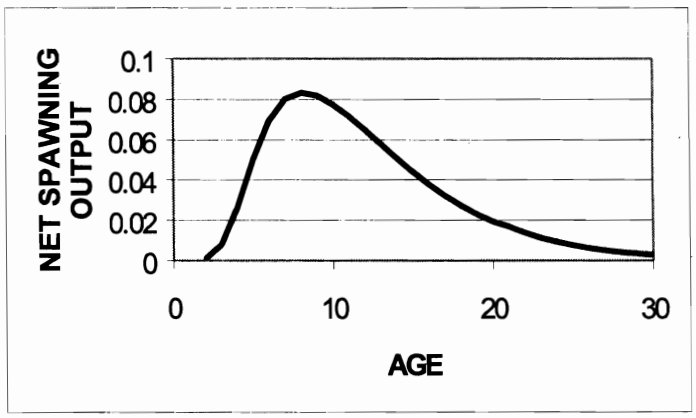

Figure 2. Net maternity function for bocaccio, normalized to unit area.

Simulation Model

The simulation model tracks abundances at age, with an accumulator at age 21+. Values of weights at age, selectivity and fecundity are taken from Appendix 1 of MacCall et al. (1999).

Population simulations begin with the 1999 age composition, and the age 1 recruitment strength in year 2000 is set according to one of three scenarios described below (see "Initial Conditions"). Subsequent recruitments are generated by a random draw of one of the historical values of R/S, which is multiplied by current spawning output (S) to obtain the following year's recruitment. For each recreated sequence of R/S values, three sets of simulations are run corresponding to the three recruitment scenarios. In each case, the time (number of years) to reach the rebuilding target at F=0 (Tmin) is first determined. Then the value of fishing mortality rate is determined that allows the stock to achieve the rebuilding abundance in the maximum allowable length of time (Tmax=Tmin+12). The model simulated a maximum of 300 years. One hundred of these simulations (i.e., with one hundred different sequences of reproductive successes) were run in order to obtain percentage probabilities of successful rebuilding within the required time frame.

Initial conditions: Initial age structure used in the simulations is taken from the most recent stock assessment (MacCall et al. 1999). However, that assessment does not include an estimate of the strength of the 1999 year class, which appears to be larger than any seen in recent years according to anecdotal reports. The strong 1999 year class is likely to be a demographically important component of the population, and should not be ignored in rebuilding projections.

Three possible strengths of the 1999 year class are considered (Figure 3): It could be equivalent to the 1991 year class ("low"), the 1988 year class ("medium"), or the 1984 year class ("high"). Even the "low" value of the 1999 year class would require that reproductive success, in recruits per spawning output, was equal to that in 1988, the highest ever observed. The alternative reproductive successes associated with the "medium" and "high" values would be far higher than any value observed previously (Figure 4).

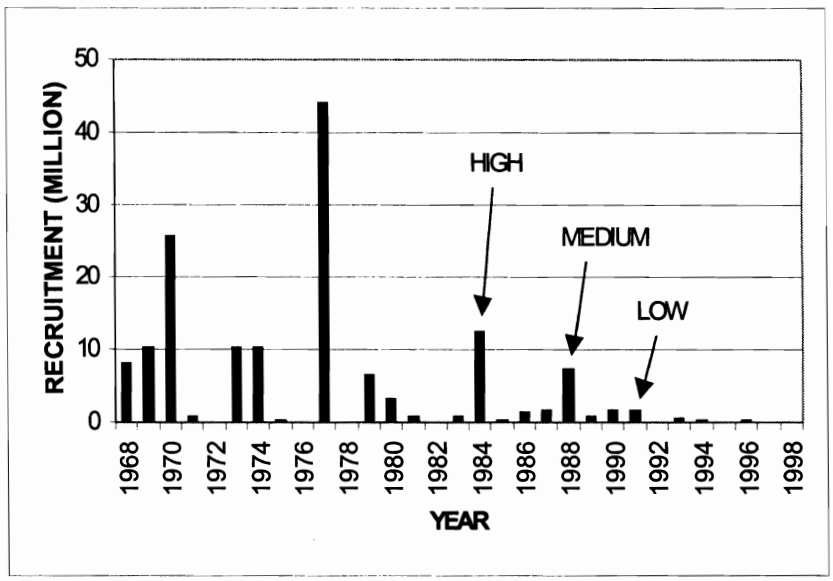

Figure 3. History of bocaccio year class strengths, showing reference for three alternative values assumed for 1999.

The rebuilding projection is driven by resampling of historical values of reproductive success (Figure 4) without adjustment for population size effects (the slope of the relationship between log spawning success and spawning output is not significantly different from 0). Values of R/S for years prior to 1977 (the first year of length composition information) are presumably imprecise, and were not used. Each of the three alternative 1999 recruitment models includes the

corresponding 1999 value of R/S in the values to be resampled. The medium and high recruitment cases generate very high 1999 values of R/S, which contributes to a corresponding large increase in model resource productivity for those cases.

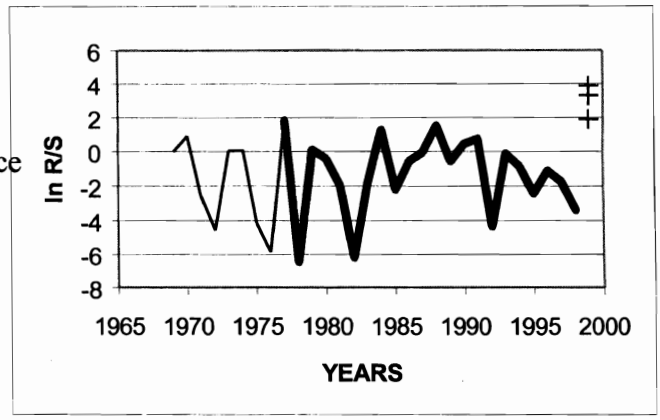

Figure 4. History of log reproductive success. Heavy line indicates values that were resampled. Markers show possible 1999 values. A ln(R/S) value of -0.25 is needed for replacement at F=0.

1999 year class: Because the three different 1999 recruitment cases result in very different management recommendations, some attempt to quantify the 1999 year class strength is desirable. Fish impingement data from electric power generating stations in southern California (K. Herbinson, Southern California Edison, pers. comm) provide information that helps resolve this problem. Two power plants at San Onofre provide records from1984 to March, 1999. A plot of the number of days on which impinged bocaccio were observed shows a general relationship to the historical recruitment strengths from the stock assessment. The 1991, 1988 and 1984 counts are generally higher than the counts from years known to have weaker recruitment. The 1999 data cover only the first three months of the year, but the number of positive station-days already exceeds previously observed values. A strict quantitative interpretation is probably not warranted. The relationship between the 1984 and 1988 points is counter to the corresponding estimated year class strengths, and argues that the relationship is not precise. However, a reasonable qualitative conclusion would be that the 1999 year class is probably at the strong end of the three alternative scenarios in the rebuilding plan.

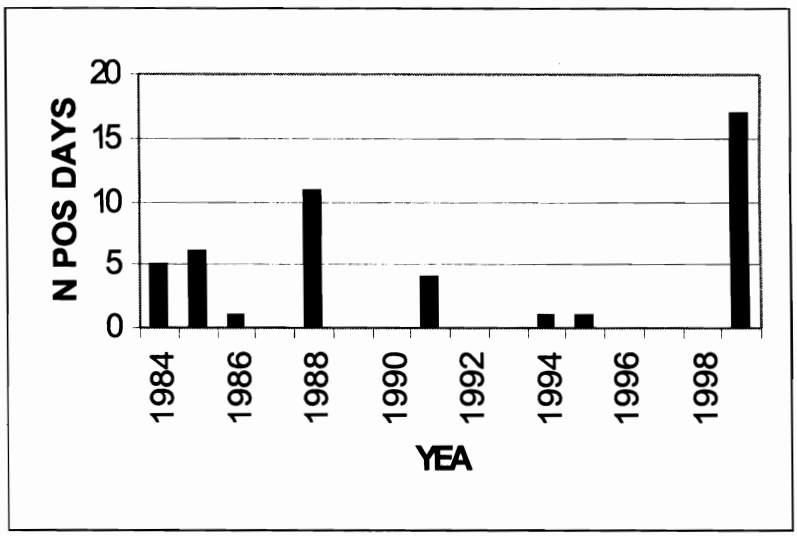

Figure 5. Number of days in which impinged bocaccio were observed at two San Onofre electric power generating stations through March, 1999 (data supplied by K. Herbinson, Southern California Edison).

Projections

Table 1 presents the probabilities of rebuilding under alternative constant fishing rates. Catch levels given in the table are associated with the respective fishing rate and assumed strength of the 1999 year class. The medium and high 1999 recruitment scenarios anticipate an additional recreational catch of 1999 year class bocaccio in year 2000. One-year-old fish are not normally available to commercial fisheries, so an alternative calculation of catch of age 2+ fish is presented as the amount that can be allocated among fishery segments in year 2000. Rebuilding policies are based on a constant harvest rate, given the selectivity curve, and are most easily summarized by the catches in 2000, 2001 and 2002 (Table 1). Probability of successful rebuilding is related directly to year 2000 catch in Figure 6.

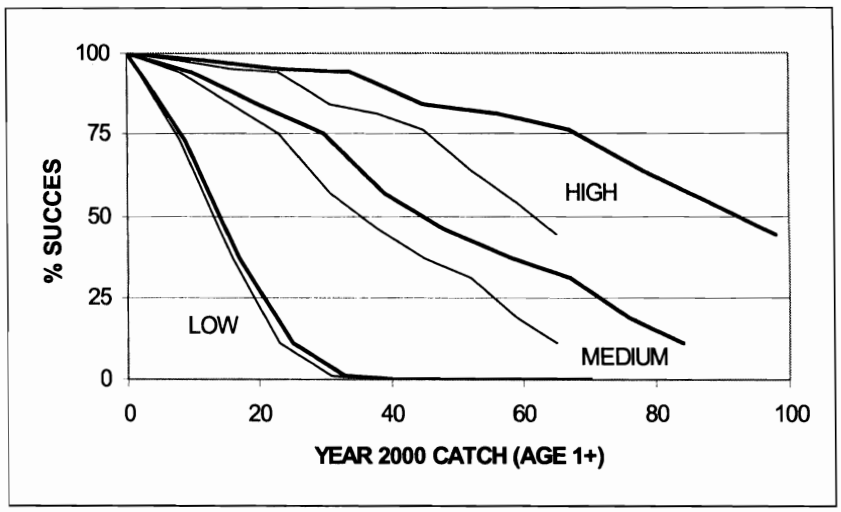

Figure 6. Probability of rebuilding within the required time period as related to total catch in year 2000. Three recruitment scenarios are shown. Heavy line is catch of age 1+; light line is corresponding catch of age 2+; the difference is one-year-old fish that are available only to recreational fisheries.

The catch levels indicated for year 2000 will require severe restrictions on fishing opportunities. An alternative approach could include a phase-in period, during which fishing effort is reduced progressively. Higher initial catches may result in delayed rebuilding or equivalently, in decreased chances of successfully rebuilding within the required time. Those effects are quantified by the simulation model, assuring that the phase-in strategy meets all requirements.

Table 2 summarizes the performance of alternative rebuilding policies in which the catch is held constant for the first three years (2000-2002), and reverts to a constant harvest rate in the fourth year (2003). Four levels of constant catch are considered, 80, 100, 120 and 140 mt. The simulation model approximates these levels by adjusting fishing effort. Table 2 shows that fishing effort must be reduced progressively to maintain the specified constant catch. This is caused by the increase in available biomass as the strong 1999 year class grows older. As expected, higher initial constant catch levels result in delayed rebuilding and decrease percentage success–in the medium 1999 year class scenario, a 140 mt constant catch delays median rebuilding times by about three years and decreases percentage success by 6 to 8 percentage points.

For comparison, Table 2 also summarizes the performance of these phase-in policies under the high 1999 year class strength scenario. Because the behavior of the population in this second scenario is dominated by rare extremely large recruitments, the higher catches during the initial phase-in period have little influence on rebuilding performance at the relatively low constant harvest rates being considered (cf. Table 1, which shows that the high 1999 year class scenario allows much higher harvest rates). Although such a large ratio of recruits to parental spawning output may be possible at low biomasses, it is questionable whether similar high ratios would be equally likely to occur at higher abundances.

Acknowledgement

Kevin Herbinson (Southern California Edison) provided useful data on bocaccio impingement at the San Onofre power plants, allowing improved estimates of the strength of the 1999 year class.

References

Conser, R. 1999 In prep. Report of the PFMC-SSC workshop on rebuilding plans.

MacCall, A. 1999. A preview of bocaccio rebuilding (4/15/99). .

MacCall, A., S. Ralston, D. Pearson and E. Williams. 1999. Status of bocaccio off California in 1999, and outlook for the next millennium. Prepared for the PFMC.

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. Probabilities of bocaccio rebuilding under a constant harvest rate, assuming three alternative1999 year class strengths. Catch is projected for three years; PERCENT SUCCESS is percentage of simulations achieving rebuilding schedule; MEDIAN TIME is median time (years) to reach rebuilding target. **Bold** entries indicate that more than one half the simulations achieved rebuilding requirements.

LOW 1999 YEAR CLASS

F RATE INDEX	CATCH AGE 2+ 2000	CATCH AGE 1+ 2000	CATCH AGE 1+ 2001	CATCH AGE 1+ 2002	PERCENT SUCCESS	MEDIAN TIME
0.00	**0**	**0**	**0**	**0**	**100**	**76**
0.01	**8**	**9**	**9**	**11**	**73**	**87**
0.02	16	17	17	21	37	104
0.03	23	25	26	31	11	136
0.04	31	33	34	40	1	162
0.05	38	41	42	50	0	245
0.06	45	48	49	59	0	300
0.07	52	55	57	67	0	300
0.08	59	63	64	76	0	300
0.09	65	70	71	84	0	300

MEDIUM 1999 YEAR CLASS

F RATE INDEX	CATCH AGE 2+ 2000	CATCH AGE 1+ 2000	CATCH AGE 1+ 2001	CATCH AGE 1+ 2002	PERCENT SUCCESS	MEDIAN TIME
0.00	**0**	**0**	**0**	**0**	**100**	**26**
0.01	**8**	**10**	**15**	**25**	**94**	**27**
0.02	**16**	**20**	**29**	**49**	**84**	**30**
0.03	**23**	**30**	**43**	**73**	**70**	**33**
0.04	**31**	**39**	**58**	**96**	**57**	**37**
0.05	38	48	71	120	46	42
0.06	45	58	85	142	37	49
0.07	52	67	99	164	31	58
0.08	59	76	112	186	19	68
0.09	65	84	125	208	11	90

HIGH 1999 YEAR CLASS

F RATE INDEX	CATCH AGE 2+ 2000	CATCH AGE 1+ 2000	CATCH AGE 1+ 2001	CATCH AGE 1+ 2002	PERCENT SUCCESS	MEDIAN TIME
0.00	**0**	**0**	**0**	**0**	**100**	**20**
0.01	**8**	**12**	**20**	**38**	**98**	**20**
0.02	**16**	**23**	**41**	**76**	**95**	**21**
0.03	**23**	**34**	**61**	**114**	**89**	**22**
0.04	**31**	**45**	**81**	**151**	**84**	**22**
0.05	**38**	**56**	**101**	**188**	**81**	**23**
0.06	**45**	**67**	**120**	**224**	**76**	**24**
0.07	**52**	**78**	**140**	**259**	**64**	**27**
0.08	**59**	**88**	**159**	**294**	**54**	**30**
0.09	65	98	179	329	44	36

INITIAL CATCH	F RATE INDEX	CATCHES (age 1+) C2000	C2001	C2002	C2003	EFFORT INDEX (1998 = 1.0) F2000	F2001	F2002	F2003	MEDIAN YRS	MEDIAN DELAY	PCENT SUCCSFL
assume med1999												
n/a	0.03	30	44	75	110	0.14	0.14	0.14	0.14	33	4	70%
80	0.03	80	81	82	106	0.39	0.27	0.16	0.14	34	5	68%
100	0.03	100	101	102	104	0.49	0.34	0.21	0.14	34	6	67%
120	0.03	120	121	123	102	0.59	0.41	0.25	0.14	37	7	65%
140	0.03	140	142	144	100	0.70	0.48	0.30	0.14	37	7	62%
assume hi1999												
forced	0.03	30	44	75	181	0.12	0.10	0.09	0.14	21	1	89%
80	0.03	80	81	82	177	0.34	0.19	0.10	0.14	22	1	88%
100	0.03	100	101	102	174	0.42	0.24	0.13	0.14	22	1	87%
120	0.03	120	121	123	172	0.51	0.29	0.16	0.14	23	1	87%
140	0.03	140	142	143	169	0.59	0.34	0.18	0.14	23	1	87%
assume med1999												
n/a	0.04	39	58	99	145	0.19	0.19	0.19	0.19	37	9	57%
80	0.04	80	81	82	142	0.40	0.27	0.16	0.19	37	9	56%
100	0.04	100	101	102	139	0.50	0.34	0.21	0.19	37	10	55%
120	0.04	120	121	123	136	0.60	0.42	0.25	0.19	37	11	53%
140	0.04	140	142	144	133	0.71	0.49	0.30	0.19	40	12	51%
assume hi1999												
forced	0.04	39	58	99	240	0.17	0.14	0.12	0.19	22	1	84%
80	0.04	80	81	82	237	0.34	0.19	0.10	0.19	22	1	84%
100	0.04	100	101	102	233	0.43	0.24	0.13	0.19	22	1	84%
120	0.04	120	121	123	230	0.52	0.29	0.16	0.19	22	1	84%
140	0.04	140	142	143	226	0.60	0.34	0.19	0.19	22	1	84%