Bocaccio Rebuilding Analysis for 2003 (Draft 2, May 2003)

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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 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 new stock assessment (MacCall et al. 1999) found that under weak recruitment, the index of bocaccio spawning output was about half the the estimate made in 1996, but at that time preliminary indications of a strong 1999 year class allowed some optimism. Under the assumption that the 1999 yearclass was similar in size to the 1984 yearclass (the "Medium 1999 Year Class" scenario in MacCall 1999), the rebuilding OY for the bocaccio fishery was set at 100mt for 2000-2002.

A bocaccio assessment conducted in 2002 (MacCall 2002a) indicated that the 1999 year class was weaker than had been assumed, and was at or below the low end of the range considered in the 1999 analyses. The low estimated abundance was partially due to the effect of a very low 2001 abundance index from the Triennial Trawl Survey. A rebuilding analysis (MacCall and He 2002a, using SSC Rebuilding Analysis V2.1) indicated that the stock could not be rebuilt with 50% probability within the time limit specified by the National Standard Guidelines. This was due to a combination of very little average surplus production and the "deficit" imposed by the catches that had been taken in 2000-2002. The 2003 fishery management approach was to keep the mortality rate as low as possible (catch not to exceed 20mt) while providing limited opportunities to fish in times and areas that had low likelihood of impacting bocaccio. A "sustainability analysis" indicated that this rate of fishing would have a low probability of driving abundance to such a low level that Endangered Species Act listing would be warranted (MacCall and He 2002b).

Knowing that the 2002 fishery would provide the first reliable information on the strength of the important 1999 yearclass, the stock assessment author agreed with the Pacific Fishery Management Council that a re-assessment in 2003 would be worthwhile. This re-assessment would also provide an opportunity to address a number of technical issues (such as the assumed natural mortality rate of bocaccio) that could not be considered in 2002 because of scheduling constraints.

The re-assessment (MacCall 2003) included new CPUE and length composition information from recreational fisheries in 2002, and CalCOFI larval abundances up to early 2003, all of which indicated an increase in abundance. The assumed natural mortality rate was reduced to 0.15 which is more consistent with information on longevity of bocaccio. The assessment indicated a strong 1999 yearclass, and a clear increase in abundance since 1999. This rebuilding analysis is primarily based on the STATc model described in MacCall (2003).

Management Reference Points

$B_{unfished}$. Unfished biomass is estimated by multiplying average recruitment (R) by the spawning output per recruit achieved when the fishing mortality rate is zero ($SPR_{F=0} = 2.499$, spawning output in billion eggs, recruitment in thousand fish at age 1). The estimated unfished spawning output (S) is 13387 billion eggs, based on the average recruitment from spawning years between 1950 and 1985. This time period was chosen as representing a presumably "natural" range of stock abundance. Because recruitment is highly variable, this calculation of unfished abundance is imprecise (CV $\geq$ 10%, variability is underestimated because estimated recruitment in the first ten years is held constant).

B_{msy}. The rebuilding target is the spawning abundance level that produces MSY. This value cannot be determined directly for bocaccio, so this analysis uses the proxy value of 40% of estimated unfished spawning abundance. Estimated B_{msy} is 5355 billion eggs.

Current status: Current (2003) spawning output is 984 billion eggs, which is 7.4% of the estimated unfished abundance, and 18% of estimated $\mathbf{B_{msy}}$. Historical abundance relative to the rebuilding target is shown in Figure 1.

Mean generation time. Mean generation time of bocaccio is estimated from the net maternity function, and is 14 years. This value reflects the lower natural mortality rate assumed in 2003.

Simulation Model

The rebuilding model (SSC Rebuilding Analysis software V2.6) simulates population abundance for 500 years, and 2000 replicate simulations were used in this analysis. The model tracks male and female abundances at age, with an accumulator at age 21+. Values of weights at age, composite selectivity and fecundity are taken from MacCall (2003), and are given in the input data for the rebuilding model (Appendix 1). Population simulations begin with the 2002 age composition. Subsequent recruitments (R) are generated by a random draw of one of the historical values of R/S (from spawning years1970 to 2000, during which recruitment was relatively well estimated), which is multiplied by current spawning output (S) to obtain the following year's recruitment at age 1. Resampling R/S is supported by the nearly constant

pattern of historical R/S values (Figure 2), whereas the strong historical decline in recruitment strengths argues against resampling recruitments directly (Figure 3). Values of R/S are also unrelated to S (Figure 4), indicating no value in use of the stock-recruitment relationship as the basis for simulated recruitments.

Rebuilding is assumed to have begun in 2000, the first year in which catches are set to zero for calculation of $\mathbf{T}_{min}$, the length of time it would take to rebuild in the absence of fishing. The distribution of simulated $\mathbf{T}_{min}$ ranges from about 10 to 40 years (Figure 5). The median (50% probability) rebuilding time is 18 yr. The maximum allowable length of time to rebuild ($\mathbf{T}_{max}$) is this value plus one generation time (14 yr), or 32 yr from the first year of rebuilding, which is 2032. The maximum allowable fishing mortality rate is that which would allow the stock to achieve the target abundance in calendar year 2032, with a probability of 50%. This fishing rate is 0.0709 (peak F), and the associated maximum rebuilding catch is 423mt in 2004. Options with higher probabilities of success and/or earlier rebuilding times are usually adopted by the PFMC, and are given in Table 1.

Simulated individual rebuilding trajectories are erratic (Figure 6). The time series of percentiles of simulated trajectories (Figure 7) is more informative. Note that the fishing rate is reset to $\mathbf{F}_{msy}$ upon rebuilding.

Consideration of Alternative STAR Models

The STATc model that serves as the basis of this rebuilding analysis is intermediate between two models (STARb1 and STARb2) developed by the STAR Panel for the purposes of bracketing the uncertainty in the bocaccio assessment. Model STARb1 omits data from the Triennial Surveys, and holds estimated recruitment constant to 1959, whereas model STARb2 omits the recreational CPUE data and holds estimated recruitment constant to 1969. Model STATc omits neither data source, holds estimated recruitment constant to 1959, and places a low emphasis on the stock-recruitment relationship to stabilize estimates of recent (post-1999) recruitment. Comparative results for the two alternative STAR models are shown in Table 2.

Decision Analysis

The three models (STARb1, STARb2 and STATc) correspond to alternative "true" states of nature, and management is faced with establishing a harvest policy. Table 3 is a decision table that considers four alternative 70% probability constant mortality rate harvest policies: three corresponding to the respective models, and a fourth policy proposed by the GMT that sets 2004 catch equal to the average of the STARb1 and STARb2 values. Table 4 shows the approximate level of fishing effort (scaled relative to 2002) that would be necessary to achieve constant harvest rate policies corresponding to 2004 catches of 200 through 500 Mtons. The effort level changes because selectivity varies as fish from strong year classes grow in length.

Analysis of Sustainability

The 2002 rebuilding analysis was based on a very low productivity scenario, and management was constrained by the risk of driving the stock to very low abundances. This risk was addressed by a "sustainability analysis" that estimated fishing rates which would associated with no further decline in abundance. This analysis indicates that a fishing rate of 0.17 (2004 catch of 959mt) would have a 50% chance of no further decline, and a fishing rate of 0.15 (2004 catch of 864mt) would have an 80% probability of no further decline. The fishing rates given by this rebuilding analysis are less than half these sustainable rates, and the probability of further decline is negligibly small.

References

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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).

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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.

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. Results of bocaccio rebuilding analysis (model STATc).

Fishing rate	0.0721	0.0615	0.0498	0.0383	0
OY	439.1	376.5	306.3	236.5	0
Prob to rebuild by Tmax	50	60	70	80	96.5
Median time to rebuild	28	25.1	22.7	20.4	15.5
Prob overfished after rebuild	0	0	0	0	0
Median time to rebuild (yrs)	28	25.1	22.7	20.4	15.5

Table 2. Sensitivity analysis: alternative STAR Panel models.

STARb1					
Fishing rate	0.1014	0.0914	0.0801	0.067	0
OY	784.1	709.8	624.8	525.6	0
Prob to rebuild by Tmax	50	60	70	81	99.9
Median time to rebuild	25	22.5	20.1	18.1	11.6
Prob overfished after rebuild	0	0	0	0	0
Median time to rebuild (yrs)	25	22.5	20.1	18.1	11.6

STARb2					
Fishing rate	0.0729	0.0643	0.0541	0.043	0
OY	333.5	295.2	249.6	199.2	0
Prob to rebuild by Tmax	50	60	70	80	97.6
Median time to rebuild	30	27.4	25.2	23.1	17.2
Prob overfished after rebuild	0	0	0	0	0
Median time to rebuild (yrs)	30	27.4	25.2	23.1	17.2

Table 3. Decision table treating three alternative models as true states of nature. Four management decisions are given, corresponding to the correct decision under the three models, and a fourth decision based on average catch from the STARb1 and STARb2 models. Values in bold indicate the correct decision for the associated model if it is true.

	True Model (State of Nature)		
	STARb1	STATc	STARb2
Management Decision: STARb1			
C2004	**624.8**	624.7	624.8
F	**0.0801**	0.1039	0.1403
medianTreb(years)	**20.1**	41.6	81.1
Prob Rebuild by Tmax	**70%**	19%	3%
STATc			
C2004	307.2	**306.3**	307
F	0.0387	**0.0498**	0.0669
medianTreb(years)	14.7	**22.7**	28.1
Prob Rebuild by Tmax	94%	**70%**	58%
STARb2			
C2004	250	248.8	**249.6**
F	0.0314	0.0403	**0.0541**
medianTreb(years)	13.9	20.7	**25.2**
Prob Rebuild by Tmax	96%	79%	**70%**
GMT: avg(b1,b2)			
C2004	438.3	436.9	438
F	0.0556	0.0717	0.0966
medianTreb(years)	16.5	27.9	25.5
Prob Rebuild by Tmax	88%	50%	39%

Table 4. Future catches and levels of fishing effort relative to 2002 for alternative constant harvest rates beginning in 2004 (based on STATc model).

C2004(MT)	200	300	400	500	200	300	400	500
F	0.035	0.055	0.0774	0.103*	0.035	0.055	0.0774	0.103*
Year	Catch				Effort rel to 2002 level			
2004	200	300	400	501	84%	131%	182%	240%
2005	199	294	386	475	80%	125%	174%	229%
2006	192	280	363	439	76%	118%	164%	216%
2007	185	267	342	409	72%	112%	156%	206%
2008	182	260	329	389	69%	108%	152%	200%
2009	183	258	324	377	68%	107%	150%	198%
2010	186	260	322	370	68%	107%	150%	198%

* Fmsy

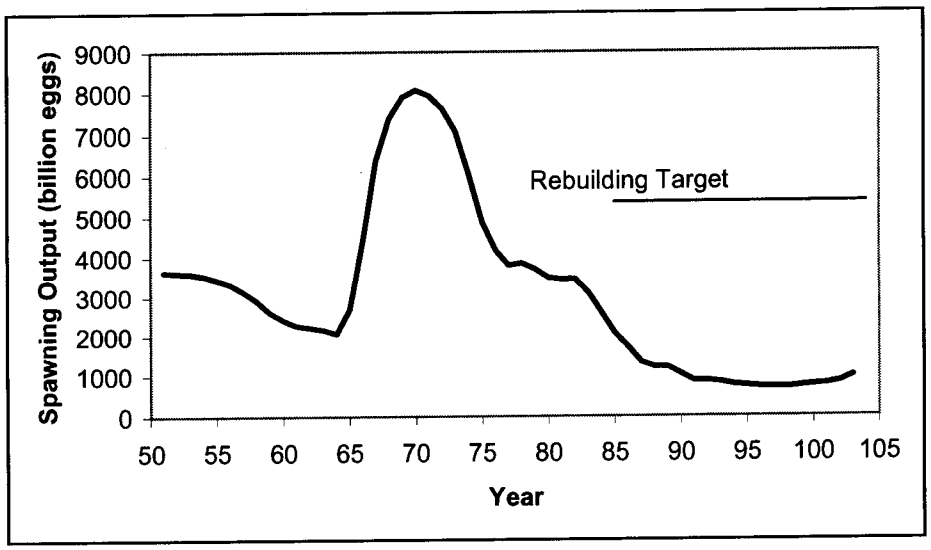


Figure 1. Historical bocaccio abundance (measured as spawning output). Rebuilding target is 40% of estimated unfished abundance.

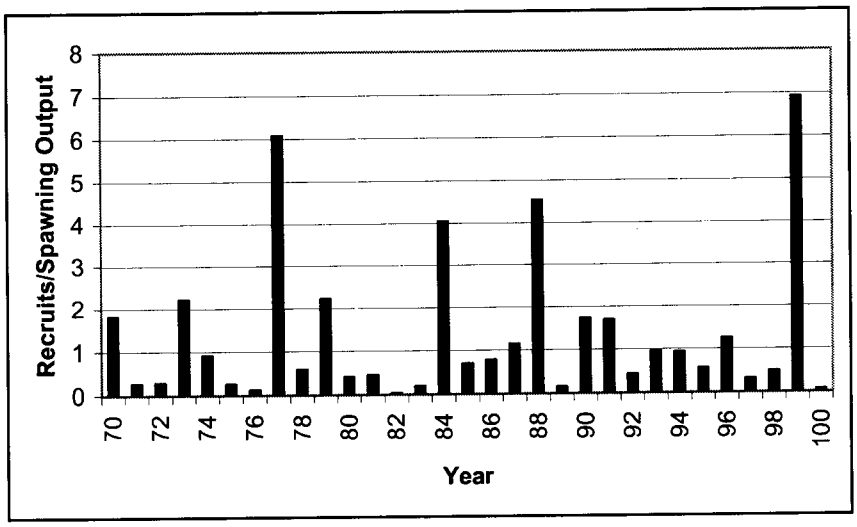


Figure 2. History of estimated bocaccio reproductive successes, plotted by birth year.

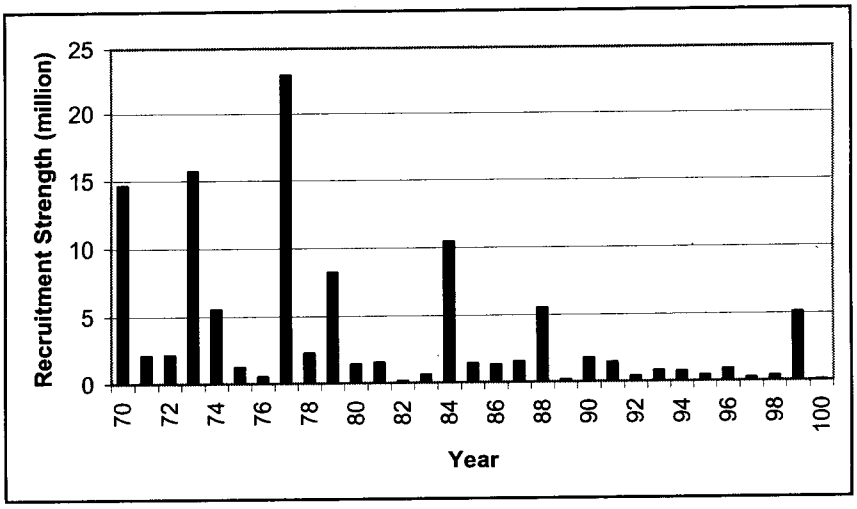


Figure 3. History of estimated bocaccio recruitments, plotted by birth year.

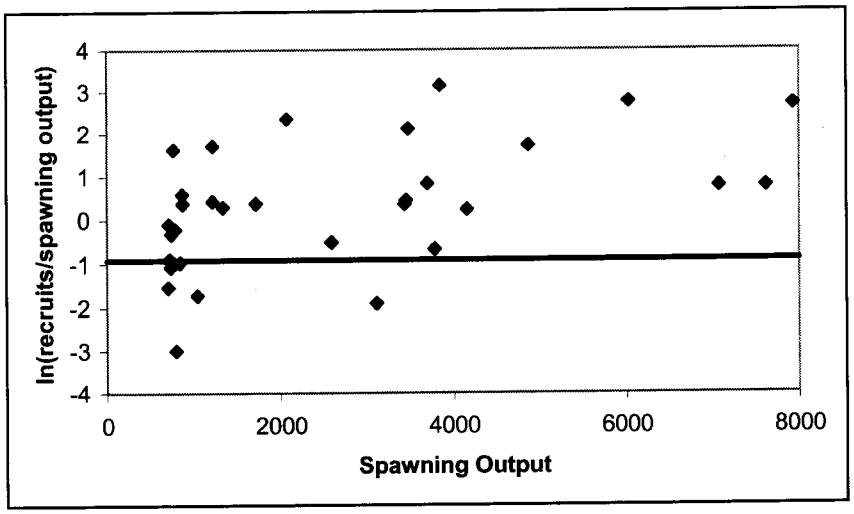


Figure 4. Relationship of log spawning success to parental abundance. Horizontal line is replacement level at F=0.

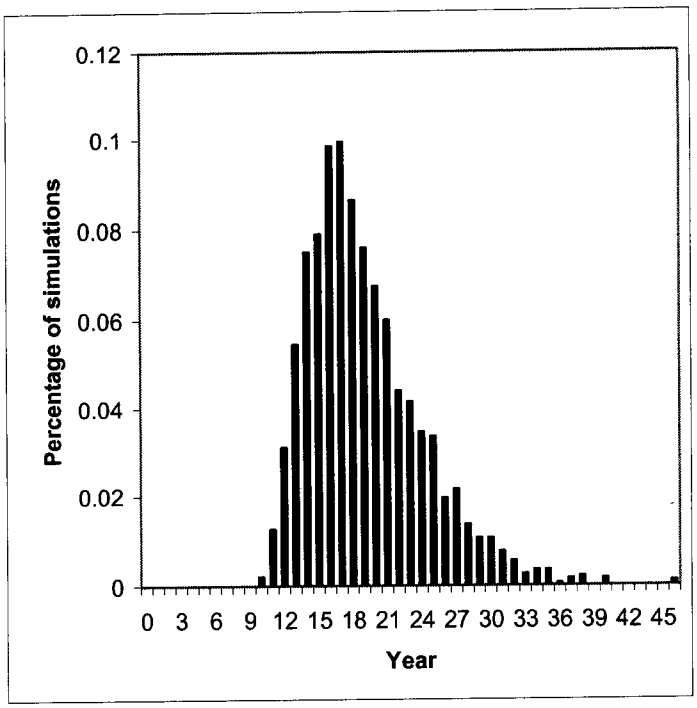


Figure 5. Distribution of simulated rebuilding times in the absence of fishing.

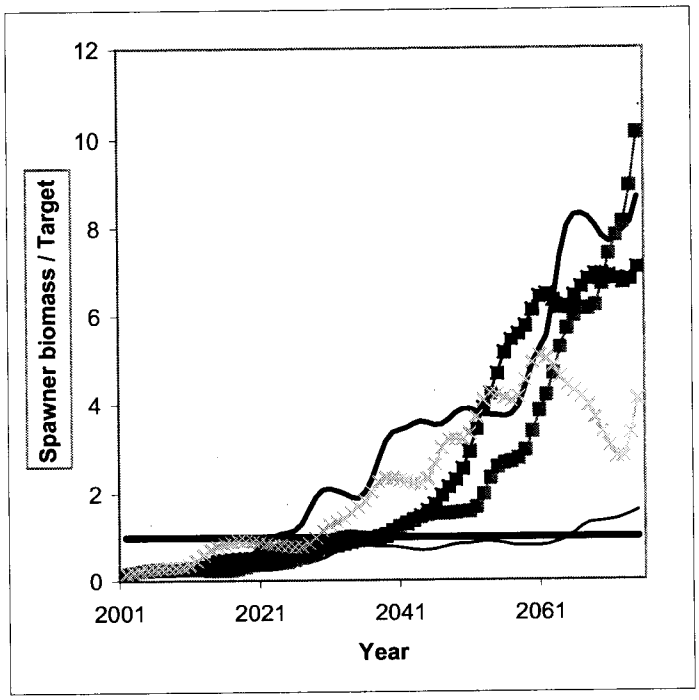


Figure 6. Example individual rebuilding trajectories.

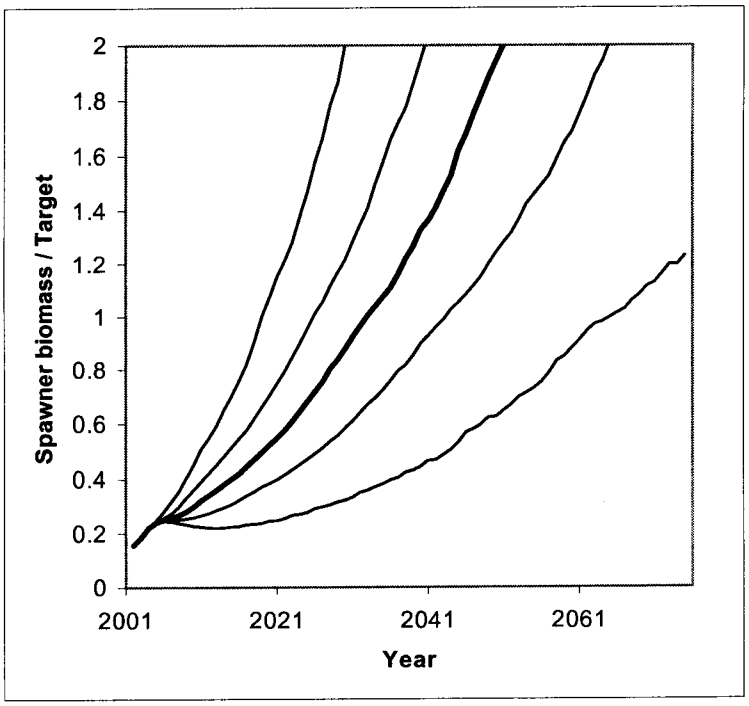


Figure 7. Envelope of bocaccio rebuilding trajectories, based on STATc model (lines are 5, 25, **50**, 75 and 95 percentiles of simulations).

Appendix 1. Input file for SSC Rebuilding Analysis based on STSTc assessment model.

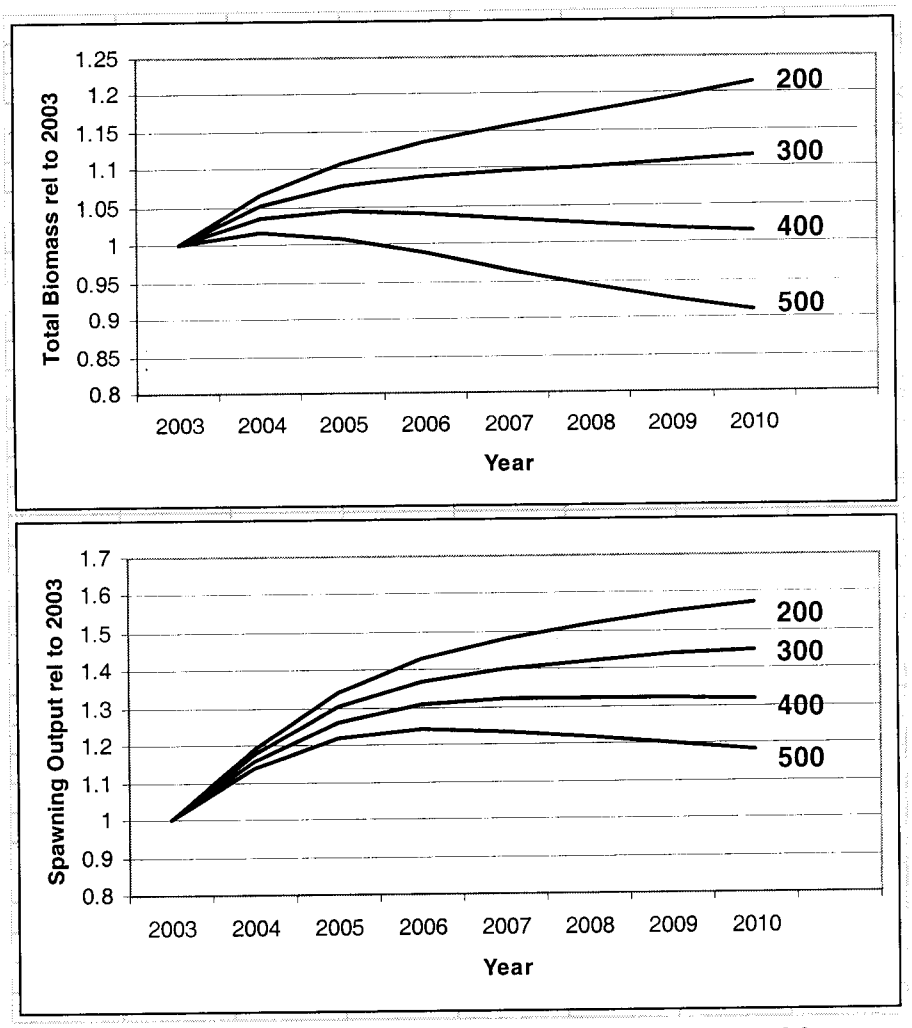
```
# Title
bocaccio 2003 model POSTSTAR.P03 (STATC) resample to 2001
# Number of sexes
2
# Age range to consider (minimum age; maximum age)
1 21
# Number of fleets to consider
1
# First year of the projection
2002
# Year declared overfished
2000
# Is the maximum age a plus-group (1=Yes;2=No)
1
# Generate future recruitments using historical recruitments (1), historical recruits/spawner (2), or a stock-recruitment (3)
2
# Constant fishing mortality (1) or constant Catch (2) projections
1
# Pre-specify the year of recovery (or -1) to ignore
-1
# Fecundity-at-age
# 1 2 3 4 5 6 7 8 9 ... 21+
 0.000   0.002   0.026   0.131   0.325   0.547   0.762   0.965   1.160   1.345   1.513   1.659   1.781
         1.882   1.965   2.032   2.086   2.129   2.163   2.191   2.265
# Age specific information (Females then males) weight and selectivit
# Females
 0.223   0.499   0.878   1.313   1.771   2.227   2.663   3.071   3.446   3.783   4.074   4.319   4.522
         4.690   4.828   4.939   5.028   5.100   5.157   5.203   5.328
 0.166   0.501   0.792   0.965   0.987   0.903   0.775   0.647   0.545   0.477   0.436   0.411   0.396
         0.386   0.379   0.373   0.369   0.366   0.364   0.362   0.357
# Males
 0.223   0.463   0.770   1.101   1.430   1.742   2.025   2.276   2.495   2.681   2.839   2.972   3.082
         3.174   3.250   3.313   3.365   3.408   3.442   3.471   3.560
 0.167   0.466   0.725   0.906   0.995   1.000   0.958   0.898   0.833   0.772   0.717   0.671   0.633
         0.602   0.578   0.559   0.545   0.533   0.524   0.517   0.501
# Age specific information (Females then males), natural mortality and numbers at age
# Females
 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
 259     21      1819    101     52      176     64      87      72      24      62      50      3
         60      11      6       4       21      1       0       17
# Males
 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
 259     21      1822    101     52      178     64      88      72      24      62      49      3
         54      9       4       3       12      0       0       5
# Initial age-structure (for Tmin)
 2535    145     77      263     95      128     104     34      88      70      4       85      15
         8       6       29      1       0       1       1       22
 2535    145     77      265     96      132     108     36      91      72      4       78      12
         6       4       17      1       0       0       0       6
# Year for Tmin Age-structure
 2000
# Number of simulations
 2000
# Recruitment and Spanwer biomasses
```

Number of historical assessment years
52
Historical data: Year, Recruitment, Spawner biomass, Used to compute B0, Used to project based
on R, Used to project based on R/S

1951	3523	3630	1	0	0
1952	3523	3611	1	0	0
1953	3523	3597	1	0	0
1954	3523	3536	1	0	0
1955	3523	3446	1	0	0
1956	3523	3335	1	0	0
1957	3523	3138	1	0	0
1958	3523	2909	1	0	0
1959	3523	2617	1	0	0
1960	1259	2413	1	0	0
1961	1135	2273	1	0	0
1962	10756	2217	1	0	0
1963	47503	2165	1	0	0
1964	785	2066	1	0	0
1965	711	2690	1	0	0
1966	898	4404	1	0	0
1967	1574	6368	1	0	0
1968	2059	7382	1	0	0
1969	2432	7892	1	0	0
1970	1161	8073	1	0	1
1971	14610	7928	1	0	1
1972	2134	7617	1	0	1
1973	2143	7073	1	0	1
1974	15665	6026	1	0	1
1975	5527	4864	1	0	1
1976	1252	4153	1	0	1
1977	507	3780	1	0	1
1978	22964	3845	1	0	1
1979	2278	3696	1	0	1
1980	8213	3477	1	0	1
1981	1423	3433	1	0	1
1982	1549	3449	1	0	1
1983	149	3109	1	0	1
1984	597	2587	1	0	1
1985	10436	2074	1	0	1
1986	1450	1718	1	0	1
1987	1333	1337	0	0	1
1988	1529	1216	0	0	1
1989	5501	1217	0	0	1
1990	179	1040	0	0	1
1991	1799	866	0	0	1
1992	1455	870	0	0	1
1993	380	838	0	0	1
1994	804	780	0	0	1
1995	728	738	0	0	1
1996	408	721	0	0	1
1997	901	711	0	0	1
1998	216	704	0	0	1
1999	342	734	0	0	1
2000	5071	764	0	0	1
2001	50	790	0	0	1
2002	517	843	0	0	0

Number of years with pre-specified catches
2

```
# Catches for years with pre-specified catches
2002 200
2003 100
# Number of future recruitments to override
1
# Process for overiding (-1 for average otherwise index in data list)
2003      0          0
# Which probability to product detailed results for (1=0.5,2=0.6,etc.)
1
# Steepness and sigma-R  and auto-correlations
 0.39  1.000000 0.0
# Target SPR rate (FMSY Proxy)
0.500000
# Target SPR information: Use (1=Yes) and power
0 20
# Discount rate (for cumulative catch)
0.100000
# Truncate the series when 0.4B0 is reached (1=Yes)
0
# Set F to FMSY once 0.4B0 is reached (1=Yes; 2=Apply 40:10 rule after recovery)
2
# Percentage of FMSY which defines Ftarget
0.900000
# Maximum possible F for projection (-1 to set to FMSY)
2
# Conduct MacCall transition policy (1=Yes)
0
# Defintion of recovery (1=now only;2=now or before)
2
# Results for rec probs by Tmax (1) or 0.5 prob for various Ttargets
1
# Produce the risk-reward plots (1=Yes)
0
# Calculate coefficients of variation (1=Yes)
0
# Number of replicates to use
20
# First Random number seed
-89102
# Conduct projections for multiple starting values (0=No;else yes)
0
# File with multiple parameter vectors
MCMC.PRJ
# Number of parameter vectors
100
# User-specific projection (1=Yes); Output replaced (1->6)
0 5
# Catches and Fs (Year; 1/2 (F or C); value); Final row is -1
2004 2 20.0
-1 -1 -1
# Split of Fs
2002 1
-1 1
# Proportion of target B0
0.400000
```



Bocaccio Supplemental Figure: STATc model projections of future total biomass and spawning output relative to 2003 for alternative constant harvesting rates, expressed as 2004 catch in MT. Future recruitment is assumed to be average R/S from stock-recruit curve. The increase in spawning output is mainly due to maturation of the 1999 year class.