Bocaccio Rebuilding Analysis for 2002 (final revised version)

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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. A new stock assessment (MacCall et al. 1999) found that under continuing recruitment failure, 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.

The most recent stock assessment (MacCall 2002) is based on a wide variety of information from both Central and Southern California. The new estimate of the strength of the 1999 year class is at or below the low end of the range considered in the 1999 analyses. A initial 2002 bocaccio rebuilding analysis (dated June, 2002) was conducted using the SSC Rebuilding Analysis (V1.5) developed by Andre Punt of the PFMC-SSC. That analysis incorporated information developed in the 2002 bocaccio stock assessment, but used the entire time series of recruitments and recruits per spawners to do the rebuilding projections, giving an estimated rebuilding OY of 5.8 tons and a maximum rebuilding time of 106 years. That scenario was associated with a 50% probability of successful rebuilding on or before calendar year 2108; a 60% rebuilding probability was not feasible even with elimination of all fishing. (Note: The June 2002 rebuilding analysis is no longer valid, and is superseded by this document.)

At the June 2002 meeting of the PFMC, the Scientific and Statistical Committee recommended that the bocaccio rebuilding analysis separate the time periods used for estimation of unfished biomass (the early portion of the series) from the time period of recruitment successes used for projecting future recruitments (the recent portion of the series), according to the default procedure recommended in the SSC's rebuilding guidelines. The Council subsequently directed the authors to bring the rebuilding analysis into compliance with the SSC's recommendation.

The following rebuilding analysis utilizes a newer version of the SSC Rebuilding Analysis (V2.1) and attempts to comply with the SSC guidelines and Council instructions.

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 ($SPR_{F=0}$ = 1.3806, spawning output in billion eggs, recruitment in thousand fish at age 1). The estimated unfished spawning output (S) is 19849 billion eggs, based on the average recruitment between 1953 and 1985. This time period was chosen as representing a presumably "natural" range of stock abundance. Beginning in 1986, abundance was lower than at any earlier time in the history of biomass estimates (Figure 1). Because recruitment is highly variable, this calculation of unfished abundance is imprecise (CV = 31%) as can be seen in Figure 2.

B_{msy}. The rebuilding target is the spawning abundance level that produces MSY. This value cannot be determined directly for bocaccio, so we use the proxy value of 40% of estimated unfished spawning abundance. Estimated B_{msy} is 7939 billion eggs.

Current status: Current spawning output is 720 billion eggs, which is 3.6% of the estimated unfished abundance, and 9.1% of estimated **B_{msy}**.

Mean generation time. Mean generation time of bocaccio is estimated from the net maternity function, and is 12 years.

Simulation Model

The rebuilding 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 (2002), and are given in Appendix 1. Population simulations begin with the 2002 age composition. Subsequent recruitments are generated by a random draw of one of the historical values of R/B (from 1953 to 1999[1]), which is multiplied by current spawning output (S) to obtain the following year's recruitment. Resampling R/S is supported by the nearly constant pattern of historical R/S values (Figure 3), whereas the strong historical decline in recruitment strengths argues against resampling recruitments directly (Figure 4). Simulations extend to a maximum of 500 years, and the maximum number of simulations allowed by the program (N=10000) was used to minimize the imprecision in the analysis.

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[1] The SSC guidelines indicate a preference for resampling R/S from the more recent portion of the time series, thus better representing current expectations. This rebuilding analysis does not conform to that guideline, and resamples values from the full time series. The rationale is that there is no trend with either time or biomass in the historical R/S values, indicating that they are all equally likely under current conditions. Moreover, if the high 1963 value is not included in the resampling pool, abundance does not tend to increase even in the absence of fishing.

Rebuilding is assumed to have begun in 2000. The new SSC Rebuilding Analysis (V2.1) projects a zero catch scenario forward from the 1999 starting conditions as re-estimated in the most recent stock assessment in order to determine $\mathbf{T_{min}}$ (this is another source of difference from the previous rebuilding analysis). The model assumes a 2002 catch of 100MT.

The distribution of simulated times (number of years) to reach the rebuilding target at F=0 ($\mathbf{T_{min}}$) is wide, ranging from about 20 years to over 500 years, which is the maximum length of time considered in the simulations (Figure 5). The mode (most frequent) rebuilding time is about 60 years. The median (50% probability) rebuilding time is 98 yr (SE = 1 yr). The maximum length of time to rebuild ($\mathbf{T_{max}}$) is this value plus one generation time (12 yr), less the time already elapsed since the start of rebuilding (3 yr), or 106 years. The maximum allowable fishing mortality rate is that which would allow the stock to achieve the target abundance in 106 years (i.e., calendar year 2108), with a probability of 50%. **This fishing rate, and the associated rebuilding catch is zero**, as there is no level of fishing that accomplishes rebuilding at any time between $\mathbf{T_{min}}$ and $\mathbf{T_{max}}$.[2] In most rebuilding analyses, options with a higher probability of success (e.g., 60%) and/or earlier rebuilding times are considered, but these probability levels and rebuilding schedules are not feasible or resolvable in this case.

Simulated individual rebuilding trajectories are erratic (Figure 6). The time series of percentiles of simulated trajectories (Figure 7) is more informative. A peculiar feature of the boccacio simulations is that the median abundance (dark line in Figure 7) does not reach the target level after 106 years ($\mathbf{T_{max}}$). Although 50% of the simulations achieved the target level <u>at some time</u> on or before 106 years (thus qualifying as having been rebuilt), many of those trajectories subsequently declined so that only about 40% are currently at or above the target after 106 years. This property is consistent with the erratic behavior of individual abundance trajectories (Figure 6). Note that the rebuilding fishing rate is maintained throughtout the simulation, and the fishing rate is not reset to $\mathbf{F_{msy}}$ upon rebuilding. If the fishing rate is reset to $\mathbf{F_{msy}}$, a larger portion of the simulations decline after rebuilding is achieved.

Consideration of Alternative Natural Mortality Rate

There is uncertainty regarding the best value of natural mortality rate to use in the bocaccio stock assessment. The assessment approved by the 2002 STAR Panel was based on M=0.2 (the same value that was used in the 1999 assessment). The justification for an alternative value of M=0.15 is given by Ralston et al. (1996), and that value was used in the 1996 assessment. Rebuilding projections based on M=0.15 are presented here in association with the sensitivity analysis in the 2002 assessment, and use the newest version (V2.1) of the Rebuilding Analysis. For the case of M=0.15, the minimum rebuilding time, $\mathbf{T_{min}}$, is 58 years, and $\mathbf{T_{max}}$ is 68

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[2] It is possible that some very small level of fishing may satisfy a 50% probability of rebuilding by $\mathbf{T_{max}}$, but the imprecision of the simulations (even at N=10,000) does not allow resolution of the effect of very small catches.

years. The maximum probability of rebuilding by $\mathbf{T_{max}}$ is 53.6%, and the 2003 catch corresponding to a fishing rate with a 50% probability of rebuilding by $\mathbf{T_{max}}$ is 4.4 tons.

Analysis of Sustainability

Bocaccio occur as by-catch in many fisheries, not all of which are managed by the PFMC. Thus it may not be possible to achieve a fishing rate that is truly zero. The following analysis (Table 1) describes the projected long-term effects of various low levels of fishing on the bocaccio stock. The simulations are based on constant fishing rates (associated with corresponding catch levels for 2003) that result in various probabilities of "no further stock decline" in 100 years, i.e., the projected spawning output is at least 720 billion eggs (the 2002 value) as of calendar year 2102. Probability levels range from 50% to 90%; the latter is the highest probability that can be achieved, given a zero fishing rate. Also associated with these results are probability levels of rebuilding on or before $\mathbf{T_{max}}$, or calendar year 2108. Even though the stock may be projected to increase, the high degree of variability results in some "worst case" risk of decline. The risk of decline is measures by the five percentile level of abundance at the end of 25 years and 100 years. These values are also expressed as percentages of the current abundance.

References

MacCall, A. 2002. Status of bocaccio off California in 2002. Prepared for the PFMC.

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 sustainability analysis.

				Risk (five percentile of abundance)			
Probability (%) of No Decline by 2102	Catch in 2003	Fishing Mortality Rate	Percent of Cases Rebuilt by 2108	after 25 years		after 100 years	
				Spawning Output (billion eggs)	2027 Abundance Relative to 2002	Spawning Output (billion eggs)	2102 Abundance Relative to 2002
50%	79	0.094	7%	73.1	10%	2.5	0%
60%	61	0.071	12%	85.8	12%	5.5	1%
70%	42	0.049	21%	102.6	14%	13.3	2%
80%	22	0.026	33%	126.1	18%	30.7	4%
85%	11	0.012	41%	145.2	20%	52.7	7%
90%	0	0.000	49%	157.5	22%	86.3	12%

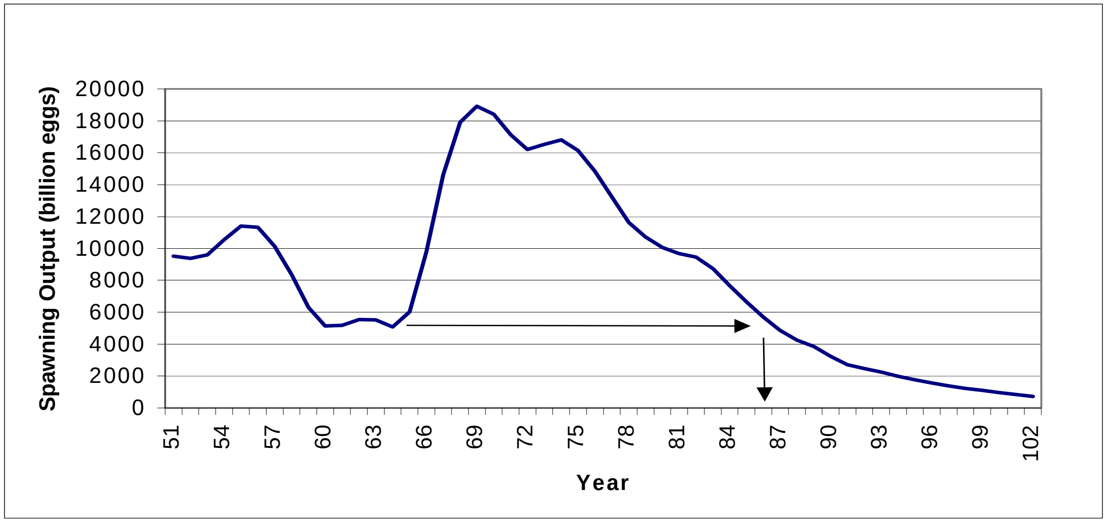

Figure 1. Time series of bocaccio abundance, showing rationale for using years 1953 to 1986 as basis for estimating unfished abundance (see text).

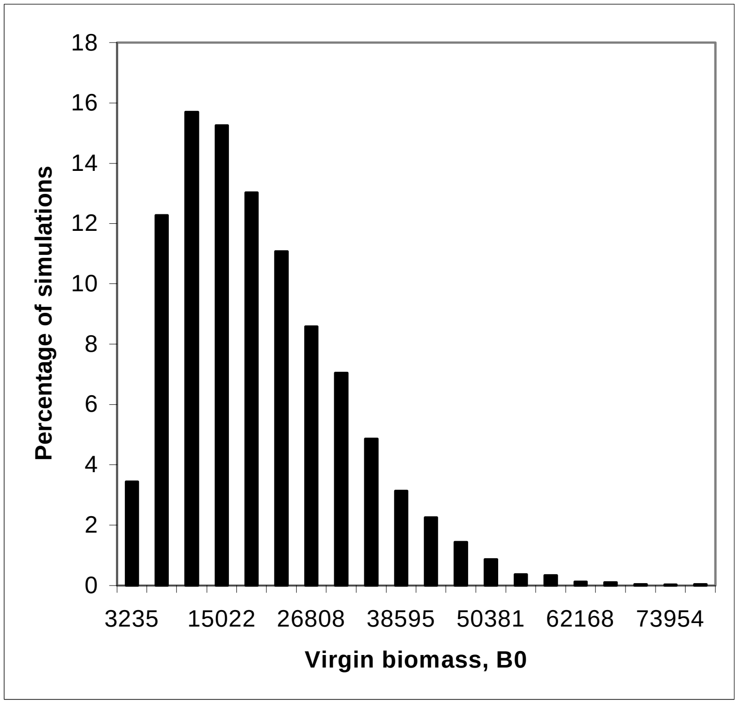

Figure 2. Distribution of simulated unfished abundances (measured as spawning output in billions of eggs).

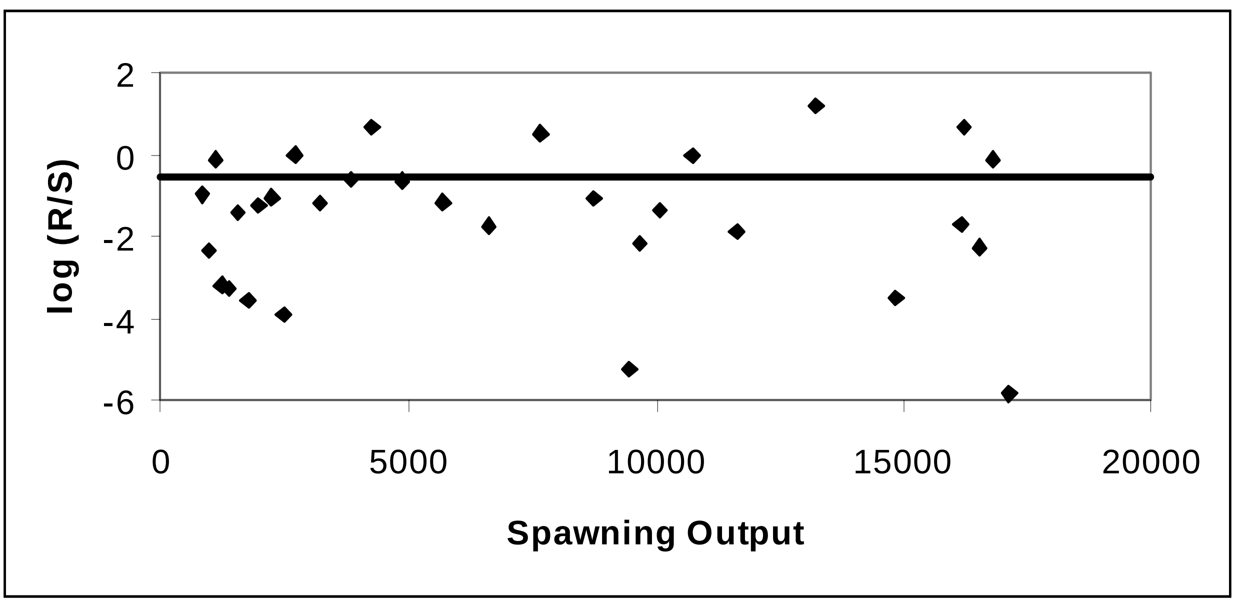

Figure 3. Historical bocaccio reproductive success related to parental abundance. Horizontal line is replacement level in the absence of fishing.

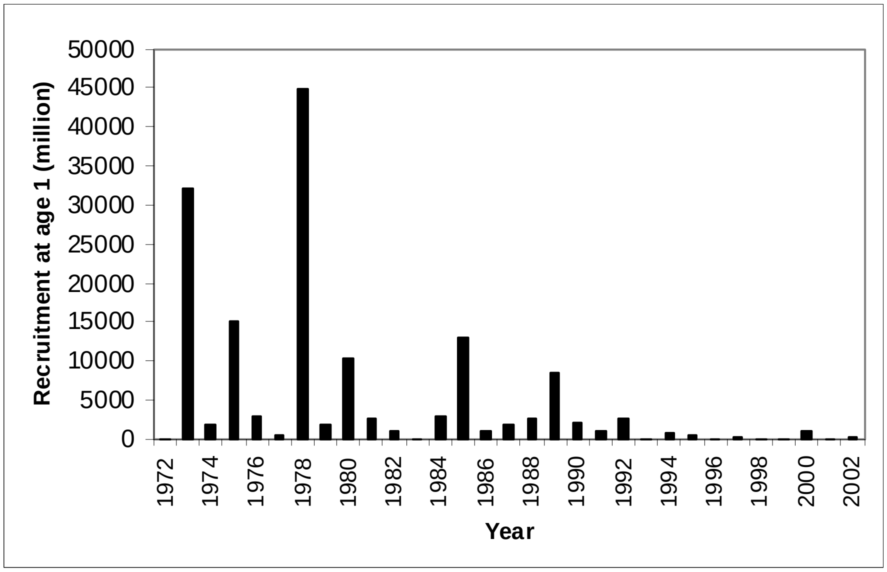

Figure 4. Historical series of bocaccio recruitments.

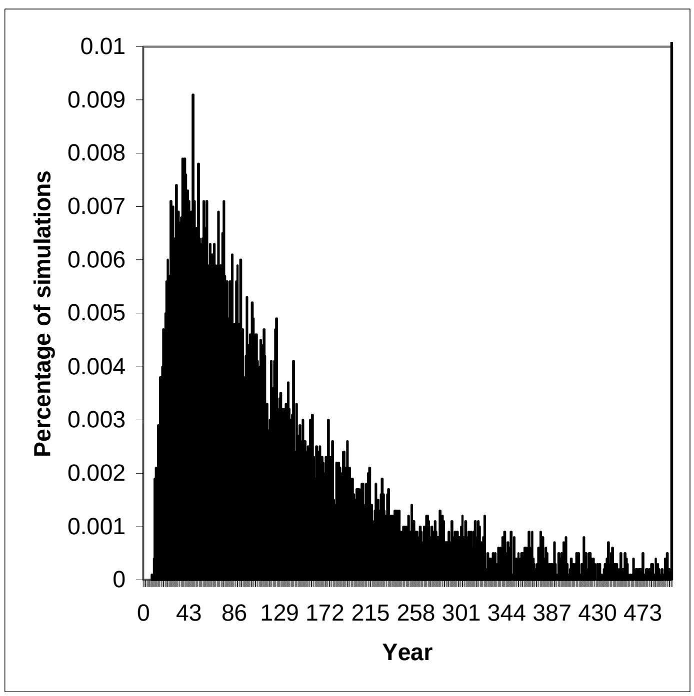

Figure 5. Distribution of simulated bocaccio rebuilding times in the absence of fishing.

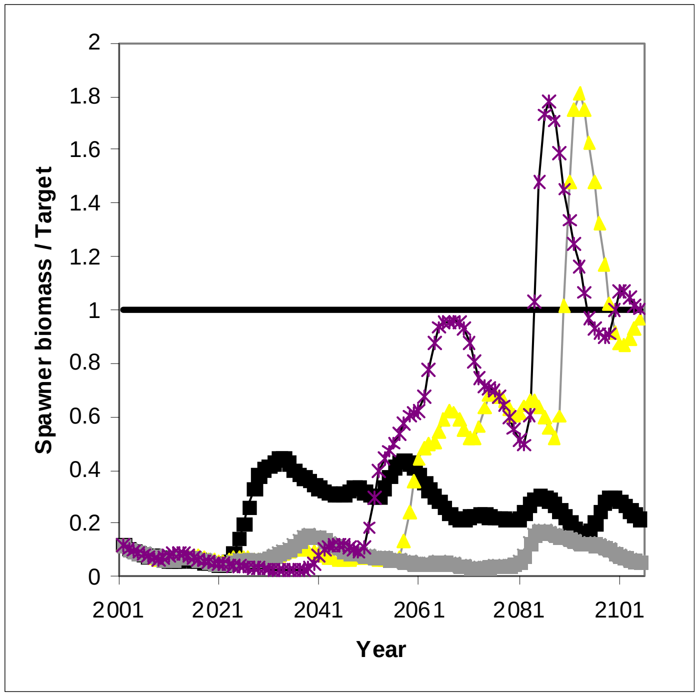

Figure 6. Simulated bocaccio rebuilding trajectories, under scenario of no fishing.

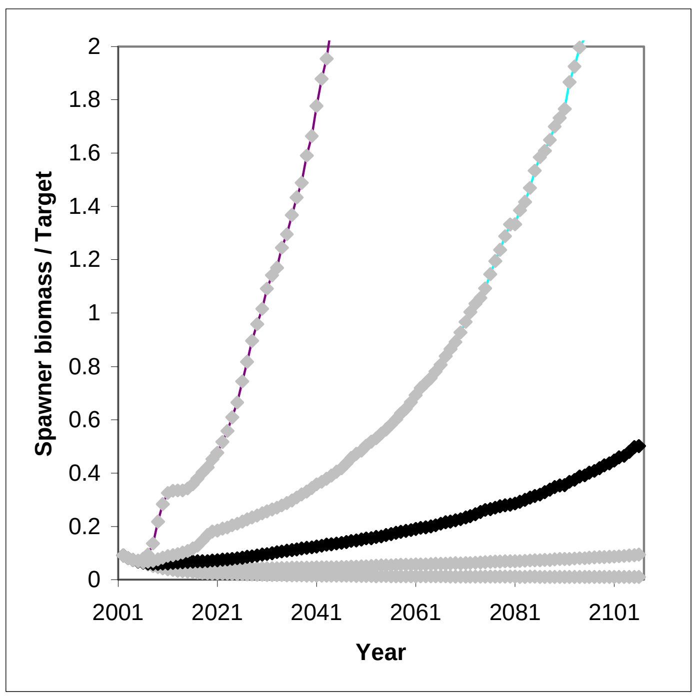

Figure 7. Time series of relative abundance expressed as percentiles (5, 25, **50**, 75, 95) of simulations under scenario of no fishing.

Appendix: Input file for SSC rebuilding analysis.

```
#Title
Bocaccio - default new1 - B0 <=1986
# Number of sexes
2
# Age range to consider (minimum age; maximum age)
1 21
# First year of projection
2002
# Year declared overfished
1999
# 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
#  3  4  5  6  7  8  9 10
0.0000      0.0018      0.0242      0.1224      0.3104      0.5362      0.7541
      0.9552      1.1442      1.3211      1.4838      1.6315      1.7634
      1.8796      1.9808      2.0683      2.1428      2.2060      2.2594
      2.3042      2.4610
# Age specific information (Females then males), M, weight, selectivity and
numbers
# Females
0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2
0.2 0.2
0.2142      0.4922      0.8601      1.2841      1.7392      2.1965      2.6236
      3.0185      3.3812      3.7072      3.9958      4.2487      4.4677
      4.6563      4.8176      4.9551      5.0713      5.1692      5.2516
      5.3206      5.5526
0.297077    0.843938    0.999140    0.899828    0.730868    0.559329    0.4200
34    0.312984    0.235168    0.181857    0.145744    0.121238    0.103611
      0.091574    0.082545    0.075666    0.070937    0.067068    0.064058
      0.061479    0.055460
158.2 35.4  251.7 8.8   6.7   38.8  4.0   34.8  36.7  1.7   63.3  16.2  23.2
      63.5  13.1  6.2   2.9   25.6  4.6   0.1   87.8
# Males
0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2
0.2 0.2
0.2154      0.4451      0.7275      1.0347      1.3451      1.6467      1.9313
      2.1867      2.4054      2.5913      2.7515      2.8888      3.0058
      3.1046      3.1874      3.2567      3.3144      3.3625      3.4021
      3.4348      3.5419
0.300086    0.782029    1.000000    0.974205    0.881771    0.767412    0.6543
42    0.558899    0.483663    0.424334    0.376182    0.337059    0.306105
      0.281599    0.262683    0.248065    0.236457    0.226999    0.219690
      0.213672    0.198624
158.2 35.4  255.2 8.9   6.6   37.2  3.8   32.3  33.2  1.5   55.1  13.4  18.2
      46.4  8.7   3.7   1.5   11.1  1.8   0     20.4
# Initial age-structure (for Tmin)
25.0  21.0  118.0 11.0  90.0  88.0  4.0   135.0 33.0  47.0  126.0 26.0  12.0
      6.0   49.0  9.0   0.0   2.0   5.0   16.0  144.0
```

```
25.0  21.0  118.0 11.0  93.0  91.0  4.0   137.0 32.0  42.0  105.0 19.0  8.0
      3.0   24.0  4.0   0.0   1.0   1.0   4.0   36.0
# Year for Tmin Age-structure
1999
# Number of simulations
10000
# Recruitment and Spanwer biomasses
# Number of historical assessment years
49
# Historical data: Year, Recruitment, Spawner biomass, Used to compute B0,
Used to project based
# on R, Used to project based on R/S
1954      50   10537  1  0  0
1955      50   11402  1  0  0
1956      50   11324  1  0  1
1957      96   10133  1  0  1
1958   53201    8365  1  0  1
1959    9922    6296  1  0  1
1960     580    5135  1  0  1
1961     769    5166  1  0  1
1962    8713    5538  1  0  1
1963  169111    5526  1  0  1
1964     388    5066  1  0  1
1965     232    6006  1  0  1
1966     219    9753  1  0  1
1967     256   14630  1  0  1
1968     478   17909  1  0  1
1969    7360   18927  1  0  1
1970   92424   18429  1  0  1
1971     154   17121  1  0  1
1972      50   16216  1  0  1
1973   31983   16526  1  0  1
1974    1752   16808  1  0  1
1975   15045   16150  1  0  1
1976    2955   14840  1  0  1
1977     455   13233  1  0  1
1978   44923   11621  1  0  1
1979    1779   10731  1  0  1
1980   10397   10065  1  0  1
1981    2660    9678  1  0  1
1982    1127    9459  1  0  1
1983      50    8735  1  0  1
1984    3053    7666  1  0  1
1985   12986    6629  1  0  1
1986    1170    5699  1  0  1
1987    1801    4867  0  0  1
1988    2587    4249  0  0  1
1989    8436    3846  0  0  1
1990    2078    3222  0  0  1
1991     998    2703  0  0  1
1992    2732    2466  0  0  1
1993      50    2239  0  0  1
1994     795    1976  0  0  1
1995     569    1749  0  0  1
1996      50    1556  0  0  1
1997     379    1383  0  0  1
1998      52    1217  0  0  1
1999      50    1089  0  0  1
```

```
2000     971     961  0  0  1
2001      93     832  0  0  0
2002     316     720  0  0  0
# Number of years with pre-specified catches
1
# catches for years with pre-specified catches
2002 100.0
# Number of future recruitments to override
0
# Process for overiding (-1 for average otherwise index in data list)
# Which probability to product detailed results for (1=1.5,2=0.6,etc.)
5
# Steepness and sigma-R
0.5 0.5
# Target SPR rate (FMSY Proxy)
0.5
# Target SPR information: Use (1=Yes) and power
0 20
# 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
# Percentage of FMSY which defines Ftarget
0.9
# 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
10
# First Random number seed
-89102
# User-specific projection (1=Yes); Output replaced (1->6)
1 5
# Catches and Fs (Year; 1/2 (F or C); value); Final row is -1
2003 2 0.0
2004 1 0.0
2104 1 0.0
-1 -1 -1
```