Bocaccio Rebuilding Analysis for 2005

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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 number of bocaccio stock assessments (MacCall et al. 1999, MacCall 2002, MacCall 2003a, MacCall 2005) and rebuilding analyses (MacCall 1999, MacCall and He 2002, MacCall 2003b) have now been conducted since the stock was declared overfished. 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).

The 2003 stock assessment examined three models of bocaccio. One of those, the STATc model, was used as the basis for subsequent fishery management and as the basis of FMP Amendment 16-3. The 2005 bocaccio stock assessment updated the 2003 STATc model, and is the basis of this rebuilding analysis. Also, the 2005 assessment is the first new assessment since the formal Rebuilding Plan (FMP Amendment 16-3) was established.

IMPORTANT NOTE: In preparing this rebuilding analysis, an error was discovered in the Rebuilding Plan, Amendment 16-3. Although the PFMC clearly selected a bocaccio rebuilding plan with $\mathbf{P_0}$ (probability of reaching rebuilding target by $\mathbf{T_{max}}$) of 70%, the corresponding value of $\mathbf{T_{targ}}$ (year with a 50% probability of reaching the target) was incorrectly specified as 2023. The 2003 rebuilding analysis indicated that a 50% probability rebuilding would require 23 years, but this assumed a beginning date of 2004 (the first simulated year). Accordingly, the correct value of $\mathbf{T_{targ}}$ was 2027. Both values of $\mathbf{T_{targ}}$ are examined in the present analysis.

Management Performance

Details of management performance are provided in Table 1. The rebuilding OY was set at 100 MT for 2000-2002 as a transition to a constant fishing mortality rate policy beginning in 2003. This was a learning period for fishery management, which required unprecedented restrictions on both commercial and recrerationa fishing opportunities. Actual harvest exceeded management targets in the first three years, but with a smaller excess by the third year. In response to the 2002 bocaccio assessment, which indicated very low productivity, the 2003 OY was set at 20MT, and the retained catch was about 12MT. Including mortality of estimated discards, estimated 2003 total kill was 22MT. Based on the 2003 assessment, which showed a much more productive stock, the 2004 OY was set at 250MT, but management used an operational target of 199MT; the final catch was 78MT. Discards brought the estimated 2004 kill to 83MT. Thus, recent management has shown substantial improvement in performance, and has been achieving total removals at (2003) or well below (2004) maximum target levels. The anticipated bocaccio mortality in 2005 also is expected to fall well below the maximum level set by the OY.

Table 1. Recent history of bocaccio management performance.

	Commercial			Recreational			Total			ABC	OY
Year	Catch	Discard	Total	Catch	Discard	Total	Catch	Discard	Total		
1995	730	*	730	31	2	33	761	2	763	1700	1700
1996	480	*	480	89	4	93	569	4	573	1700	1700
1997	324	*	324	146	11	157	470	11	481	265	265
1998	157	*	157	51	0	51	208	0	208	230	230
1999	73	*	73	120	4	124	193	4	197	230	230
2000	25	49	74	103	9	112	128	58	186	164	100
2001	22	76	98	103	6	109	125	82	207	122	100
2002	21	30	51	82	2	84	103	32	135	122	100
2003	1	10	11	9	2	11	10	12	22	244	<20
2004	12	10	22	54	8	62	66	18	84	400	199
2005									150**	566	307

* Discarded commercial catch was not estimated and is assumed to be negligible.
** Anticipated 2005 bocaccio mortality given in June 2005 GMT document dated "6/16/06 17:45" [actual year 2005]

Simulation Model

This analysis uses the SSC Default Rebuilding Analysis (version 2.8a). All data and parameters use as input to this analysis were taken from the STATc model in the 2005 assessment. An example input file is given in Appendix A. Future recruitments were simulated by re-sampling estimated historical recruits/spawning output (**R/B**) ratios from years 1970 to 2005. Re-sampling **R/B** values is justified by the estimated Mace-Doonan steepness value of ***h*** = 0.211 in the 2005 stock assessment. This value of steepness indicates negligible curvature in the estimated stock-recruitment relationship. Probability distributions are based on 2000 simulations.

As a comparability check, the input data from the 2003 rebuilding analysis were run in this most recent version of the SSC simulation model, and results were identical to those in the original 2003 analysis. Note that due to differences in model structure, the projections made by the SSC model may differ from projections made by the Stock Synthesis model used in the 2005 stock assessment (MacCall 2005).

Rebuilding Parameters/Management Reference Points

$B_{unfished}$: Unfished biomass (measures as spawning output) 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). Based on the 2005 bocaccio assessment, the estimated unfished spawning output (**$B_{unfished}$**) is 13325 billion eggs (compared with 13387 billion eggs estimated in the 2003 rebuilding analysis), 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 $ 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 PFMC proxy value of 40% of estimated unfished spawning output. Estimated **B_{msy}** is 5330 billion eggs (compared with 5355 billion eggs in the 2003 rebuilding analysis).

Current status: According to the 2005 stock assessment as modified for input to the SSC Rebuilding Analysis model, current (2005) spawning output is 1419 billion eggs, which is 27% of the estimated **B_{msy}**. This is a substantial increase over the 2003 values. 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.

The following table summarizes results of the 2003 and 2005 rebuilding analyses. Reference years are unchanged by the 2005 update.

Table 2. Parameters and reference points for rebuilding

Date of Analysis	2003	2005
Assessment model used as basis	STATc	STATc update
First year of rebuilding	2000	2000
Present year (Final year of assessment)	2003	2005
First simulated year	2004	2006
Tmin	2018	2018
Mean Generation Time	14	14
Tmax	2032	2032
Prob rebuild by Tmax	0.7	
Rebuild SPR	0.693	
Exploitation Rate	0.0498	
Ttarg from 2003 Rebuilding Analysis	2027	
Ttarg from Amendment 16-3 (wrong)	2023	

Results of Simulations

Table 3 is a suite of projections requested by the GMT. Because of the alternative interpretations of $\mathbf{T_{targ}}$ for bocaccio, two versions of run #2 are presented: Version "a" uses $\mathbf{T_{targ}}$ = 2027 and version "b" uses $\mathbf{T_{targ}}$ = 2023. Both values of $\mathbf{T_{targ}}$ are also considered in run #1.

Table 3. Rebuilding projections requested by the GMT.

Run #	**Prob (recovery)**	**By**	**Based on**
#1 (default)	Estimated	Current T_{TARGET}	Current SPR
#2 (T_{TARGET} with 50% prob)	0.5	Current T_{TARGET}	Estimated SPR
#3 (#1 based on T_{MAX})	Estimated	Current T_{MAX}	Current SPR
#4 (#2 based on T_{MAX})	P_0	Current T_{MAX}	Estimated SPR
#5 (#3 with re-estimated T_{MAX})	Estimated	T_{MAX} (re-estimated)	Current SPR
#6 (#4 with re-estimated T_{MAX})	P_0	T_{MAX} (re-estimated)	Estimated SPR

Projection results, including time series of median catch and median spawning output relative to the rebuilding target are shown in Table 4. Because the value of $\mathbf{T_{max}}$ did not change from the 2003 value, some of the GMT-requested runs are identical (3 and 5, 4 and 6), and Table 4 is condensed accordingly. Results for four additional runs are also shown: cases of **F**=0, catches under ABC ($\mathbf{F_{50\%}}$) and the 40-10 rules, an 80% probability of achieving the rebuilding target by $\mathbf{T_{max}}$, and a "scorecard F projection" requested by the GMT (John Field, Pers. Comm.). The latter projection is based on a constant harvest rate equivalent to a 2005 catch of 148.9 mtons. Catches and biomasses projected under an ABC (i.e., $\mathbf{F_{msy}}$ proxy = $\mathbf{F_{50\%}}$) harvest policy do not correspond to the ABC for individual years under other policies, but rather represent projections under the maximum allowable harvest rate. Also note that the **F**=0 projection now has a median rebuilding date of 2022 because of actual catches taken during 2000-2006 (i.e., this scenario represents no harvest beginning in 2007) as opposed to the original $\mathbf{T_{min}}$ of 2018 which assumed no harvest beginning in 2000.

Simulated individual rebuilding trajectories are erratic due to rare large recruitments (Figure 1). The time series of percentiles and medians of simulated catch and abundance trajectories (Figures 2, 3, 4) provide a more informative overview of likely rebuilding performance and uncertainty.

Table 4. Results of rebuilding projections. Bold numbers are specifications for runs (see Table 3). Shaded cells indicate median abundance exceeds rebuilding target. Where applicable, rebuilding policy reverts to 40-10 policy upon achieving target abundance.

Run	re-do 2003	1a, 1b, 3, 5	2a	2b	4, 6	F=0	F50%(ABC)	40-10 Policy	P=0.8 by Tmax	Scorecard F
SPR	0.693	0.692	0.717	0.883	0.705	1.000	**0.5**	**variable**	0.777	0.844
F	0.0498	**0.0498**	0.0450	0.0166	0.0475	**0**	0.0971	**variable**	0.034	**0.023**
P(by 2023)	0.316	0.240	0.270	**0.5**	0.254	0.638	0.0445	0.284	0.37	0.448
P(by 2027)	0.517	0.458	**0.5**	0.726	0.48	0.8365	0.1145	0.5	0.726	0.688
P(by 2032)	**0.7**	0.678	0.720	0.9	**0.7**	0.958	0.228	0.706	**0.8**	0.868
T(P=0.5)	2027	2028	2027	2023	**2028**	2022	2044	2027	2026	2024
Median Catch										
2004	306									
2005	308	*150*	*150*	*150*	*150*	*150*	*150*	*150*	*150*	*148.9*
2006	309	*150*	*150*	*150*	*150*	*150*	*150*	*150*	*150*	147
2007	316	314	284	106	300	0	602	38	216	147
2008	337	316	287	109	302	0	585	53	219	150
2009	368	334	304	118	319	0	601	73	234	161
2010	400	359	328	129	344	0	627	101	254	176
2011	429	388	356	142	373	0	664	137	277	194
2012	457	425	390	158	408	0	707	187	306	215
2013	483	462	426	175	444	0	753	252	336	237
2014	520	498	460	192	479	0	785	327	365	259
2015	555	535	495	211	516	0	825	424	395	283
2016	594	567	526	228	547	0	848	532	423	305
Median Spawning Output Relative to Target										
2005	0.25	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
2006	0.26	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
2007	0.28	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
2008	0.29	0.31	0.31	0.31	0.31	0.31	0.30	0.31	0.31	0.31
2009	0.31	0.31	0.32	0.33	0.31	0.33	0.30	0.33	0.32	0.32
2010	0.33	0.32	0.33	0.34	0.33	0.35	0.30	0.35	0.33	0.34
2011	0.36	0.34	0.35	0.37	0.34	0.38	0.31	0.38	0.35	0.36
2012	0.38	0.36	0.37	0.40	0.36	0.42	0.31	0.40	0.38	0.39
2013	0.41	0.38	0.39	0.43	0.39	0.46	0.33	0.44	0.41	0.42
2014	0.44	0.41	0.42	0.47	0.42	0.51	0.34	0.48	0.44	0.46
2015	0.47	0.44	0.45	0.52	0.45	0.56	0.35	0.52	0.48	0.50
2016	0.50	0.48	0.49	0.57	0.48	0.62	0.37	0.56	0.52	0.55
2017	0.53	0.51	0.53	0.62	0.52	0.69	0.39	0.61	0.56	0.60
2018	0.57	0.55	0.56	0.68	0.55	0.76	0.40	0.64	0.61	0.65
2019	0.61	0.58	0.60	0.73	0.59	0.82	0.42	0.68	0.65	0.70
2020	0.65	0.61	0.64	0.79	0.63	0.90	0.43	0.72	0.69	0.75
2021	0.69	0.65	0.68	0.85	0.66	0.98	0.45	0.76	0.74	0.81
2022	0.73	0.69	0.72	0.92	0.71	1.07	0.46	0.79	0.79	0.87
2023	0.78	0.73	0.77	0.97	0.75	1.16	0.48	0.83	0.85	0.94
2024	0.84	0.78	0.82	1.01	0.80	1.28	0.50	0.87	0.91	1.02
2025	0.90	0.84	0.88	1.05	0.86	1.40	0.51	0.90	0.95	1.11
2026	0.95	0.89	0.93	1.08	0.91	1.53	0.53	0.94	1.00	1.19
2027	0.98	0.94	0.97	1.12	0.95	1.67	0.55	0.97	1.03	1.28
2028	1.02	1.00	1.00	1.16	0.99	1.82	0.56	1.01	1.07	1.38
2029	1.06	1.06	1.04	1.21	1.02	2.00	0.58	1.05	1.10	1.49
2030	1.10	1.13	1.07	1.25	1.06	2.18	0.60	1.08	1.14	1.61
2031	1.14	1.20	1.11	1.31	1.10	2.38	0.63	1.13	1.19	1.73
2032	1.19	1.28	1.16	1.37	1.14	2.61	0.65	1.18	1.24	1.87
2033	1.24	1.37	1.22	1.43	1.19	2.88	0.68	1.24	1.30	2.04

Analysis of Sustainability

Under the fishing rates given by this rebuilding analysis, the probability of further long-term decline in bocaccio abundance is negligibly small (less than one percent over the next 100 years).

Acceptable Biological Catch (ABC) in 2007 and 2008

The value of ABC for 2007 is 602mtons, as given by the median catch for the ABC scenario in Table 4, which is conditional on actual catches of 150 mtons in 2005 and 2006. Table 5 shows that ABC for 2008 depends weakly on the actual catch in 2007, which in turn is influenced by the choice of rebuilding policies.

Table 5. Median estimated values of ABC in 2008.

Assumed catch in 2005	150	150	150	150
Assumed catch in 2006	150	150	150	150
Assumed catch in 2007	100	150	200	300
2008 ABC (median)	621	618	614	607

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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.

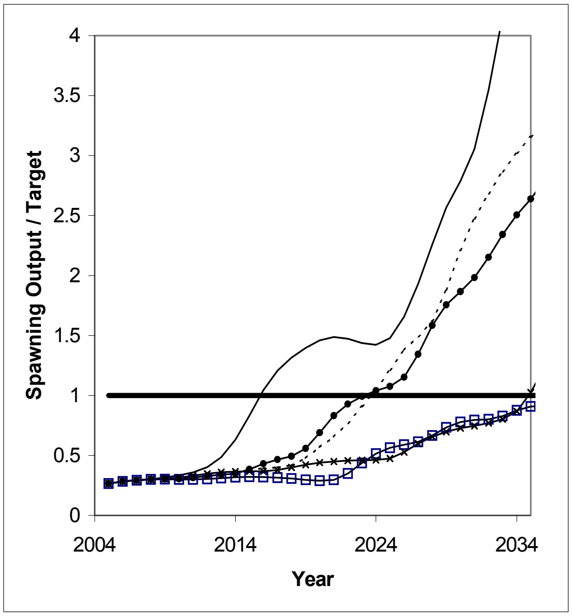

Figure 1. Example individual rebuilding trajectories for bocaccio.

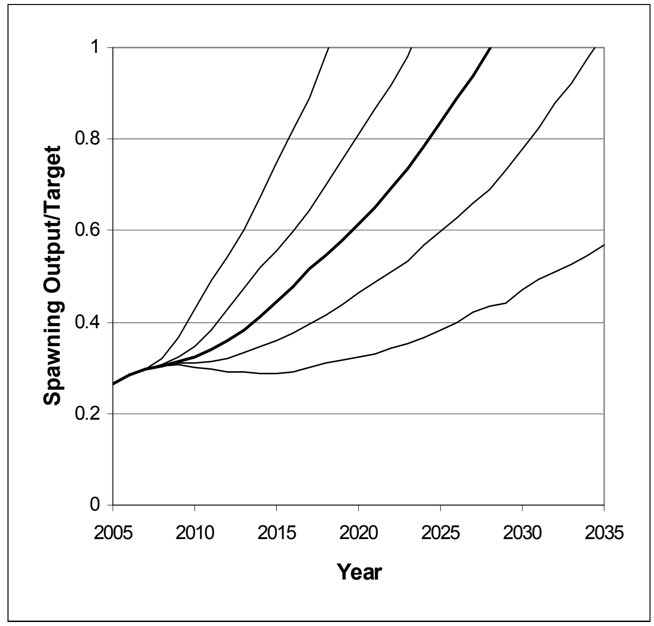

Figure 2. Envelope of rebuilding trajectories for GMT run 1 (current F = 0.0498). Lines are 5, 25, 50, 75 and 95 percentiles of 2000 simulations.

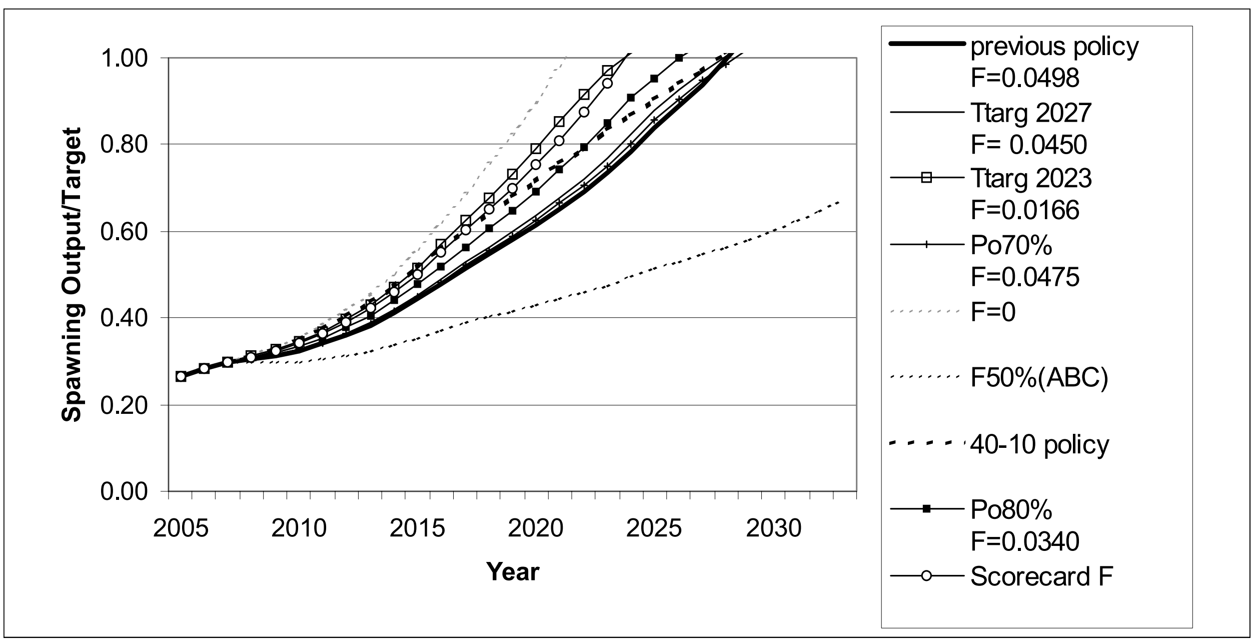

Figure 3. Median trajectories of abundance (relative to rebuilding target) for various cases in Table 4.

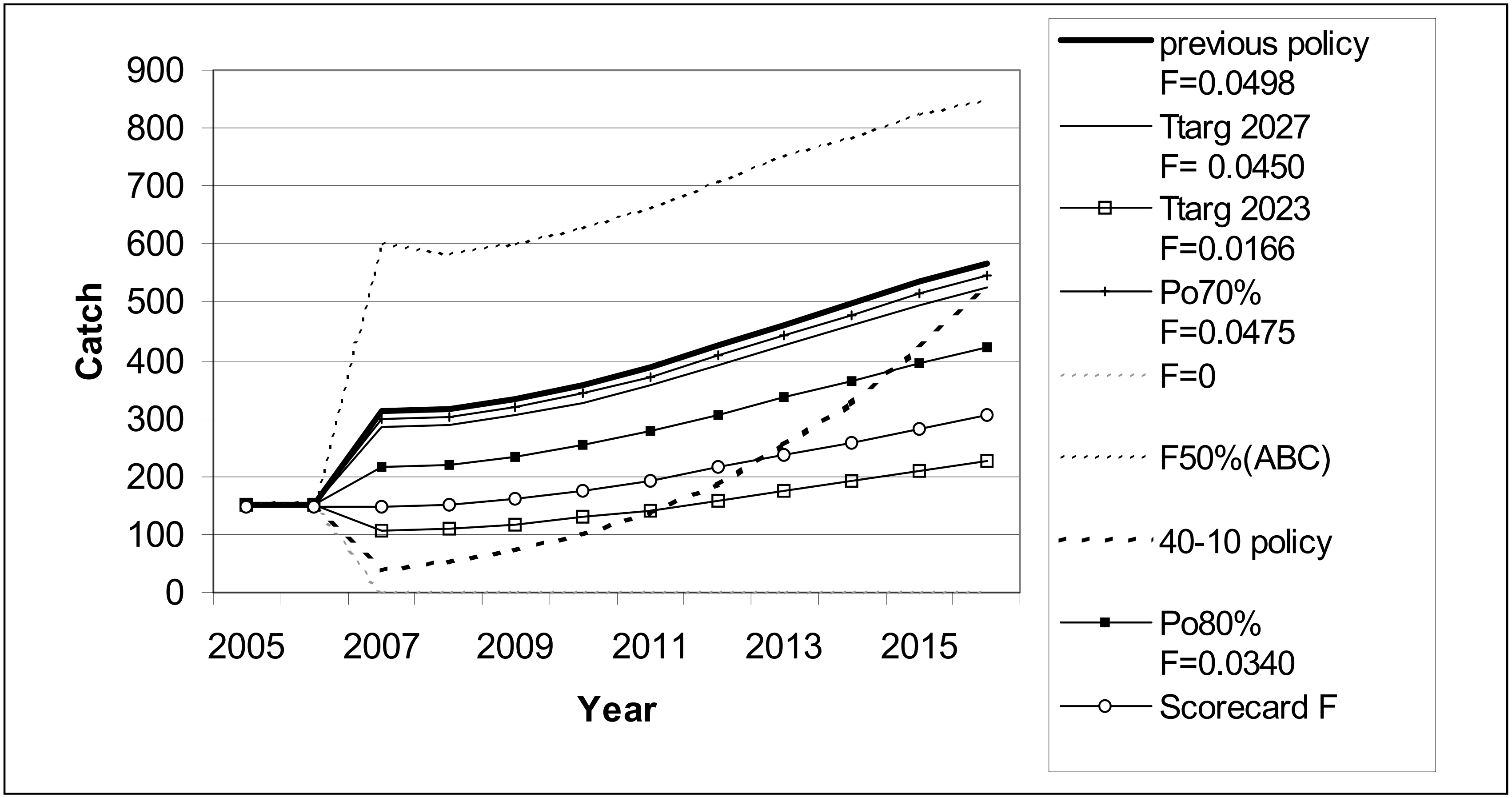

Figure 4. Median trajectories of catch for various cases in Table 4.

Appendix A. Projection data file for Run 1a.

```
# Title
bocaccio 2005 model STATC2005 resample to 2005 use current SPR=0.693 F=0.0498
# 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
2005
# 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
# Fishing mortality based on SPR (1) or actual rate (2)
2
# Pre-specify the year of recovery (or -1) to ignore
21
# 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
 442     575     151     91      13      1147    65      34      115     40      57      47      15
         40      32      2       40      7       4       3       24
# 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
 442     575     151     91      13      1150    65      35      115     40      57      47      15
         41      32      2       36      6       3       2       11
# Initial age-structure (for Tmin)
 2618    154     83      279     96      134     109     34      92      73      4       89      16
         9       6       29      1       0       1       1       21
 2618    154     83      280     98      138     113     36      96      76      4       83      13
         7       4       18      1       0       0       0       6
# Year for Tmin Age-structure
 2000
# Number of simulations
```

2000
Recruitment and Spanwer biomasses
Number of historical assessment years
55
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	3659	1	0	0
1952	3523	3640	1	0	0
1953	3523	3626	1	0	0
1954	3523	3564	1	0	0
1955	3523	3474	1	0	0
1956	3523	3362	1	0	0
1957	3523	3164	1	0	0
1958	3523	2933	1	0	0
1959	3523	2638	1	0	0
1960	2278	2432	1	0	0
1961	1268	2292	1	0	0
1962	1698	2247	1	0	0
1963	53828	2225	1	0	0
1964	767	2073	1	0	0
1965	602	2509	1	0	0
1966	802	4092	1	0	0
1967	1247	6054	1	0	0
1968	1860	7092	1	0	0
1969	2041	7610	1	0	0
1970	3091	7785	1	0	1
1971	15118	7626	1	0	1
1972	1732	7319	1	0	1
1973	2039	6841	1	0	1
1974	15668	5910	1	0	1
1975	5451	4821	1	0	1
1976	1258	4139	1	0	1
1977	511	3783	1	0	1
1978	23029	3860	1	0	1
1979	2367	3714	1	0	1
1980	8090	3499	1	0	1
1981	1395	3470	1	0	1
1982	1520	3488	1	0	1
1983	151	3144	1	0	1
1984	586	2610	1	0	1
1985	10474	2087	1	0	1
1986	1413	1723	1	0	1
1987	1332	1337	0	0	1
1988	1550	1212	0	0	1
1989	5564	1214	0	0	1
1990	167	1035	0	0	1
1991	1822	863	0	0	1
1992	1485	873	0	0	1
1993	374	844	0	0	1
1994	830	789	0	0	1
1995	755	751	0	0	1
1996	413	737	0	0	1
1997	953	731	0	0	1
1998	234	728	0	0	1
1999	362	760	0	0	1
2000	5235	795	0	0	1
2001	50	825	0	0	1
2002	291	878	0	0	1
2003	413	1038	0	0	1

```
2004    1342    1261    0    0    1
2005    885     1430    0    0    1
# Number of years with pre-specified catches
2
# Catches for years with pre-specified catches
2005 150
2006 150
# 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=0.5,2=0.6,etc.)
2
# Steepness and sigma-R  and auto-correlations
  0.211  1.000000 0.0
# Target SPR rate (FMSY Proxy)
0.5
# 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
# Definition of the "40-10" rule
10 40
# 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)
1 2 0 0.5
# Catches and Fs (Year; 1/2 (F or C); value); Final row is -1
2007 1 0.0498
-1 -1 -1
# Split of Fs
2005 1
2006 1
-1 1
```

Time varying weight-at-age (1=Yes;0=No)
0
File with time series of weight-at-age data
HakWght.Csv