Exhibit C.3
Supplement NMFS Report
June 2002

Rebuilding Analysis for Canary Rockfish: Update to Incorporate Results of Coastwide Assessment in 2002

June 2002

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Summary

The rebuilding analysis for canary rockfish was first conducted in 2000 based on the 1999 stock assessment. This document updates the analysis based upon the 2002 assessment.

The target spawning stock biomass is 40% of the unfished spawning stock biomass (Bzero). The method to calculate Bzero is improved to incorporate more historical information and results in a higher level than estimated in 2000. Spawning stock abundance reached a low of 6.6% of the unfished level in 2000, the year of the overfished declaration. By 2002 it had increased to 7.9%.

The mean generation time is 19 years. The time to rebuild with no fishingis year 2057. This is longer than the previous estimate of 2041 primarily because of the higher Bzero level.

The rate of rebuilding is based on the estimated spawner-recruitment relationship with steepness of 0.33. Based on this relationship, Fmsy = F73%; MSY = 622 mt; Bmsy = 45% of Bzero; and ABC in 2003 is 116 mt at the estimated Fmsy and 256 mt at the default F50% proxy for Fmsy.

The table below shows the initial OY associated with a range of rebuilding targets.

Pr(rebuild by 2076)	Year to 50% Pr(rebuild)	OY in 2003
50%	2076	45 mt
60%	2074	41 mt
70%	2071	36 mt
80%	2068	30 mt

Rate of rebuilding is most sensitive to the steepness of the spawner-recruitment relationship. Improved ocean conditions could cause higher steepness, but no evidence yet. The level of allowable catch during rebuilding is sensitive to the recreational:commercial allocation because of their difference in selectivity for young versus old fish.

Introduction

The stock assessment for canary rockfish in 1999 documented that the stock had declined below the overfished level (25% of Bzero) in the northern area (Columbia and U.S. Vancouver INPFC areas; Crone et al., 1999) and in the southern area (Williams et al., 1999). Canary rockfish was determined to be in an "overfished" state on Jan. 1, 2000 which initiated development of a rebuilding plan. The first rebuilding analysis (Methot, 2000) used results from the northern area assessment to project rates of potential stock recovery. The stock was found to have extremely low productivity, defined as production of recruits in excess of the level necessary to maintain the stock at its current, low level. Rates of recovery were highly dependent upon the level of recent recruitment, which could not be estimated with high certainty. The initial rebuilding OY for 2001 and 2002 was set at 93 mt based upon: a 50% probability of rebuilding by the year 2057, a medium level for these recent recruitments, and maintaining a constant catch (93 mt) throughout the rebuilding period.

The purpose of this document is to use results of the updated canary rockfish stock assessment (Methot and Piner, 2002) to update estimates of the potential rate of rebuilding of canary rockfish. The basic results of this assessment are summarized in the Assessment Summary below. In addition to using results from the updated assessment, the following changes were made at the request of the Council's Groundfish Management Team:

a. Use a constant exploitation rate, as in most other rebuilding plans, rather than a constant catch;

b. Evaluate sensitivity to the allocation between recreational and commercial fishing sectors.

The rebuilding analysis was conducted using software developed by A. Punt (version 2.0). The analysis involves six steps:

(1) examine the recruitment-spawner information to determine levels of historical and current recruitment;

(2) determine unfished level of spawning biomass (Bzero) in order to calculate target levels for rebuilding (Btarget);

(3) calculate the generation time (Gentim), which affects the maximum allowable duration of rebuilding;

(4) determine expected levels of recruitment during the rebuilding period;

(5) calculate the time to 50% probability of rebuilding with no fishing mortality (Tmin);

(6) finally, calculate the year to 50% probability of rebuilding (Ttarget) associated with various levels of fishing mortality. This is subject to the constraint that Ttarget must be no more than Tmax. Tmax is 10 years if Tmin is less than 10 years, and is Tmin plus Gentim otherwise. The selection of Ttarget between Tmin and Tmax is a management decision and is beyond the scope of the rebuilding analysis.

Assessment Summary

The updated assessment for canary rockfish (Methot and Piner, 2002) has several features that influence the rebuilding analysis:

1. The assessment is now coastwide (California to Washington) so the ad hoc adjustment for the southern area is not needed as it was in Methot (2000). The previous assessments (Crone et al., 1999; Williams et al., 1999) did not have a strong biological rationale for the north-south split, and the present assessment's review of patterns in growth and distribution does not support a split at the Eureka-Columbia border. However, uncertainty regarding the contribution of canary rockfish in Canada to the U.S. assessment area remains unresolved.

2. The previous dichotomy between natural mortality and dome-shaped selectivity to explain the low occurrence of old females is blended into one assessment scenario that links female natural mortality to maturation and allows for dome-shaped selectivity. This does not fully resolve the issue, but does eliminate the need for a rebuilding analysis for each mortality/selectivity scenario.

3. The assessment start year was moved from 1967 back to 1941 because the previous assessment had found that historical catch levels were relatively large and that the model was estimating a historical recruitment level that was greater than the recruitment level of the 1967-1977 period. The recruitment level from 1967-1977 had been used to estimate the unfished recruitment in the previous rebuilding analysis, but this level is now seen to be a better estimate of the recruitment level at MSY, which is substantially less than the unfished recruitment level.

4. The strong pattern of declining recruitment at low spawning stock levels was noted in the previous assessment and is now quantified by fitting a spawner-recruitment curve. This curve allows calculation of maximum long-term average yield (MSY), the fishing mortality rate that would produce MSY (Fmsy), and the equilibrium level of spawning stock biomass associated with MSY (Bmsy). The curve also provides a basis for calculation of the level of unfished recruitment (Rzero) and projection of recruitment levels into the future.

5. A large focus of the uncertainty in the previous rebuilding analysis was with regard to the magnitude of recruitment from the 1995 to 1997 year classes as they appeared among the smallest size groups occurring in the 1998 trawl survey. The new assessment does not find these recruitments to be large in subsequent fishery and survey data, and the new method of projecting future recruitments from the spawner-recruitment curve diminishes the influence of any one year's estimate of recruitment.

Rebuilding Calculations

<u>Spawner-Recruit Relationship</u>
The level of recruitment has declined from a level of 3907 thousand fish in the unfished state, to 2549 thousand in 1967-1977, 1918 thousand during 1978-1993, and only 713 thousand during

1994-1999 (Table 1, Figure 1). As long as this lowest level of recruitment persists, the stock cannot rebuild to the 40% biomass level, even without fishing. However, the decline is considered to be primarily a result of the declining level of spawner abundance, so recruitment should increase as the spawning stock is rebuilt.

The critical factor influencing the rate of rebuilding is the degree to which recruitments will be above the replacement level, thus able to rebuild the stock and potentially support a small harvest during rebuilding. Since the level of recruitment is not much above the replacement level (Figure 2), rebuilding will be extremely slow. The expected level of recruitment is determined by the steepness parameter of the Beverton-Holt formula. The canary rockfish assessment in 2002 provides results for three levels of steepness: the steepness level initially estimated within the model (0.289, lower dashed line in Figure 2), the best-estimate of steepness obtained from a focused examination of the recruitment-spawner information (0.33, solid line), and a higher steepness level (0.36, upper dashed line) which provides a contrast to the 0.289 level. The steepness of 0.33 is the best estimate of the level of recruitment to be expected as the stock begins to rebuild.

This low level of steepness is conditional upon all the downward trend in recruitment being caused by the decline in spawner abundance. Other fish species often have steepness levels near 0.7 (Myers, 1999) and Dorn's (2000) meta-analysis of rockfish found a level of approximately 0.67. If some of this recruitment downtrend for canary rockfish has been because of long-term shifts in the ocean climate, then it is possible that a future shift in the ocean climate will cause an upward shift in recruitment and future estimates of the spawner-recruitment steepness will be higher and representative of a longer-term environmental average. As an illustration of such a shift, a spawner-recruitment curve with steepness of 0.5 is shown on Figure 2. Although there are signs of a shift in the ocean climate towards a more productive regime in 1999 and evidence of stronger sablefish, whiting, and salmon survival in 1999, there is yet no evidence of such a shift for canary rockfish. Only time will tell.

The year-to-year variability of recruitment is also important for the rebuilding analysis. The log-normal variability of recruitment about the curve is approximately 0.4, and this level will be used in the forecasts of future recruitment. This lognormal variability is used in lieu of resampling the from the individual year estimates of recruitment deviations.

ABC, Overfishing and Fmsy

The current Council policy for the calculation of ABC is to apply an exploitation rate based on F50%. This would be 256 mt in 2003. However, the calculation of the spawner-recruitment relationship demonstrates that F50% is not a sustainable harvest policy for canary rockfish because of the low spawner-recruitment steepness. The estimate of Fmsy is 0.0601 year^{-1} and corresponds to F73% [1]. This rate would result in an ABC of 116 mt in 2003. Once rebuilt, fishing at F73% would be expected to produce an average catch of 622 mt from a biomass that would average 45% of the unfished level.

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[1] This instantaneous fishing mortality rate is for the age(s) with selectivity equal to 1.0. Because of the dome-shaped selectivity pattern (Table 2), the rate for other ages is less.

Unfished Abundance Level

The previous rebuilding analysis considered three possible methods for calculating the level of recruitment expected under unfished conditions. The selected method was based upon the estimated recruitments from the early (1967-1977) portion of the assessment time series, but an alternative based upon the model's higher estimate of initial recruitment levels was also considered. The new assessment starts in 1940 and provides stronger evidence that recruitment had already begun to decline by 1967. It shows that recruitment during 1967-1977 is at about the reduced level expected at MSY, rather than the higher level expected from an unfished stock. This higher, unfished level of recruitment is used as the basis for Bzero in this updated rebuilding analysis, although a comparative run will be made using the updated estimates of the 1967-1977 recruitments. Bzero is calculated as the product of the initial, unfished level of recruitment in the assessment model (3907 thousand fish) and the level of female spawning biomass per recruit that occurs in the absence of fishing (8.135).

Expected Recruitment Level

Three methods of calculating recruitment during rebuilding were considered. These are random resampling of observed recruitment levels, random resampling of observed levels of recruits/spawner (R/S) and random generation of lognormal deviations from the estimated spawner-recruitment relationship. The first method is not reasonable because of the large change in recruitment level observed during the time series. The second method has been used in some other rebuilding analyses and the previous canary rockfish analysis, but there are aspects of this approach that may not be the best that can be done with available information. In particular, it is difficult to objectively select the time frame of the recent period from which to re-sample. If it is short enough to accurately represent recent recruitment, it will not have enough observations to fully represent the frequency distribution of future possible recruitments. Also, this method incorporates no population compensation. . It is effectively a linear spawner-recruitment relationship, so leads to exponential population growth as the stock increases above its current low level.

The third method incorporates compensation in the form of the spawner-recruitment curve and was used in this rebuilding analysis. This third method has several desirable features:

1. Reproduces current low recruitment levels while spawning biomass remains low;
2. Smoothly increases mean recruitment (and decreases recruits per spawner) towards the unfished level as spawning biomass increases;
3. Parametric sampling from the lognormal distribution generates a smoother frequency distribution of future recruitments (in comparison to resampling from the model's time series of annual recruitment deviations) thus provides rebuilding calculations that are less sensitive to individual historical recruitment estimates.

Rebuilding in the Absence of Fishing - Tmin

The best estimate of the unfished time to 50% probability of rebuilding is the year 2057 (Tmin in Table 4 for the BASELINE MODEL column). The level of steepness greatly affects the time to rebuild: year 2049 with a steepness of 0.36, 2057 with the best steepness estimate of 0.33, and 2077 with a steepness of 0.289.

With the previous method for calculating the unfished biomass level, the target biomass level is lower and would be achieved more quickly. There is a 50% probability of achieving this lower level by 2044 (Table 3), which is only 3 years greater than the Tmin (2041) calculated in the initial canary rockfish rebuilding analysis (Methot, 2000). However, this lower target biomass level is not the best estimate of Bzero. In fact, the recruitment level that generates the previous Bzero level is close to the expected recruitment at MSY (Methot and Piner, 2002).

Generation Time

Generation time is calculated as the mean age of female spawners, weighted by age-specific spawn production (Table 2), in an unfished population. It is calculated to be 19 years in the new assessment in which female natural mortality increases at older ages in proportion to maturation. This is intermediate between the 16.8 and 24.7 years calculated for the two natural mortality scenarios in the 1999 assessment (Crone et al., 1999) and used in the 2000 rebuilding analysis. Note that the generation time was erroneously reported as 16 years in the June 2002 version of the 2002 assessment document.

Maximum Allowable Rebuilding Time - Tmax

With Tmin at 2057, the Tmax would be 19 years greater, or 2076. However, two years have elapsed since the stock was declared overfished. The low level of catch during these two years has a small, but unquantified, delay on Tmin. Consequently, the Ttarget (year with 50% expectation of achieving the rebuilt level) should be set less than Tmax.

Rebuilding with Fishing

If the exploitation rate is set to Fmsy, then the stock will not have a 50% probability of rebuilding until 2094, even with the 40:10 adjustment which would set the OY to zero until the stock rebuilt to the 10% biomass level. The year 2094 exceeds Tmax and does not meet the requirement to have a 50% probability of rebuilding before 2076.

At a reduced fishing mortality rate of 0.0242 $year^{-1}$ there is a 50% probability of rebuilding by 2076 (Table 4), and the OY in 2003 would be 45 mt. This harvest level corresponds to the maximum permissible Ttarget.

Lower harvest rates will result in an earlier Ttarget year, a higher probability of being rebuilt by Tmax, and a lower OY in 2003 (Figure 4). Results shown in Figure 4 and Figure 5 are calculated for 50, 60, 70 and 80% probabilities of being rebuilt by Tmax. For these probabilities, the OY in 2003 ranges from 30 to 45 mt. By 2023, the range of expected OY would be 57 to 81 mt (Figure 5). These calculations at 50, 60, 70 and 80% are particular points along a continuum (Figure 4). If socio-economic considerations lead to the need to consider other levels, then interpolation form the results presented here is technically reasonable.

Because future recruitment will vary around the spawner-recruitment relationship (Figure 2), there is variability in the estimate of time to rebuild. Figure 6 shows this variability for a 60% probability of rebuilding

Other Factors Affecting Rebuilding

One factor affecting the level of allowable harvest during rebuilding is the age selectivity of the combined fisheries. Because recreational fisheries take younger fish, their per-ton impact on rebuilding is greater than that of the commercial fisheries which take a broad age range of older fish. Table 4 shows the trade-off for 80:20, 50:50, and 20:80 splits of catch between recreational and commercial fisheries.

The most significant factor affecting the rate of rebuilding, and the level of sustainable fishery post-rebuilding, is the steepness of the spawner-recruitment relationship. If steepness is 0.289, rather than 0.33, then the Tmin is extended by 20 years!. Steepness levels near 0.7 are normal and Dorn's (2000) review of steepness for rockfish found an average value near 0.6 when he included rockfishes off Alaska and off the west coast. If future steepness for canary rockfish increases to 0.5 rebuilding will accelerate, but will still have a Tmin that is 30 years away (Table 3).

The assessment area extends northward to the US-Canada border, but the trawl survey which extends northward to about 49° N shows that canary rockfish abundance is often high near the border. Canadian catch has been near 200 mt in recent years, so the combined impact of the US and Canadian fisheries could be greater than the levels forecast here as necessary for rebuilding. A combined US and Canadian stock assessment is advised to improve the estimate of total fishery impact.

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Table 1. Time series of canary rockfish abundance, recruitment and total catch as estimated in Methot and Piner (2002).

Year	Total Biomass	Female Spawning Biomass	Age 1 Recruitment	Exploitation Rate	Total Catch
Unfished	94062	31782	3907	0	0
Initial Equilibrium	85325	29848	3907	0.006	500
1941	85326	29848	3948	0.006	500
1942	85331	29847	3948	0.040	3363
1943	82235	28852	3948	0.043	3491
1944	79153	27860	3867	0.049	3842
1945	75842	26792	3783	0.060	4500
1946	71975	25538	3691	0.060	4296
1947	68496	24417	3579	0.059	4041
1948	65438	23449	3476	0.016	1069
1949	65720	23626	3384	0.016	1017
1950	66016	23829	3401	0.019	1223
1951	66029	23941	3420	0.023	1500
1952	65686	23919	3431	0.023	1474
1953	65325	23871	3429	0.025	1618
1954	64769	23725	3424	0.026	1657
1955	64147	23525	3410	0.026	1662
1956	63505	23294	3391	0.030	1878
1957	62625	22960	3369	0.032	1989
1958	61731	22577	5788	0.035	2156
1959	60790	22134	3750	0.032	1910
1960	60237	21803	3058	0.029	1760
1961	60040	21561	6281	0.025	1483
1962	60276	21481	2871	0.023	1388
1963	60670	21521	2703	0.026	1571
1964	60937	21582	5547	0.019	1129
1965	61668	21895	2116	0.018	1122
1966	62263	22268	1275	0.043	2690
1967	60889	22060	1271	0.032	1950
1968	60066	22142	2007	0.039	2331
1969	58585	22015	3467	0.027	1578
1970	57769	22078	3530	0.027	1542
1971	56881	21982	2795	0.028	1585
1972	55841	21662	1653	0.030	1682
1973	54592	21124	1973	0.046	2516
1974	52392	20159	3035	0.037	1918
1975	50859	19455	2182	0.038	1921
1976	49347	18792	2618	0.032	1561
1977	48302	18314	3513	0.046	2181
1978	46650	17622	1833	0.066	3060
1979	44149	16596	3158	0.091	3995
1980	40822	15246	3701	0.103	4138
1981	37514	13968	1288	0.086	3174
1982	35365	13106	2443	0.158	5538

Year	Total Biomass	Female Spawning Biomass	Age 1 Recruitment	Exploitation Rate	Total Catch
1983	30699	11340	2134	0.160	4853
1984	26897	9883	1962	0.089	2361
1985	25885	9543	2091	0.107	2748
1986	24436	9083	2341	0.095	2299
1987	23415	8788	1344	0.136	3148
1988	21395	8088	1275	0.143	3038
1989	19404	7355	1986	0.171	3283
1990	17090	6438	1488	0.175	2932
1991	15118	5667	1227	0.219	3255
1992	12739	4683	1255	0.236	2960
1993	10644	3831	1169	0.212	2212
1994	9286	3254	830	0.134	1220
1995	8969	3130	1342	0.132	1168
1996	8657	3037	766	0.178	1508
1997	7899	2762	449	0.180	1399
1998	7160	2512	374	0.204	1444
1999	6266	2195	516	0.142	883
2000	5887	2102	454	0.030	177
2001	6197	2312	435	0.015	90
2002	6540	2524	477	0.014	89

Table 2. Life history parameters, fishery selectivity (with 50:50 commercial:recreational allocation) and population numbers at age in 2002.

	Females					Males			
Age	Fecundity	M	Weight	Selectivity	InitN	M	Weight	Selectivity	Init N
1	0.000	0.060	0.047	0.000	238.4	0.06	0.032	0.000	238.4
2	0.000	0.060	0.133	0.008	205.0	0.06	0.119	0.007	205.0
3	0.004	0.060	0.265	0.193	201.1	0.06	0.260	0.193	201.1
4	0.022	0.060	0.435	0.980	213.0	0.06	0.441	0.980	213.0
5	0.081	0.060	0.635	0.997	136.8	0.06	0.645	1.000	136.8
6	0.216	0.061	0.855	0.576	140.3	0.06	0.858	0.587	140.3
7	0.441	0.064	1.085	0.354	208.9	0.06	1.069	0.373	209.1
8	0.735	0.070	1.319	0.278	318.7	0.06	1.269	0.297	319.3
9	1.057	0.079	1.550	0.253	167.6	0.06	1.455	0.266	168.1
10	1.377	0.088	1.775	0.241	199.9	0.06	1.623	0.248	198.3
11	1.676	0.096	1.988	0.233	173.4	0.06	1.774	0.236	166.5
12	1.945	0.102	2.190	0.226	126.2	0.06	1.907	0.227	117.8
13	2.188	0.107	2.378	0.220	104.8	0.06	2.023	0.220	99.2
14	2.401	0.110	2.552	0.214	95.4	0.06	2.124	0.214	95.0
15	2.594	0.113	2.711	0.210	43.4	0.06	2.210	0.210	46.4
16	2.762	0.114	2.856	0.204	32.7	0.06	2.285	0.206	37.0
17	2.913	0.116	2.988	0.199	39.5	0.06	2.348	0.203	44.6
18	3.048	0.117	3.107	0.194	22.9	0.06	2.402	0.201	25.2
19	3.166	0.117	3.214	0.182	13.5	0.06	2.448	0.199	15.1
20	3.270	0.118	3.310	0.172	9.4	0.06	2.486	0.197	11.4
21	3.362	0.118	3.396	0.164	7.2	0.06	2.519	0.196	9.5
22	3.445	0.119	3.473	0.157	2.7	0.06	2.546	0.195	3.8
23	3.520	0.119	3.541	0.139	5.6	0.06	2.569	0.194	8.4
24	3.584	0.119	3.602	0.127	3.7	0.06	2.589	0.193	5.7
25	3.884	0.119	3.900	0.118	45.3	0.06	2.700	0.192	23.5

Table 3. Rebuilding results with alternative levels of Bzero or spawner-recruitment steepness. Baseline model with best steepness estimate is in Table 3.

	Rzero from 67-77 (old method)	Low Steepness	High Steepness	Recruitment Upshift **speculative**
Spawn-recruit steepness	0.33	0.289	0.36	0.50
comm:recr allocation	50:50	50:50	50:50	50:50
F(msy)	F73%	F79%	F69%	F55%
Bmsy/Bzero	45%	45%	43%	40%
MSY (mt)	622	461	728	1395
2003 ABC (mt)				
@ F50%	256	256	256	256
@ Fmsy	116	87	137	222
Btarget (fem. spawn biomass)	8296	12713	12713	12713
Tmin	2044	2077	2049	2032
Tmax	2063	2096	2068	2051
% reb. by Tmax	50%	50%	50%	50%
F	0.0272	0.0136	0.0322	0.0695
OY in 2003 (mt)	51	26	61	129
Yr to 50% reb.	2063	2096	2068	2051
% reb. by Tmax	60%	60%	60%	60%
F	0.0249	0.0116	0.0297	0.0665
OY in 2003 (mt)	47	22	56	124
Yr to 50% reb.	2061	2092	2066	2050
% reb. by Tmax	70%	70%	70%	70%
F	0.0226	0.0096	0.0265	0.0634
OY in 2003 (mt)	43	18	50	118
Yr to 50% reb.	2058	2089	2064	2048
% reb. by Tmax	80%	80%	80%	80%
F	0.0194	0.0071	0.0234	0.0592
OY in 2003 (mt)	36	13	44	110
Yr to 50% reb.	2055	2085	2062	2046
Fmsy with 40:10				
% reb. by Tmax	19%	13%	22%	35%
OY in 2003 (mt)	11	0	0	0
Yr to 50% reb.	2079	2127	2082	2058

Table 4. Rebuilding results with alternative selectivities based upon different commercial:recreational allocation.

	Recreational	BASELINE MODEL Even	Commercial
Spawn-recruit steepness	0.33	0.33	0.33
comm:recr allocation	20:80	50:50	80:20
F(msy)	F73%	F73%	F73%
Bmsy/Bzero	44%	45%	45%
MSY (mt)	525	622	749
2003 ABC (mt)			
@ F50%	218	256	309
@ Fmsy	99	116	140
Btarget (fem. spawn biomass)	12713	12713	12713
Tmin	2057	2057	2057
Tmax	2076	2076	2076
% reb. by Tmax	50%	50%	50%
F	0.0317	0.0242	0.0161
OY in 2003 (mt)	37	45	57
Yr to 50% reb.	2076	2076	2076
% reb. by Tmax	60%	60%	60%
F	0.0289	0.0220	0.0147
OY in 2003 (mt)	34	41	52
Yr to 50% reb.	2074	2074	2074
% reb. by Tmax	70%	70%	70%
F	0.0253	0.0193	0.0129
OY in 2003 (mt)	29	36	45
Yr to 50% reb.	2071	2071	2071
% reb. by Tmax	80%	80%	80%
F	0.0212	0.0161	0.0108
OY in 2003 (mt)	25	30	38
Yr to 50% reb.	2068	2068	2068
Fmsy with 40:10			
% reb. by Tmax	20%	19%	19%
OY in 2003 (mt)	0	0	0
Yr to 50% reb.	2093	2094	2094

Table 5. Time series of median catch, probability of rebuilding (with P=0.6 by 2076 and with F=0.0), anf the median spawning biomass relative to the unfished level.

Year	Median Catch P=0.6	Pr(rebuilt) P=0.6	Pr(rebuilt) F=0	Median(SPB)/Bzero P=0.6	Median(SPB)/Bzero F=0
2003	41	0.000	0.000	0.085	0.085
2004	42	0.000	0.000	0.090	0.091
2005	43	0.000	0.000	0.094	0.095
2006	45	0.000	0.000	0.097	0.099
2007	47	0.000	0.000	0.099	0.102
2008	48	0.000	0.000	0.101	0.104
2009	50	0.000	0.000	0.103	0.107
2010	52	0.000	0.000	0.105	0.110
2011	54	0.000	0.000	0.107	0.112
2012	55	0.000	0.000	0.109	0.116
2013	57	0.000	0.000	0.112	0.119
2014	59	0.000	0.000	0.115	0.123
2015	60	0.000	0.000	0.118	0.128
2016	62	0.000	0.000	0.122	0.132
2017	64	0.000	0.000	0.125	0.137
2018	65	0.000	0.000	0.128	0.141
2019	67	0.000	0.000	0.132	0.146
2020	69	0.000	0.000	0.136	0.151
2021	71	0.000	0.000	0.139	0.156
2022	73	0.000	0.000	0.142	0.161
2023	75	0.000	0.000	0.146	0.166
2024	77	0.000	0.000	0.150	0.171
2025	79	0.000	0.000	0.154	0.176
2026	81	0.000	0.000	0.157	0.182
2027	83	0.000	0.000	0.161	0.187
2028	85	0.000	0.000	0.165	0.192
2029	87	0.000	0.000	0.169	0.198
2030	89	0.000	0.000	0.173	0.204
2031	91	0.000	0.000	0.176	0.209
2032	93	0.000	0.000	0.181	0.216
2033	95	0.000	0.000	0.186	0.222
2034	98	0.000	0.000	0.190	0.229
2035	100	0.000	0.000	0.194	0.235
2036	103	0.000	0.000	0.198	0.241
2037	104	0.000	0.000	0.203	0.248
2038	106	0.000	0.000	0.208	0.255
2039	109	0.000	0.000	0.212	0.262
2040	111	0.000	0.000	0.217	0.269
2041	114	0.000	0.002	0.221	0.275

Year	Median Catch P=0.6	Pr(rebuilt) P=0.6	F=0	Median(SPB)/Bzero P=0.6	F=0
2042	117	0.000	0.005	0.226	0.283
2043	120	0.000	0.010	0.230	0.290
2044	122	0.000	0.018	0.235	0.297
2045	124	0.000	0.024	0.240	0.305
2046	127	0.000	0.033	0.245	0.312
2047	129	0.001	0.047	0.251	0.321
2048	131	0.001	0.072	0.256	0.329
2049	135	0.001	0.105	0.262	0.338
2050	137	0.002	0.143	0.267	0.346
2051	139	0.002	0.189	0.272	0.354
2052	141	0.004	0.229	0.278	0.362
2053	143	0.007	0.281	0.284	0.371
2054	145	0.009	0.331	0.289	0.378
2055	149	0.015	0.404	0.294	0.386
2056	152	0.020	0.457	0.298	0.393
2057	155	0.023	0.514	0.304	0.403
2058	157	0.032	0.558	0.310	0.411
2059	160	0.042	0.624	0.314	0.419
2060	163	0.057	0.696	0.319	0.427
2061	166	0.078	0.754	0.325	0.435
2062	169	0.093	0.797	0.330	0.443
2063	172	0.116	0.832	0.335	0.451
2064	174	0.140	0.856	0.341	0.460
2065	177	0.170	0.887	0.349	0.472
2066	180	0.207	0.905	0.356	0.482
2067	182	0.235	0.922	0.361	0.491
2068	185	0.278	0.940	0.367	0.498
2069	187	0.314	0.953	0.372	0.508
2070	191	0.359	0.963	0.378	0.516
2071	194	0.391	0.973	0.384	0.525
2072	197	0.432	0.980	0.390	0.534
2073	200	0.472	0.984	0.396	0.542
2074	202	0.508	0.989	0.401	0.550
2075	205	0.556	0.993	0.407	0.559
2076	207	0.601	0.994	0.413	0.568

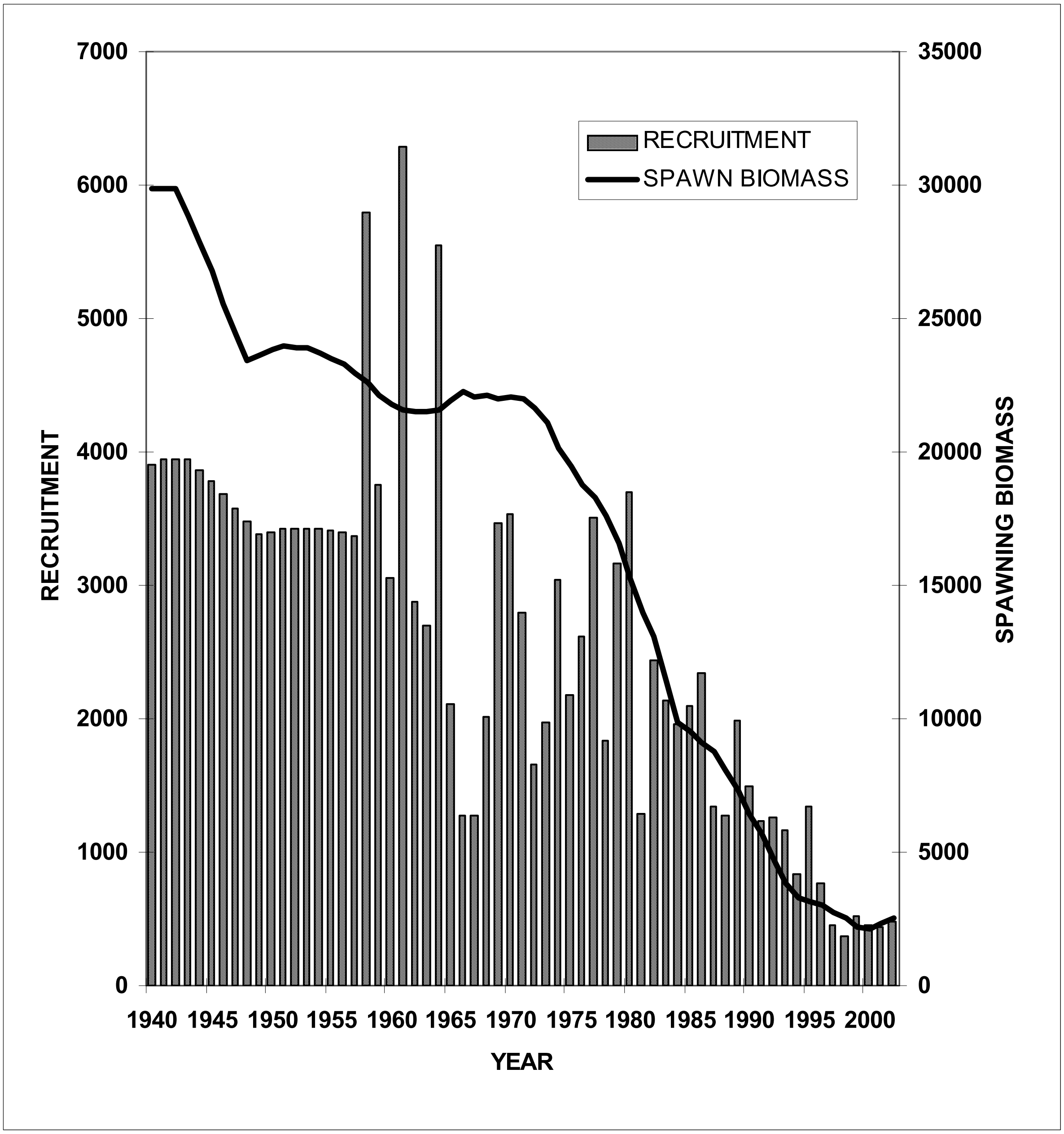

Figure 1 Time series of age 1 recruitment and female spawning biomass.

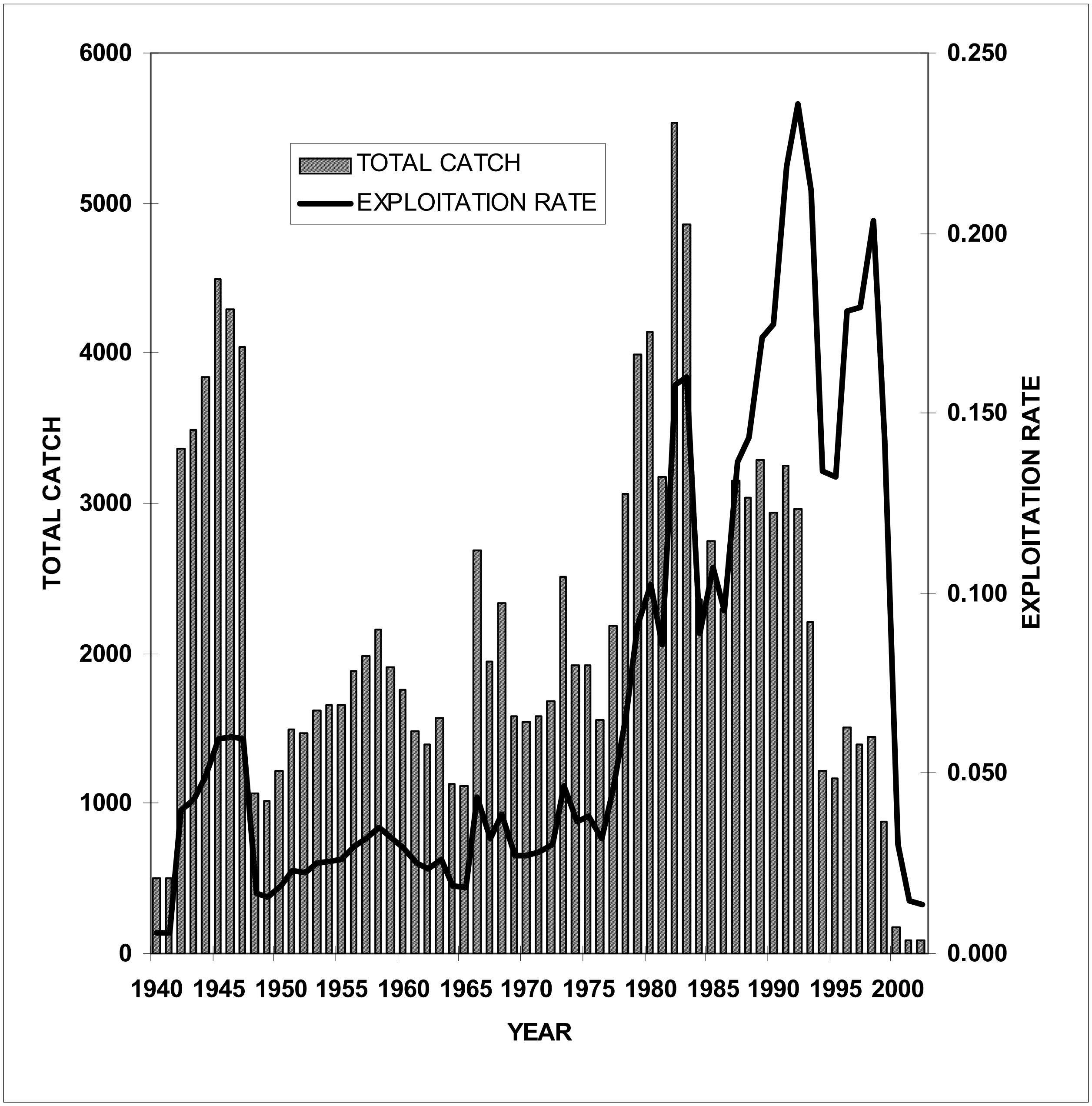

Figure 2 Time series of total catch and exploitation rate.

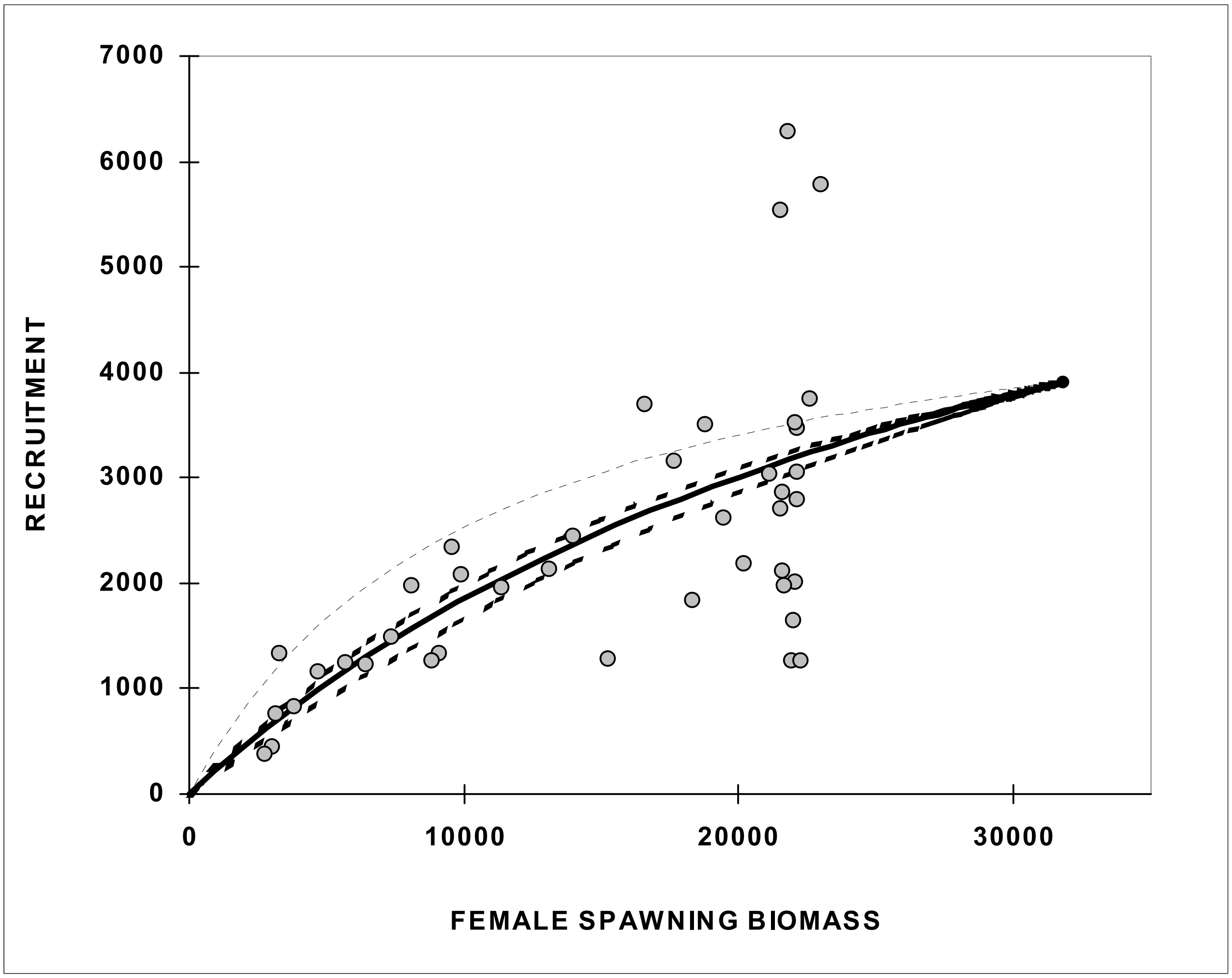

Figure 3 Recruitment-spawner relationship. Bold line is the best estimate of steepness (0.33). Bracketing dashed lines are steepness of 0.289 and 0.36. The light upper line has a steepness of 0.50 which is clips the upper edge of recent recruitments and is closer to the general rockfish steepness level estimated by Dorn (2000).

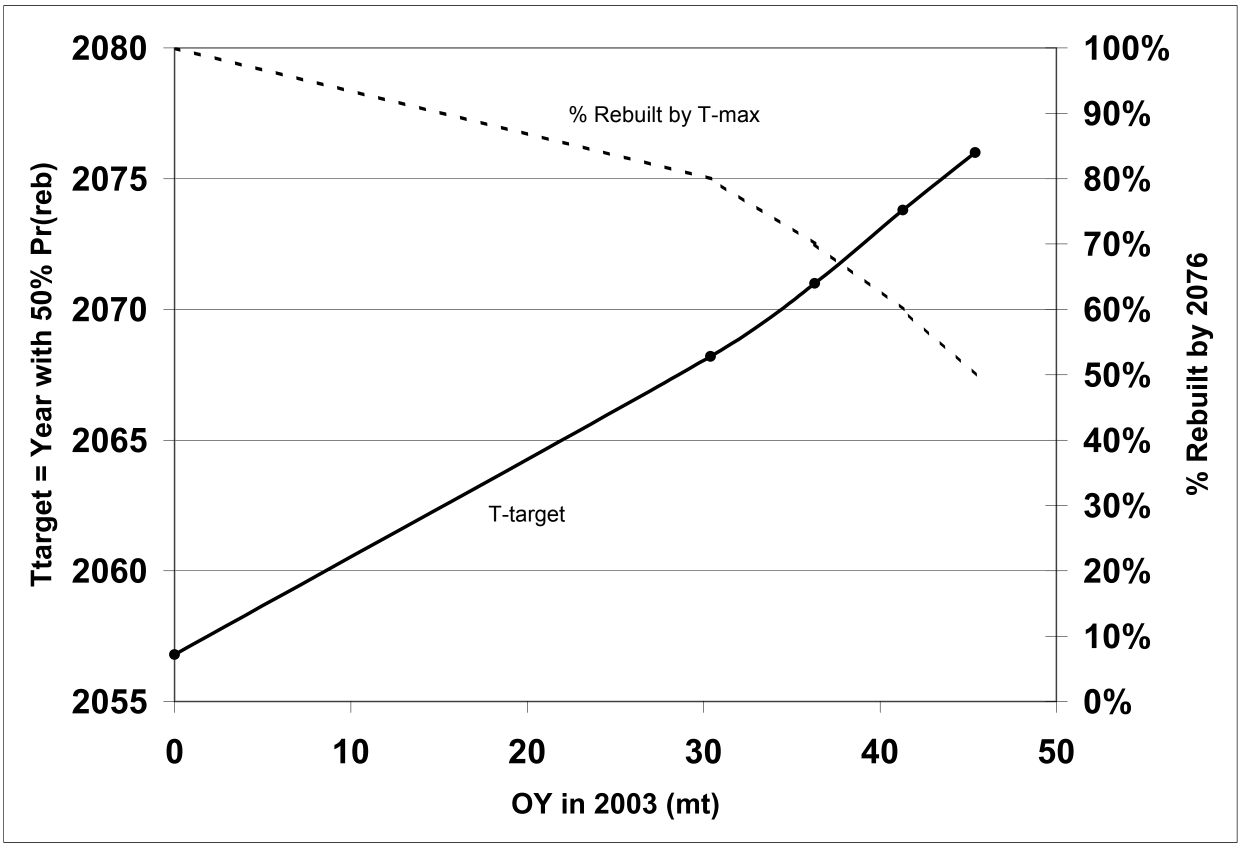

Figure 4 Trade-off between OY in 2003, the year (Ttarget) with 50% probability of achieving the rebuilt level, and the probability of achieving the rebuilt level before Tmax (2076). Each calculation is based upon a constant exploitation rate being applied throughout the rebuilding period.

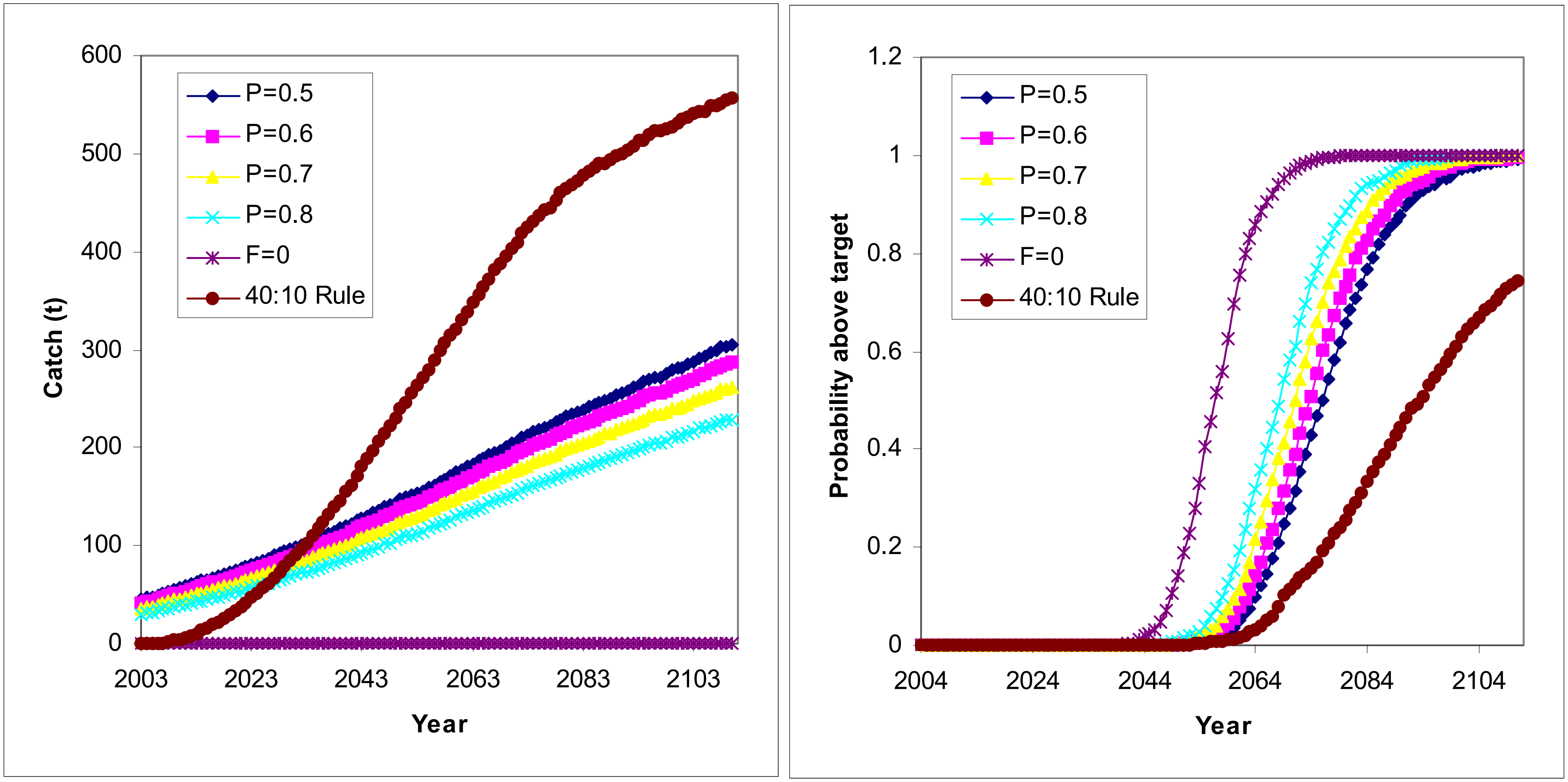

Figure 5. Time series of expected catch level and expected probability of achieving the rebuilt biomass level (40% of Bzero).

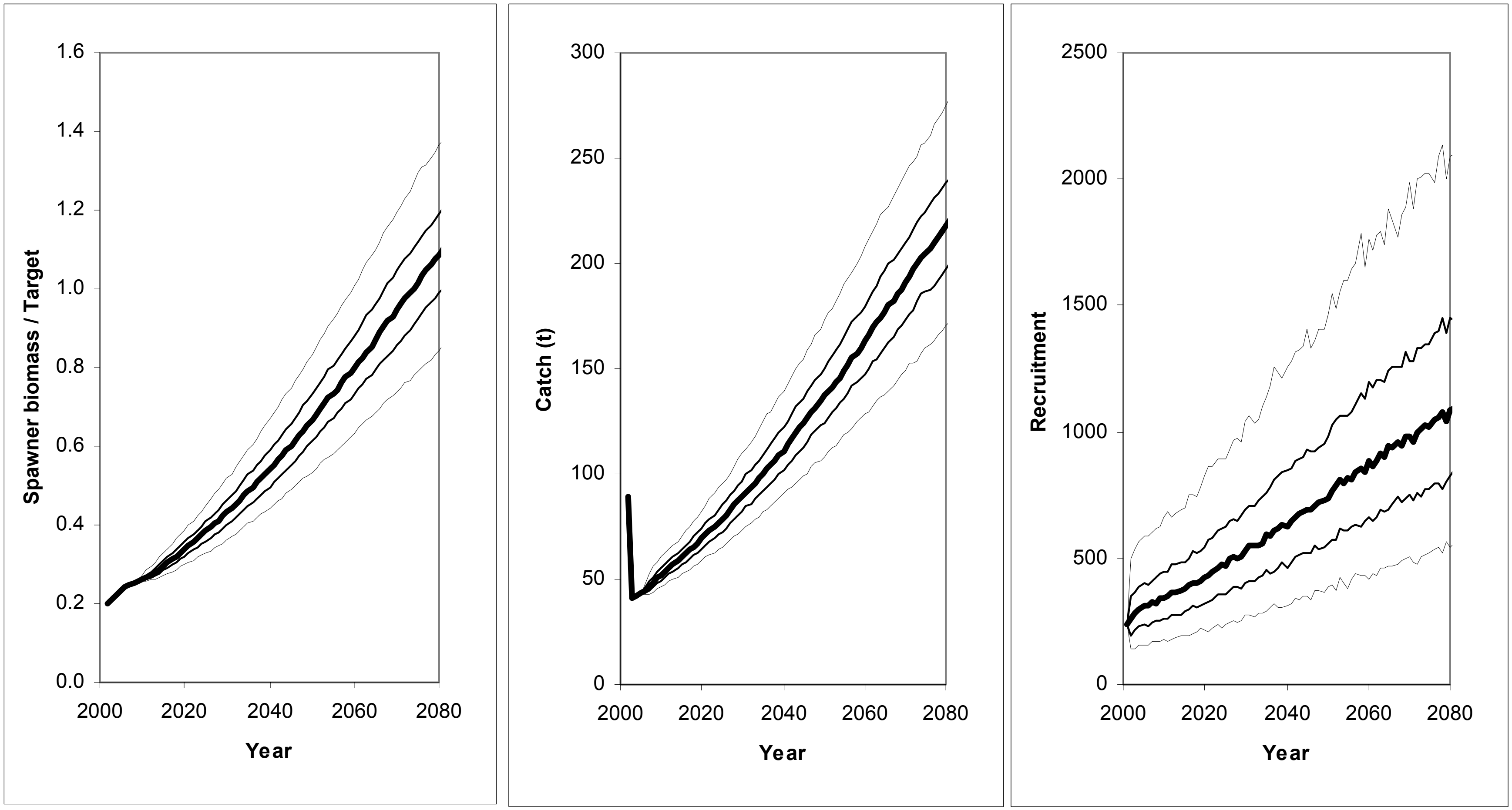

Figure 6. Time series of spawning biomass, catch and recruitment with probability of rebuilding by 2076 at 60%. The 5%, 25%, 50%, 75% and 95% percentiles are shown.

Appendix. Input file for rebuilding analysis.

```
#Title,
Canary rockfish - 50:50 comm:recr
# Number of sexes,
2,
# Age range to consider (minimum age; maximum age),
1,25
# First year of projection,
2002,
# Year declared overfished,
2000,
# Is the maximum age a plus-group (1=Yes;2=No),
1,
# Generate future recruit using: hist. recr (1); hist recr/spawn (2); or a stock-recruit (3),
3,
# Constant fishing mortality (1) or constant Catch (2) projections,
1,
# Pre-specify the year of recovery (or -1) to ignore,,,,,,,,,,,,,,,,,,,,,,,
-1,,,,,,,,,,,,,,,,,,,,,,,,
# FECUNDITY @ AGE,,,,,,,,,,,,,,,,,,,,,,,
# AGES    1   25,,,,,,,,,,,,,,,,,,,,,,,
0,0.00027,0.00371,0.02219,0.08128,0.21632,0.44051,0.73468,1.0571,1.3774,1.67588,1.94472,
2.18776,2.40143,2.59443,2.76175,2.9133,3.04797,3.16579,3.27028,3.36204,3.44522,3.51975,
3.58399,3.8844,
# AGE INFO: M,WT,SELEX,NUMBERS,,,,,,,,,,,,,,,,,,,,
# FEMALE,,,,,,,,,,,,,,,,,,,,,,,
    .06000,    .06000,    .06000,    .06001,    .06013,    .06097,    .06402,    .07037,
.07903,    .08804,    .09594,    .10201,    .10672,    .10999,    .11259,    .11425,
.11561,    .11664,    .11734,    .11787,    .11822,    .11857,    .11893,    .11910,
.11928,
    .04700,    .13300,    .26500,    .43500,    .63500,    .85500,   1.08500,   1.31900,
 1.55000,   1.77500,   1.98800,   2.19000,   2.37800,   2.55200,   2.71100,   2.85600,
  2.98800,   3.10700,   3.21400,   3.31000,   3.39600,   3.47300,   3.54100,
3.60200,   3.90000,
    .00026,    .00760,    .19323,    .97956,    .99727,    .57631,    .35398,    .27796,
.25278,    .24120,    .23283,    .22566,    .21951,    .21429,    .20992,    .20391,
.19868,    .19413,    .18210,    .17184,    .16358,    .15690,    .13934,    .12706,
.11833,
  238.35288,   204.98610,   201.08574,   212.96610,   136.79802,   140.27095,   208.92664,
318.68570,   167.58476,   199.88103,   173.39323,   126.20521,   104.82539,    95.38803,
43.40654,    32.73907,    39.54165,    22.86064,    13.47217,     9.44046,     7.20839,
2.67660,     5.62894,     3.65099,    45.27893,
```

MALE
.06000, .06000, .06000, .06000, .06000, .06000, .06000, .06000,
.06000, .06000, .06000, .06000, .06000, .06000, .06000, .06000,
.06000, .06000, .06000, .06000, .06000, .06000, .06000, .06000,
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1.45500, 1.62300, 1.77400, 1.90700, 2.02300, 2.12400, 2.21000, 2.28500,
2.34800, 2.40200, 2.44800, 2.48600, 2.51900, 2.54600, 2.56900,
2.58900, 2.70000,
.00020, .00748, .19307, .97977, 1.00000, .58666, .37252, .29673,
.26567, .24776, .23562, .22675, .21991, .21443, .20996, .20628,
.20326, .20077, .19874, .19708, .19572, .19463, .19374, .19302,
.19245,
238.35288, 204.98708, 201.08975, 212.98472, 136.82954, 140.32663, 209.07910,
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46.41686, 36.97260, 44.57084, 25.18530, 15.14766, 11.36878, 9.50305,
3.80037, 8.44462, 5.72975, 23.50413,
NUMBER OF SIMULATIONS,,,,,
1000,,,,
TIME SERIES,,,,,
NUMBER OF HISTORICAL YEARS + 2,,,,,
64,,,,,
YR, RECR, SPBIO,USE_IN_Bzero,USE_IN_R, USE_IN_R/S
#,,,,,
1900,3907,31782,1,0,0
1901,3907,29848,0,0,0
1941,3948,29848,0,0,0
1942,3948,29847,0,0,0
1943,3948,28852,0,0,0
1944,3867,27860,0,0,0
1945,3783,26792,0,0,0
1946,3691,25538,0,0,0
1947,3579,24417,0,0,0
1948,3476,23449,0,0,0
1949,3384,23626,0,0,0
1950,3401,23829,0,0,0
1951,3420,23941,0,0,0
1952,3431,23919,0,0,0
1953,3429,23871,0,0,0
1954,3424,23725,0,0,0
1955,3410,23525,0,0,0
1956,3391,23294,0,0,0
1957,3369,22960,0,0,0
1958,5788,22577,0,0,0
1959,3750,22134,0,0,0

1960,3058,21803,0,0,0
1961,6281,21561,0,0,0
1962,2871,21481,0,0,0
1963,2703,21521,0,0,0
1964,5547,21582,0,0,0
1965,2116,21895,0,0,0
1966,1275,22268,0,0,0
1967,1271,22060,0,0,0
1968,2007,22142,0,0,0
1969,3467,22015,0,0,0
1970,3530,22078,0,0,0
1971,2795,21982,0,0,0
1972,1653,21662,0,0,0
1973,1973,21124,0,0,0
1974,3035,20159,0,0,0
1975,2182,19455,0,0,0
1976,2618,18792,0,0,0
1977,3513,18314,0,0,0
1978,1833,17622,0,0,0
1979,3158,16596,0,0,0
1980,3701,15246,0,0,0
1981,1288,13968,0,0,0
1982,2443,13106,0,0,0
1983,2134,11340,0,0,0
1984,1962,9883,0,0,0
1985,2091,9543,0,0,0
1986,2341,9083,0,0,0
1987,1344,8788,0,0,0
1988,1275,8088,0,0,0
1989,1986,7355,0,0,0
1990,1488,6438,0,0,0
1991,1227,5667,0,0,0
1992,1255,4683,0,0,0
1993,1169,3831,0,0,0
1994,830,3254,0,0,0
1995,1342,3130,0,0,0
1996,766,3037,0,0,0
1997,449,2762,0,0,0
1998,374,2512,0,0,0
1999,516,2195,0,0,0
2000,454,2102,0,0,0
2001,435,2312,0,0,0
2002,477,2524,0,0,0

Number of years with pre-specified catches,,,,,
1,,,,,
catches for years with pre-specified catches,,,,,
2002,89,,,,
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,
0.330, 0.4
Target SPR rate (FMSY Proxy),
0.73
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
Conduct MacCall transition policy (1=Yes),
0,
Defintion of recovery (1=now only;2=now or before)
2
Produce the risk-reward plots (1=Yes)
0
Calculate coefficients of variation (1=Yes)
0
Number of replicates to use
1
First Random number seed
-89102