Rebuilding Analysis for Pacific Ocean Perch for 2003
(July 2003)

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1. Introduction

The Pacific Fishery Management Council (PFMC) adopted Amendment 11 to its Groundfish Management Plan in 1998. This amendment established a definition for an overfished stock of 25% of the unfished spawning biomass ($0.25B_0$). NMFS determined that a rebuilding plan was required for Pacific Ocean perch (*Sebastes alutus*) in March 1999 based on the most recent stock assessment at that time (Ianelli and Zimmerman, 1998). The PFMC began developing a rebuilding plan for Pacific Ocean perch (based upon a rebuilding analysis; August 1999; A. MacCall, pers. comm.) and submitted this plan to NMFS in February 2000. However, NMFS deferred adoption of the plan until the stock assessment was updated and reviewed, which was later that year (Ianelli *et al.*, 2000). Punt (2002) conducted a rebuilding analysis for Pacific Ocean perch based on the stock assessment conducted by Ianelli *et al*. (2000) that was consistent with the Terms of Reference for rebuilding analyses developed by the PFMC SSC (SSC, 2001). That rebuilding analysis is henceforth referred to as "the previous analysis".

The Pacific Ocean perch stock assessment has now been updated (Hamel *et al*., 2003). This assessment, similar to that of Ianelli *et al*. (2000), involves fitting an age-structured population dynamics model to catch, catch-rate, length-frequency, age-composition, and survey data. Ianelli *et al*. (2000) and Hamel *et al*. (2003) both present results based on maximum likelihood and Bayesian estimation frameworks. The rebuilding analysis conducted by Punt (2002) was based on the estimates corresponding to the maximum of the posterior density function (the MPD estimates) from Model 1c of Ianelli *et al*. (2000) because the STAR panel that evaluated the 2000 Pacific Ocean perch stock assessment selected this model variant as the "best assessment" (PFMC, 2000). In contrast, the STAR panel that evaluated the 2003 assessment of Pacific Ocean perch endorsed both the MPD estimates and the distributions for the model outputs that arose from the application of the MCMC algorithm to sample equally likely parameter vectors from the posterior distribution (PFMC, 2003).

This revision to the rebuilding analysis for Pacific Ocean perch involves a number of selections. Some of these selections are taken to be the same as those on which the rebuilding analysis conducted by Punt (2002) was based. In contrast, the outcomes from the Pacific Ocean perch STAR panel and the contents of Amendment 16 to the Groundfish FMP lead to the following new issues that require resolution (the selections on which the 2002 rebuilding analysis was based are listed in parenthesis):

a) Should be projections be based on the MPD estimates or the sample from the full Bayesian posterior (MPD estimates).
b) Should T_{max} (the maximum allowable rebuild period[3]) be re-estimated given that estimates of commercial selectivity-at-age and natural mortality have changed, or should T_{max} be fixed at the year, 2042, determined during the previous rebuilding analysis (T_{max} was estimated; there was no previous rebuilding analysis).

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[3] The maximum allowable rebuild period, T_{max}, is defined as ten years if the resource can be rebuilt to $0.4B_0$ in fewer than ten years or the minimum possible rebuild period, T_{min}, plus one mean generation.

c) Should the OY for 2004 be computed using a harvest strategy that is based on a pre-specified value for: (a) P_{max} (the probability of recovery to the proxy for B_{MSY} of $0.4B_0$ by T_{max}), (b) T_{target} (the year in which the probability of recovery to the proxy for B_{MSY} of $0.4B_0$ equals 0.5), or (c) the fishing mortality rate during the rebuilding period (P_{max} was pre-specified).
d) How should future recruitments be generated: (a) by resampling historical recruitments, (b) by resampling historical recruits / spawning output ratios, or (c) by generating recruitments from the fitted stock-recruitment relationship (resampling historical recruitments).

In the absence of explicit guidance on appropriate selections, an attempt has been made in this document to present results for a range of variants of the rebuilding analysis. The next section elaborates on the various specifications and identifies a set of rebuilding analyses to capture the factors outlined above. This section is followed by a section that outlines the results. The final section of this document lists detailed results for the Groundfish Management Team's preferred set of specifications.

2. Specifications

2.1 Selection of B_0

It is common (and indeed recommended by the SSC) to define B_0 in terms of the recruitment in the first years of the assessment period. However, this rebuilding analysis and that of Punt (2002) determines B_0 from the fitted stock-recruitment relationship because this seems inherently more consistent with the assumptions underlying the original stock assessment. The MPD estimate of B_0 is 39,198 units of spawning output[4] while the posterior median and 90% intervals for B_0 are 37,230 units of spawning output and (29,035; 47,393). These values for B_0 are substantially lower than that on which the previous rebuilding analysis was based (60,212 units of spawning output). The change to B_0 is due primarily to the revisions to the historical catches. The MPD estimate of the depletion of the spawning output of the start of 2003 is 0.254 while posterior median and 90% intervals are 0.277 (0.201; 0.384).

2.2 Generation of future recruitment

Recruitment in the assessment and projection models for Pacific Ocean perch relate to the abundance of animals aged 3 years. The assessment of Pacific Ocean perch by Ianelli *et al*. (2000) and Hamel *et al*. (2003) both include the assumption that, *apriori*, recruitment is related to spawning output according to a Beverton-Holt stock-recruitment relationship. The rebuilding analysis conducted by Punt (2002) ignored this relationship and instead based the projections on resampling historical recruitments from those for the years 1965-98. This approach was consistent with the then SSC practice.

Figure 1 plots the MPD estimates of recruitment and recruits / spawning output from the assessments conducted by Ianelli *et al*. (2000) and Hamel *et al*. (2003). The rationale for generating future recruitment by sampling historical recruitment for the previous rebuilding analysis was that 1965-98 was a period of relative stability in recruitment while the recruitment estimates for 1999 and 2000 were highly imprecise. In contrast to recruitment, recruits / spawning output showed an increasing trend over time. The situation is now slightly more complicated because there is no longer an obvious increasing trend in recruits / spawning output with time. One of the reasons for the change in results from the 2000 to the 2003 assessment is that the assumed variability of recruitment was increased from 0.76 to 1 and the recruitment residuals were assumed to temporally uncorrelated *apriori*. Although resampling historical recruitment (now from the years 1965-2001) forms the base-line for

[4] Spawning output is defined in terms of mt of mature females.

the analyses of this document, sensitivity is also explored to generating future recruitment by resampling recruits / spawning output and by using the fitted stock-recruitment relationship.

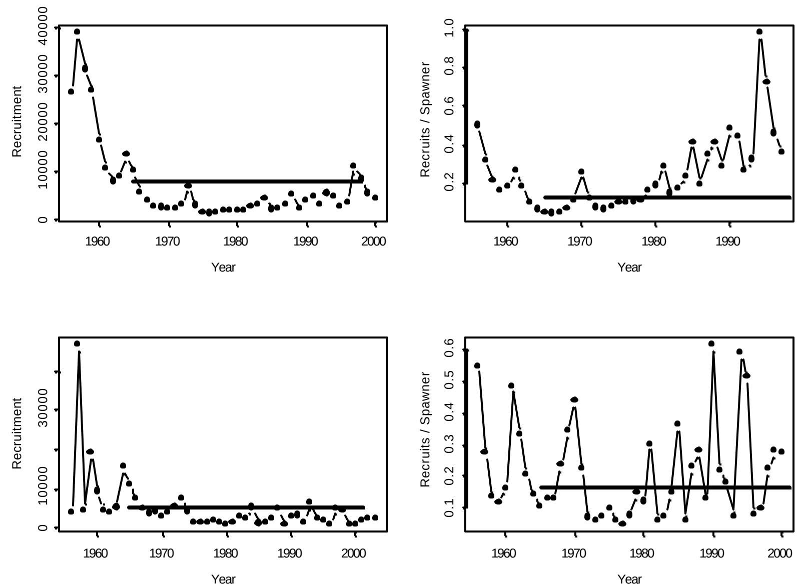

Figure 1 : Recruitment and recruits per spawner for assessments of Pacific Ocean perch conducted in 2000 and 2003 (upper and lower panels respectively). The horizontal line in the left panel indicates the recruitment corresponding to B_0 (the range of this line indicates the years used when generating future recruitment) and that in the right panel indicates the virgin recruits per spawner ratio.

2.3 Mean generation time

The mean generation time is defined as the mean age weighted by net spawning output (see Figure 2 for a plot of net spawning output *versus* age based on the MPD estimates). The estimate of natural mortality from the 2003 assessment is slightly higher than that from the 2000 assessment with the consequence that the "best estimate" of the mean generation time is now 29 / 28 years (MPD estimates / full posterior estimates) instead of 30 years.

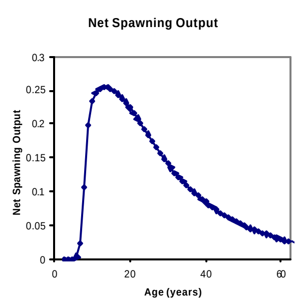

Figure 2 : MPD relationship between net spawning output and age for Pacific Ocean perch.

2.4 The harvest strategies

As noted in the introduction, there are many different ways to define the rebuilding harvest strategy. Table 1 summarizes those options considered in the analyses of this paper. The rebuild fishing mortality of 0.01025yr^{-1} is taken from the rebuild fishing mortality computed by Punt (2002) after accounting for the difference in selectivity at the reference age (age 10). Results are not shown for different choices for T_{target} because T_{target} and P_{max} are highly correlated. Results (OYs and probabilities of recovery) for different choices for T_{target} can be determined by interpolation.

Table 1: Harvest strategy options considered in this document.

Case	Future recruitment	T_{max}	$F_{rebuild}$	P_{max}
A	Recruits	2042	0.01025	Re-estimated
B	Recruits	2042	Re-estimated	0.5, 0.6, 0.7, 0.8, 0.9
C	Recruits	Re-estimated	Re-estimated	Re-estimated
D	Recruits / spawner	2042	0.01025	Re-estimated
E	Recruits / spawner	2042	Re-estimated	0.5, 0.6, 0.7, 0.8, 0.9
F	Recruits / spawner	Re-estimated	Re-estimated	Re-estimated
G	Beverton-Holt s-r	2042	0.01025	Re-estimated
H	Beverton-Holt s-r	2042	Re-estimated	0.5, 0.6, 0.7, 0.8, 0.9

The options in Table 1 explore the sensitivity of the results to the method used to generate future recruitment, how T_{max} is determined (re-estimated or fixed to the value selected in the previous rebuilding analysis) and to the harvest strategy (pre-specified rebuild fishing mortality or pre-specified probability of recovery to $0.4B_0$ by T_{max}).

2.5 Other specifications

The calculations of this document were performed using Version 2.7 of the rebuilding software developed by Punt (2003) and the results are based on 1,000 Monte Carlo replicates (analyses based on the MPD estimates) and 5,000 Monte Carlo replicates (analyses based on the random samples from the full Bayesian posterior distribution). The selection of 1,000 replicates is based on the evaluation of Monte Carlo precision conducted by Punt (2002). The analyses based on full posterior distribution involve 5 simulations for each of 1,000 samples for the posterior.

The definition of "recovery by year *y*" in this analysis is that the spawning output reaches $0.4B_0$ by year *y* (even if it subsequently drops below this level due to recruitment variability). Appendix 1 lists the MPD estimates for the biological and technological parameters and the age-structure of the population at the start of 2000 / 2003, while Appendix 2 lists the MPD time-series of recruitment and spawning output. The input to the rebuilding program for the 'Cases A/B' rebuilding analysis for the case in which the projections are based on the MPD estimates is given as Appendix 3. The catch for 2003 was set to 377t (the Council-selected *OY* for 2003).

3. Results

3.1 Time-to-recovery

Figure 3 shows the distribution for the number of years beyond the year 2000 that it would have taken to recover to $0.4B_0$ had there been no harvest since 2000 and future recruitment is generated by resampling historical recruitments (the base-case analysis). Results are shown for analyses based on the MPD estimates (left panel) and the full Bayesian posterior (right panel). As expected, the distribution based on the full Bayesian posterior has a much longer tail than that based on the MPD estimates. The median time to recover to $0.4\ B_0$ in the absence of catches with 50% probability is T_{min}. The values for T_{min} (17 and 14 years respectively for the MPD and full Bayesian results) are greater than the value of T_{min} from the previous rebuilding analysis (12 years). If T_{max} is determined using the new information on the biology and the age-structure of the population in 2000, it changes from 2042 to 2046 if the calculations are based on the MPD estimates but remains at 2042 if the calculations are based on the full Bayesian posterior distribution.

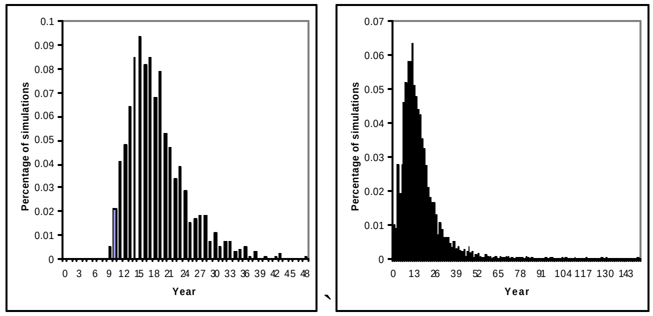

Figure 3 : Time to recover to $0.4B_0$ in the absence of catches from 2000 for the base-case analysis. The results based on the MPD estimates are shown in the left panel and those based on full Bayesian posterior in the right panel.

3.2 OYs and fishing mortalities

Tables 2 and 3 list some key output statistics for six rebuild strategies (probabilities of recovery in the maximum allowable rebuild period of 0.5, 0.6, 0.7, 0.8 and 0.9, the 40-10 rule, the ABC rule, and the strategy of setting fishing mortality from 2004 equal to $0.01025 yr^{-1}$). Table 2 lists results based on the MPD estimates. Results are shown in Table 2 for the base-case analysis of Punt (2002) as well as for each of the analysis options outlined in Table 1. Table 3 lists results based on the full Bayesian posterior; note that the results for cases A-C are listed together because if, as noted above, future recruitment is generated by resampling historical recruitments and T_{max} is re-estimated, the estimate of T_{max} equals the value (2042) calculated previously by Punt (2002). The probabilities of recovery in Tables 2 and 3 are not exactly 50, 60, etc. because of the limited number of recruitments on which the projections are based, and the accuracy of the numerical search procedure employed.

Table 2: Four management-related quantities for six rebuild strategies for the projections based on the MPD estimates.

Scenario / Quantity	Rebuild Strategy							
	P_{max}=0.5	P_{max}=0.6	P_{max}=0.7	P_{max}=0.8	P_{max}=0.9	40-10 rule	ABC rule	Fixed F
2002 Rebuilding analysis (T_{max}=2042)								
Fishing mortality rate	0.0107	0.0094	0.0079	0.0065	0.0046			
OY_{2002} (mt)	456.7	402.2	339.3	277.3	196.4	773.3	1384.7	
P_{max}	50	60.1	70.1	80	90.0	0.3	0.0	
T_{target}	2042	2031.7	2025.2	2019.7	2016.0	N/A	N/A	
Cases A / B (T_{max}=2042)								
Fishing mortality rate	0.0293	0.0259	0.0218	0.0181	0.0131			0.01025
OY_{2004} (mt)	448.7	396.9	334.7	278.8	202.2	449.3	840.5	158.1
P_{max}	50.0	60.0	69.9	80.1	90.0	12.2	2.0	93.9
T_{target}	2042.0	2036.6	2031.6	2028.6	2024.8	N/A	N/A	2023.3
Case C (T_{max}=2046)								
Fishing mortality rate	0.0313	0.0281	0.0245	0.0208	0.0163			0.01025
OY_{2004} (mt)	478.3	431.1	375.5	318.9	250.8	449.3	840.5	158.1
P_{max}	50.0	60.1	70.0	80.1	90.0	14.1	3.4	96.4
T_{target}	2046.0	2039.9	2034.9	2030.8	2027.2	N/A	N/A	2023.3
Cases D / E (T_{max}=2042)								
Fishing mortality rate	0.0106	0.0084	0.0061	0.0034	0			0.01025
OY_{2004} (mt)	162.9	129.3	94.9	52.9	0.1	449.3	840.5	158.1
P_{max}	50.1	60.1	69.9	80.1	88.2	0.0	0.0	51.6
T_{target}	2042.0	2038.5	2035.6	2032.4	2029.3	N/A	N/A	N/A
Case F (T_{max}=2057)								
Fishing mortality rate	0.0167	0.0146	0.0128	0.0102	0.0071			0.01025
OY_{2004} (mt)	256.4	225.6	197.1	157.2	109.4	449.3	840.5	158.1
P_{max}	50.0	60.1	70.0	80.1	90.0	0.1	0.0	79.9
T_{target}	2057.0	2050.9	2046.3	2041.4	2036.5	N/A	N/A	2041.5
Cases G / H (T_{max}=2042)								
Fishing mortality rate	0.0381	0.0326	0.0268	0.0218	0.0145			0.01025
OY_{2004} (mt)	581.4	498.9	410.2	334.5	222.6	449.3	840.5	158.1
P_{max}	49.9	60.1	69.9	80.0	89.9	40.4	21.5	95.5
T_{target}	2042.1	2035.8	2031.4	2028.2	2024.3	N/A	N/A	2022.8

Table 3: Four management-related quantities for six rebuild strategies for the projections based on the full posterior distribution.

Scenario / Quantity	Rebuild Strategy							
	P_{max}=0.5	P_{max}=0.6	P_{max}=0.7	P_{max}=0.8	P_{max}=0.9	40-10 rule	ABC rule	Fixed F
Cases A / B / C (T_{max}=2042)								
Fishing mortality rate	0.0387	0.0322	0.0257	0.0184	0.0094			0.01025
OY_{2004} (mt)	664.4	555.1	443.6	318.1	163.0	612.6	979.9	178.1
P_{max}	50.0	60.0	70.1	80.0	90.0	38.9	27.9	89.2
T_{target}	2042.0	2032.1	2026.4	2021.5	2017.6	N/A	N/A	2017.9
Cases D / E (T_{max}=2042)								
Fishing mortality rate	0.0182	0.0132	0.0082	0.0029	0			0.01025
OY_{2004} (mt)	315.5	228.9	142.7	51.1	0.1	612.6	979.9	178.1
P_{max}	50.0	60.0	69.9	80.0	84.7	14.8	10.8	65.9
T_{target}	2042.0	2033.3	2027.2	2023.0	2029.5	N/A	N/A	2029.5
Case F (T_{max}=2049)								
Fishing mortality rate	0.0207	0.0162	0.0116	0.0064	0.0001			0.01025
OY_{2004} (mt)	358.3	281.1	201.9	112.2	1.7	612.6	979.9	178.1
P_{max}	50.0	60.1	70.0	80.0	89.9	16.2	11.2	73.1
T_{target}	2049.0	2038.4	2031.2	2025.6	2021.2	N/A	N/A	2029.5
Cases G / H (T_{max}=2042)								
Fishing mortality rate	0.043	0.034	0.0248	0.0156	0.0043			0.01025
OY_{2004} (mt)	737.1	584.9	428.6	271	74.9	612.8	979.9	178.1
P_{max}	50.0	60.0	70.0	80.0	89.9	50.5	37.6	85.2
T_{target}	2042.0	2031.7	2025.3	2020.3	2016.5	2041.4	N/A	2018.5

4. Selection of a preferred variant

The Council interim choice for P_{max} is 70% (J. DeVore, PFMC, pers. commn). The range for the 2004 OY in Tables 2 and 3 for this choice for P_{max} is 95t – 444t. The results for a fixed rebuild fishing mortality of 0.01025yr^{-1} should be interpreted with some caution because the commercial selectivity pattern on which the projections are based from the 2003 assessment differs notably from that based on the 2000 assessment (Figure 4).

The Groundfish Management Team (GMT) selected four of the cases in Table 2 and 3 for further examination. These four cases differ in terms of the parameters on which the projections are based (MPD estimates or Bayesian posterior values) and whether future recruitment is generated by resampling historical recruitments or historical recruits / spawning output ratios (i.e. cases C and F in Tables 2 and 3). All four cases involve re-estimating T_{max} rather than fixing it equal to 2042.

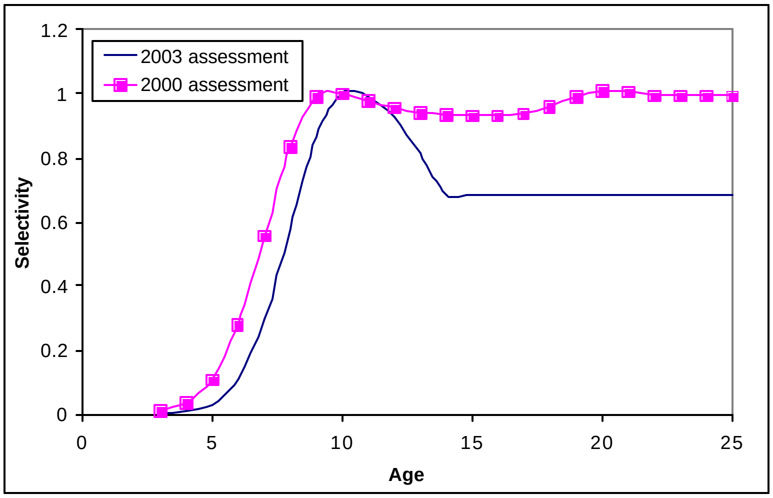

Figure 4 : The selectivity patterns on which (a) the projections of the present paper are based (2003 assessment) and (b) the projections of Punt (2002) were based (2000 assessment).

Figures 5 and 6 contrast the time-trajectory of the probability of recovery for the eight rebuild strategies for the four “preferred variants”, along with the envelopes (5%, 25%, 50%, 75% and 95%) of the time-trajectories for catch and the ratio of spawning output to $0.4B_0$.

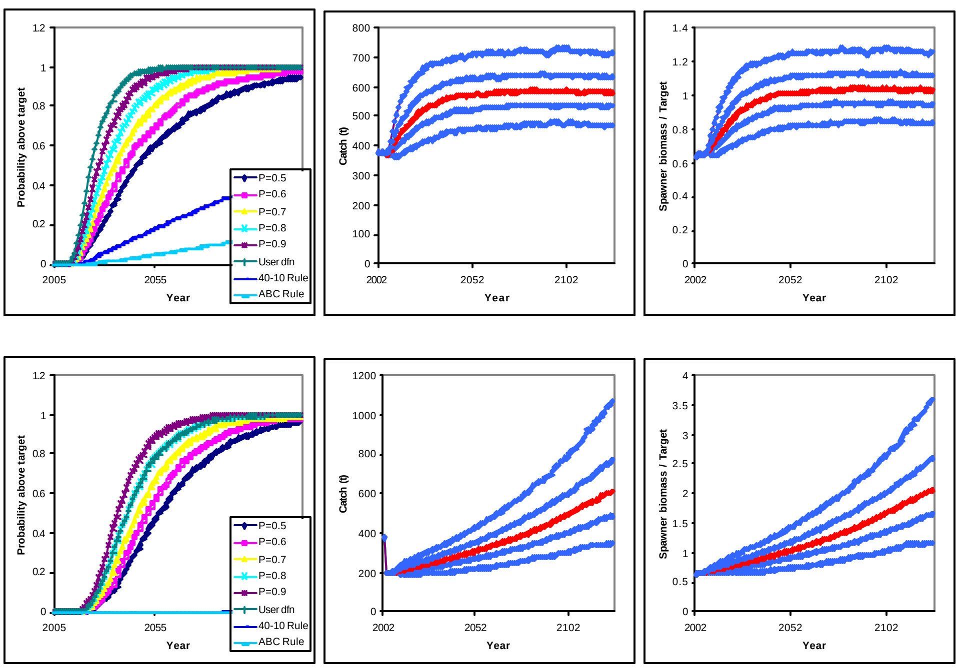

Figure 5 : Time trajectories of the probability of recovery for eight rebuild strategies, of the catch for a 0.7 probability of recovery, and of the spawning output expressed relative to $0.4B_0$ for a 0.7 probability of recovery. The upper panels pertain to the projections based on generating future recruitment by resampling from the historical recruitments and the lower panels pertain to the projections based on generating future recruitment by resampling historical recruits / spawning output ratios. The results in this figure are based on the MPD estimates of the model parameters

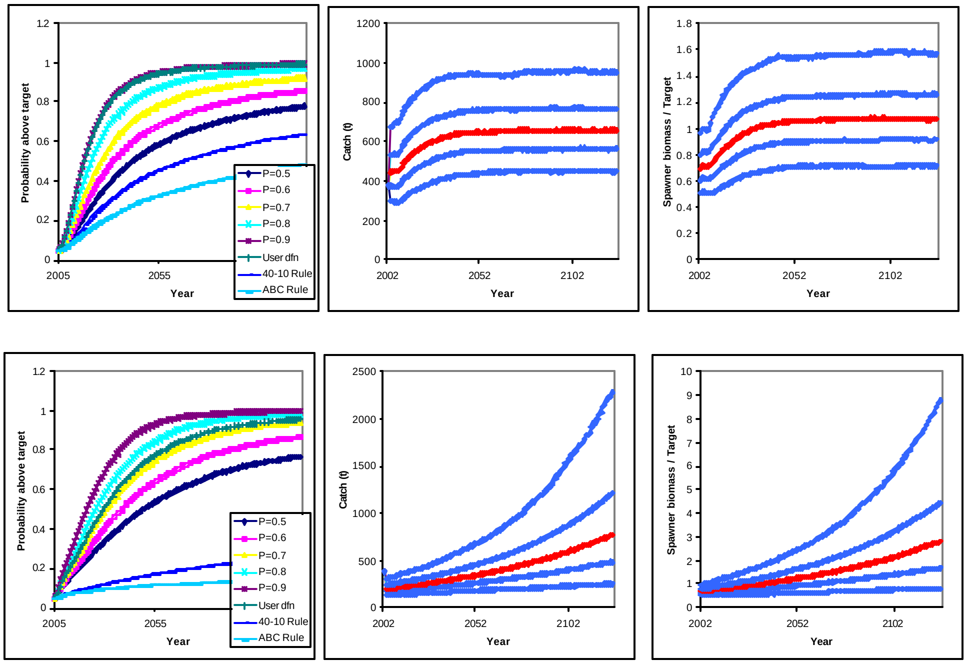

Figure 6 : Time trajectories of the probability of recovery for eight rebuild strategies, of the catch for a 0.7 probability of recovery, and of the spawning output expressed relative to $0.4B_0$ for a 0.7 probability of recovery. The upper panels pertain to the projections based on generating future recruitment by resampling from the historical recruitments and the lower panels pertain to the projections based on generating future recruitment by resampling historical recruits / spawning output ratios. The results in this figure are based on 1,000 parameters vectors sampled from the posterior distribution.

Appendix 4 lists the envelopes for the annual catch and the ratio of the spawning output to the target level for a 0.7 probability of rebuild. Note that this ratio is calculated each point in time – the probability of having reached $0.4B_0$ sometime before a given year is at least as great as that listed in Appendix 4 and shown in the right panels of Figures 5 and 6 for that year. Appendix 5 lists the annual catches (2003+) for six of the eight harvest strategies in Tables 2 and 3 as well as for a harvest strategy for there is a 50% probability of rebuild by T_{mid} (the average of T_{min} and T_{max}) for each of the four "preferred variants".

The GMT requested that the STAT team evaluate the consequences of catches of 200t and 400t over the next ten years (2004-2013). Table 4 therefore lists the value of the ratio of the spawning output at the start of 2014 to the target spawning output for three harvest regimes (constant fishing mortality equal to that needed to achieve of 0.7 probability of recovery by T_{max}, a constant catch of 200t and a constant catch of 400t) for each of the four "preferred variants.

Table 4: Spawning output at the start of 2014 expressed relative to the target spawning output (median and 90% intervals) for three harvest regimes and four cases.

Case	Constant fishing mortality (P_{max}=0.7)			Constant 200*t* catch			Constant 400*t* catch		
MPD estimates									
C	0.651	0.753	0.905	0.699	0.808	0.972	0.642	0.750	0.914
F	0.654	0.722	0.819	0.653	0.723	0.824	0.596	0.665	0.766
Bayesian outputs									
C	0.554	0.825	1.230	0.604	0.908	1.361	0.552	0.847	1.292
F	0.541	0.810	1.241	0.534	0.814	1.263	0.481	0.754	1.189

References

Hamel, O.S., Stewart, I.J. and A.E. Punt. 2003. Status and future prospects for the Pacific Ocean Perch resource in waters off Washington and Oregon as assessed in 2003.

Ianelli, J.N., Wilkins, M. and S. Harley. 2000. Status and future prospects for the Pacific Ocean Perch resource in waters off Washington and Oregon as assessed in 2000. In: Appendix to "Status of the Pacific coast groundfish fishery through 2000 and recommended Acceptable Biological Catches for 2001". Stock Assessment and Fishery Evaluation. Pacific Fishery Management Council, Portland, OR.

Ianelli, J.N. and M. Zimmerman. 1998. Status and future prospects for the Pacific Ocean perch resource in waters off Washington and Oregon as assessed in 1998. In: "Status of the Pacific coast groundfish fishery through 1998 and recommended Acceptable Biological Catches for 1999". Stock Assessment and Fishery Evaluation. Pacific Fishery Management Council, Portland, OR.

Pacific Fishery Management Council. 2000. Pacific Ocean Perch STAR Panel Report. In "Status of the Pacific Coast Groundfish Fishery Through 2000 and Recommended Biological Catches for 2001: Stock Assessment and Fishery Evaluation". (Document prepared for the Council and its advisory entities) Pacific Fishery Management Council, Portland, OR.

Pacific Fishery Management Council. 2003. Pacific Ocean Perch STAR Panel Report.

Punt, A.E. 2002. Revised Rebuilding Analysis for Pacific Ocean Perch (July 2002). Pacific Fishery Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR.

Punt, A.E. 2003. SSC default rebuilding analysis. Technical specifications and user manual. Ver. 2.7. (Draft document, available from author).

Scientific and Statistical Committee (SSC). 2001. SSC terms of reference for groundfish rebuilding analysis. Pacific Fishery Management Council, Portland, Oregon.

Appendix 1 : Biological and technological parameters used for the rebuilding analyses based on the MPD estimates.

Age	Fecundity	Weight (kg)	Selectivity	*N* (2000)	*N* (2003)
3	0.000	0.169	0.002	800	2464
4	0.000	0.241	0.008	636	2337
5	0.000	0.317	0.032	3846	1700
6	0.004	0.396	0.110	4316	682
7	0.028	0.474	0.298	528	541
8	0.137	0.550	0.580	1240	3259
9	0.274	0.622	0.868	1490	3623
10	0.339	0.690	1.000	3950	437
11	0.375	0.752	0.991	770	1015
12	0.404	0.809	0.928	1556	1212
13	0.431	0.861	0.815	1160	3212
14	0.454	0.908	0.687	288	628
15	0.475	0.950	0.687	1649	1276
16	0.494	0.987	0.687	657	956
17	0.510	1.021	0.687	331	238
18	0.525	1.050	0.687	255	1360
19	0.538	1.076	0.687	1165	542
20	0.550	1.099	0.687	442	273
21	0.560	1.119	0.687	500	210
22	0.569	1.137	0.687	234	961
23	0.576	1.153	0.687	125	364
24	0.583	1.166	0.687	143	413
25+	0.589	1.178	0.687	4291	3954

Appendix 2 : MPD historical series of spawning output and recruitment.

Year	Recruitment (age 3)	Spawning output
1956	3898	35119
1957	46839	33896
1958	4409	32733
1959	19185	32215
1960	9260	31789
1961	4415	31817
1962	3821	33501
1963	5197	35107
1964	15426	34744
1965	11164	34427
1966	7295	31909
1967	4954	23135
1968	3643	17328
1969	4141	15549
1970	2982	17377
1971	4071	18321
1972	5329	18779
1973	7584	18995
1974	4095	18695
1975	1329	18446
1976	1149	18501
1977	1376	18459
1978	1806	18847
1979	1123	18680
1980	875	18097
1981	1454	17154
1982	2762	16238
1983	2185	15567
1984	5176	14384
1985	1017	13285
1986	1189	12317
1987	2132	11581
1988	4795	11166
1989	745	10762
1990	2646	10283
1991	3133	9813
1992	1376	9190
1993	6303	8965
1994	2149	8629
1995	1648	8342
1996	656	8259
1997	5065	8218
1998	4275	8468
1999	670	8776
2000	800	8872
2001	1889	9052
2002	2464	9372
2003	2464	9946

Appendix 3 : The input file for the base-case rebuilding analysis (MPD estimates)

#Title
POP - STAR panel model
Number of sexes
1
Age range to consider (minimum age; maximum age)
3 25
Number of fleets
1
First year of projection
2003
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)
1
Constant fishing mortality (1) or constant Catch (2) projections
1
Pre-specify the year of recovery (or -1) to ignore
38
Fecundity-at-age
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
3.84E-06 4.03E-05 0.000392248 0.003560962 0.028260766 0.1374925 0.273954602 0.338584679 0.375081501 0.404469053 0.430553194
0.453991276 0.4749965 0.493739 0.510395 0.52515 0.53818 0.549655 0.559745 0.568595 0.576345 0.58313 0.589055
Age specific information (Females then males) weight selectivity
#
0.169105 0.240603 0.317273 0.395966 0.474162 0.54997 0.62206 0.689572 0.752022 0.80921 0.861146 0.907988 0.949993 0.987478 1.02079 1.0503
1.07636 1.09931 1.11949 1.13719 1.15269 1.16626 1.17811
0.002154 0.008375 0.032416 0.110330 0.297810 0.579697 0.868444 1.000000 0.990673 0.927875 0.814533 0.686966 0.686966 0.686966 0.686966
0.686966 0.686966 0.686966 0.686966 0.686966 0.686966 0.686966 0.686966
M and initial age-structure
#
0.0526361 0.0526361 0.0526361 0.0526361 0.0526361 0.0526361 0.0526361 0.0526361 0.0526361 0.0526361 0.0526361 0.0526361 0.0526361
0.0526361 0.0526361 0.0526361 0.0526361 0.0526361 0.0526361 0.0526361 0.0526361 0.0526361 0.0526361
2463.69 2337.28 1699.75 682.296 541.265 3259.45 3622.79 437.317 1015.29 1211.88 3212.1 628.309 1276.09 955.836 237.811 1360.39 542.225
272.914 210.123 960.879 364.385 412.502 3954.24
Initial age-structure
799.597 635.505 3846.28 4316.28 527.898 1240.19 1489.59 3949.7 770.03 1555.66 1160.42 288.259 1648.98 657.25 330.808 254.698 1164.71
441.684 500.008 233.711 125.105 143.106 4291.15
Year for Tmin Age-structure
2000
Number of simulations
1000
recruitment and biomass
Number of historical assessment years
49
Historical data
year recruitment spawner in B0 in R project in R/S project
1955 5279.19 39291.2 1 0 0
1956 3897.88 35118.8 0 0 0
1957 46838.90 33895.8 0 0 0
1958 4409.30 32733.1 0 0 0
1959 19184.60 32215.0 0 0 1
1960 9260.10 31789.3 0 0 1
1961 4415.37 31816.8 0 0 1
1962 3820.53 33500.9 0 0 1
1963 5196.77 35106.9 0 0 1
1964 15426.00 34744.3 0 0 1
1965 11164.10 34427.2 0 1 1
1966 7294.69 31908.9 0 1 1
1967 4953.68 23135.0 0 1 1
1968 3642.96 17328.3 0 1 1
1969 4140.89 15549.4 0 1 1
1970 2981.68 17377.4 0 1 1
1971 4071.25 18321.4 0 1 1
1972 5329.40 18778.6 0 1 1
1973 7583.54 18994.9 0 1 1
1974 4095.29 18695.3 0 1 1
1975 1329.08 18445.7 0 1 1
1976 1148.89 18500.8 0 1 1

```
1977  1376.37 18459.0 0 1 1
1978  1806.22 18847.0 0 1 1
1979  1122.56 18680.1 0 1 1
1980   875.23 18096.5 0 1 1
1981  1453.82 17154.3 0 1 1
1982  2761.61 16237.8 0 1 1
1983  2184.85 15566.5 0 1 1
1984  5175.53 14384.4 0 1 1
1985  1016.60 13284.5 0 1 1
1986  1189.49 12317.3 0 1 1
1987  2131.66 11580.9 0 1 1
1988  4795.20 11165.8 0 1 1
1989   744.88 10761.7 0 1 1
1990  2645.72 10282.6 0 1 1
1991  3133.39  9812.9 0 1 1
1992  1375.93  9190.4 0 1 1
1993  6303.47  8964.7 0 1 1
1994  2148.51  8628.6 0 1 1
1995  1647.70  8341.7 0 1 1
1996   656.19  8258.9 0 1 1
1997  5064.59  8218.2 0 1 1
1998  4275.34  8468.3 0 1 1
1999   669.92  8775.7 0 1 1
2000   799.60  8872.3 0 1 1
2001  1888.79  9051.8 0 1 1
2002  2463.69  9371.7 0 0 0
2003  2463.69  9945.9 0 0 0
# Number of years with pre-specified catches
1
# catches for years with pre-specified catches
2003 377
# 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.)
3
# Steepness sigma-R Auto-correlation
0.531877 1.00 0.00
# 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 (2)
1
# Produce the risk-reward plots (1=Yes)
0
# Calculate coefficients of variation (1=Yes)
0
# Number of replicates to use
20
# Random number seed
-89102
# Conduct projections for multiple starting values (0=No;else yes)
0
# File with multiple parameter vectors
MCMC.POP
# Number of parameter vectors
1000
```

User-specific projection (1=Yes); Output replaced (1->6)
1 7 0 0.3
Catches and Fs (Year; 1/2 (F or C); value); Final row is -1
2004 1 0.01025
-1 -1 -1
Split of Fs
2003 1
-1 1

Appendix 4 : The envelopes (5%, 25%, 50%, 75% and 95% distribution points) for the annual catch and the annual ratio of the spawner output to $0.4B_0$ for a 0.7 probability of recovery.

(a) Projections based on the MPD estimates; Future recruitment = recruits

Year	Spawner output / $0.4B_0$					Annual catch (t)				
	5%	25%	50%	75%	95%	5%	25%	50%	75%	95%
2003	0.6343	0.6343	0.6343	0.6343	0.6343	377.0	377.0	377.0	377.0	377.0
2004	0.6509	0.6509	0.6509	0.6509	0.6509	375.5	375.5	375.5	375.6	375.6
2005	0.6486	0.6486	0.6486	0.6486	0.6486	375.8	375.8	375.9	376.0	376.1
2006	0.6458	0.6458	0.6458	0.6459	0.6459	373.0	373.2	373.5	373.9	374.6
2007	0.6497	0.6498	0.6501	0.6505	0.6511	370.7	371.5	372.6	374.5	377.2
2008	0.6560	0.6571	0.6587	0.6619	0.6661	366.6	369.5	373.0	378.5	387.4
2009	0.6554	0.6614	0.6692	0.6834	0.7036	365.4	372.4	381.7	393.1	413.9
2010	0.6497	0.6654	0.6854	0.7096	0.7571	365.3	380.0	395.7	414.6	450.9
2011	0.6445	0.6752	0.7035	0.7368	0.7993	363.9	388.3	409.0	435.7	483.2
2012	0.6449	0.6860	0.7195	0.7630	0.8377	363.6	395.2	420.6	453.6	507.1
2013	0.6461	0.6966	0.7382	0.7871	0.8678	363.5	401.1	431.7	467.7	531.3
2014	0.6510	0.7074	0.7527	0.8094	0.9048	367.9	408.0	440.5	480.2	551.1
2015	0.6589	0.7206	0.7675	0.8268	0.9350	373.6	413.6	449.4	488.9	564.6
2016	0.6645	0.7302	0.7829	0.8460	0.9597	378.4	420.4	455.6	497.5	573.4
2017	0.6724	0.7400	0.7963	0.8656	0.9873	382.1	427.7	462.0	505.6	586.6
2018	0.6802	0.7526	0.8068	0.8844	1.0101	388.0	433.3	468.6	516.7	597.6
2019	0.6906	0.7640	0.8238	0.9014	1.0276	390.8	437.9	478.7	528.3	605.3
2020	0.6952	0.7738	0.8414	0.9191	1.0478	391.9	445.3	486.0	536.3	619.1
2021	0.6993	0.7877	0.8512	0.9340	1.0692	394.6	451.2	491.5	542.7	623.0
2022	0.7015	0.7967	0.8644	0.9526	1.0886	398.7	456.4	499.4	548.7	633.0
2023	0.7055	0.8076	0.8781	0.9635	1.1026	402.5	459.6	506.7	556.2	637.2
2024	0.7149	0.8140	0.8912	0.9745	1.1111	404.2	463.7	513.4	563.9	643.4
2025	0.7213	0.8226	0.9013	0.9887	1.1302	407.2	467.4	515.3	570.6	647.1
2026	0.7272	0.8272	0.9081	1.0020	1.1443	412.6	473.9	519.5	575.0	661.8
2027	0.7345	0.8340	0.9159	1.0112	1.1513	415.9	476.3	522.5	578.5	663.8
2028	0.7385	0.8407	0.9212	1.0122	1.1601	417.5	478.6	527.1	580.7	669.8
2029	0.7410	0.8439	0.9326	1.0205	1.1756	419.9	479.5	533.1	583.5	674.7
2030	0.7482	0.8523	0.9404	1.0277	1.1801	421.8	483.1	536.1	586.2	677.7
2031	0.7525	0.8567	0.9451	1.0306	1.1828	420.7	487.0	537.9	591.0	675.9
2032	0.7520	0.8629	0.9474	1.0392	1.1833	425.0	493.4	539.0	594.9	681.1
2033	0.7543	0.8688	0.9547	1.0473	1.1869	428.7	495.3	542.4	598.3	678.3
2034	0.7627	0.8766	0.9597	1.0540	1.1855	432.2	498.4	546.7	602.0	678.1
2035	0.7696	0.8806	0.9656	1.0570	1.1886	438.2	498.7	548.9	603.2	680.2
2036	0.7764	0.8837	0.9700	1.0633	1.1943	443.5	502.3	553.7	607.0	685.1
2037	0.7838	0.8881	0.9766	1.0675	1.2035	440.1	502.7	553.8	611.0	686.6
2038	0.7841	0.8916	0.9766	1.0776	1.2055	442.2	506.5	558.8	612.8	686.5
2039	0.7893	0.8931	0.9815	1.0791	1.2088	445.9	507.2	559.5	613.3	692.5
2040	0.7892	0.8982	0.9910	1.0803	1.2124	450.9	511.2	561.9	614.4	693.7
2041	0.7965	0.9063	0.9951	1.0834	1.2178	448.5	513.6	564.4	618.6	690.4
2042	0.7984	0.9107	0.9985	1.0874	1.2150	450.4	516.0	564.6	619.0	698.9
2043	0.7991	0.9150	1.0013	1.0864	1.2246	447.2	520.9	565.9	619.9	698.1
2044	0.7949	0.9220	1.0044	1.0903	1.2259	448.3	519.5	569.9	622.0	696.7
2045	0.7972	0.9214	1.0088	1.0938	1.2297	454.1	521.1	571.3	621.1	699.7
2046	0.8060	0.9216	1.0087	1.0937	1.2340	454.7	520.8	571.2	620.9	702.8
2047	0.8059	0.9259	1.0112	1.0969	1.2351	453.7	520.1	572.2	623.0	703.7

2048	0.8067	0.9244	1.0101	1.0997	1.2308	453.9	521.0	570.1	626.2	695.6
2050	0.8120	0.9208	1.0101	1.1077	1.2366	458.8	518.4	571.4	628.8	706.9

(b) Projections based on the MPD estimates; Future recruitment = recruits / spawner

Year	Spawner output / $0.4B_0$					Annual catch (t)				
	5%	25%	50%	75%	95%	5%	25%	50%	75%	95%
2003	0.6343	0.6343	0.6343	0.6343	0.6343	377.0	377.0	377.0	377.0	377.0
2004	0.6509	0.6509	0.6509	0.6509	0.6509	197.1	197.1	197.1	197.1	197.1
2005	0.6543	0.6543	0.6543	0.6543	0.6543	198.9	199.0	199.0	199.0	199.1
2006	0.6571	0.6571	0.6571	0.6572	0.6572	199.1	199.2	199.2	199.4	199.7
2007	0.6664	0.6665	0.6666	0.6668	0.6673	199.2	199.5	199.8	200.3	201.5
2008	0.6775	0.6781	0.6790	0.6806	0.6845	197.9	198.7	199.8	201.3	204.8
2009	0.6800	0.6834	0.6877	0.6955	0.7125	197.3	199.4	202.0	205.5	212.5
2010	0.6734	0.6823	0.6928	0.7085	0.7369	196.5	200.6	205.5	212.5	223.0
2011	0.6657	0.6814	0.6989	0.7239	0.7570	194.1	200.7	207.6	218.2	231.5
2012	0.6615	0.6824	0.7053	0.7376	0.7791	191.0	200.2	208.9	222.1	238.6
2013	0.6566	0.6844	0.7133	0.7493	0.8008	189.0	200.0	211.1	225.4	243.6
2014	0.6544	0.6873	0.7215	0.7624	0.8186	188.1	200.9	213.5	228.1	249.5
2015	0.6517	0.6912	0.7308	0.7714	0.8346	188.2	202.7	216.1	230.5	253.8
2016	0.6520	0.6957	0.7357	0.7805	0.8458	188.0	204.2	218.3	233.7	257.1
2017	0.6496	0.7024	0.7421	0.7892	0.8633	188.8	206.4	220.0	236.0	261.4
2018	0.6526	0.7056	0.7495	0.7978	0.8739	190.2	207.9	222.3	239.4	265.3
2019	0.6526	0.7110	0.7569	0.8107	0.8901	190.1	210.4	224.5	243.8	270.8
2020	0.6496	0.7175	0.7657	0.8246	0.9125	189.5	211.1	227.1	246.9	275.6
2021	0.6468	0.7198	0.7733	0.8340	0.9273	190.0	212.4	228.9	249.8	281.1
2022	0.6521	0.7233	0.7803	0.8470	0.9454	191.3	213.7	231.8	252.9	284.1
2023	0.6584	0.7288	0.7864	0.8545	0.9550	192.4	215.2	234.1	256.3	287.3
2024	0.6610	0.7317	0.7957	0.8659	0.9745	193.1	215.5	237.7	259.0	294.1
2025	0.6602	0.7359	0.8033	0.8774	0.9956	193.6	217.1	238.5	260.7	297.9
2026	0.6633	0.7398	0.8097	0.8828	1.0025	194.2	219.0	241.5	264.0	301.8
2027	0.6652	0.7472	0.8202	0.8915	1.0183	194.9	221.2	242.8	266.4	306.5
2028	0.6674	0.7508	0.8267	0.9021	1.0439	193.8	222.5	244.8	269.7	312.2
2029	0.6686	0.7571	0.8311	0.9141	1.0585	195.2	224.0	247.2	273.7	319.3
2030	0.6707	0.7650	0.8404	0.9282	1.0693	196.9	225.6	249.7	276.1	319.7
2031	0.6756	0.7694	0.8498	0.9334	1.0859	195.9	226.8	251.9	278.5	324.2
2032	0.6713	0.7758	0.8572	0.9428	1.1018	196.3	228.7	254.0	281.6	326.0
2033	0.6707	0.7798	0.8656	0.9571	1.1094	197.1	230.4	256.4	285.1	332.9
2034	0.6708	0.7870	0.8701	0.9708	1.1172	197.8	232.0	258.5	290.4	336.6
2035	0.6646	0.7925	0.8803	0.9845	1.1351	196.0	234.2	261.1	293.0	341.6
2036	0.6667	0.7967	0.8905	0.9980	1.1505	196.4	235.1	264.8	297.6	344.4
2037	0.6740	0.8031	0.9019	1.0080	1.1692	198.3	237.4	266.3	300.6	349.8
2038	0.6791	0.8119	0.9080	1.0159	1.1826	198.5	239.6	268.4	303.3	355.1
2039	0.6808	0.8152	0.9120	1.0287	1.1987	200.3	241.9	271.1	305.9	358.5
2040	0.6880	0.8231	0.9193	1.0394	1.2175	202.4	244.7	274.3	308.8	365.4
2041	0.6934	0.8368	0.9280	1.0469	1.2405	203.9	246.6	276.2	310.5	370.4
2042	0.6977	0.8424	0.9400	1.0500	1.2565	205.5	248.5	279.8	313.7	374.4
2043	0.6984	0.8479	0.9482	1.0674	1.2694	207.1	250.7	281.7	317.9	377.4
2044	0.7064	0.8516	0.9608	1.0851	1.2840	207.0	252.4	285.2	321.9	384.3
2045	0.7112	0.8598	0.9715	1.0907	1.2982	207.4	253.3	287.8	325.8	388.8
2046	0.7137	0.8638	0.9797	1.1069	1.3103	209.1	255.1	291.7	330.0	397.4
2047	0.7207	0.8711	0.9906	1.1173	1.3348	212.0	257.0	292.4	334.7	401.7
2048	0.7236	0.8825	0.9998	1.1344	1.3497	213.8	258.8	295.2	338.3	407.1
2049	0.7247	0.8842	1.0067	1.1426	1.3720	214.3	261.3	298.7	341.5	410.6

2050	0.7335	0.8908	1.0160	1.1563	1.3885	214.6	265.5	301.2	345.7	419.3

(c) Projections based on the Bayesian estimates; Future recruitment = recruits

Year	Spawner output / $0.4B_0$					Annual catch (t)				
	5%	25%	50%	75%	95%	5%	25%	50%	75%	95%
2003	0.5053	0.6048	0.6939	0.7975	0.9618	377.0	377.0	377.0	377.0	377.0
2004	0.5167	0.6232	0.7146	0.8208	0.9960	298.8	374.4	443.6	527.3	672.9
2005	0.5133	0.6190	0.7103	0.8229	0.9942	299.3	373.6	447.3	532.6	679.1
2006	0.5094	0.6152	0.7102	0.8160	0.9894	290.8	372.1	446.9	537.1	695.3
2007	0.5076	0.6171	0.7143	0.8241	0.9974	289.5	373.2	449.2	534.3	698.0
2008	0.5067	0.6218	0.7242	0.8410	1.0342	287.6	373.8	450.4	537.6	698.2
2009	0.5105	0.6307	0.7406	0.8643	1.0843	294.2	382.3	459.6	549.7	717.1
2010	0.5163	0.6429	0.7558	0.8855	1.1182	303.5	394.5	474.1	569.5	738.0
2011	0.5276	0.6588	0.7739	0.9091	1.1462	312.0	407.2	487.8	583.9	756.3
2012	0.5370	0.6744	0.7921	0.9301	1.1695	320.5	417.0	499.8	600.0	772.6
2013	0.5444	0.6887	0.8092	0.9508	1.2027	327.6	425.4	511.7	613.1	783.7
2014	0.5537	0.7015	0.8252	0.9696	1.2303	335.7	433.5	521.0	625.8	801.2
2015	0.5608	0.7124	0.8405	0.9878	1.2508	339.9	440.9	528.9	636.0	811.3
2016	0.5680	0.7250	0.8558	1.0072	1.2761	346.6	448.7	537.0	644.6	820.9
2017	0.5738	0.7347	0.8692	1.0245	1.3025	352.7	456.1	544.1	653.0	826.8
2018	0.5837	0.7448	0.8809	1.0377	1.3245	354.9	461.4	553.3	659.8	839.2
2019	0.5927	0.7564	0.8926	1.0533	1.3406	359.6	467.8	559.0	667.2	847.6
2020	0.6007	0.7684	0.9053	1.0680	1.3475	365.4	473.3	564.7	676.2	855.6
2021	0.6101	0.7779	0.9151	1.0784	1.3651	369.7	480.1	572.1	681.4	865.9
2022	0.6155	0.7867	0.9287	1.0929	1.3805	374.9	484.9	578.1	688.6	871.9
2023	0.6251	0.7942	0.9395	1.1044	1.3945	378.2	490.0	583.7	695.1	872.7
2024	0.6309	0.8030	0.9478	1.1153	1.4057	379.3	493.2	587.9	697.6	884.5
2025	0.6355	0.8111	0.9564	1.1246	1.4161	386.6	498.7	591.0	704.9	892.5
2026	0.6427	0.8162	0.9626	1.1337	1.4265	390.4	503.7	596.4	710.6	899.3
2027	0.6465	0.8236	0.9705	1.1412	1.4362	395.7	506.3	600.9	713.6	905.9
2028	0.6492	0.8319	0.9784	1.1487	1.4436	397.3	511.0	603.5	717.9	910.4
2029	0.6520	0.8374	0.9863	1.1555	1.4526	399.5	515.2	606.5	719.1	913.9
2030	0.6580	0.8430	0.9912	1.1600	1.4539	405.2	518.2	612.6	721.1	917.4
2031	0.6611	0.8497	0.9969	1.1668	1.4563	407.4	519.5	616.2	724.8	919.0
2032	0.6623	0.8517	1.0038	1.1695	1.4672	408.5	523.2	619.2	728.6	923.0
2033	0.6642	0.8575	1.0106	1.1774	1.4786	412.5	524.0	623.9	729.7	924.2
2034	0.6677	0.8628	1.0160	1.1836	1.4866	414.4	527.9	626.2	731.7	930.9
2035	0.6713	0.8633	1.0212	1.1884	1.4936	418.9	530.3	627.8	735.7	933.4
2036	0.6764	0.8678	1.0251	1.1946	1.5046	418.0	534.6	629.9	738.6	929.7
2037	0.6769	0.8709	1.0254	1.1976	1.5119	418.8	537.0	631.8	741.4	932.3
2038	0.6795	0.8735	1.0268	1.2059	1.5185	423.4	538.0	633.7	741.3	933.4
2039	0.6830	0.8777	1.0311	1.2093	1.5207	427.0	537.9	636.7	744.4	938.1
2040	0.6837	0.8787	1.0345	1.2128	1.5291	427.3	540.8	637.3	746.2	940.1
2041	0.6889	0.8814	1.0354	1.2137	1.5308	428.4	542.1	639.1	749.6	938.5
2042	0.6897	0.8850	1.0373	1.2169	1.5314	426.8	545.2	641.1	750.9	936.8
2043	0.6946	0.8852	1.0421	1.2176	1.5489	428.0	546.0	641.9	752.2	939.2
2044	0.6937	0.8884	1.0430	1.2205	1.5433	431.1	548.7	642.2	753.0	943.0
2045	0.6963	0.8912	1.0447	1.2281	1.5479	433.0	548.3	644.0	754.0	939.3
2046	0.6988	0.8936	1.0461	1.2316	1.5457	434.0	547.5	644.2	753.6	943.6
2047	0.7009	0.8958	1.0461	1.2333	1.5447	434.3	548.9	646.9	754.4	948.0
2048	0.7016	0.8956	1.0505	1.2363	1.5374	435.1	549.2	646.5	758.4	946.1

2049	0.7011	0.8960	1.0509	1.2361	1.5399	438.4	548.6	647.0	756.3	942.6
2050	0.7065	0.8972	1.0535	1.2350	1.5387	438.4	549.8	648.9	759.4	944.1

(d) Projections based on the Bayesian estimates; Future recruitment = recruits / spawner

Year	Spawner output / $0.4B_0$					Annual catch (t)				
	5%	25%	50%	75%	95%	5%	25%	50%	75%	95%
2003	0.5053	0.6048	0.6939	0.7975	0.9618	377.0	377.0	377.0	377.0	377.0
2004	0.5167	0.6232	0.7146	0.8208	0.9960	135.8	170.4	201.9	239.8	306.7
2005	0.5188	0.6260	0.7195	0.8318	1.0053	137.2	171.6	205.8	246.0	313.8
2006	0.5191	0.6284	0.7262	0.8361	1.0121	134.1	172.6	208.2	249.8	324.9
2007	0.5246	0.6377	0.7386	0.8524	1.0276	134.1	174.3	210.1	251.1	332.4
2008	0.5280	0.6471	0.7546	0.8763	1.0799	133.0	173.5	211.3	253.4	332.4
2009	0.5290	0.6553	0.7672	0.8990	1.1256	135.3	176.9	213.6	258.9	340.8
2010	0.5331	0.6596	0.7755	0.9134	1.1485	137.6	179.7	217.8	264.3	349.2
2011	0.5332	0.6641	0.7848	0.9247	1.1706	137.9	181.1	219.7	268.8	355.1
2012	0.5358	0.6685	0.7941	0.9389	1.1920	137.9	182.5	221.8	271.1	358.5
2013	0.5408	0.6753	0.8008	0.9482	1.2195	139.6	184.0	223.9	274.1	362.3
2014	0.5406	0.6814	0.8100	0.9608	1.2410	140.4	185.5	226.2	275.1	366.4
2015	0.5405	0.6890	0.8187	0.9743	1.2625	141.9	186.8	228.5	278.9	372.2
2016	0.5435	0.6924	0.8290	0.9854	1.2860	142.9	188.5	230.8	282.9	378.3
2017	0.5454	0.6998	0.8379	0.9986	1.3064	144.4	191.2	233.7	287.2	383.2
2018	0.5498	0.7041	0.8451	1.0117	1.3268	146.1	193.1	235.5	291.1	387.9
2019	0.5517	0.7094	0.8556	1.0263	1.3507	146.1	193.9	238.1	294.1	396.1
2020	0.5543	0.7149	0.8674	1.0372	1.3770	147.3	195.5	241.6	298.7	400.9
2021	0.5577	0.7196	0.8746	1.0516	1.3995	149.3	198.2	243.6	301.8	408.9
2022	0.5567	0.7230	0.8850	1.0642	1.4263	149.7	199.5	245.9	305.9	415.4
2023	0.5599	0.7291	0.8944	1.0789	1.4516	150.8	201.3	248.5	309.9	422.0
2024	0.5654	0.7337	0.9046	1.0989	1.4842	150.8	203.4	251.0	313.9	430.4
2025	0.5658	0.7387	0.9154	1.1142	1.5144	151.1	204.8	253.0	317.7	432.6
2026	0.5656	0.7437	0.9221	1.1310	1.5450	151.9	206.0	257.0	321.7	439.9
2027	0.5669	0.7509	0.9350	1.1459	1.5774	153.0	207.8	260.3	324.7	447.3
2028	0.5718	0.7583	0.9431	1.1616	1.6028	154.9	209.5	263.0	329.8	453.2
2029	0.5720	0.7638	0.9554	1.1732	1.6250	155.9	211.7	265.7	335.0	462.8
2030	0.5728	0.7719	0.9667	1.1916	1.6521	156.6	213.6	268.4	338.6	471.6
2031	0.5734	0.7774	0.9765	1.2101	1.6764	157.0	216.6	271.1	343.2	482.0
2032	0.5742	0.7855	0.9874	1.2277	1.7097	158.0	217.9	273.9	347.9	489.8
2033	0.5749	0.7916	0.9985	1.2464	1.7333	158.7	218.7	276.6	352.7	497.5
2034	0.5788	0.7980	1.0086	1.2620	1.7703	161.6	220.5	280.6	357.6	506.6
2035	0.5819	0.8059	1.0206	1.2812	1.8123	161.2	223.9	283.8	361.9	513.7
2036	0.5841	0.8124	1.0314	1.2972	1.8414	162.5	225.7	286.1	366.2	518.6
2037	0.5864	0.8214	1.0388	1.3113	1.8778	162.9	227.7	288.2	370.1	529.0
2038	0.5903	0.8274	1.0516	1.3321	1.9031	164.1	229.5	292.4	374.2	537.9
2039	0.5916	0.8355	1.0666	1.3476	1.9311	166.1	232.3	295.6	379.2	546.6
2040	0.5892	0.8387	1.0777	1.3604	1.9577	167.0	234.2	298.8	383.4	559.3
2041	0.5910	0.8453	1.0895	1.3795	1.9909	168.3	236.6	302.3	387.5	570.3
2042	0.5950	0.8511	1.1029	1.4014	2.0280	170.6	238.6	304.9	392.2	580.3
2043	0.5986	0.8604	1.1160	1.4241	2.0786	170.8	240.3	309.1	397.8	582.9
2044	0.5989	0.8694	1.1273	1.4470	2.1096	170.2	242.6	312.6	403.9	593.2
2045	0.6042	0.8756	1.1402	1.4719	2.1440	171.7	243.8	315.9	411.7	607.5
2046	0.6026	0.8845	1.1513	1.4904	2.1953	173.6	246.3	319.5	417.6	613.1
2047	0.6036	0.8907	1.1642	1.5154	2.2389	174.5	248.6	323.2	424.6	624.4
2048	0.6094	0.8986	1.1772	1.5420	2.2827	175.3	251.2	326.9	430.6	632.9
2049	0.6118	0.9051	1.1899	1.5582	2.3110	176.0	253.1	329.4	436.1	645.5

2050	0.6174	0.9116	1.2018	1.5791	2.3467	176.8	255.1	333.3	441.1	651.5

Appendix 5 : Median annual catches (t) for the six rebuilding strategies.

(a) Projections based on the MPD estimates; Future recruitment = recruits

Year	Prob=0.5	Prob=0.6	Prob=0.7	Prob=0.8	Prob=0.9	40-10 rule	ABC rule	T_{mid}
2003	377	377	377	377	377	377	377	377
2004	478	431	376	319	251	449	840	352
2005	476	430	376	320	253	443	822	353
2006	471	426	373	319	252	433	799	351
2007	468	424	373	319	253	434	781	351
2008	467	424	373	320	255	441	769	351
2009	476	433	382	328	262	459	776	360
2010	492	448	396	341	272	491	793	373
2011	507	463	409	353	282	523	809	386
2012	520	475	421	363	291	553	822	397
2013	533	487	432	373	300	581	835	408
2014	542	496	441	381	307	604	843	416
2015	551	505	449	390	314	629	852	425
2016	558	512	456	396	319	647	856	431
2017	564	519	462	402	325	660	858	438
2018	572	526	469	407	330	679	867	444
2019	584	537	479	417	338	702	880	454
2020	591	544	486	424	344	718	883	461
2021	596	550	492	429	348	732	890	466
2022	606	558	499	436	354	751	900	474
2023	614	566	507	442	360	764	906	481
2024	620	572	513	448	366	776	913	487
2025	622	575	515	451	369	774	908	489
2026	625	578	520	455	371	779	913	494
2027	629	582	523	458	375	786	915	496
2028	634	586	527	462	378	785	919	501
2029	641	593	533	467	382	792	924	507
2030	643	596	536	470	385	792	924	510
2031	644	597	538	473	388	799	923	512
2032	646	599	539	474	389	793	922	513
2033	649	602	542	478	392	797	926	516
2034	654	606	547	481	395	808	935	520
2035	656	609	549	483	397	812	935	522
2036	661	614	554	487	401	815	938	527
2037	662	614	554	487	401	822	942	527
2038	667	619	559	492	405	824	946	532
2039	667	620	559	493	406	821	941	533
2040	670	622	562	496	409	821	944	536
2041	671	624	564	497	410	825	945	537
2042	672	624	565	499	411	827	946	538
2043	675	627	566	499	412	828	947	539
2044	678	630	570	503	415	836	951	543
2045	680	632	571	505	417	830	950	545
2046	679	632	571	505	417	822	949	545
2047	679	632	572	505	417	823	950	546
2048	676	630	570	504	416	825	947	544
2049	675	628	569	503	416	821	944	543
2050	678	630	571	506	418	818	946	545

(b) Projections based on the MPD estimates; Future recruitment = recruits / spawner

Year	Prob=0.5	Prob=0.6	Prob=0.7	Prob=0.8	Prob=0.9	40-10 rule	ABC rule	T_{mid}
2003	377	377	377	377	377	377	377	377
2004	256	226	197	157	109	449	840	179
2005	258	227	199	159	111	443	822	181
2006	258	227	199	160	111	433	798	182
2007	258	228	200	160	112	432	779	182
2008	257	228	200	161	113	434	760	182
2009	260	230	202	163	114	437	751	184
2010	263	234	206	166	117	439	747	188
2011	266	236	208	168	118	438	738	190
2012	267	237	209	169	119	439	727	191
2013	269	239	211	171	121	442	722	193
2014	272	242	213	173	122	446	714	196
2015	274	245	216	175	124	448	709	198
2016	277	247	218	177	126	449	700	200
2017	278	248	220	179	127	446	691	202
2018	281	251	222	181	129	449	683	204
2019	283	253	225	183	131	451	674	206
2020	286	256	227	185	133	451	666	209
2021	287	258	229	187	134	451	658	211
2022	290	261	232	190	136	456	652	213
2023	293	263	234	192	138	457	644	216
2024	296	267	238	195	140	462	639	219
2025	297	267	238	196	141	458	629	220
2026	300	270	242	199	144	461	622	223
2027	301	271	243	200	145	459	611	224
2028	303	274	245	202	146	458	604	226
2029	305	276	247	204	148	455	597	228
2030	308	279	250	207	150	458	589	231
2031	310	281	252	209	152	458	582	233
2032	312	283	254	211	154	456	574	235
2033	314	285	256	213	156	458	566	237
2034	316	287	258	215	157	456	559	240
2035	319	290	261	218	159	460	553	242
2036	322	294	265	221	162	464	549	246
2037	324	295	266	222	163	464	541	247
2038	326	297	268	224	165	458	533	249
2039	328	300	271	227	167	457	528	252
2040	331	303	274	230	170	459	522	255
2041	333	305	276	232	171	460	514	257
2042	337	309	280	235	174	462	509	261
2043	338	310	282	237	176	468	501	263
2044	342	314	285	241	179	469	497	266
2045	344	316	288	243	181	469	491	269
2046	348	320	292	247	184	466	486	272
2047	348	321	292	248	185	465	477	273
2048	351	324	295	250	187	463	472	276
2049	354	327	299	254	190	466	467	279
2050	357	330	301	256	192	468	461	282

(c) Projections based on the Bayesian estimates; Future recruitment = recruits

Year	Prob=0.5	Prob=0.6	Prob=0.7	Prob=0.8	Prob=0.9	40-10 rule	ABC rule	T_{mid}
2003	377	377	377	377	377	377	377	377
2004	664	555	444	318	163	613	980	505
2005	663	557	447	323	167	594	966	508
2006	655	553	447	325	169	581	934	506
2007	653	554	449	327	171	585	923	507
2008	649	553	450	330	173	589	909	507
2009	657	562	460	338	179	607	912	517
2010	673	577	474	350	186	640	923	532
2011	688	593	488	362	193	672	937	547
2012	702	605	500	372	199	698	946	559
2013	715	618	512	382	205	724	953	572
2014	723	627	521	390	211	746	958	580
2015	732	636	529	398	216	762	966	590
2016	740	644	537	404	220	776	971	598
2017	748	652	544	410	224	791	973	605
2018	754	660	553	417	228	806	979	614
2019	762	667	559	423	232	817	982	620
2020	767	673	565	428	235	826	986	626
2021	775	680	572	435	240	840	991	633
2022	780	686	578	440	243	851	993	639
2023	784	692	584	445	247	858	1000	645
2024	788	695	588	450	250	865	1001	649
2025	791	699	591	452	252	866	1004	652
2026	796	703	596	457	255	869	1007	657
2027	800	709	601	462	258	872	1009	662
2028	802	711	604	464	260	879	1010	664
2029	806	714	607	467	262	889	1012	667
2030	811	720	613	471	265	890	1014	674
2031	816	724	616	475	267	891	1014	677
2032	819	728	619	478	269	896	1017	681
2033	822	731	624	482	272	895	1017	685
2034	822	732	626	484	274	895	1019	687
2035	823	734	628	487	275	896	1019	689
2036	826	737	630	488	276	898	1018	691
2037	826	738	632	490	278	898	1017	693
2038	831	740	634	492	279	900	1021	694
2039	832	742	637	495	281	905	1023	698
2040	833	743	637	496	282	903	1025	698
2041	834	744	639	498	284	903	1027	699
2042	836	747	641	500	285	906	1027	702
2043	837	747	642	500	286	904	1025	702
2044	837	749	642	501	287	907	1024	703
2045	839	750	644	502	288	904	1024	704
2046	841	751	644	504	289	906	1028	704
2047	841	753	647	505	290	907	1027	708
2048	841	753	646	506	290	904	1029	708
2049	840	752	647	506	290	902	1028	707
2050	839	753	649	508	291	905	1029	709

(d) Projections based on the Bayesian estimates; Future recruitment = recruits / spawner

Year	Prob=0.5	Prob=0.6	Prob=0.7	Prob=0.8	Prob=0.9	40-10 rule	ABC rule	T_{mid}
2003	377	377	377	377	377	377	377	377
2004	358	281	202	112	2	613	980	265
2005	363	286	206	115	2	594	966	269
2006	364	288	208	117	2	581	932	271
2007	365	290	210	118	2	583	920	274
2008	365	290	211	119	2	580	899	274
2009	367	293	214	121	2	575	889	277
2010	372	297	218	124	2	574	880	281
2011	373	299	220	125	2	568	864	283
2012	375	302	222	127	2	564	849	285
2013	377	303	224	128	2	562	835	287
2014	379	306	226	130	2	559	825	290
2015	381	309	229	132	2	556	811	293
2016	383	310	231	133	2	553	797	295
2017	385	313	234	136	2	552	784	298
2018	387	315	236	137	2	548	771	299
2019	389	318	238	139	2	546	759	302
2020	392	322	242	141	2	541	744	306
2021	393	324	244	143	2	536	736	308
2022	394	325	246	145	2	533	722	310
2023	397	328	249	147	2	533	711	313
2024	400	331	251	149	2	531	701	315
2025	401	333	253	150	2	528	689	317
2026	404	337	257	153	3	529	679	321
2027	408	340	260	155	3	530	668	324
2028	410	343	263	157	3	531	658	328
2029	413	346	266	159	3	530	647	331
2030	415	349	268	161	3	526	636	333
2031	416	351	271	163	3	528	629	336
2032	419	354	274	166	3	525	619	339
2033	421	356	277	168	3	525	609	341
2034	424	360	281	171	3	522	602	345
2035	427	363	284	174	3	524	593	348
2036	430	366	286	175	3	522	584	351
2037	431	368	288	178	3	522	576	353
2038	434	372	292	180	3	523	566	357
2039	436	374	296	182	3	519	558	359
2040	439	378	299	185	3	514	552	364
2041	441	382	302	187	3	513	543	367
2042	443	383	305	190	3	513	534	369
2043	446	388	309	193	3	512	525	374
2044	449	391	313	196	3	511	519	377
2045	451	394	316	199	4	509	511	380
2046	454	397	319	202	4	508	505	383
2047	458	401	323	204	4	512	495	387
2048	460	405	327	207	4	509	490	391
2049	463	408	329	210	4	509	484	393
2050	464	410	333	212	4	510	480	396