Rebuilding Analyses for Overfished Groundfish Stocks

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NOAA Fisheries
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Introduction

At the September 2005 PFMC meeting in Portland, the Council took action on agenda item F.7, which dealt with developing procedures for evaluating progress towards attaining rebuilding targets when overfished stocks have been re-assessed. This year 23 stock assessments have been completed, of which eight pertained to overfished species, including lingcod, widow, canary, yelloweye, bocaccio, POP, cowcod, and darkblotched rockfish. Prior to the September meeting authors of these assessments were provided instructions and guidance that requested them to complete a series of rebuilding "runs" as outlined in Agenda Item F.7a, Attachment 1, September 2005). The six runs were:

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

In addition, the Council adopted a policy (see Agenda Item F.7.c, Supplemental GMT Report, September 2005, *Alternative 5*) for revising harvest rates when progress was deemed to be inadequate. The essence of the adopted policy is to maintain the current rebuilding harvest rate (SPR) when: (1) the probability of recovery by the existing T_{target} is greater than 45% and (2) the probability of recovery by the existing T_{target} is less than 55% ***or*** the probability of recovery by T_{max} is less than 80%[1]. In situations where the first condition is not met, rebuilding is deemed inadequate and the harvest rate would be lowered, if possible within the constraints imposed by the existing T_{target}. If, however, rebuilding was determined to be impossible by T_{target}, even if all fishing was eliminated, the plan could be revised. Conversely, if the second of these conditions is false (i.e., $P_{target} > 55\%$ and $P_{max} > 80\%$) then the Council retained the option to increase the rebuilding harvest rate, as long as P_{max} did not fall below 80%.

Assuming the runs were completed, the first condition can be evaluated by examining the results of Run #1. Specifically, if the estimated probability of recovery by the existing T_{target} is greater than 0.45 then progress is considered adequate. If progress is inadequate, results from run #2 can be used to determine the harvest rate that will allow recovery by

[1] At the time this report was prepared there was uncertainty regarding whether the T_{max} referred to in *Alternative 5* pertained to the old (current) T_{max} or the new (re-estimated) value. Pending clarification of this issue by the Council and the GMT, results from Runs #3 and #5 should be used to evaluate whether or not rebuilding progress is sufficiently ahead of schedule such that the harvest rate could be increased.

T_{target}. Furthermore, the second condition can be evaluated by examining results of Runs #1, #3, and #5 to determine the estimated probability of recovery by T_{max} if fishing continues at the current rate (see footnote 1).

The SSC groundfish sub-committee met the week of September 26-30, 2005 at the Alaska Fisheries Science Center, Sand Point Facility and reviewed rebuilding analyses for 6 of the overfished stocks (bocaccio, cowcod, darkblotched rockfish, Pacific Ocean perch, widow rockfish, and yelloweye rockfish) . A rebuilding analysis for lingcod was not conducted because results from this year's stock assessment indicate that the stock has recovered to the $B_{40\%}$ target level, at least on a coastwide basis, which is how the stock is managed by the PFMC. In addition, the rebuilding analysis for canary rockfish was completed in the week that followed the meeting and it was reviewed by panelists by email. What follows are stock-specific summaries and rebuilding projections pertaining to the seven remaining overfished groundfish stocks (including canary rockfish but excluding lingcod), which the review panel collectively endorses as being the best available scientific information.

Bocaccio

A new rebuilding analysis for bocaccio was presented to the review panel by Dr. Alec MacCall. Using the Council's *Alternative 5* as a criterion for assessing adequacy of progress, results from the bocaccio analysis indicate that rebuilding is barely adequate based upon the T_{target} calculated from the previous rebuilding analysis (see Run #1a where the probability of rebuilding by T_{target} = 2027 is 46%), but is actually behind schedule relative to the T_{target} that was ultimately adopted in Amendment 16-3 to the groundfish FMP (see Run #1b where the probability of rebuilding by T_{target} = 2023 is 24%). This discrepancy was revealed during the latest rebuilding analysis and is apparently due to mis-specification of the start year to which the 23 year rebuilding target was added (2000 instead of 2004). Rebuilding is slightly behind schedule according to Run #1a due to small changes in estimates of recruitments. Rebuilding is significantly behind schedule based upon Run #1b, but would be behind schedule based upon the previous rebuilding analysis as well, which leads to a paradoxical situation. If the intent of the Council was to adopt a 70% probability of rebuilding by T_{max}, which is linked directly to T_{target} = 2027, then results from Runs #1a and #2a should take precedence and T_{target} in the rebuilding plan should be revised.

The updated estimate of T_{max} is unchanged from the last analysis (2032). In all rebuilding runs, both 2005 and 2006 were given projected catch of 150 mt instead of the OY values based upon the advice of the GMT representative on the panel. Future recruitments were projected using recruits-per-spawner, which method is supported by the modeled steepness of 0.211 in the 2005 assessment.

There have been many changes in the management of bocaccio and management performance has recently been very good. Given the highly variable nature of this stock there could be changes in management based upon future rebuilding analyses. For example, there are preliminary indications that the 2003 year-class is relatively strong.

	Bocaccio			10 Year Projections				
Year	Run #1a	Run #1b	Run #2a	Run #2b	Run #3	Run #4	Run #5	Run #6
P	0.458	0.24	0.50	0.50	0.678	0.70	0.678	0.70
SPR	0.692	0.692	0.717	0.883	0.692	0.705	0.692	0.705
F	0.0498	0.0498	0.045	0.0166	0.0498	0.0475	0.0498	0.0475
T	T_{target}=2027	T_{target}=2023	T_{target}=2027	T_{target}=2023	T_{max}=2032	T_{max}=2032	T_{max}=2032	T_{max}=2032
2007	314	314	284	106	314	300	314	300
2008	316	316	287	109	316	302	316	302
2009	334	334	304	118	334	319	334	319
2010	359	359	328	129	359	344	359	344
2011	388	388	356	142	388	373	388	373
2012	425	425	390	158	425	408	425	408
2013	462	462	426	175	462	444	462	444
2014	498	498	460	192	498	479	498	479
2015	535	535	495	211	535	516	535	516
2016	567	567	526	228	567	547	567	547

footnote: case "a" is for T_{target}=2027 based on P_0=0.70; case "b" is for FMP T_{target}=2023

Cowcod

Based on the new stock assessment parameters, the rebuilding analysis indicates that the stock is rebuilding ahead of schedule (see Run #1 where the probability of rebuilding by T_{target} = 0.81). Moreover, at the current SPR the stock has a 82% probability of rebuilding to the target by the current (old) T_{max} (Run #3) and a 75% probability of rebuilding by the new, re-estimated T_{max} (Run #5). Hence, there is ambiguity as to whether or not rebuilding is sufficiently ahead of schedule so as to allow for an increase of the harvest rate as specified under *Alternative 5* (see footnote 1). However, because: (1) the rebuilding "surplus" is very small (i.e., 82% is not much greater than 80%), (2) the specified OYs are quite small in magnitude, and (3) results from Runs #3 and #5 are identical, in practice the discrepancy is unlikely to affect cowcod management to any appreciable degree. The STAR panel also notes that the increase in the probability of rebuilding is not due to a change in stock condition, but is a result of structural changes in the model, primarily the use of a spawner-recruit model to estimate recruitments.

The rebuilding analysis for cowcod was presented to the STAR panel by Dr. Kevin Piner. The stock assessment that forms the basis for this rebuilding plan is much simpler than most of the other stock assessments that have been conducted recently, and thus contains very few input parameters on which to model uncertainty. The previous rebuilding analysis was based on the 1999 stock assessment (Butler *et al*., 1999), which used a delay-difference model. The new rebuilding analysis is based on a new assessment conducted in 2005 (Piner *et al*., 2005), wherein recruitment is described by a Beverton and Holt spawner-recruit model. To incorporate uncertainty into the rebuilding projections, a range of steepness values were entered into the model, centered on the base case value (h=0.5) with a symmetrical range bounded by h=0.25 and h=0.75 and standard deviation = 0.1. Recruitments are re-sampled from this synthetic posterior with the frequency determined by this probability distribution.

	Cowcod		10 Year Projections			
Year	Run #1	Run #2	Run #3	Run #4	Run #5	Run #6
P	0.81	0.50	**0.82**	0.60	**0.75**	0.60
SPR	0.78	0.601	0.78	0.63	0.78	0.69
F	0.009	0.021	0.009	0.019	0.009	0.015
T	T_{target}=2090	T_{target}=2090	T_{max}=2099	T_{max}=2099	T_{max}=2074	T_{max}=2074
2007	6	12	**6**	11	**6**	9
2008	6	13	**6**	11	**6**	9
2009	6	13	**6**	11	**6**	9
2010	6	13	**6**	12	**6**	9
2011	6	13	**6**	12	**6**	9
2012	6	13	**6**	12	**6**	10
2013	6	13	**6**	12	**6**	10
2014	7	13	**7**	12	**7**	10
2015	7	14	**7**	12	**7**	10
2016	7	14	**7**	13	**7**	10

Darkblotched Rockfish

The 2005 assessment of darkblotched rockfish resulted in a number of major changes to the model. In particular, the natural mortality rate was increased from 0.05 to 0.07 yr^{-1}, which had a strong influence on rebuilding projections. For example, the $F_{50\%}$ harvest rate rose from 0.0319 to 0.0463, representing a 45% increase. In addition, the new estimate of T_{min} is now 8 years and the generation time has dropped from 33 to 24 years, resulting in a decline of T_{max} from 2044 to 2033. In the rebuilding analysis a variety of projections were completed, including all four scenarios outlined in the SSC Terms of Reference for Rebuilding Analysis. In the 2003 analysis the preferred alternative was to invoke the environmental hypothesis and to project population growth by re-sampling recruits. The same approach was taken this year (model labeled A1).

Results of the darkblotched rockfish rebuilding analysis were presented by Dr. Jean Rogers via conference call and are summarized in the table below. The projections show that the stock is rebuilding substantially ahead of schedule (see Run #1, probability of rebuilding before the current T_{target} = 0.962). Note that the existing rebuilding SPR is 0.50 because the ABC (calculated at $F_{50\%}$) was actually lower than the rebuilding yield. Thus, the ABC set a cap on harvest during rebuilding.

Another peculiarity with darkblotched rockfish is that the revised assessment now indicates that rebuilding could occur within 10 years (by 2011). If required to do so, results from Run #7 provide the Council with the needed information. This scenario is presented for completeness, although it should be emphasized that for the last few years the Council has been operating under a policy wherein T_{target} = 2030. Imposing a new estimate of T_{min} at this point effectively moves the finish line midway through rebuilding.

	Darkblotched Rockfish	10 Year Projections					
Year	Run #1	Run #2	Run #3	Run #4	Run #5	Run #6	Run #7
P	0.962	0.50	0.986	0.90	0.972	0.90	0.50
SPR	0.500	0.381	0.500	0.434	0.500	0.461	missing
F	0.0463	0.0701	0.0463	0.0583	0.0463	0.0531	0.032
T	T_{target}=2030	T_{target}=2030	T_{max}=2044	T_{max}=2044	T_{max}=2033	T_{max}=2033	T_{max}=2011
2007	456	> ABC	456	> ABC	**456**	> ABC	**317**
2008	487	> ABC	487	> ABC	**487**	> ABC	**343**
2009	500	> ABC	500	> ABC	**500**	> ABC	**355**
2010	519	> ABC	519	> ABC	**519**	> ABC	**373**
2011	530	> ABC	530	> ABC	**530**	> ABC	**385**
2012	538	> ABC	538	> ABC	**538**	> ABC	**395**
2013	546	> ABC	546	> ABC	**546**	> ABC	**403**
2014	553	> ABC	553	> ABC	**553**	> ABC	**412**
2015	558	> ABC	558	> ABC	**558**	> ABC	**418**
2016	560	> ABC	560	> ABC	**560**	> ABC	**422**

Pacific Ocean Perch (POP)

The new POP rebuilding analysis completed and presented by Dr. Owen Hamel indicates that the stock is rebuilding ahead of schedule, despite being slightly more depleted. At the current rate of rebuilding, there is nearly a 60% probability of rebuilding to the old T_{target} at the old SPR (Run #1). Moreover, there is a 78% probability of rebuilding by the old T_{max} (Run #3) and there is a 79% probability of rebuilding by the new T_{max}. Thus, there is no rebuilding "surplus" as defined under *Alternative 5*, regardless of which T_{max} is used (see footnote 1). Accelerated rebuilding of the POP stock is due primarily to recent above average year-classes entering the fishery. The new rebuilding analysis is based on a stock assessment update. As in the previous assessment, the new analysis is based on re-sampling from historical recruitments (1965-2003) using the MCMC algorithm (Punt, 2002). The principal differences between the previous assessment and the new one is the inclusion of updated fishery age and length composition data, new survey age data, and the removal of water hauls from the triennial survey data. The new rebuilding analysis indicates that the stock is slightly more depleted than estimated in the 2003 assessment (2005 depletion = 27.6% of B_0, whereas 2003 depletion = 27.7%). Other revisions include a slightly lower estimated value for B_0 and an increase in T_{max} from 2042 to 2043 in the new rebuilding projections.

Depending on the interpretation of T_{max}, Runs #3 and #5 in the table below conform to the GMT's recommendations and Council adopted policy (*Alternative 5*). Note, however, that the time series of catch from each of these two runs is identical.

	Pacific Ocean Perch		10 Year Projections			
Year	Run #1	Run #2	Run #3	Run #4	Run #5	Run #6
P	0.597	0.50	0.782	0.70	0.789	0.70
SPR	0.696	0.633	0.696	0.644	0.696	0.640
F	0.0231	0.0304	0.0231	0.0290	0.0231	0.0295
T	T_{target}=2021	T_{target}=2021	T_{max}=2042	T_{max}=2042	T_{max}=2043	T_{max}=2043
2007	397	522	**397**	498	**397**	506
2008	412	538	**412**	514	**412**	522
2009	431	561	**431**	536	**431**	544
2010	455	588	**455**	564	**455**	572
2011	473	609	**473**	583	**473**	591
2012	482	617	**482**	592	**482**	600
2013	488	621	**488**	597	**488**	605
2014	498	633	**498**	608	**498**	616
2015	508	643	**508**	618	**508**	626
2016	519	655	**519**	630	**519**	638

Widow Rockfish

The new widow rockfish rebuilding analysis indicates that rebuilding is much ahead of schedule (Run #1 probability of rebuilding by current T_{target} = 96%). The probability of rebuilding by the old T_{max} is also substantially greater than 80% (P = 98%), as is the probability of rebuilding by the new T_{max} (P = 94%). Thus, both indicate there is a rebuilding "surplus" that could be considered under *Alternative 5* by determining the harvest that would rebuild with 80% probability (see footnote 1). However, results from that type of analysis are presently only available for the new T_{max} scenario (see Run #7).

Accelerated rebuilding is due to changes in the 2005 model that affect estimates of steepness and depletion, both of which are greater than in the 2003 assessment. For example, the previous rebuilding analysis estimated a rebuilding fishing mortality rate of 0.0093, equivalent to an SPR of 0.936, whereas the new SPR estimate is 0.834. The panel also requested that 40:10 OY projections be included in the table. However, due to the low estimated productivity of widow rockfish, this harvest control rule may be overly aggressive, as the proxy harvest rate ($F_{50\%}$) is apparently too high to maintain the stock near the $B_{40\%}$ target level.

Dr. Xi He presented results of four different assessment models, including the base model (Model T2), which was characterized by natural mortality of 0.125 and steepness of 0.28. Depletion rate in this base model is 31.1%, versus 22.4% in 2003 assessment. It is noteworthy that the new assessment indicates that the stock never fell below the $B_{25\%}$ minimum stock size threshold and may therefore never have been overfished. Three methods of generating future recruitments were considered including: (1) a Beverton-Holt spawner-recruit curve (as the base case), (2) recruits-per-spawner, and (3) recruits-per-spawner with pre-specified 2005-2007 (3-year old) recruitments based on estimates from the Santa Cruz survey (2002-2004). The panel accepted the STAT team's use of the spawner-recruit curve (method 1) for generating future recruitments and that the base model (T2) be used for all analyses.

	Widow Rockfish		10 Year Projections					
Year	Run #1	Run #2	Run #3	Run #4	Run #5	Run #6	Run #7	40:10
P	0.9625	0.50	0.9765	0.60	0.9395	0.60	0.80	<0.001
SPR	0.936	0.798	0.936	0.81	0.936	0.834	0.886	N/A
F	0.0093	0.0354	0.0093	0.0329	0.0093	0.0283	0.0188	N/A
T	T_{target}=2038	T_{target}=2038	T_{max}=2042	T_{max}=2042	T_{max}=2033	T_{max}=2033	T_{max}=2033	N/A
2007	447	1683	**447**	1568	**447**	1352	**903**	4249
2008	464	1716	**464**	1601	**464**	1385	**931**	4161
2009	466	1696	**466**	1586	**466**	1375	**930**	3899
2010	460	1650	**460**	1544	**460**	1343	**913**	3583
2011	453	1606	**453**	1505	**453**	1311	**895**	3305
2012	447	1575	**447**	1476	**447**	1287	**881**	3102
2013	448	1564	**448**	1468	**448**	1282	**880**	2980
2014	448	1556	**448**	1460	**448**	1277	**878**	2875
2015	452	1561	**452**	1467	**452**	1283	**884**	2805
2016	454	1557	**454**	1463	**454**	1282	**885**	2729

Yelloweye Rockfish

A yelloweye rockfish presentation was made to the panel by Mr. Farron Wallace and Dr. Tien-Shui Tsou. They reported that the existing estimate of SPR from the rebuilding analysis conducted in 2002 was based on an improperly specified length at 50% maturity (40 cm rather than 42 cm). Moreover, the STAT team was unable to recover the final 2002 rebuilding files that would be needed to recreate the exact SPR used in the 2002 rebuilding plan. Nonetheless, an effort was made to estimate the 2002 rebuilding SPR using the existing rebuilding fishing mortality rate ($F=0.0153\ yr^{-1}$), which yielded a value of 0.591. The 2005 stock assessment update of yelloweye rockfish largely resulted in changes to life history parameters, including growth, aging error, maturity, fecundity, and selectivity. Collectively, these changes would be expected to have a significant effect on the rebuilding SPR rate, all other things being equal. As a result, the review panel concluded that rebuilding runs #1, #3, and #5, which utilize the old estimate of SPR, were not essential and that efforts to improve estimation of this statistic should be abandoned.

Rebuilding projections for yelloweye rockfish were based on parametric sampling from the spawner-recruit curve, as was the 2002 analysis. Results of the analyses are presented in the following table. Note that run #1, which measures the probability of rebuilding by the current T_{target} using the existing SPR rate, indicates that rebuilding is impossible. In order to maintain the current T_{target} stipulated in Amendment 16-3 to the groundfish FMP, the SPR must be increased from 0.591 to 0.754 (see Run #2). Run #6 describes a rebuilding scenario consistent with the new stock assessment and the Council's original intent (i.e., $P_0 = 0.8$).

	Yelloweye Rockfish		10 Year Projections			
Year	Run #1	Run #2	Run #3	Run #4	Run #5	Run #6
P	0.00	0.50	0.001	0.80	0.003	0.80
SPR	0.591	0.764	0.591	0.744	0.591	0.717
F	0.0233	0.0118	0.0233	0.0129	0.0233	0.0143
T	T_{target}=2058	T_{target}=2058	T_{max}=2071	T_{max}=2071	T_{max}=2080	T_{max}=2080
2007	34.6	**16.8**	34.6	18.5	34.6	**21.0**
2008	34.7	**17.0**	34.7	18.8	34.7	**21.3**
2009	34.9	**17.3**	34.9	19.0	34.9	**21.5**
2010	35.0	**17.5**	35.0	19.2	35.0	**21.7**
2011	35.1	**17.7**	35.1	19.4	35.1	**22.0**
2012	35.2	**17.9**	35.2	19.6	35.2	**22.2**
2013	35.4	**18.1**	35.4	19.9	35.4	**22.4**
2014	35.5	**18.3**	35.5	20.1	35.5	**22.6**
2015	35.7	**18.6**	35.7	20.3	35.7	**22.9**
2016	35.9	**18.8**	35.9	20.6	35.9	**23.1**

Canary Rockfish

The canary rockfish stock assessment was reviewed initially at a STAR panel held at the NWFSC Montlake Laboratory August 15-19th and was subsequently considered by the SSC at its meeting in Portland from September 19-21st. At that time, several concerns were raised and the assessment was referred to the "mop-up" STAR panel for further consideration. At that meeting Dr. Richard Methot presented results from the canary rockfish assessment and interacted with members of the panel to address their concerns. Ultimately, two models were presented that were considered equally plausible by the SSC and both were carried into an integrated rebuilding analysis, although that analysis was not completed until after the meeting adjourned. Thus, what is summarized here is drawn from a document prepared by Dr. Methot titled "Updated Rebuilding Analysis for Canary Rockfish Based on Stock Assessment in 2005" that is dated October 2005.

The rebuilding analysis for canary rockfish integrates over a great deal of uncertainty, including that associated with two distinct models, i.e., the *NoDiff* and *Diff* scenarios. Both of these treat selectivity as a function of length, but in the former the selectivity curves of males and females are the same, whereas the latter allows for sex-specific differences in selectivity at the cost of additional parameters. The analysis combined the two models by drawing equally from the model-specific probability distributions of the steepness parameter. Aside from steepness, other sources of uncertainty that were integrated in the analysis were numbers at age in the base year (2004), selectivity patterns, and residual variance in recruitment (σ_r). The blended analysis was endorsed by the panel and estimated that B_0 is 34,155 mt, B_{2005} is 3,176 mt, and that current depletion is 9.4%. Results presented below show that rebuilding is currently ahead of schedule according to the current T_{target} (P = 57%), but not greatly so (Run #3 probability of rebuilding by the old T_{max} is 58.5%, whereas Run #5 probability of rebuilding by the new T_{max} is 55.4%). Following the revision rule adopted by the Council, the current harvest rate would therefore be maintained (Run #5). It is worth noting however, that the new re-estimated T_{max} (at a 60% probability of rebuilding) is now earlier than the existing T_{target}.

	Canary Rockfish		10 Year Projections			
Year	Run #1	Run #2	Run #3	Run #4	Run #5	Run #6
P	0.574	0.50	0.585	0.60	0.554	0.60
SPR	0.887	0.816	0.887	0.903	0.887	0.935
F	missing	missing	missing	missing	missing	missing
T	T_{target}=2074	T_{target}=2074	T_{max}=2076	T_{max}=2076	T_{max}=2071	T_{max}=2071
2007	43.2	73.4	43.2	37.0	**43.2**	24.1
2008	44.5	75.0	44.5	38.1	**44.5**	24.8
2009	45.1	75.8	45.1	38.6	**45.1**	25.3
2010	46.4	77.6	46.4	39.8	**46.4**	26.0
2011	48.6	81.0	48.6	41.7	**48.6**	27.3
2012	51.1	85.0	51.1	43.9	**51.1**	28.8
2013	54.1	89.7	54.1	46.5	**54.1**	30.6
2014	56.5	93.3	56.5	48.6	**56.5**	32.0
2015	58.7	96.7	58.7	50.6	**58.7**	33.3
2016	61.0	100.1	61.0	52.5	**61.0**	34.7