Updated Rebuilding Analysis for Canary Rockfish
Based on Stock Assessment in 2005

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Summary

The rebuilding analysis for canary rockfish was first conducted in 2000 based on the 1999 stock assessment then updated in 2002 on the basis of the first coastwide assessment. The 2005 stock assessment, as amended following SSC review in September 2005, included a base model and an alternative model based on a different configuration regarding male-female selectivity. The two models were considered equally plausible by the SSC and both are carried into the rebuilding analysis. By re-sampling from alternative input parameter sets, the rebuilding analysis result now integrates across the two alternate models, the probability profile of different spawner-recruitment steepness levels within each model, and the variability in future recruitments. As a result, this document dated Oct. 7, 2005 is a complete replacement for the preliminary rebuilding analysis presented to the SSC in September.

The mean estimate of the B_0 is 34,155 mt of female spawning biomass and the stock is at 9.4% of this level at the beginning of 2005 when integrated across the steepness profiles for each model. The steepness of the spawner-recruitment relationship, which largely determines the rate of increase in recruitment as the stock rebuilds, is 0.32 in the base model, 0.45 in the alternate model, and has a mean estimate of 0.40 when integrated across the probability profiles for the two models. The estimated generation time increased from 19 years in the 2002 model to 23 years due to a decrease in the estimate of natural mortality for older females. The current OY of about 47 mt is not overfishing and the stock is expected to continue rebuilding at that level of harvest. The current rebuilding harvest rate would produce an OY of 43 mt in 2007 and has a 57.4% probability of rebuilding by the current T_{target} (2074) and a 58.5% probability of rebuilding by the current T_{max} (2076). Because this new analysis is now able to incorporate 3 sources of uncertainty, rather than just 1, it takes rather large changes in harvest rate (and short-term OY) to make large changes in the probability of rebuilding. The harvest rate that would produce a 50% probability of rebuilding by T_{target} (2074) is twice the level that would produce a 60% probability of rebuilding by T_{max} (2076).

Introduction

The stock assessment for canary rockfish in 1999 documented that the stock had declined below the overfished level (25% of B_0) 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 and development of a rebuilding plan was initiated while preliminary rebuilding estimates were implemented through adjustments of annual management measures. 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. The initial rebuilding OY for 2001 and 2002 was set at 93 mt based upon a 50% probability of rebuilding by the year 2057 and maintaining a constant catch throughout the rebuilding period. The rebuilding analysis was updated in 2002 (Methot and Piner, 2002) to incorporate the coastwide assessment results and to switch to a constant exploitation rate, as in other west coast groundfish rebuilding plans. The results of the 2002 assessment and rebuilding analysis indicated that the spawning stock abundance, as a percentage of its unfished level, reached a low of 6.6% in 2000, the year of the overfished declaration. By 2002 it had increased to 7.9%. The generation time was calculated to be 19 years. The rate of rebuilding was based on the estimated spawner-recruitment relationship with steepness of 0.33 and sampling lognormally distributed random recruitment deviations around this relationship. The time to rebuild with no fishing, T_{min}, was estimated to be year 2057. The T_{max} was calculated to be the year 2076 (2057 plus 19 years for the generation time) and the T_{target} was set to 2074 on the basis of a rebuilding rate that would achieve a 60% probability of rebuilding by 2076. This rebuilding harvest rate produced an OY in 2003 of 41 mt. The rate of rebuilding was most sensitive to the steepness of the spawner-recruitment relationship. In addition, the 2002 analysis demonstrated the sensitivity of the OY to the commercial:recreational allocation because of the difference in selectivity between the two gear groups. Final rebuilding calculations were based upon a 50:50 commercial:recreational split in catch. The rebuilding plan that incorporated these results was completed as Amendment 16 to the groundfish fishery management plan in 2003.

This document presents an updated rebuilding analysis based upon the stock assessment in 2005 (Methot and Stewart, 2005).

Assessment Summary

Methot and Stewart (2005) used data through 2004 and a revised assessment model to update the coastwide assessment of canary rockfish. Primary changes included:

- Addition of the 2004 trawl survey and catch data through 2004
- Recalculation of all historical fishery catch and size/age composition data
- Extend model time series back to 1916
- Include new calibration of ageing method
- Convert from age-based selectivity to size-based selectivity

- Implement the assessment in the ADMB-coded Stock Synthesis 2 using length-based selectivities

This update to the canary rockfish rebuilding analysis incorporates additional changes made as a result of the SSC review of the canary rockfish assessment, Sept. 27-30, 2005; Seattle, WA. After examining several issues that had not been specifically examined in the assessment (trawl survey catchability, recruitment variability, and juvenile recruitment survey) the SSC recommended no changes to the base model. However, the SSC concluded that the parametric variance around a single base model underestimated the overall uncertainty in the canary rockfish assessment. After re-examining some of the sensitivity analyses included in the assessment, the SSC concluded that an alternative configuration of the male-female selectivity parameters was as plausible as the base model. The two model scenarios are labeled here as Diff (base) and NoDiff (alternate).

NoDiff - The 2002 assessment model had been configured to allow for a difference in the age-selectivity for older females relative to males. Because females grow larger than males and because the model was being shifted to length-selectivity, this pre-STAR model configuration did not allow for a difference in length-selectivity between larger females and males.

Diff – Alternative model configurations considered during the STAR panel meeting disclosed that allowing for a differential selectivity for larger sized female canary rockfish provided a modestly significant improvement in the fit to the overall data set. This difference is allowed in the 3 trawl fisheries (northern Cal, Oregon, and Washington) and the trawl survey and required that 8 additional model parameters be estimated. Because of the improved statistical fit, this model was adopted as the post-STAR base model and used as the basis for the rebuilding analysis.

Another change that occurred at the STAR panel was the extent of re-weighting of data variance on the basis of the model's goodness-of-fit to the data in preliminary model runs. The post-STAR Diff model had re-weighted all data elements, which resulted in some down-weighting of the trawl survey biomass index. In order to assure consistent performance between the Diff and NoDiff models, the post-SSC configurations continued to allow re-weighting of the age and length composition data, but not the trawl survey biomass index.

After considerable deliberation, the SSC concluded that the Diff base model and the NoDiff alternate model should both be included in the rebuilding analysis as equally probable scenarios and that the uncertainty within each configuration should also be represented in the rebuilding analysis. The maximum likelihood estimates for the two models are shown in Table 1. Other quantities necessary for the rebuilding analysis are shown in Tables 2 and 3.

Rebuilding Calculations

The rebuilding analysis was conducted using software developed by A. Punt (version 2.8a, April 2005). This software conducts stochastic simulations of future stock abundance and determines levels of future fishing mortality that are consistent with specified probabilities and time frames for rebuilding. The steps when conducting a rebuilding analysis are:

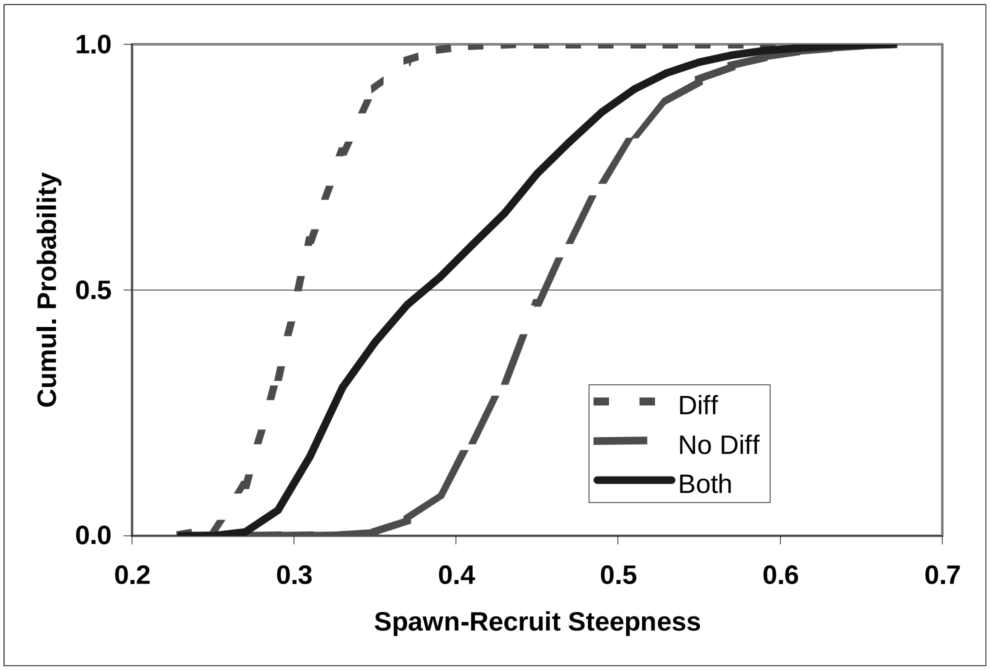
1. Estimation of the unfished level of abundance, B_0 (and hence the rebuilding target, $0.4B_0$);
2. Selection of a method to generate future recruitment;
3. Specification of the mean generation time;
4. Calculation of the minimum rebuilding time, $T_{min;}$
5. Calculation of the maximum possible rebuilding time, $T_{max;}$
6. Identification and analysis of alternative harvest strategies.

Estimation of B_0

The stock assessment was conducted using the Stock Synthesis 2 software (Methot, 2005). In this model, annual recruitments are defined as deviations from a long-term spawner-recruitment relationship. Thus, this relationship provides the required information about the central tendency of recruitments. A Beverton-Holt relationship was used in the assessment and trial model runs with a Ricker relationship produced nearly identical results. The modeled time series started in 1916, the year in which canary rockfish catch is first detected. This is earlier than the start year of 1941 used in the 2002 assessment. Although the cumulative catch prior to 1941 in the 2005 assessment is similar to the initial equilibrium catch level of 500 mt per annum used in the 2002 assessment, the difference in start year has an effect on the B_0 estimate because of the low spawner-recruitment steepness. With the initial equilibrium catch approach, the R_0 level of recruitment is applied, even though the initial equilibrium catch is reducing the spawning biomass. This is a satisfactory assumption as long as the catch is not too high and the spawner-recruitment steepness is not low. With the long time series approach, the initial equilibrium catch is zero, so no approximation is necessary, and the estimated level of recruitment declines from R_0 as the annual catches reduce the spawning biomass. For canary rockfish, this contributes to a higher level for R_0 in the 2005 assessment than in the 2002 assessment.

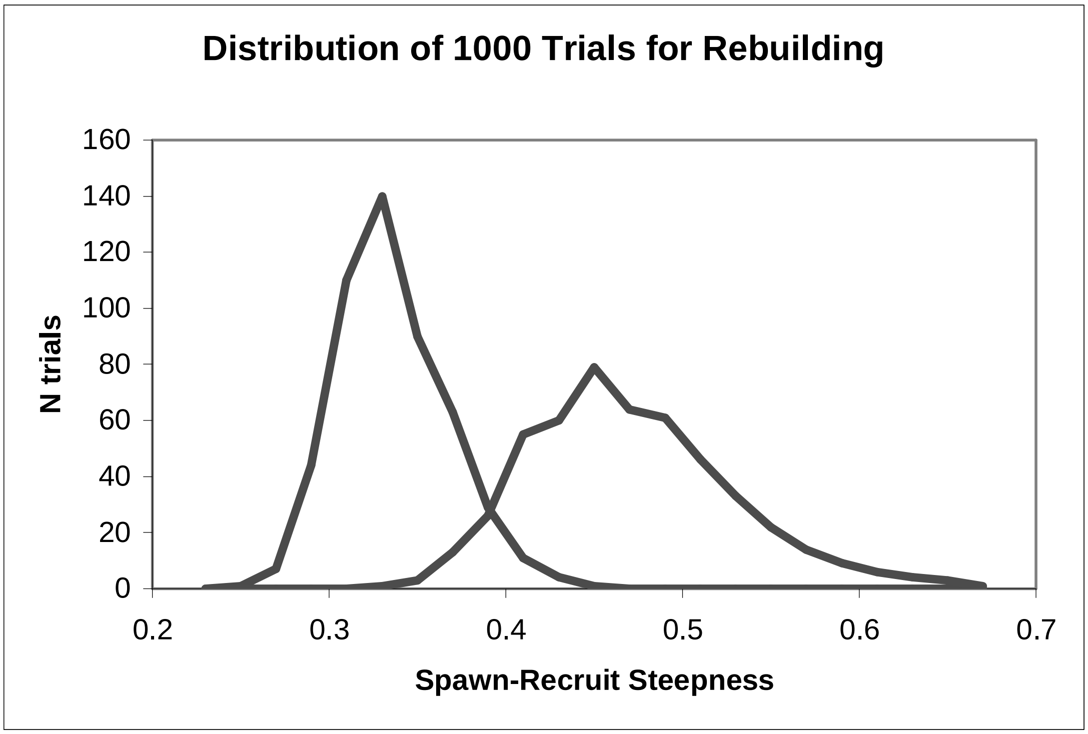
The uncertainty in the Diff model had been characterized both by the parametric estimate of variance for model outputs and by conducting a profile along a range of values for the spawner-recruitment steepness parameter. These alternative estimates of uncertainty were shown in the assessment document to be very similar, although low. The single maximum likelihood estimate from the Diff model (with an estimated steepness of 0.32) was used for the preliminary rebuilding analysis presented to the SSC in September 2005, and the upper 95% range (steepness = 0.38) was used in a rebuilding run to characterize uncertainty. In order to much more fully characterize the uncertainty, the following procedure was used:

1. Conduct a profile on the steepness parameter for the Diff model and for the NoDiff model (Table 4). Steepness values ranged from 0.23 to 0.67 with a step of 0.02 to create these profiles covering the range over which there was more than negligible probability. The NoDiff model fits better at a higher steepness values and over a broader range. The best-fitting NoDiff model fits best at a steepness of 0.45 and produces an ending biomass level that is approximately twice as high as the ending biomass in the Diff model.



While this procedure captures much more of the uncertainty in the model results than has been possible in most other assessments, it still is not a complete solution. A fuller solution is beyond the realistic capacity of our computing systems. It might include a larger set of alternative plausible model configurations, each with an objectively assigned probability, and a full MCMC investigation of the uncertainty regarding all parameters within each model configuration.

2. Re-scale the Diff and NoDiff probability distributions into discrete frequency distributions with N equal to 500 for each (because they were equally weighted in the SSC's conclusion). Note that the "Both" distribution shown above is for illustration only and is not used subsequently.



<u>Generation of future recruitment</u>

The parametric, spawner-recruitment method for forecasting future recruitments has several desirable features and alternatives such as re-sampling from observed recruits per spawner were not considered. Use of the parametric approach:

- Reproduces current low recruitment levels while spawning biomass remains low, thus mimics a recruits per spawner approach;
- Smoothly increases mean recruitment (and decreases recruits per spawner) towards the unfished level as spawning biomass increases, thus is fully consistent with the R_0 estimate;
- 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.

The estimated spawner-recruitment relationship that tracks the central tendency of recruitment as the stock was fished down over the past few decades also provides a logical basis for estimating future recruitment levels as the stock rebuilds. The estimated steepness of the Beverton-Holt spawner-recruitment relationship was 0.329 in the base model and 0.45 in the alternate model (Table 4). The base model estimate indicates a very un-resilient stock, but the value is nearly identical to the estimate in the 2002 assessment (0.33). 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, although canary was below the average. Some other west coast groundfish stocks (such as widow rockfish, bocaccio and yelloweye rockfish) have low estimated steepness levels.

These steepness estimates are conditioned upon the long-term trend in recruitment being due solely to changes in the abundance of spawners. If some of the 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. Until this happens, there is not sufficient contrast in the spawner-recruitment-climate data to separate the effects of long-term climate from the steepness of the spawner-recruitment relationship.

Capturing Uncertainty

The uncertainty in model structure and the uncertainty in steepness were propagated into the rebuilding analysis by the following procedure:

Create 1000 input vectors for the rebuilding program according to the frequency distribution shown above. There are 500 vectors from the Diff model and 500 from the NoDiff model. Each input vector corresponds to an assessment model run with either the Diff or NoDiff configuration and with a steepness value fixed at a value between 0.23 and 0.67, step 0.02. There are 11 unique Diff vectors that get included from 1 to 140 times according to their probability. There are 18 unique NoDiff vectors that get included from 1 to 79 times. Overall, the 19 unique vectors differ in steepness value, numbers at age in the base year (2004) for the rebuilding analysis and, to a lesser degree, in the estimated selectivity patterns for the fisheries.

The year-to-year variability of recruitment is also important for the rebuilding analysis. The lognormal standard deviation of recruitment used in the assessment is 0.4, and this level of variability is used in the forecasts of future recruitment. This is a lower level of recruitment variability than assumed for several other stocks, but the output level of recruitment variability in the canary assessment is lower still.

Run the rebuilding analysis program with 6000 iterations. During these 6000 iterations, the program will cycle through the 1000 input vectors 6 times. Run times were approximately 5 hours. This number of iterations was sufficient to produce smooth probability profiles in the final rebuilding output. More iterations probably would be needed where sigmaR is higher. In each iteration, the program simulates a random sequence of future recruitment deviations. The program accumulates and summarizes the results of the 6000 iterations, then produces estimates of B_{zero}, T_{min}, and other rebuilding parameters that includes uncertainty due to model configuration, parameter variability within model configuration (to the extent this is captured by the steepness profile), and variability in future recruitment sequences. This is substantially more inclusive of multiple sources of uncertainty than typical rebuilding analyses, including the preliminary canary rockfish rebuilding analysis which was based on a single Diff run (with steepness near 0.32) and included a steepness = 0.38 run only as a sensitivity analysis. The new analysis also produces a single average result, but this average integrates across the 3 sources of uncertainty, thus includes the possibility that canary rockfish productivity is much greater or lesser than the current "best" estimate.

In order to better understand the effect of the use of a distribution of steepness values, the new model was run using only the 500 Diff input vectors and with the harvest rate set equal to the current rebuilding rate (SPR=88.7%). This is simply for illustration and does not represent an evaluation because it is only including half of the total possible input possibilities. The median result is similar to the results from the preliminary rebuilding analysis but, as expected, the distribution is much broader so there is a greater probability of rebuilding even with use of just the Diff scenario:

Model	OY in 2007	Median Year to Rebuild	Pr(rebuild by 2076)	Pr(rebuild by 2076 with F=0)
H=0.32	28.4 mt	2119	0%	3.0%
Blend across h distribution	30.8 mt	2098	18.7%	40.8%

Generation Time

Generation time is calculated as the mean age of female spawners, weighted by age-specific spawn production in the absence of fishing mortality. The values used for these calculations are in Table 2. The updated estimate in the 2005 assessment is 23 years. This is 4 years longer than the estimate of 19 years in the 2002 assessment. The increased generation time is primarily due to a lower estimate of natural mortality for older female canary rockfish and partly due to improved estimates of weight-at-age.

Rebuilding Scenarios

In order to project the effect of the fishery on the rate of rebuilding, it is necessary to quantify the fishery's pattern of selectivity and effect on the spawning potential of the stock. The assessment in 2005 stratified the fishery into 10 sectors based on gear (trawl, non-trawl, recreational) and section of the coast. For the purpose of conducting the rebuilding analysis, the latitudinal strata were combined to produce an estimate of gender-specific body weight and age-selectivity for each of the 3 major gear types due to program limitations on number of fishery types in the rebuilding software. The Oregon trawl, Oregon-Washington non-trawl, and Oregon-Washington recreational fisheries were selected to represent these 3 major gear types because they had the greatest catch level in 2004. The resulting selectivity and weight at age are in Table 3.

The relative F for the 3 gear groups was set to 0.112 for trawl, 0.021 for nontrawl and 0.867 for recreational in order to achieve a 50:50 split of catch biomass between recreational and commercial and to preserve the trawl vs.nontrawl proportion observed in 2004. The 50:50 commercial:recreational split is based on the Council's selection of this allocation following the rebuilding analysis conducted in 2002. These proportions of F were obtained from the SS2 assessment model because the rebuilding software does not output the catch biomass for each gear type. It should be noted that future adjustments in the catch proportions may need to be made as the stock and OY rebuild to levels that are larger than the capacity of the recreational fishery.

In the assessment model (Methot and Stewart, 2005), it was determined that the fishery harvest rate for rebuilding corresponded to a SPR of 88.7%.

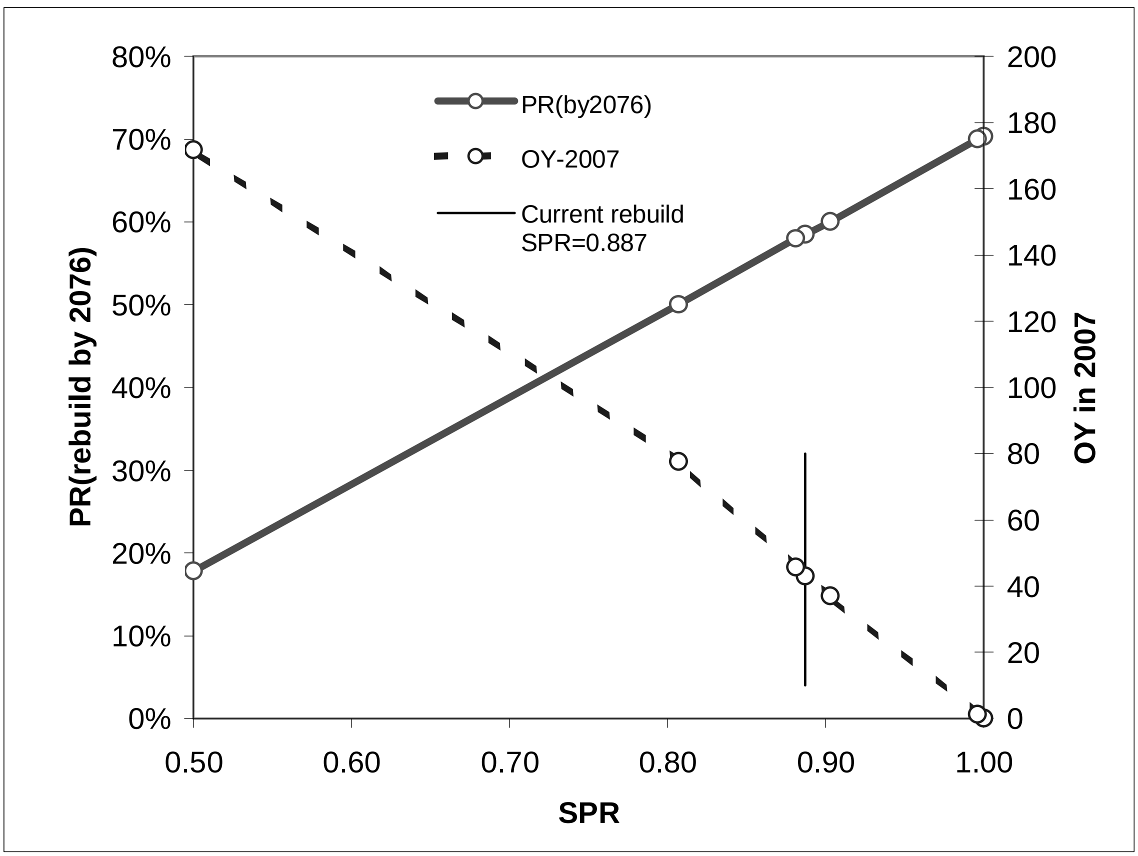
<u>Runs 1 and 3:</u> These two runs determine the probability of rebuilding by the current T_{target} (2074) and T_{max} (2076) if the current harvest rate is continued. In the assessment model (Methot and Stewart, 2005), it was determined that the fishery exploitation rate for rebuilding corresponded to a SPR of 88.7%. At this rate, the probability of rebuilding by the current T_{target} is 57.4% and the probability of rebuilding by the T_{max} is 58.5% as shown in the column labeled *Current*. These two probabilities were 50% and 60% respectively in the 2002 rebuilding analysis, so the probability of rebuilding by T_{target} has increased while the probability of rebuilding by T_{max} has decreased. The two probabilities move closer together in the current analysis because inclusion of more uncertainty causes the probability profile to flatten relative to the steep probability profile that occurred when the only uncertainty was in the future recruitment variability. Maintaining the current harvest rate would produce an average OY in 2007 of 43 mt, which is slightly lower than the current 47 mt OY. The OY in 2007 that would correspond to SPR=50% is 171mt, so the current OY is less than a third of the overfishing level. However the harvest rate corresponding to SPR=50% has only a 17.8% chance of rebuilding by 2076. Note that even if F=0, there is only a 70% chance of rebuilding by T_{max} because in the integrated analysis there is a small probability that the stock has very low productivity. Overall, changes in the SPR rate to achieve improvements in the probability of rebuilding above 50% would have a dramatic effect on the OY as shown in the Figure below:

Rebuilding runs conducted with the current T_{target} (2074).

RUN	2								1
	50%	60%	70%	80%	90%	Tmid	F=0	40-10 Rule	Current
Fishing rate	0.0298	0.0132	0	0	0	0.0173	0	0	
SPR RATE	0.816	0.914	1.000	1.000	1.000	0.889	0.000	0.000	0.887
OY in 2007	73.4	32.5	0	0	0	42.5	0	0	43.2
Prob to rebuild by T_{max} (2074)	50.0	59.9	68.4	68.4	68.4	57.5	68.4	36.6	57.4
Median year to rebuild	2074	2060	2053	2053	2053	2063	2053	2111	2063

Rebuilding runs conducted with the current T_{max} (2076).

RUN	50%	4 60%	70%	80%	90%	Tmid	F=0	40-10 Rule	3 Current
Fishing rate	0.032	0.015	5E-04	0	0	0.019	0	0	
SPR RATE	80.7%	90.3%	99.6%	100%	100%	88.1%	100%		88.7%
OY in 2007 (mt)	77.6	37	1.3	0	0	45.7	0	0	43.2
Prob to rebuild by T_{max} (2076)	50.0%	59.9%	70.0%	70.3%	70.3%	58.0%	70.3%	37.6%	58.5%
Prob to rebuild by Ttarget (2074)									57.3%
Median year to rebuild	2076	2061	2053	2053	2053	2064	2053	2111	2063



Runs 2 and 4: Run 2 shows that increasing the harvest rate to a level that reduces SPR to 81.6% would create a probability of rebuilding by T_{target} (2074) equal to 50% and would produce an OY equal to 73.4 mt in 2007. Run 4 shows that decreasing the harvest rate to increase SPR to 90.3% would reduce the 2007 OY to 37 mt and increase the probability of rebuilding by T_{max} back to 60%. The movement of these two changes in opposite directions is caused by the shift from a low uncertainty rebuilding projection in 2002 that caused the 50% and 60% probabilities of rebuilding to occur close together in time (2074 and 2076), to an analysis that incorporates more of the uncertainty.

Runs 5 and 6: Recalculation of T_{min} and generation time with the current model (integrating over two scenarios and probability of steepness) produces the following results:

Model	T_{min}	Generation Time	T_{max}
2002	2057	19	2076
2005 – integrated	2048	23	2071

Run 5 - The current harvest rate would produce a 55.4% probability of rebuilding on or before the recalculated T_{max} (2071).

Run 6 - Reducing the harvest rate to produce a SPR of 93.5% would restore the 60% probability of rebuilding by T_{max} and would produce an OY of 24.1 mt in 2007.
By interpolation from values in the table below, a harvest rate with SPR equal to 87.8% would produce an OY of 47 mt in 2007 and would result in a probability of rebuilding on or before 2071 of 54.5%.

Rebuilding runs conducted with the recalculated T_{max} (2071).

RUN		6						5	
	50%	60%	70%	80%	90%	Tmid	F=0	Current	ABC
Fishing rate	0.0271	0.0097	0	0	0	0.0152	0.000		
SPR RATE	83.1%	93.5%	100.0%	100.0%	100.0%	90.1%		88.7%	50.0%
OY	66.8	24.1	0	0	0	37.4	0	43.2	171.8
Prob to rebuild by Tmax	50.0	60.0	66.0	66.0	66.0	56.8	66.0	55.4	17.8
Median time to rebuild	64	51	45.9	45.9	45.9	54.4	45.9	56.2	-1
Prob overfished after rebuild	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Median time to rebuild (yrs)	2071.0	2058.0	2052.9	2052.9	2052.9	2061.4	2052.9	2063.2	
Probability above current spawning outptut in 100 years	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.7
Probability above current spawning outptut in 200 years	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.0
Probability below 0.01B0 in 100 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Probability below 0.01B0 in 200 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Lower 5th percentile, spawning output / target in Tmax	0.287	0.395	0.474	0.474	0.474	0.358	0.474	0.343	0.121
Median spawning output / target in Tmax	0.999	1.267	1.445	1.445	1.445	1.180	1.445	1.143	0.514
Upper 5th percentile, spawning output / target in Tmax	1.869	2.185	2.379	2.379	2.379	2.077	2.379	2.034	1.212

The table below summarizes the results of the rebuilding analyses requested by the SSC and GMT to evaluate the adequacy of progress in rebuilding and the degree of correction needed if any adjustment is considered necessary.

Run #	**Prob (recovery)**	**By**	**Based on**	**OY in 2007**
#1 (default)	Estimated: 57.4%	Current T_{target}(2074)	Current SPR (88.7%)	43.2 mt
#2 (T_{TARGET} with 50% prob)	50%	Current T_{target} (2074)	Estimated SPR (81.6%)	73.4 mt
#3 (#1 based on T_{MAX})	Estimated: 58.5%	Current T_{max} (2076)	Current SPR (88.7%)	43.2 mt
#4 (#2 based on T_{MAX})	P_0 (60%)	Current T_{max} (2076)	Estimated SPR: 90.3%	37.0 mt
#5 (#3 with re-estimated T_{MAX})	Estimated: 55.4%	Estimated T_{max}: 2071	Current SPR (88.7%)	43.2 mt
#6 (#4 with re-estimated T_{MAX})	P_0 (60%)	Estimated T_{max}: 2071	Estimated SPR (93.5%)	24.1 mt

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Table 1. Results of the stock assessment in 2005. These 2 configurations are the results of changes made during the September 2005 SSC review and are considered equally plausible.

		Base Configuration (Diff)					Alternate Configuration (No Diff)				
Year	Catch	Spbio	Recruit	TotBio	Age 3+ Bio	Catch/ 3+Bio	Spbio	Recruit	TotBio	Age 3+ Bio	Catch/ 3+Bio
Vir	0	34798	4728	93807	93315		33872	4357	88074	87621	NA
Equ	0	34798	4728	93807	93315	0.000	33872	4357	88074	87621	0.000
1916	474	34798	4728	93807	93315	0.005	33872	4357	88074	87621	0.005
1917	749	34574	4712	93307	92816	0.008	33634	4347	87583	87130	0.009
1918	794	34246	4689	92567	92077	0.009	33279	4333	86851	86399	0.009
1919	520	33909	4666	91817	91329	0.006	32917	4318	86108	85657	0.006
1920	543	33695	4650	91360	90874	0.006	32690	4309	85659	85209	0.006
1921	459	33482	4635	90903	90419	0.005	32463	4299	85210	84762	0.005
1922	415	33312	4623	90546	90063	0.005	32285	4292	84862	84415	0.005
1923	491	33170	4613	90244	89763	0.005	32136	4286	84572	84125	0.006
1924	457	33006	4601	89880	89401	0.005	31963	4278	84223	83777	0.005
1925	529	32864	4590	89560	89081	0.006	31816	4272	83920	83475	0.006
1926	726	32701	4578	89180	88703	0.008	31645	4265	83561	83117	0.009
1927	616	32466	4561	88624	88148	0.007	31396	4254	83029	82586	0.007
1928	627	32284	4548	88190	87715	0.007	31207	4246	82624	82181	0.008
1929	596	32105	4534	87758	87285	0.007	31023	4237	82224	81782	0.007
1930	709	31945	4522	87367	86895	0.008	30862	4230	81869	81428	0.009
1931	711	31745	4507	86879	86409	0.008	30659	4221	81420	80980	0.009
1932	547	31551	4493	86403	85934	0.006	30464	4212	80987	80548	0.007
1933	467	31429	4483	86096	85629	0.005	30350	4207	80726	80287	0.006
1934	450	31343	4477	85870	85404	0.005	30277	4204	80549	80111	0.006
1935	473	31265	4471	85661	85195	0.006	30214	4201	80392	79955	0.006
1936	460	31179	4464	85430	84965	0.005	30144	4198	80216	79779	0.006
1937	433	31099	4458	85211	84747	0.005	30082	4195	80056	79619	0.005
1938	370	31029	4453	85018	84554	0.004	30034	4193	79923	79487	0.005
1939	337	30984	4449	84884	84421	0.004	30013	4192	79852	79415	0.004
1940	422	30950	4447	84778	84315	0.005	30005	4191	79810	79374	0.005
1941	476	30882	4441	84587	84124	0.006	29961	4189	79685	79249	0.006
1942	413	30793	4434	84345	83883	0.005	29895	4186	79510	79074	0.005
1943	1244	30737	4430	84162	83701	0.015	29863	4185	79395	78959	0.016
1944	1964	30382	4402	83185	82725	0.024	29495	4167	78484	78049	0.025
1945	4141	29762	4353	81563	81106	0.051	28828	4135	76928	76495	0.054
1946	2755	28396	4241	77924	77474	0.036	27327	4059	73350	72922	0.038
1947	1816	27571	4171	75773	75331	0.024	26431	4011	71260	70837	0.026
1948	1541	27127	4133	74622	74187	0.021	25960	3985	70171	69753	0.022
1949	1583	26828	4107	73787	73356	0.022	25649	3967	69400	68985	0.023
1950	1959	26541	4082	72942	72515	0.027	25352	3950	68623	68211	0.029
1951	1936	26134	4045	71754	71330	0.027	24925	3925	67512	67101	0.029
1952	1902	25738	3219	70586	70194	0.027	24516	3278	66435	66049	0.029
1953	1753	25367	3217	69472	69110	0.025	24137	3269	65421	65059	0.027
1954	1949	25041	3263	68527	68190	0.029	23816	3307	64583	64241	0.030

1955	1961	24648	3360	67391	67049	0.029	23427	3394	63565	63219	0.031
1956	1998	24251	3521	66206	65854	0.030	23041	3544	62520	62164	0.032
1957	2576	23833	3761	64944	64574	0.040	22640	3770	61419	61047	0.042
1958	2619	23192	4059	63093	62699	0.042	22001	4055	59749	59354	0.044
1959	2452	22522	4354	61199	60775	0.040	21346	4331	58053	57631	0.043
1960	2479	21903	4387	59479	59035	0.042	20760	4348	56544	56101	0.044
1961	2160	21254	3901	57760	57323	0.038	20155	3883	55041	54606	0.040
1962	2207	20715	3238	56411	56014	0.039	19679	3249	53909	53514	0.041
1963	2071	20160	2734	55118	54778	0.038	19191	2764	52827	52486	0.039
1964	1485	19663	2496	54081	53789	0.028	18767	2534	51989	51694	0.029
1965	1756	19438	2558	53693	53424	0.033	18629	2592	51788	51514	0.034
1966	3616	19178	2969	53061	52782	0.069	18442	2986	51332	51049	0.071
1967	1954	18296	3559	50623	50305	0.039	17558	3528	49062	48744	0.040
1968	2327	18081	3350	49741	49398	0.047	17395	3308	48342	48001	0.048
1969	1559	17741	2644	48394	48065	0.032	17094	2649	47158	46831	0.033
1970	1524	17686	2505	47724	47431	0.032	17105	2521	46647	46355	0.033
1971	1521	17577	3011	47085	46801	0.032	17065	3028	46158	45873	0.033
1972	1604	17394	3868	46464	46135	0.035	16952	3809	45672	45345	0.035
1973	2482	17110	3599	45716	45351	0.055	16730	3571	45052	44689	0.056
1974	1863	16445	3649	44108	43723	0.043	16092	3657	43565	43182	0.043
1975	1862	16047	3335	43108	42742	0.044	15737	3345	42676	42309	0.044
1976	1460	15658	2347	42147	41826	0.035	15385	2372	41813	41490	0.035
1977	2048	15426	3056	41692	41390	0.049	15200	3102	41445	41139	0.050
1978	3074	15001	2487	40729	40455	0.076	14797	2518	40556	40279	0.076
1979	3461	14200	1244	38809	38577	0.090	13980	1303	38703	38466	0.090
1980	4132	13320	2651	36623	36401	0.114	13065	2741	36580	36352	0.114
1981	3372	12255	2526	33818	33593	0.100	11972	2670	33827	33592	0.100
1982	5374	11504	1273	31705	31484	0.171	11212	1377	31763	31530	0.170
1983	4858	9993	2162	27677	27471	0.177	9655	2312	27782	27562	0.176
1984	2396	8673	2725	24249	24033	0.100	8310	3027	24412	24176	0.099
1985	2731	8336	890	23110	22912	0.119	7992	1031	23339	23121	0.118
1986	2244	7848	1444	21587	21414	0.105	7529	1640	21896	21702	0.103
1987	3147	7495	1368	20504	20374	0.154	7210	1653	20914	20763	0.152
1988	2767	6723	1699	18558	18401	0.150	6471	2093	19085	18898	0.146
1989	3270	6088	1303	16899	16747	0.195	5876	1716	17553	17364	0.188
1990	2751	5220	1129	14713	14571	0.189	5055	1543	15507	15322	0.180
1991	3170	4562	1293	12998	12869	0.246	4460	1941	13957	13776	0.230
1992	2822	3701	655	10867	10761	0.262	3675	1044	12000	11844	0.238
1993	2187	2975	897	9065	8967	0.244	3041	1562	10407	10250	0.213
1994	1205	2482	1057	7853	7762	0.155	2646	1938	9439	9279	0.130
1995	1190	2409	547	7468	7382	0.161	2658	1040	9316	9159	0.130
1996	1531	2318	374	7000	6933	0.221	2668	745	9136	9010	0.170
1997	1441	2060	366	6132	6087	0.237	2531	728	8597	8510	0.169
1998	1513	1781	824	5313	5258	0.288	2395	1737	8164	8050	0.188
1999	856	1443	276	4338	4287	0.200	2212	605	7566	7460	0.115
2000	181	1319	196	3933	3889	0.046	2252	462	7533	7439	0.024
2001	123	1442	327	4146	4118	0.030	2544	799	8128	8063	0.015
2002	104	1580	380	4400	4368	0.024	2865	966	8773	8695	0.012
2003	48	1717	407	4640	4601	0.010	3187	1053	9387	9289	0.005

2004	38	1862	436	4890	4847	0.008	3518	1134	9985	9875	0.004
2005	N/A	1995	466	5112	5066		3829	1182	10534	10417	

Table 2. Age-specific natural mortality and female fecundity. Numbers at age (thousands) in 2000 are for the Tmin calculation and numbers at age in 2004 are the basis for projections. These values are from the base model reviewed by the STAR in September 2005. The integrated rebuilding analysis uses 38 (2 models and a range of steepness levels) unique init N vectors to represent alternative outcomes.

	Females				Males		
Age	Fecundity	M	Init N	Init N Tmin	M	Init N	Init N (Tmin)
0	0.00004	0.06	196.31	88.65	0.06	196.31	88.65
1	0.00004	0.06	172.86	120.26	0.06	172.86	120.26
2	0.00004	0.06	152.33	335.91	0.06	152.33	335.91
3	0.00016	0.06	123.56	140.12	0.06	123.56	140.12
4	0.00184	0.06	69.68	136.47	0.06	69.66	136.33
5	0.01202	0.06	93.96	184.11	0.06	93.82	183.10
6	0.05066	0.06	258.78	318.14	0.06	258.06	314.19
7	0.14742	0.064	105.08	230.15	0.06	105.02	226.13
8	0.31891	0.068	98.16	136.29	0.06	98.60	133.17
9	0.55367	0.072	127.00	203.28	0.06	128.65	196.47
10	0.82297	0.077	212.96	127.29	0.06	217.84	121.03
11	1.09879	0.081	150.98	103.58	0.06	155.90	96.17
12	1.36261	0.085	87.95	96.39	0.06	91.49	86.89
13	1.60522	0.089	129.37	57.86	0.06	134.80	50.71
14	1.82361	0.093	80.01	47.42	0.06	83.11	40.75
15	2.018	0.093	64.61	23.21	0.06	66.20	19.74
16	2.19001	0.093	59.89	56.85	0.06	59.98	48.43
17	2.34176	0.093	35.93	33.63	0.06	35.11	29.07
18	2.47539	0.093	29.54	14.41	0.06	28.29	12.78
19	2.59291	0.093	14.49	20.23	0.06	13.74	18.51
20	2.69616	0.093	35.57	14.85	0.06	33.77	14.01
21	2.78678	0.093	21.07	4.96	0.06	20.30	4.79
22	2.86625	0.093	9.04	7.16	0.06	8.94	7.04
23	2.93589	0.093	12.71	6.27	0.06	12.96	6.23
24	2.99684	0.093	9.33	3.46	0.06	9.82	3.45
25	3.05017	0.093	3.12	3.63	0.06	3.36	3.62
26	3.09678	0.093	4.51	2.98	0.06	4.94	2.96
27	3.1375	0.093	3.95	2.25	0.06	4.38	2.21
28	3.17306	0.093	2.18	1.87	0.06	2.43	1.81
29	3.20408	0.093	2.29	1.13	0.06	2.55	1.08
30	3.23114	0.093	1.88	0.75	0.06	2.08	0.70
31	3.25473	0.093	1.42	0.64	0.06	1.56	0.58
32	3.27529	0.093	1.18	0.67	0.06	1.27	0.59
33	3.2932	0.093	0.72	0.60	0.06	0.76	0.52
34	3.30881	0.093	0.47	0.43	0.06	0.49	0.36
35	3.32239	0.093	0.40	0.33	0.06	0.41	0.27
36	3.33422	0.093	0.42	0.28	0.06	0.42	0.22
37	3.34452	0.093	0.38	0.27	0.06	0.37	0.21
38	3.35348	0.093	0.27	0.28	0.06	0.26	0.22
39	3.36128	0.093	0.21	0.31	0.06	0.19	0.23
40	3.36806	0.093	2.25	2.43	0.06	2.06	2.03

Table 3. Age, gender, and fleet-specific body weight and selectivity. Fleet 1 is trawl, fleet 2 in non-trawl, and fleet 3 is recreational. These values are from the best-fitting Base model; steepness specific values are used in the blended rebuilding analysis and do not differ noticeably for these quantities.

	Fleet 1 (F)		Fleet 2 (F)		Fleet 3 (F)		Fleet 1 (M)		Fleet 2 (M)		Fleet 3 (M)	
Age	Weight	Selectivity	Weight	Selectivity	Weight	Selectivity	Weight	Selectivity	Weight	Selectivity	Weight	Selectivity
0	0.037	0	0.037	0	0.037	0	0.037	0	0.037	0	0.037	0
1	0.037	0	0.037	0	0.037	0	0.037	0	0.037	0	0.037	0
2	0.053	0	0.05	0	0.062	0.001	0.059	0	0.056	0	0.068	0.001
3	0.166	0.001	0.155	0.002	0.176	0.041	0.182	0.001	0.169	0.002	0.189	0.057
4	0.353	0.005	0.326	0.014	0.309	0.328	0.373	0.006	0.344	0.017	0.322	0.394
5	0.577	0.025	0.536	0.058	0.437	0.78	0.584	0.033	0.544	0.065	0.45	0.845
6	0.792	0.096	0.748	0.159	0.572	0.972	0.78	0.117	0.737	0.166	0.584	1
7	0.986	0.233	0.947	0.321	0.714	0.879	0.953	0.276	0.914	0.317	0.723	0.893
8	1.166	0.405	1.137	0.505	0.854	0.691	1.108	0.474	1.077	0.484	0.858	0.714
9	1.339	0.56	1.321	0.67	0.997	0.513	1.25	0.66	1.23	0.634	0.989	0.552
10	1.51	0.672	1.502	0.794	1.157	0.377	1.382	0.801	1.372	0.75	1.122	0.427
11	1.679	0.742	1.679	0.877	1.345	0.281	1.506	0.893	1.504	0.834	1.262	0.335
12	1.843	0.78	1.849	0.93	1.558	0.217	1.62	0.949	1.624	0.89	1.406	0.27
13	2.001	0.799	2.012	0.961	1.776	0.177	1.724	0.979	1.732	0.928	1.545	0.225
14	2.148	0.807	2.164	0.978	1.982	0.151	1.817	0.993	1.829	0.952	1.672	0.195
15	2.285	0.809	2.306	0.988	2.166	0.134	1.9	0.999	1.914	0.968	1.783	0.173
16	2.41	0.807	2.437	0.993	2.328	0.123	1.973	1	1.988	0.978	1.878	0.159
17	2.523	0.804	2.556	0.996	2.469	0.116	2.036	0.998	2.053	0.985	1.958	0.148
18	2.626	0.8	2.663	0.998	2.593	0.111	2.091	0.996	2.109	0.989	2.026	0.141
19	2.718	0.795	2.759	0.999	2.702	0.107	2.138	0.993	2.157	0.992	2.083	0.135
20	2.801	0.791	2.845	0.999	2.797	0.105	2.178	0.989	2.198	0.994	2.132	0.131
21	2.875	0.786	2.921	1	2.88	0.103	2.212	0.986	2.233	0.995	2.172	0.127
22	2.941	0.782	2.988	1	2.953	0.102	2.241	0.983	2.263	0.996	2.206	0.125
23	2.999	0.778	3.047	1	3.016	0.101	2.266	0.981	2.288	0.997	2.235	0.123
24	3.051	0.775	3.1	1	3.072	0.1	2.287	0.979	2.31	0.998	2.259	0.121
25	3.097	0.772	3.146	1	3.121	0.099	2.305	0.977	2.328	0.998	2.28	0.12

26	3.137	0.769	3.186	1	3.163	0.099	2.32	0.975	2.343	0.998	2.297	0.119
27	3.172	0.766	3.221	1	3.2	0.098	2.332	0.974	2.356	0.999	2.311	0.118
28	3.203	0.764	3.252	1	3.232	0.098	2.343	0.973	2.367	0.999	2.324	0.117
29	3.23	0.762	3.279	1	3.261	0.098	2.352	0.972	2.376	0.999	2.334	0.117
30	3.254	0.76	3.303	1	3.285	0.097	2.36	0.971	2.384	0.999	2.342	0.116
31	3.275	0.759	3.324	1	3.307	0.097	2.366	0.97	2.39	0.999	2.35	0.116
32	3.293	0.757	3.342	1	3.325	0.097	2.371	0.97	2.396	0.999	2.356	0.116
33	3.309	0.756	3.357	1	3.342	0.097	2.376	0.969	2.401	0.999	2.361	0.115
34	3.323	0.755	3.371	1	3.356	0.097	2.38	0.969	2.404	0.999	2.365	0.115
35	3.335	0.754	3.383	1	3.368	0.097	2.383	0.968	2.408	0.999	2.369	0.115
36	3.345	0.753	3.394	1	3.379	0.097	2.386	0.968	2.41	0.999	2.372	0.115
37	3.355	0.753	3.403	1	3.388	0.097	2.388	0.968	2.413	0.999	2.374	0.115
38	3.363	0.752	3.41	1	3.396	0.097	2.39	0.968	2.415	0.999	2.376	0.115
39	3.37	0.752	3.417	1	3.403	0.096	2.392	0.967	2.416	0.999	2.378	0.115
40	3.376	0.751	3.423	1	3.41	0.096	2.393	0.967	2.418	0.999	2.38	0.115

Table 4. Probability distributions based on steepness profiles for the base and alternate model configurations.

	Steepness	Prob	Bzero	B2005	B2005/ Bzero	Rzero
Diff	0.23	0.000	38363	1075	0.028	5593
	0.25	0.001	37429	1235	0.033	5357
	0.27	0.007	36609	1406	0.038	5162
	0.29	0.044	35913	1590	0.044	4994
	0.31	0.110	35312	1788	0.051	4850
	0.33	0.140	34784	2001	0.058	4725
	0.35	0.090	34309	2238	0.065	4622
	0.37	0.063	33894	2474	0.073	4519
	0.39	0.029	33514	2734	0.082	4434
	0.41	0.011	33169	3010	0.091	4359
	0.43	0.004	32854	3302	0.101	4292
	0.45	0.001	32564	3610	0.111	4232
	0.47	0.000	32299	3933	0.122	4179
NoDiff	0.31	0.000	37551	1728	0.046	4988
	0.33	0.001	36854	1975	0.054	4861
	0.35	0.003	36231	2240	0.062	4749
	0.37	0.013	35654	2527	0.071	4653
	0.39	0.026	35160	2826	0.080	4563
	0.41	0.055	34680	3151	0.091	4487
	0.43	0.060	34268	3478	0.102	4416
	0.45	0.079	33863	3839	0.113	4355
	0.47	0.064	33496	4182	0.125	4303
	0.49	0.061	33171	4582	0.138	4249
	0.51	0.046	32866	4974	0.151	4203
	0.53	0.033	32585	5376	0.165	4162
	0.55	0.022	32324	5786	0.179	4124
	0.57	0.014	32082	6203	0.193	4090
	0.59	0.009	31857	6624	0.208	4059
	0.61	0.006	31647	7046	0.223	4031
	0.63	0.004	31451	7469	0.237	4005
	0.65	0.003	31268	7889	0.252	3981
	0.67	0.001	31097	8306	0.267	3959
Means						
Diff	0.336		34703	2089	0.060	4710
NoDiff	0.471		33607	4263	0.128	4320
Both	0.403		34155	3176	0.094	4515
MPD						
Diff	0.329		34798	1995	0.057	4728
NoDiff	0.451		33826	3844	0.114	4355

Table 5. Projection Table. Note that decades of 2030-2060 are compressed.

	Catch				Spawning Biomass					Pr(Rebuilt)				
Year	Run-4 P=0.6 by 2076	Current	Run-2 P=0.5 by 2074	Run-6 P=0.6 by 2071	F=0	Run-4 P=0.6 by 2076	Current	Run-2 P=0.5 by 2074	Run-6 P=0.6 by 2071	F=0	Run-4 P=0.6 by 2076	Current	Run-2 P=0.5 by 2074	Run-6 P=0.6 by 2071
2007	37.0	43.2	73.4	24.1	3091	3091	3091	3091	3091	0.000	0.000	0.000	0.000	0.000
2008	38.1	44.5	75.0	24.8	3240	3227	3225	3215	3232	0.000	0.000	0.000	0.000	0.000
2009	38.6	45.1	75.8	25.3	3368	3341	3336	3314	3350	0.000	0.000	0.000	0.000	0.000
2010	39.8	46.4	77.6	26.0	3484	3440	3433	3398	3455	0.000	0.000	0.000	0.000	0.000
2011	41.7	48.6	81.0	27.3	3601	3539	3529	3479	3560	0.000	0.000	0.000	0.000	0.000
2012	43.9	51.1	85.0	28.8	3723	3641	3627	3561	3669	0.001	0.000	0.000	0.000	0.001
2013	46.5	54.1	89.7	30.6	3827	3723	3706	3623	3759	0.004	0.001	0.001	0.001	0.002
2014	48.6	56.5	93.3	32.0	3946	3819	3798	3698	3863	0.006	0.004	0.004	0.002	0.005
2015	50.6	58.7	96.7	33.3	4078	3926	3901	3783	3977	0.009	0.006	0.006	0.004	0.007
2016	52.5	61.0	100.1	34.7	4220	4043	4014	3875	4104	0.013	0.009	0.008	0.006	0.011
2017	54.2	62.9	102.8	35.9	4379	4175	4142	3985	4245	0.017	0.012	0.012	0.009	0.014
2018	56.0	64.9	105.7	37.1	4561	4327	4289	4108	4408	0.021	0.016	0.016	0.012	0.018
2019	58.0	67.2	109.1	38.5	4745	4482	4438	4231	4573	0.029	0.020	0.019	0.015	0.023
2020	59.8	69.2	111.9	39.8	4941	4639	4590	4364	4743	0.036	0.026	0.024	0.018	0.030
2021	61.5	71.2	114.7	40.9	5124	4792	4739	4490	4906	0.047	0.033	0.030	0.022	0.036
2022	63.3	73.1	117.5	42.2	5319	4960	4903	4629	5082	0.059	0.040	0.038	0.027	0.046
2023	65.3	75.5	120.9	43.6	5528	5129	5064	4763	5265	0.068	0.049	0.045	0.033	0.058
2024	67.3	77.7	123.8	45.0	5735	5298	5227	4898	5447	0.082	0.059	0.056	0.039	0.065
2025	69.3	79.9	127.1	46.4	5951	5474	5397	5038	5636	0.098	0.068	0.064	0.047	0.077
2026	71.7	82.6	130.9	48.1	6153	5642	5559	5175	5817	0.118	0.079	0.073	0.054	0.091
2027	73.5	84.7	133.7	49.4	6349	5795	5704	5294	5981	0.134	0.092	0.086	0.061	0.108
2028	75.9	87.4	137.6	51.1	6567	5968	5872	5430	6171	0.154	0.107	0.100	0.069	0.123
2029	79.0	90.9	142.5	53.2	6765	6129	6027	5559	6343	0.173	0.123	0.115	0.078	0.138
2030	80.6	92.7	145.1	54.3	6999	6309	6199	5695	6542	0.192	0.137	0.129	0.090	0.156
2040	105.8	120.9	183.6	72.2	9635	8388	8190	7300	8810	0.356	0.288	0.275	0.217	0.314
2050	134.3	153.0	227.6	92.3	12796	10822	10512	9123	11467	0.472	0.408	0.395	0.330	0.428

2060	162.1	183.9	269.6	112.2	16096	13335	12913	11013	14246	0.567	0.490	0.477	0.412	0.515
2061	165.2	187.4	274.0	114.4	16430	13583	13141	11187	14528	0.575	0.499	0.485	0.418	0.524
2062	167.8	190.3	278.5	116.2	16768	13826	13378	11387	14808	0.582	0.505	0.491	0.424	0.531
2063	170.2	192.8	281.7	117.8	17088	14113	13644	11556	15088	0.590	0.511	0.498	0.432	0.539
2064	173.5	196.6	287.1	120.3	17413	14329	13872	11737	15341	0.600	0.517	0.506	0.440	0.546
2065	176.5	199.9	291.4	122.5	17702	14581	14099	11935	15613	0.609	0.526	0.512	0.445	0.556
2066	179.5	203.8	297.0	124.6	18068	14861	14362	12156	15926	0.618	0.533	0.518	0.453	0.563
2067	182.5	206.8	301.4	126.4	18421	15170	14662	12385	16232	0.627	0.539	0.526	0.459	0.570
2068	185.3	210.0	305.9	128.5	18779	15397	14880	12554	16527	0.636	0.549	0.533	0.465	0.578
2069	187.6	212.7	309.1	130.3	19103	15611	15091	12744	16750	0.643	0.555	0.540	0.470	0.585
2070	190.1	215.4	313.2	132.0	19445	15945	15391	12929	17125	0.652	0.562	0.548	0.477	0.592
2071	192.5	218.1	315.8	133.6	19738	16190	15604	13106	17366	0.660	0.569	0.554	0.484	0.600
2072	194.9	221.1	320.8	135.4	20095	16425	15858	13342	17618	0.670	0.574	0.559	0.490	0.607
2073	197.7	224.2	324.5	137.3	20390	16633	16071	13503	17873	0.676	0.582	0.567	0.496	0.613
2074	200.3	227.1	328.9	139.1	20736	16897	16304	13655	18129	0.684	0.589	0.574	0.500	0.620
2075	203.5	230.2	332.2	141.2	20951	17133	16507	13832	18400	0.693	0.594	0.580	0.505	0.627
2076	205.2	232.9	337.5	142.6	21277	17331	16727	14019	18625	0.703	0.599	0.585	0.510	0.635
2077	207.9	235.6	341.1	144.5	21565	17553	16932	14233	18899	0.714	0.606	0.591	0.515	0.642
2078	210.7	238.4	345.6	146.4	21866	17805	17177	14384	19139	0.723	0.611	0.596	0.519	0.646
2079	213.8	242.1	349.9	148.5	22144	18038	17405	14558	19415	0.732	0.617	0.602	0.524	0.653
2080	216.3	244.9	353.8	150.4	22436	18270	17626	14742	19656	0.740	0.624	0.608	0.530	0.661

Table 6. Input file for the updated rebuilding analysis. Note that these inputs for fishery selectivity and weight-at-age, numbers-at-age in 2000 and 2004, and the steepness value are superceded by values read from the MCMC.prj file.

```
#Title
Canary
# Number of sexes
2
# Age range to consider (minimum age; maximum age)
0	40
# Number of fleets
3
# First year of projection
2004
# 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)
3
# Constant fishing mortality (1) or constant Catch (2) projections
1
# Fishing mortality based on SPR (1) or actual rate (2)
1
# Pre-specify the year of recovery (or -1) to ignore
-1
# Fecundity-at-age
#
3.80E-05	3.80E-05	3.80E-05	0.000162861	0.00184254	0.0120233
	0.0506613	0.147419	0.318907	0.553672	0.822968
	1.09879	1.36261	1.60522	1.82361	2.018	2.19001
	2.34176	2.47539	2.59291	2.69616	2.78678
	2.86625	2.93589	2.99684	3.05017	3.09678	3.1375
	3.17306	3.20408	3.23114	3.25473	3.27529	3.2932
	3.30881	3.32239	3.33422	3.34452	3.35348
	3.36128	3.36806
# Age specific information (Females then males) weight selectivity
# female wt and selex fleet 1=trawl
0.037	0.037	0.053	0.166	0.353	0.577	0.792	0.986	1.166	1.339	1.51	1.679
	1.843	2.001	2.148	2.285	2.41	2.523	2.626	2.718	2.801	2.875	2.941
	2.999	3.051	3.097	3.137	3.172	3.203	3.23	3.254	3.275	3.293	3.309
	3.323	3.335	3.345	3.355	3.363	3.37	3.376
0	0	0	0.0006	0.0046	0.0254	0.0955	0.2333	0.4052	0.5603	0.6722	0.7417
	0.7803	0.7994	0.8073	0.809	0.8073	0.804	0.7998	0.7954	0.7909	0.7865	0.7824
```

```
        0.7785 0.775  0.7718 0.7689 0.7664 0.7641 0.7621 0.7603 0.7587 0.7574 0.7562
        0.7551 0.7542 0.7534 0.7527 0.7521 0.7516 0.7511
# female wt and selex fleet 2=nontrawl
0.037   0.037  0.05   0.155  0.326  0.536  0.748  0.947  1.137  1.321  1.502  1.679
        1.849  2.012  2.164  2.306  2.437  2.556  2.663  2.759  2.845  2.921  2.988
        3.047  3.1    3.146  3.186  3.221  3.252  3.279  3.303  3.324  3.342  3.357
        3.371  3.383  3.394  3.403  3.41   3.417  3.423
0       0      0.0001 0.0018 0.0139 0.0577 0.1593 0.3209 0.5053 0.6697 0.7938 0.8775
        0.9297 0.9606 0.9782 0.988  0.9934 0.9964 0.998  0.9989 0.9994 0.9997 0.9998
        0.9999 1      1      1      1      1      1      1      1      1      1
        1      1      1      1      1      1      1
# female wt and selex fleet 3=recreational
0.037   0.037  0.062  0.176  0.309  0.437  0.572  0.714  0.854  0.997  1.157  1.345
        1.558  1.776  1.982  2.166  2.328  2.469  2.593  2.702  2.797  2.88   2.953
        3.016  3.072  3.121  3.163  3.2    3.232  3.261  3.285  3.307  3.325  3.342
        3.356  3.368  3.379  3.388  3.396  3.403  3.41
0.0003  0.0003 0.0008 0.0409 0.3284 0.7803 0.9718 0.8794 0.6905 0.5131 0.3765 0.2808
        0.2174 0.1767 0.1507 0.1341 0.1232 0.1159 0.1109 0.1074 0.1049 0.1031 0.1017
        0.1006 0.0998 0.0991 0.0986 0.0982 0.0979 0.0976 0.0974 0.0972 0.097  0.0969
        0.0968 0.0967 0.0966 0.0965 0.0965 0.0964 0.0964
# male wt and selex fleet 1=trawl
0.037   0.037  0.059  0.182  0.373  0.584  0.78   0.953  1.108  1.25   1.382  1.506
        1.62   1.724  1.817  1.9    1.973  2.036  2.091  2.138  2.178  2.212  2.241
        2.266  2.287  2.305  2.32   2.332  2.343  2.352  2.36   2.366  2.371  2.376
        2.38   2.383  2.386  2.388  2.39   2.392  2.393
0       0      0      0.0008 0.0062 0.0332 0.1173 0.2758 0.4743 0.6597 0.8006 0.8934
        0.9486 0.9785 0.9932 0.999  1      0.9984 0.9957 0.9925 0.9892 0.9862 0.9834
        0.9809 0.9788 0.9769 0.9753 0.9739 0.9727 0.9717 0.9709 0.9702 0.9696 0.9691
        0.9686 0.9683 0.968  0.9677 0.9675 0.9673 0.9672
# male wt and selex fleet 2=nontrawl
0.037   0.037  0.056  0.169  0.344  0.544  0.737  0.914  1.077  1.23   1.372  1.504
        1.624  1.732  1.829  1.914  1.988  2.053  2.109  2.157  2.198  2.233  2.263
        2.288  2.31   2.328  2.343  2.356  2.367  2.376  2.384  2.39   2.396  2.401
        2.404  2.408  2.41   2.413  2.415  2.416  2.418
0       0      0.0001 0.0023 0.0172 0.0651 0.1663 0.3171 0.4843 0.634  0.7505 0.8337
        0.8903 0.9276 0.952  0.9677 0.9779 0.9846 0.989  0.9919 0.994  0.9954 0.9964
        0.9971 0.9976 0.998  0.9983 0.9985 0.9987 0.9988 0.999  0.999  0.9991 0.9992
        0.9992 0.9993 0.9993 0.9993 0.9993 0.9994 0.9994
# male wt and selex fleet 3=recreational
0.037   0.037  0.068  0.189  0.322  0.45   0.584  0.723  0.858  0.989  1.122  1.262
        1.406  1.545  1.672  1.783  1.878  1.958  2.026  2.083  2.132  2.172  2.206
        2.235  2.259  2.28   2.297  2.311  2.324  2.334  2.342  2.35   2.356  2.361
        2.365  2.369  2.372  2.374  2.376  2.378  2.38
0.0003  0.0003 0.001  0.0566 0.3936 0.8454 1      0.8932 0.7136 0.5522 0.4269 0.335
        0.2699 0.2251 0.1945 0.1734 0.1587 0.1482 0.1406 0.1349 0.1307 0.1274 0.1248
```

0.1228 0.1212 0.12 0.1189 0.1181 0.1174 0.1168 0.1164 0.116 0.1157 0.1154
0.1152 0.115 0.1149 0.1147 0.1146 0.1145 0.1145
M and initial age-structure for 2004
female
0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.0641414 0.0682827
0.0724241 0.0765654 0.0807068 0.0848481 0.0889895
0.0931308 0.0931308 0.0931308 0.0931308 0.0931308
0.0931308 0.0931308 0.0931308 0.0931308 0.0931308
0.0931308 0.0931308 0.0931308 0.0931308 0.0931308
0.0931308 0.0931308 0.0931308 0.0931308 0.0931308
0.0931308 0.0931308 0.0931308 0.0931308 0.0931308
0.0931308 0.0931308
196.309 172.862 152.333 123.561 69.6801 93.9562
258.776 105.084 98.161 127.003 212.959 150.977
87.9514 129.371 80.0138 64.6072 59.8895
35.9335 29.5418 14.4934 35.5668 21.0718
9.04251 12.7051 9.334 3.11781 4.50744 3.95273
2.18302 2.28984 1.87866 1.41981 1.17918
0.715485 0.472064 0.403646 0.424542 0.381926
0.273987 0.2054 2.25308
male
0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06
0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06
0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06
0.06 0.06 0.06 0.06 0.06 0.06 0.06
196.309 172.862 152.333 123.561 69.6593 93.8179
258.058 105.017 98.6002 128.654 217.841
155.895 91.4869 134.795 83.1082 66.1958
59.9837 35.1084 28.2924 13.7383 33.7682
20.2994 8.93796 12.9585 9.81795 3.36164
4.94088 4.37515 2.42662 2.54572 2.07895
1.55518 1.27287 0.758189 0.489321 0.407954
0.417722 0.365907 0.255851 0.187343 2.05869
Initial age-structure female then male for year 2000 (Ydeclared)
88.6505 120.258 335.905 140.122 136.467 184.105
318.135 230.151 136.288 203.284 127.289
103.577 96.3896 57.8577 47.4205 23.2091
56.8455 33.6257 14.4112 20.2264 14.8462
4.95519 7.15896 6.27433 3.46345 3.63135
2.97817 2.25003 1.86817 1.13325 0.747538
0.639076 0.67205 0.604503 0.433607 0.325026
0.278582 0.269905 0.284131 0.305275 2.42644
88.6505 120.258 335.905 140.12 136.328 183.102
314.187 226.133 133.165 196.473 121.027
96.1679 86.8863 50.7059 40.7535 19.7435
48.4326 29.066 12.7799 18.5069 14.0079 4.79234

7.03892 6.22943 3.45345 3.62153 2.95653
2.21107 1.80929 1.0775 0.695287 0.579594 0.593405
0.51975 0.363393 0.266072 0.223315 0.212382
0.219973 0.23307 2.03463

Year for Tmin Age-structure
2000
Number of simulations
6000
recruitment and biomass
Number of historical assessment years
90
Historical data
year recruitment spawner in B0 in R project in R/S project

1915	4760	34921	1	0	0
1916	4760	34921	0	0	0
1917	4744	34698	0	0	0
1918	4720	34370	0	0	0
1919	4696	34034	0	0	0
1920	4680	33820	0	0	0
1921	4664	33606	0	0	0
1922	4651	33437	0	0	0
1923	4641	33294	0	0	0
1924	4628	33130	0	0	0
1925	4617	32988	0	0	0
1926	4605	32824	0	0	0
1927	4587	32590	0	0	0
1928	4573	32407	0	0	0
1929	4559	32228	0	0	0
1930	4547	32066	0	0	0
1931	4531	31865	0	0	0
1932	4516	31671	0	0	0
1933	4506	31547	0	0	0
1934	4499	31459	0	0	0
1935	4493	31380	0	0	0
1936	4486	31291	0	0	0
1937	4479	31209	0	0	0
1938	4473	31138	0	0	0
1939	4469	31090	0	0	0
1940	4467	31053	0	0	0
1941	4461	30982	0	0	0
1942	4454	30891	0	0	0
1943	4449	30832	0	0	0
1944	4420	30476	0	0	0
1945	4369	29856	0	0	0
1946	4253	28492	0	0	0
1947	4181	27668	0	0	0

1948	4142	27223	0	0	0
1949	4115	26922	0	0	0
1950	4088	26634	0	0	0
1951	4051	26226	0	0	0
1952	3213	25829	0	0	0
1953	3211	25456	0	0	0
1954	3259	25128	0	0	0
1955	3356	24732	0	0	0
1956	3519	24333	0	0	0
1957	3760	23911	0	0	0
1958	4061	23266	0	0	0
1959	4359	22592	0	0	0
1960	4393	21968	0	0	0
1961	3904	21314	0	0	0
1962	3237	20768	0	0	0
1963	2732	20207	0	0	0
1964	2493	19704	0	0	0
1965	2556	19472	0	0	0
1966	2969	19206	0	0	0
1967	3563	18322	0	0	0
1968	3353	18103	0	0	0
1969	2642	17760	0	0	0
1970	2503	17700	0	0	0
1971	3009	17587	0	0	0
1972	3871	17401	0	0	0
1973	3600	17113	0	0	0
1974	3646	16446	0	0	0
1975	3343	16046	0	0	0
1976	2339	15655	0	0	0
1977	3052	15420	0	0	0
1978	2494	14993	0	0	0
1979	1236	14192	0	0	0
1980	2636	13313	0	0	0
1981	2527	12248	0	0	0
1982	1268	11498	0	0	0
1983	2135	9989	0	0	0
1984	2722	8670	0	0	0
1985	876	8332	0	0	0
1986	1426	7843	0	0	0
1987	1350	7488	0	0	0
1988	1667	6715	0	0	0
1989	1276	6078	0	0	0
1990	1097	5209	0	0	0
1991	1245	4547	0	0	0
1992	626	3684	0	0	0
1993	846	2954	0	0	0

1994	990	2456	0	0	0
1995	509	2377	0	0	0
1996	348	2280	0	0	0
1997	336	2013	0	0	0
1998	757	1725	0	0	0
1999	255	1376	0	0	0
2000	177	1239	0	0	0
2001	296	1350	0	0	0
2002	344	1475	0	0	0
2003	367	1597	0	0	0
2004	393	1730	0	0	0

```
# Number of years with pre-specified catches
3
# catches for years with pre-specified catches
2004	38
2005	47
2006	47
# 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 sigma-R Auto-correlation
0.321245	0.4	0
# 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
# Definition of the "40-10" rule
10	40
```

```
# Produce the risk-reward plots (1=Yes)
0
# Calculate coefficients of variation (1=Yes)
0
# Number of replicates to use
1
# Random number seed
-89102
# Conduct projections for multiple starting values (0=No;else yes)
1
# File with multiple parameter vectors
MCMC.PRJ
# Number of parameter vectors
1000
# User-specific projection (1=Yes); Output replaced (1->6)
1       9       0       0.5
# Catches and Fs (Year; 1/2/3 (F or C or SPR); value); Final row is -1
2007    3       .887
-1      -1      -1
# Split of Fs (2004     0.27    0.05    2.1)
2004    .112    .021    .867
-1      1       1       1
# Time varying weight-at-age (1=Yes;0=No)
0
# File with time series of weight-at-age data
HakWght.Csv
```

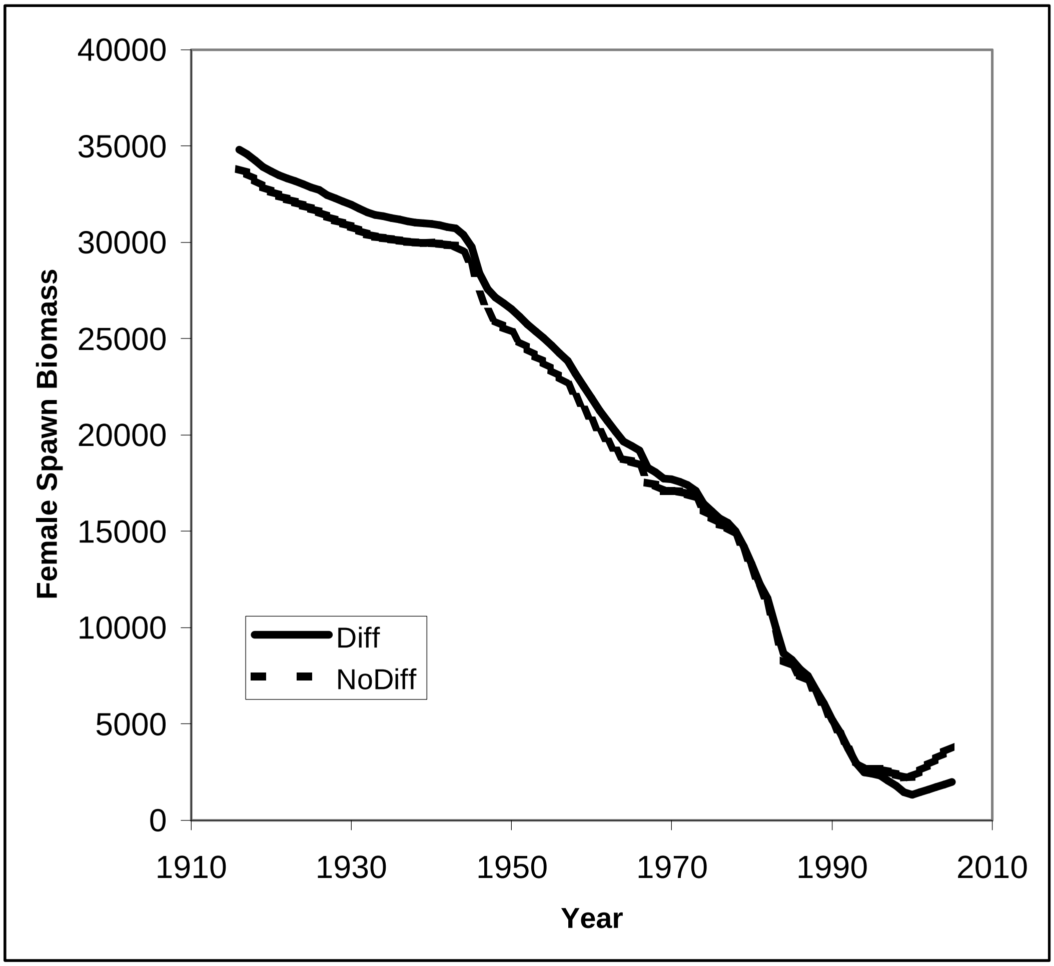


Figure 1. Estimated time series of spawning stock biomass from base model (Diff) and alternative model (NoDiff).

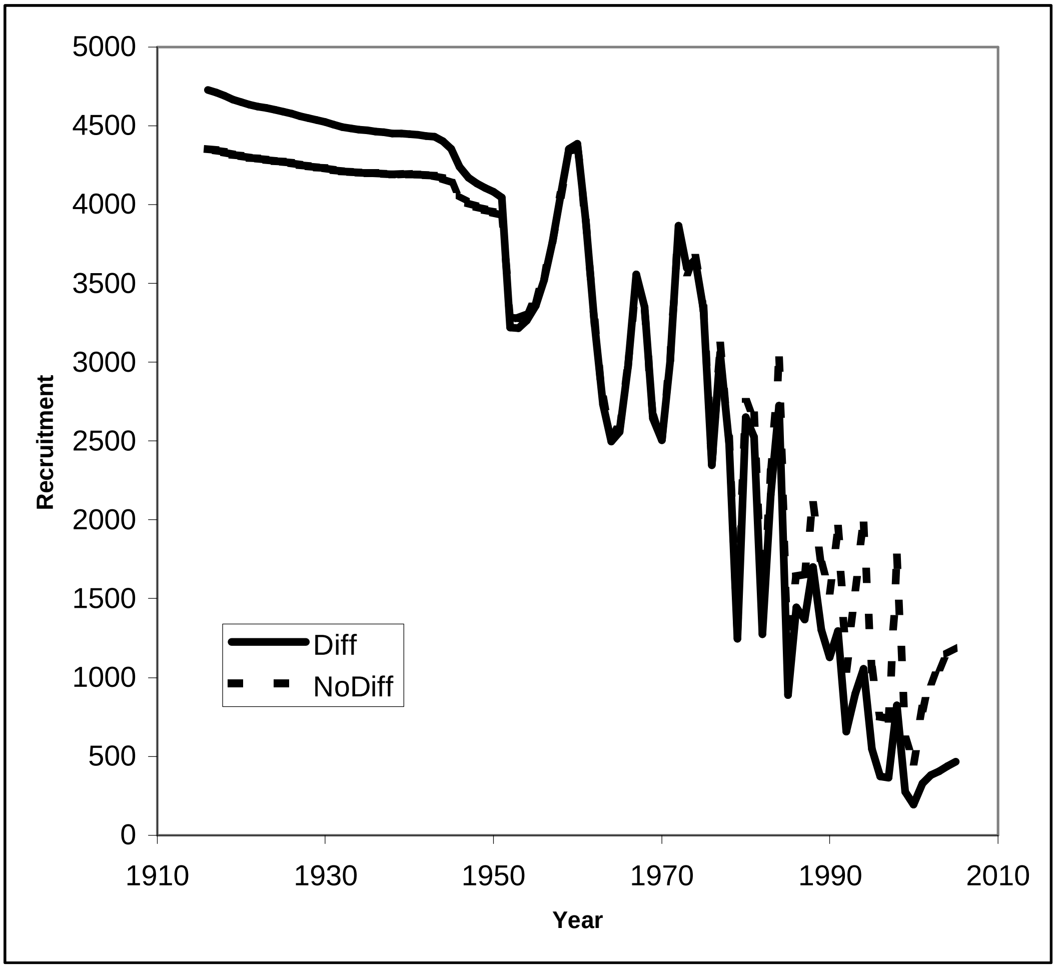


Figure 2. Estimated time series of recruitment from base model (Diff) and alternative model (NoDiff).

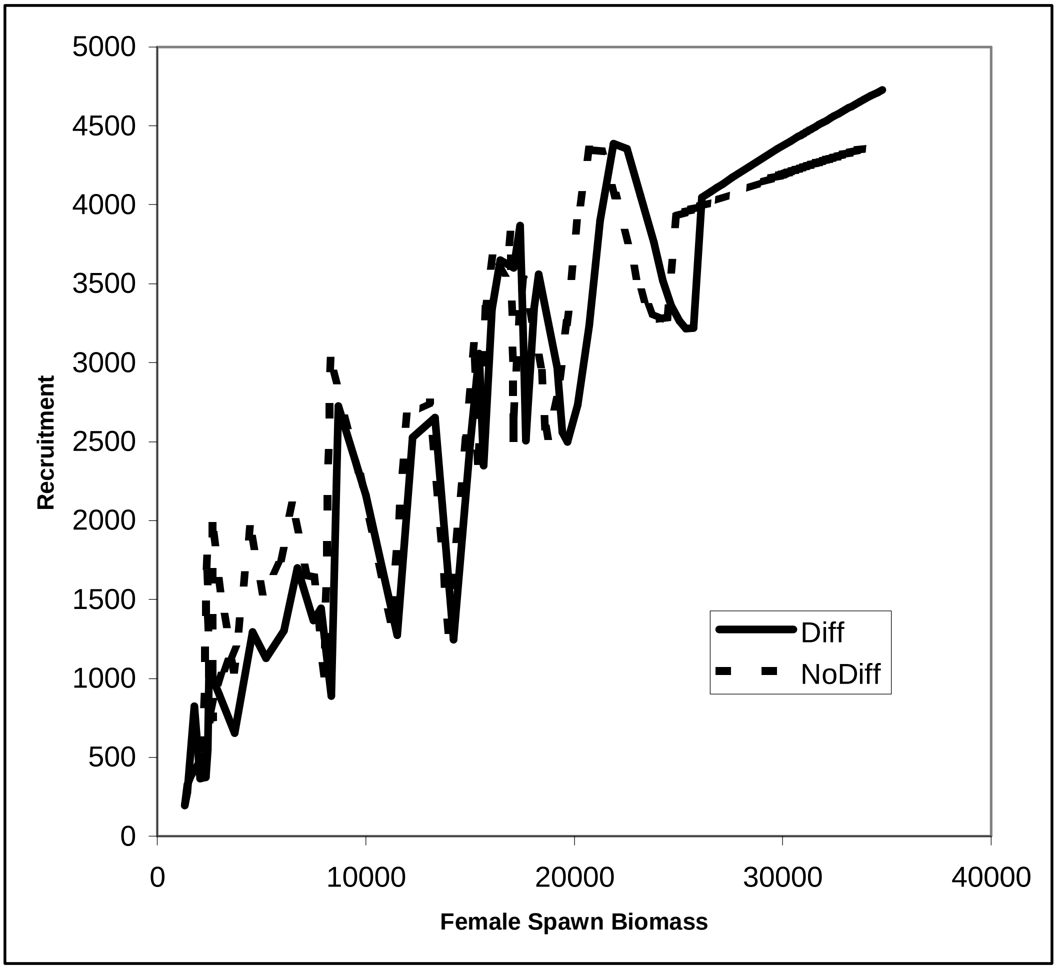


Figure 3. Spawner-recruitment relationship.

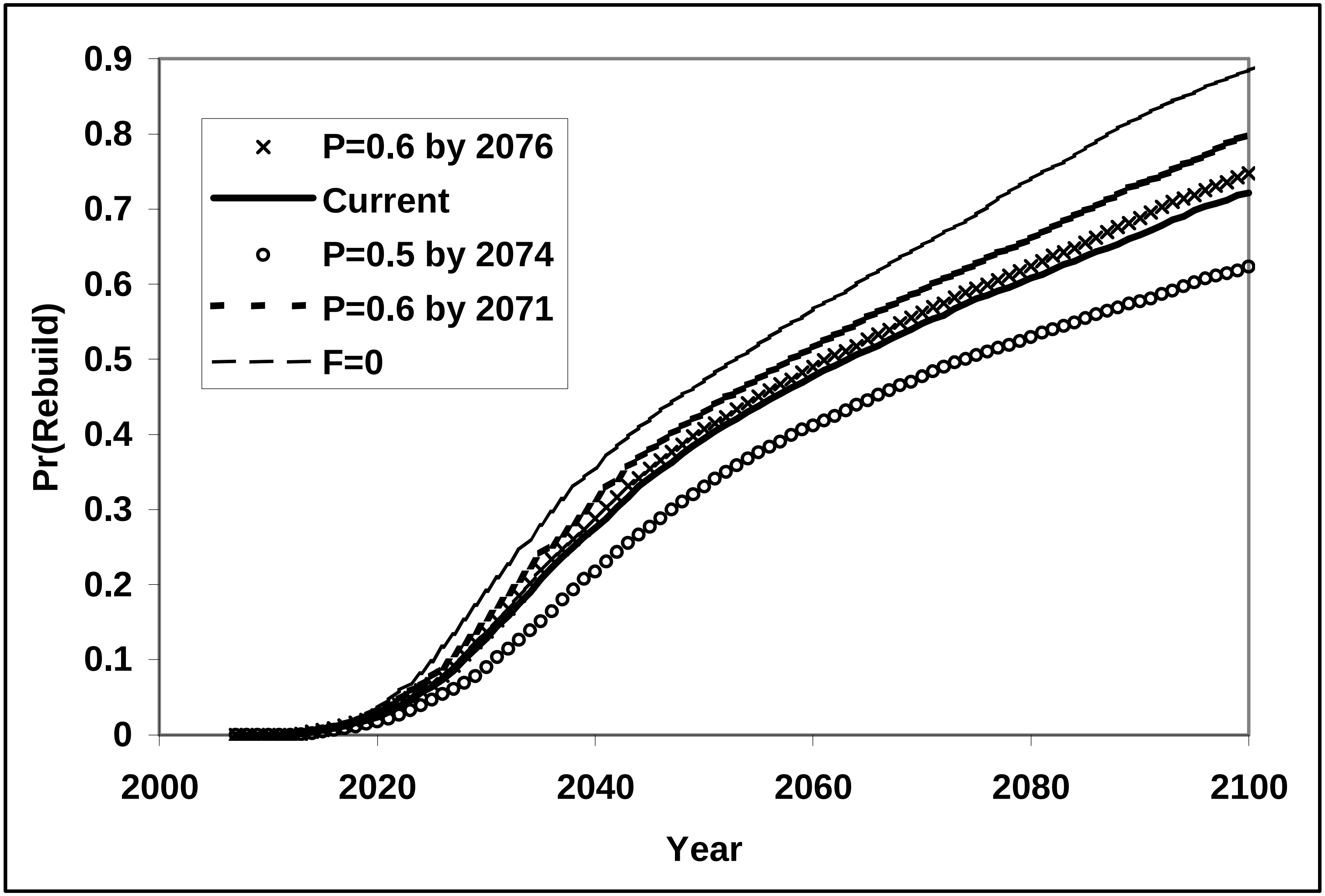
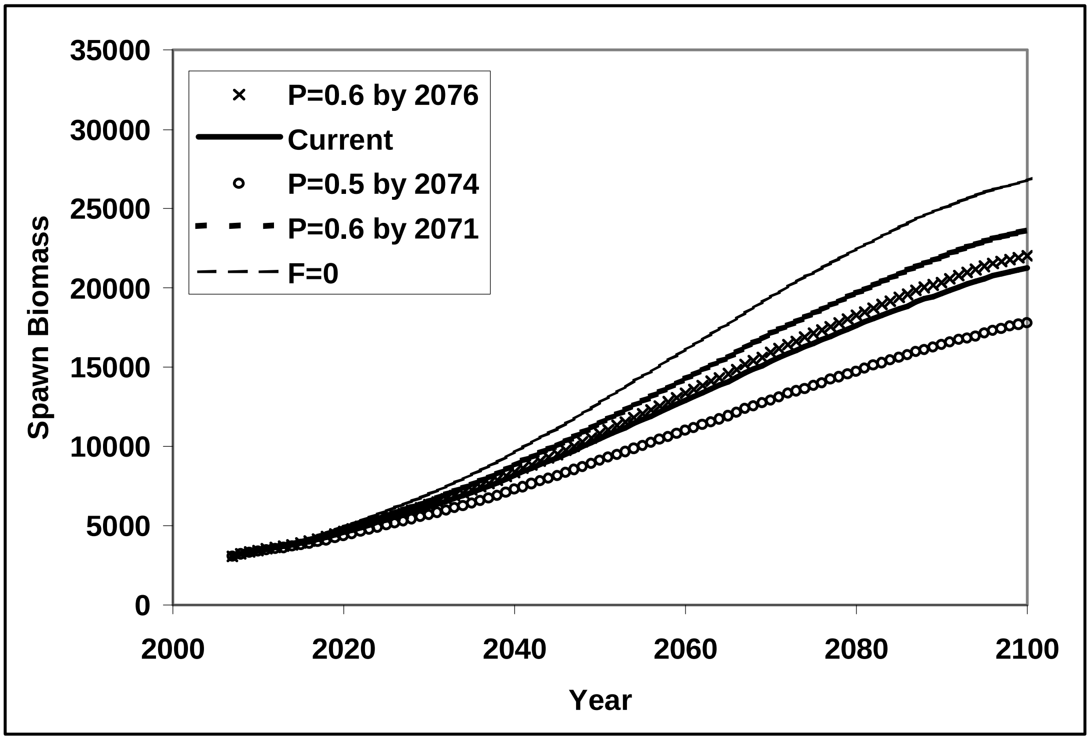


Figure 4. Alternative rebuilding scenarios.



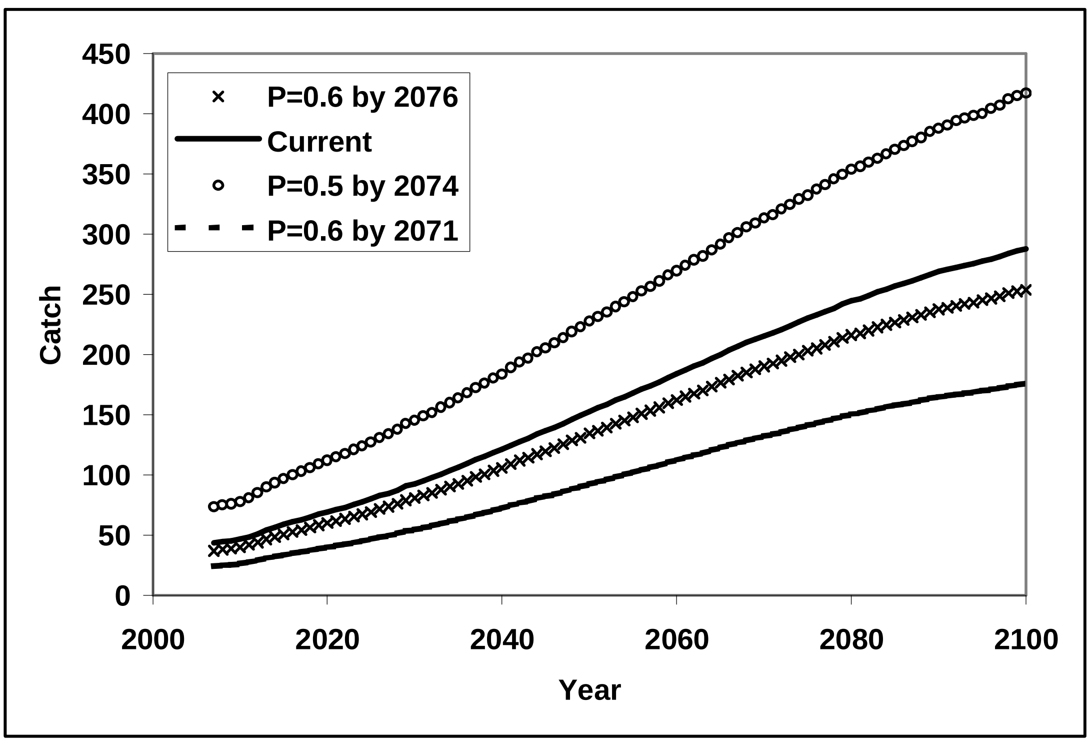


Figure 5. Catch and spawning biomass for F=0 and 4 alternative harvest strategies.