Agenda Item F.2.a
Attachment 3
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DRAFT
SSC TERMS OF REFERENCE FOR GROUNDFISH REBUILDING ANALYSIS

DRAFT REVISED VERSION
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Note: This version of the Terms of Reference does not include any changes that might be needed owing to the implementation of ACLs, as how ACLs will be implemented is currently not known.

Table of Comments

1. Introduction

Amendment 11 to the Groundfish Fishery Management Plan (FMP) established a harvest control rule for determining optimum yields (OYs). The 40:10 policy was designed to prevent stocks from falling into an overfished condition. Part of the amendment established a default overfished threshold equal to 25% of the unexploited population size[1] (B_0), or 50% of B_{MSY}, if known. By definition, groundfish stocks falling below that level are designated to be in an overfished state ($B_{25\%} = 0.25 \times B_0$[2]). To prevent stocks from deteriorating to that point, the policy specified a precautionary threshold equivalent to 40% of B_0. The policy requires that OY, when expressed as a fraction of the allowable biological catch (ABC), be progressively reduced at stock sizes less than $B_{40\%}$. Because of this linkage, $B_{40\%}$ has sometimes been interpreted to be a proxy measure of B_{MSY}, i.e., the stock biomass that results when a stock is fished at F_{MSY}. In fact, theoretical results support the view that a robust biomass-based harvesting strategy would be to maintain stock size at about 40% of the unfished level (Clark 1991, 2002). In the absence of a credible estimate of B_{MSY}, which can be very difficult to estimate (MacCall and Ralston 2002), $B_{40\%}$ is a suitable proxy to use as a rebuilding target.

Under the Magnuson-Stevens Act (MSA), it is required that rebuilding plans need to be developed for stocks that have been designated to be in an overfished state. Amendment 12 of the Groundfish FMP provided a framework within which rebuilding plans for overfished groundfish resources could be established. Amendment 12 was challenged in Federal District Court and found not to comply with the requirements of the MSA because rebuilding plans did not take the form of an FMP, FMP amendment, or regulation. In response to this finding, the Council developed Amendment 16-1 to the Groundfish FMP which covered three issues, one of which was the form and content of rebuilding plans.

The Council approach to rebuilding depleted groundfish species, as described in rebuilding plans, was re-evaluated and adjusted under Amendment 16-4 in 2006 so they would be consistent with a recent opinion rendered by the Ninth Circuit Court of Appeals in *Natural Resources Defense Council, Inc. and Oceana, Inc.* v. *National Marine Fisheries Service, et al.*, 421 F.3d 872 (9th Cir. 2005), and with National Standard 1 of the MSA. The court affirmed the MSA mandate that rebuilding periods "be as short as possible, taking into account the status and

[1] The absolute abundance of the mature portion of a stock is loosely referred to here in a variety of ways, including: population size, stock biomass, stock size, spawning stock size, spawning biomass, spawning output; i.e., the language used in this document is sometimes inconsistent and/or imprecise. However, the best fundamental measure of population abundance to use when establishing a relationship with recruitment is spawning output, defined as the total annual output of eggs (or larvae in the case of live-bearing species), accounting for material effects (if these are known). Although spawning biomass is often used as a surrogate measure of spawning output, for a variety of reasons a non-linear relationship often exists between these two quantities (Rothschild and Fogarty 1989; Marshall *et al*. 1998). Spawning output should, therefore, be used to measure the size of the mature stock when possible.

[2] Estimates of stock status are typically obtained by fitting statistical models of stock dynamics to survey and fishery data. In recent years, the bulk of stock status determinations have been based on Stock Synthesis II, an age- and size-structured population dynamics model (Methot 2005, 2007). Stock assessment models can be fitted using Maximum Likelihood or Bayesian methods. For both types of estimation methods, a stock is considered to be in an overfished state if the best point estimate of stock size is less than 25% of unfished stock size. This corresponds to the maximum likelihood estimate for estimation methods based on Maximum Likelihood methods, to the maximum of the posterior distribution (MPD) for estimation methods in which penalties are added to the likelihood function, and to the mode of the posterior distribution for Bayesian analyses.

biology of any overfished stocks of fish, the needs of fishing communities, recommendations by international organizations in which the United States participates, and the interaction of the overfished stock of fish within the marine ecosystem" (Section 304(e)). The court opinion also recognized that some harvest of overfished species could be accommodated under rebuilding plans to avoid disastrous economic impacts to West Coast fishing communities dependent on groundfish fishing. This harvest can only be incidental and unavoidable in fisheries targeting healthy stocks and, under Amendment 16-4 rebuilding plans, more emphasis was placed on shorter rebuilding times and the trade-off between rebuilding periods and associated socioeconomic effects.

Rebuilding Plans include several components, one of which is a rebuilding analysis. Simply put, a rebuilding analysis involves projecting the status of the overfished resource into the future under a variety of alternative harvest strategies to determine the probability of recovery to B_{MSY} (or its proxy $B_{40\%}$) within a pre-specified time-frame.

2. Overview of the Calculations Involved in a Rebuilding Analysis

This document presents guidelines for conducting a basic groundfish rebuilding analysis that meets the minimum requirements that have been established by the Council's Scientific and Statistical Committee (SSC), those of Amendment 16-1 of the Groundfish FMP, and those arising from the 9th Circuit Court decision. It also outlines the appropriate documentation that a rebuilding analysis needs to include. These basic calculations and reporting requirements are essential elements in all rebuilding analyses to provide a standard set of base-case computations, which can then be used to compare and standardize rebuilding analyses among stocks. The steps when conducting a rebuilding analysis are:

1. Estimation of B_0 (and hence B_{MSY} or its proxy).
2. Selection of a method to generate future recruitment.
3. Specification of the mean generation time.
4. Calculation of the minimum possible rebuilding time, T_{MIN}.
5. Identification and analysis of alternative harvest strategies and rebuilding times.

The specifications in this document have been implemented in a computer package developed by Dr André Punt (University of Washington). This package can be used to perform rebuilding analyses for routine situations. However, the SSC encourages analysts to explore alternative calculations and projections that may more accurately capture uncertainties in stock rebuilding than the standards identified in this document, and which may better represent stock-specific concerns. In the event of a discrepancy between the generic calculations presented here and a stock-specific result developed by an individual analyst, the SSC groundfish subcommittee will review the issue and recommend which results to use.

The SSC also encourages explicit consideration of uncertainty in projections of stock rebuilding, including comparisons of alternative states of nature using decision tables to quantify the impact of model uncertainty (see Section 8 below).

3. Estimation of B_0

B_0, defined as mean unexploited spawning output, can be estimated from the fit of some form of spawner-recruit model or empirically using the estimates of recruitment from the stock assessment. Most of the recent assessments of west coast groundfish have been based on stock assessments that integrate the estimation of the spawner-recruit model with the estimation of other population dynamic parameters. These stock assessments therefore link the recruitments for the early years of the assessment period with the average recruitment corresponding to B_0. Estimates of B_0 from empirical methods will not be the same as those estimated as an embedded parameter within an assessment model. As a result, the estimate of B_0 from the stock assessment model should be the default for the B_0 used in rebuilding analyses when the stock assessment integrates the spawner-recruit model. Justification for the use an empirical estimate of B_0 is therefore needed when a direct estimate of B_0 is available from a stock assessment model, and the difference in B_0 estimates must also be documented. Stock assessment models which integrate the estimation of the spawner-recruit model also provide estimates of B_{MSY}. However, at this time, the SSC recommends that these estimates not be used as the target for rebuilding. Rather, the rebuilding target should be taken to be $0.4B_0$ in all cases.

For the purpose of estimating B_0 empirically, analysts should select a sequence of years, within which recruitment is believed to be reasonably representative of the natality from an unfished stock. The average recruitment for these years can then be multiplied by the spawning output-per-recruit in an unfished state (which depends on growth, maturity, fecundity and natural mortality) to estimate equilibrium unfished spawning output. In selecting the appropriate sequence of years, analysts have generally utilized years in which stock size was relatively large, in recognition of the paradigm that groundfish recruitment is positively correlated with spawning stock size (Myers and Barrowman 1996). Moreover, due to the temporal history of exploitation in the West Coast groundfish fishery (see Williams 2002), this has typically led to consideration of the early years from an assessment model[3]. Thus, for example, in the case of widow rockfish, the time period within which recruitments were selected when estimating B_0 was 1958-62 (He *et al*. 2003).

An alternative view of the recruitment process is that it depends to a much greater degree on the environment than on adult stock size. For example, the decadal-scale regime shift that occurred in 1977 (Trenberth and Hurrell 1994) is known to have strongly affected ecosystem productivity and function in both the California Current and the northeast Pacific Ocean (Roemmich and McGowan 1995; MacCall 1996; Francis *et al*. 1998; Hare *et al*. 1999). With the warming that ensued, West Coast rockfish recruitment appears to have been adversely affected (Ainley *et al*. 1993; Ralston and Howard 1995). Thus, if recruitment was environmentally forced, it would be more sensible to use the full time series of recruitments from the stock assessment model to estimate B_0. These two explanatory factors are highly confounded for West Coast groundfish, i.e., generally high biomass/favourable conditions prior to 1980 and low biomass/unfavourable

[3] Individual recruitments estimated from age-structured stock assessment models do not all exhibit the same precision or accuracy. Recruitments estimated at the very beginning of the modeled time period may suffer from mis-specification of the initial condition of the population (e.g., an assumed equilibrium age structure). Likewise, recruitments estimated at the end of the sequence may be imprecise due to partial recruitment of recent year classes. Thus, it may be advisable to trim the beginning and/or ending year-classes to address this problem

conditions combined with increasing fishing impacts on groundfish stocks thereafter. Using all recruitments to estimate B_0 will therefore usually result in a lower value of B_0 (and hence target spawning output) than when an abbreviated series of recruitments is taken from early in the time series.

There is no incontrovertible evidence to favour one of these two hypotheses over the other. For example, both theoretical and observational considerations support the view that groundfish recruitment will decline with spawning output (e.g., Myers and Barrowman 1996; Brodziak *et al*. 2001). On the other hand, recent advances in our understanding of the North Pacific Ocean indicate that profound changes have occurred in the marine ecosystem since the turn of the last century (PICES 2005). In fact, an argument can be made that the effects of environmental and density-dependent factors on the spawner-recruit relationship are additive (e.g., Jacobson and MacCall 1995), which may allow us to quantitatively determine the relative importance of these two factors in the future.

For each of these two empirical methods of estimating B_0, the actual distribution for B_0 can be approximated by re-sampling recruitments, from which the probability of observing any particular stock biomass can be obtained. This approach was taken in the original bocaccio rebuilding analysis (MacCall 1999), where it was concluded that the first year biomass was unlikely to have occurred if the entire sequence of recruitments were used to determine B_0.

4. Selection of a Method to Generate Future Recruitment

On can project the population forward once the method for generating future recruitment has been specified, given the current state of the population from the most recent stock assessment (terminal year estimates of numbers at age and their variances) and the rebuilding target. There are several ways of generating future recruitment, but they fundamentally reduce to two basic kinds of approaches. These are: (1) base future recruitments on an empirical evaluation of spawner-recruit estimates and (2) use the results of a fitted spawner-recruit model (e.g., the Beverton-Holt or Ricker curves). To date, rebuilding analyses have been conducted using both approaches, and both are acceptable, as long as due consideration is given to the advantages and disadvantages of both. Ideally, reference points (e.g., B_0, B_{MSY} and F_{MSY}) and the results from projections should be compared to better assess the actual extent of uncertainty associated with these quantities.

4.1 Fitting a Spawner-Recruit Model

It is possible generate future recruitments by fitting spawner-recruit models to the full time series of spawner-recruit data. SS2-based assessments all assume a structural spawner-recruit model, either estimating or pre-specifying the steepness of the curve[4]. Ideally, the use of spawner-recruit models allows the data (or prior information) to determine the extent of compensation rather than assuming either one of two extremes (constant recruitment or constant recruits/spawner), and is also more internally consistent if the original assessment assumed a particular form of spawner-

[4] The "steepness" of a spawner-recruit curve is related to the slope at the origin and is a measure of a stock's productive capacity. It is expressed as the proportion of virgin recruitment that is produced by the stock when reduced to $B_{20\%}$, and ranges between 0.2 and 1.0.

recruit model. However, this approach can be criticized because stock productivity is constrained to behave in a pre-specified manner according to the particular spawner-recruit model chosen, and there are different models to choose from, including the Beverton-Holt and Ricker formulations. These two models can produce very different reference points, but are seldom distinguishable statistically. Moreover, there are statistical issues when a spawner-recruit model is estimated after the assessment is conducted, including: (1) time-series bias (Walters 1985), (2) the "errors in variables problem" (Walters and Ludwig 1981), and (3) non-homogeneous variance and small sample bias (MacCall and Ralston 2002). Thus, analyses based on a spawner-recruit model should include a discussion of the rationale for the selection of the spawner-recruit model used (e.g. estimated within the assessment model, estimated outside of the model based on the estimates of spawning output and recruitment), and refer to the estimation problems highlighted above and whether they are likely to be relevant and substantial for the case under consideration. A rationale for the choice of spawner-recruit model should also be provided. In situations where steepness is based on a spawner-recruit meta-analysis (e.g., Dorn 2002), the reliability of the resulting relationship should be discussed.

4.2 Empirical Approaches

There are two ways to use empirical estimates of recruitment from a stock assessment to generate future recruitment, both of which utilize estimates at the tail end of the time series (i.e., the most recent estimates). These two methods have formed the basis of several rebuilding analyses that have been accepted by the SSC.

(1) Recent recruitment is standardized to the amount of the spawning output (recruits-per-spawner, R/S_i). Annual R/S_i is then randomly re-sampled and multiplied by S_i to obtain year-specific stochastic values of R_i.
(2) Recent recruitments are randomly re-sampled to determine the year-specific stochastic values of R_i.

Note that use of R/S_i as the basis for projecting the population forward ties recruitment values in a directly proportional manner to spawning output; if spawning output doubles, resulting recruitment will also double, all other things being equal. As the stock rebuilds, this becomes an increasingly untenable assumption because there is no reduction in reproductive success at very high stock sizes, which is to say there is no compensation (i.e., steepness = 0.2). In contrast, re-sampling R_i values, results in errors in the opposite direction. Namely, recruitment does not increase as stock size increases as would be expected of most rebuilding stocks. This type of calculation effectively implies perfect compensation (i.e., steepness = 1). Thus, these two ways of projecting the population forward (using re-sampled R_i or re-sampled R/S_i) bracket the range of population responses that are likely to occur in the real world. The method selected to generate future recruitment should ensure that potential recruitment values are consistent with stock sizes between the current level and the rebuilding target, i.e., they would be considered plausible throughout the duration of rebuilding projection.

5. Determination of the Minimum and Maximum Times to Recovery

The minimum time to recovery (denoted T_{MIN}) is defined as the median time for a stock to recover to the target stock size, starting from the time when a rebuilding plan was actually implemented (usually the year after the stock was declared overfished) to when the target level is first achieved, assuming no fishing occurs. Next, the mean generation time should be calculated as the mean age of the net maturity function. A complication that can occur in the calculation of mean generation time, as well as B_0 (see above), is when growth and/or reproduction have changed over time. In such instances, the parameters governing these biological processes should typically be fixed at their most recent, contemporary, values, as this best reflects the intent of "prevailing environmental conditions" as stated in the NMFS Guidelines for National Standard 1. Exceptions may occur if there are good reasons for an alternative specification (e.g., using growth and maturity schedules that are characteristic of a stock that is close to B_{MSY}).

Although no longer used directly in Council decision-making for overfished stocks, rebuilding analyses should report the maximum time to recovery (denoted T_{MAX}). T_{MAX} is ten years if T_{MIN} is less than 10 years. If T_{MIN} is greater than or equal to 10 years, T_{MAX} is equal to T_{MIN} plus one mean generation. Likewise, rebuilding analyses should report an estimate of the median number of years needed to rebuild to the target stock size if all future fishing mortality is eliminated from the first year for which the Council is making a decision about[5] ($T_{F=0}$). This will typically differ from T_{MIN}.

Finally, when a stock rebuilding plan has been implemented for some time and recruitments have been estimated from an assessment, it may be that explicit, year-specific estimates of recruitment are available for the earliest years of the rebuilding time period. In such instances, rebuilding forecasts should be conducted setting the recruitments from the start of the rebuilding plan to the current year based on the estimates from the most recent assessment, rather than through re-sampling methods (see above).

6. Harvest During Rebuilding

The Council is required to rebuild overfished stocks in a time period that is as short as possible, but can extend this period to take into account the needs of fishing communities. The simplest rebuilding harvest strategy to simulate and implement is a constant harvest rate or "fixed F" policy. All rebuilding analyses should, therefore, consider fixed F strategies. Other strategies are possible, including constant catch and phase-in strategies, in which catch reductions are phased-in before the OYs transition to a fixed F strategy. In these latter cases, analysts should always assess whether fishing mortality rates exceed F_{MSY} (or its proxy), as this would constitute overfishing.

Analysts should consider a broad range of policy alternatives to give the Council sufficient scope on which to base a decision. The following represent a minimum set of harvest policies that should be reported:

[5] This year will generally not be the current year, but rather the year following the current two-year cycle.

1. The spawning potential ratio[6] listed in the Rebuilding Plan in the FMP (Amendment 16-4 for the stocks that are currently overfished) [only stocks already under rebuilding plans].
2. The spawning potential ratio corresponding to the optimum yields adopted for the current year (or biennium) [only stocks already under rebuilding plans].
3. The spawning potential ratio on which the current optimum yields were based [only stocks already under rebuilding plans; this spawning potential ratio will differ from that in 2) if the stock assessment has changed substantially since the last assessment].
4. The spawning potential ratio which will rebuild the stock to the target level with 0.5 probability by the T_{TARGET} specified in the FMP [only stocks already under rebuilding plans].
5. The spawning potential ratio which will rebuild the stock to the target level with 0.5 probability by the T_{MAX} specified in the FMP [only stocks already under rebuilding plans].
6. The spawning potential ratio which will rebuild the stock to the target level with 0.5 probability by the T_{MAX} calculated using the most recent biological and fishery information.
7. The ABC and 40:10 control rules.
8. No harvest.
9. Spawning potential ratios which achieve recovery to the target level with 0.5 probability for years between $T_{\mathrm{F=0}}$ and T_{MAX}. These spawning potential ratios should be selected by calculating the median rebuilding times under the most conservative rebuilding strategy (i.e., $T_{\mathrm{F=0}}$) and the most liberal, allowable rebuilding strategy (i.e. T_{MAX}) and then selecting intermediate time intervals in even quartile increments. That is, if $T_{\mathrm{F=0}}$ is 20 years and T_{MAX} = 60 years, then the intermediate alternatives would have rebuilding times of 30, 40 and 50 years, respectively.

These polices should be implemented within the projection calculations in the year for which the Council is making a decision. For example, for assessments conducted in 2009 (using data up to 2008), the harvest decisions pertain to OYs for 2011 and 2012. In this case, the catches for 2009 and 2010 should be set to the OYs established by the Council for those years.

Many other harvest policies could be implemented by the Council, based on whatever circumstances may mitigate against a constant harvest rate approach. Consequently, analysts should be prepared to respond to requests by the Council for stock-specific projections on an individual case-by-case basis.

7. Evaluating Progress Towards Rebuilding

There are no agreed criteria for assessing the adequacy of the progress towards rebuilding for species that are designated to be in an overfished state and are under a Rebuilding Plan. The SSC currently reviews each stock on a case-by-case basis, considering the following two questions: (1) have cumulative catches during the period of rebuilding exceeded the cumulative OY that was available, and (2) what is the difference between the year in which recovery is predicted to

[6] The Spawning Potential Ratio (SPR) is a measure of the expected spawning output-per-recruit, given a particular fishing mortality rate and the stock's biological characteristics, i.e., there is a direct mapping of SPR to F (and *vice versa*). SPR can therefore be converted into a specific fishing mortality rate in order to calculate OYs.

occur under the current SPR (T_{REBUILD}) and the current adopted T_{TARGET}? If the difference between T_{REBUILD} and T_{TARGEST} is minor, progress towards rebuilding will be considered to be adequate. In contrast, if the difference between T_{REBUILD} and T_{TARGET} is major, it will be necessary to define a new T_{TARGET}. As an initial step in this direction, a new maximum time to rebuild T_{MAX}^{N} will be computed based on the specifications outlined in Section 5. Analysts will be asked to assess whether the currently adopted SPR will readily rebuild the stock before T_{MAX}^{N}.

Adequacy of progress will be evaluated when the SSC groundfish subcommittee reviews the draft rebuilding plans. Analysts should provide the information needed to address the two questions listed above. If the SSC agrees that progress is not sufficient, the draft rebuilding analysis documents will need to be updated to include T_{MAX}^{N} and the probability that the currently adopted harvest rate (SPR) will rebuild the stock before T_{MAX}^{N}.

8. Decision Analyses / Considering Uncertainty

The calculation of T_{MIN} and the evaluation of alternative harvest strategies involve projecting the population ahead taking account of uncertainty about future recruitment. There are several reasons for considering model and parameter uncertainty when conducting a rebuilding analysis. For example, if several assessment model scenarios were considered equally plausible by the assessment authors or, alternatively, one model was preferred by the assessment authors and another was preferred by the STAR Panel.

The uncertainty associated other parameters, such as the rate of natural mortality and the current age-structure of the population, can also be taken into account. This can be achieved in a variety of ways. For example, if the uncertainty relates to the parameters within one structural model, this uncertainty can be reflected by basing projections on a number of samples from a distribution which reflects this uncertainty (such as a Bayesian posterior distribution or bootstrap samples). Alternatively, projections can be conducted for each model and the results appropriately weighted when producing the final combined results if the uncertainty pertains to alternative structural models.

A decision table is an appropriate means to express the implications of uncertainty in model structure when an "integrated" approach, as outlined in the previous paragraph, is not adopted. Construction of decision tables when projections are based on a constant harvest rate policy is, however, not entirely straightforward. One way to achieve this is to conduct projections for each alternative model in turn and record the median (or mean) time-trajectory of catches. The decision table is then based on projections with a set of pre-specified time-series of catches. If probabilities were assigned to each alternative model by the assessment authors and STAR Panel, these must be reported with the decision table.

9. Documentation

It is important for analysts to document their work so that any rebuilding analysis can be repeated by an independent investigator at some point in the future. Therefore, all stock assessments and rebuilding analyses should include tables containing the specific data elements that are needed to adequately document the analysis. Clear specification of the exact assessment scenario(s) used as the basis for the rebuilding analysis is essential. Therefore, linkages with the most recent stock assessment document should be clearly delineated (e.g., through references to tables or figures). This is important because assessments often include multiple scenarios that usually have important implications with respect to stock rebuilding.

The minimum information that should be presented in a rebuilding analysis is:

- Date on which the analysis was conducted, and specifications for the software used for the analysis (including the version number), along with an example of the program's input file, ideally for the base (most likely) case. Documentation and basis for the number of simulations on which the analyses are based should also be provided. The software and data files on which the rebuilding analyses are based should archived with the stock assessment coordinator.
- Rebuilding parameters. For each alternative model, a table (see Table 1 for an example based on canary rockfish) should be produced which lists: (a) the year in which the rebuilding plan commenced, (b) the present year, (c) the first year that the evaluated harvest policy calculates OY, (d) T_{MIN}, (e) mean generation time, (f) T_{MAX}, (g) $T_{\mathrm{F=0}}$, (h) the estimate of B_0 and the target recovery level, (i) the current SPR, (j) the current $\mathrm{T}_{\mathrm{TARGET}}$ and (k) the estimate of current stock size.
- Results of harvest policy projections (see, for examples, Tables 2-5; Figures 1-3). The following information should be provided for each harvest policy evaluated: (a) the year in which recovery to the target level occurs with 0.5 probability, (b) the SPR for the first year of the projection period, (c) the probably of recovery by the current $T_{\mathrm{TARGET,}}$ (d) the probably of recovery by the current T_{MAX}, (e) tables of median time-trajectories (from the present year to T_{MAX}) of: (i) spawning output relative to the target level, (ii) probability of being at or above the target level, (iii) ABC, and (iv) optimum yield. Median time-trajectories of SPR should be provided for the projection based on the 40:10 rule and any phase-in harvest policies that have been specified.
- The information needed to assess progress towards rebuilding (e.g. catches and OYs during the rebuilding period) and any additional information based on the review of adequacy of progress by the SSC (e.g. T_{MAX}^{N}).
- Median and 95% intervals for: (a) summary / exploitable biomass, (b) spawning output (in absolute terms and relative to the target level), (c) recruitment, (d) catch, (e) landings (if different from catch), (f) ABC, and (g) SPR for the actual harvest strategy selected by the Council.
- The rationale for the approach used to estimate B_0 and to generate future recruitment.
- The biological information on which the projections are based (show results for each alternative model):
    - Natural mortality rate by age and sex.
    - Individual weight by age and sex.
    - Maturity by age.
    - Fecundity by age.
    - Selectivity-at-age by sex (and fleet).
    - Population numbers (by age and sex) for the year the rebuilding plan commenced.
    - Population numbers (by age and sex) for the present year.

- o How fishing mortality was allocated to fleet for rebuilding analyses based on multiple fleets.

Notes:

- Much of the biological information will be stored in the input file for the projection software and doesn't need to be repeated unless there is good reason to do so.
- For cases in which the projections take account of uncertainty about the values for the biological parameters (e.g., using the results from bootstrapping or samples from a Bayesian posterior distribution), some measure of the central tendency of the values (e.g., the mode or median) should be provided and the individual parameter values should be archived with the stock assessment coordinator.
- Rebuilding analyses may be based on selectivity-at-age vectors constructed by combining estimates over fleets. If this is the case, the rebuilding analysis needs to document how the composite selectivity-at-age vector was constructed.

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Table 1. Summary of rebuilding reference points for canary rockfish (based on Stewart (2007)).

Parameter	Values
Year declared overfished	2000
Current year	2007
First OY year	2009
T_{MIN}	2019
Mean generation time	22
T_{MAX}	2041
$T_{F=0}$ (beginning in 2009)	2019
B_0	32,561
Rebuilding target ($B_{40\%}$)	13,024
Current SPR	0.887
Current T_{TARGET}	2063
SB_{2007}	10,544

Table 2. Results of rebuilding alternatives for canary rockfish (based on Stewart (2007)).

	Run #			
	1	2	3	4
50% prob. recovery by:	2019	2021	2035	2041
SPR_{TARGET}	100%	88.7%	62.0%	59.2%
2009 OY (mt)	0.0	155.2	636.9	700.0
2009 ABC (mt)	936.9	936.9	936.9	936.9
2010 OY (mt)	0.0	155.0	623.1	683.1
2010 ABC (mt)	941.4	935.4	916.7	914.2
Probability of recovery				
2071 (T_{MAX})	97.1%	84.6%	73.5%	70.0%
2048 (T_{MIN})	76.4%	75.0%	64.8%	56.9%
2053 ($T_{F=0}$ from 2007)	79.4%	75.3%	67.9%	61.3%
2063 (T_{TARGET})	91.4%	78.8%	72.0%	66.8%

Table 3. Probability of recovery for four rebuilding alternatives for canary rockfish (based on Stewart (2007)). Note that after 25 years the table is compressed.

	Run #			
	1	2	3	4
2007	0.250	0.250	0.250	0.250
2008	0.250	0.250	0.250	0.250
2009	0.250	0.250	0.250	0.250
2010	0.250	0.250	0.250	0.250
2011	0.250	0.250	0.250	0.250
2012	0.250	0.250	0.250	0.250
2013	0.250	0.250	0.250	0.250
2014	0.250	0.250	0.250	0.250
2015	0.250	0.250	0.250	0.250
2016	0.251	0.250	0.250	0.250
2017	0.284	0.257	0.250	0.250
2018	0.407	0.288	0.250	0.250
2019	0.550	0.366	0.250	0.250
2020	0.660	0.473	0.256	0.251
2021	0.702	0.561	0.260	0.256
2022	0.732	0.633	0.267	0.261
2023	0.742	0.681	0.279	0.267
2024	0.746	0.707	0.290	0.275
2025	0.749	0.725	0.309	0.281
2026	0.749	0.735	0.321	0.293
2027	0.749	0.742	0.341	0.300
2028	0.750	0.746	0.358	0.313
2029	0.750	0.746	0.376	0.324
2030	0.750	0.747	0.402	0.336
2031	0.750	0.749	0.424	0.348
2041	0.750	0.750	0.586	0.500
2051	0.781	0.751	0.671	0.601
2061	0.895	0.776	0.714	0.660
2071	0.971	0.846	0.735	0.700

Table 4. Median spawning biomass (mt) for four rebuilding alternatives for canary rockfish (based on Stewart (2007)). Note that after 25 years the table is compressed.

	Run #			
	1	2	3	4
2007	10,544	10,544	10,544	10,544
2008	10,841	10,841	10,841	10,841
2009	11,073	11,073	11,073	11,073
2010	11,258	11,197	11,010	10,985
2011	11,383	11,260	10,880	10,831
2012	11,463	11,274	10,701	10,627
2013	11,524	11,268	10,501	10,403
2014	11,607	11,280	10,318	10,197
2015	11,751	11,351	10,186	10,041
2016	11,987	11,508	10,133	9,964
2017	12,328	11,765	10,163	9,969
2018	12,738	12,089	10,251	10,029
2019	13,181	12,432	10,357	10,113
2020	13,685	12,838	10,520	10,247
2021	14,236	13,293	10,721	10,419
2022	14,773	13,731	10,909	10,583
2023	15,350	14,210	11,130	10,775
2024	15,941	14,674	11,345	10,966
2025	16,500	15,133	11,515	11,105
2026	17,015	15,536	11,679	11,251
2027	17,517	15,959	11,852	11,391
2028	18,045	16,348	11,999	11,515
2029	18,600	16,811	12,211	11,699
2030	19,093	17,183	12,329	11,799
2031	19,528	17,519	12,432	11,877
2041	23,511	20,635	13,491	12,751
2051	26,282	22,743	14,238	13,357
2061	27,862	24,058	14,655	13,689
2071	28,903	24,832	15,097	14,073

Table 5. Median catches (mt) for four rebuilding alternatives for canary rockfish (based on Stewart (2007)). Note that after 25 years the table is compressed.

	Run #			
	1	2	3	4
2007	0.0	44.0	44.0	44.0
2008	0.0	44.0	44.0	44.0
2009	0.0	155.2	636.9	700.0
2010	0.0	155.0	623.1	683.1
2011	0.0	157.5	621.9	680.2
2012	0.0	163.7	635.4	693.4
2013	0.0	171.5	654.9	713.1
2014	0.0	179.7	675.9	734.4
2015	0.0	186.9	691.6	750.1
2016	0.0	193.4	705.3	763.1
2017	0.0	198.7	713.8	770.8
2018	0.0	205.1	724.3	780.5
2019	0.0	210.6	733.9	789.5
2020	0.0	216.8	744.3	798.9
2021	0.0	222.0	753.8	807.8
2022	0.0	228.3	765.2	818.8
2023	0.0	234.0	769.3	821.3
2024	0.0	239.0	778.8	830.7
2025	0.0	245.3	786.9	837.4
2026	0.0	250.0	795.2	845.3
2027	0.0	257.0	807.6	856.9
2028	0.0	261.7	814.0	862.9
2029	0.0	267.3	821.5	868.6
2030	0.0	272.3	830.5	877.2
2031	0.0	276.5	836.3	882.5
2041	0.0	318.0	897.1	938.2
2051	0.0	346.9	937.3	972.9
2061	0.0	365.2	967.1	1,002.9
2071	0.0	377.7	985.9	1,019.3

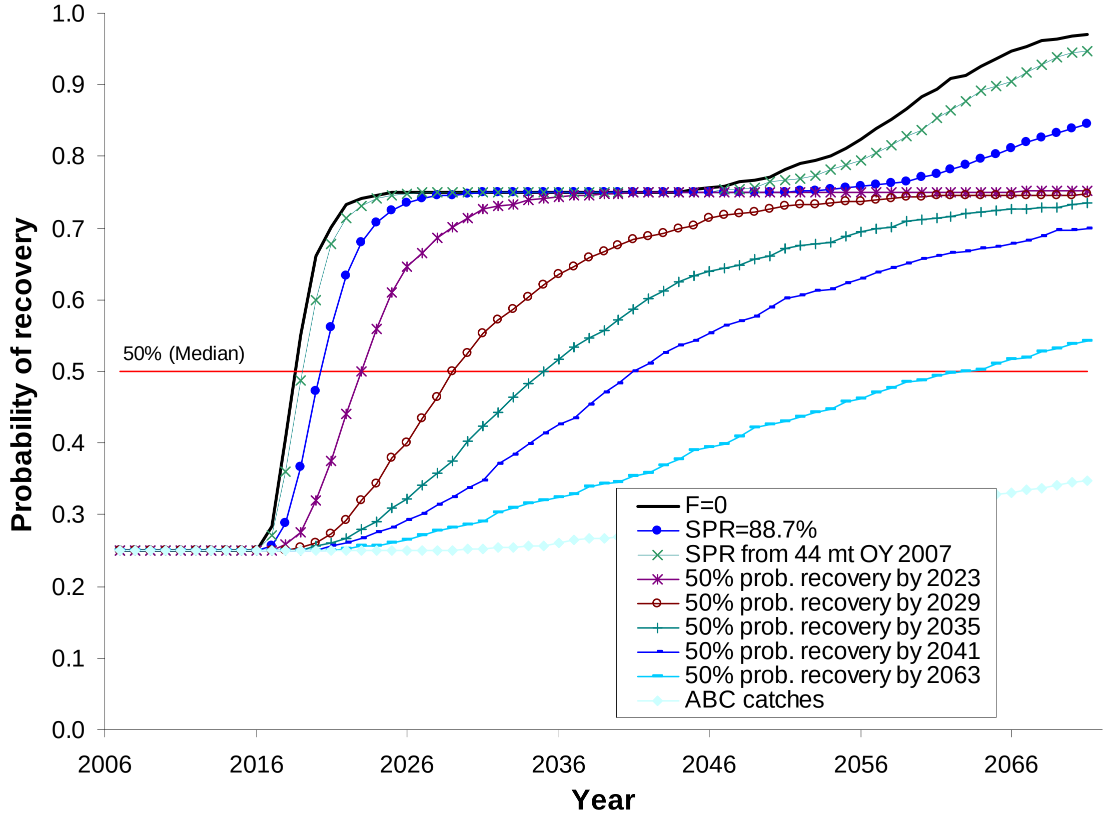

Figure 1. Probability of recovery for nine rebuilding alternatives for canary rockfish.

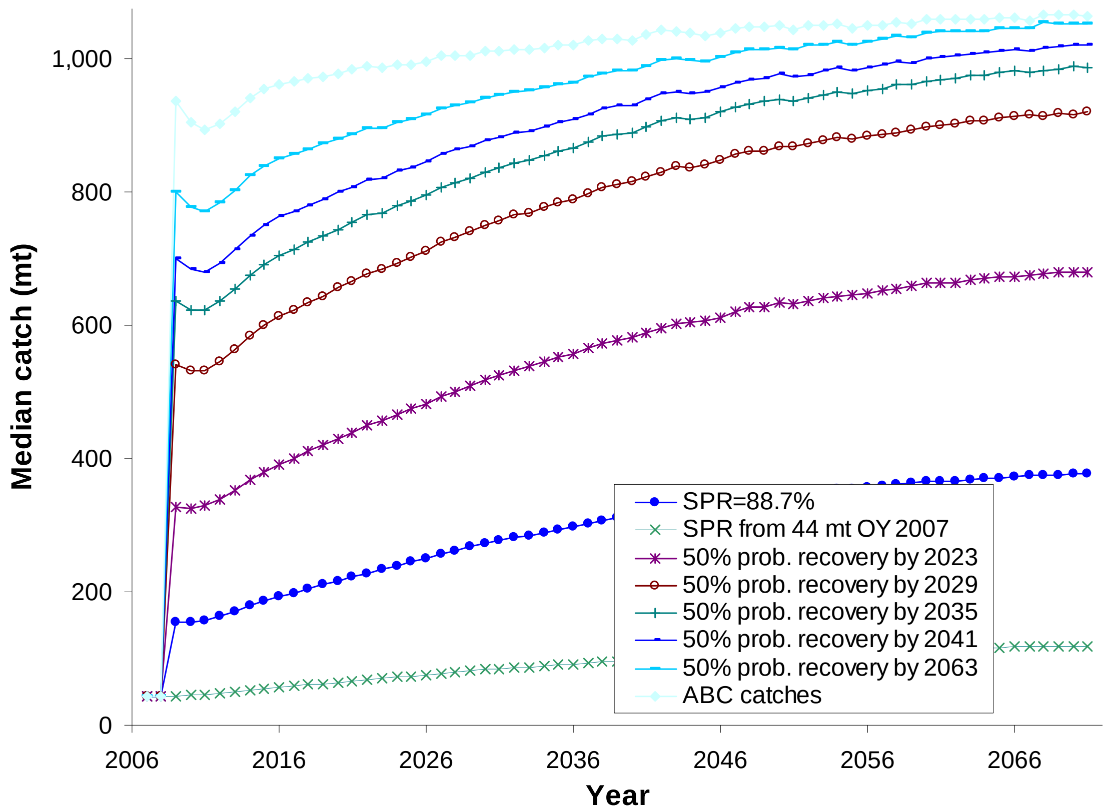

Figure 2. Projected median catch (mt) for nine rebuilding alternatives for canary rockfish.

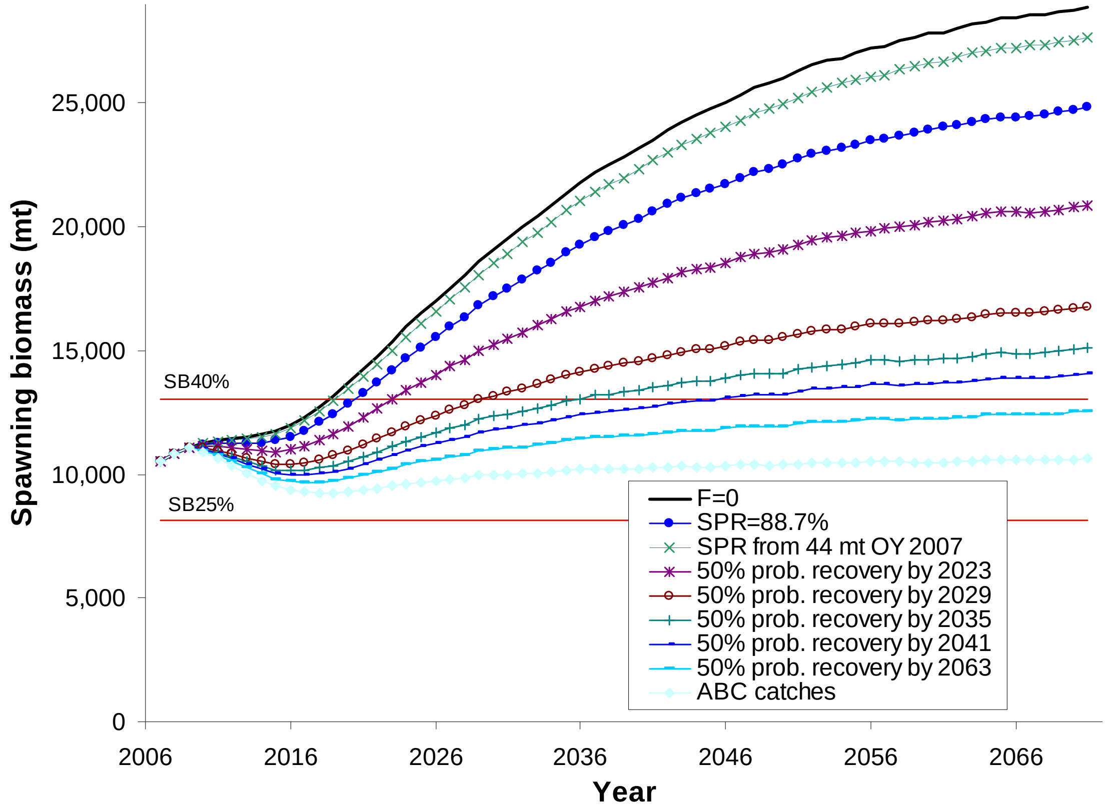

Figure 3. Projected median spawning biomass (mt) for nine rebuilding alternatives for canary rockfish.