

**DRAFT**  
**SSC Terms of Reference for Groundfish Rebuilding**  
**Analysis**

**Draft Revised Version**  
**(xx March 2008)**

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 current not known.

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# 1. Introduction

Amendment 11 to the Groundfish Fishery Management Plan (FMP) established a harvest control rule for determining optimum yields (OY). 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<sup>1</sup> ( $B_0$ ). By definition, groundfish stocks falling below that level are designated to be in an overfished state ( $B_{25\%} = 0.25 \times B_0$ <sup>2</sup>). 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 simply 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 (9<sup>th</sup> 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 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

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<sup>1</sup> 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). 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.

<sup>2</sup> 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, and the maximum of the posterior distribution (MPD) for estimation methods based on Bayesian methods or those in which penalties are added to the likelihood function.

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 9<sup>th</sup> Circuit 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 harvest strategies using decision tables to quantify the impact of model uncertainty (see Section 8 below).

## **3. Estimation of $B_0$**

$B_0$  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 of 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<sup>3</sup>. 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 conditions 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 belief that groundfish recruitment will decline with spawning output (e.g., Myers and Barrowman 1996; Brodziak *et al.*

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<sup>3</sup> 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 years classes to address this problem

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 century (PICES 2005). In fact, a strong 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

One 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 to 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<sup>4</sup>. 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-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

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<sup>4</sup> 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 typically is expressed as the proportion of virgin recruitment that remains when a stock has been reduced to  $B_{20\%}$ .

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. 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 a number of 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  $R/S_i$ ) includes a range of alternatives that is likely to encompass the real world.

In the absence of any other information, rebuilding projections based on re-sampling recruits-per-spawner are generally to be favoured over projections based resampling recruitment because stocks that have declined into an overfished condition are more likely to be unproductive (i.e., low steepness). Note that the implied lack of compensation in rebuilding projections using this method is not likely to be a serious liability over the long term because it is based on re-sampling recent recruits-per-spawner. The set of  $R/S_i$  values used to generate future recruitment will be revised based on a new set of recent recruitments obtained from the latest stock assessment as progress toward rebuilding is evaluated in the future. The  $R/S_i$  series will tend to a lower mean value if the stock actually demonstrates a compensatory response during the course of rebuilding. Although projections based on resampling  $R/S_i$  represents a logical standard procedure, projections that resample absolute recruitment ( $R_i$ ) would be quite useful in establishing the overall uncertainty in the rebuilding analysis by providing an alternative approach. Moreover, a credible argument that a stock is relatively productive, as evidenced perhaps by observed high recruitment at low spawning output, may serve as a basis for favouring projections that utilize recent absolute recruitments.

## 5. Determination of the Minimum and Maximum Times to Recovery

The minimum time to recovery (denoted  $T_{\text{MIN}}$ ) 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 “current environmental conditions” as stated in the NOAA Fisheries National Standard Guidelines. 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  $B_{\text{MSY}}$ ).

Although no longer used directly in Council decision-making for overfished stocks, rebuilding analyses should report the maximum time to recovery (denoted  $T_{\text{MAX}}$ ).  $T_{\text{MAX}}$  is ten years if  $T_{\text{MIN}}$  is less than 10 years. If  $T_{\text{MIN}}$  is greater than or equal to 10 years,  $T_{\text{MAX}}$  is equal to  $T_{\text{MIN}}$  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<sup>5</sup> ( $T_{\text{F}=0}$ ). This will typically differ from  $T_{\text{MIN}}$ .

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 using actual “realized” recruitments for years for which they are available, rather than through re-sampling methods (see above). The manner in which this is achieved will depend on how future recruitments are generated in the rebuilding analysis: (1) use the absolute recruitments if recent recruitments are re-sampled, (2) use the  $R/S_i$  values for each year multiplied by the projected  $S_i$  if recruits-per-spawner are re-sampled, and (3) use the recruitment deviation for each year if future recruitment is generated from a spawner-recruit model.

## 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 the needs of fishing communities into account. 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 the 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  $F_{\text{MSY}}$  (or its proxy), as this would constitute overfishing.

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<sup>5</sup> This year will generally not be the current year, but rather the year following the current two-year cycle.

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:

1. The spawning potential ratio<sup>6</sup> 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 in place for the most current year (or biennium) [only stocks already rebuilding plans].
3. The spawning potential ratio on which the current optimum yields were based [only stock already rebuilding plans; this spawning potential ratio will differ from 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  $T_{F=0}$  and  $T_{MAX}$ . These spawning potential ratios should be selected by calculating the median rebuilding times under the most conservative rebuilding strategy (i.e.  $T_{F=0}$ ) and the most liberal, allowable rebuilding strategy (i.e.  $T_{MAX}$ ) and then selecting intermediate time intervals in even quartile increments. That is, if  $T_{F=0}$  is 20 years and  $T_{MAX} = 60$  years, then the intermediate alternatives would have rebuilding times of 30, 40 and 50 years, respectively.

These policies should be implemented within the projection calculations in the year for which the Council is making a decision. For example, for assessments conducted in 2007 (using data up to 2006), the harvest decisions pertain to OYs for 2009 and 2010. In this case, the catches for 2007 and 2008 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, at present, 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

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<sup>6</sup> 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.

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 occur under the current SPR ( $T_{REBUILD}$ ) and the current adopted  $T_{TARGET}$ ? If the difference between  $T_{REBUILD}$  and  $T_{TARGET}$  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. 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 likelihood 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 involves 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 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 be archived with the stock assessment coordinator.
- Rebuilding parameters. For each alternative model, a table 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)  $T_{F=0}$ , (h) the estimate of  $B_0$  and the target recovery level, and (i) the estimate of current stock size.
- Results of harvest policy projections. 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 probability of recovery by the current  $T_{TARGET}$ , (d) the probability 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.
  - 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 combing 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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