TERMS OF REFERENCE

FOR THE

GROUNDFISH REBUILDING ANALYSIS FOR 2025-26

DRAFT MARCH 2024

Published by the Pacific Fishery Management Council

Please cite this publication as:

Pacific Fishery Management Council (PFMC). 2024. Terms of Reference for the Groundfish Rebuilding Analysis for 2025-2026. Pacific Fishery Management Council, Portland, Oregon. XX p.

Commented [1]: Update in Final version once all edits complete.

TABLE OF CONTENTS

Acronyms Used in the Document

The following will include a list of common acronyms used in this document.

ABC – Acceptable Biological Catch
ACL – Annual Catch Limit
ACT – Annual Catch Target
FMP – Groundfish Fishery Management Plan
GMT – Groundfish Management Team
MSA – Magnuson-Stevens Fishery Conservation and Management Act
MSY – Maximum Sustainable Yield
mt – Metric tons
NMFS – National Marine Fisheries Service
OFL – Overfishing Limit
PFMC – Pacific Fishery Management Council
SPR – Spawning Potential Ratio
SSC – Scientific and Statistical Committee
STAR – Stock Assessment Review (panel)

1. INTRODUCTION

Amendment 11 to the Pacific Coast Groundfish Fishery Management Plan (FMP) established a default overfished threshold equal to 25% of the unexploited female spawning output[1] (B_0), or 50% of B_{MSY}, if known. By definition, groundfish stocks falling below that level were designated to be in an overfished state ($B_{25\%} = 0.25 \times B_0$[2]). To reduce the likelihood that stocks would decline to that point, the policy specified a precautionary threshold equivalent to 40% of B_0. The policy required that the annual catch limit (ACL), when expressed as a fraction of the allowable biological catch, 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 female spawning output that results when a stock is fished at F_{MSY}. In fact, theoretical results support the view that a robust biomass-based harvesting strategy for most rockfish (*Sebastes* spp.) 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 for most groundfish.

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) requires that U.S. fishery management councils avoid overfishing by setting ~~annual catch limits (~~ACLs~~)~~. Stock assessments provide overfishing l~~evel~~imit (OFL) estimates, and an acceptable biological catch (ABC) is derived from the OFL by reducing the OFL to account for scientific uncertainty. The ACL cannot exceed the ABC.

Following the 2008 assessment season, the Pacific Fishery Management Council ("Council") revised the reference points for flatfish, as separate from other groundfish species. The reference points include a ~~n~~ maximum sustainable yield (MSY) proxy fishing rate of $F_{30\%}$, a target spawning output of $B_{25\%}$ and an overfished threshold of $B_{12.5\%}$. Similarly, the 40:10 policy has been replaced by a 25:5 policy for flatfish.

Under the MSA, rebuilding plans are required 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

[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 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 maternal 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 3, 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% (rockfish and roundfish) and 12.5% (flatfish) 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. The median of the Bayesian posterior is not used for determination of overfished status.

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 the 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 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 severe economic impacts to U.S. w~~W~~est c~~C~~oast fishing communities dependent on groundfish fishing. 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 p~~P~~lans 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) 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 and maximum times to recovery.
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 assumptions, calculations and projections that may more accurately capture uncertainties in stock rebuilding than the default 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 (see Section 8 below).

2.1. Estimation of B_0

B_0 is defined as mean unexploited female spawning output. The default approach for estimating B_0 for rebuilding analyses is to base it on some form of spawner-recruit model because most of the recent assessments of U.S. 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.

Stock assessment models that 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 because they may not be robust. Rather, the rebuilding target should be taken to be the agreed proxy for B_{MSY} (e.g., $0.4B_0$ for most groundfish stocks) in all cases.

The recruitment process depends on the environment in addition to female spawning output. 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, U.S. w~~W~~est c~~C~~oast rockfish recruitment appears to have been adversely affected (Ainley *et al*. 1993; Ralston and Howard 1995). In principle, B_0 and the approach used to generate future recruitment (see below) could take account of regime-shift effects on productivity. However, this would need to be justified (and the assumptions used for projection purposes would need to be consistent with those on which the assessment was based).

2.2. 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. The current default approach for generating future recruitment is to use the results of a fitted spawner-recruit model (e.g., the Beverton-Holt or Ricker curves), in particular because SS3-based assessments all assume a structural spawner-recruit model, either estimating or pre-specifying the steepness of the curve[3]. Moreover, this approach is consistent with that recommended above for setting B_0. This approach can, however, 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

[3] 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 $B_{20\%}$.

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, 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.

2.3. Specification of the Mean Generation Time

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}).

2.4. Calculation of the Minimum and Maximum Times to Recovery

The minimum time to recovery (denoted T_{MIN}) is defined as the median time (i.e., 50% probability) 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.

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[4] ($T_{F=0}$). 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) because this reflects the best available information regarding the recruitment during the rebuilding period.

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

2.5. Alternative Harvest Strategies 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. Such strategies should also mean that encounter rates with overfished species remain relatively constant over time, which is unlikely to be the case for constant catch strategies. All rebuilding analyses should, therefore, minimally consider fixed F (or spawning potential ratio [SPR]) strategies. However, many other strategies are possible, including constant catch and phase-in strategies, in which catch reductions are phased-in. 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 the set of harvest strategies which have been identified by the Council's Groundfish Management Team (GMT) – all rebuilding analyses should minimally include these strategies:

1) eliminate all harvest beginning in the next management cycle (i.e., estimate $T_{\mathrm{F=0}}$),
2) apply the harvest rate that would generate the ACL specified for the current year (i.e., the latest year specified in regulations),
3) apply the spawning potential ratio[5] or relevant harvest control rule in the current rebuilding plan,
4) apply the harvest rate that is estimated to lead to a 50% probability of recovery by the current T_{TARGET},
5) apply the harvest rate that is estimated to lead to a 50% probability of recovery by the T_{MAX} from the current cycle,
6) apply the harvest rate that is estimated to lead to a 50% probability of recovery by the T_{MAX} from the previous cycle,
7) apply the default (e.g., 40-10 or 25-5) harvest policy, and
8) apply the ABC harvest rate (i.e., F_{MSY} less the uncertainty buffer).

For all of these strategies, except for numbers 1 and 8, the median catch streams from each run should be used as the harvest strategy in a follow-up run to evaluate the result of following the actual catch advice from the harvest policies above. In other words each of strategies 2-7 should be run twice; once with a given sequence of harvest rates and then using the median catches obtained from the first run. If the catch for a given year under one of the harvest strategies exceeds the ABC for that year, the catch should be set to the ABC (this is done automatically in the rebuilding software).

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 2017 (using data up to 2016), the harvest decisions pertain to OFLs, ABCs and ACLs for 2019 and 2020. In this case, the

[5] 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 ACLs.

catches for 2017 and 2018 should be set to the ACLs established by the Council for those years. Rebuilding analyses should assume, as a default, full ACL removals under each harvest strategy for the projection period.

Commented [MB2]: This should be updated for the current cycle example years….

Many other harvest policies could be implemented by the Council. Consequently, analysts should be prepared to respond to requests by the Council for stock-specific projections on an individual case-by-case basis.

3. Evaluating Progress Towards Rebuilding

The National Standard 1 (NS1) guidelines advise the Secretary of Commerce may find that adequate rebuilding progress is not being made if:

(1) $F_{rebuild}$ or the annual catch limit (ACL) associated with $F_{rebuild}$ is being exceeded, and accountability measures (AMs) are not effective at correcting for the overages, nor addressing any biological consequences to the stock or stock complex resulting from the overage when it is known.

(2) The rebuilding expectations of the stock or stock complex have significantly changed due to new and unexpected information about the status of the stock.

Section 4.6.3.4 of the Pacific Coast Groundfish Fishery Management Plan codifies the NS1 guidelines and specifies the SSC and Council roles in evaluating rebuilding plans and updating key rebuilding parameters. The SSC currently reviews each new stock assessment, rebuilding analysis, and catch report for species managed under a rebuilding plan to determine whether the result of that model or models show a rebuilding trajectory that varies from the previously-predicted trajectory to a significant degree. If the variation between the stock assessments and rebuilding analyses for a particular species do not show significant differences in the rebuilding trajectory for that species, the Council will likely not need to revise the T_{TARGET} or harvest control rule for that species. The Council considers the SSC advice and makes their recommendations on adequacy of rebuilding progress to NMFS. NMFS, in consultation with the Council, will evaluate rebuilding adequacy using the criteria contained in the NS1 guidelines. The Secretary of Commerce will make the final determination on the adequacy of rebuilding progress and will notify the Council if rebuilding progress is not adequate. In that case, the Magnuson-Stevens Act requires a new rebuilding plan be developed within two years.

4. 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. Rebuilding analyses need to include the model and parameter uncertainty from multiple models or parameter uncertainty where practicable and justify exclusion of known uncertainties. 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 stock assessment review (STAR) ~~P~~panel. Accounting for implementation uncertainty (i.e., the realized catch differing from the set ACL) is needed for cases in which the catch of the overfished stock is likely to differ appreciably from the set ACLs.

The uncertainty associated with 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, if there are multiple models (e.g., different structural assumptions regarding data weights, use of data sources, etc.) 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. In the case of assessments for which a decision table has been produced, the weights assigned to each model on which the decision table is based would be those assigned by the STAR p~~P~~anel (and endorsed/modified by the SSC).

Implementation uncertainty can take many forms. Two common ways to model implementation uncertainty are (a) the realized catch is distributed about the ACL (i.e., the catch equals the ACL on average), and (b) the realized catch is distributed about the ACL, but the expected catch is less [or greater] than the ACL. The latter case is appropriate if past data suggest that ACLs will be undercaught given management arrangements.

5. DOCUMENTATION

The analysts are responsible for conducting a complete and technically sound rebuilding analysis that conforms to accepted standards of quality, and in accordance with these Terms of Reference (TOR). 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. 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 rebuilding analysis document should follow the outline below.

1) Title page and list of preparers – the names and affiliations of the analysts either alphabetically or as first and secondary authors.
2) Summary – condensed overview and results of the rebuilding analyses.
3) Introduction – scientific name; years when species declared overfished; summary of assessment efforts (when first assessed, brief overview of subsequent assessments and rebuilding analyses).
4) Overview of the most recent stock assessment – main assumptions, estimated stock status, sources of uncertainty, alternative states of nature used in the decision table, 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) OFL, (g) ABC, and (h) SPR for the actual harvest strategy selected by the

Council.

5) Management performance under rebuilding – brief overview and a table comparing Overfishing Limit (OFL), Annual Catch Limit (ACL), and catch (i.e., landings plus discard) for each year of the rebuilding period.
6) Rebuilding calculations
   - Specifications for the software used for the analysis (including the version number); date on which the analysis was conducted; the program's input files (should be included as an Appendix).
   - The rationale for the approach used to estimate B_0 and to generate future recruitment.
   - The biological information on which the projections are based (e.g., 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).
   - Description of how fishing mortality is allocated (and selectivity applied) to each fleet for rebuilding analyses based on multiple fleets.
   - Description of how uncertainty in input parameters from the stock assessment in the rebuilding analysis is accounted for.
   - List and description of alternate rebuilding strategies analyzed.
7) Results
   - Summary of rebuilding reference points. 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 the ACL, (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, (i) the current SPR, (j) the current T_{TARGET} and (k) the estimate of current stock size.
   - Results of harvest policy projections (see, for examples, Tables 2-6; Figures 1-3). The following information should be provided for each harvest policy evaluated: (a) the first year in which recovery to the target level occurs with at least 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) probability of the stock dropping below the female spawning biomass in the present year and the year the stock was declared overfished, (f) 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) OFL, (iv) ABC, and (v) ACL. Median time-trajectories of SPR should be provided for the projection based on the 40:10 rule (as applied to the ABC) and any phase-in harvest policies that have been specified.
8) Acknowledgements
9) Literature cited

The software and data files on which the rebuilding analyses are based should be archived with the stock assessment coordinator. Much of the biological information will be stored in the input file for the projection software and does not 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.

6. LITERATURE CITED

Ainley, DG, RH Parrish, WH Lenarz, and WJ Sydeman. 1993. Oceanic factors influencing distribution of young rockfish (*Sebastes*) in central California: a predator's perspective. CalCOFI Rept. 34:133-139.

Clark, WG. 1991. Groundfish exploitation rates based on life history parameters. Can. J. Fish. Aquat. Sci. 48:734-750.

Clark, WG. 2002. $F_{35\%}$ revisited ten year later. N. Am. J. Fish. Manage. 22:251-257.

Dorn, MW. 2002. Advice on west coast rockfish harvest rates from Bayesian meta-analysis of stock-recruit relationships. N. Am. J. Fish. Manag. 22:280-300.

Francis, RC, SR Hare, AB Hollowed, and WS Wooster. 1998. Effects of interdecadal climate variability on the oceanic ecosystems of the NE Pacific. Fish. Oceanogr. 7(1):1-21.

Hamel, O.S. 2011. Rebuilding Analysis for Pacific Ocean Perch in 2011. Pacific Fishery Management Council. Portland, OR.

Hare, SR, NJ Mantua, and RC Francis. 1999. Inverse production regimes: Alaska and west coast salmon. Fisheries 24(1):6-14.

MacCall, AD. 1996. Patterns of low-frequency variability in fish populations of the California Current. CalCOFI Rept. 37:100-110.

MacCall, AD and S Ralston. 2002. Is logarithmic transformation really the best procedure for estimating stock-recruitment relationship? N. Am. J. Fish. Manage. 22:339-350.

Methot, R. 2005. Technical description of the stock synthesis II assessment program. Version 1.17-March 2005.

Methot, R. 2007. User manual for the Integrated analysis program stock synthesis 2 (SS2). Model version 2.00c. March 2007.

Marshall, CT, OS Kjesbu, NA Yaragina, P Solemdal, and Ø Ulltang. 1998. Is spawner biomass a sensitive measure of the reproductive and recruitment potential of northeast arctic cod? Can. J. Fish. Aquat. Sci. 55:1766-1783.

Ralston, S, and DF Howard. 1995. On the development of year-class strength and cohort variability in two northern California rockfishes. Fish. Bull, US 93:710-720.

Roemmich, D, and J McGowan. 1995. Climatic warming and the decline of zooplankton in the California Current. Science 267:1324-1326.

Rothschild, BJ, and MJ Fogarty. 1989. Spawning stock biomass as a source of error in stock-recruitment relationships. J. Cons. Int. Explor. Mer. 45:131-135.

Stewart, IJ. 2007. Rebuilding analysis for canary rockfish based on 2007 stock assessment. Pacific Fishery Management Council, 7700 NE Ambassador Palce, Suite 200, Portland, Oregon, 97220.

Trenberth, KE, and JW Hurrell. 1994. Decadal atmosphere-ocean variations in the Pacific. Clim. Dyn. 9:303-319.

Walters, CJ. 1985. Bias in the estimation of functional relationships from time series data. Can. J. Fish. Aquat. Sci. 42:147-149.

Walters, CJ, and D. Ludwig. 1981. Effects of measurement errors on the assessment of stock-recruitment relationships. Can. J. Fish. Aquat. Sci. 38:704-710.

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

Parameter	Values
Year declared overfished	2000
Current year	2007
First ACL 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)). (This table should include the OFL, ABC and ACL).

	Run #			
	1	2	3	4
50% prob. recovery by:	2019	2021	2035	2041
SPR_{TARGET}	100%	88.7%	62.0%	59.2%
2009 ACL (mt)	0.0	155.2	636.9	700.0
2009 ABC (mt)	936.9	936.9	936.9	936.9
2010 ACL (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

Table 6. Ten Year ACL/OFL projections for Pacific ocean perch (from Hamel 2011).

Case	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**		**11**		**12**
RUN	**F=0**		**2045**		**SPR for ACTs**		**SPR for ACLs**		**SPR from ACTs**		**SPR from ACLs**		**2055**		**2060**		**2065**		**2071**		**40-10**		**OFL**
SPR	1		0.943		0.880		0.864		0.858		0.839		0.826		0.792		0.762		0.738		>=0.500		0.500
T50%	2043		2045		2050		2051		2052		2054		2055		2060		2065		2071		*		*
P2045	57.3%		50.0%		40.2%		38.7%		37.9%		35.8%		34.4%		31.0%		29.3%		27.9%		25.0%		25.0%
P2071	85.5%		81.1%		75.0%		73.2%		72.6%		70.1%		68.0%		62.0%		55.8%		50.0%		25.3%		25.2%
10 Year projected **Catch levels** and OFLs at SPR rate above:																							
	ACL	OFL	**ACL**	OFL	**ACL**	OFL	**ACL**	OFL	**ACL**	OFL	**ACL**	OFL	**ACL**	OFL	**ACL**	OFL	**ACL**	OFL	**ACL**	OFL	**ACL**	OFL	**ACL=OFL**
2013	**0**	844	**58**	844	**131**	844	**150**	844	**158**	844	**182**	844	**199**	844	**247**	844	**291**	844	**328**	844	**554**	844	**844**
2014	**0**	867	**60**	865	**134**	862	**153**	861	**161**	861	**186**	860	**203**	860	**251**	858	**295**	857	**332**	855	**565**	848	**838**
2015	**0**	899	**62**	895	**138**	890	**158**	889	**166**	888	**191**	887	**209**	885	**258**	882	**303**	879	**341**	877	**586**	861	**842**
2016	**0**	935	**64**	929	**143**	922	**164**	919	**172**	919	**198**	916	**216**	915	**266**	910	**312**	905	**350**	901	**607**	878	**850**
2017	**0**	969	**66**	961	**147**	951	**169**	948	**177**	947	**204**	944	**222**	941	**273**	935	**320**	929	**359**	924	**623**	892	**856**
2018	**0**	999	**68**	988	**151**	976	**173**	972	**182**	971	**209**	967	**227**	964	**280**	956	**327**	948	**366**	942	**632**	901	**858**
2019	**0**	1025	**70**	1012	**154**	997	**177**	993	**185**	991	**213**	986	**232**	983	**285**	973	**332**	964	**372**	956	**635**	907	**857**
2020	**0**	1048	**71**	1033	**157**	1015	**180**	1010	**189**	1009	**217**	1003	**235**	999	**289**	987	**337**	977	**376**	968	**637**	911	**854**
2021	**0**	1071	**73**	1054	**160**	1034	**183**	1028	**192**	1026	**220**	1019	**239**	1015	**293**	1002	**341**	990	**381**	980	**643**	915	**852**
2022	**0**	1095	**74**	1076	**163**	1053	**187**	1047	**195**	1044	**224**	1037	**243**	1032	**298**	1017	**346**	1004	**386**	993	**651**	919	**850**

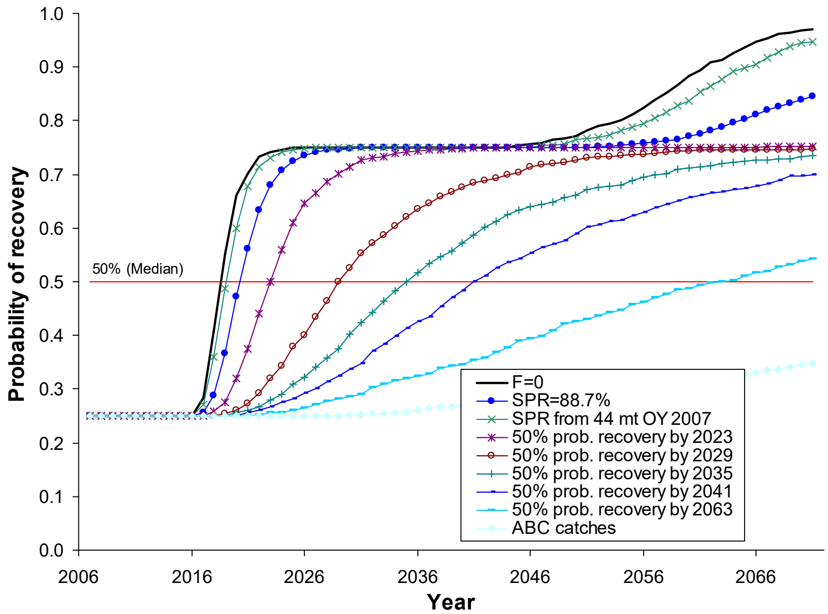

Figure 1. Probability of recovery for nine rebuilding alternatives for canary rockfish.

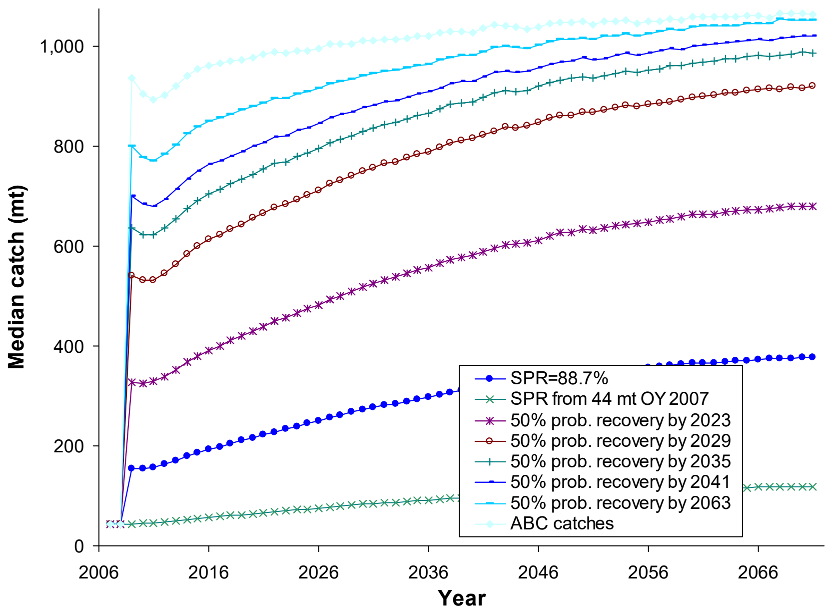

Figure 2. Projected median catch (mt) for nine rebuilding alternatives for canary rockfish.

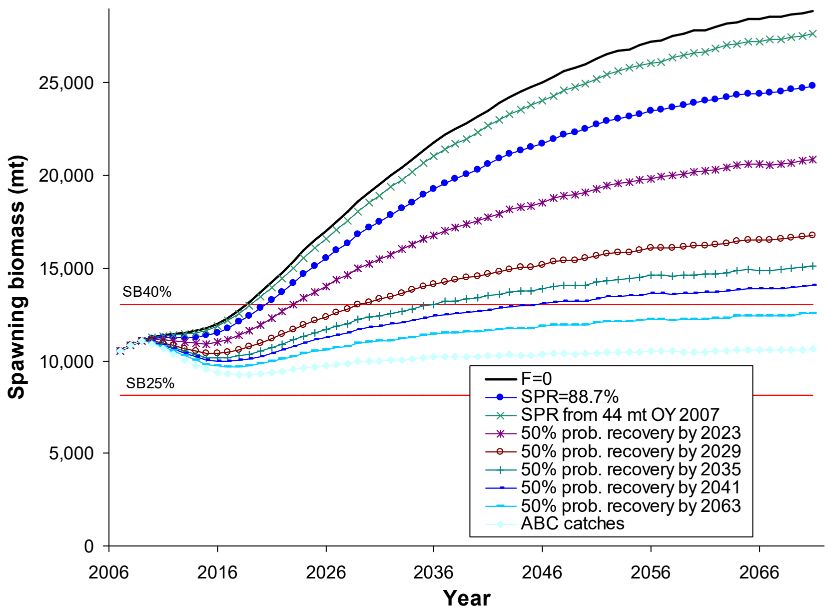

Figure 3. Projected median spawning biomass (mt) for nine rebuilding alternatives for canary rockfish.