TERMS OF REFERENCE

FOR THE

GROUNDFISH
STOCK ASSESSMENT AND REVIEW PROCESS FOR 2009-2010

DRAFT
DECEMBER 2008

Roster published by the Pacific Fishery Management Council pursuant to National Oceanic and Atmospheric Administration contract number NA05NMF4410008.

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Introduction

The purpose of this document is to convey expectations and responsibilities for various participants in the groundfish stock assessment review (STAR) process, and outline the guidelines and procedures for a peer review process for the Pacific Fishery Management Council. The STAR panel process is designed to establish a peer review process as referenced in the 2006 Reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act, which states that " the Secretary and each Regional Fishery Management Council may establish a peer review process for that Regional Fishery Management Council for scientific information used to advise the Regional Fishery Management Council about the conservation and management of the fishery (see Magnuson-Stevens Act section 302(g)(1)(E)). If a peer review process is established, it should investigate the technical merits of stock assessments and other scientific information used by the Council's Scientific and Statistical Committee (SSC). The peer review process is not a substitute for the SSC and should work in conjunction with the SSC." This document will be included in the Council's Statement of Organization, Practices and Procedures as part of the review process that will verify the scientific advice from the SSC.

Parties involved in implementing the peer review process described here are the Pacific Fishery Management Council members (Council), Council staff, and members of the Council's Advisory Bodies, including the SSC, the Groundfish Management Team (GMT), the Groundfish Advisory Subpanel (GAP), the National Marine Fisheries Service (NMFS), state agencies, and interested persons. The STAR process is a key element in an overall process designed to review the technical merits of stock assessments and other scientific information used by the SSC. This process will allow the Council to make timely use of new fishery and survey data, to analyze and understand these data as completely as possible, to provide opportunity for public comment, and to assure that the results are as accurate and error-free as possible.

This current edition of the Terms of Reference reflects many recommendations from previous participants in the STAR process, including STAR panel members, SSC members, stock assessment teams (STATs), Council staff, and Council advisory groups. Nevertheless, no set of guidelines can be expected to deal with every contingency, and all participants should anticipate the need to be flexible and to address new issues as they arise.

Hilborn and Walters (1992) define stock assessments as involving "the use of various statistical and mathematical calculations to make quantitative predictions about the reactions of fish populations to alternative management choices." In this document, the term "stock assessment" includes activities, analyses and reports, beginning with data collection and continuing through to scientific recommendations and information presented to the Council and its advisors. Stock assessments provide the fundamental basis for management decisions on groundfish harvests. To best serve that purpose, stock assessments should attempt to identify and quantify major uncertainties, balance realism and parsimony, and make best use of the available data.

STAR Goals and Objectives

The goals and objectives for the groundfish assessment and review process are to:

a) Ensure that groundfish stock assessments provide the kinds and quality of information required by the Council process.
b) Satisfy the Magnuson-Stevens Fisheries Conservation and Management Act (MSA) and other legal requirements.
c) Provide a well-defined, Council-oriented process that ensures groundfish stock assessments are the "best available" scientific information, and facilitates use of the information by the Council. In this context, "well-defined" means with a detailed calendar, explicit responsibilities for all participants, and specified outcomes and reports.
d) Provide an independent external review of groundfish stock assessment work.
e) Increase understanding and acceptance of groundfish stock assessment and review work by all members of the Council family.
f) Identify research needed to improve assessments, reviews, and fishery management in the future.
g) Use assessment and review resources effectively and efficiently.

All parties have a stake in assuring adequate technical review of stock assessments. NMFS, as the designee of the Secretary of Commerce, must determine that the best scientific advice has been used when it approves fishery management recommendations made by the Council. The Council uses advice from the SSC to determine whether the information on which it will base its recommendation is the "best available" scientific advice. Fishery managers and scientists providing technical documents to the Council for use in management need to assure that the work is technically correct. Program reviews, in-depth external reviews, and peer-reviewed scientific publications are used by federal and state agencies to provide quality assurance for the basic scientific methods used to produce stock assessments. However, the time-frame for this sort of review is not suited to the routine examination of assessments that are, generally, the primary basis for a harvest recommendation.

The Council and the Secretary Commerce have primary responsibility to create and foster a successful STAR process. The Council will oversee the process and involve its standing advisory committees, especially the SSC. NMFS will provide a coordinator to facilitate and assist in overseeing the process. Together they will consult with all interested parties to plan, prepare terms of reference, and develop a calendar of events and a list of deliverables for final approval by the Council. NMFS and the Council will share fiscal and logistical responsibilities.

Stock Assessment Priorities

Stock assessments for west coast groundfish are conducted to assess abundance, trends, and appropriate harvest levels for these species. Assessments use statistical population models to analyze and integrate a variety of survey, fishery, and biological data. Due to the large number of groundfish species that have never been assessed, it is the goal of the Council to increase substantially the number of assessed stocks. A constraint on reaching that objective is the Council's multi-year management regime, which limits assessment activities to odd years only (e.g., 2009).

The SSC recommended and the Council adopted in April 2006 a new process to initiate development of criteria for prioritizing stock assessments that may include such factors as: 1) economic or regional importance, 2) overfished status, 3) demographic sensitivity, 4) time elapsed since the last assessment (NMFS encourages assessments be updated at least once every 5 years), 5) data richness, 6) potential risk to the stock from the current or foreseeable management regime, and 7) qualitative trends from fishery-independent surveys (if available), etc. In establishing stock assessment priorities a number of factors are considered, including:

1. Assessments should take advantage of new information, especially indices of abundance from fishery-independent surveys.
2. Overfished stocks that are under rebuilding plans should be evaluated to ensure that progress towards achieving stock recovery is adequate.
3. Any stock assessment that is considered for use in management should be submitted through normal Council channels and reviewed at STAR panel meetings.
4. The proposed stocks for assessment should be discussed by the Council at least a year in advance to allow sufficient time for assembly of relevant assessment data and for arrangement of STAR panels.

Terms of Reference for STAR panels and Their Meetings

The principal responsibilities of the STAR panel are to review stock assessment documents, data inputs, analytical models, and to provide complete STAR panel reports for all reviewed species. The objective of the STAR panel review is to complete a detailed evaluation of the results of a stock assessment, which puts the panel in a good position to advance the best available scientific information to the Council. The STAR panel's work includes:

1. reviewing draft stock assessment documents and any other pertinent information (e.g., previous assessments and STAR panel reports, if available);
2. working with STAT Teams to ensure assessments are reviewed as needed;
3. documenting meeting discussions; and
4. reviewing revised stock assessment documents before they are forwarded to the SSC.

In most circumstances a STAR Panel will include a chair appointed from the SSC's Groundfish Subcommittee and three other experienced stock assessment analysts. Of these three other members, at least one should be familiar with west coast groundfish stock assessment practices and at least one should be appointed from the Center for Independent Experts (CIE). Selection of STAR panelists should aim for balance between outside expertise and in-depth knowledge of west coast fisheries, data sets available for those fisheries, and modeling approaches applied to

west coast groundfish species. Reviewers should not have financial or personal conflict of interests. The majority of panelists should be experienced stock assessment scientists (i.e., individuals who have done stock assessments using current methods). STAR panelists should be knowledgeable about the specific modeling approaches being reviewed, which in most cases will be statistical age- and/or length-structured assessment models. Every attempt should be made to identify one reviewer that can consistently attend all panels. It is recognized that the pool of qualified reviewers is limited, and that staffing of STAR panels is subject to constraints that may make it difficult to achieve these objectives. In addition to panel members, STAR meetings will include GMT and GAP advisors with responsibilities described in their terms of reference. STAR panels normally meet for one week.

In general no more than 2 full assessments will be reviewed by a STAR panel. In exceptional circumstances this number may be exceeded, if the SSC and NMFS Stock Assessment Coordinator (SAC) conclude that it is advisable, feasible, and/or necessary to do so. When separate assessments are conducted at the sub-stock level (i.e., black rockfish) each assessment will be considered a full assessment for review purposes. Contested assessments, in which alternative assessments are brought forward by competing STAT teams using different modeling approaches, will typically require additional time (or panel members) to review adequately, and should be scheduled accordingly. While contested assessments are likely to be rare, they can be accommodated in the STAR panel review process. STAR panels should thoroughly evaluate each analytical approach, comment on the relative merits of each, and, when conflicting results are obtained, attempt to identify the reasons for the differences. STAR panels are charged with selecting a preferred base model, which will be more difficult when there are several modeling approaches from which to choose.

The STAR panel chair is responsible for: 1) developing an agenda for the STAR panel meeting, 2) ensuring that STAR panel members and STAT teams follow the Terms of Reference, 3) participating in the review of the assessment, 4) guiding the STAR panel and STAT team to mutually agreeable solutions, and 5) coordinating review of final assessment documents.

The STAR panel, STAT Team, GAP and GMT advisors, and all interested parties are legitimate meeting participants that must be accommodated in discussions. It is the STAR panel chair's responsibility to manage discussions and public comment so that work can be completed.

The STAR panel's terms of reference solely concern technical aspects of the stock assessment. It is therefore important that the panel should strive for a risk neutral perspective in its reports and deliberations. Assessment results based on model scenarios that have a flawed technical basis, or are questionable on other grounds, should be identified by the panel and excluded from the set upon which management advice is to be developed. It is recognized that a broad range of results should be reported to better define the scope of the accepted model results. The STAR panel should comment on the degree to which the accepted model scenarios describe and quantify the major sources of uncertainty, and the degree to which the probabilities associated with these scenarios are technically sound. The STAR panel may also provide qualitative comments on the probability of various model results, especially if the panel does not believe that the probability distributions calculated by the STAT capture all major sources of uncertainty.

Recommendations and requests to the STAT Team for additional or revised analyses must be clear, explicit and in writing. A written summary of discussion on significant technical points and lists of all STAR panel recommendations and requests to the STAT Team are required in the STAR panel's report. This should be completed (at least in draft form) prior to the end of the meeting. It is the chair and panel's responsibility to carry out any follow-up review work that is required.

Under ideal circumstances, the STAT Team and STAR panel should strive to reach a mutual consensus on a single base model, but it is essential that uncertainty in the analysis be captured and communicated to managers. A useful way of accomplishing this objective is to bracket the base model along what is deemed to be the dominant dimension of uncertainty (e.g., spawner-recruit steepness or R_0, natural mortality rate, survey catchability, recent year-class strength, weights on conflicting CPUE series, etc.). Alternative models should show contrast in their management implications, which in practical terms means that that they should result in different estimates of current stock size, stock depletion, and acceptable biological catch (ABC).

Once a base model has been bracketed on either side by alternative model scenarios, which capture the overall degree of uncertainty in the assessment, a 2-way decision table analysis (states-of-nature versus management action) is the preferred way to present the repercussions of uncertainty to management. An attempt should be made to

develop alternative model scenarios such that the base model is considered twice as likely as the alternative models, i.e., the ratio of probabilities should be 25:50:25 for the low stock size alternative, the base model, and the high stock size alternative (Figure 1). Potential methods for assigning probabilities include using the statistical variance of the model estimates of stock size, posterior Monte Carlo simulation, or expert judgment, but other approaches are encouraged as long as they are fully documented. Bracketing of assessment results could be accomplished in a variety of ways, but as a matter of practice the STAR panel should strive to identify a single preferred base model when possible, so that averaging of extremes doesn't become the *de facto* choice of management.

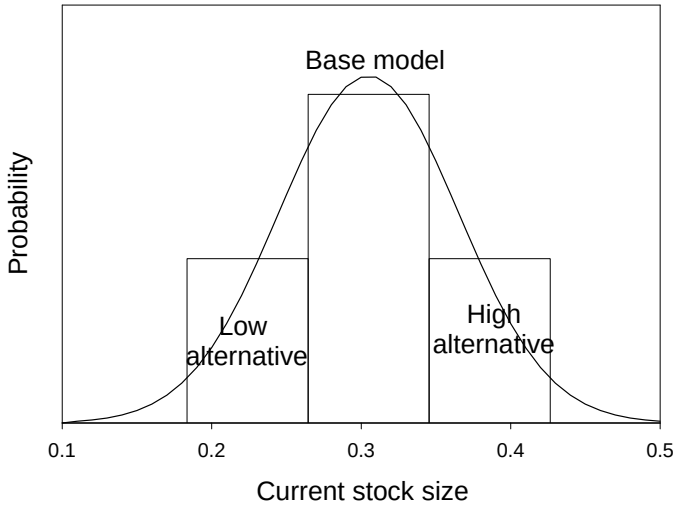

Figure 1. Example of assigning probabilities to alternative models using uncertainty in the estimate of current stock size.

To the extent possible, additional analyses required in the stock assessment should be completed during the STAR panel meeting. It is the obligation of the STAR panel chair, in consultation with other panel members, to prioritize requests for additional STAT Team analyses. Moreover, in situations where a STAT team arrives with a well-considered, thorough assessment, it may be that the panel can conclude its review in less time than has been allotted to the meeting (i.e., early dismissal of a STAT Team is an option for well-constructed assessments). If follow-up work by the STAT Team is required after the review meeting, then it is the panel's responsibility to track STAT Team progress. In particular, the chair is responsible for communicating with STAT Teams (by phone, e-mail, or any convenient means) to determine if the revised stock assessment and documents are complete and ready to be used by managers in the Council family. If stock assessments and reviews are not complete at the end of the STAR panel meeting, then the work must be completed prior to the SSC meeting where the post-STAR draft assessment is reviewed. Any post-STAR drafts of the stock assessment must be reviewed by the STAR panel or the chair if delegated that authority by the STAR panel. Assessments cannot be given to Council staff for distribution unless first endorsed by the STAR panel chair. Likewise, the final draft that is published in the Council's Stock Assessment and Fishery Evaluation (SAFE) document must also be approved by the STAR panel chair prior to being accepted by Council staff.

The STAR panel's primary duty is to conduct a peer review of an assessment that is presented by a STAT Team; STAR panel meetings are not workshops. In the course of this review, the panel may ask for a reasonable number of sensitivity runs, additional details of existing assessments, or similar items from the STAT team. It would not be unusual for this evaluation to result in a change to the initial base model, provided both the STAR panel and the STAT team agree. The STAR panels are expected to be judicious in their requests of the STAT teams, recognizing that some issues uncovered during review are best flagged as research priorities, and dealt with more effectively and comprehensively between assessments. The STAR panel may also request additional analysis based on an alternative approach. However, the STAR panel is not authorized to conduct an alternative assessment representing its own views that are distinct from those of the STAT Team, nor can it impose an alternative assessment on the Team. Similarly, the panel should not impose as a requirement their preferred methodologies when such is a matter

of professional opinion. Rather, if the panel finds that an assessment is inadequate, it should document and report that opinion and, in addition, suggest remedial measures that could be taken by the STAT team prior to the scheduled mop-up panel review to rectify whatever perceived shortcomings may exist. The SSC will make a final recommendation on whether an assessment should be reviewed during the mop-up panel.

STAT Teams and STAR panels are required to make a good-faith attempt to resolve any areas of disagreement during the meeting. Occasionally, fundamental differences of opinion remain between the STAR panel and STAT Team that cannot be resolved by discussion. In such cases, the STAR panel must document the areas of disagreement in its report. In exceptional circumstances, the STAT team may choose to submit a supplemental report supporting its view, but in the event that such a step is taken, an opportunity must be given to the STAR panel to prepare a rebuttal. These documents will then be appended to the STAR panel report as part of the record of the review meeting. Likewise, STAR panel members may have fundamental disagreements that cannot be resolved during the STAR panel meeting. In such cases, STAR panel members may prepare a minority report that will become part of the record of the review meeting. The SSC will then review all information pertaining to STAR panel or STAR panel/STAT team disputes, and issue its recommendation.

The STAR panel is responsible for determining if a stock assessment document is sufficiently complete according to Appendix B. It is also the panel's responsibility to identify assessments that cannot be reviewed or completed for any reason. The panel's decision that an assessment is complete should be made by consensus. If a panel cannot reach agreement, then the nature of the disagreement must be described in the panel's report. Moreover, if a stock assessment is deemed to be stable in its approach to data analysis and modeling, the STAR panel should recommend that the assessment be considered as an update during the next stock assessment cycle.

For some species the available data will be insufficient to calculate reliable estimates of F_{MSY} (or its proxy), B_{MSY} (or its proxy), ending biomass or unfished biomass, etc. Typically, results from a "data-poor" assessment are unable to produce all of the required reporting elements outlined in Appendix B (Outline for Groundfish Stock Assessment Documents). In particular, estimation of current exploitable biomass and/or stock depletion may be impossible, although both quantities are essential components of the Council's current 40-10 groundfish harvest policy. Nonetheless, information that is potentially useful to management is often generated in a data-poor assessment, e.g., current spawning potential ratio (SPR). Therefore, in situations where the STAT team is unable to produce a full assessment with all the model outputs required by the Council's default harvest control rule, a "Data Report" can be developed that summarizes all the pertinent findings of the stock assessment. To the extent practicable Appendix B will serve as a guide to the contents of a Data Report.

It is the responsibility of the STAR panel, in consultation with the STAT Team, to consider the validity of inferences that can be drawn from an analysis presented in a Data Report. If useful but incomplete results have been developed, the panel should review the reliability and appropriateness of the methods used to draw conclusions about stock status and/or exploitation potential and either recommend or reject the analysis on the basis of its ability to introduce useful information into the management process. If the STAR panel believes that important information has been developed, it should forward its findings and conclusions to the SSC and Council for consideration during the setting of ABCs and optimum yields (OYs). The current harvest control rule cannot be applied using the results from a Data Report. However, these results can be used for management decision-making. For example, a Data Report could provide information on the trend in abundance and hence changes from status quo management. A key section of the Data Report is that on research needed to improve the assessment. Highlighting research priorities in a Data Report should increase the likelihood that future stocks assessments will satisfy the Groundfish Stock Assessment Terms of Reference.

The STAR panel chair is expected to attend Council meetings and GMT meetings (when requested) and where stock assessments and harvest projections are discussed to explain the reviews and provide other technical information and advice. The chair, in coordination with the STAT team, is responsible for providing the Stock Assessment Coordinator and Council staff with a suitable electronic version of the panel report.

Suggested Template for STAR Panel Report

1. Summary of the STAR panel meeting containing:
   A. Name and affiliation of STAR panel members;
   B. List of analyses requested by the STAR panel, the rationale for each request, and brief summary of the STAT response to the request; and

C. Description of base model and alternative models used to bracket uncertainty.
2. Comments on the technical merits and/or deficiencies in the assessment and recommendations for remedies.
3. Explanation of areas of disagreement regarding STAR panel recommendations:
   A. Among STAR panel members (including concerns raised by GAP and GMT representatives); and
   B. Between the STAR panel and STAT Team.
4. Unresolved problems and major uncertainties, e.g., any special issues that complicate scientific assessment, questions about the best model scenario.
5. Management, data, or fishery issues raised by the GMT or GAP representatives during the STAR panel.
6. Prioritized recommendations for future research and data collection.

Terms of Reference for Groundfish STAT Teams

In order to be sufficient for peer review, the STAT team will carry out its work according to these terms of reference and the calendar for groundfish stock assessments.

All relevant stock assessment workshops should be attended by all STAT team members. The STAT Team shall include in both the STAR panel draft and final assessment all data sources that include the species being assessed, identify which are used in the assessment, and provide the rationale for data sources that are excluded. The STAT Team is obliged to keep the GAP representative informed of the specific data being used in the stock assessment. The STAT team is expected to initiate contact with the GAP representative at an early stage in the process, and to be prepared to respond to concerns about the data that might be raised. The STAT Team should also contact the GMT representative for information about changes in fishing regulations that may influence data used in the assessment.

STAT teams are strongly encouraged to develop assessments in a collaborative environment, such as by forming working groups, holding pre-assessment workshops, and consulting with other stock assessment scientists. STAT teams are also encouraged to also organize independent meetings with industry and interested parties to discuss issues, questions, and data. Each STAT Team will appoint a representative to coordinate work with the STAR panel. Barring exceptional circumstances, all STAT team members should attend the STAR panel meeting.

Each STAT Team conducting a full assessment will appoint a representative who will be available to attend the Council meeting where the SSC is scheduled to review the assessment, and will typically give presentations of the assessment to the SSC and to other Council advisory bodies. In addition, the STAT Team should be prepared to respond to GMT requests for model projections during the GMT's development of ABC and OY alternatives.

The STAT Team is responsible for preparing three versions of the stock assessment document: 1) a complete "draft" including an executive summary (except for decision tables) for discussion at the stock assessment review meeting; 2) a "revised draft" for distribution to the Council and advisory bodies for discussions about preliminary ABC and OY levels; 3) a "final" version to be published in the SAFE report. Post-STAR panel drafts must be reviewed by the STAR panel prior to being submitted to Council staff, but these reviews are limited to editorial issues, verifying that the required elements are included according to the Terms of Reference, and confirming that the document reflects the discussions and decisions made during the STAR panel. Other than changes authorized by the SSC, only editorial and other minor alterations should be made between the "revised draft" and "final" versions. The STAT Team will provide "draft" assessment documents to the STAR panel chair, Council staff, and the NMFS SAC three weeks in advance of the STAR panel meeting to allow timely review of the draft assessment to ensure the required elements of a draft assessment are included according to the Terms of Reference. If the draft assessment is judged complete, the NMFS groundfish SAC will distribute the draft assessment and relevant supporting materials to the STAR panel, Council staff, the SSC Groundfish subcommittee, and GMT and GAP representatives at least two weeks prior to the STAR panel meeting.

Complete, fully-developed assessments are critical to the STAR panel process. Draft assessments will be evaluated for completeness prior to the STAR panel meeting, and assessments that do not satisfy minimum criteria will not be reviewed. The full draft assessment document should be available for distribution three weeks prior to the STAR panel meeting to determine if it is sufficient for review. The STAR panel chair, Council staff, and the NMFS SAC will make an initial recommendation, which will then be reviewed by the SSC Groundfish Subcommittee members, if it is determined that the draft assessment is not sufficiently complete. In such cases, a list of deficiencies will be provided to the STAT Team to allow completion of the draft assessment prior to distribution to the STAR panel. The draft document should include all elements listed in Appendix B except the: 1) decision table, 2) harvest

projections, 3) population abundance tables, 4) point-by-point responses to current STAR panel recommendations, and 5) acknowledgements. Incomplete assessments or those provided after the requisite deadlines in Appendix A will be either moved to the mop-up panel, or postponed to a subsequent assessment cycle. In general, the mop-up panel will not be able to review more than two assessments, so the options are limited for assessments that are not completed on time.

The STAT Team is responsible for bringing computerized data and working assessment models to the review meeting in a form that can be analyzed on site. STAT Teams should take the initiative in building and selecting candidate models and should have several complete models ready to present to the STAR panel and be prepared to discuss the merits of each. The STAT team should identify a candidate base model, fully documented in the draft assessment, for STAR panel consideration. Fully developed assessments that are properly documented should require less time to review and approve than poorly constructed, incomplete assessments.

In most cases, the STAT Team should produce a complete draft of the assessment within three weeks of the end of the STAR panel meeting, including any internal agency review. In any event, the STAT Team must finalize the assessment document before the briefing book deadline for the Council meeting at which the assessment is scheduled for review.

The STAT Team and the STAR panel may disagree on technical issues regarding an assessment, but a complete stock assessment must include a point-by-point response by the STAT Team to each of the STAR panel's recommendations. Estimates and projections representing all sides of the disagreement need to be presented to, reviewed by, and commented upon by the SSC.

For stocks that are projected to fall below overfished thresholds, the STAT Team must complete a rebuilding analysis according to the SSC's Terms of Reference for Groundfish Rebuilding Analyses. It is recommended that this analysis be conducted using the rebuilding software developed by Dr. Andre Punt (aepunt@u.washington.edu). The STAT Team is also responsible for preparing a document that summarizes the results of the rebuilding analysis.

Electronic versions of final assessment documents, rebuilding analyses, parameter files, data files, and key output files will be sent by the STAT Teams to Council staff and the SAC for inclusion in a stock assessment archive. Any tabular data that are inserted into the final documents in and object format should also be submitted in alternative forms (e.g., spreadsheets), which allow selection of individual data elements.

Terms of Reference for Stock Assessment Updates

The STAR process is designed to provide a comprehensive, independent review of a stock assessment. In other situations a less comprehensive review of assessment results is desirable, particularly in situations where a "model" has already been critically examined and the objective is to simply update the model by incorporating the most recent data. In this context a model refers not only to the population dynamics model *per se*, but to the particular data sources that are used as inputs to the model, the statistical framework for fitting the data, and the analytical treatment of model outputs used in providing management advice, including reference points, the ABC and OY. These terms of reference establish a procedure for a limited but still rigorous review for stock assessment models that fall into this latter category. However, it is recognized that what in theory may seem to be a simple update, may in practice result in a situation that is impossible to resolve in an abbreviated process. In these cases, it may not be possible to update the assessment – rather the assessment may need to be revised in the next full assessment review cycle.

Qualification

The SSC will determine whether a stock assessment qualifies as an update under these terms of reference. Recommendation by a STAR panel or the SSC that a full assessment is suitable for an update will be a principal criterion in this determination. To qualify, a stock assessment must carry forward its fundamental structure from a model that was previously reviewed and endorsed by a STAR panel. In practice this means similarity in: a) the particular sources of data used, b) the analytical methods used to summarize data prior to input to the model, c) the software used in programming the assessment, d) the assumptions and structure of the population dynamics model underlying the stock assessment, e) the statistical framework for fitting the model to the data and determining goodness of fit, f) the procedure for weighting of the various data components, and g) the analytical treatment of model outputs in determining management reference points, including F_{MSY}, B_{MSY}, and B_0. A stock assessment

update is appropriate in situations where no significant change in these seven factors has occurred, other than extending time series of data elements within particular data components used by the model (e.g., adding information from a recently completed survey and an update of landings). Extending CPUE time series based on fitted models (i.e., GLM models) will require refitting the model and updating all values in the time series. Assessments using updated CPUE time series qualify as updates if the CPUE standardization models follow applicable criteria for assessment models described above. In practice there will always be valid reasons for altering a model, as defined in this broad context, although, in the interests of stability, such changes should be resisted as much as possible. Instead, significant alterations should be addressed in the next subsequent full assessment and review.

Composition of the Review panel

The Groundfish Subcommittee of the SSC will conduct the review of a stock assessment update. A lead reviewer for each updated assessment will be designated by the chair of the Groundfish Subcommittee from among its membership, and it will be the lead reviewer's responsibility to ensure the review is completed properly and that a written report of the proceedings is produced. In addition, the GMT and the GAP will designate one person each to participate in the review.

Review Format

All stock assessment updates will be reviewed during a single meeting of the SSC Groundfish Subcommittee scheduled early in the assessment cycle. This meeting may precede or follow a normally scheduled SSC meeting. The review process will be as follows. The STAT team preparing the update will distribute the updated stock assessment to the review panelists at least two weeks prior to the review meeting. In addition, Council staff will provide panelists with a copy of the last stock assessment reviewed under the full STAR process, as well as the previous STAR panel report. Review of stock assessment updates is not expected to require analytical requests or model runs during the meeting, although large or unexpected changes in model results may necessitate some model exploration. The review will focus on two crucial questions: 1) has the assessment complied with the terms of reference for stock assessment updates and 2) are new input data and model results sufficiently consistent with previous data and results that the updated assessment can form the basis of Council decision-making. If either of these criteria is not met, then a full stock assessment will be required.

STAT Team Deliverables

Since there will be limited opportunities for revision during the review meeting, it is the STAT team's responsibility to provide the panel with a completed update at least two weeks prior to the meeting. To streamline the process, the team can reference whatever material it chooses, including that presented in the previous stock assessment (e.g., a description of methods, data sources, stock structure, etc.). However, it is essential that any new information being incorporated into the assessment be presented in enough detail, so that the Groundfish Subcommittee can determine whether the update satisfactorily meets the Council's requirement to use the best available scientific information. Of particular importance will be a retrospective analysis showing the performance of the model with and without the updated data streams. Likewise, a decision table that highlights the consequences of alternative states of nature would be useful to the Council in adopting annual specifications. Similarly, if any minor changes to the "model" structure are adopted, above and beyond updating specific data streams, a sensitivity analysis to those changes will be required.

In addition to documenting changes in the performance of the model, the STAT Team will be required to present key assessment outputs in tabular form. Specifically, the STAT Team's final update document should include the following:

- Title page and list of preparers;
- Executive Summary (see Appendix C);
- Introduction;
- Documentation of updated data sources;
- Short description of overall model structure;
- Complete base-run results, including a tabular summary of total and spawning stock biomass and recruitment time series;
- Uncertainty analysis, including retrospective analysis, decision table, etc.; and

- 10 year harvest projections under the default harvest policy.

Groundfish Subcommittee Report

The Groundfish Subcommittee will issue a report that will include the following items:

- Name and affiliation of panelists;
- Comments on the technical merits and/or deficiencies of the update;
- Explanation of areas of disagreement among panelists and between the panel and STAT team; and
- Recommendation regarding the adequacy of the updated assessment for use in management.

Council Staff Responsibilities

A Council staff officer will be assigned to coordinate, monitor and document the STAR process. The Council staff officer will be responsible for timely issuance of meeting notices and distribution of stock assessment documents, stock summaries, meeting minutes, and other appropriate documents. The Council staff officer will monitor compliance with the Terms of Reference for the 2009-10 groundfish STAR process. The Council staff officer will coordinate materials and presentations for Council meetings relevant to final Council adoption of groundfish stock assessments. Council staff will also collect and maintain file copies of reports from each STAR Panel (containing items specified in the STAR Panel Terms of Reference), the outline for groundfish stock assessment documents, SSC, GMT, and GAP comments and reports, letters from the public, and any other relevant information. At a minimum, the stock assessments (STAT reports, STAR Panel reports, and stock summaries) should be published and distributed in the Council annual SAFE document.

A primary role for the Council staff officer assigned to the 2009-10 STAR process will be to monitor STAR Panel and SSC activities to ensure compliance with these Terms of Reference. The Council staff officer will coordinate with the STAR Panel chair and the NMFS SAC in a review of STAT documents to assure they are received on time, are consistent with the Terms of Reference, and are complete. If the STAT materials are obviously not in compliance with the Terms of Reference, the Council staff officer will return the materials to STAT authors with a list of deficiencies, a notice that the deadline has expired, or both. The Council staff officer will attend all STAR panel meetings to ensure continuity and adherence to the Stock Assessment Terms of Reference. The Council staff officer will identify inconsistencies with the Terms of Reference that occur during STAR Panels and work with the STAR Panel chair to develop solutions and to correct them. The Council staff officer will review the Executive Summary for consistency with the Terms of Reference. Inconsistencies will be identified and the authors requested to make appropriate revisions in time for the appropriate SSC and GMT meetings, when an assessment is considered. The Council staff officer will also coordinate and monitor SSC review of stock assessments and STAR Panel reports to ensure compliance with these Terms of Reference and the independent review requirements of Council Operating Procedure 4. The Council staff officer will also identify one STAR Panel member with experience conducting west coast groundfish stock assessments.

National Marine Fisheries Service Responsibilities

NMFS Northwest Fisheries Science Center (NWFSC) will provide a SAC to work with the Council, other agencies, groups, or interested persons that carry out assessment work to assist in organizing the STAT and STAR Panels. Since most assessments are conducted by NMFS STATs, the SAC will work with assessment authors to develop a draft list of assessments to be considered by the Council. The SAC also will develop a draft STAR Panel schedule for review by the Council. The SAC will identify two independent STAR panelists following criteria for reviewer qualifications. The SAC will make every effort to identify one independent reviewer that can attend all STAR Panels to provide consistency among reviews. The costs associated with these two reviewers will be borne by NOAA Fisheries. The SAC will coordinate with STAT authors to facilitate delivery of materials by scheduled deadlines and in compliance with other requirements of these Terms of Reference, to the extent possible and with the assistance of the assigned Council staff officer and the STAR Panel chair.

Following any modifications to the stock assessments resulting from STAR Panel reviews and prior to SSC review, the SAC will assist the Council staff officer in reviewing the Executive Summary for consistency with the Terms of Reference. Inconsistencies will be identified and the authors requested to make appropriate revisions in time for the appropriate SSC and GMT meetings.

STAT Team Responsibilities

The STAT is responsible for conducting a complete and technically sound stock assessment that conforms to accepted standards of quality, and make sure that work is carried out in a timely fashion according to the calendar and terms of reference. The STAT will conduct its work and activities in accordance with the Terms of Reference for Groundfish STAT Teams. The final product of the STAT will be a stock assessment document that follows the outline specified in Appendix B.

GMT Responsibilities

The GMT is responsible for identifying and evaluating potential management actions based on the best available scientific information. In particular, the GMT makes ABC and OY recommendations to the Council based on estimated stock status, uncertainty about stock status, and socioeconomic and ecological factors. The GMT will use stock assessments, STAR panel reports, and other information in making their recommendations. The GMT's preliminary ABC recommendation will be developed at a meeting that includes representatives from the SSC, STAT Teams, STAR panels, and GAP. A GMT representative(s) will be appointed by the chair of the GMT to track each stock assessment, and will serve as advisor to the STAT Team and STAR panel. The GMT representative will participate in review discussions, but will not serve as a member of the panel. The GMT representative should be prepared to advise the STAT Team and STAR panel on changes in fishing regulations that may influence data used in the assessment and the nature of the fishery in the future.

The GMT will not seek revision or additional review of the stock assessments after they have been reviewed by the STAR panel. The GMT chair will communicate any unresolved issues to the SSC for consideration. Successful separation of scientific (i.e., STAT Team and STAR panels) from management (i.e., GMT) work depends on stock assessment documents and STAR reviews being completed by the time the GMT meets to discuss preliminary ABC and OY levels. However, the GMT can request additional model projections, based on reviewed model scenarios, in order to develop a full evaluation of potential management actions.

GAP Responsibilities

The chair of the GAP will appoint a representative to track each stock assessment and attend the STAR panel meeting. The GAP representative will serve as advisor to the STAT Team and STAR panel. It is especially important that the GAP representative be included in the STAT team's discussion and review of all the data sources being used in the assessment, prior to development of the stock assessment model. It is the responsibility of the GAP representative to insure that industry concerns about the adequacy of data being used by the STAT Team are expressed at an early stage in the process. The GAP representative will participate in review discussions as an advisor to the STAR panel, in the same capacity as the GMT advisor.

The GAP representative, along with STAT and SSC representatives, will attend the GMT meeting at which ABC recommendations are made. The GAP representative will also attend subsequent GMT, Council, and other necessary meetings where the assessment is discussed.

The GAP representative may provide appropriate data and advice to the STAR panel and GMT and will report to the GAP on STAR panel and GMT meeting proceedings.

SSC Responsibilities

The SSC will participate in the stock assessment review process and will provide the Council and its advisory bodies with technical advice related to the stock assessments and the review process. The SSC will assign one of its members to act as chair of each STAR panel. Following the STAR panel meeting, the STAR panel chair will review the revised stock assessment and STAR panel report for consistency with the Terms of Reference. This member is not only expected to attend the assigned STAR panel meeting, but also the GMT meeting at which ABC recommendations are made (should the need arise), and Council meetings when groundfish stock assessment agenda items are discussed (see calendar in Appendix A). Specifically, if requested, the STAR panel chair will present the STAR panel report to the GMT if it requires assistance in interpreting the results of a stock assessment. In addition, the chair will present the panel's report at SSC and Council meetings. However, to insure independence in the SSC's review of stock assessments and STAR panel proceedings, SSC members who served on a STAT Team or STAR panel for a particular stock assessment are required to recuse themselves when that stock assessment is reviewed by the SSC, except to answer questions or present factual information. Other SSC members will be assigned the roles of discussion lead and rapporteur. The SSC's review constitutes a final independent check of the stock assessment that takes into consideration both the stock assessment and the STAR panel report.

It is the SSC's responsibility to review and endorse any additional analytical work requested by the GMT after the stock assessment has been reviewed by the STAR panels. In addition, the SSC will review and advise the GMT and Council on projected ABCs and OYs and, in addition, will serve as arbitrator to resolve disagreements between the STAT Team and the STAR panel.

Appendix A: 2009-2010 Stock Assessment Review Calendar

Panel	Dates	Location	Species 1	Species 2	Pre-STAR Draft Deadline a/	Post-STAR Briefing Book Deadline b/
Whiting	Feb. 3-6	Seattle, WA	Pacific Whiting	NA	Jan. 12	Feb. 18
1	May 4-8	Newport, OR	Petrale sole	Splitnose	Apr. 13	May 27
Updates	June 10-11	June Council meeting	POP, Darkblotched	Canary, Cowcod	NA	May 27
2	July 13-17	Santa Cruz, CA	Bocaccio	Widow	June 22	Aug. 26
3	July 27-31	Seattle, WA	Lingcod	Cabezon	July 6	Aug. 26
4	Aug. 3-7	Seattle, WA	Yelloweye	Greenstriped	July 13	Aug. 26
Mop-Up	Sept. 28-Oct. 1	Seattle, WA	TBD	TBD	Sep. 7	Oct. 14

a/ Pre-STAR draft assessments are due to Council staff and the NMFS SAC three weeks in advance of the STAR meeting. This allows one week to correct deficiencies prior to distribution to the STAR panel members two weeks in advance of the STAR panel.

b/ Post-STAR draft assessments to be reviewed by the SSC are due to Council staff two weeks in advance of the SSC meeting. This due date is a guideline since, in some cases (e.g., Pacific whiting), there is not enough time to prepare the post-STAR draft in time for the briefing book deadline.

Appendix B: Outline for Groundfish Stock Assessment Documents

This is an outline of items that should be included in stock assessment reports for groundfish managed by the Pacific Fishery Management Council. The outline is a working document meant to provide assessment authors with flexible guidelines about how to organize and communicate their work. All items listed in the outline may not be appropriate or available for each assessment. Also, items flagged with asterisks (*) are optional for draft assessment documents prepared for STAR panel meetings but should be included in the final document. In the interest of clarity and uniformity of presentation, stock assessment authors and reviewers are encouraged (but not required) to use the same organization and section names as in the outline. It is important that time trends of catch, abundance, harvest rates, recruitment and other key quantities be presented in tabular form to facilitate full understanding and follow-up work.

A. Title page and list of preparers – the names and affiliations of the stock assessment team (STAT) either alphabetically or as first and secondary authors

B. Executive Summary (see attached template and example in Appendices C and D).

C. Introduction
   1. Scientific name, distribution, the basis for the choice of stock structure, including regional differences in life history or other biological characteristics that should form the basis of management units.
   2. A map depicting the scope of the assessment and identifying boundaries for fisheries or data collection strata.
   3. Description of fisheries for this species off Canada or Alaska, including references to any recent assessments of those stocks.
   4. Important features of life history that affect management (e.g., migration, sexual dimorphism, bathymetric demography).
   5. Important features of current fishery and relevant history of fishery.
   6. Summary of management history (e.g., changes in mesh sizes, trip limits, or other management actions that may have significantly altered selection, catch rates, or discards).
   7. Management performance – a table or tables comparing acceptable biological catches, optimum yields, landings, and catch (i.e., landings plus discard) for each area and year

D. Assessment
   1. Data
      a. Landings by year and fishery, historical catch estimates, discards (generally specified as a percentage of total catch in weight and in units of mt), catch-at-age, weight-at-age, abundance indices (typically survey and CPUE data), data used to estimate biological parameters (e.g., growth rates, maturity schedules, and natural mortality) with coefficients of variation (CVs) or variances if available. Include complete tables and figures and date of extraction.
      b. Sample size information for length and age composition data by area, year, gear, market category, etc., including both the number of trips and fish sampled.
      c. All data sources that include the species being assessed, which are used in the assessment, and provide the rationale for data sources that are excluded.
   2. History of modeling approaches used for this stock – changes between current and previous assessment models
      a. Response to STAR panel recommendations from the most recent previous assessment.
      b. Report of consultations with GAP and GMT representatives regarding the use of various data sources in the stock assessment.
   3. Model description
      a. Complete description of any new modeling approaches.
      b. Definitions of fleets and areas.
      d. Assessment program with last revision date (i.e., date executable program file was compiled).
      e. List and description of all likelihood components in the model.
      f. Constraints on parameters, selectivity assumptions, natural mortality, assumed level of age reader agreement or assumed ageing error (if applicable), and other assumed parameters.
      g. Description of stock-recruitment constraints or components.
      h. Description of how the first year that is included in the model was selected and how the population state at the time is defined (e.g., B_0, stable age structure, etc.).

i. Critical assumptions and consequences of assumption failures.

4. Model selection and evaluation
   a. Evidence of search for balance between model realism and parsimony.
   b. Comparison of key model assumptions, include comparisons based on nested models (e.g., asymptotic vs. domed selectivities, constant vs. time-varying selectivities).
   c. Summary of alternate model configurations that were tried but rejected.
   d. Likelihood profile for the base-run (or proposed base-run model for a draft assessment undergoing review) configuration over one or more key parameters (e.g., M, h, Q) to show consistency among input data sources.
   e. Residual analysis for the base-run configuration (or proposed base-run model in a draft assessment undergoing review) e.g., residual plots, time series plots of observed and predicted values, or other approaches. Note that model diagnostics *are* required in draft assessments undergoing review.
   f. Convergence status and convergence criteria for the base-run model (or proposed base-run).
   g. Randomization run results or other evidence of search for global best estimates.
   h. Evaluation of model parameters. Do they make sense? Are they credible?
   i. Are model results consistent with assessments of the same species in Canada and Alaska? Are parameter estimates (e.g., survey catchability) consistent with estimates for related stocks?
   5. Point-by-point response to the STAR panel recommendations.* (Not required in draft assessment undergoing review.)
6. Base-run(s) results
   a. Table listing all explicit parameters in the stock assessment model used for base runs, their purpose (e.g., recruitment parameter, selectivity parameter) and whether or not the parameter was actually estimated in the stock assessment model.
   b. Population numbers at age × year × sex (if sex-specific M, growth, or selectivity) (May be provided as a text file).* (Not required in draft assessment undergoing review.)
   c. Time-series of total, summary, and spawning biomass, depletion relative to B_0, recruitment and fishing mortality or exploitation rate estimates (table and figures).
   d. Selectivity estimates (if not included elsewhere).
   e. Stock-recruitment relationship.
7. Uncertainty and sensitivity analyses. The best approach for describing uncertainty and the range of probable biomass estimates in groundfish assessments may depend on the situation. Important factors to consider include:
   a. Parameter uncertainty (variance estimation conditioned on a given model, estimation framework, data set choice, and weighting scheme), including likelihood profiles of important assessment parameters (e.g., natural mortality). This also includes expressing uncertainty in derived outputs of the model and estimating CVs by an appropriate methods (e.g., bootstrap, asymptotic methods, Bayesian approaches, such as MCMC).
   b. Sensitivity to data set choice and weighting schemes (e.g., emphasis factors), which may also include a consideration of recent patterns in recruitment.
   c. Sensitivity to assumptions about model structure, i.e., model specification uncertainty.
   d. Retrospective analysis, where the model is fitted to a series of shortened input data sets, with the most recent years of input data being dropped.
   e. Historical analysis (plot of actual estimates from current and previous assessments).
   f. Subjective appraisal of the magnitude and sources of uncertainty.
   g. If a range of model runs is used to characterize uncertainty it is important to provide some qualitative or quantitative information about relative probability of each.
   h. If possible, ranges depicting uncertainty should include at least three runs: (a) one judged most probable; (b) at least one that depicts the range of uncertainty in the direction of lower current biomass levels; and (c) one that depicts the range of uncertainty in the direction of higher current biomass levels. The entire range of uncertainty should be carried through stock projections and decision table analyses.

E. <u>Reference points (biomass and exploitation rate).</u>
   1. Unfished spawning stock biomass, summary age biomass, and recruitment.
   2. Reference points based on $B_{40\%}$ (spawning biomass, SPR, exploitation rate, equilibrium yield).
   3. Reference points based on default SPR proxy (spawning biomass, SPR, exploitation rate, equilibrium yield).

4. Reference points based on MSY (if estimated) (spawning biomass, SPR, exploitation rate, equilibrium yield).
5. Equilibrium yield curve showing various B_{MSY} proxies (see attached example).

F. Harvest projections and decision tables* (Not required in draft assessment undergoing review.)
1. Harvest projections and decision tables (i.e., a matrix of states of nature versus management action) should cover the plausible range of uncertainty about current biomass and the full range of candidate fishing mortality targets used for the stock or requested by the GMT. These should at least include calculation of the ABC based on F_{MSY} (or its proxy) and the OY that is implied under the Council's 40:10 harvest policy. Ideally, the alternatives described in the decision table will be drawn from a probability distribution which describes the pattern of uncertainty regarding the status of the stock and the consequences of alternative future management actions. Where alternatives are not formally associated with a probability distribution, the document needs to present sufficient information to guide assignment of approximate probabilities to each alternative. Decision tables should follow the format of the example Executive Summary for canary rockfish (Appendix D of this document) in which the columns represent the states of nature and the rows the management decisions. In most cases, management decisions will represent the sequence of catches obtained by applying the Council 40-10 harvest policy to each state of nature; however other alternatives may be suggested by the GMT as being more relevant to Council decision-making. For example, when recent catches are much less than the OY, there may be more interest in status quo projections.
2. Information presented should include biomass, stock depletion, and yield projections of ABC and OY for ten years into the future, beginning with the first year for which management action could be based upon the assessment.

G. Regional management considerations.
1. Discuss whether a regional management approach make sense for the species from a biological perspective.
2. If there are insufficient data to analyze a regional management approach, what are the research and data needs to answer this question?

H. Research needs (prioritized).

I. Acknowledgments-include STAR panel members and affiliations as well as names and affiliations of persons who contributed data, advice or information but were not part of the assessment team. * (Not required in draft assessment undergoing review.)

J. Literature cited.

K. An appendix with the complete parameter and data in the native code of the stock assessment program. (For a draft assessment undergoing review, these listings can be provided as text files or in spreadsheet format.)

Appendix C: Template for Executive Summary Prepared by STAT Teams

Stock: species/area, including an evaluation of any potential biological basis for regional management

Catches: trends and current levels-include table for last ten years and graph with long term data

Data and assessment: date of last assessment, type of assessment model, data available, new information, and information lacking

Unresolved problems and major uncertainties: any special issues that complicate scientific assessment, questions about the best model scenario, etc.

Reference points: management targets and definition of overfishing, including the harvest rate that brings the stock to equilibrium at $B_{40\%}$ (the B_{MSY} proxy) and the equilibrium stock size that results from fishing at the default harvest rate (the F_{MSY} proxy).

Stock biomass: trends and current levels relative to virgin or historic levels, description of uncertainty-include table for last 10 years and graph with long term estimates

Recruitment: trends and current levels relative to virgin or historic levels-include table for last 10 years and graph with long term estimates

Exploitation status: exploitation rates (i.e., total catch divided by exploitable biomass, or the annual SPR harvest rate) – include a table with the last 10 years of data and a graph showing the trend in fishing mortality relative to the target (y-axis) plotted against the trend in biomass relative to the target (x-axis).

Management performance: catches in comparison to ABC and OY values for the most recent 10 years (when available), overfishing levels, actual catch and discard.

Forecasts: ten-year forecasts of catch, summary biomass, spawning biomass, and depletion.* (Not required in draft assessments undergoing review.)

Decision table: projected yields (ABC and OY), spawning biomass, and stock depletion levels for each year.* (Not required in draft assessments undergoing review.)

Research and data needs: identify information gaps that seriously impede the stock assessment.

Rebuilding Projections: principal results from rebuilding analysis if the stock is overfished.* This section should be included in the Final/SAFE version assessment document but is not required for draft assessments undergoing review. See Rebuilding Analysis Terms of Reference for detailed information on rebuilding analysis requirements.

Summary Table: as detailed in the attached example.

Hilborn, R., and C. J. Walters. 1992. Quantitative fisheries stock assessment: Choice, dynamics and uncertainty. Chapman and Hall.

Appendix D: Example of a Complete Stock Assessment Executive Summary

Executive Summary

Stock

This assessment reports the status of the canary rockfish (*Sebastes pinniger*) resource off the coast of the United States from southern California to the U.S.-Canadian border using data through 2006. The resource is modeled as a single stock. Spatial aspects of the coast-wide population are addressed through geographic separation of data sources/fleets where possible and consideration of residual patterns that may be a result of inherent stock structure. There is currently no genetic evidence that there are distinct biological stocks of canary rockfish off the U.S. coast and very limited tagging data to describe adult movement, which may be significant across depth and latitude. Future efforts to specifically address regional management concerns will require a more spatially explicit model that likely includes the portion of the canary rockfish stock residing in Canadian waters off Vancouver Island.

Catches

Catch of canary rockfish is first reported in 1916 in California. Since that time, annual catch has ranged from 46.5 mt in 2004 to 5,544 in 1982 and totaled almost 150,000 mt over the time-series. Canary rockfish have been primarily caught by trawl fleets, on average comprising ~85% of the annual catches, with the Oregon fleet removing as much as 3,941 mt in 1982. Historically just 10% of the catches have come from non-trawl commercial fisheries, although this proportion reached 24% and 358 mt in 1997. Recreational removals have averaged just 6% of the total catch, historically, but have become relatively more important as commercial landings have been substantially reduced in recent years. Recreational catches reached 59% of the total with 30 mt caught in 2003. Total catches after 1999 have been reduced by an order of magnitude in an attempt to rebuild a stock determined to be overfished on the basis of the 1999 assessment.

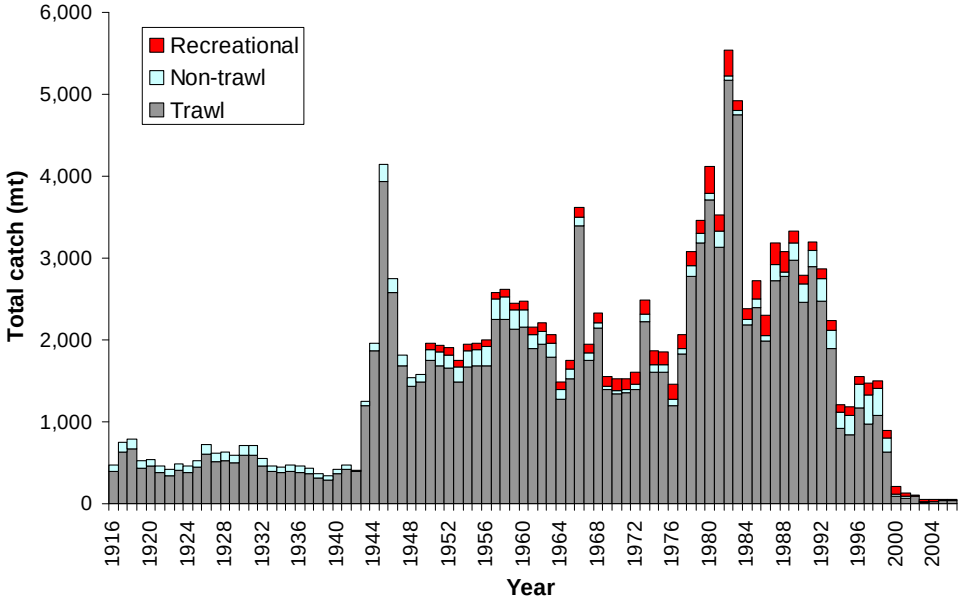

Figure a. Canary rockfish catch history by major source, 1916-2006.

Table a. Recent commercial fishery catches (mt) by fleet.

Year	Southern California trawl	Northern California trawl	Oregon trawl	Washington trawl	Southern California non-trawl	Northern California non-trawl	Oregon-Washington non-trawl	At-sea whiting bycatch
1997	31.96	142.66	589.85	203.44	29.78	73.80	254.42	3.63
1998	8.41	149.45	716.05	203.01	23.33	57.25	250.13	5.47
1999	7.36	96.25	387.85	139.97	8.53	28.59	123.97	5.63
2000	1.71	11.24	46.62	32.66	2.52	5.50	10.25	2.35
2001	1.44	9.43	33.13	19.65	1.60	4.96	11.00	4.05
2002	0.36	14.62	32.60	33.29	0.02	0.08	3.15	5.24
2003	0.23	0.31	5.02	6.24	0.00	0.08	6.89	0.93
2004	0.61	1.95	7.67	7.73	0.02	0.06	4.68	5.22
2005	0.72	2.84	4.91	25.90	0.06	0.09	1.79	1.44
2006	3.57	2.28	2.91	15.64	0.00	0.00	3.11	1.09

Data and Assessment

This assessment used the Stock Synthesis 2 integrated length-age structured model. The model includes catch, length- and age-frequency data from 11 fishing fleets, including trawl, non-trawl and recreational sectors. Biological data is derived from both port and on-board observer sampling programs. The National Marine Fisheries Service (NMFS) triennial bottom trawl survey and Northwest Fisheries Science Center (NWFSC) trawl survey relative biomass indices and biological sampling provide fishery independent information on relative trend and demographics of the canary stock. The Southwest Fisheries Science Center (SWFSC)/NWFSC/Pacific Whiting Conservation Cooperative (PWCC) coast-wide pre-recruit survey provides a source of recent recruitment strength information.

New analysis of the triennial survey data led to separating the series into two parts (1980-1992, 1995-2004) to allow for potential changes in catchability due to timing of survey operations. Accommodation of potential changes in fishery selectivity due to management actions including the adoption of canary-specific trip limits in 1995, small-footrope requirements in 1999, closure of the RCA in 2002 and use of selective flatfish trawl starting in 2005 was also added in this assessment. These and other changes have resulted in a change in the estimate of current stock status and large increase in the perception of uncertainty regarding this quantity in comparison to the most recent 2005 and earlier assessments.

The base case assessment model includes parameter uncertainty from a variety of sources, but underestimates the considerable uncertainty in recent trend and current stock status. For this reason, in addition to asymptotic confidence intervals (based upon the model's analytical estimate of the variance near the converged solution), two alternate states of nature regarding stock productivity (via the steepness parameter of the stock-recruitment relationship) are presented. The base case model (steepness = 0.51) is considered to be twice as likely as the two alternate states (steepness = 0.35, 0.72) based on the results of a meta-analysis of west coast rockfish (M. Dorn, personal communication). In order to best capture this source of uncertainty, all three states of nature will be used as probability-weighted input to the rebuilding analysis.

Stock biomass

Canary rockfish were relatively lightly exploited until the early 1940's, when catches increased and a decline in biomass began. The rate of decline in spawning biomass accelerated during the late 1970s, and finally reached a minimum (13% of unexploited) in the mid 1990s. The canary rockfish spawning stock biomass is estimated to have been increasing since that time, in response to reductions in harvest and above average recruitment in the preceding decade. However, this trend is very uncertain. The estimated relative depletion level in 2007 is 32.4% (~95% asymptotic interval: 24-41%, ~75% interval based on the range of states of nature: 12-56%), corresponding to 10,544 mt (asymptotic interval: 7,776-13,312 mt, states of nature interval: 4,009-17,519) of female spawning biomass in the base model.

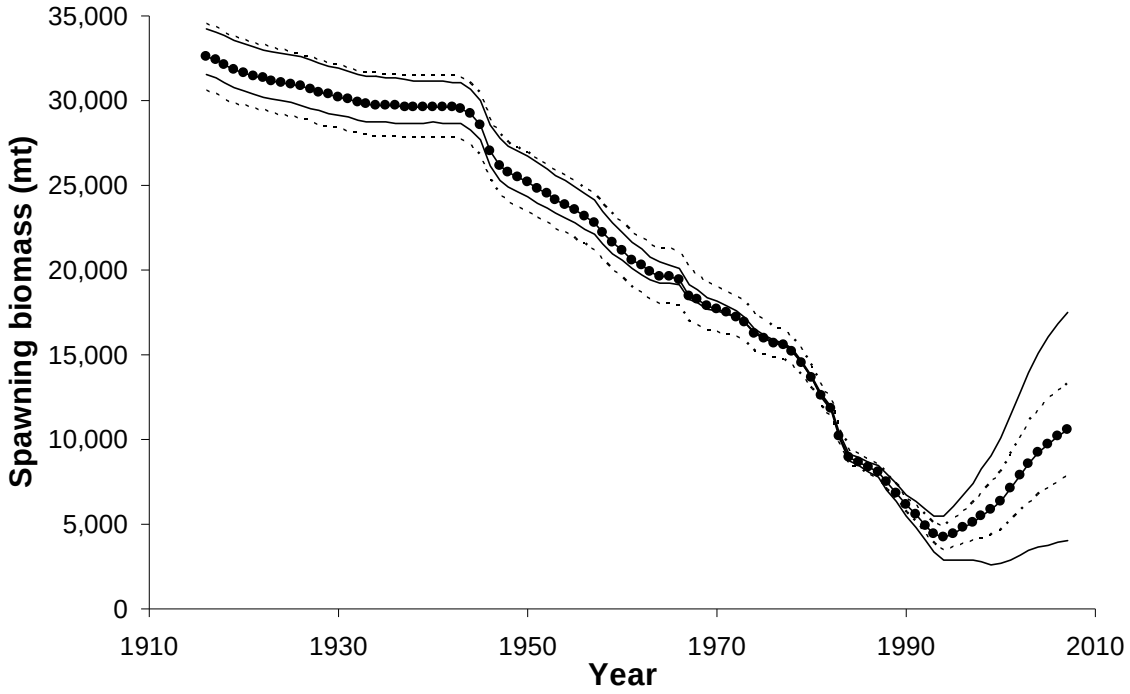

Figure b. Estimated spawning biomass time-series (1916-2007) for the base case model (round points) with approximate asymptotic 95% confidence interval (dashed lines) and alternate states of nature (light lines).

Table b. Recent trend in estimated canary rockfish spawning biomass and relative depletion level.

Year	Spawning biomass (mt)	~95% confidence interval	Range of states of nature	Estimated depletion	~95% confidence interval	Range of states of nature
1998	5,499	4,177-6,820	2,761-8,241	16.9%	NA	8.1-26.2
1999	5,826	4,296-7,357	2,610-9,073	17.9%	NA	7.6-28.8
2000	6,364	4,618-8,111	2,644-10,144	19.5%	NA	7.7-32.2
2001	7,149	5,190-9,109	2,918-11,477	22.0%	NA	8.5-36.4
2002	7,910	5,750-10,070	3,184-12,779	24.3%	NA	9.3-40.6
2003	8,603	6,264-10,942	3,417-13,985	26.4%	NA	10.0-44.4
2004	9,226	6,736-11,715	3,628-15,076	28.3%	NA	10.6-47.9
2005	9,749	7,140-12,359	3,795-16,019	29.9%	NA	11.1-50.9
2006	10,183	7,482-12,884	3,918-16,825	31.3%	23.1-39.4	11.4-53.4
2007	10,544	7,776-13,312	4,009-17,519	32.4%	24.1-40.7	11.7-55.6

Recruitment

The degree to which canary rockfish recruitment declined over the last 50 years is closely related to the level of productivity (stock-recruit steepness) modeled for the stock. High steepness values imply little relationship between spawning stock and recruitment, while low steepness values cause a strong correlation. After a period of above average recruitments, recent year-class strengths have generally been low, with only 1999 and 2001 producing large estimated recruitments (the 2007 recruitment is based only on the stock-recruit function). There is little information other than the pre-recruit index to inform the assessment model about recruitments subsequent to 2002, so those estimates will likely be updated in future assessments. As the larger recruitments from the late 1980s and early 1990s move through the population in future projections, the effects of recent poor recruitment will tend to slow the rate of recovery.

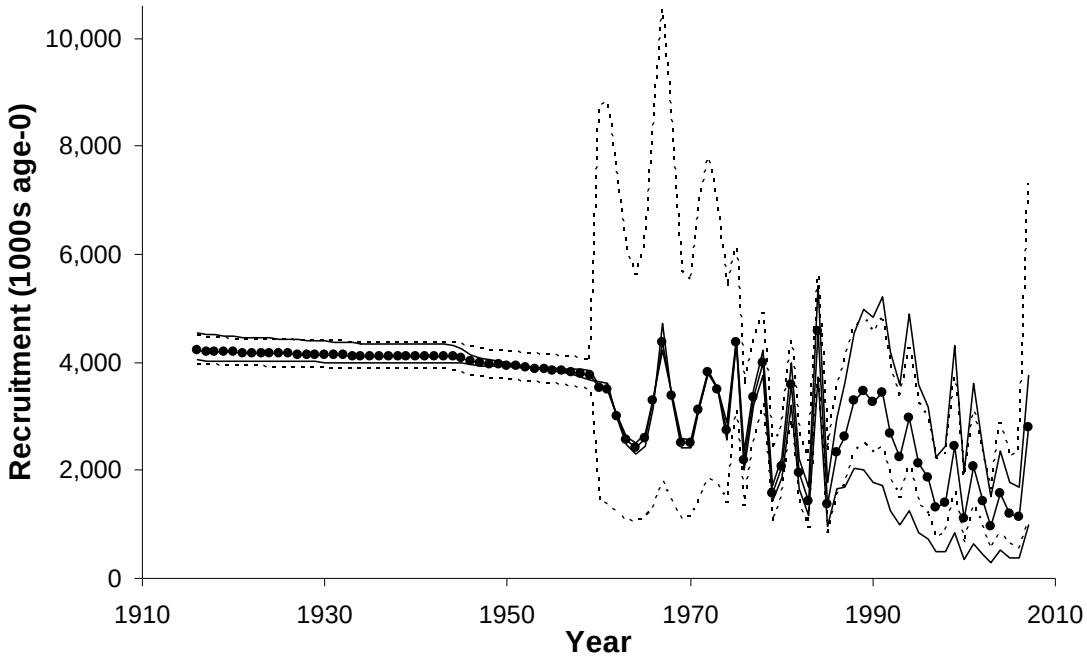

Figure c. Time series of estimated canary rockfish recruitments for the base case model (round points) with approximate asymptotic 95% confidence interval (dashed lines) and alternate states of nature (light lines).

Table c. Recent estimated trend in canary rockfish recruitment.

Year	Estimated recruitment (1000s)	~95% confidence interval	Range of states of nature
1998	1,391	841-2,299	484-2,453
1999	2,449	1,606-3,735	841-4,318
2000	1,099	638-1,893	351-1,938
2001	2,061	1,359-3,124	643-3,613
2002	1,432	905-2,267	447-2,383
2003	955	547-1,667	302-1,515
2004	1,565	854-2,869	520-2,373
2005	1,182	627-2,231	390-1,771
2006	1,144	548-2,389	367-1,699
2007	2,807	1,078-7,313	991-3,745

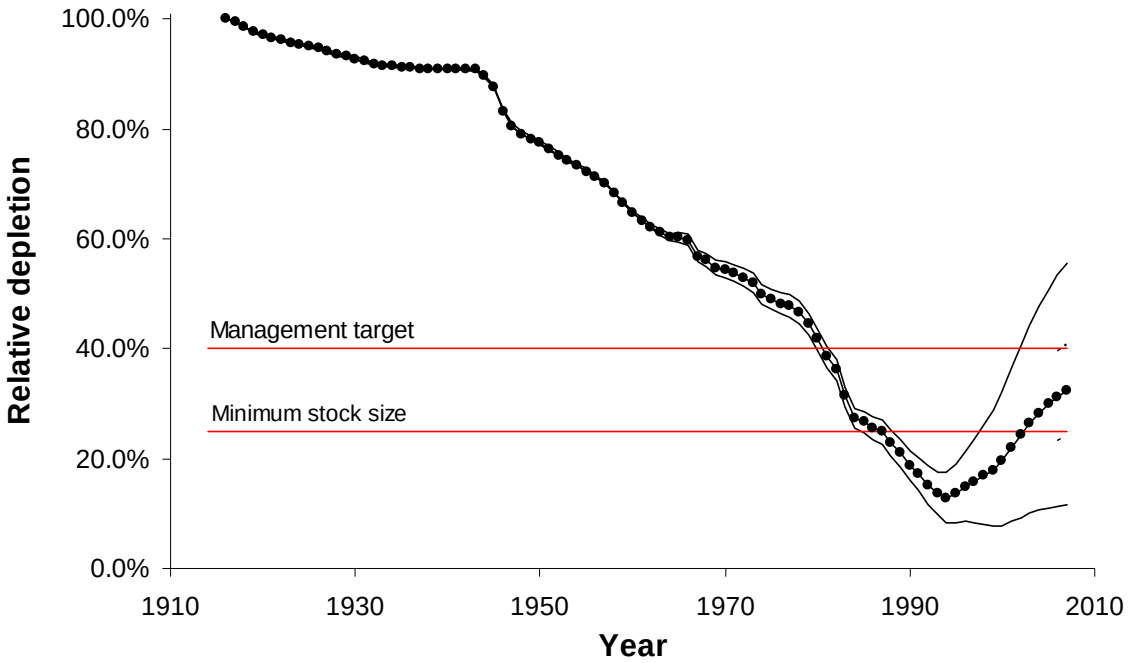

Figure d. Time series of depletion level as estimated in the base case model (round points) with approximate asymptotic 95% confidence interval (2006-2007 only, dashed lines) and alternate states of nature (light lines).

Reference points

Unfished spawning stock biomass was estimated to be 32,561 mt in the base case model. This is slightly smaller than the equilibrium value estimated in the 2005 assessment. The target stock size ($SB_{40\%}$) is therefore 13,024 mt. Maximum sustained yield (MSY) applying current fishery selectivity and allocations (a 'bycatch-only' scenario) was estimated in the assessment model to occur at a spawning stock biomass of 12,394 mt and produce an MSY catch of 1,169 mt (SPR = 52.9%). This is nearly identical to the yield, 1,167 mt, generated by the SPR (54.4%) that stabilizes the stock at the $SB_{40\%}$ target. The fishing mortality target/overfishing level (SPR = 50.0%) generates a yield of 1,161 mt at a stock size of 11,161 mt.

When selectivity and allocation from the mid 1990s (1994-1998) was applied, to mimic reference points under a targeted fishery scenario, the yield increased to 1,578 mt from a slightly smaller stock size (12,211 mt), but a similar rate of exploitation (SPR=52.5%). This is due to higher relative selection of older and larger fish when the fishery was targeting instead of avoiding canary rockfish. These values are appreciably higher than those from previous assessment models due primarily to the difference in steepness.

Exploitation status

The abundance of canary rockfish was estimated to have dropped below the $SB_{40\%}$ management target in 1981 and the overfished threshold in 1987. In hindsight, the spawning stock biomass passed through the target and threshold levels at a time when the annual catch was averaging more than twice the current estimate of the MSY. The stock remains below the rebuilding target, although the spawning stock biomass appears to have been increasing since 1999. The degree of increase is very sensitive to the value for steepness (state of nature), and is projected to slow as recent (and below average) recruitments begin to contribute to the spawning biomass. Fishing mortality rates in excess of the current F-target for rockfish of $SPR_{50\%}$ are estimated to have begun in the late 1970s and persisted through 1999. Recent management actions appear to have curtailed the rate of removal such that overfishing has not occurred since 1999, and recent SPR values are in excess of 95%. Relative exploitation rates (catch/biomass of age-5 and older fish) are estimated to have been less than 1% since 2001. These patterns are largely insensitive to the three states of nature.

Table d. Recent trend in spawning potential ratio (SPR) and relative exploitation rate (catch/biomass of age-5 and older fish).

Year	Estimated SPR (%)	Range of states of nature	Relative exploitation rate	Range of states of nature
1997	31.6%	16.9-41.9	0.0889	0.0607-0.1652
1998	33.2%	16.8-44.3	0.0873	0.0576-0.1778
1999	48.9%	26.1-61.0	0.0506	0.0323-0.1146
2000	84.0%	65.7-89.7	0.0112	0.0070-0.0271
2001	89.7%	76.5-93.5	0.0067	0.0041-0.0165
2002	92.2%	81.9-95.1	0.0050	0.0031-0.0126
2003	95.4%	88.3-97.2	0.0023	0.0014-0.0058
2004	96.3%	90.6-97.8	0.0020	0.0012-0.0051
2005	96.3%	90.5-97.7	0.0021	0.0013-0.0055
2006	96.5%	90.7-97.9	0.0019	0.0011-0.0049

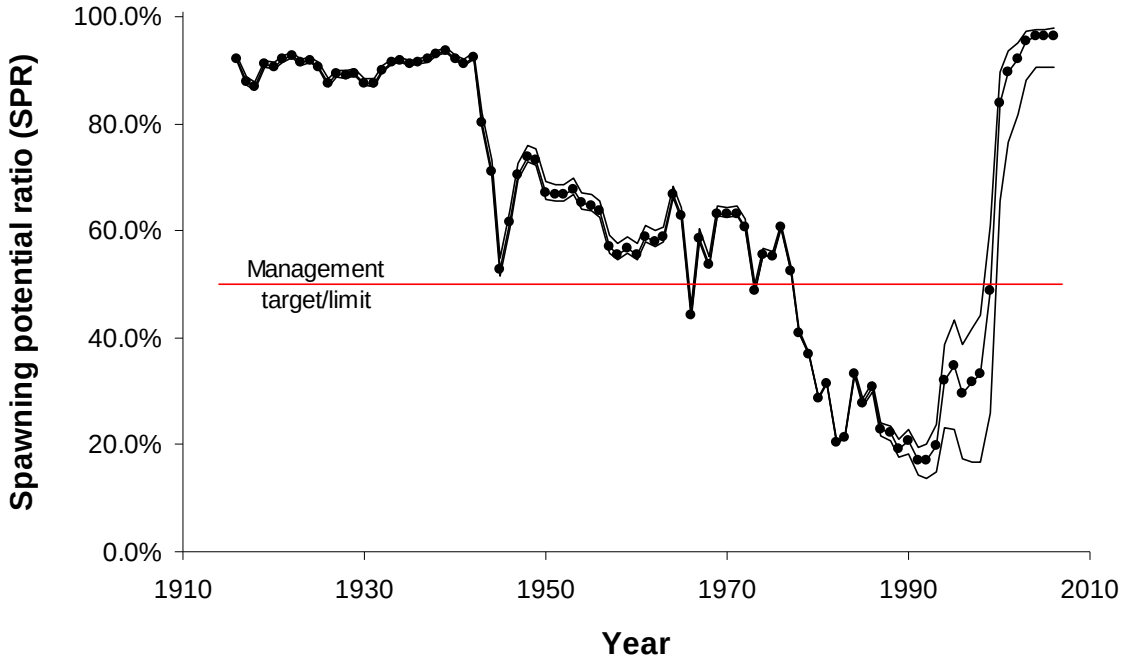

Figure e. Time series of estimated spawning potential ratio (SPR) for the base case model (round points) and alternate states of nature (light lines). Values of SPR below 0.5 reflect harvests in excess of the current overfishing proxy.

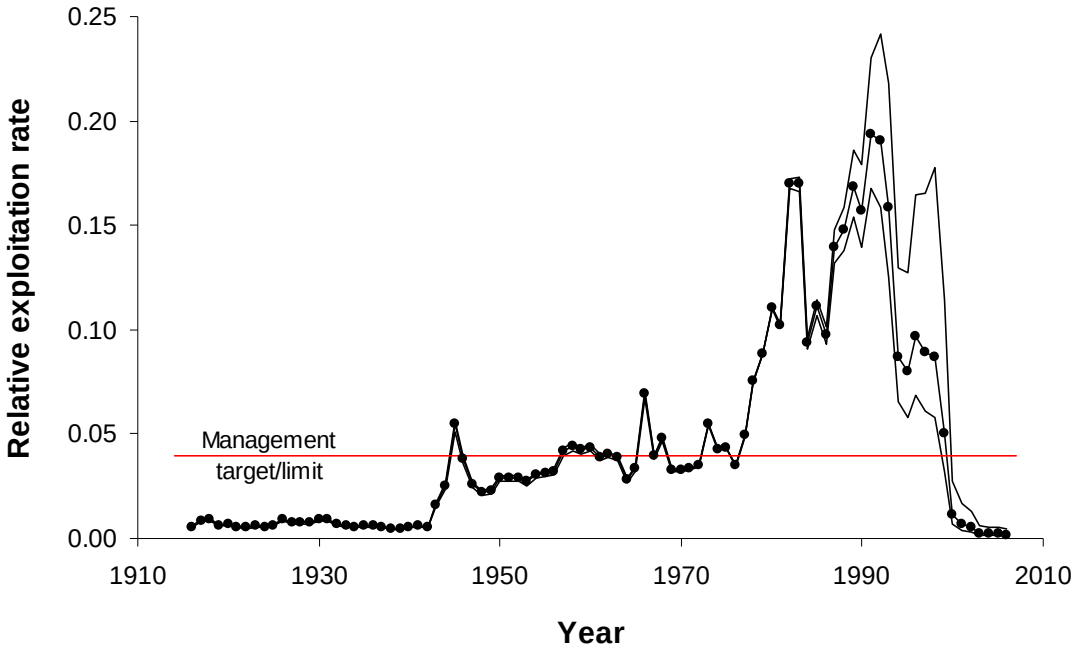

Figure f. Time series of estimated relative exploitation rate (catch/age 5 and older biomass, lower panel) for the base case model (round points) and alternate states of nature (light lines). Values of relative exploitation rate in excess of horizontal line are above the rate corresponding to the overfishing proxy from the base case.

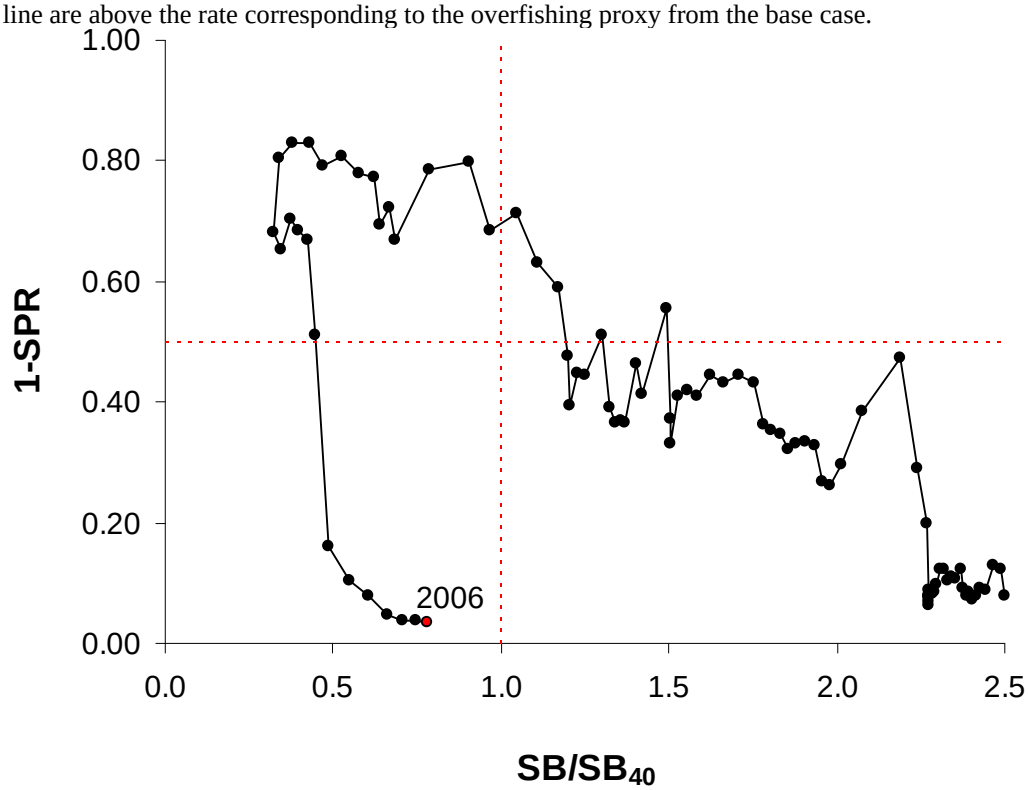

Figure g. Estimated spawning potential ratio relative to the proxy target of 50% vs. estimated spawning biomass relative to the proxy 40% level from the base case model. Higher biomass occurs on the right side of the x-axis, higher exploitation rates occur on the upper side of the y-axis.

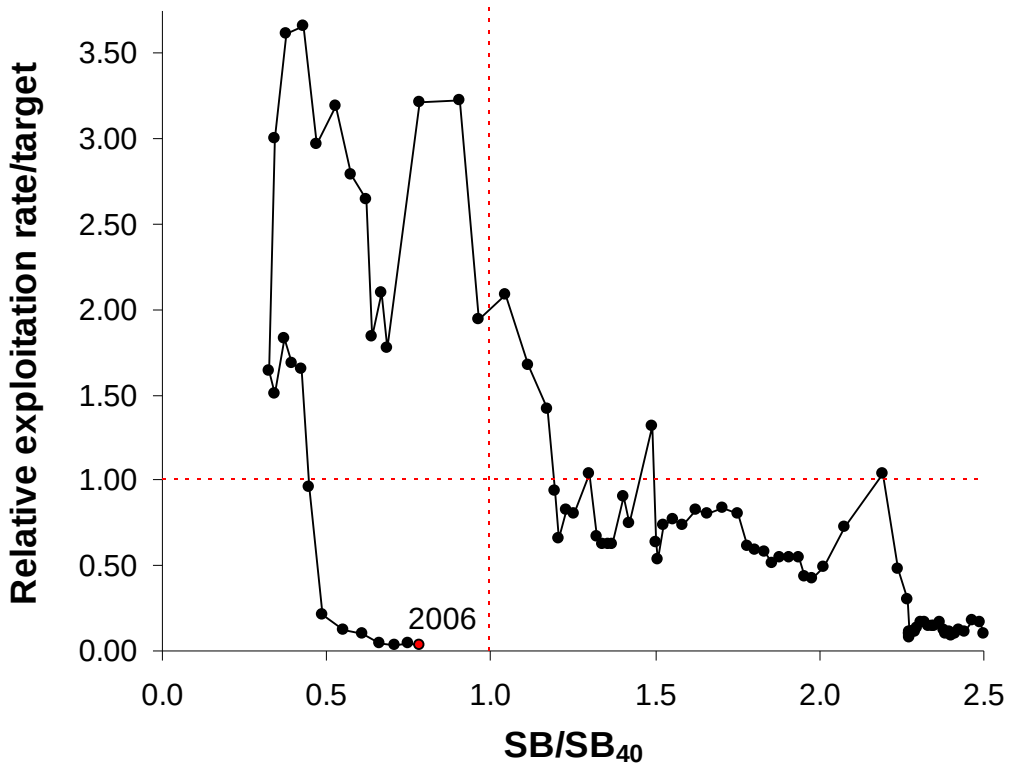

Figure g. Phase plot of estimated fishing intensity vs. relative spawning biomass for the base case model. Fishing intensity is the relative exploitation rate divided by the level corresponding to the overfishing proxy (0.040). Relative spawning biomass is annual spawner abundance divided by the 40% rebuilding target.

Management performance

Following the 1999 declaration that the canary rockfish stock was overfished the canary OY was reduced by over 70% in 2000 and by the same margin again over the next three years. Managers employed several tools in an effort to constrain catches to these dramatically lower targets. These included: reductions in trip/bag limits for canary and co-occurring species, the institution of spatial closures, and new gear restrictions intended to reduce trawling in rocky shelf habitats and the coincident catch of rockfish in shelf flatfish trawls. In recent years, the total mortality has been near the OY, but well below the ABC. Since the overfished determination in 1999, the total 7-year catch (644 mt) has been only 13% above the sum of the OYs for 2000-2006. This level of removals represents only 35% of the sum of the ABCs for that period. The total 2006 catch (47 mt) is <1% of the peak catch that occurred in the early 1980s.

Table e. Recent trend in estimated total canary rockfish catch and commercial landings (mt) relative to management guidelines.

Year	ABC (mt)	OY (mt)	Commercial landings (mt)[1]	Total Catch (mt)
1997	1,220[2]	1,000[2]	1,113.8	1,478.8
1998	1,045[2]	1,045[2]	1,182.4	1,494.2
1999	1,045[2]	857[2]	665.7	898.0
2000	287	200	60.6	208.4
2001	228	93	42.8	133.6
2002	228	93	48.6	106.8
2003	272	44	8.5	51.0
2004	256	47.3	10.7	46.5
2005	270	46.8	10.9	51.4
2006	279	47	8.2	47.1

[1]Excludes all at-sea whiting, recreational and research catches.
[2]Includes the Columbia and Vancouver INPFC areas only.

Unresolved problems and major uncertainties

Parameter uncertainty is explicitly captured in the asymptotic confidence intervals reported throughout this assessment for key parameters and management quantities. These intervals reflect the uncertainty in the model fit to the data sources included in the assessment, but do not include uncertainty associated with alternative model configurations, weighting of data sources (a combination of input sample sizes and relative weighting of likelihood components), or fixed parameters. Specifically, there appears to be conflicting information between the length- and age-frequency data regarding the degree of stock decline, making the model results sensitive to the relative weighting of each. This issue is explored in the assessment, but cannot be fully resolved at this time. The relationship between the degree of dome in the selectivity curves and the increase in female natural mortality with age remains a source of uncertainty that is included in model results, as it has been in previous assessments for canary rockfish. Uncertainty in the steepness parameter of the stock-recruitment relationship is significant and will likely persist in future assessments; this uncertainty is included in the assessment and rebuilding projections through explicit consideration of the three states of nature.

Forecasts

The forecast reported here will be replaced by the rebuilding analysis to be completed in September-October 2007 following SSC review of the stock assessment. In the interim, the total catch in 2007 and 2008 is set equal to the OY (44 mt). The exploitation rate for 2009 and beyond is based upon an SPR of 88.7%, which approximates the harvest level in the current rebuilding plan. Uncertainty in the rebuilding forecast will be based upon the three states of nature for steepness and random variability in future recruitment deviations for each rebuilding simulation. Current medium-term forecasts predict slow increases in abundance and available catch, with OY values for 2009 and 2010 increasing by nearly four times the value of 44 mt from the 2005 assessment. This is largely attributable to the revised perception of steepness, based on meta-analysis of other rockfish species. The following table shows the projection of expected canary rockfish catch, spawning biomass and depletion.

Table f. Projection of potential canary rockfish ABC, OY, spawning biomass and depletion for the base case model based on the SPR= 0.887 fishing mortality target used for the last rebuilding plan (OY) and $F_{50\%}$ overfishing limit/target (ABC). Assuming the OY of 44 mt is met in 2007 and 2008.

Year	ABC (mt)	OY (mt)	Age 5+ biomass (mt)	Spawning biomass (mt)	Depletion
2007	973	44	25,995	10,544	32.4%
2008	978	44	26,417	10,840	33.3%
2009	981	162	26,859	11,072	34.0%
2010	980	162	26,995	11,194	34.4%
2011	992	164	27,018	11,254	34.6%
2012	1,026	169	27,440	11,266	34.6%
2013	1,074	177	27,985	11,260	34.6%
2014	1,124	185	28,656	11,280	34.6%
2015	1,171	193	29,445	11,368	34.9%
2016	1,214	200	30,332	11,545	35.5%
2017	1,253	207	31,297	11,812	36.3%
2018	1,290	213	32,317	12,156	37.3%

Decision table

Because canary rockfish is currently managed under a rebuilding plan, this decision table is only intended to better compare and contrast the base case with uncertainty among states of nature. The results of the rebuilding plan will integrate these three states of nature as well as projected recruitment variability. Further, various alternate probabilities of rebuilding by target and limit time-periods as well as fishing mortality rates will be evaluated in the rebuilding analysis. Relative probabilities of each state of nature are based on a meta-analysis for steepness of west coast rockfish (M. Dorn, AFSC, personal communication). Landings in 2007-2008 are 44 mt for all cases. Selectivity and fleet allocations are projected at the average 2003-2006 values.

Table g. Decision table of 12-year projections for alternate states of nature (columns) and management options (rows) beginning in 2009. Relative probabilities of each state of nature are based on a meta-analysis for steepness of west coast rockfish (M. Dorn, AFSC, personal communication). Landings in 2007-2008 are 44 mt for all cases. Selectivity and fleet allocations are projected at the average 2003-2006 values.

			State of nature					
			Low steepness (0.35)		Base case (steepness = 0.51)		High steepness (0.72)	
Relative probability			0.25		0.5		0.25	
Management decision	Year	Catch (mt)	Depletion	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion	Spawning biomass (mt)
Rebuilding SPR 88.7% catches from low steepness state of nature	2009	56	12.0%	4,099	34.0%	11,072	59.0%	18,583
	2010	56	12.0%	4,100	34.5%	11,236	60.1%	18,932
	2011	56	11.9%	4,078	34.8%	11,339	60.8%	19,156
	2012	59	11.8%	4,042	35.0%	11,396	61.2%	19,270
	2013	62	11.7%	4,003	35.1%	11,436	61.3%	19,313
	2014	65	11.6%	3,979	35.3%	11,502	61.4%	19,343
	2015	67	11.6%	3,984	35.7%	11,638	61.7%	19,423
	2016	70	11.7%	4,025	36.4%	11,866	62.2%	19,590
	2017	72	12.0%	4,102	37.4%	12,188	63.0%	19,852
	2018	74	12.3%	4,209	38.7%	12,591	64.1%	20,199
Rebuilding SPR 88.7% catches from base case	2009	162	12.0%	4,099	34.0%	11,072	59.0%	18,583
	2010	162	11.8%	4,058	34.4%	11,194	60.0%	18,890
	2011	164	11.7%	3,994	34.6%	11,254	60.5%	19,069
	2012	169	11.4%	3,914	34.6%	11,266	60.8%	19,138
	2013	177	11.2%	3,831	34.6%	11,260	60.7%	19,135
	2014	185	11.0%	3,762	34.6%	11,280	60.7%	19,118
	2015	193	10.9%	3,719	34.9%	11,368	60.8%	19,150
	2016	200	10.8%	3,710	35.5%	11,545	61.2%	19,266
	2017	207	10.9%	3,733	36.3%	11,812	61.8%	19,475
	2018	213	11.0%	3,781	37.3%	12,156	62.8%	19,767
Rebuilding SPR 88.7% catches from high steepness state of nature	2009	273	12.0%	4,099	34.0%	11,072	59.0%	18,583
	2010	271	11.7%	4,014	34.2%	11,150	59.8%	18,845
	2011	272	11.4%	3,905	34.3%	11,164	60.3%	18,978
	2012	277	11.0%	3,780	34.2%	11,130	60.3%	19,001
	2013	285	10.7%	3,654	34.0%	11,079	60.2%	18,951
	2014	293	10.3%	3,542	34.0%	11,055	60.0%	18,891
	2015	300	10.1%	3,459	34.1%	11,100	59.9%	18,880
	2016	307	9.9%	3,408	34.5%	11,235	60.2%	18,953
	2017	313	9.9%	3,389	35.2%	11,461	60.7%	19,122
	2018	319	9.9%	3,394	36.1%	11,763	61.5%	19,374
Status quo (catch = 44 mt)	2009	44	12.0%	4,099	34.0%	11,072	59.0%	18,583
	2010	44	12.0%	4,104	34.5%	11,241	60.1%	18,937
	2011	44	11.9%	4,088	34.9%	11,349	60.8%	19,166
	2012	44	11.8%	4,057	35.0%	11,411	61.2%	19,285
	2013	44	11.7%	4,024	35.2%	11,456	61.4%	19,334
	2014	44	11.7%	4,005	35.4%	11,529	61.5%	19,371
	2015	44	11.7%	4,018	35.8%	11,673	61.8%	19,459
	2016	44	11.9%	4,069	36.6%	11,911	62.3%	19,635
	2017	44	12.1%	4,157	37.6%	12,244	63.2%	19,908
	2018	44	12.5%	4,277	38.9%	12,660	64.3%	20,268

Research and data needs

Progress on a number of research topics would substantially improve the ability of this assessment to reliably and precisely model canary rockfish population dynamics in the future and provide better monitoring of progress toward rebuilding:

1. Expanded Assessment Region: Given the high occurrence of canary rockfish close to the US-Canada border, a joint US-Canada assessment should be considered in the future.
2. Many assessments are deriving historical catch by applying various ratios to the total rockfish catch prior to the period when most species were delineated. A comprehensive historical catch reconstruction for all rockfish species is needed, to compile a best estimated catch series that accounts for all the catch and makes sense for the entire group.
3. Habitat relationships: The historical and current relationship between canary rockfish distribution and habitat features should be investigated to provide more precise estimates of abundance from the surveys, and to guide survey augmentations that could better track rebuilding through targeted application of newly developed survey technologies. Such studies could also assist determining the possibility of dome-shaped selectivity, aid in evaluation of spatial structure and the use of fleets to capture geographically-based patterns in stock characteristics.
4. Meta-population model: The spatial patterns show patchiness in the occurrence of large vs. small canary; reduced occurrence of large/old canary south of San Francisco; and concentrations of canary rockfish near the US-Canada border. The feasibility of a meta-population model that has linked regional sub-populations should be explored as a more accurate characterization of the coast-wide population's structure. Tagging of other direct information on adult movement will be essential to this effort.
5. Increased computational power and/or efficiency is required to move toward fully Bayesian approaches that may better integrate over both parameter and model uncertainty.
6. Additional exploration of surface ages from the late 1970s and inclusion into or comparison with the assessment model, or re-aging of the otoliths could improve the information regarding that time period when the stock underwent the most dramatic decline. Auxiliary biological data collected by ODFW from recreational catches and hook-and-line projects may also increase the performance of the assessment model in accurately estimating recent trends and stock size.
7. Due to inconsistencies between studies and scarcity of appropriate data, new data is needed on both the maturity and fecundity relationships for canary rockfish.
8. Re-evaluation of the pre-recruit index as a predictor of recent year class strength should be ongoing as future assessments generate a longer series of well-estimated recent recruitments to compare with the coast-wide survey index.
9. Meta-analysis or other summary of the degree of recruitment variability and the relative steepness for other rockfish and groundfish stocks should be ongoing, as this information is likely to be very important for model results (as it is here) in the foreseeable future.

Rebuilding projections

The rebuilding projections will be presented in a separate document after the assessment has been reviewed in September 2007.

Table h. Summary of recent trends in estimated canary rockfish exploitation and stock levels from the base case model; all values reported at the beginning of the year.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Commercial landings (mt)[1]	1,182.4	665.7	60.6	42.8	48.6	8.5	10.7	10.9	8.2	NA
Total catch (mt)	1,494.2	898.0	208.4	133.6	106.8	51.0	46.5	51.4	47.1	NA
ABC (mt)	1,045[2]	1,045[2]	287	228	228	272	256	270	279	172
OY	1,045[2]	857[2]	200	93	93	44	47.3	46.8	47.0	44
SPR	33.2%	48.9%	84.0%	89.7%	92.2%	95.4%	96.3%	96.3%	96.5%	NA
Exploitation rate (catch/age 5+ biomass)	0.0873	0.0506	0.0112	0.0067	0.0050	0.0023	0.0020	0.0021	0.0019	NA
Age 5+ biomass (mt)	17,125	17,733	18,659	20,078	21,275	22,333	23,583	24,402	25,317	25,995
Spawning biomass (mt)	5,499	5,826	6,364	7,149	7,910	8,603	9,226	9,749	10,183	10,544
~95% Confidence interval	4,177-6,820	4,296-7,357	4,618-8,111	5,190-9,109	5,750-10,070	6,264-10,942	6,736-11,715	7,140-12,359	7,482-12,884	7,776-13,312
Range of states of nature	2,761-8,241	2,610-9,073	2,644-10,144	2,918-11,477	3,184-12,779	3,417-13,985	3,628-15,076	3,795-16,019	3,918-16,825	4,009-17,519
Recruitment (1000s)	1,391	2,449	1,099	2,061	1,432	955	1,565	1,182	1,144	2,807
~95% Confidence interval	841-2,299	1,606-3,735	638-1,893	1,359-3,124	905-2,267	547-1,667	854-2,869	627-2,231	548-2,389	1,078-7,313
Range of states of nature	484-2,453	841-4,318	351-1,938	643-3,613	447-2,383	302-1,515	520-2,373	390-1,771	367-1,699	991-3,745
Depletion	16.9%	17.9%	19.5%	22.0%	24.3%	26.4%	28.3%	29.9%	31.3%	32.4%
~95% Confidence interval	NA	NA	NA	NA	NA	NA	NA	NA	23.1-9.4	24.1-40.7
Range of states of nature	8.1-26.2	7.6-28.8	7.7-32.2	8.5-36.4	9.3-40.6	10.0-44.4	10.6-47.9	11.1-50.9	11.4-53.4	11.7-55.6

[1]Excludes all at-sea whiting, recreational and research catches.
[2]Includes the Columbia and Vancouver INPFC areas only.

Table i. Summary of canary rockfish reference points from the base case model. Values are based on 1994-1998 fishery selectivity and allocation to better approximate the performance of a targeted fishery rather than a bycatch-only scenario.

Quantity	Estimate	~95% Confidence interval	Range of states of nature
Unfished spawning stock biomass (SB_0, mt)	32,561	30,594-34,528	34,262-31,498
Unfished 5+ biomass (mt)	86,036	NA	91,980-82,744
Unfished recruitment (R_0, thousands)	4,210	3,961-4,458	4,540-4,035
Reference points based on $SB_{40\%}$			
MSY Proxy Spawning Stock Biomass ($SB_{40\%}$)	13,024	12,237-13,811	12,599-13704.7
SPR resulting in $SB_{40\%}$ ($SPR_{SB40\%}$)	54.4%	54.4-54.4	45.8-68.5
Exploitation rate resulting in $SB_{40\%}$	0.0457	NA	0.0277-0.0600
Yield with $SPR_{SB40\%}$ at $SB_{40\%}$ (mt)	1,574	1,477-1,672	996-2,034
Reference points based on SPR proxy for MSY			
Spawning Stock Biomass at SPR (SB_{SPR})(mt)	11,161	10,487-11,835	1,654-14,053
$SPR_{MSY\text{-}proxy}$	50.0%	NA	NA
Exploitation rate corresponding to SPR	0.0528	NA	0.0524-0.0539
Yield with $SPR_{MSY\text{-}proxy}$ at SB_{SPR} (mt)	1,572	1,476-1,668	238-1,962
Reference points based on estimated MSY values			
Spawning Stock Biomass at *MSY* (SB_{MSY}) (mt)	12,211	11,529-12,893	9,524-15,042
SPR_{MSY}	52.5%	52.1-52.8	37.0-70.5
Exploitation Rate corresponding to SPR_{MSY}	0.0487	NA	0.0254-0.0794
MSY (mt)	1,578	1,481-1,675	1,002-2,104

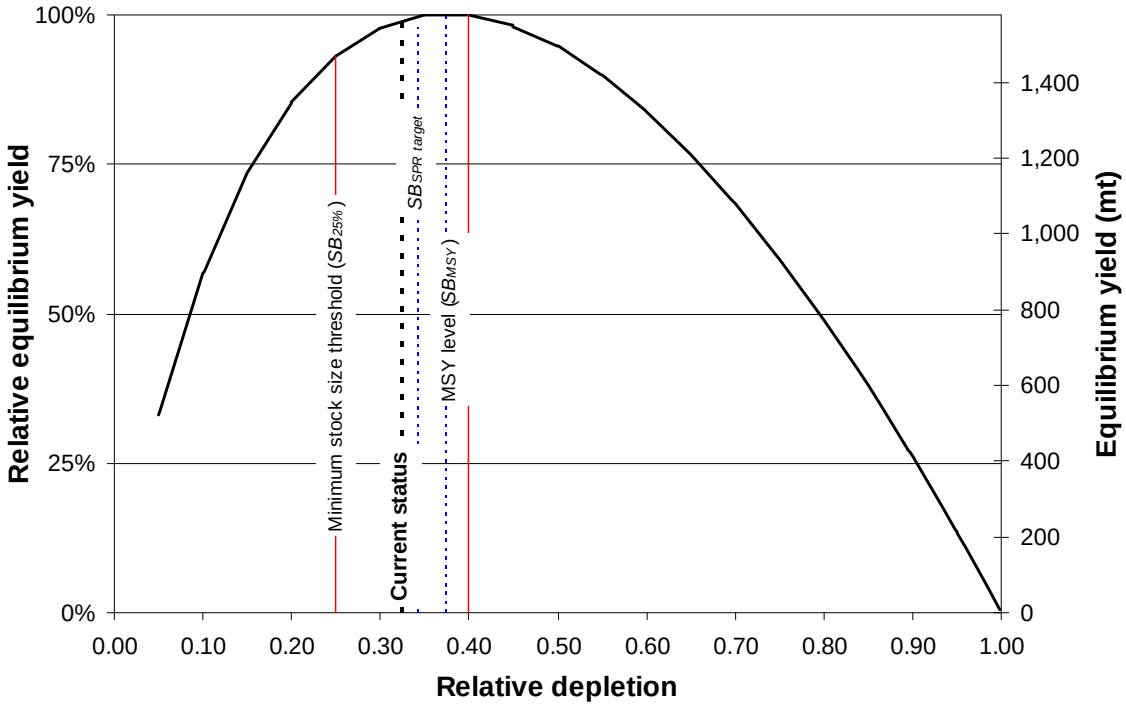

Figure h. Equilibrium yield curve (derived from reference point values reported in table i) for the base case model. Values are based on 1994-1998 fishery selectivity and allocation to better approximate the performance of a targeted fishery rather than a bycatch-only scenario.