Report on the 2007 Stock Assessment Review for Chilipepper Rockfish & Bocaccio

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1. Executive Summary

1.1. Impetus and goals for the review

The STAR Panel met at Santa Cruz, CA, from June 25-29, 1970, to review the stock assessment documents, the data inputs and the analytical methods of the stock assessments for bocaccio and chilipepper rockfish, which had been produced for the Pacific Fishery Management Council and the NMFS. The STAR Panel's task was to assess the technical merits of the two assessments, probing the results to assess their reliability and working with the STAT to reach a mutual consensus on a single base model, and then to identify two models, the results of which would bracket the results of the base model and reflect the uncertainty associated with its results. Bocaccio was last subjected to a full stock assessment in 2003, at which time the spawning biomass was estimated to be 7.4% of the unfished spawning biomass. In an update assessment in 2005, the estimate of spawning biomass had increased slightly to 10.7% of the unfished level. The last full stock assessment for chilipepper rockfish was undertaken in 1998, at which time the stock was not considered to be overfished.

1.2. Summary of findings, main conclusions, and recommendations

The STAR Panel and STAT were able to refine the stock assessment for chilipepper rockfish to produce a base case and to identify cases representing lower and upper estimates of uncertainty for this base case. The estimate of current depletion of spawning biomass associated with the base case was 0.7, while the values reflecting the lower and upper cases were 0.46 and 0.78, respectively. The STAR Panel accepted that an update assessment had been prepared for bocaccio rather than a full assessment, but recognised that acceptance/rejection of this update assessment lay outside their terms of reference. The STAR Panel therefore restricted its advice to ways in which future assessments for bocaccio might be improved.

There is a need to develop:

- a consistent and reliable reconstruction of historical catches for total rockfish and for each rockfish species, with estimates of the envelope of feasible values around the best estimate.
- methods of analysing the available data that take into account the manner in which these data were collected and the changes in fishing practices and the distribution of fishing through time.
- appropriate diagnostic outputs to assess the extent to which external factors have influenced the input data and to which the effect of these factors has been taken into account
- further fishery-wide, fishery-independent time series of data that are immune to changes in fishing practice or impact of regulations.

In the case of bocaccio, there is a need to move the assessment from Stock Synthesis I to a more appropriate and flexible model framework. Following this, a full assessment for bocaccio would be desirable.

2. Introduction

2.1. Background

At its November 2006 meeting, the Pacific Fishery Management Council determined the assessments which were required in 2007 to inform the management decisions to be made in 2008 and 2009. These included full assessments of the status of the stocks of bocaccio rockfish *Sebastes paucispinis* and chilipepper rockfish *Sebastes goodie* in the waters off the west coast of the United States. Specifically, the Pacific Fishery Management Council and NOAA's National Marine Fisheries Service sought "a determination of the condition and status of the fishery resources relative to current definitions for overfished status, summaries of available data included in the models, and impacts of various management scenarios on the status of the stocks".

For bocaccio, the underlying question was whether the stock, which had been recognised as being overfished in the late 1990s, continued to rebuild in accordance with earlier projections in response to the regulatory changes that had been introduced for this and other rockfish species. For chilipepper rockfish, which, at its last assessment in 1998 (Ralston *et al*., 1998), was found not to be overfished or experiencing overfishing, the question was the extent to which the biomass of this species had increased in response to those same regulations. At previous reviews of the assessments for bocaccio and chilipepper rockfish, uncertainty relating to historical catches, the reliability of the indices of abundance and size/age composition data and the value of natural mortality had been remarked upon by the various STAR Panels.

2.2. Terms of Reference

The terms of reference for the STAR Panel, as set out in the document, "GROUNDFISH STOCK ASSESSMENT AND REVIEW PROCESS FOR 2007-2008", are presented in Appendix 1.

2.3. Panel membership

The STAR Panel comprised:

- David Sampson, Scientific and Statistical Committee (SSC) Representative, Panel Chair
- Patrick Cordue, Center for Independent Experts (CIE)
- Norman Hall, Center for Independent Experts (CIE)
- Kevin Piner, NOAA Fisheries Service, Southwest Fisheries Science Center

Other participants included:

- Advisors:
  Gerry Richter, Groundfish Advisory Subpanel (GAP) Representative
  John DeVore, Groundfish Management Team (GMT) Representative
- Stock Assessment Teams (STAT):
  Chilipepper rockfish

John Field, NOAA Fisheries Service, Southwest Fisheries Science Center, Fisheries Ecology Division.

Bocaccio

Alec D. MacCall, NOAA Fisheries Service, Southwest Fisheries Science Center, Fisheries Ecology Division.

2.4. Date and place

The STAR Panel met to review the stock assessments for bocaccio and chilipepper rockfish on June 25-29, 2007, at NOAA Fisheries Service, Southwest Fisheries Science Center, Fisheries Ecology Division, 110 Shaffer Road, Santa Cruz, California.

2.5. Description of review activities

After welcoming the participants to the review and appointing rapporteurs for the two assessments (bocaccio – Dr Kevin Piner; chilipepper rockfish – Dr Norman Hall), the STAR Panel considered how, within its terms of reference, it might handle the update rather than full assessment that had been provided for bocaccio. It was decided that, while it would be appropriate to review the update assessment and offer advice that might assist in ensuring that the bocaccio assessment satisfied the requirements for such an assessment, the determination of whether or not those requirements were satisfied was the responsibility of the SSC, not the STAR Panel. It was also decided that it would be appropriate to consider aspects of the bocaccio assessment and offer advice for future stock assessments. Note that the resource limitations that apparently resulted in the production of an update rather than full assessment for bocaccio should be considered when planning future assessments.

The STAR Panel considered presentations by Drs Field and MacCall relating to the chillipepper and bocaccio rockfish respectively, and after discussion, proposed further analyses to investigate various aspects of the two assessments. Details of these requests, the responses, and requests for further investigation are reported below for each assessment.

Chilipepper rockfish

The Panel considered the assessment that had been prepared by the STAT using Stock Synthesis II (SS2) and the results that had been obtained following the production of the draft assessment report. Problems in obtaining convergence when fitting conditional age-at-length data had led to dropping the conditional age-at-length approach in favour of using both age and length compositions in the assessment. The Panel agreed with the suggestion of the STAT that the juvenile core survey index should be eliminated from the assessment due to its apparently high imprecision and lack of information content, the latter likely to be the result of inadequate spatial coverage of the chilipepper rockfish stock. The Panel also agreed with the STAT that, as the CalCOFI

survey covers only the fringe of the spatial extent of the chilipepper rockfish stock and the signal from the survey is likely to be misleading, it would also

be appropriate to eliminate this survey index from the input data for the assessment model.

The STAT had encountered difficulties when attempting to tune the SS2 model while estimating *M*, and it appeared to the STAR Panel that these difficulties were probably the result of tensions between various data sets. The Panel sought to explore the possibility that the tension arose from the use of age and length compositions, where the former were derived from subsamples of the fish used in deriving the length compositions. The STAR Panel advised that, if age composition data were present, the values of the emphasis factors, i.e. lambda, should be set to 0.1 for the associated length composition data, otherwise lambda should remain set at 1; the values of lambda for the age composition data should remain set at 1. To assess whether the subsamples of fish selected for ageing were biased, the STAR Panel requested that the STAT investigate whether the length composition of the subsample of aged fish matched the length composition of the non-aged fish from the same sample. Seeking to investigate the source of tension, the STAR Panel requested that the STAT run a trial reference model without time-varying growth (*K*), using trawl cpue indices, recreational cpue, triennial survey, combined survey, and coast-wide juvenile indices, with *h* fixed at a reasonable value, and with *M* for females fixed and the offset of *M* for males being estimated. The STAT was requested to tune the model, and then produce a profile plot over *M* showing the contribution of the various likelihood components together with estimates of the various selectivity parameters, initial spawning biomass and depletion. The STAR also requested exploration by the STAT of the spatial distribution over time of samples in the recreational data from observers.

The STAT produced a reference model with *M* for females fixed at 0.16 $year^{-1}$ and *h* fixed at 0.57, the value estimated for chilipepper rockfish by Dr M. Dorn using his recently-completed meta-analysis of the parameters of the stock-recruitment relationship for other west coast rockfish. The values of lambda for the length compositions for which there were associated age compositions were reduced to 0.1. Dr Patrick Cordue, a STAR Panelist, advised that, overnight, he had developed a likelihood function that was more appropriate for use when age compositions are derived from subsamples of the fish from which the length compositions had been derived and when both the age and length compositions were included in SS2 (an appendix describing the equations would be prepared for inclusion in the STAR Panel's Report). Values of biomass and abundance indices predicted by the tuned model failed to reveal indications of the strong year classes for 1984 and 1991 that had been observed in the input data. Predictions of the CPFV cpue index also failed to reflect the decline apparent in the time series of these data. Profile plots revealed tension between the trawl cpue and other indices of abundance.

Plots of the length compositions of the aged versus non-aged samples of chilipepper rockfish revealed a length bias towards larger fish in many of the age samples. Because of the size difference between male and female chilipepper rockfish, males were less likely than females to be included in such length-biased subsamples. The STAT was therefore requested to identify subjectively those age samples that appeared to exhibit length bias and filter

these from the data to be used in subsequent analyses. The STAR Panel also requested removal of several samples with infeasible numbers of large males, which appeared likely to be the result of incorrect sex classification.

Details of the spatial distribution over time of the recreational CPFV data indicated a potential for bias associated with a small number of samples, comprising large numbers of fish, which were collected in the years prior to 1994. The STAR Panel requested that the STAT test whether a block-year interaction was present in the generalized linear model (GLM) analysis of these data and advised that fish from depths greater than 80 (units not reported in STAT's presentation) should be excluded from the GLM analysis for subsequent runs of SS2. The STAT also demonstrated that analysis of the CPFV recreational cpue data using the Stephens and MacCall (2004) filter produced similar results to those produced by the GLM. Data supplied by Dr Tom Helser demonstrated that the generalized linear mixed model (GLMM) analysis produced good fits for the indices of abundance from the triennial and combined trawl survey data. Dr Helser had suggested that the difference between the area swept and GLMM estimates of abundance was due to the presence of occasional large catches of chilipepper rockfish and the use of a log-normal distribution in the GLMM approach. The STAR Panel accepted that it would be appropriate to adopt the GLMM rather than area-swept indices of abundance for subsequent runs.

To investigate the results from the SS2 in more detail, the STAR Panel requested the STAT to link the RecFIN length composition data to the recreational fishery and the CPFV observer length composition data to the CPFV survey cpue and estimate the parameters for the associated selectivity curves and for the triennial survey. The STAT was also requested to increase progressively the emphasis factor for the recreational observer CPFV cpue index from 1 to 5, 10, ... until the predictions from SS2 matched this index, and to investigate the changes in the likelihood contribution of the various components associated with the different values of lambda. The STAR Panel also requested a profile over *R0* of the contributions to the likelihood of the various data sets.

The STAT reported that it had proved impossible to detect block-year interactions in the GLM for the CPFV observer data as the data were too sparse. Due to a misunderstanding, the length compositions associated with the length-biased age subsamples were "turned off" in the SS2 run rather than the biased age compositions. A slightly greater depletion resulted from the use of GLMM rather than swept-area results for the triennial and combined trawl surveys. Linking the RecFIN length compositions to the recreational fishery and the CPFV observer length compositions to the CPFV survey cpue index produced little further change in the spawning biomass trajectory. Increasing the value of lambda for the CPFV survey cpue index reduced the biomass estimate, increased the value of depletion, improved the fit to the CPFV cpue and triennial cpue indices, and produced a poorer fit to the trawl cpue data. However, even with lambda set to 25, the presence of the strong 1984 year class was still not apparent in the predictions of the CPFV cpue index. Further exploration by the STAT, setting lambda for the CPFV cpue index to 5, using

dome-shaped selectivity for both age and length in the recreational cpue survey, and introducing time-varying growth, produced a slight signal of the strong year class in the predictions of the CPFV cpue index. The predicted length frequencies produced by this configuration of SS2 reflected the bimodality present in these data. Use of length-based selectivity alone failed to produce equivalent bimodality.

Following consideration of these results, the STAR Panel requested that the STAT re-instate the incorrectly-removed length compositions and remove the associated length-biased age samples. The STAT was then requested to set lambda for the CPFV survey cpue data back to 1 and run SS2 to produce a reference against which to compare the results of subsequent runs. Following this, the STAT was requested to explore sex-specific selection curves using either age or length selection, but not both, to determine an appropriate selection pattern that would produce predictions of the CPFV cpue index that matched the time series of these data. Finally, using the resulting selection curve, the STAT was requested to produce a profile analysis based on *R0* to explore the tension among the different data sets.

When the length-based selectivity for the CPFV recreational survey was replaced by an age-based curve, the latter became asymptotic and the fit to the CPFV cpue data appeared to improve slightly. Unfortunately, the request to explore sex-specific selectivity had been overlooked and the resulting profile plots did not provide the information sought by the STAR. Accordingly, the STAT was requested to complete these requests. The STAR Panel also requested that the STAT explore whether alternative time blocking might be developed to reflect external environmental variables likely to produce time-varying growth of chilipepper rockfish.

Following its exploration of alternative selection curves, the STAT reported that it had been unable to produce a sex-specific age-based or length-based selection curve that could provide as good a fit to the CPFV cpue data as that obtained from an age- and length-based selection curve. While examining the profile plots produced for *R0*, it became apparent that it was difficult to assess the extent to which certain data sets influenced the likelihood as the likelihood contributions had not been adjusted to take the values of lambda into account. Time-blocking based on the Pacific Decadal Oscillation (PDO) appeared to provide an appropriate basis for blocking time periods. An improved fit resulted from the use of this index, but the value of the growth coefficient *K* for the last of the six PDO-based time blocks was far lower than the values of *K* in earlier time blocks.

The STAR Panel asked the STAT to explore briefly whether it might be possible to drive the value of the growth coefficient *K* using PDO, rather than through time-blocking. Depending on the results of this, the STAT was requested to implement time-varying *K* using either PDO to drive growth or PDO-based blocking, with an informed prior to avoid the low value of *K* in the last period, and using both age- and size-based selectivity for the CPFV cpue survey, and thereby to create a tuned base run of SS2. The STAT was requested to demonstrate that the tuned run had converged adequately and to

generate standard outputs and diagnostics. Profile plots for *R0* were then to be produced, taking the value of lambda into account.

The STAT reported that the use of PDO to drive growth appeared encouraging and was worth further investigation. However, in the time available, it had not been possible to improve on the use of the PDO-based blocking periods. A value of 0.5 as the SD on the deviations of *K* had been applied as the slightly informative prior. Jittering of the model had resulted, however, in four different solutions, two with high likelihoods and two with low, apparently associated with a flip-flop between a high then low value for the offset of *K* in the last two time periods, or a low then high value.

The STAR Panel requested further exploration of convergence either with the last two time blocks combined, or with the standard deviation on the prior for *K* set to 0.35 rather than 0.5. It also requested that the STAT produce results for the five-block rather than six block model, firstly using 0.5 as the standard deviation on the prior for the deviations of *K* and then turning off all priors. Finally, with the five-block run without priors, the STAT was asked to clean up the initial values and phasing, to calculate the values of the catchabilities analytically, and then to use jittering and alternative phasing to confirm that the model had converged. If so, a full set of diagnostic results and profile plots on *R0* accounting for lambda were to be produced. Providing these were satisfactory, the STAR Panel proposed that this should become the base model for the assessment.

Use of a prior of 0.35 still resulted in a low value of *K* in the last period, whereas merging of the last two periods resulted in a value of *K* intermediate between the values of the last two periods in the six-block model. Use of a value of 0.5 with the five-block model did not make a great difference to the results and the STAR Panel therefore decided that it would be appropriate to remove all priors. Results from jittering suggested that there were still problems with convergence that were likely to affect profile plots.

A request was made to the STAT to set the process error added to the CPFV cpue survey indices to zero and re-run the model, confirming through jittering and alternative phasing that convergence had been attained and that the model could be adopted as a base model. Using this model, the STAT was asked to explore the dimensions of uncertainty associated with high and low values for historical catch (half and double), *M*, and *h*. Biomass trajectories, depletion estimates and tables of likelihood contributions were to be produced for each run. The STAT was also requested to explore further whether it would be possible to derive an appropriate sex-specific, age-based selectivity for the CPFV survey to produce an equivalent fit to the CPFV cpue indices. For this, the STAT was requested to increase the emphasis of both CPFV cpue indices and length compositions to 20, and to assess whether the resulting selection patterns were sensible. If so, the STAT was asked to de-emphasise the two data sets, and to use the resulting selectivity pattern and, if necessary, parameter estimates, to re-fit in the hope of producing plausible results that could be compared against those produced by the current candidate base model.

Following consideration of the results, the STAR Panel recommended acceptance of the candidate model as the base model for the assessment and accepted that, of the variables considered, *h* was likely to provide the most useful axis of uncertainty. The STAR Panel proposed that the mean values of *h* for the lower and upper 25% of values of the prior distribution for *h*, i.e. a normal distribution with mean = 0.573 and sd of 0.183, should be used to determine results that could be considered representative of the lower and upper 25% of values. A good fit to the CPFV cpue indices was obtained using sex-specific, age- and length-based selectivity when increased emphasis was placed on both CPFV cpue indices and length compositions, however results from jittering still indicated problems with convergence. The STAT advised that it had been necessary to reduce the CVs on observation error for the triennial and combined trawl cpues externally rather than through adjustment to process error within SS2. The STAR Panel noted that further consideration needed to be given to this issue, *i.e.* how to handle CV adjustments when model RMSE is better than measurement CV.

The STAR Panel requested the STAT to complete its exploration of the potential of estimating an appropriate sex-specific, age-based selectivity and to produce a comparison of the results of this with those produced by the base model. The STAR Panel also requested the STAT to run the base model using *h*=0.34 and 0.81, and thereby obtain results representative of the lower and upper 25% of values, respectively, using jittering to ensure that each run had converged.

While further development was required, results obtained by the STAT demonstrated that it would be possible to develop an age-based, sex-specific selectivity curve to replace the current age- and length-based selectivity curve. Although convergence was still a problem, estimates of depletion for the base model, and for the lower and upper values of *h*, were 0.7, 0.46 and 0.78 respectively. The STAR Panel accepted these results as representing the required base case and lower and upper estimates.

Bocaccio rockfish

The Panel considered the bocaccio assessment with respect to each of the Terms of Reference for an update assessment and noted that the assessment appeared to be in accordance with those requirements. The Panel advised the STAT that the assessment, which used Stock Synthesis I, should be run using up-to-date catch data from the CalCOM database.

The Panel requested further investigation of the influence of the assumption that, at the start of the historical catch data for bocaccio, there was an equilibrium catch of 2000 tons. Was this consistent with the time series of historical rockfish catches (all species) and the ratio of bocaccio to total rockfish? Was the model sensitive to this value, and what might be the impact if the value was 1000 tons or 3000 tons? What would be the impact if the catches had not been in equilibrium, but had increased from a value of zero catch in 1916 to 2000 tons in 1930? Examination of the ratio of bocaccio to

total rockfish in historical catches suggested that the assumed value of 2000 tons is possibly ~25% too high, and the need for developing a sound historical reconstruction of bocaccio landings was reinforced by the presence of trends in total rockfish landings in different regions that were likely to reflect spatial and temporal changes in bocaccio landings. Depletion estimates and estimates of unfished biomass were shown to be sensitive to alternative values of initial equilibrium biomass, with higher values of initial equilibrium biomass producing higher estimates of unfished biomass, similar estimates of current biomass and greater estimates of depletion. Constraints on array dimensions in Stock Synthesis (SS1) did not permit exploration of the impact of ramping up the catch, however, a modified run with zero catch in 1930 and constant catch of 2000 tons till the start of the catch series used in the assessment model suggested a higher unfished biomass than that obtained using an equilibrium initial catch of 2000 tons.

The Panel requested further exploration to assess the reliability of the model prediction of favourable recent recruitment. For this, the tension between recent values of recreational cpue and abundance indices from the triennial survey was removed by eliminating those recent values in the recreational cpue series, noting that these values had been subjected to adjustment for bag limits and discards. The resulting model was to be used as a working model for subsequent exploration, in which the influence of the selectivity patterns for the triennial survey and of the potential changes in fishing practices for the recreational fishery in southern California (i.e. south of Point Conception) were investigated. Through examination of the species composition of recreational catches in RecFIN trips, the Panel sought to determine whether the recreational fishery was likely to have changed its behaviour and thereby changed its selectivity. The trajectory of biomass estimates was affected only slightly by the removal of the last three RecFIN cpue values from the time series. The species composition of RecFIN catches suggested that the focus of fishing in northern California had moved inshore. This finding suggests that selectivity of recreational fishing in this region is likely to have changed, increasing the uncertainty of the estimate of the strength of recruitment of the 2003 year class. In southern California, the species composition of the RecFIN catches suggested a slight shift offshore, a finding consistent with the increase in selectivity of larger fish resulting when selectivity for the southern recreational fishery was explored to assess how it might have changed in recent years. However, this latter assessment appeared to confirm the presence of a strong 2003 year class.

2.6. Disclaimer

The information in this report has been provided by way of review only. The author makes no representation, express or implied, as to the accuracy of the information and accepts no liability whatsoever for either its use or any reliance placed on it.

2.7. Acknowledgements

Thanks are expressed to the personnel at the SWFSC for making the review such an interesting and positive experience, and particularly to Dr Field for his input and the many analyses that he undertook during the week.

3. Summary of Available Information

3.1. Chilipepper rockfish

The data available for the chilipepper rockfish assessment included time series of commercial catches for trawl, hook and line, and setnet and of recreational catches, age and length compositions from the commercial trawl, hook and line, and gillnet catches, and from the combined trawl survey, length compositions from the recreational CPFV observer survey, RecFIN recreational catches, and triennial and combined trawl surveys, and the following indices of abundance: trawl logbook cpue, a cpue index calculated from recreational CPFV observer survey data, abundance indices derived from the triennial trawl surveys, the combined trawl surveys, the juvenile rockfish midwater trawl surveys, and the coast-wide juvenile rockfish surveys, and a larval abundance index calculated from CalCOFI data. While M was initially estimated, it was subsequently fixed at M=0.16 year^{-1} in the course of the meeting. Growth was estimated in the model.

3.2. Bocaccio

The data available for the bocaccio assessment included time series of commercial catches for trawl, hook and line, and setnet, and of recreational catches from southern and central/northern California, length compositions from each of these fisheries and from the triennial trawl survey, and the following indices of abundance: trawl logbook cpue, cpues calculated for northern and southern California from RecFIN data, a cpue index calculated from CPFV data, an abundance index derived from the triennial trawl survey, and a larval index of spawning output derived from CalCOFI data. A fixed value of M=0.15 year^{-1} was imposed and growth was estimated in the assessment model.

4. Review of Information used in the Assessment

Note that the material below is derived from the draft assessment reports, and from other background material provided for the review (see Appendix 2). For full details, reference should be made to these documents.

4.1. Chilipepper rockfish

Stock structure

The available data support the view that there is a single stock of chilipepper rockfish, which is broadly distributed between Punta Colnett, Mexico, and

Cape Blanco, Oregon, with greatest abundance between Point Conception and Cape Mendocino, California.

Life history data

The species is viviparous, with females extruding larvae from December to February. The larvae and juveniles have an extended 150-day pelagic phase before settling in shallow water. Size compositions indicate the fish move offshore as they become larger with adults typically located at depths of 100-300 m, but often found in mid-water.

Ageing – The potential bias associated with surface ageing of otoliths has been recognised and otoliths now appear to be aged using the break and burn approach. While the extent to which different age readers produce results that agree or to which the independent readings taken at different times by a single reader agree has been assessed, no evidence was presented in the assessment document that the ages determined from otolith reading were valid.

Growth – The assessment document notes that the age and length data for chilipepper rockfish were derived from fishery samples, and by implication, subject to selection bias. For this reason, growth is estimated in the assessment model. Plots of average size at age suggest that growth may be time-dependent.

Weight at length – Derived from 233 females and 220 males collected in the Triennial trawl surveys.

Maturity at length – Derived from fitting a logistic regression model relating maturity to length. A more detailed description of the data that were used in this assessment is required as the assessment document provides no indication as to how maturity was ascertained or the period within the year over which these data were collected.

Natural mortality – The estimates used in the 1998 assessment were initially used, i.e. 0.23 and 0.25 year^{-1} for females and males, respectively, but M was subsequently estimated in the model. As with most assessments, the value of M is highly uncertain and there is a need to ensure that management decisions resulting from the assessment are robust with respect to this uncertainty.

Catch data

Commercial catches by trawl, hook and line, and gillnet
The commercial catch of rockfish in 1880 was assumed to be zero. Between 1881 and 1891, estimates of the total commercial rockfish landings were interpolated between zero and the 1839 tons, the value reported for 1892. Total rockfish landings between 1892 and 1926 were taken as the values reported by Sette and Fieldler (1928), as cited by Field (2007), with unreported values derived by interpolation. Values between 1928 and 1978, by region, were obtained from the records of the California Department of Fish and Game. These data were derived from the "fish-tickets" , *i.e.* receipts, that

markets and packing facilities are required to complete for catches landed in a port region in California by commercial fishers (URL: http://las.pfeg.noaa.gov:8080/las_fish1/doc/names_describe.html). Catches are presumed to come from Californian waters. Commercial landings of rockfish, by gear type and region, were obtained for California from CalCOM and for Oregon from PacFIN. Again, these data appear to have been derived from fish tickets. Landings of rockfish from foreign fishing vessels are presumably derived from Rogers (2003).

Estimates of the proportions of the total rockfish catch taken by different fishing gears for the earlier period of the historical catch reconstruction were derived using estimates reported by various authors, with gaps filled using assumptions based on descriptions of the fishery and the fishing gears used in different regions through time. Prior to 1941, it is assumed that 5% of the catch was taken by trawl, and the remainder by hook and line (based on Phillips (1939), as cited by Field (2007)). Between 1941 and 1943, it was assumed that 25, 50 and 75% or rockfish catch was caught by trawl in 1941, 1942, and 1943, respectively, and that the remainder were caught by hook and line. Between 1944 and 1953, 90% of the catch was assumed to be taken by trawl and 10% by hook and line. Estimates for 1953 to 1977 were based on the proportions of trawl-caught rockfish reported by Nitsos (1965), Orcutt (1969) and Gunderson *et al.* (1974)), as cited by Field (2007), with interpolation for data in unreported years. The proportion of rockfish caught by each type of fishing gear between 1978 and 2006 was derived from the CalCOM and PacFIN databases.

Estimates of the proportion of chilipepper rockfish to all rockfish in the catches taken by the different fishing gears for various regions and periods from 1892 to 1979 were derived from values recorded in various reports, supplemented by assumptions. Data for California for 1962-63 were derived from Nitsos (1965), as cited by Field (2007), while data for 1973 came from Gunderson *et al.* (1974), as cited by Field (2007). Data for 1978-79 were based on CalCOM estimates.

Estimates of the commercial landings of chilipepper rockfish for the period till 1979 were calculated by the STAT using the estimates of total rockfish catch, the proportions of catch by gear type in the different regions and the proportions of chilipepper rockfish in those catches by the different fishing gears in the different regions. Estimates of commercial chilipepper rockfish landings from 1978 to 2006 were obtained from CalCOM, which provides the expansion of port sampling data to total landings.

Estimates of the discards of chilipepper rockfish were obtained by the STAT from observations of discards of bocaccio and chilipepper rockfish by trawl fleet in Monterey and Conception areas, but no details of the sampling program are provided in the draft assessment report. It is assumed that, prior to 2002, discards were negligible. Subsequently, 46, 11, 70, and 65% of total catch (discarded plus landed catch) in 2002, 2003, 2004, and 2005, respectively. These figures suggest that estimates of the proportion of the

catch discarded may be rather imprecise. It was assumed by the STAT that the proportion discarded in 2006 was the same as in 2005.

Recreational catch
Estimates of the recreational landings of chilipepper rockfish from the waters north and south of Point Conception between 1928 and 1979 were based the numbers of fish caught as reported in Commercial Passenger Fishing Vessels (CPFV) logbooks, estimated species composition, and average weight information. From 1980 to 2006, estimates of the recreational catches from the waters north and south of Point Conception were extracted from the RecFIN database, where these data are based on data collected by MRFSS.

Abundance indices

Commercial trawl logbook cpue
A time series of cpue indices extending from 1980 to 1996 was derived by Ralston *et al.* (1998) from the trawl logbook data. The CV of the estimates was assumed by the STAT to be 0.25, rather than the value of 0.1 used by Ralston *et al.* (1998). The STAT also considered two alternative series developed by Ralston (1999).

Recreational CPFV observer survey cpue
A time series of cpue indices for 1987 to 1998 was derived by the STAT from the CFDG recreational CPFV observer data using (a) a GLM, and (b) filtering using the Stephens and MacCall (2004) approach. The latter produced similar results to those of the GLM when location and depth information were used.

Triennial trawl survey biomass indices
A time series of biomass indices for the NMFS triennial trawl surveys between 1980 and 2004 was derived using (a) area swept, (b) a delta-GLM, and (c) a GLMM.

Norwest Center Combined trawl survey biomass indices
A time series of biomass indices was derived from the NWFSC combined trawl survey data for 2003-2006 using (a) area swept and (b) a GLMM.

Juvenile rockfish midwater trawl survey indices
A time series of indices for 1984 to 2004 was derived from the SWFSC midwater trawl survey.

Coast-wide juvenile rockfish survey
A time series for 2001 to 2006 was derived from data from the SWFSC for the coast-wide juvenile rockfish survey and, for several years, from data from the Pacific Whiting Conservation Cooperative and NWFSC.

CalCOFI larval abundance indices
A time series of abundance estimates for chilipepper rockfish, extending from 1950 to 2006 but with many years for which estimates could not be derived, was calculated from the CalCOFI database using a delta-GLM. This survey only covers the fringe of the spatial range of the chilipepper rockfish stock.

Length/age composition

Age and length composition for commercial trawl, hook and line, and gillnet
Length composition data were extracted by the STAT from the CalCOM database for trawl (ages from 1978 to 2005, lengths from 1978 to 2006), hook and line (ages from 1985 to 2002 with some missing years, lengths from 1980 to 2006 with some missing years), and gillnet (ages and lengths from 1983 to 1998). Age bins used in SS2 ranged from 1-20 years with an accumulator bin at 21 years. Length bins used 2 cm classes with accumulator bins for fish < 16 and > 52 cm. Expanded length composition data were extracted from CalCOM, and the effective sample size was assumed equal to the number of subsamples of landings. Age data represent individual aged fish, not catch-weighted values, and were treated initially by the STAT as conditional age-at-length data with effective sample size assumed to be the square root of the number of fish in the given length bin.

Length composition from recreational CPFV observer survey
Length composition data for 1987 to 1998 were extracted from the CDFG's observer survey data for the recreational fishery. The gender of the fish was not known and effective sample size was assumed to be the number of trips per year.

Length composition for RecFIN recreational data
Length composition data for recreational catches from 1980 to 2002 were obtained from the RecFIN database, with data expansion as produced by RecFIN. These data were not used in producing the initial assessment described in the draft assessment report, but were introduced during the STAR.

Length composition of triennial trawl survey catches
Length compositions were available for data collected from the catches of the triennial trawl survey from 1977 to 2004. Effective sample size was assumed to be the number of hauls.

Length and age composition for catches from Norwest Center Combined Trawl Survey
Length compositions of samples collected from the catches taken in the combined trawl survey were available for 2003 to 2006, and an age composition was available for 2004. The data appear to be dominated by the strong 1999 year class.

Effort

Fishing effort enters the assessment model through the fishery-dependent abundance indices (see above).

Other

Steepness of the stock-recruitment relationship – The assessment report noted that an updated meta-analysis of the values of steepness for other rockfish, undertaken by Dr M. Dorn, produced an estimate of 0.573 (sd=0.183) for the steepness of chilipepper rockfish.

4.2. Bocaccio

Stock structure

The bocaccio stock is described by MacCall (2003) as ranging "from Northern Baja California, Mexico, to the California-Oregon border, but with a functional northern limit of Bodega Bay". No data relating to the genetic composition of the stock are presented in that or subsequent assessment documents.

Life history data

No description of the life history of bocaccio is presented in MacCall (2003) or in subsequent assessment documents.

Ageing – MacCall (2003) reports that age determinations of bocaccio are "known to be imprecise" and, accordingly, the assessment model is length-based rather than age- and length-based.

Growth – Growth curves are estimated in the assessment model (MacCall, 2003) and thus rely upon the information derived from modal progression in length composition data.

Weight at length – Examination of the data file for Stock Synthesis (SS1) presented by MacCall (2003) suggests that the relationship between weight and length for bocaccio was derived by Ralston from data collected from the 1995 triennial trawl survey.

Maturity at length – The length at 50% maturity is taken as the value reported by Wyllie Echeverria (1987), *i.e.* 47.6 cm FL.

Natural mortality – The value of natural mortality used in the assessment was 0.15 $year^{-1}$, as was recommended by the 2003 STAR Panel and subsequently used in the 2003 assessment. Considerable uncertainty surrounds this estimate.

Catch data

Commercial catch by trawl, hook and line, and set net

The time series of historical commercial catches of bocaccio, disaggregated by type of fishing gear, was reconstructed using the procedure developed by Ralston and Ianelli (1996) (cited by MacCall, 2003, but no reference provided) and subsequently used by MacCall (1999) (cited by MacCall, 2003, but no reference provided). Catches by foreign fishing vessels were as estimated by

Rogers (2003). Commercial catches since 1998 were obtained from the CalCOM database. Estimates of discard rate for trawls were apparently provided by Jim Hastie, NWFSC, but no details are provided of the method by which these were obtained. In the absence of estimates of discard rate for hook and line and for set net gears, the trawl discard rate was applied to catches from all commercial gears.

Recreational

Details of recreational catches and recent discards were obtained from the RecFIN database.

Abundance indices

Trawl logbook cpue
This index of abundance was derived by Ralston (1999) from the data recorded in trawl log books between 1982 and 1986.

RecFIN cpue North and RecFIN cpue South
MacCall (2003) has described the method by which indices of abundance were derived from data recorded in the RecFIN database for the regions north and south of Point Conception for 1980 to 2002. The method is based on a delta-GLM of adjusted records in trips in which the species composition is such that the probability of catching bocaccio exceeds a specified threshold. The adjustment allows for the discard rate reported in the RecFIN database. A correction was applied to account for the two-fish bag limit. A question not posed by the 2007 STAR Panel due to its decision to drop recent recreational cpue data was whether correction for the bag limit was likely to produce an overestimate of catch as discards had already been taken into account.

CDFG Partyboat cpue
An index of abundance was derived using data recorded by onboard monitoring of partyboat catches between 1988 and 1998. The method used in filtering and processing the data was described by MacCall (2003).

Triennial trawl survey cpue
Abundance indices for bocaccio were derived from a log-transformed GLM of catches recorded during the triennial trawl surveys from 1977 to 2004.

CalCOFI index of spawning output
An index of spawning output was derived by applying a delta-lognormal GLM to data from CalCOFI surveys from 1951 to 2006 (see MacCall (2003) for method).

Length composition

Length compositions of commercial catches by trawl, hook and line, and setnet
Length compositions of commercial catches (sexes combined) by the different fishing gears were extracted from the CalCOM database for years ranging

from 1978 to 2006, however, due to the decline in landings in recent years, data are only available for the trawl fishery in 2004 and the hook and line fishery in 2006.

Length composition of recreational catches in North and South
Data on the length compositions of recreational catches (sexes combined) were extracted from the RecFIN database, the CDFG on-board partyboat sampling database and a set of data from the southern Californian partyboat fishery (MacCall, 2003). Data extend from 1975 to 2006 and 1980 to 2006 for southern and northern California, respectively.

Length composition of triennial trawl survey
Length composition data (by sex) were obtained from the triennial trawl survey and extend from 1977 to 2004

Effective sample size
According to MacCall (2003), the estimates of effective sample size for the length compositions from the different sources that were used in the assessment are derived from regressions of estimates of effective sample size on the actual numbers of fish measured or actual number of "sample clusters" (although the precise meaning of the latter term is not defined).

Effort

Fishing effort enters the assessment model through the fishery-dependent abundance indices (see above).

Other

Using the results of a recent meta-analysis for the parameters of the Beverton and Holt stock-recruitment relationship for west coast rockfish stocks, Dr M. Dorn has provided an estimate of steepness for bocaccio of $h = 0.44$.

5. Review of the Assessment Results

5.1. Chilipepper rockfish

The chillipepper rockfish fishery was represented by an age- and size-based model implemented using Stock Synthesis II (SS2), version 2.00b. After considerable exploration of the tensions exhibited by the different data sets, it proved possible to capture the abundance trends and patterns in length composition data using a configuration of SS2 in which the selectivity of the CPFV data was assumed to be both age- and length-based. The axis of uncertainty selected for use in the assessment was based on the steepness of the stock-recruitment relationship, h. For the base model, h was set to the estimate for chilipepper rockfish derived by Dr M. Dorn from a recent meta-analysis of the parameters of the stock-recruitment relationship for other west coast rockfish. The values of h selected to represent the lower and upper 25 percentiles of the range of uncertainty were calculated as the mean values of h in the lower and upper 25 percentiles of the prior probability distribution for h for chilipepper rockfish, *i.e.* a normal distribution with mean = 0.573 and sd of

0.183. This yielded values of *h* of 0.34 and 0.81. Depletion estimates from the runs of SS2 using the final model configuration accepted by the STAR Panel were 0.7 for the base model and 0.46 and 0.78 for the lower and upper 25% regions of uncertainty.

5.2. Bocaccio

The update assessment produced by the STAT appeared to be consistent with the requirements for such assessments. The STAR Panel advised that it would be appropriate to run the assessment using updated values of commercial catch data extracted from the CalCOM database.

6. Review of Scientific Advice

6.1. Chilipepper rockfish

The assessment model that resulted from the explorations undertaken by the STAT in response to the requests of the STAR Panel appears to be the most appropriate that is currently available. There is a need, however, to ensure that no errors were introduced or required changes overlooked as a consequence of the pressure for rapid response imposed by the STAR process. Provided no significant errors are detected, it would be appropriate to use the results of the final base run, and of the runs that bracket this to provide an indication of uncertainty, as the basis for advice to fisheries managers. However, the STAR Panel is aware that, within the time frame available for review and the methods that were currently available, a full exploration of the parameter space and its implications for the uncertainty of assessment results was not possible.

6.2. Bocaccio

The update assessment produced by the STAT appears to use methods that are consistent with those presented following the full stock assessment for bocaccio that was undertaken in 2003. Input data have been corrected where errors have been detected, and time series of data have been updated. The STAR Panel has advised that recent CalCOM data should be input to the assessment and that this should be re-run to provide up-to-date results. In its assessment report, the STAT has presented the results obtained when using the model configurations STARB1 and STARB2 proposed by the STAR Panel at the 2003 assessment, together with the results from the STATc configuration run with steepness fixed at the value of *h* estimated for bocaccio from the recent meta-analysis undertaken by Dr M. Dorn. While the STARB1 and STARB2 provide an indication of some of the uncertainty associated with use of inconsistent data sets, and use of the fixed value of *h* provides a more realistic assessment with the assumptions of the STATc model configuration, a full resolution of the implications of the inconsistencies among data sets and exploration of uncertainty is not yet possible given the constraints of SS1.

7. Summary of findings, conclusions, and recommendations

7.1. Chilipepper rockfish

The STAR Panel advised that attention needed to be given to developing a reliable reconstruction of catch history for chilipepper rockfish, including not only the best estimates of values but also the envelope of values between time series of low and high estimates of historical catch, such that future assessments might ensure that advice takes the uncertainty relating to the historical reconstruction into account. As has been identified by other STAR Panels, this need is common to all rockfish fisheries and the most cost-effective approach to reconstructing these data and producing results that are consistent among these fisheries is for a single coordinated research study to be undertaken with the objective of determining appropriate time series (and envelopes of uncertainty) for all rockfish species. An accessible database for the reconstructed catch histories of all rockfish should be established.

Where there are common inputs to the assessments for different rockfish stocks, there would be advantage in producing a concise set of documents to provide details of those common data sources and methods.

The STAR Panel identified a need for establishment of a meta-database to provide a comprehensive overview of all relevant data sources and information regarding changes in fishing practices, fishing fleets, sampling, or analytical methods such that data may be correctly interpreted and used. Some inefficiency in accessing data from different sources was noted, and data access issues need to be reviewed such that access to data for assessment is facilitated.

The changes in fishing practices that appear to have accompanied the introduction of regulations to constrain exploitation of bocaccio, i.e. discarding, the shift in spatial distribution of fishing, etc., have affected the consistency of the time series of cpue and length composition data. Future assessments for chilipepper rockfish would benefit from the development of an independent time series of data using volunteer fishers operating at selected, fixed sites in accordance with a well-designed sampling protocol.

Appropriate, validated methods to derive recreational cpue indices and to take the recent changes in the spatial distribution of fishing into account should be developed. Although the assessment model developed during the STAR assumed that CPFV cpue was a reliable index, a more detailed evaluation of the data taking into account changes in fishing practice and the impact of regulations may reveal inadequacies of the index.

Otoliths are available from samples of some catches from triennial and combined trawl surveys. These should be read and the data included in the assessment to provide additional information on length at age and time-varying growth. Validation of ageing methods appears to be required.

It was noted during the review that, when non-independent age and length samples are included in the assessment, it is inappropriate to tune these samples as if they were independent. A method of jointly tuning the age and length samples should be developed. Rather than applying an ad hoc down-weighting of the emphasis factor of the length sample when an age sample derived from a subsample is included in the assessment, an appropriate likelihood should be calculated for the combination of both length and age data using the approach proposed by Dr Patrick Cordue in an appendix to the STAR Report.

Rather than using a sex-specific, age- and length-based selection curve for the CPFV observer data, a sex-specific age-based curve would appear to be more appropriate as there is no obvious rationale for the use of the composite curve. Further work to determine such a selectivity curve is urged.

Problems relating to the convergence of the assessment model, as revealed by jitter analysis, require resolution to ensure that results of the assessment and of exploration of model uncertainty and tension among different likelihood components represent values from fully-converged models.

The possibility of relating growth directly to environmental variables rather than using time-blocking should be pursued.

Consideration should be given to the inclusion of spatial structure in the model, through splitting the fishery into regions north and south of Point Conception.

Following further refinement of input data, e.g. identifying the envelope of feasible historical catch values, development of an age-based, sex-specific selection curve for the CPFV data and further resolution of the inconsistencies and tensions among different data sets, there would be value in exploring the uncertainty of the chilipepper rockfish assessment through use of MCMC.

7.2. Bocaccio

The bocaccio rockfish fishery was represented by a size-based model implemented using Stock Synthesis I (SS1). This constrained exploration of potential improvements for future stock assessments. Clearly, a move from SS1 to a more appropriate assessment model, such as SS2 or CASAL, would be highly desirable.

The STAR Panel noted that advice offered by the STAR Panels for the bocaccio assessment of 2003 and the update assessment of 2005 had not yet been acted upon. The STAR Panel advised strongly that the comments of these earlier STAR Panels needed to be reviewed and considered in future stock assessments for bocaccio.

Runs of SS1 using alternative reconstructions of historical catch data provided evidence that assessment results for bocaccio were sensitive to these data. Accordingly, the STAR Panel advised that attention needed to be given to

developing a reliable reconstruction of catch history for bocaccio, including not only the best estimates of values but also the envelope of values between time series of low and high estimates of historical catch, such that future assessments might ensure that advice takes the uncertainty relating to the historical reconstruction into account. This need is common to all rockfish fisheries and the most cost-effective approach to reconstructing these data is for a single coordinated research study to be undertaken with the objective of determining appropriate time series (and envelopes of uncertainty) for all rockfish species.

The current STATc assessment model produces an infeasible estimate of the steepness of the stock-recruitment relationship. For future assessments, it would be appropriate to impose an informed prior probability on this parameter.

The reliability of the data that are input to a stock assessment is crucial in determining the soundness of the results of that assessment. There is an ongoing need to assess for each data set the extent to which the sampling frame and protocol produce data that accurately represent the variables that are assumed to be measured, and to which the methods used to analyse the resulting data are appropriate, thereby producing reliable input data for the stock assessment model. Inconsistencies between data sets and tensions among the different components contributing to the likelihood function frequently result from inappropriate or inadequate sampling, time-varying changes in the distribution of fishing and/or changes in the age composition of the stock, or the use of inappropriate methods when calculating input data. The STAR Panel advised that the data used in the bocaccio assessment should be subjected to detailed review before they were used in the next assessment. Of particular concern, the STAR Panel noted that changes in fishing that accompanied the introduction of management constraints were likely to have affected the consistency of the time series. Careful selection of data used in the assessment is required to ensure that the data contribute reliable information. A detailed description of the data sources, an evaluation of time-varying factors that might have influenced those data and how the data might be corrected for the effects of those factors, a detailed description of the methods of analysis used to produce the input data, and diagnostic information to allow assessment of the reliability of the resulting input data should be included in the stock assessment report for each assessment.

Appropriate models, which take into account the way in which the data were collected, should be used to analyse the length composition data. While this might be done internally in the stock assessment model, consideration should be give to processing the data externally to convert the length composition data to age composition data, such that cohort- and year-specific growth can be explored.

The changes in fishing practices that appear to have accompanied the introduction of regulations to constrain exploitation of bocaccio, i.e. discarding, the shift in spatial distribution of fishing, etc., have affected the consistency of the time series of cpue and length composition data. Future

assessments would benefit from the development of an independent time series of data using volunteer fishers operating at selected, fixed sites in accordance with a well-designed sampling protocol.

Review of future stock assessments for bocaccio would be facilitated by the production of more detailed, self-contained stock assessment reports. It is frustrating to need to refer continually to documents produced for earlier assessments. Sufficient data should be provided in the current assessment report to demonstrate to the reader that the assessment is sound. Where there are common inputs to the assessments for different stocks, there would be advantage in producing a concise set of documents to provide details of those common data sources and methods. There is also a need for a meta-database to provide an overview of the relevant data sources, together with sufficient information to ensure correct interpretation.

Greater clarity of the methods which are used to collate and expand the miscellaneous sets of length composition data, *i.e.* data from different samples, is required. Metadata describing the recreational fisheries and the changes that have been induced by the management regulations should be developed to aid in developing more appropriate representations of the fishery. In particular, consideration should be given to developing a research project to develop appropriate, validated methods to derive recreational cpue indices and to take the recent changes in the spatial distribution of fishing into account. In this regard, it was noted by the STAR Panel that further validation of the Stephens and MacCall (2004) approach is still required.

Age reading should be developed for bocaccio as age data are typically more informative than length composition data. While the resulting ages for bocaccio are considered to be imprecise, the results obtained from using imprecise age composition data may well be better than those from length composition data.

Following the move of the model to a more appropriate assessment framework such as SS2, refinement of input data, and resolution of the inconsistencies and tensions among different data sets, there would be value in exploring the uncertainty of the assessment through use of MCMC.

8. Implications

As with most assessments, the precision of the estimates of current recruitment strength is typically lower than that of preceding years due to the fact that there is limited information regarding the recently-recruited year classes in the data as they have only been present in the fishery for a limited number of years. However, when coupled with the impact on the time series of input data that resulted from the changes in fishing practice that accompanied the restrictions that were introduced to reduce the exploitation of bocaccio, the imprecision of recent estimates of recruitment strength becomes even greater. With this uncertainty, much of the information on the strength of the recovery of the bocaccio stock or improvement in the biomass of the chilipepper stock is likely to rely on the estimate of the steepness of the stock-recruitment

relationship, for which limited information is available from the time series of input data. In addition, estimates of depletion appear sensitive to the time series of historical catch estimates. The implications of this are set out below.

There is a need to develop, using all available data, a consistent and reliable reconstruction of historical catches for total rockfish and for each rockfish species, with estimates of the envelope of feasible values around the best estimate. At present, there is duplication in reconstruction effort among scientists responsible for different species and potential inconsistency in the approaches used.

There is a need to develop methods for analysing the available data from the fishery and the various surveys that take into account the manner in which these data were collected and the changes in fishing practices and distribution of fishing through time. It is not possible to improve on the data that have already been collected, but it is possible to review these data carefully and to develop more appropriate methods to analyse these data before they are input to the assessment model, or to use them in the assessment model in a more appropriate way. There should be development of appropriate diagnostic outputs to assess the extent to which external factors have influenced these data and to which the effect of these factors has been taken into account by the methods used in analysing those data. The assessment model used should allow appropriate use and exploration of the available data. In particular, the use of SS1 for assessment of bocaccio is inadequate and inappropriate.

There is a need to develop further fishery-wide, fishery-independent time series of data that are immune to changes in fishing practice or impact of regulations. Consideration should be given to the proposal to develop an independent time series of data using volunteer fishers operating at selected, fixed sites in accordance with a well-designed sampling protocol.

Increasing reliance is being placed in stock assessments for various rockfish species on the use of informative priors for the estimate of steepness of the stock-recruitment relationship for those species. In considering both the bocaccio and chilipepper rockfish assessments, use was made of the estimate derived for steepness for each species using the results of the meta-analysis of this parameter that had been undertaken by Dr M. Dorn using data from other rockfish. Noting that there was limited information regarding steepness that could be derived from the bocaccio data using SS1, and difficulties in estimating this parameter for chilipepper rockfish using SS2, it is important that the reliability of the data on which the meta-analysis was based is carefully assessed.

9. Primary sources of uncertainty

9.1 Chilipepper rockfish

The following sources of uncertainty were identified

- Validity of the ages determined from otoliths

Age-composition data play a key role in the stock assessment for chilipepper rockfish, yet no evidence was presented in the assessment documents that the ages assigned as a result of otolith reading were valid. A search of the Internet revealed that John Mello had undertaken a validation study that used the monthly prevalence of opaque edges on otoliths from chilipepper rockfish collected in 1987 to suggest that opaque annuli were formed annually. However, a search of Aquatic Sciences and Fisheries Abstracts failed to detect a published peer-reviewed paper on the topic. Evidence of annual formation of annuli and determination of the age at which the first annulus is formed should be presented in the stock assessment documents, together with information on how the ages of the fish are determined in the period when the new annulus becomes delineated, *i.e.* is the width of the opaque/translucent zone taken into account at this time.

- Estimates of natural mortality

  The value of natural mortality remains highly uncertain. While the Harvest Policy Workshop stressed the importance of continuity of the assumptions used in successive stock assessments, it also highlighted the need to explore the uncertainty associated with this parameter by plotting the profile likelihood for *M* and by producing alternative model configurations using alternative values of this parameter. The latter would allow consideration of the implications for management of the uncertainty in *M*.

- Time series of historical data

  As identified earlier, a consistent and reliable reconstruction of historical catches for total rockfish and for each rockfish species, with estimates of the envelope of feasible values around the best estimate needs to be developed such that the associated uncertainties can be fully explored.

- Model structure

  A dominant feature of the chilipepper stock is its spatial structure, which has had a marked influence on the fishery that exploits that stock. In his stock assessment report, Field (2007) records that young fish settle in shallow water and then, with size and age, move to deeper water to occupy depths from 100 to 300 metres as adults. He also reports that "they are uncommon north of Cape Blanco (Oregon) and south of Punta Colnett (Baja California Norte), and [the] region of greatest abundance is found between Point Conception and Cape Mendocino, California". Field (2007) notes that, while chilipepper rockfish were "historically an important recreational target in Southern California waters", their importance in Northern California was minimal until the 1970s when recreational effort moved offshore to target fish in deeper waters. The region in which fish were landed was an important factor in assessing the fishing gear used and the species composition of catches of rockfish and thereby determining the historical catches of chilipepper rockfish.

While abundance estimates attempt to take changes in depth distribution into account, there is considerable potential for shifts in the distribution of fishing and/or of the stock to affect the size and age composition of the fish that are collected from fishery-dependent samples. Assumptions of constant selectivity patterns are likely to become inadequate if such shifts occur. Assumptions of constant selectivity and time-varying growth may need to be complemented by considering also the possibility of time-varying selectivity and constant growth. The development of a reliable fishery-independent survey for chilipepper rockfish to provide indices of relative abundance and samples of age and size composition representative of the stock, taking into account the size/age-based spatial distribution of the stock, would improve the stock assessment. The size/age-dependent spatial structure evident for the stock and the influence that this has on the fishery suggests strongly that consideration should be given to developing a spatially-structured fishery assessment model to complement the current single-area assessment model for chilipepper rockfish.

9.2 Bocaccio

The following sources of uncertainty were identified

- Age composition of fish

  Current estimates of age composition are derived by the assessment model using the information contained in length composition, fishery and survey data. No information on age composition is input to the assessment model, and thus this represents a major uncertainty of the current assessments. Piner *et al.* (2006) have reported that, although difficult to age, the formation of annuli in the otoliths of bocaccio from waters off the coast of Washington state was annual. While Cailliet (2002) had found that otolith-based age estimates of older fish from central California were underestimated, a view later supported by Andrews *et al.* (2005) for fish from the same region that were aged using the otolith break-and-burn method, Piner *et al.* (2006) detected no bias with ages that they determined using a similar break-and-burn approach. Andrews *et al.* (2005) supported the use of transverse sectioning of otoliths for ageing bocaccio as this improved the quality of the age estimates of the fish. The availability of reliable age-composition data would improve the stock assessment for bocaccio considerably. Nevertheless, the difficulty encountered when ageing bocaccio appears likely to affect the precision of the resulting age-composition data. However, the improvement in the quality of the stock assessment that could result from the use of even imprecise age-composition data needs to be assessed as these data have the potential of providing considerably greater information than can be obtained from length-composition data.

- Estimates of natural mortality

  The value of natural mortality remains highly uncertain. While the Star Panel of 2003 selected to remain with the estimate of $M = 0.15$ year^{-1} that

had been used by Ralston *et al.* (1996), as cited by Helser *et al.* (2003), the uncertainty associated with this estimate needs to be considered when assessing the status of the bocaccio stock and the implications of such assessment for management. Alternative estimates need to be considered and likelihood profiles over a range of different values of *M* need to be evaluated.

- Time series of historical data

  As identified earlier, a consistent and reliable reconstruction of historical catches for total rockfish and for each rockfish species, with estimates of the envelope of feasible values around the best estimate needs to be developed such that the associated uncertainties can be fully explored.

- Model structure

  Use of Stock Synthesis I as the modelling platform continues to constrain the flexibility of the stock assessment model. As with chilipepper rockfish, spatial structure of the bocaccio stock and the influence that this has on the distribution of fishing effort are causes for concern. In addition to developing a revised single-area stock assessment model for bocaccio using a modern stock assessment tool such as Stock Synthesis II or CASAL, consideration should be given to developing a complementary spatially-structured assessment model.

10. Strengths and weaknesses of current approaches

10.1 Chilipepper rockfish

The use of the Stock Synthesis II modelling framework has provided considerable flexibility for stock assessment of the chilipepper rockfish fishery and allowed use of much of the available data. However, as with all models, the limitations of the input data constrain the ability of the model. Thus, without sufficient information content, and with a complex non-linear model with numerous parameters, which interact in their influence on the resulting estimates of dependent variables, it is difficult for a fishery model to determine precise estimates of parameters such as natural mortality and the steepness of the stock-recruitment relationship. Although an informative prior can be imposed to supply some of the missing information, the reliability of the resulting estimates depends on the quality of the prior probability distribution that was imposed. The quality of data used in meta-analyses that generate priors such as that of the steepness of the stock-recruitment relationship needs to be carefully assessed to ensure that the resulting prior is likely to be valid.

Determination of an appropriate base case for chilipepper rock fish required considerable subjective exploration of alternative forms of the selectivity patterns of the different fishing gears and of alternative time-blocking configurations for time-varying growth. There would be considerable value if such searching could be automated (allowing for the possibility of alternative

equally-appropriate model configurations) and thus become more objective, while still exposing the range of uncertainty present as a result of model structure.

10.2 Bocaccio

The current assessment framework is inadequate and needs to be replaced by a more appropriate assessment tool such as Stock Synthesis II or CASAL, which would provide the flexibility required to explore fully alternative model configurations or parameter uncertainties. While consistent with the spatial resolution and disaggregation of the current input data, the single-area hypothesis of the current model framework appears somewhat inappropriate as a description of the stock and the associated fishery. There would be value in exploring the results of both single-area and spatially-structured assessment models.

11. Alternative model configurations or formulations

For bocaccio, it is recommended that the model framework be updated to Stock Synthesis II or CASAL. It is also recommended that, for both species:

- Consideration is given to developing spatially-structured models for both chilipepper rockfish and bocaccio to complement the single-area assessment models for those species.
- A consistent and reliable reconstruction of historical catches for total rockfish and for each rockfish species, with estimates of the envelope of feasible values around the best estimate is developed such that the associated uncertainties can be fully explored.
- The approach used to explore the fit of alternative model configurations is automated, thereby emulating the subjective approach that is currently employed for each species and replacing it by a more objective approach. The automated approach should identify alternative, equally appropriate model formulations. In assessing the potential for automation, it is noted that Stock Synthesis II allows for inclusion or exclusion of different data sets through appropriate settings of emphasis factors, and options exist for selection of alternative forms of selectivity curves. Note that in attempting to identify alternative model configurations or formulations based on a modeller's experience, an exhaustive search over the space of all such configurations is not undertaken and it is likely that some equally-viable or better alternatives will be overlooked.
- Uncertainty in the results of stock assessment using a complex, dynamic fishery model relates to a combination of the quality of the input data, the alternative assumptions and model formulations employed, and the imprecision of the parameter estimates and predictions. In its review of the chilipepper rockfish assessment, the STAR Panel identified the steepness of the stock-recruitment relationship as a factor that characterised the uncertainty associated with the stock assessment for this species, however time was not available within the review period for a full assessment of uncertainty. A detailed exploration of uncertainty is required for both the chilipepper rockfish and bocaccio assessments.

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Appendix 1: Terms of Reference for STAR Panels and Their Meetings

The terms of reference for the STAR Panel, as set out in the document, "**GROUNDFISH STOCK ASSESSMENT AND REVIEW PROCESS FOR 2007-2008"**, were as follows:

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. Most groundfish stocks are assessed infrequently and each assessment and review should result in useful advice 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.

STAR Panels include a chairman appointed from the SSC and at least two other members with experience gained from having conducted stock assessments on the U. S. west coast or elsewhere. The total number of STAR Panel members (including the chair) should be 3 unless extenuating circumstances such as a large number of stock assessments scheduled for review at the STAR Panel dictate more reviewers. 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.

The STAR Panel is responsible for determining if a stock assessment document is sufficiently complete according to Appendix B. It is 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 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. Results of these data-poor assessments typically will not meet the requirements of an assessment according to the Terms of Reference and, in those instances, each STAR Panel should consider what inferences can be drawn from the analysis presented by the STAT Team. The panel should review the reliability and appropriateness of any methods used to draw conclusions about stock status and exploitation potential and either recommend or reject the analysis on the basis of its ability to introduce useful information into the management process.

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.

The primary goal of the STAR Panel 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. 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 transmitted 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 R0, 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 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 (Fig. 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.

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 (Fig. 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.

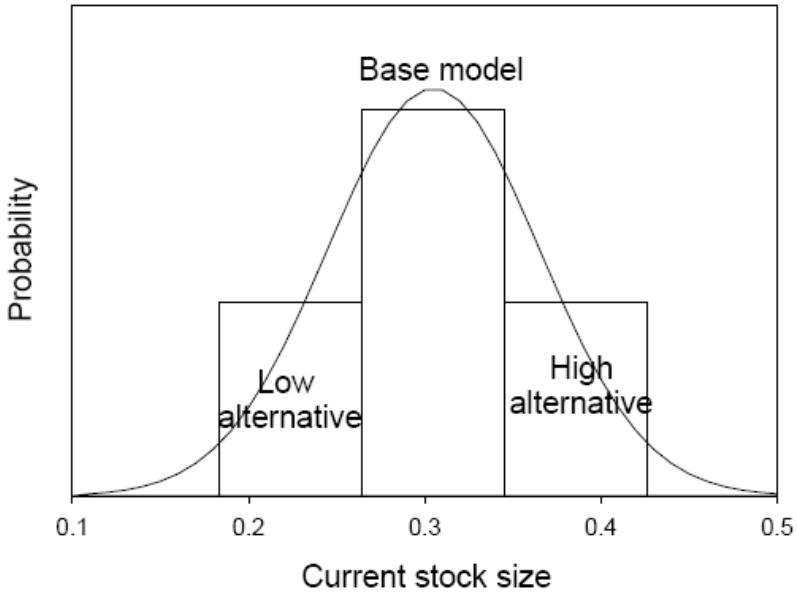

Figure 1. Example of assigning probabilities to alternative models using uncertainty in the estimate of current stock size.

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 chairperson, in consultation with other Panel members, to prioritize requests for additional STAT Team analyses. 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 all Panel members (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 GMT meeting where the assessments and preliminary ABC levels are discussed.

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.

STAT Teams and STAR Panels are likely to disagree on certain technical issues. If the STAR Panel and STAT Team disagree, the STAR Panel must document the areas of disagreement in its report. The STAR Panel may also request additional analysis based on an alternative

approach. However, the STAR Panel's primary duty is to conduct a peer review of the assessment that is presented. 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. 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. 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 to rectify whatever perceived shortcomings may exist. Where fundamental differences of opinion remain between the STAR Panel and STAT Team, which cannot be resolved by mutual discussion, the SSC will review the dispute and will issue its own recommendation.

The STAR Panel chair is expected to attend GMT and Council meetings where stock assessments and harvest projections are discussed to explain the reviews and provide other technical information and advice. The chair 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. Minutes of the STAR Panel meeting containing

    A. Name and affiliation of STAR Panel members; and

    B. List of analyses requested by the STAR Panel, the rationale for each request, and brief summary of the STAT response to the request.

    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

Appendix 2: Bibliography of all material provided

I. Current Draft Stock Assessments

A. Status of Chilipepper rockfish off of the West Coast in 2007. John Field

B. Status of bocaccio off California in 2007. Alec D. MacCall

II. Background Materials

A. 2006 Workshop Summary Reports

1. A Summary Report from the NWFSC Bottom Trawl Survey Workshop held October 31 – November 2, 2006 in Seattle, Washington. NOAA Fisheries, NWFSC, FRAM Division.
2. A Summary Report from the WC Groundfish Data/Modeling Workshop held August 8-10, 2006 in Seattle, Washington. NOAA Fisheries, NWFSC, FRAM Division.
3. Report of the Groundfish Harvest Policy Evaluation Workshop, Southwest Fisheries Science Center, La Jolla, California. December 18-20, 2006. A Workshop Sponsored by the Scientific and Statistical Committee of the Pacific Fishery Management Council
4. Pre-Recruit Survey Workshop. September 13-15, 2006. Southwest Fisheries Science Center, Santa Cruz, California. A Summary Report Prepared by Jim Hastie NOAA Fisheries, Northwest Fisheries Science Center and Stephen Ralston, NOAA Fisheries, Southwest Fisheries Science Center.

B. Previous Stock Assessments and STAR Panel Reports

1. Status of chilipepper rockfish stock in 1998. Stephen Ralston, Donald E. Pearson and Julie A. Reynolds. 1998.

1a. STAR Panel report on the chilipepper rockfish (Sebastes goodei) assessment. 1998.

2. Status of bocaccio off California in 2003. Alec D. MacCall.

2a. STAR Panel report on bocaccio. 2003.

3. Status of bocaccio off California in 2005. Alec C. MacCall.

3a. STAR Panel report on bocaccio. 2005.

C. SS2 Model Related

1. SS2 Zip File – includes User's Manual, example files, and powerpoint presentations
2. R Software Zip File – Code developed by Ian Stewart to perform model diagnostics and plotting of SS2 output. This is not an official SS2 add-on and is not part of the NOAA toolbox. File contains User's Guide, example files as well as powerpoint presentations.

D. Terms of Reference (TORs) for the West Coast Groundfish Stock Assessment and Review Process for 2007-2008. The Scientific and Statistical Committee (SSC) of the Pacific Fishery Management Council. 2006.

E. GAO Report: Pacific Groundfish: Continued Efforts Needed to Improve Reliability of Stock Assessments. United States General Accounting Office, Report to Congressional Requesters. June 2004.

F. Coastwide Pre-Recruit Indices from SWFSC and PWCC/NWFSC Midwater Trawl Surveys (2001-2006). Stephen Ralston. April 6, 2007.

III. Meeting Materials

A. Draft Agenda

B. STAR Panel Meeting Location Information

C. Driving Directions to NMFS/SWFSC/FED

D. List of STAR Panel Participants

IV. Material received just prior to the meeting or at the meeting

A. Addendum to Draft Chilipepper Rockfish Stock Assessment (June 22) – John Field
B. Updated data and control files for SS2 chilipepper assessment
C. Status of bocaccio off California in 2007. 2nd draft. - Alec D. MacCall
D. STAT 2007 responses to comments and recommendations in 2003 and 2005 STAR reports.

Appendix 3: Statement of Work

This appendix contains the Statement of Task that formed part of the consulting agreement between the University of Miami and the author.

STATEMENT OF WORK

General

The Stock Assessment Review (STAR) meeting is a formal, public, multiple-day meeting of stock assessment experts who serve as a peer-review panel for one or more stock assessments. External, independent review of West Coast groundfish stock assessments is an essential part of the STAR panel process that is designed to make timely use of new fishery and survey data, analyze and understand these data as completely as possible, provide opportunity for public comment, and assure the best available science is used to inform management decisions.

The stock assessments will report the status of the bocaccio and chilipepper rockfish resources off the west coast of the United States using age and/or size-structured stock assessment models. Specifically, the information includes a determination of the condition and status of the fishery resources relative to current definitions for overfished status, summaries of available data included in the models, and impacts of various management scenarios on the status of the stocks. The information is provided to the Pacific Fishery Management Council and NOAA's National Marine Fisheries Service to be used as the basis of their management decisions, which are subsequently approved and disseminated by the Secretary of Commerce through NOAA and NMFS.

The consultant will participate in the Stock Assessment and Review (STAR) Panel of the Pacific Fishery Management Council (PFMC) for the review of the bocaccio and chilipepper rockfish stock assessments. The consultant should have expertise in fish population dynamics with experience in the integrated analysis type of modeling approach, using age- and size-structured models, use of MCMC to develop confidence intervals, and use of Generalized Linear Models in stock assessment models.

The Pacific Fishery Management Council's Scientific and Statistical Committee requests that "all review panelists should be experienced stock assessment scientists, i.e., individuals who have done actual stock assessments using current methods. 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" (SSC's Terms of Reference for Stock Assessments and STAR Panel Process for 2007-2008)

Documents to be provided to the consultants prior to the STAR Panel meeting include:

- Current drafts of the bocaccio and chilipepper stock assessments;
- Most recent previous stock assessments and STAR panel reports for bocaccio and chilipepper rockfish;
- An electronic copy of the data, the parameters, and the model used for the assessments (if requested by reviewer);

- The Terms of Reference for the Stock Assessment and STAR Panel Process for 2007-2008;
- Summary reports from the West Coast Groundfish "Off-Year" stock assessment improvement workshops held in 2006;
- Stock Synthesis 2 (SS2) Documentation; and
- Additional supporting documents as available.

Specifics

Consultant's duties should not exceed a maximum total of 14 days: several days prior to the meeting for document review; the 5-day meeting; and several days following the meeting to complete the written report. The report is to be based on the consultant's findings, and no consensus report shall be accepted.

The consultant's tasks consist of the following:

1) Become familiar with the draft stock assessments and background materials.
2) Actively participate in the STAR Panel to be held in Santa Cruz, California from June 25-29, 2007. Participants are strongly encouraged to voice all comments during the STAR Panel so the assessment teams can address the comments during the Panel meeting.
3) Comment on the primary sources of uncertainty in the assessment.
4) Comment on the strengths and weaknesses of current approaches.
5) Recommend alternative model configurations or formulations as appropriate during the STAR panel.
6) Complete a final report after the completion of the STAR Panel meeting.
7) No later than July 13, 2007 submit a written report consisting of the findings, analysis, and conclusions (see Annex I for further details), addressed to the "University of Miami Independent System for Peer Review," and sent to Dr. David Die, via e-mail to ddie@rsmas.miami.edu, and to Mr. Manoj Shivlani, via e-mail to mshivlani@rsmas.miami.edu.

Submission and Acceptance of Reviewer's Report

The CIE shall provide via e-mail the final reports of the consultants in pdf format to Dr. Lisa L. Desfosse for review by NOAA Fisheries and approval by the COTR, Dr. Stephen K. Brown by July 27, 2007. The COTR shall notify the CIE via e-mail regarding acceptance of the report. Following the COTR's approval, the CIE shall provide the COTR with pdf versions of the final report.

Annex 1 to Appendix 1: Contents of Panelist Report

1. The report shall be prefaced with an executive summary of findings and/or recommendations.

2. The main body of the report shall consist of a background, description of review activities, summary of findings (including answers to the questions in this statement of work), and conclusions/recommendations.

3. The report shall also include as separate appendices the bibliography of all materials provided by the Center for Independent Experts and a copy of the statement of work.

Appendix 4: Acronyms and Abbreviations

CalCOFI	California Cooperative Oceanic Fisheries Investigations
CalCOM	California Cooperative Survey - commercial landings sampling program
CDFG	California Department of Fish and Game
CPFV	Commercial Passenger Fishing Vessels
GLM	Generalized linear model
GLMM	Generalized linear mixed model
MRFSS	Marine Recreational Fisheries Statistics Survey
PacFIN	Pacific Coast Fisheries Information Network
RecFIN	Recreational Fisheries Information Network