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Consultant Report on:

Pacific Hake (Whiting) in U.S. and Canadian Waters 2006

6-10 February 2006 Seattle, Washington

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Executive Summary

This report is based upon a review of the Pacific Hake (Whiting) in U.S. and Canadian Waters 2006 stock assessment documents, together with some data analyses and discussions at a STAR Panel review meeting 6-10 February 2006 in Seattle, Washington.

The data used in the stock assessment are generally considered of good quality, with the possible exception of the total catches before 1977, when catches were reported by foreign vessels without any verification.

As in the previous hake assessments, the greatest single source of uncertainty is the estimate of the acoustic survey scale parameter *q*. This is an important issue because this parameter estimate affects the total biomass estimate. It does not, however, greatly affect the biomass trends and therefore the estimate of the exploitation level. With the current data, the survey *q* cannot be estimated reliably.

It is recommended that information on the survey *q* parameter is sought for the next stock assessment. In the short term, it may be possible to generate a subjective prior probability from experts on the acoustic surveys. In the longer term it should be possible to collect data informative on survey *q* from designed fishing experiments. Depletion or fishing experiments can also be used to estimate not only trawl and acoustic survey *q*'s, but also selectivity which may also improve the reliability of the assessment.

The transfer of the model to the new Stock Synthesis II software appears to have been successful. The basic model gives very similar results to previous models, increasing confidence in the new software. The principles used in the design of the new assessment, namely parsimony and using less-derived data, are improvements over previous hake models. Increased parsimony should increase confidence in the fitted parameters, and fitting models to data that has undergone minimum processing should avoid introducing artefacts from the data manipulation process.

Catches based on harvest rule seem unrealistic for projections, and the harvest rule, if strictly applied, would drive the SSB below its 25% limit reference point. This would suggest the optimum yield definition needs to be reassessed.

The quota estimates based on the harvest rule are not robust to estimates of the survey *q*. The quota is an absolute value based on the estimates of biomass, which are very sensitive to the survey *q* estimate. This can only be addressed by improving the *q* estimate (i.e. collect data informative on *q*) or choosing an alternative management approach based on managing the exploitation rate directly rather than using quotas.

Background

The coastal stock of Pacific hake (*Merluccius productus*) is currently the most abundant groundfish population in the Californian Current system. The fishery is shared by Canada and the United States, but the population is modelled as a single stock. The United States and Canadian fishing fleets are managed separately, which allows some account to be taken of the spatial variability in the North-South population structure.

The stock assessment is carried out or updated annually and a review is required as part of the STAR panel process and of the new U.S./Canada agreement. The agreement has yet to be ratified, but is nevertheless guiding the process. A new stock assessment has been completed for 2006, with the assessment implemented in Stock Synthesis II, which is new stock assessment software. Nevertheless the model is basically the same as in previous assessments.

Review Activities

The stock assessment documents were received prior to the meeting and consisted of the printed stock assessments and considerable background material on compact disk (See Annex I Bibliography). The stock assessment meeting was held at the Northwest Fisheries Centre in Seattle, Washington 6-10 February 2006, where a presentation was given and discussions took place.

The review panel was made up of three experts, including the external CIE reviewer. The STAT team also attended the meeting and presented the stock assessment activities. The meeting was held in public and other scientists and stakeholders were present to observe and comment on the assessment. This report is based upon a review of the documents received, some analyses of data and discussions at the meeting. This report does not repeat findings of the main STAR panel report, which needs to be consulted for the panel's views on these assessments.

Data Sources

Summary of Findings

There are various sources of information which are used in the stock assessment model: the fishery dependent total catches, length compositions and conditional age-at-length compositions for the U.S. and Canadian fleets, and the fishery independent acoustic survey biomass index, length and conditional age-at-length compositions. The data are generally considered of good quality, with the possible exception of the total catches before 1977, when catches were reported by foreign vessels without any verification, and certain acoustic survey data which is currently excluded from the analysis.

The results in terms of the absolute population size are most sensitive to the estimate of the survey scale parameter q. This has been assumed in the past to equal 1.0, that is the survey detects all biomass within each transect. This is an important issue because the survey provides almost all the information on the size of the total biomass. Although the survey q parameter value affects the total biomass estimate, it has little effect on the biomass trends and therefore little effect on the estimate of relative level of exploitation. The fitted model appears to estimate q poorly, with an unrealistically low value. This is a common problem in stock assessment, when the model has trouble detecting, and therefore fitting to, the depletion caused by fishing.

The assessment results are also sensitive to the acoustic survey selectivity function. Older larger fish are generally rarer in the survey than might be expected if selectivity does not decline with age (dome-shaped selectivity). Changing selectivity by size and age can be explained by larger fish aggregating in deeper water where they are more difficult to detect. The survey however should be capturing differences in the north-south migration among different aged fish which elsewhere might explain differences in selectivity among the fishing fleets.

A dome-shaped selectivity is justified for the U.S. fleet catches as larger fish migrate north away from the U.S. fishing grounds. For the Canadian fleet, it is possible that a logistic selectivity could be used with little loss in fit to the data.

Another issue which may introduce problems into the interpretation of the survey data is potential changes of the survey q over time, which could come about through changes in survey equipment and methodology. The acoustic survey works through the survey scientists subjectively selecting backscatter aggregations. Through necessity, a noise threshold below which signals are ignored must be applied in an attempt to remove signals which are not thought to be associated with hake biomass. The threshold used has been higher in southern areas where non-hake backscatter would bias estimates. The threshold on the most recent survey has been adjusted in response to the sea conditions. How much this threshold affects the final index is not clear and it is possible that a correction could improve the index by reducing bias. Not changing the threshold is not necessarily a good option as precision is probably higher when a lower threshold is applied and choosing a threshold for the worst conditions would probably make poor use of the survey data.

The recruitment surveys (Santa Cruz and the PWCC/NMFS surveys) should prove useful as the time series develops. These indices should be able to predict future recruitments in the model, which currently, as with any catch-at-age model, can only be estimated retrospectively. Hence such indices can greatly improve short term projections and therefore lead to better management decision-making. As indicated in the report, the most likely problem is the spatial distribution of survey effort relative to the distribution of juveniles.

Conclusions and Recommendations

It would be useful to develop a single prior on survey q, rather than attempting to “bracket” the uncertainty through two extreme choices as done at present. A prior could be subjective or be an output posterior PDF from other research. A single informed prior on q should simplify the results, and could be built from:

- Independent point estimates from interviews of experts (or a probability density from each expert if few experts are available) and/or obtaining estimated q parameters from elsewhere where they use similar acoustic methods for similar species. A number of independent point estimates can be combined into a single non-parametric density using kernel smoothers forming a mixture distribution (see Press, 1989[1]). It is recommended to get independent estimates rather than a consensus, as the difference in opinion gives a measure of uncertainty.

[1] Press S.J. 1989. Bayesian statistics: principles, models and applications. Wiley and sons, New York.

- Put a prior on fixed parameters in the analysis of the raw acoustic data and generate a prior for survey *q* in this way. This should produce similar results as the previous suggestion, but experts may find it easier to provide priors on parameters other than the derived *q*.
- Conduct tagging or fishing experiments to estimate survey *q* and selectivity.

Depletion or fishing experiments to estimate trawl and acoustic survey *q*'s and selectivity could be very informative. However, such an experiment will need careful design as hake clearly migrate, so the assumption usually required for the analysis of fishing experiments, that the population is closed, will be violated to some degree. To minimise the effects of migration, the experiment will need to apply a very high fishing mortality over a short time in an area which is enclosed as much as possible. Fishing and an acoustic survey should be carried out simultaneously. The experiment may help identify problems that might be occurring with the survey methods, as well as provide information on *q* and selectivity. For example, it is possible that fishing may cause aggregations to disperse.

It would be valuable to apply bias correction based on the choice of acoustic survey noise threshold. The main concern is how, and the degree to which, the survey *q* has varied within the time series. The simplest approach would be to check whether the choice of threshold and sea conditions could have affected trends in the estimated biomass. If corrections applied to the acoustic survey would not uncover trends in biomass, they will have little impact on the overall results, although the issue remains as one of improving survey accuracy.

Further research is required on the recruitment indices to ensure they are able to predict recruitment to the fishery with reasonable accuracy. Research would probably indicate an adjustment in survey design is necessary to ensure that recruitment events are not missed.

Stock Synthesis II Assessment Model

Summary of Findings

The transfer of the model to the new Stock Synthesis II software appears to have been successful. The basic model gives very similar results to previous models, as might be expected. The new platform should allow increased confidence in the results in the sense that a single piece of software can be tested and controlled more easily. The current model provides a good basis for providing management advice, notwithstanding the issues of uncertainty.

The principles used in design of the new assessment, namely parsimony and using less derived data, are improvements over previous hake models. Increased parsimony should increase confidence in the fitted parameters and fitting models to data that have undergone minimum processing should avoid introducing artefacts from the data manipulation process.

The decrease in biomass indicated by the model coincides with an increase in catches. However, it clearly does not completely explain the decline, and the model has estimated a period 1985-1998 where there was no strong recruitment and slower growth since 1980. Further evidence from the model that the changes in the data cannot be explained by increased catches alone is the tendency of the model to fit a low survey q, so that the biomass is very large and the change in catches has a relatively insignificant effect. Therefore the decline in biomass and SSB needs to be explained through a combination of factors.

It appears that of the length and age compositions have the largest influence on the model, and in particular a strong influence on population trends. The change in growth parameters suggest that older fish are being found at a smaller size. While this is a significant factor explaining the fall in biomass in the model, there is no similar fall in the acoustic survey biomass index which remains essentially flat throughout the series. As the decrease in growth rate coincides with the fall in biomass, it is not density dependent.

It is also possible that there have been other contributions to the decline in biomass, such as a change in condition, which would be evident as a change in the length-weight relationship parameters. However, it is likely that such a pattern, if significant, would have been detected either from the sampling programme or by the processing industry.

The results are very sensitive to allowing dome shaped selectivity for the survey. Apart from a better fit of the model to the data, there is no evidence that dome shaped selectivity is appropriate for the survey. It is quite plausible that dome shaped selectivity should apply, and the improved fit to the data is a strong justification. However, given the sensitivity of the results, it would increase confidence if some additional evidence could be obtained to support the shape of the selectivity curve. It should also be noted that as catchability falls with age, estimates of the population size at age become less accurate. In this case, as this “unobserved” biomass only forms a small part of the overall SSB, this is not likely to be a problem.

More reliable estimates of selectivity may be obtained from studying the distribution of fish along the coast. It may be possible to research selectivity patterns linked to the latitude and water temperature or other covariates. It should be noted that simple examination of the relationship between selectivity and environmental variables has not yielded any strong pattern, so it may be difficult to identify patterns with the available data.

Increased natural mortality with age might be used to explain the decline in numbers of larger, older fish in the trawl catches rather than selectivity. Such increased mortality has not been reported elsewhere and it is generally believed that fish mortality decreases with size. However, it is possible that stress due to spawning and aggregations may make fish more vulnerable to predation. Even if this would turn out to be true, the general results and management recommendations would remain largely unaffected, as any change applies equally to the exploited and unexploited stock.

No stock-recruitment relationship has been detected. The steepness parameter proposed at this meeting for the Beverton and Holt stock recruitment relationship seemed more biologically reasonable, although there is no empirical support for any particular value. Of more concern has been the consistently low recruitment between 1988 and 1999. This could be due to any number of reasons, including random chance. However, it is a common pattern for fisheries similar to the hake fishery to become dependent on the odd strong year class, which can greatly increase risks to the stock. The fishery is currently dependent on a new strong recruitment to replace the strong 1999 year class. While recruitment is not under direct control of management, it may be worth considering whether fishing disrupts spawning and therefore decreases spawning success.

The problem of providing appropriate estimates of variance of the survey indices has not been achieved. The way the data are treated makes it difficult to provide a statistically valid estimate of the variance. Nevertheless, some objective relative weight for each index point would help the assessment.

Conclusions and Recommendations

The model is very complex and the way the different data influence the model is not necessarily immediately obvious. Various diagnostics in future assessments could help understand how the model interacts with the data. The log-likelihood could in future be routinely reported broken down into the 3 main sources (US fleet, Canadian fleet and survey) and 3 data types (age compositions, length compositions, and biomass survey) making 7 likelihood components, with the possible addition of the recruitment index. By applying extreme weights to the different data sources, it should be possible to identify where the signals from the different data conflict, leading to a greater understanding of the data and model.

The effect of the changes in growth rate has not been fully explored in this assessment. It seems that the changes in growth help explain observed patterns in the data, but changing the size of animals may produce a variety of other effects. The current selectivity functions are age-based. Converting to size-based selectivity may affect the estimated growth changes through time and make the model less sensitive to the dome-shaped selectivity pattern. It could also, of course, lead to a worse fit of the model, but would still be worth exploring. It may also be worth exploring the effect of linking natural mortality to size. A decreasing growth rate could be linked to higher natural mortality (Lorenzen, 1996[2]) also helping to explain the fall in biomass.

Given some difficulties with the older catch and acoustic survey data, and assuming more recent data is generally more reliable, exclusion of older data at least for a sensitivity run of the model, should be considered as a standard run in the stock assessment. The poor model fit to older data could be due to changes in biological processes and of the methods of data collection. Most obviously, the acoustic survey biomass index does not match the decline in biomass indicated by the stock assessment model 1984-1999. For this assessment, it was found that the results are robust to the inclusion or exclusion of these data.

Control Rules and Management Advice

Summary of Findings

Catches based on the harvest rule seem unrealistic for the projections and reflect the survey *q*, which cannot be estimated reliably. This makes the quota-based management risky.

The harvest rule also appears to be unstable and, if strictly applied, would drive the SSB below its 25% limit reference point. This would suggest the optimum yield definition needs to be re-assessed.

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[2] Lorenzen, K. 1996. The relationship between body weight and natural mortality in fish: a comparison of natural ecosystems and aquaculture. *J. Fish Biol.* **49**: 627-647.

Conclusions and Recommendations

The harvest rule does not appear to manage individual year classes well. A rule based on managing strong year classes to ensure maintaining the SSB would appear to be more suitable. The harvest rule could take into account recruitment indices, once a recruitment survey have been made validated.

While the general results indicating the state of the stock are robust to estimates of the survey q, the quota estimates based on the harvest rule are not. The quota is an absolute value based on the estimates of biomass which are very sensitive to the survey q estimate. This can only be addressed by improving the q estimate (i.e. collect data informative on q) or choosing an alternative management approach based on managing fishing mortality directly (such as effort control) rather than using quotas.

Appendix I: Bibliography

A compact disk was provided with considerable background material. The main documents subject to review were the following:

Draft Stock Assessment of Pacific Hake (Whiting) in U.S. and Canadian Waters in 2006 Thomas E. Helser, Ian J. Stewart, Guy W. Fleischer, Steve Martell

Draft Stock Assessment of Pacific Hake (Whiting) in U.S. and Canadian Waters in 2006 APPENDIX A: SS2 Control and Data files

A Summary Report from the Stock Assessment Modeling Workshop held October 25-29, 2004 at the Northwest Fisheries Science Center Seattle, Washington Northwest Fisheries Science Center, FRAM Division March 16, 2005

Technical Description of the Stock Synthesis II Assessment Program Version 1.17 – March 2005. Richard D. Methot, NOAA Fisheries Seattle, WA

User Manual for the Assessment Program Stock Synthesis 2 (SS2) Model Version 1.21 Jan 20, 2006. Richard Methot NOAA Fisheries Seattle, WA

STAR Panel Terms of Reference: Groundfish Stock Assessment and Review Process for 2005-2006.

STAR Panel Report on the Stock Assessment of Pacific Hake (Whiting) in U.S. and Canadian Waters in 2003.

Stock Assessment of Pacific Hake (Whiting) in U.S. and Canadian Waters in 2003 Thomas E. Helser, Richard D. Methot, and Guy W. Fleischer.

Report of the Joint Canadian and U.S. Pacific Hake/Whiting Stock Assessment Review Panel conducted on February 1-3, 2005.

Stock Assessment of Pacific Hake (Whiting) in U.S. and Canadian Waters in 2004. Thomas E. Helser, Guy W. Fleischer, Steve Martell, Nathan Taylor

Appendix II: Statement of Work

Consulting Agreement between the University of Miami and Dr. Paul Medley

January 20, 2006

General

External, independent review of the Pacific hake (Whiting) stock assessment work is an essential part of the STAR panel process and a requirement of the U.S./Canada agreement regarding the offshore hake/whiting resources, although this agreement has not yet been ratified. The stock assessment will provide the basis for the management of the Pacific hake (Whiting) resource off the Pacific coast of Canada and the U.S.

The reviewer will participate in the Stock Assessment and Review (STAR) Panel of the Pacific Fishery Management Council (PFMC) for the review of the stock assessment of Pacific hake (Whiting) in the U.S. and Canadian waters. The reviewer should have expertise in fish population dynamics with emphasis on age-structured statistical catch-at-age modelling and experience with AD Model Builder. Documents to be provided to the reviewer prior to the STAR Panel meeting include:

- Current draft Pacific hake stock assessment report;
- Most recent previous Pacific hake stock assessment;
- An electronic copy of the data, the parameters, and the model used for the assessments (if requested by the reviewers).

Specific

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

The reviewer's tasks consist of the following:

1. Become familiar with the draft Pacific hake stock assessment and background materials.
2. Actively participate in the STAR Panel to be held in Seattle, Washington from February 6-10, 2006.
3. Comment on the primary sources of uncertainty in the assessment.
4. Comment on the strengths and weaknesses of the 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 February 24, 2006, 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 the Reviewer's Report

The CIE shall provide via e-mail the reviewer's final report in pdf format by March 9, 2006 to the COTR, Dr. Stephen K. Brown (Stephen.K.Brown@noaa.gov), for review and approval by NOAA Fisheries. Approval shall be based only on compliance with this statement of work. 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 a pdf version of the final report with a digitally signed cover letter.

Annex 1: Contents of the 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 the review activities, summary of findings, and conclusion/recommendations.
3. The report shall also include as separate appendices the bibliography of all materials provided by the Centre for Independent Experts and a copy of the statement of work.