Joint U.S.-Canada Scientific Review Group Report

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Introduction

Under the authority of the Agreement Between The Government of The United States of America and The Government of Canada on Pacific Hake/Whiting (here after referred to as "the Treaty"), the Scientific Review Group (SRG) met in Seattle, Washington, 18 to 21 February 2014 to review the draft stock assessment document prepared by the Canada/US Joint Technical Committee (JTC), the acoustic survey conducted by both nations in 2013, and the biomass estimate derived from that survey. The SRG based its terms of reference on the language of the Treaty and on the Pacific Fishery Management Council's Stock Assessment and Review (STAR) terms of reference; the Joint Management Committee (JMC) has now approved these as the formal Terms of Reference for the SRG. The SRG was composed of two US, two Canadian and two independent members designated by the JMC based on recommendations from the Advisory Panel (AP). The JMC also appointed two industry advisors to assist the SRG in its deliberations. The SRG has amended its Terms of Reference to reflect these recent appointments.

The meeting convened at 9AM Tuesday, February 18, 2014, Michelle McClure (meeting chair) welcomed attendees and after a round of introductions reviewed the agenda and SRG Terms of Reference and assigned reporting duties.

Conclusions

1. The 2013 acoustic-trawl survey was successfully completed. For the second time, the US portion of the survey was conducted in conjunction with the acoustic-trawl survey for sardine, and we understand that a Center for Independent Experts review of the combined survey has been conducted from which a final report is due shortly. Members of the SRG would appreciate the opportunity to see that report. We also note that conducting surveys in consecutive years between 2011 and 2013 precluded the survey teams' ability to address research and technological development concerns raised in previous reviews.

2. The survey results included a relative biomass estimate of 2.42 Mmt (million metric tons), an increase from the 2012 survey estimate of 1.38 Mmt. The survey and fishery were mostly age 3 fish (76.2% survey; 66.9% fishery by numbers). In U.S. waters this 2010 cohort was strongly dominant, but in Canadian waters the 1999, 2005, 2006, and 2008 year classes also were present in significant numbers. The 2013 survey has verified that the 2010 year class is strong, but as always, some uncertainty remains about the precise size of the cohort.

3. Since 2011, the survey biomass estimate has been developed using a kriging (smoothing) methodology, applied to the entire time series. This year, the method resulted in considerable extrapolated biomass (approximately 28% of the total or 0.67 Mmt) outside

the surveyed areas being included in the total biomass estimate. Given the pattern and amount of the extrapolated biomass in an area with no supporting observations, the SRG has concerns about this extrapolation, and provides recommendations later in this report to address this issue. A stock-assessment sensitivity run incorporating a lower 2013 survey biomass that excluded the extrapolated areas (1.75 Mmt) resulted in a default 2014 median harvest recommendation from the $F_{40\%}$ - 40:10 harvest policy that was approximately 14.6% (127K mt) lower than the corresponding estimate in the base assessment.

4. The 2014 base assessment model differs from the 2013 base model by the inclusion of time-varying selectivity in the fishery. We endorse the inclusion of this component, the utility of which was demonstrated through the Management Strategy Evaluation (MSE) tools developed by the JTC.

5. The median female spawning biomass[1] estimated by the assessment is 1.72 Mmt at the beginning of 2014. This is the largest spawning biomass estimate in the assessment time series since 1992. In the absence of fishing, biomass would be expected to increase through 2016, because of the very large 2010 year class and the above average 2008 year class.

6. The model forecasts that, to have an equal probability of being above or below the target $F_{40\%}$ fishing intensity, a catch of 825K mt in 2014 and 660K mt in 2015 could be achievable.

7. As noted, there is now greater certainty that the 2010 year class is strong, since it has been observed as 2 and 3 year olds in both the survey and fishery, but confidence intervals around its magnitude are still wide. The median estimate of 2010 year class strength is 15.4 billion recruits, compared to a median average recruit value of 2.7 billion recruits. Unless the assessment estimates are badly mistaken, this cohort will be a significant contributor to the fishery in 2014 and for several years beyond. A conservative estimate of year class strength based on the median of the lower 10% of the model (i.e., the 5th percentile) is 8.5 billion recruits. If 2010 recruitment truly is in this lower 10% range, the assessment model estimates a catch of 190K mt would allow the stock to maintain its current biomass level, which is well above historic levels and B_{40} from 2014 to 2015; a 2014 catch up to 500K mt is estimated to maintain the stock above B_{40} at the start of 2015.

8. The SRG recommends that the decision tables developed by the JTC at the SRG's request

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[1] The assessment uses Bayesian estimation. Summary results are reported here as medians of the estimated posterior distributions.

be used in harvest decision-making. Those tables give the expected effects of various catch levels on stock size and other stock benchmarks.

9. The JTC made excellent progress in developing and using their Management Strategy Evaluation tools to investigate the use of time-varying fishery selectivity in the assessment model, and we commend them for this effort. We recommend continued development and use of this tool to address other questions, such as those highlighted in our research recommendations.

10. The MSE has provided some insight to evaluate and interpret the current harvest control rule and survey frequency.

- *Survey frequency:* We note that the added information value of an annual survey, as estimated by the current MSE, was relatively low; however, this result is based on a limited set of operating model scenarios that preclude making a formal recommendation on survey frequency at this point. We believe that in some circumstances, an annual survey would be very informative. In our research recommendations (below), we suggest areas of future MSE evaluation of survey frequency and the development of an age-1 index that would be informative.
- *Harvest control rule:* The MSE indicates that strict adherence to the treaty's $F_{40\%}$ - 40:10 harvest control rule would result in a substantial long-term (but not short-term) probability that the stock would decline below the B_{40} reference point (assessment, Appendix A). (To date, the JMC has recommended lower quotas than those prescribed by the treaty's harvest control rule.) This finding demonstrates the usefulness of the MSE in evaluating long-term consequences of harvest control rules.

The next stage of MSE development will continue to benefit from inputs from all parties.

Overview of Scientific Results

The 2013 Hake Acoustic Survey was completed successfully through the efforts of both U.S. and Canadian research vessels. Like last year, the U.S. portion of the survey was conducted jointly with a summer survey of sardine. Unlike last year, all operations-both acoustic and fishing-of this sardine-hake survey were conducted aboard a single vessel. This allowed greater certainty about the correspondence between acoustic signal and sampled fish. Overall, the survey was successful in covering the apparent summer range of hake using protocols consistent with those previously used in the time series.

The resulting estimate of total coast-wide biomass was developed using methods very

similar to those used last year. The survey group estimated a relative biomass of 2.42 Mmt, an increase from the 2012 survey biomass estimate of 1.38 Mmt. This year's survey was dominated by age-3 fish (over 76% of individuals were estimated to be from the 2010 year class). Sensitivity analyses indicated that the total-biomass estimate was sensitive to the grid size used for estimation and the search radius used in kriging. Because in several places, hake were found near the end of transects, this year's biomass estimate included extrapolation in a relatively large area that was not surveyed, primarily along the California coast. The SRG has a number of concerns about this large proportion of extrapolated biomass and has a number of research suggestions to improve the estimation process in the future. To better quantify our concerns, the SRG requested a sensitivity run of the model excluding this extrapolation. This run resulted in a 127K mt decrease in the catch recommendation from the $F_{40\%}$ - 40:10 harvest policy.

The assessment model differed from last year's model by the inclusion of time-varying fishery selectivity. The value of this addition was demonstrated through various MSE simulations indicating that the probability of generating a false signal of stock status was substantially lower. The probability of inadvertently fishing the stock to levels below target was also lower when time-varying selectivity was included. We endorse the use of the assessment model as configured.

The continued development of the MSE was scientifically useful, and, we believe, will show great management value. We note that the MSE currently uses an operating model and an assessment model that are essentially identical in structure. This configuration is expected to result in overly favorable inferences about management procedures because there is no mismatch between the simulated "true" population (i.e., the operating model) and the assessment model. In reality, some mismatch between the true population and the assessment model is likely. We suggest that additional work using less-well paired models is appropriate (see below) and would provide greater insight into the relative performance of different management procedures given uncertainty about true population dynamics.

SRG Research Recommendations

Here we provide a number of recommendations for research and development in the coming year, ordered from highest to lowest priority.

- Work related to the development of the biomass estimate from the acoustic survey. As noted above, a considerable fraction (28%) of this year's acoustic biomass estimate was derived through extrapolation in offshore areas not sampled. The extrapolated area was considerably enlarged this year, from about 10 nm to, in some areas off California, about 40 nm wide. The SRG noted that the proportion of estimated biomass from extrapolation is large this year; that estimated densities in extrapolated areas often do not decrease with

greater distance offshore as expected; and that estimated survey variance does not increase towards the offshore edge of the extrapolated area. Sensitivity runs of kriged biomass estimates made at the SRG's request demonstrated that these tendencies were moderated with contraction of the search radius used in extrapolation. A sensitivity run of the assessment without the extrapolated biomass showed moderate sensitivity to this issue, resulting in a 14.6% decline in the recommended catch from the 40-10 harvest rule.

- o Therefore, the SRG recommends conducting simulation studies of the extrapolation methods used in kriging, with the aim of quantifying and reducing bias and variance, ensuring consistency from year to year, and ensuring that edge effects in extrapolation do not unduly influence acoustic survey biomass estimates. Studies should include, but not be limited to (1) quantifying the effect of search radius on kriged survey biomass estimates and identifying an optimal search radius for kriging; (2) examining whether the heuristic algorithm used to expand search radius in cases with insufficient data may produce biased results with certain patterns of hake biomass distribution; (3) examining whether changes in the extent of the extrapolation area from year to year due to the expansion in the search radius algorithm may bias survey biomass estimates in some years; and (4) determining whether the algorithms now used provide sensible density estimates at edges of the extrapolation area.
- o Unless simulations show that a variable extrapolation area provides more reliable estimates, the SRG recommends that extrapolation be limited to a smaller and consistent area, perhaps no larger than10 nm from the offshore edge of sampling, and that the entire survey time series be re-estimated with a consistent extrapolation area in each year.
- o It has not been demonstrated that the correlation structure in northern and southern waters is sufficiently similar to justify a pooled approach for kriging. The SRG recommends investigation of the potential utility of dividing the stock area into Northern and Southern areas (corresponding roughly to Canadian and U.S. waters, as empirically appropriate) for purposes of calculating the variogram.
- o The estimated survey variance is extremely small, based on the smoothed surface produced by kriging instead of the underlying data, and is highly dependent on the size of the cells in the kriged grid. The SRG recommends that further study be given to methods of estimating the variance of the estimated survey biomass so that the estimate meaningfully reflects all sources of variance.

● Inclusion of Mexican fishery. The SRG understands that a relatively small (2,000 mt), but potentially growing fishery has begun in Mexico. This fishery apparently targets primarily larger fish (69% of the harvested individuals in 2012-2013 were over 1 kg). Given the location and size of these fish, it is possible that this fishery is also affecting

the spawning population of hake harvested by the U.S. and Canadian fishery. The SRG recommends that additional information about this fishery – including the stock structure delineation suggested below – be obtained and considered in future modeling efforts.

- Acoustic research
    - o For the survey, we think it is important to record more information on the decision process used for assigning locations for trawl sites. (This is a continuing recommendation of the SRG over several years.) Some tows are taken for target verification (e.g., for species composition), and some are for hake size-composition sampling. This extra information is important for measuring the survey variance associated with the trawls and to ensure consistency.
    - o Age-1 index development. Because the current acoustic survey biomass estimate does not include fish below age 2, a large recruitment (when it occurs) cannot be confirmed for several years, especially if surveys are conducted only every-other year. A reliable index of age-1 hake abundance would always be a valuable data input to the stock assessments, and especially when high recruitment events occur. The SRG recommends continuing preliminary research on the potential of obtaining an index from the acoustic survey.

- Hake biology and ecology. The SRG believes that a greater understanding of hake biology and ecology, derived from both existing data and active field research would be of great utility in formulating realistic assessments and projections for evaluating management strategies. Factors that should be investigated include:
    - o Stock structure and delineation – this should include temporal and spatial delineation of stocks in the U.S., Canada, and preferably also in Mexico.
    - o Patterns and rates of migration – this work could be conducted in coordination with stock structure research.
    - o Complete maturity schedules and ovary analysis, including better standardization of maturity categorization (meaning differentiating between immature spawners and those that have skipped spawning, and so forth).
    - o Estimate age- and/or condition-specific fecundity.
    - o Oceanographic and ecological drivers of distribution and abundance, including temperature, upwelling, currents, productivity (e.g. ocean color), predator and prey abundance and more.

- Target strength, target verification, measurement of diffuse hake in low backscatter regions. Ongoing field research focused on evaluating and updating the target strength (TS)–length relationship for Pacific Hake should be continued, as errors in the predicted TS-length relationship can translate into errors in survey biomass estimates.

- Effect of survey direction and duration. The northward migration of hake, coinciding in time with progression of the survey from south to north, may cause a positive bias in survey biomass estimates (if fish are double-counted). The current belief is that the survey moves fast enough along the coast that a large bias is unlikely. The SRG suggests that the potential bias could be estimated via a simulation study that models migration and sampling processes. As noted in last year's SRG report, if the magnitude of bias is consistent from year-to-year, then the effect of double-counting is being dealt with as a component of the survey catchability. However, if the timing of the survey in relation to migration timing varies among years, then development of a method to quantify and correct this bias could be important.

- Inter-vessel calibrations. This is an important aspect of quality control in this assessment. The SRG notes that calibration of acoustic gear is performed regularly on vessels conducting the survey; however, potential differences among vessels (e.g., the *Bell Shimada* and the *W.E. Ricker*) due to different hull shapes and engine noise have not been quantified. We recommend periodic inter-vessel calibration studies be conducted.

SRG Recommendations for Management Strategy Evaluation Topics

The JTC conducted a good deal of work on the Management Strategy Evaluation in 2013-2014. In particular, the JTC demonstrated the utility of the MSE approach in experiments on varying fishery selectivity. The SRG encourages the JTC to further expand the MSE framework and offers the following suggestions to guide the JTC's work with the MSE during 2014. We have separated recommendations for the MSE from general research recommendations (above) in order to have a cohesive set of suggestions for this effort. The recommendations are organized in rough order of priority, and the first recommendations should be regarded as of similarly high priority as those in the previous section.

- The SRG encourages the JTC and the JMC to engage in discussions that will better define the objectives for managing the fishery so that performance can be defined objectively and quantitatively in the context of the MSE.

- The MSE work to date suggests that strict adherence to the default 40:10 harvest control rule would likely result in suboptimal performance of the fishery. The MSE framework is a powerful tool for exploring the potential benefits and risks of different harvest control rules and overall harvest strategies, and the SRG recommends that the JTC continue to pursue this research direction with input from the JMC, the AP and the MSE steering committee.

- The current (2014) assessment model makes numerous simplifying structural assumptions. By having an operating model that is more complicated than the

stock assessment model, the MSE framework could be used to evaluate the sensitivity of stock assessment results to simplifying assumptions, much as the JTC used the MSE to evaluate the performance of the 2013 assessment model and its lack of time-varying fishery selection. The SRG encourages the JTC to consider including structural mismatches in future MSE experiments to evaluate the model uncertainties that are inherent but currently unmeasured in the stock assessment results.

- We suggest that the JTC explore the effects of harvest on different ages on overall sustainability of the stock and distribution across the U.S. and Canadian fisheries. This exploration can take the form of relatively simple simulation studies of demographics and population dynamics initially. As additional information about drivers of migration and recruitment is developed, the potential for including spatial components in the MSE would be worth investigation.

- Although the results of the MSE experiments during 2013 indicate that having an annual acoustic survey is less important when the assessment model has time-varying fishery selectivity than when it does not, it seems premature to dismiss the potential benefits of an annual survey. The relatively high information content of the fishery data compared to the survey data in the MSE scenarios considered to date may be an artifact of the simplified dynamics of the MSE's operating model. The SRG encourages the JTC to conduct additional MSE experiments with a revised operating model to evaluate the system performance under scenarios with different survey designs, for example annual versus biennial surveys, and surveys with and without an age-1 abundance index.

- The SRG encourages the JTC to consider using the MSE framework to explore which stock assessment uncertainties have the greatest relative impact on management performance, to help inform the setting of research priorities. For example, in the current assessment model the prior distribution on natural mortality (M) is updated considerably by the data, but the causes for this remain unclear. The MSE framework could be used to determine whether mis-specifying M in the assessment model compared to the operating model has a large impact on management performance. If it does, more research effort could be allocated to improving our understanding of M, including potential changes in its value over time and among ages.

- The SRG recommends that the JTC explore variation in recruitment in the short and long term. In the short term, we suggest that the current recruitment patterns be modeled. Specifically, in the current MSE framework, both the operating model and assessment model assume that recruitment deviations are uncorrelated, but the estimated recruitment deviations suggest negative lag-1 and lag-2 autocorrelation. It would likely be worthwhile to also include these in the short-term assessment projections. In the longer term, it is important to understand if there are oceanographic or ecological processes that influence recruitment variability. The SRG encourages the JTC to consider ongoing and future studies in its development of future MSE operating models.

SRG Recommendations for Process, Roles and Responsibilities

The SRG discussed a number of process issues relating to the conduct of their work and the interaction between the SRG and other treaty entities. The following recommendations and questions were generated from that discussion:

- *In future reviews, include acoustic/assessment expertise* –A substantial portion of the SRG meeting this year was spent discussing the acoustic survey sampling protocol and estimation methods. In future years, the SRG would benefit from a consultant with expertise in acoustic survey design and estimation to help inform the discussion and review of the survey. Ideally, this person would also have experience in fisheries stock assessment, to help bridge the acoustic survey and stock assessment fields.
- *SRG contributions to MSE* – the SRG co-chairs are members of the MSE steering committee and are able to contribute advice to the JTC on development and refinement of the MSE. The SRG suggests that the co-chairs be charged with delivering the SRG suggestions to the MSE steering committee for formal consideration and prioritization. The SRG also suggests that the MSE steering committee is an appropriate forum for consideration of questions from the JMC or other treaty-related bodies concerning potential impacts of alternative harvest or other management approaches.
- *Timing* – the schedule for delivery of various outputs is constrained on one end by availability of data and on the other by the need to comply with intra-governmental processes such as the need to open fishing seasons by a required date. Nevertheless, there is need for adequate time for SRG members to review documents so that they can complete the SRG's required tasks in the time allotted. The SRG requests the JMC – in consultation with the SRG and JTC – examine the time schedule to see if additional flexibility can be achieved.
- *Decision table contents and format* – the SRG worked with the JTC to develop a decision table that we believe has sufficient information and characterization of risk associated with harvest choices for the JMC and the AP to develop harvest recommendations. We suggest that clear guidance be offered from the JMC to the JTC about which metrics and presentations are most helpful, and that this be formalized in the terms of reference to the JTC.