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, 23 to 25 February 2016 to review and prepare a report for the Joint Management Committee (JMC) on the draft 2016 stock assessment document prepared by the Canada/US Joint Technical Committee (JTC) and the 2015 acoustic survey and biomass index estimate along with research on the acoustic survey methodology conducted by both nations in 2015.

The Scientific Review Group provides independent peer review of the Joint Technical Committee's (JTC) work. The SRG is composed of two U.S.A., 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's formal terms of reference, which were approved by the JMC in 2014, charge it with:

1. Reviewing the stock assessment criteria and methods and survey methodologies used by the Joint Technical Committee;

2. Providing annually, by March 1, unless otherwise specified by the Joint Management Committee, a written technical report of the stock assessment and its scientific advice on annual potential yield; and

3. Performing other duties and functions as directed by the Joint Management Committee.

The SRG meeting convened at 9:40AM Tuesday, February 23, 2016. John Holmes (meeting co-chair) welcomed attendees and after a round of introductions reviewed the agenda and SRG Terms of Reference and then assigned reporting duties. He noted that there was a short time between the end of the meeting and the March 1 reporting deadline and indicated that he expected the SRG report would be mostly drafted and approved by the end of the meeting on February 25. In addition to the eight SRG members, there were 24 participants at the meeting representing the AP, JMC, JTC, Survey Team, and stakeholders (Attachment 1). On February 24 and 25, Michelle McClure (meeting co-chair) chaired the meeting.

Conclusions

The following points summarize the main findings of the SRG with respect to the 2016 stock assessment and 2015 acoustic survey and biomass estimate. These conclusions and the following report include values of reference points reflecting small changes made by the JTC in response to SRG comments and notes, and are consistent with the final assessment document.

1. The 2015 acoustic-trawl survey was successfully completed. The survey results included a relative biomass estimate (age 2+) of 2.156 Mmt (million metric tons), a 12% increase from the 2013 survey estimate of 1.929 Mmt. Approximately 21.4% of the estimated biomass was in Canadian waters and 78.6% in US waters. The 2010 cohort (age-5 fish) was the dominant cohort in the stock, comprising more than 50% of the fish in both survey and fishery catches.

2. The survey group has made substantive improvements to their development of the biomass estimate, and is to be commended. In particular, a geostatistical approach, kriging, has been applied to develop index estimates since 2011, and important refinements were made this year. In past applications, the pattern and amount of the extrapolated biomass has concerned

the SRG. Sensitivity tests conducted by the survey team in 2015 resulted in the selection of kriging parameters that limit extrapolation to an average of 10.7% over the time series. In addition, the survey team re-processed the historical time series (1998 to present) with these kriging parameters and refined data processing protocols, addressing issues to which kriging results are sensitive. The SRG agrees with the survey team recommendations to apply the new processing and kriging protocols to past and future surveys, including to the 1995 data that has not yet been reprocessed. The changes implemented this year are important and well-done.

3. Survey and biomass estimation efforts would continue to benefit from work in several areas. First, fully documenting the survey and biomass estimation methodology, including protocols for selecting trawl locations, justification for survey design, and kriging methodology is an important step for current and future reviews. Second, continuing to work with all survey parties (NWFSC, DFO and SWFSC) to optimize survey and research efforts given available ship time, personnel and processing resources, will help to increase efficiency. Third, continuing efforts, within both the survey and stock assessment teams, to develop and refine and use the age-1 index appropriately. Finally, continuing efforts to delineate population structure for the species will ensure that assessment efforts are targeted at appropriate demographic units; collaboration with Mexican scientists may be useful in this effort.

4. We recommend, given apparent patterns of hake distribution, that the hake survey routinely include the area from Pt. Conception northward; we anticipate that ultimately, surveys of this area would contribute to a robust time series. Similarly, we recommend that the distribution of commercial catch and fishing effort be analyzed to better characterize hake distribution, especially in offshore areas.

5. The 2016 base assessment model has the same structure as the 2015 model, with updated fishery and survey data through 2014 and new data from 2015 including fishery catch and age compositions, the 2015 acoustic survey biomass estimate, and an updated weight-at-age matrix. The SRG appreciates the decision made by the JTC to keep the model structure consistent with that used in 2015 and 2014. Updating model structure on an annual basis can lead to high variability in perceptions of stock status, and should only be undertaken if supported by compelling new information.

6. The SRG notes that uncertainty measures in the base model account only for the structure and processes included in the model. Thus, uncertainty in current stock status and projections is likely underestimated.

7. We find that the data used in the assessment model, as well as the model itself, constitute the best scientific information available for management of Pacific Hake harvest. Sensitivity analyses conducted by the JTC support our confidence in the assessment as structured; the sensitivity analyses presented were well-selected, explained and explored appropriate structural uncertainties in the model. We recommend that this suite of sensitivity analyses become standard components of the assessment process. The assessment team continues to provide extremely high quality analysis and advice for the SRG, and are to be commended for their ongoing excellent work..

8. From the base model, the median estimate of female spawning biomass at the beginning of 2016 is 1.885 million metric tonnes (Mmt), with a 95% credibility interval of 0.791 to 4.781 Mmt. The 2016 median biomass estimate increased from 2015 due to estimated very strong

recruitment in 2014 and similar-to-average recruitment in 2012. The 2010 year class continues to be influential to stock dynamics, with age-5 fish comprising more than 50% of the 2015 catch. The strength of the 2014 year class is highly uncertain because the assessment includes only one year of observation.

9. The median estimate of stock biomass at the beginning of 2016 is well above the $B_{40\%}$ and $B_{10\%}$ biomass reference points, and the estimated fishing intensity in 2015 was well below the $F_{40\%}$ target. The SRG concludes that the coastal Pacific Hake stock is not overfished and that overfishing is not occurring for this stock.

10. The decision tables presented for the base model give the expected effects of various catch levels on stock biomass and fishing intensity. The base model forecasts that median catches of 830,124 mt in 2016 and 955,423 mt in 2017 could be achievable when fishing at the $F_{40\%}$ target fishing intensity, with an equal probability of being above or below the target fishing intensity. The SRG notes again that preliminary management strategy evaluation (MSE) work on alternative harvest control rules (HCRs) discussed at the 2014 SRG meeting showed that performance of the default $F_{40\%}$ HCR, judged on a combination of conservation and harvest metrics, was poorer than similar HCRs with upper limits of 375,000 mt or 500,000 mt on annual harvest.

11. The SRG concludes that developing an operating model that is structured differently from the assessment model will be a critical element of conducting further MSE work for Pacific Hake. A spatially explicit operating model is likely necessary to examine issues involving fishing by the US and Canada with spatial dimensions, such as the availability of fish in each country. Other areas of fruitful inquiry with an MSE include evaluating alternative approaches to modeling selectivity of the fishery, evaluating juvenile indices, and management approaches and procedures for stocks with episodic strong recruitment events.

Overview of the Acoustic Survey

The acoustic survey conducted in 2015, like the last three surveys, was a collaboration between the Canadian Department of Fisheries and Oceans (DFO), and the Northwest and Southwest Fisheries Science Centers (NWFSC, SWFSC) of NOAA Fisheries. The NOAA research vessel BELL SHIMADA (SH) surveyed the abundance of both Pacific Hake and coastal pelagic species simultaneously while the DFO research vessel, WE RICKER (WER) focused on Pacific Hake. There were significant changes to the survey protocol in response to recommendations put forward during a 2014 CIE review of the survey protocol, requirements for the survey of coastal and pelagic species, SRG recommendations and in anticipation of a more northerly distribution of hake as a result of an expected strong El Niño and the impact of large area of anomalously warm water in the Gulf of Alaska (the 'warm blob' event). These included:

- Increasing the hydroacoustic transect spacing from 10 to 20 nautical miles (nmi) and incorporating some "zigzag" transects on which additional acoustic and oceanographic information was collected.
- Extending the southern limit of the survey to the U.S./Mexico border.
- Restoring oceanographic sampling to the U.S. portion of the survey (CTD, plankton casts, ADCP)

Survey elements that remained unchanged included:

- Collecting acoustic data using EK60 sounder at 18, 38 and 120 kHz on both vessels as well as 70 and 200 kHz aboard the SH.
- Using mark ID trawling and a net mounted camera to verify acoustic targets.
- Running transects across the continental shelf from 30 m depth to 1500 m or 35nmi, whichever is farther offshore.
- Full biological sampling of hake including otoliths, stomach contents, gonads, sex, length, weight).
- Western extent protocols requiring extension of transects when hake acoustic sign was observed at the end of transects.

The SH conducted survey operations between June 15th and September 10th, the WER surveyed August 22nd to September 12th. Daytime operation aboard the SH were focused on Pacific Hake while night time operations focused on CPS. Daytime operations on the WER focused on hake while night-time operations were used for oceanography. Between August 16th and 29th the WER and SH both surveyed the west coast of Vancouver Island from south to north by interleaving transects at a 20 nmi spacing effectively producing a 10 nmi grid or two independent observations at 20 nmi for this region during the same time period. The WER made a third pass north to south along the West Coast of Vancouver Island between September 8th and 12th producing a third estimate of Hake acoustic backscatter. While observations of Pacific Hake backscatter were similar between the both vessels during the August time frame, the third pass by the WER encountered significantly more Pacific Hake, including large numbers of age-1 fish.

Age 2+ hake acoustic backscatter was encountered between Point Conception, California and the northern end of Vancouver Island, with the greatest concentrations encountered off Oregon, Washington and the west coast of Vancouver Island, BC. Western extent protocols, where the survey vessel must continue seaward along a transect until no Pacific Hake backscatter is detected, were invoked on 11 transects, resulting in 82 additional nmi of acoustic transect, with the furthest seaward extent of Pacific Hake encountered between Newport and Crescent City. The Survey team had anticipated a more northerly distribution of Pacific Hake in 2015 due to warmer than usual water offshore and had planned for surveying into southeast Alaska, as occurred in 1998 when conditions were similar. However, almost no Pacific Hake were seen north of Vancouver Island.

Catches during target verification tows aboard the SH were less varied than those aboard the WER (79% hake on the SH vs 59% on the WER). This difference is largely due to a lack of Pacific Hake in the portion of the survey conducted by the WER and higher abundances of rockfish (primarily Pacific Ocean Perch, Redstripe Rockfish and Yellowmouth Rockfish) in the area. The size composition of Pacific Hake encountered in US waters was dominated by smaller age 1 (< 30 cm) fish while in Canadian waters larger fish (> 40 cm) dominated.

The estimate of adult (age 2+) biomass from the 2015 survey is the largest in the time series, at 2.156 Mmt. The estimate is predominantly age-5 fish from the very larger 2010 recruitment, with smaller but significant numbers of age-3 and age-7 fish from the 2012 and 2008 year classes. The survey team has used kriging to generate their estimate of biomass for age-2+ fish since 2011 and undertook several analyses to refine and validate their methods this year, including assessing the effects of search radius and number neighbors used for interpolation and modifying the kriging software to include a tapering function to minimize extrapolation of biomass beyond

the surveyed area. The survey team reanalyzed all surveys back to 1998 using these consistent kriging methods and parameters across all years to generate a refined time series of survey biomass estimates from 1998-2015.

In response to a 2015 SRG request, the survey team developed an index for age-1 Pacific Hake from the acoustic survey. Age-1 hake historically have been excluded from survey efforts and biomass estimation due to largely different schooling behavior than older hake, concerns about different catchability by the trawl gear, and differences in expected location during the summer months when the survey takes place. The develop of an age-1 index involved reviewing all previous years of acoustic data, identifying aggregations of age-1 fish and aggregations of mixed ages that included age-1s, partitioning mixed aggregations into age-1 and age-2+ by using relative proportions of each in target verification tows. All estimated biomass of age-1 fish was accumulated as an index. Initial comparisons show a good correlation between the age-1 index and modeled recruitment, but further work is required before the index is included as an input in to the assessment model.

The SRG notes that the U.S. and Canadian survey vessels use different mid-water trawl nets to conduct target verification tows and that these nets have significantly different selectivity for age-1 Pacific Hake and other smaller species.

The survey team is to be commended for the enormous amount of work undertaken this year, not only in the conduct of the survey but also in refining their analytical methods and reanalyzing the survey time series back to 1998.

SRG Survey and Acoustic Research Recommendations

- The SRG recommends that reanalysis of 1995 survey data be performed, as planned by the survey team, to provide an 1995 index value compatible with the index values from more recent surveys, which were considerably refined this year.
- The SRG concurs with the survey team's recommendation that the survey analytical team continue to use the improved kriging model developed for the current assessment going forward. This model includes revised kriging parameters and some data processing protocols and results in limited extrapolation.
- The SRG recommends that the survey each year include transects at least as far south as Point Conception, California. Establishing this minimum southern boundary will allow consistent and inclusive sampling of age-1 hake.
- The SRG has noted several times that better documentation is needed both for the survey itself and the subsequent analysis that generates the age-2+ biomass index. We recommend that this be given high priority.
  - For the survey, objective criteria or guidelines should be documented for such decisions as:
    - When are verification trawls made?
    - How are echo patterns determined to be age-1 hake?
    - What are western and eastern extent protocols?
  - For the biomass estimation process, formal documentation of the following would be useful:

- An operational description of the procedures followed, perhaps in the form of a flowchart, showing for each processing step, the purpose, method, data input, and data output.
    - A more technical description of both the kriging process and the sensitivity analyses conducted for the final parameterization of the limited extrapolation kriging model.
  - The documentation should be published as a NOAA Technical Memorandum or as an appendix to future assessment reports.
- The SRG recommends that the age-1 index be continued, and improved as appropriate. This index is now suitable for sensitivity analyses in the assessment or as a subject of MSE analyses, and it provides confirmatory information to management.
- The SRG recommends that the survey teams work towards either standardizing the nets across survey platforms or developing a calibration coefficient between the nets to account for their different selectivities at size.
- Offshore Hake Distribution: survey transects extend to 35 nmi offshore or 1,500 m depth, whichever is further. If hake are observed acoustically at the offshore end of a transect, the transect is extended for 0.5 nm past the last point at which hake are observed. The SRG notes that the 0.5 nmi stopping rule is based on logistical rather than scientific considerations and encourages the survey team to continue exploring the possibility that hake may be found further offshore using information such as commercial catches, pilot studies of distribution, and other surveys.
- The SRG recommends that research on the effect of survey direction and duration be conducted. The primary concern for the SRG is whether survey duration and direction affects the meaning of the results provided by the acoustic survey, because Pacific Hake may be migrating during the extended duration of the survey. A costly but effective experiment would be to conduct a double survey using two vessels: one sampling transects from north to south; the other, from south to north.
- Hake biology and ecology: The SRG noted in 2015 that the survey team has collected substantial amounts of acoustic and oceanographic data during historical surveys, and that a research plan was needed to use the data to better define hake habitat and answer related questions. The SRG is pleased to see that there are several projects underway to address this general topic, and reiterates the need for finalizing the draft research plan.
- The estimated survey variance is an underestimate of true variance, because variance calculation is based on the smoothed surface from kriging, not on the underlying data. The alternative Jolly-Hampton method estimates considerably larger variances. To clarify the degree to which the assessment model compensates for variance underestimation by using an additional variance parameter, the SRG recommends that as part of next year's survey calculations, both forms of variance be made available. The SRG recommends that the JTC conduct a sensitivity run using the Jolly-Hampton estimates.

Overview of the 2015 Stock Assessment

The 2016 assessment uses the same basic model structure as used in the past two assessments. In the model, annual catches-at-age are taken by a single coast-wide fleet beginning in 1966. The

model is informed by age-composition observations from the fishery, an age 2+ biomass index from the acoustic survey, and observations of survey age-composition based on trawl samples taken during the survey. Age-specific selection coefficients are estimated for the survey and fishery, with constrained annual variation allowed in fishery selection. The model uses a matrix of empirical weights-at-age, rather than attempting to model size-at-age, since size-at-age is very dynamic in this species. A Bayesian approach is used for parameter estimation, with informative priors specified for natural mortality and spawner-recruit steepness.

Changes from the 2015 assessment included minor revisions to the catch and the fishery age-composition series, the addition of fishery catch, age-composition and weight-at-age data for 2015, a complete revision of the survey biomass index and age-composition series, the addition of survey biomass and age-composition data for 2015, and retuning the model for the recruitment bias-adjustment ramp and age-composition weights. With these changes, the 2016 assessment estimates that 2014 recruitment is well above average and that spawning biomass at the start of 2016 increased from 2015, but the estimates of both quaantitesare highly uncertain.

The assessment included a sensitivity analysis that showed minor effects from using the current survey biomass index with limited extrapolation beyond the survey transects, compared to no extrapolation. Other sensitivity analyses explored the effects of including the age-1 acoustic survey index, the assumed maximum age for selectivity, and standard deviations of the priors on natural mortality and steepness.

SRG Assessment Recommendations

The following recommendations are listed from highest to lowest priority.

- Given the information and analyses presented to the SRG this meeting, the SRG agrees with the decision to fit the 2016 base assessment model to the survey biomass time series with limited extrapolation. This decision should be continued for the 2017 base assessment model.
- The list of sensitivity tests presented in the 2016 assessment covers the major axes of uncertainty, and should be continued in the 2017 assessment.
- Age-1 index: the SRG supports the continued development of an age-1 index from the acoustic survey, and recommends continuing to run sensitivity tests in future assessments fitted to the age-1 index.
- Sensitivity tests that changed sigma-R (which sets variability around the theoretical recruitment model) from the default value of 1.4 to values of 1.0 and 2.0 resulted in large changes to estimates of R_0 and B_0. Since this is the only parameter that showed a large impact on population status, we recommend that the value of sigma-R be explored more fully.
- Current biological evidence does not support including Pacific Hake south of Point Conception in the assessment. The SRG encourages continued collection and processing of genetic material to resolve stock structure in the California Current region, especially given increasing catches of Pacific Hake in Mexican waters.
- The SRG continues to support collection of ovaries across the range of Pacific Hake and further estimation of maturity schedules based on histological techniques. We recommend updating the current maturity ogive for the stock north of Point Conception (34°N), given that the current stock assessment is based on older information (Dorn and

Saunders 1997). We encourage the ongoing collection and processing of biological samples on survey and other platforms.

SRG Recommendations for Management Strategy Evaluation

The JTC presented the results of management strategy evaluation on the benefits of fitting the model to an age-1 acoustic index to the JMC in May 2015 and the SRG at this meeting. The goal of this work is to evaluate whether enumerating incoming recruitment before the fishery begins to take them improves management performance. Simulation results showed that inclusion of the age-1 index led to a slight reduction in the risk of severely depleting the stock, annual variation in catch, and average catch. Further work is needed, but the age-1 index provides useful information on the size of a cohort before it is exploited. The JTC also reported that they are continuing to seek input from the JMC and AP on design features and questions to be addressed by an MSE process, and noted that there is interest in a spatial operating model. Finally, the SRG was pleased to learn that a book chapter authored by JTC members describing MSE experiments exploring the performance of the default harvest control rule and alternatives, which was presented to the SRG and JMC in 2015, will be published in March 2016. The SRG offers the following suggestions to guide the JTC's work with MSE during 2016. These recommendations for MSE are separated from other research recommendations (above) in order to have a cohesive set of suggestions for this effort.

- The SRG recommends the continued development of MSE tools to evaluate the impact of uncertainty relating to data, model structure and the harvest policy for this fishery on stock status and management performance.

- The SRG encourages the JTC to continue exploring the benefits of having a young-of-the-year, age-1 acoustic survey index, or both, in the assessment model, including evaluation of both perfect and misleading indices that could inform a decision table.

- The SRG encourages the JTC to continue to engage the JMC and AP members in discussions and development of MSE operational objectives.

- The SRG recommends that the JTC develop and evaluate alternative operating models in order to consider structural mismatches in future MSE experiments.

- The SRG recommends that the JTC focus effort on determining how to model spatial and seasonal dynamics in order to capture seasonal effects and potential climate forcing influences in a spatial operating model. We request that the JTC report its progress towards the specification of a spatially explicit operating model at the next SRG meeting.

SRG Recommendations for Future Meetings

- The SRG would like to invite a presentation on the Mexican Hake fishery, research and management off the west coast of Baja California to assess the potential for and relevance of future collaboration with international partners.

- The SRG requests a full presentation of the 2016 winter survey efforts at the next SRG meeting.

Literature Cited

Dorn, M. W. and M. Saunders. 1997. Status of the coastal Pacific whiting stock in U.S. and Canada in 1997. In Appendix: Status of the Pacific Coast Groundfish Fishery Through 1997 and Recommended Biological Catches for 1998: Stock Assessment and Fishery Evaluation. Pacific Fishery Management Council. Portland, OR. 84 p.

Attachment 1

List of Participants

Name	Affiliation	Committee (if any)
Rod Moore	West Coast Seafood Processors' Assoc.	AP advisor to SRG
Al Carter	Ocean Gold Seafood	
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AP: Advisory Panel; DFO: Fisheries and Oceans Canada; NMFS: National Marine Fisheries Service; NWFSC: NMFS Northwest Fisheries Science Center; SRG: Scientific Review Group; WCR: West Coast Region; JMC: Joint Management Committee