Joint U.S.-Canada Scientific Review Group Report

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Introduction

Under the authority of the Canada/US Pacific Hake/Whiting Treaty ("The Treaty"), the Scientific Review Group (SRG) met in Seattle, Washington, 21 to 24 February, 2012, to review a draft stock assessment document prepared by the Canada/US Joint Technical Committee (JTC). With ratification of "the Treaty" by both parties, the SRG has attempted to operate fully in accordance with "the Treaty." The SRG bases its interim terms of reference on the language of the US-Canada Pacific Hake/Whiting Agreement and on the Pacific Fishery Management Council's Stock Assessment and Review (STAR) terms of reference, which have been used for Pacific hake for over ten years. The SRG was comprised of two US and two Canadian members; two additional SRG members are yet to be designated by Joint Management Committee (JMC) based on recommendations from the Advisory Panel (AP). The SRG will revisit its terms of reference before 2013 and submit proposed revisions to the JMC for approval.

The meeting convened at 9AM Tuesday, February 21, 2012, with a welcome from Dr. Jim Hastie (NWFSC, FRAM Division) followed by a round of introductions. Dr. Richard Methot (meeting chair) then reviewed the agenda, SRG interim Terms of Reference and clarified the role of the SRG advisors.

Summary Conclusions

1. The US-Canada acoustic trawl survey estimated the biomass of hake to be 521,000 mt in summer 2011. The stock was dominated by three-year old fish from the 2008 yearclass, and nearly all these fish were in U.S. waters, thus only 7% of the overall estimate of biomass was in Canadian waters at the time of the survey. Later in the year a larger fraction of the stock may have moved into Canadian waters, however the Canadian fleet was still unable to harvest its full allocation. The SRG examined several technical aspects of the survey and found it to be conducted with acceptable protocols and standardization.
2. The assessment modeling was conducted using the Stock Synthesis (SS) model, and sensitivity analyses were conducted with the Canadian Catch-Age Model (CCAM). Both models give nearly identical results when similarly configured. The SRG applauds the substantial work done by the joint assessment team over the past few years to explore alternative modeling software and assessment scenarios of various complexities. The current approach, which implements a relatively simple base case in the SS model and sensitivity runs in CCAM model, is pragmatic and parsimonious. The approach resulted in a base-case assessment model whose sensitivities were thoroughly examined. While SS and CCAM are

quite similar, their structure is different enough that a small measure of model-specification uncertainty was among the issues examined.

3. The 2011 survey estimate of stock biomass is considerably lower than the 2009 survey estimate, which results in a lower estimate of terminal stock abundance from the 2012 assessment, along with correspondingly higher estimates of recent exploitation rates. Given realistic rates of hake population growth and decline, it is highly unlikely that the population state has shifted as much as the survey estimates. The current assessment is in closer agreement with the 2011 survey estimate than with the 2009 survey estimate. The shift in perceived stock status from one assessment to the next reflects the inherent variability of a biennial acoustic survey, the major data source defining hake abundance changes over time.
4. The estimate of spawning stock abundance at the start of 2012 is at 33% of the unfished equilibrium level, which is near the long-term average expected when fishing at the default harvest rate but below the management target of 40% of the unfished equilibrium level. The stock is expected to stay near this level for the next two years as the 2008 yearclass grows and is supplemented by additional yearclasses. However, estimates of yearclass abundance for 2008 and beyond are very uncertain, and until cohorts are fully recruited to the fishery and observed for several years we do not have a good understanding of their true magnitude.
5. Although the stock is estimated to be near its target level, this situation is tenuous because of the dominance by a single yearclass. Harvesting at less than the default level in 2012 would reduce the risk of stock and fishery declines in the future.
6. Two major research recommendations are to increase the survey frequency to annual and to conduct a management strategy evaluation (MSE). An annual survey would resolve yearclass abundance more quickly and provide more stable assessment advice over time. Initiating an annual survey immediately (i.e., adding an additional full survey in 2012) is expected to provide immediate improvements to the 2013 stock assessment by helping resolve the discrepancy between the 2009 and 2011 acoustic estimates of biomass and improving precision of 2013 assessment estimates. It was noted by the acoustics team however that conducting a full-scale survey in 2012 would replace currently planned research into the development of more efficient survey methods that could provide a more cost-effective means of achieving an annual survey on an ongoing basis. Thus, while a 2012 survey would help better inform management in 2013, research into increased survey efficiency / precision could help better inform management in the long-term. Even if increased shiptime can be made available in 2012, experienced staff will be a limiting factor, so a trade-off between these short-term and long-term benefits will be necessary. The MSE

would provide a framework to test the performance of the current default harvest policy against alternative policies while taking into account the degree of recruitment fluctuations, the frequency and uncertainty of surveys, and other relevant factors.

Discussion on Acoustic/Trawl Survey

Dr. Dezhang Chu opened the meeting with a detailed presentation of the acoustic/trawl survey design, acoustic calibration technique, target verification trawl selection process, echogram scoring methodology, and biomass estimation using kriging. Since 1995 the survey has consistently covered between 35.5° and 55° N latitude, and 50 to 1500m depth along the Pacific coast of the U.S. and Canada between June and September each survey year. Prior to 2001 the survey was triennial, since then it has been biennial. Transects are mostly parallel to lines of latitude, spaced 10 Nmi apart and are assigned a random starting location in the south at the beginning of each survey. The vessels employed generally operate 15 hours a day from sunrise to sunset using 18, 38, 70, 120, and 200kHz, (only 38, 120 on Canadian vessel) transducers; 38 kHz is used for biomass estimation. Mid-water trawls are used to collect species composition information to aid in classification of the acoustic backscatter and to collect biological samples on the size and age composition of the hake targets being assessed. Trawl sampling is opportunistic and usually accounts for about 1/3 of each day's operational time. A third-wire real time scanning sonar is used to assure that catches are small enough to be manageable.

The acoustic calibration technique was discussed; the acoustic team reported that calibrations are performed in sheltered waters prior to each survey using either a standard target 38.1 mm tungsten carbide sphere or 64 mm copper sphere. The SRG asked how stable the calibrations were over time for a single vessel and how much difference there was between vessels. The acoustics team presented a plot of calibration values that showed a spread of approximately 0.5 dB for the Miller Freeman over the last two years, but less than 0.2 dB within the most recent survey (Figure 1). The consensus was that it was unlikely that drift in calibration was a significant source of variation in the acoustic estimate of biomass. They also reported that preliminary inter-vessel calibrations had been attempted, but that due to operational requirements this work is incomplete.

Dr Chu described the methods used to integrate (add up) backscatter (sound reflections from hake) over the survey frame. This starts with having two acousticians agree on and draw regions around hake targets on echograms. Thus, the method relies on the abilities and experience of individual acousticians at identifying hake, but this is supplemented with information on the frequency responses of sound reflection from different species, as seen on the echograms for the higher frequencies transducers, and the composition of nearby target-verification tows. Several sources of potential bias or error were discussed,

including use of an inaccurate target-strength relationship, misclassification of acoustic regions based on species proportions, and missed biomass due to higher than normal dispersion of hake. The team reported that they have been using the target strength relationship defined by Traynor (1996) and had confirmed this relationship in situ using the Drop Acoustic Array (DAISY). The team also reported that, of the several hundred hake regions identified during the 2011 survey, only five had been classed as containing mixed species; hence misclassification due to species misidentification was deemed a negligible source of bias for the 2011 survey.

Dr Chu continued with a description of the geostatistical approach (termed kriging) to biomass and variance estimation. Kriging can accommodate irregular survey transects and better account for patchy fish distribution than the methods used previously. The input data are a set of half Nmi biomass density values. The kriged estimates are interpolated to a 2.5 nmi grid coast wide. The kriged map is interpolating the expected density across the range of the survey, so that expected density is smoother across space than the variability among the original observations. It was noted that data were much patchier in 2011 than any other year, with much shorter spatial autocorrelation, meaning that hake schools, when encountered, were smaller. Once the grid of biomass density and variance is calculated, biomass in each cell is partitioned by length, sex and age (based on target-verification tows) to generate a composite biomass estimate for hake greater than age two. (Age one fish are excluded from the biomass estimate because of the survey's poor selectivity for this age class.) The kriging method is superior to that used previously in that it accounts for spatial autocorrelation and generates an estimate of the sampling error associated with interpolation. The approach does not account for other sources of uncertainty such as target strength, target classification, and survey extent relative to stock distribution.

The SRG asked the survey team what the implication of missed low density hake abundance might be. The team responded by producing a swept volume estimate of hake assuming the trawl catch per unit effort in tows classified as having no hake represented the background density of dispersed hake coastwide. This density was applied to areas with low or no hake, assuming this low density layer was 200 m thick, which resulted in an estimate equal to 1.4% of entire biomass index for 2011 or 7,685.4mt. Given the low estimate of this difference and the uncertainties in the survey estimate, the SRG concluded that any cryptic biomass attributable to low background densities of hake was likely negligible. The SRG recognizes that the fishery may at times fish in areas containing lower hake densities, but the bulk of the hake population is found in the large aggregations measured by the survey.

Discussion on 2011 Coastwide Acoustic Survey Result

Dr. Rebecca Thomas presented an overview of the 2011 acoustic survey. Survey activities began on June 26th aboard the NOAA Ship *BELL M. SHIMADA* and concluded on September 10th aboard the CCGS *W.E. RICKER*. Eighty transects were completed; modifications from previous years surveys included adding three additional transect at the southern extent of the survey frame to investigate the distribution of one year old fish, the re-orientation of transects off Vancouver island to make them perpendicular to the continental slope, and skipping several transects in northern BC due to time constraints.

The survey's initial estimate of biomass that was used in the draft stock assessment presented to the SRG was 553,991 mt, but this was revised downward to 521,476 mt on February 20, 2012 (the day before the meeting) to correct erroneous inclusion of age-1 hake in one transect. Approximately 92% of hake biomass was observed in US waters.

Acoustic team explanation for revision:

> One region of Age-1 hake was included in the hake biomass due to a data processing error from a change in transect numbering. The additional transects that were added to the survey to cover the Southern extent of the Age-1 hake were initially assigned negative transect numbers since they were further South than transect 1 of the designed survey. This caused a problem for the historical method of calculation in the Oracle database which is unable to process negative transect numbers. These transects were renamed 0.3, 0.5, and 0.7. In the EchoPro software, transects are selected for use in the biomass calculations in several lines of the program and in one of the lines one transect with Age-1 hake was not deselected and therefore Age-1 hake were used in the biomass calculation. We discovered the biomass error when producing our presentations for the SRG panel and Dr. Chu recalculated the biomass which resulted in a biomass of 521,476 mt with a CV 0.1018 which is a 6% decrease from the biomass used in the draft assessment.

Most biomass was observed north of Monterey, except age one fish which were found further south, with large aggregations seen around 41° N. The SHIMADA completed a few transects off northern Vancouver Island when the RICKER skipped ahead to survey pre-planned transects in an area where the fleet had been finding fish. During these transects the SHIMADA did encounter hake where the RICKER had not been seeing fish, bringing into question the comparability of the two vessel's sounders. This question was resolved when backscatter plots were examined and it was determined that the RICKER had observed hake in the transects immediately north and south of the schools identified by the SHIMADA.

When all target-verification trawls are lumped, approximately 80% of the catch by weight was hake, except off La Perouse Bank, off the southwest Vancouver Island, and in

Dixon Entrance where both walleye pollock and Pacific ocean perch were caught in significant quantities in tows that did not contain hake.

As is typical, larger and older fish were encountered as the survey progressed northward, but an atypical number of age one were encountered mostly in the south and with some scattered to the north. The 2008 year class (age 3 fish) dominated the catches. The acoustic age composition was 62% age 3s, 22% age 2s, 3-4% each of age 4, 5 and 6, with a few age 12 – 19 fish still present.

Mandated marine mammal avoidance protocols resulted in the loss of 10 opportunities to complete a target verification tow between transects 6 and 10 near Monterey. This was a transitioning area between age 1 and older hake, with approximately 14% of the biomass in transects 6-10 being age 1 fish. The missed sampling did increase uncertainty in the age proportions for these fish, but the worst case scenario (all fish assumed age 2+) would have resulted in a 15% increase in adult hake biomass coastwide. The actual impact is likely much smaller, and it could be in the other direction.

The implications of fish growth during the survey were considered. For the youngest fish (ages 1-3) there could be significant growth over the course of the survey; this is, however, confounded with larger fish at age being found further north, making it difficult to account for. The SRG concluded that any bias due to growth would be minor, compared to the variation in survey biomass estimates from year to year.

Likewise, the implications were considered of surveying a stock of fish that is migrating northward while the survey also tracks south to north, e.g. a Doppler effect. This could potentially result in seeing the same schools of hake more than once during the survey, which would lead to an inflation of the biomass estimate; however, the acoustic team responded that the survey moves fast enough for this not to be a concern. The SRG was satisfied with this response.

Discussion on US Pacific Hake (aka Whiting) Fishery

US fleets had an aggregate allocation of 290,000 tonnes, divided amongst the catcher processor (~120,000 tonnes), shore based (~100,000 tonnes), and tribal (~60,000 tonnes) fleets. The fleets caught 230,425 tonnes (79% of target), the shortfall being mainly due to uncaught tribal allocation. At-sea catches peaked in the spring and late fall (May/June, Nov/Dec) due largely to vessels leaving to participate in the Alaskan walleye pollock fishery midsummer, but also due in part to the lower bycatch rates achieved in the spring and fall. The shore based fleet displays the opposite pattern, with a slow start in the spring and peak landings in mid-summer.

Catcher processors fished predominantly in the north in spring, and by October/November/December their fishing moved further south (mainly Oregon), reversing the pattern of some previous years. This was the first year of fully rationalized fishery, consequently the mother ships worked as a co-op to optimize catch and reduce bycatch.

Catch from catcher processors was largely composed of three year olds (60% overall). The shore based catch was even more dominated by three years olds, which accounted for ~ 80% of the catch. This reflects the importance of the 2008 yearclass to this fishery and stock.

Discussion on Canadian Fishery

The Canadian fleet had an allocation in 2011 of 102,848 tonnes, plus carry over from the previous year, resulting in a Canadian TAC of ~109,000 tonnes. The total catch was 55,630 tonnes, with 9,720 tonnes of that being caught by the joint venture fleet. The shore side and at sea processor fisheries continued well into December, the JV fishery concluded on September 21st. Fishing was reported to be sporadic, aggregations were small and readily dispersed when fished, movements onto traditional fishing grounds appeared to be tidally driven with a cyclic ebb and flow of fish moving in from offshore. Approximately 30% of this year's catch was achieved by catcher processors with a significant proportion (~15-20%) coming from deep water areas not covered by survey. The fishery was dominated by 4 and 5 year olds, with a few 12s still showing up. Smaller three year old fish were not present in the Canadian zone in any numbers until August along the Canada/US border.

Discussion on Data for Assessment

Dr. Ian Stewart presented an overview of the data sources used as input for both the Stock Synthesis (SS) and Canadian Catch-Age Model (CCAM) assessment models. Both assessment models were fit to (i) fishery catch (1966 – 2011), (ii) commercial fishery age frequencies (1975 – 2011), (iii) the relative biomass index from the acoustic survey (1995 – 2011), and (iv) acoustic survey age frequencies (1995 – 2011). Other externally-derived inputs to the model included a maturity schedule, ageing error adjusted for a strong cohort effect, and a matrix of empirically-derived weight-at-ages between 1975 and 2011.

The biomass estimate series from the acoustic surveys is used as an abundance index, rather than as estimates of absolute abundance, in this assessment. Thus, a catchability coefficient (scaling coefficient) is estimated by the assessment model; this coefficient is assumed constant over time.

Limitations of relying on the acoustic survey biomass index to inform the abundance patterns of the stock were discussed, including the small number of survey observations available (only 8 data points between 1995 and 2011) and high variability between consecutive observations in some cases. Both age and climatic factors affect how far north hake migrate in any given year, but the relative contributions of these two factors are impossible to estimate from the 8 existing data points. The combination of highly variable recruitment and highly uncertain surveys give the assessment model insufficient information to resolve the magnitude of new yearclasses until they have been observed for several years in the fishery and in the survey.

The SRG considered whether updating the maturity schedule for Pacific hake should be a high research priority. The current schedule was derived in the 1990's, and the stock has undergone substantial changes in growth since that time. Updating the maturity schedule would not necessarily improve the clarity of the stock recruitment relationship within the assessment model; however, it may have a substantial effect of the calculation of reference points and current spawning biomass. It was noted that while changing reference points based on short-term temporal fluctuations in maturity schedules could have the undesirable effect of introducing higher variability into catches, such changes may be warranted if longer-term evolutionary trends were occurring. For this reason, further research into current maturity schedules for Pacific hake were endorsed as a high research priority. The issue of how often to update reference points for Pacific hake was identified as a potential research question for an MSE analysis.

Discussion on Stock Assessment Analyses

Dr. Stewart presented an overview of the assessment modelling efforts in 2012. Two independent statistical catch-at-age modelling tools were used to assess current stock status and make forecasts for future stock status: (1) the Stock Synthesis model (SS), which has been used for several hake assessments in recent years, and (2) a new Canadian Catch at Age model (CCAM). Extensive work was undertaken by the JTC in 2011 and 2012 to resolve differences between the SS and CCAM models, with the result that both models now are producing similar results. The JTC decided to use the SS model for the base case scenario for the assessment and the CCAM model to explore sensitivity scenarios. The rationale for using a single base case model rather than two side-by-side base cases, as was done in 2011, was that a single model does an adequate job of capturing perceived stock status through time and allows for more emphasis to be placed on communicating uncertainty, both within the base case model and between alternative model structures.

The base case SS model was much more parsimonious than some of the assessment models used for hake in recent years. A total of 80 parameters are estimated, including the unfished equilibrium recruitment level, spawner-recruitment steepness, natural mortality, survey catchability, an additional standard error term for the acoustic survey to represent process error, non-parametric fishery and survey selectivity parameters for each age up to age 6 (constant over all years), and 66 recruitment deviations. The model was fully Bayesian, and showed good convergence properties. While there was some confounding between equilibrium recruitment and natural mortality, this behaviour is to be expected for these types of models with limited contrast over time in the data.

The CCAM model was used to evaluate the sensitivity of the base case model results to structural uncertainty. While SS and CCAM are functionally similar, there are some differences including: (i) CCAM uses a multivariate logistic likelihood function to model catch-at-age residuals rather than a multinomial likelihood function, (ii) the partitioning of process and observation error differs, (iii) inclusion of an informative prior on survey catchability in CCAM, and (iv) the use of parametric selectivity functions in CCAM. Despite these differences, the models achieved very similar results.

The rationale for excluding time-varying selectivity was raised by the SRG. It was noted by the JTC that more complicated selectivity structures have been considered in past assessments, including dome-shaped selectivity and several forms of time-varying selectivity, but that those models were criticized as being overparameterized, requiring subjective decisions, and not robust enough to inform decision-making. The SRG concluded that while the assumption of constant selectivity over time was a simplifying assumption relative to the complexity of the actual fishery, it was a reasonable one and added stability to the model. The SRG also concluded that research effort would be more usefully directed at developing an MSE that could explore consequences of incorrectly specified selectivity than at exploring, once again, more complex selectivity scenarios in the assessment model.

A bridging analysis between the 2011 and 2012 assessments showed that the lower of biomass estimates in 2012 compared to 2011 were largely due to the 2011 acoustic survey index, which estimates the lowest relative biomass since the start of the time series in 1995.

None of the SS and CCAM model runs presented in the draft assessment document were able to fit both the 2009 and 2011 survey biomass index values. Several hypotheses about factors that could have produced such divergent indices were discussed, including bias in the 2009 index due to the presence of Humboldt squid and time-varying natural mortality or selectivity. A concern was raised that the strong yearclass signal the model is fitting in the age data may be impeding its ability to fit the survey data. To explore how much of each of the data components contributes to the objective function, the SRG

requested two additional model runs be conducted by the JTC to see if the model could be forced to fit both the 2009 and 2011 data points: (i) turn off the iterative reweighting of age comps and reduce weights on the age data significantly, and (ii) increase the weighting on the survey index. In these sensitivity runs, the model was still unable to fit both the 2009 and 2011 data points; basically, the assessment model cannot match the 2009 survey biomass index without estimating yearclass abundances that would persist into 2011 and cause a mismatch to the lower 2011 survey index. The SRG concluded that the biological dynamics of hake are not consistent with both the 2009 and 2011 index values.

The approach taken by the JTC this year, in which two modeling platforms (SS and CCAM) were parameterized in the same way in order to test their ability to produce similar assessment results, was a useful exercise because it provided additional validation of the base case. It was noted by the SRG however that future assessments do not necessarily need to follow this approach of multiple base case models; it should be left up to the JTC whether such model validation should be conducted in any given year. One option brought forward was that a second modeling platform such as CCAM be applied to the data in future years for quality assurance, but that results from the alternative model be summarized only briefly in the assessment document.

Discussion on Harvest Advice

During the review, the JTC presented results from the base case assessment model with the corrected 2012 acoustic survey biomass index presented by the acoustics team on the first day of the SRG meeting. The updated base model has a median level for current spawning stock biomass at 33% of its unfished level, and a harvest for 2012 of 252,000 mt based on the default harvest policy. The SRG requested that all results for the base case model, as well as all of the harvest decision tables presented in the executive summary of the assessment document, be revised in the final version submitted to the JMC to include the updated 2011 index. The SRG did not think any purpose would be served by requiring revision of the additional sensitivity analyses in the assessment document, given that a description of the small discrepancy between the 2011 index value used in the base case and that used in the sensitivity analyses was included in the final assessment report. The SRG concurs that the decision tables presented in the JTC report adequately represent the available harvest from the default harvest policy and from potential alternative levels of catch for 2012-2014. The SRG made several recommendations to the JTC for clarity in terminology to be used when reporting the harvest advice to the JMC.

A Canadian SRG member put forward a request that had been received from a Canadian groundfish manager to have a status quo harvest option (i.e., same as 2011 quota) added to the decision tables. The JTC agreed to make this change by replacing the 250,000 mt catch option with last year's quota in the existing decision tables.

A JMC member from Canada asked that an additional limit reference point be included that was relevant to fishery decision-making under Canadian domestic fisheries policy. In addition, it was noted that an alternative form of decision table that showed the probability of the stock being above specific biomass or fishing intensity levels in each of the next 3 years for each harvest option could be an effective means of communicating uncertainty to the JMC. In response to these suggestions, the SRG requested that an additional decision table be added to the assessment document for the base case model only. The following five projection statistics were identified for inclusion in the additional table, all of which would be conditioned on the same set of 2012 harvest values considered in the existing decision table:

1. What is probability of B_{2013} above B_{2012}
2. What is probability of B_{2013} above 40% of B_0
3. What is probability of B_{2013} above 25% of B_0
4. What is probability of B_{2013} above 10% of B_0
5. What is probability that the fishing intensity in 2012 exceeds the fishing intensity target?

SRG Research Recommendations

This section is a compilation of research recommendations, many of which have been mentioned in earlier sections. Where we support them, we have incorporated recommendations of the JTC.

Highest- priority recommendations

- Increase frequency of acoustic survey to annual. The acoustic survey provides the most important data series for estimating biomass dynamics in the stock. However, the survey's impact on the assessment is delayed by being conducted only in odd years. That limitation is especially pertinent because the stock and fishery rely on intermittent high recruitment, and such recruitment is detected by the acoustic survey when fish reach age 2 or 3, (up to three years after recruitment), by which time they are part of the fishery. The SRG recommends that the survey be conducted annually, which would improve management's ability to react to both strong and weak recruitments. It would also reduce the

period of uncertainty following survey values (e.g., 2009) that when modeled does not appear compatible with other information. .

- The SRG recognizes that initiating an annual survey immediately (i.e., adding an additional full survey in 2012) would provide immediate improvements in the precision of the assessment, which would in turn improve the information available for management decisions in the next few years. Given that fishery data alone has proved unsuccessful at informing the scale of current abundance in the past, a 2012 survey point could be the only way to resolve the magnitude of the 2008 year class prior to decision-making in 2013.
- In response to this recommendation, the acoustics team expressed concerns that implementing a full scale survey in 2012 would come at the expense of other work planned by the survey team in 2012. In particular, the survey team plans to conduct additional work on target strength in 2012, which will help improve the accuracy of future surveys, and to conduct work designed to provide for a joint survey of hake and sardine, which will provide a more cost-effective means of achieving an annual survey on an ongoing basis. The SRG believes that an attempt to do a limited hake survey plus the long-term work is not advisable because a limited hake survey (e.g. fewer transects) would produce results that are even more uncertain than those from a full survey. The SRG agreed with the acoustics team that conducting a survey in 2012 would only be beneficial if resources were available for a full-scale survey in both Canadian and US waters.
- The SRG concluded that while a 2012 survey would help better inform management in 2013, research into increased survey efficiency / precision could help better inform management in the long-term. In the absence of increased resource allocation to the 2012 survey, a trade-off between these short-term and long-term benefits will be necessary, especially due to the limited number of experienced personnel available..

- Management strategy evaluation (MSE). The SRG recommends that a management strategy evaluation framework be developed for this fishery. Such a framework would allow the JTC to provide better guidance to the JMC on how different forms of management (i.e., the combination of data collection, stock assessment, and harvest decision rules) affect trade-offs between potential management objectives, among them magnitude and stability of yield. In addition, an MSE can elucidate which management strategies are more or less robust to unavoidable biological and assessment uncertainties, which are considerable in a fishery that relies on periodic large recruitments. Conducting an MSE will require

a significant commitment of resources by the JTC, and the SRG considers it a high priority.

    - In simulating the acoustic survey in an MSE, we recommend that observation errors be drawn from a mixture distribution, rather from a single statistical distribution. The mixture would have a minority of observations drawn from a distribution with considerably wider tails (larger variance) than the majority. This recommendation stems from the observation that in this assessment (and in others the panel is familiar with), the majority of survey biomass index values were fit quite well, and a minority fit quite poorly.

Other recommendations

- Inter-vessel calibrations. The SRG notes that calibration of acoustics gear is performed regularly on vessels conducting the survey; however, potential differences among vessels have not yet been quantified fully. We recommend periodic inter-vessel calibrations. Based on comments from experts, the SRG believes that about 10% of the survey budget might be needed for such work. This is an important aspect of quality control in this assessment.

- Age-1 or -0 index development. Because the current acoustic survey does not develop an index of fish below age 2, a large recruitment (when it occurs) cannot be confirmed for several years, especially given surveys only in odd years. An index of abundance of young (age-0 and/or age-1) hake could speed reaction of stock assessments to high recruitment events. Preliminary research has been done on the potential of obtaining an index from the acoustic survey. The SRG recommends that research be carried forward.

- Life-history data improvements. Present information on maturity at age is from a single study in the 1990s. A new study of maturity at age is in progress, which the SRG strongly supports. The SRG recommends regular collection and analysis of life-history data such as growth, fecundity, and maturity at age, rather than relying on static values from the literature.

- Survey extent. Based on comments from an industry participant, the SRG recommends that the survey team explore the seaward extent of hake distribution, particularly at the northern end of the range, and that some portion of the survey be extended seaward if warranted. The commenter stated that substantial hake

catches have been made over the last 5 years seaward of acoustic transects in Canadian waters. The SRG was unable to evaluate this situation, because data are protected by privacy regulations.

- Survey variance. The SRG recommends that research be continued on more complete estimation of variance in the acoustic survey. We refer to estimation from survey characteristics, independent of the stock-assessment model. Current variance estimates are a product of the kriging procedure and thus reflect only statistical sampling error, but the SRG believes (and assessment results confirm) that other physical and biological processes contribute the majority of variance. It was noted that AFSC scientists have been working on a similar problem, and that discussions and collaboration would be useful.

  In connection with the preceding recommendations, the SRG acknowledges that additional data collection and analysis will require significant additional resources from both nations, a commitment that seems to be warranted, given the importance of this stock to both nations.

  The SRG also notes that statistical and simulation studies could be useful, in many cases, in choosing or refining the most fruitful approaches to data improvement.

- The SRG recommends that use of commercial vessels in acoustic or biological sampling be explored as one way to expand sampling. This might include scientific analysis of echo data collected by commercial vessels in the course of fishing.

- Target characterization and verification. The SRG recommends that, as part of statistical studies to evaluate improved sampling options, that an increasing the number of target-verification tows and conducting target-strength research be considered. This could reduce uncertainty in assigning species and demographic characteristics to acoustic signals. Potentially, this could be done in collaboration with industry.

- Exploration of separability assumption in the assessment model; i.e., the assumption that selectivity is constant over time. The SRG recommends that, as a sensitivity analysis, the JTC examine the effects of relaxing the separability assumption in the assessment model. This could be done by fitting a simple tuned catch-age model (e.g., ADAPT) to the catch-at-age data and survey index. Observing that such a model could not improve the survey fit would further

confirm that the 2009 and 2011 survey estimates are incompatible with each other.

Editorial Suggestions

The SRG recommends some changes to terminology used in the assessment report, with the aim of making the report more easily understandable to those less familiar with local terminology. In particular, two concepts should be expressed more clearly:

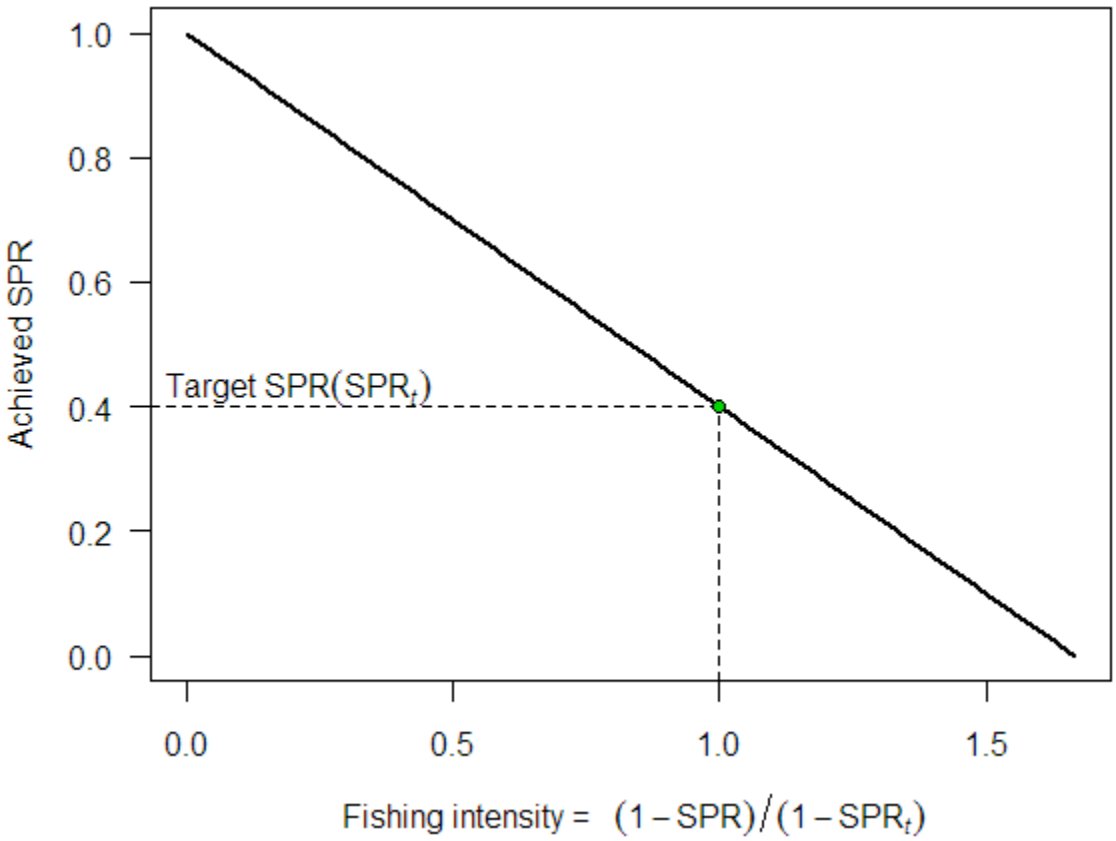
- Fishing intensity. This term is used in several places, and it should be used wherever it appropriate (instead of SPR) to describe the ratio,

  FI=((1-SPR))/((1-SPRt)),

  where SPRt is the target SPR.

It could be called "Fishing intensity based on SPR" if that seems better to the JTC. The use of "SPR" is a poor choice, because that acronym already carries two other meanings in the fishery literature (spawning per recruit and spawning potential ratio).

A diagram such as this one might help non-specialists interpret values of fishing intensity better:



- Depletion. This term is used idiosyncratically in some assessments in this region, in that the quantity labeled "depletion" is proportional to female spawning stock; i.e., higher "depletion" means more fish. This term should be supplemented by a term that more accurately explains, in English, what is meant; i.e., female spawning biomass relative to its average equilibrium value in an unfished stock. The SRG recommends that alternative, plain English terminology be used in the future.

SRG Recommendations on Harvest Advice

As a review group the SRG endorses the base case model recommended by the Joint Technical Committee with minor revision, updated harvest projections are is provided in the JTC decision tables.

1. The median estimate of the stock's current status (female spawning stock) is 33% of its average unfished equilibrium level. While this is substantially below the estimates in the 2011 assessment, it is very close to the average level expected while fishing long-term at the default harvest policy. However, the current stock biomass is dominated by a single yearclass, born in 2008.

a. Footnote: The average biomass level expected from fishing at F40%, which is a per recruit calculation, is less than the target biomass level of B40% because the spawner-recruitment relationship causes a decline in mean recruitment level as the spawning biomass is reduced to the 30-40% range;

2. The estimate of the stock's recent exploitation rate is slightly above the exploitation rate corresponding to the target SPR of F40%. The increased estimate of exploitation rate, compared to the 2011 assessment, is principally due to the current assessment estimating lower biomass, corresponding to higher-than-intended exploitation rates, over the past few years.

3. These estimates of current stock status and recent exploitation rates are highly uncertain.
    a. Estimated abundance of the 2008 yearclass, which currently dominates the stock, is highly uncertain. Because of this uncertainty, the spawning stock abundance in 2012 has a 25% chance of being lower than 22 % of the unfished level, and 25% chance of being higher than 51% of the unfished level. The range of this uncertainty is well-documented by the JTC.
    b. The uncertainty in the assessment is largely driven by two things. One is the large year-to-year fluctuation in recruitment of hake. This natural process can be monitored by current and improved surveys, but not controlled. The other contributor is performance of the acoustic survey, which in some years seems to not track the stock's abundance as expected. Despite extensive discussions with the JTC, the acoustic survey team, and industry members at the SRG meeting, the source of these acoustic survey differences remains elusive. The combination of high recruitment fluctuation, high survey uncertainty, and biennial surveys means that the assessment model cannot resolve the magnitude of new yearclasses until they have been observed for several years in the fishery and survey.
    c. In particular, the 2009 survey estimated high hake biomass, dominated by the 2005 and 2006 yearclasses. Then the 2011 survey produced a much lower biomass estimate, dominated by only the three-year-old 2008 yearclass. The current assessment cannot match the 2009 survey biomass index without estimating yearclass abundances that would persist into 2011 and cause a mismatch to the lower 2011 survey index. That is why the SRG concluded that the 2009 and 2011 survey estimates are incompatible with one another. The hindsight from future assessments could provide estimates of stock status in 2012 much different than the current estimate. Such uncertainty is not unexpected, given hake biology and current survey frequency.

d. If the acoustic survey could be conducted annually, the assessment model should more quickly estimate the abundance of incoming yearclasses and provide more stable results over time. We expect that the recommended management strategy evaluation (MSE) could quantify the degree of improvement to be expected.

4. The current default harvest policy, F40% with a down-ramp in F when biomass is below B40%, does not explicitly consider fluctuating age structure and the degree of uncertainty in each year's assessment advice. Thus, a modified harvest policy may be more suitable for this stock.

5. The fact that the stock is dominated by one young yearclass creates substantial risk to the stock's spawning potential if the TAC is calculated from median estimates, and the magnitude of this yearclass is subsequently found to be smaller than the median estimate (i.e., the true magnitude is toward the lower end of its range of estimated uncertainty in 2012). Large changes in estimates have occurred in the past. For example, the 2012 result is in the lower 2.5% of estimates forecast from the 2011 assessment. The SRG emphasizes that the stock's capacity to generate large yearclasses which support a sustainable fishery is likely to be lower at low stock sizes. Therefore, the JMC may want to consider a more conservative management strategy while the stock continues to be supported by only one yearclass.