Joint U.S.-Canada Scientific Review Group Report for 2020

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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 (hereafter referred to as "the Treaty"), the Scientific Review Group (SRG) met in Seattle, Washington, February 25-28, 2020 to review the draft stock assessment document prepared by the Canada/US Joint Technical Committee (JTC), progress on an MSE focused on Pacific Hake/Whiting, and the results of the coastwide acoustic survey conducted by both nations in 2019. 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, which the Joint Management Committee (JMC) approved as the formal Terms of Reference for the SRG. The SRG is composed of two US, two Canadian, and two independent members designated by the JMC, based on recommendations from the Advisory Panel (AP), and two industry advisors from the AP.

The Scientific Review Group provides independent peer review of the Joint Technical Committee's work. The SRG is charged with:

1. Reviewing the stock assessment data 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 09:00 Tuesday, February 25, 2020. Jim Hastie (SRG co-chair) welcomed attendees and after a round of introductions reviewed the agenda (Attachment 1) and SRG Terms of Reference and then assigned reporting duties. It was noted that the SRG was expected to submit its report to the JMC by March 4, 2020. Meeting participants represented the AP, JMC, JTC, Acoustics Team, MSE Technical Team, and stakeholders (Attachment 2). **Text highlighted in bold throughout this report is a request from the SRG for more information or analysis.**

Conclusions

The following points summarize the main findings of the SRG with respect to the 2020 stock assessment and acoustic survey research.

1. The structure of the 2020 assessment model is similar to the 2019 model, but includes a different prior distribution for the parameters that weight the age-composition data, removes the constraint that estimated recruitment deviations must sum to zero, and uses the average of the most recent five years (rather than all years) of weight-at-age data in calculating forecasts. Additional data for the 2020 assessment included weight-at-age data from 300 samples taken on the Canadian portion of the 2017 survey, 2019 fishery catch and age data, 2019 survey index and age-composition, and combined 2019 survey and fishery weight-at-age data. The uncertainty measures in this assessment are based on the data, structure and processes included in the model. Thus, uncertainty in current stock status and projections is likely underestimated.

2. The SRG considers the 2020 assessment report and appendices to present the best available scientific information on Pacific Hake/Whiting. The SRG appreciates the thoughtful responses of the JTC to its requests for analyses in the 2019 SRG report.

3. An acoustic survey was conducted from June 13 to September 15, 2019, proceeding north from Point Conception, CA, (34.5°N) to Dixon Entrance, BC (54°N). The 2019 survey estimated age 2+ biomass is 1.723 Mt (million tonnes), a 21% increase from the 2017 survey biomass estimate of 1.418 Mt.

4. The new data added to the 2020 assessment did not change the pattern of recruitment estimates but did change the estimates of recruitment in some years. The estimate of 2010 recruitment increased by 1.8 billion fish, which is 13% higher than in the 2019 assessment. Similarly, the 2014 and 2016 recruitment estimates increased by 1 billion and 0.6 billion fish, respectively, in the 2020 assessment. The 2010 year class is the second highest in the time series (after that for 1980) and the 2014 year class size is well above average at 9.4 billion fish (fifth highest in the time series) but smaller than the 2010 year class, which is estimated to be 15.3 billion fish. There is more certainty that the 2016 year class is above average and that the 2017 year class is about average due to observations of both cohorts as 3- and 2-yr old fish, respectively, in the 2019 survey.

5. It is unusual for this stock to be supported by multiple above average cohorts simultaneously as at this time. The 2010, 2014, 2016, and 2017 cohorts are predicted to comprise 12%, 29%, 24%, and 10%, respectively, of the stock biomass at the start of 2020.

6. The base-case model estimates that median female spawning biomass at the beginning of 2020 is 1.196 Mt, with a 95% credible interval from 0.550 to 2.508 Mt. This estimate represents a spawning biomass that is 65% of the unfished level, with a 95% credible interval of 31% to 129%. The joint probability that the stock is both below $B_{40\%}$ at the beginning of 2020 and above the target relative fishing intensity (a measure of the relative magnitude of fishing often expressed as a percentage) of $F_{40\%}$ in 2019 is estimated to be 4.3%.

7. Total exploitable stock biomass (age 2+, males and females) at the beginning of 2020 is estimated to be 2.640 Mt, with a 95% credible interval of 1.243 to 5.498 Mt.

8. The decision and risk tables presented for the base-case model report the expected effects of various catch levels on stock biomass and fishing intensity and reflect a substantial amount of the joint uncertainty related to equilibrium assumptions that influences the calculation of unfished biomass, B_0. The base-case model forecasts that catches of 558,094 t in 2020 and 438,261 t in 2021 could be achievable when fishing at the $F_{40\%}$ reference point level (calculated using average selectivity over the last 5 years), with an equal probability of being above or below the reference point. Applying the default harvest control rule (HCR; calculated using average selectivity across all years) yields an allowable catch of 666,548 t for 2020 and 484,844 t in 2021, but applying the HCR in both years increases the probability that the stock is below $B_{40\%}$ to 58% by 2022.

9. The projections also show that even in the absence of fishing, the stock is expected to decline from 65% to 62% of unfished biomass, with a 12% probability that the stock will be below $B_{40\%}$ by 2022.

10. The U.S. portion of the 2019 survey was accompanied by Saildrones for the first time, which collected acoustic backscatter data along the same transects (to the extent possible), within 3-

5 days of the FSV *Bell M. Shimada*. The Acoustics Team reported that four Saildrones were able to cover the full spatial extent of the acoustic/trawl survey in U.S. waters in 70 days. The results of those trials highlighted that the acoustic data were relatively good when compared to acoustic data collected by the survey vessel. Analysis of these data is ongoing and the results are expected to be informative regarding the utility of Saildrones as a system to supplement acoustic data collection by survey vessels. Several unresolved logistical issues need to be addressed to ensure comparability with the current acoustic/trawl survey, particularly trawl sampling to collect species composition and biological data used to interpret the acoustic backscatter data. **The SRG recommends continuing the evaluation of the Saildrone performance and, if there is acceptable compatibility, then the development of approaches to address the collection of species and biological data with which to interpret the Saildrone backscatter data.**

11. The SRG reviewed the second round of results from the Pacific Hake/Whiting management strategy evaluation (MSE) and is encouraged by the progress that has occurred on this important tool for providing strategic advice. Operating model development, following conditioning, now shows similar trends in the biomass time series and the estimation model can mimic the stock assessment model. This review also highlighted the need for further work on objectives related to conservation of the Pacific Hake stock, variability in yield and total yield. **The SRG continues to support ongoing MSE development and progress.**

12. While some of the current MSE results are informative to coast-wide management of Pacific Hake, further work is needed to model movement in realistic ways and to develop spatial objectives for management. The MSE's comparison of alternative realizations of harvest shows that the default harvest control rule does not perform as well as the modeled interpretations of JMC TAC selections or actual fleet catches in achieving fishery objectives identified thus far within the MSE process. The results also show that with the default HCR more frequent surveys results in better achievement of objectives such as maximization of long-term catch, although the analysis does not compare associated changes in survey costs and fishery revenues.

13. The SRG reviewed results from the Fisheries and the Environment (FATE) project on environmentally driven predictions of Pacific Hake/Whiting distribution and abundance. The J-SCOPE ROMS model was used to provide forecasts of temperature at 250m depth. Four forecasting models were developed using combinations of latitude, longitude, temperature at 250 m, and distance to the shelf break as covariates and all show reasonably high skill at forecasting the presence/absence of Pacific Hake in 2019 relative to observed distribution in the 2019 survey. Distance to the shelf-break was the best predictor of Pacific Hake presence in these models. This forecasting ability is limited by the spatial domain of the J-SCOPE ROMS model, which encompasses Oregon to the southern portion of Vancouver Island. **The SRG supports the continuation of this work and anticipates further improvements in forecasting skill with the introduction of transport covariates and other covariates of stock structure. The SRG believes that results of the FATE project are useful in refining the MSE operating model and in examining potential impacts of global climate change scenarios on the Pacific Hake/Whiting stock.**

14. The SRG appreciates the efforts of the Acoustics Team to plan and successfully conduct a high quality acoustic/trawl survey, in the face of the shutdown and furlough of NOAA employees in January 2019 and uncertainty regarding availability of Saildrones until two

weeks prior to beginning the survey. Despite these obstacles, the Acoustics Team successfully delivered the survey and biomass index estimate on time and continues to present the information in informative ways.

2020 Stock Assessment

Overview

The 2020 assessment uses the same basic model structure as used in assessments since 2014. The model begins in 1966, and catches are modeled as being taken by a single coast-wide fleet. The model is informed by catch and age-composition observations from the fishery, an age 2+ biomass index from the acoustic/trawl survey, and observations of survey age-composition from trawl samples taken during the survey. Age-specific selectivity for ages 1 to 6 is estimated for the fishery and ages 2 to 6 for the survey, with constrained annual variation allowed in fishery selection up to age 6. The base model uses a matrix of empirical (observed) weights-at-age to calculate fecundity, catches and total biomass and continues the approach, first applied in the 2018 assessment, of using Dirichlet multinomial likelihoods to estimate the weighting of the age-composition data. The model also uses the same input value used in the 2018 assessment model for the fixed parameter ($\Phi = 1.40$) that controls the year-to-year variation in fishery selection parameters. A Bayesian approach is used for parameter estimation, with informative priors specified for natural mortality and spawner-recruit steepness. Changes from the 2019 assessment include updates to historical fishery catch, age-composition, and weight-at-age data, the addition of 2019 values for these inputs and the 2019 age 2+ biomass value estimated by the acoustic survey in 2019, and the use of mean weights-at-age from the most recent five years (2015-2019), rather than the most recent three years, to estimate fecundity and biomass in the forecast.

The 2020 base model implements informed priors to estimate weightings of fishery and survey age-composition data and the removal of the constraint that recruitment deviations must sum to zero. The zero-sum constraint ensures that average recruitment deviations are consistent with the estimate of R_0, which by definition is average recruitment in an unfished stock. Since R_0 is used to calculate unfished spawning biomass (B_0), estimates of relative spawning biomass are affected by this change. The removal of the constraint was not a choice of the JTC, but was necessary because an error was detected in the ADMB code which is used to perform the MCMC simulations calculating the uncertainty of estimated quantities in the assessment model. The SRG and the JTC explored the issue during the meeting and it was noted that a well tested solution for the ADMB code error is not available at present. As the stock is currently well above $B_{40\%}$, management decision-making in 2020 is not expected to be affected. However, it would be prudent to consider alternative approaches to estimating references points that are not dependent on equilibrium R_0 estimates. **The SRG concurs with the approach in the 2020 base model of using the long-term averages of weight-at-age, fecundity, and selectivity for equilibrium calculations and the most recent five years for forecasts, and recommends investigating alternative approaches to estimating unfished recruitment for the calculation of references points.**

The 2020 assessment included the suite of sensitivity analyses that the SRG has requested as a standard package: alternative standard deviations of the priors for natural mortality, alternative values for steepness, alternative values for sigmaR (σ_R, a parameter limiting recruitment variability), and inclusion of the experimental age-1 acoustic survey index. Sensitivity runs also

were conducted to illustrate the sensitivity of the 2020 assessment results to alternative data-weighting methods, flexibility of time-varying selectivity (Φ), and alternative parameterizations of time-varying selectivity. An additional sensitivity run was conducted to evaluate the effect of using the no-U-turn sampler (NUTS) algorithm to estimate parameter uncertainty in place of the random walk Metropolis MCMC algorithm used in the 2020 base model and previous base models. The sensitivity runs do not show significant departures from the base model, with a consistent pattern of large increases in biomass in early 2010s, although the scale of biomass can change for some sensitivities. The NUTS sensitivity results are sufficiently promising to consider implementing the NUTS algorithm in the 2021 assessment.

SRG Recommendations and Conclusions for the Pacific Hake Stock Assessment

The SRG thanks the JTC for its detailed responses to its 2019 recommendations and has several additional recommendations for future iterations of the Pacific Hake stock assessment.

1. The SRG notes that σ_R is an influential parameter and that determining the choice of σ_R remains a challenge and encourages the JTC to continue to work on the issue.
2. The JTC described efforts and collaborations with the ICES Methods WG to address the issue of estimating the variance parameter (Φ) for time-varying selectivity. Results from this collaboration are expected to inform the 2021 assessment. The SRG encourages ongoing work to develop approaches to estimating variance parameters.
3. The SRG notes that the removal of the zero-sum constraint on recruitment deviations has implications on the estimate of R_0 and the perception of stock status based on relative spawning biomass. As the stock is currently well above $B_{40\%}$, management decision-making is not expected to be affected in 2020. **The SRG recommends that the JTC explore alternative methods of estimating reference points, including dynamic reference points or reference points based on a defined time period. There is some urgency to this work as biomass is declining and the relative spawning biomass may fall below the target level ($B_{40\%}$) within 2 years.**
4. The SRG notes that age-composition data sample sizes are high in recent years, increasing the weight of fishery age-composition data relative to the survey data. Artificially downweighting the sample sizes for recent years had a significant impact on assessment results. **The SRG recommends (1) that the JTC undertake simulations to investigate the effect of downweighting age-composition data on management performance, and (2) that the JTC explore temporal trends in sample sizes and appropriate ways of estimating the annual variability in age-composition data.**
5. Two possible approaches to downweighting the fishery age-composition data were discussed during the SRG meeting: (1) add time-blocking to allow changes in the estimated Dirichlet-multinomial parameter that controls the effective sample size for the fishery age-composition data, and (2) investigate annual age-composition data among different fleets outside of the model. The first approach, although relatively easy to implement, does not resolve the potential problem that the input sample size in the current base model is measured using a mixture of metrics (the number of sampled tows for at-sea samples versus the number of sampled trips for shore-side samples). **The SRG recommends that the JTC undertake an analysis of the annual age-composition data in a more disaggregated form (e.g., by fleet)**

outside of the model to evaluate the sources of between-sample variability in the fishery age-compositions (month, year, fleet, sample size, etc.) and whether the variability relates to simple metrics of sample size such as the number of sampled tows, the number of sampled trips, and the number of sampled fish.

6. The SRG encourages work to develop a picture of the Pacific Hake reproductive cycle both seasonally and at the life-time scale based on histological and physiological measurements. In addition, the SRG notes that Canadian samples and those from the winter research cruises should be included in the maturity analysis. **The SRG encourages continued sampling to improve understanding of the Pacific Hake reproductive cycle**.
7. **The SRG strongly supports the ongoing genetic analyses to determine whether there are genetic differences between Pacific Hake from the area south of Point Conception and other regions.**
8. The SRG notes that the no-U-turn sampler (NUTS) algorithm is more efficient and explores parameter space more fully than the MCMC algorithm used to estimate parameter uncertainty in the current and previous base assessment models. **The SRG supports the use of NUTS for the base model and sensitivity runs in the 2021 assessment.**
9. **The SRG recommends sensitivity analyses structured as follows, if NUTS is used in the 2021 base model: (1) using the random walk Metropolis MCMC algorithm as in the 2020 assessment, and (2) using NUTS when including the age-1 index in the base model.**
10. **The SRG also recommends the following additional sensitivities (conducted if possible using NUTS, but otherwise using MLE): steepness, natural mortality, σ_R, alternative standard deviations for time-varying selectivity, increasing maximum age for constant selectivity and downweighting fishery age-composition data.**
11. The SRG notes that there are currently multiple strong cohorts in the stock where previously there was only one strong cohort during the period of sample collection for the ageing error matrix that supports the assessment model. **Based on this observation, the SRG recommends that an ageing error study using samples collected during the past decade be conducted in conjunction with the Committee of Age Reading Experts (CARE).**
12. **The SRG recommends that historical sources of data be investigated to determine whether they can be used to supplement the weight-at-age matrix**, including unaged otolith samples (and associated data) from the 1970s that may be available in the Burke Museum in Seattle.

2019 Summer Acoustic Survey

A joint U.S. – Canada acoustic trawl survey was conducted in 2019. The survey was conducted from June 13 to September 15, covering the area from Point Conception (34.5°N) to Dixon Entrance (54°N). A total of 113 parallel transects were surveyed (78 in U.S. waters, 35 in Canadian waters), with the majority of transects in U.S. water using 10 nautical mile (nmi) spacing and 10-20 nmi spacing in Canadian waters. Fourteen transects in U.S. waters were extended further offshore to ensure all Pacific Hake were surveyed, adding 82.3 nmi or 2.7% additional transect distance in U.S. waters. An inter-vessel calibration was previously conducted between the FV *Nordic Pearl* (Canadian) and the FSV *Bell M. Shimada* (U.S.) during the 2017 survey, using a side-by-side design. The survey design in U.S. waters included 10 planned

skipped transects resulting in 20 nmi spacing (to keep within allotted sea days on the *Bell M. Shimada*), but two of these transects were added back to the survey grid while underway, resulting in eight skipped transects. The Acoustics Team collected a full suite of acoustic, biological, and oceanographic data through 93 mid-water trawls, 5 Methot tows, and 295 CTD casts and they presented data highlights and distributional comparisons.

The SRG recognizes the efforts of the Acoustics Team for completing its analysis of the age-1 index for inclusion as a sensitivity run in the annual Pacific Hake assessment and for producing the Jolly-Hampton variance estimates as recommended previously. **The SRG encourages the Acoustics Team to continue to work on better quantifying the survey variance.**

Recommendations and Conclusions for the 2019 Survey

1. **The SRG recommends the continued surveying and analysis of Age-1 Pacific Hake for further consideration of inclusion in the annual Pacific Hake assessment and the MSE process.**
2. The SRG would like to have a better understanding of the guidelines, protocols, and decision rules used in conducting verification trawls and then associating composition data from the limited number of hauls to unsampled backscatter, and **recommends that the Acoustics Team provide documentation at the next SRG meeting in 2021. The SRG is also interested in characterizing how uncertainty in interpreting acoustic signals affects trawl successes and failures and encourages the Acoustics Team to consider how this could be accomplished**.
3. The SRG noted that kriging produced counter-intuitive results in Dixon Entrance because this is the only area in which the transects are oriented north-south rather than the east-west. **The SRG recommends that the Acoustics Team explore whether the transect orientation needs further consideration during the spatial autocorrelation analysis.**
4. To assist the review of the biennial survey and Acoustics Team research and provide a public record of results, **the SRG requests that the Acoustics Team generate a report annually that summarizes research activities conducted during the previous year and the survey for that year, if it occurred, including survey design, how the survey was conducted, unusual events that might affect data interpretation, and results and responses to SRG requests. This report should be provided to the SRG for review two weeks prior to the SRG meeting. The SRG in consultation with the Acoustics Team, will develop a Terms of Reference for this reporting in advance of the next SRG meeting in 2021.**
5. **The SRG recommends that the Acoustics Team finish its documentation of survey methods and protocols and the history of changes in the survey and publish this documentation as technical reports for each country.**
6. The SRG has found previous analysis of commercial catch and fishing effort to be extremely informative. This analysis showed that the survey area almost completely encompasses the area fished commercially. **The SRG recommends conducting this kind of analysis on a regular basis to ensure that the survey is achieving its goal of covering the entire summer range of Pacific Hake.**

7. **The SRG also recommends that the biomass estimation process flowchart reviewed at the 2018 SRG meeting be included in both the survey methods and protocol documentation and the annual report when survey results reported.**
8. **The SRG recommends that the Acoustics Team report the Kriging SD on maps of kriged biomass rather than kriging CV for consistency and ease of interpretation across the entire range.**
9. **The SRG recommends investigating other sources of uncertainty in the acoustic biomass estimate such as target strength, haul stratification, species ID, etc.**
10. **The SRG requests that the Acoustics Team provide an estimate of Pacific Hake biomass in the transect extensions of the 2019 and previous surveys at the 2021 SRG meeting.**

Survey-Related Research

The SRG received an informative presentation on Saildrone survey work in U.S. waters during the 2019 survey. The goal of this research is to determine whether Saildrones can be used to collect acoustic data from which biomass estimates can be made and supplement the main effort on the survey vessels. The Acoustics Team reported that four Saildrones were deployed and surveyed within 3 days of the FSV *Bell M. Shimada* 68% of the time and within 5 days 84% of the time. The Saildrones surveyed 85 transects within U.S. waters in 70 days and a preliminary look at the data showed reasonable coherence with the survey vessel data, i.e., both echograms showing hake aggregations in the same locations and similar times. The Acoustics Team is presently conducting a blind analysis (blind to knowledge of trawl and survey files collected on the survey vessel) of the Saildrone acoustic data to identify hake backscatter distribution and then to compare these results to those from the survey vessel. A biomass estimate will be made from the Saildrone acoustic data combined with biological data collected by the survey vessel.

The quality of acoustic data collected by Saildrones varies depending on weather conditions. Saildrones are relatively slow, moving at about 3 knots; vehicle speed and noise increase with wind speed, resulting in lower data quality. Saildrones have difficulty making progress in low wind conditions, requiring several days to complete a transect that requires a few hours on a survey vessel. The quality of data collected by Saildrones is especially poor in turbulent ocean conditions (storms, high wind events) because these vehicles are relatively small and lightweight and therefore prone to substantial pitch and roll, which produces frequent acoustic ping dropouts (no data) relative to the survey vessel data. The Acoustics Team is investigating methods to filter acoustic datasets to removed dropped pings and analyze the remaining data for biomass estimation purposes.

An important limitation of the Saildrone technology is an inability to collect species composition and biological data used to interpret the acoustic backscatter data. This limitation presents logistical challenges to implementing Saildrones within the current acoustic/trawl survey context. Several alternative biological data sources could be considered including observer/industry data from the area in which Saildrones are operating, and bottom trawl survey data from the area. A postdoctoral scholar will be hired by the Northwest Fisheries Science Center to inform the debate on whether unmanned survey vehicles (USV – e.g., Saildrones) can be used to supplement FSV surveys.

Recommendations

1. **The SRG encourages the Acoustics Team to present its backscatter analysis and comparisons between Saildrones and the survey vessel at the next SRG meeting** as these results will inform the implementation of Saildrone technology to supplement the existing vessel-based survey approach.
2. The Saildrone represents a promising new technology. The SRG notes that an analysis of the ability of Saildrones to reproduce vessel survey results is underway. However, because the Saildrone has no capacity to physically sample species in the water column for identification and age-compositions that inform the interpretation of acoustic data, its deployment alone is less informative than the current survey. Several options have been developed for using Saildrones to supplement the vessel-based survey. **The SRG recommends that the Acoustics Team continue to explore and refine these options and their implications for the survey and survey results, and the SRG looks forward to reviewing their findings at future meetings.**

Management Strategy Evaluation (MSE) and Supporting Analyses

The SRG received a draft technical report from the MSE Technical Team which provides an overview of the implementation of a MSE process for Pacific Hake. The technical report includes the motivation and goals of the MSE as scoped by the JMC and the Management Strategy Evaluation Working Group (MSEWG – consisting of JMC, AP, JTC, and MSE Team members), technical documentation for the spatially explicit (two area) closed-loop simulation model, climate change and selectivity scenarios, and exploration of additional uncertainties. The work was undertaken by the MSE Technical Team, including the coordinator (Kristen Marshall, NOAA) and a postdoctoral scholar (Nis Jacobsen), with contributions from Ian Taylor (NOAA).

The MSE closed-loop simulation model consists of (1) an operating model which describes hypotheses of the "true" population and spatial dynamics of Pacific Hake, and (2) a simulated management procedure (MP = data + estimation model + harvest control rule, HCR). The complexities and uncertainties of the Pacific Hake population and fishery dynamics are represented within the operating model. The estimation model implemented in the management procedure is structurally different than the population dynamics model, but parameterized similarly, and is blind to the "true" stock status. This approach allows closed-loop simulation to be used to test how well the data, estimation (stock assessment) model, and default HCR perform when the assessment differs from the underlying reality.

The operating model includes four seasons and two areas (Canada and the US), with movement between areas depending on the age of fish and season. Movement in seasons 2 and 3 is primarily northward (with a small fraction of southward movement). Movement back into the US for spawning occurs in season 4 (with a small fraction of spawning occurring in Canada). Older individuals have a greater probability of moving north and young fish (0-2 yrs.) do not move. Seasonal movement patterns are fixed over time.

The operating model (OM) is written in R and the estimation model used in the simulated MP is a catch-age model written in Template Model Builder (TMB). The TMB estimation model mimics the structure of the current SS3 stock assessment model: estimates of spawning biomass and stock status were nearly identical between the TMB estimation model and the 2018 SS3 stock assessment model. The OM is conditioned to the coastwide time series of survey biomass

and proportions at age and is initialized using R_0 and initial M values from SS3 (this study used the 2018 Pacific Hake assessment). Conditioning involves manually tuning movement parameters to get the simulated age and index data to match aspects of the input data by country.

This stage of MSE development was guided by the following goals (specified by the JMC):

1. Evaluate the performance of current Pacific Hake harvest strategy under alternative hypotheses about current and future environmental conditions;
2. Better understand the effects of Pacific Hake distribution and movement on both countries' ability to catch fish; and
3. Better understand how fishing in each country affects the availability of fish to the other country in future years.

A number of measurable "ends" objectives are described in the draft report however the presented results from the simulations focus primarily on examining performance metrics of the default MP (40/10 rule) and do not at this stage comment on the ability of a given MP to meet the objectives.

The reported performance metrics are:

- $S < 0.1S_0$;
- $S > 0.4S_0$;
- $0.1S_0 < S > 0.4S_0$;
- AAV (average annual variability in catch);
- Long-term catch; and
- Short-term catch.

The simulations explore a number of selectivity and climate change scenarios, as well as an investigation of management procedures related to survey frequency and implementation variability. The default MP was compared with three MP variations: historical TAC, realized catch, and 50% standard HCR with a 180,000 t floor. Alternative survey frequency MPs are also explored with performance metrics from the 40/10 rule compared under annual, biennial and triennial survey frequencies.

Operating model scenarios demonstrate progress towards meeting these goals:

- Climate change scenarios describe an increase in maximum northward movement rates over time due to warmer temperatures and a reduction in the proportion of fish moving southward to spawn (goals 1 and 2); and
- Selectivity scenarios explore increased selectivity of younger fish by the US fleet (goals 2 and 3).

Recommendations for Next Steps in the MSE:

1. **The SRG supports the MSE Technical Team's intention to produce a comprehensive NOAA technical report detailing the modeling and results.**
2. Since MSE results can inform improvements to estimation models and MPs used for short-term tactical decision-making, **the SRG requests the technical report highlight any results that may be relevant to improving methods currently used to inform short-term tactical decisions (e.g., uncertainties within the stock assessment model and/or form of MPs).**

3. Objectives are a key component in an MSE, and the MSE Technical Team presented a broad set of objectives defined by the MSEWG, from which performance metrics were derived. **The SRG recommends that the MSE Technical Team continue to communicate with stakeholders and managers to clearly define objectives related to conservation of the Pacific Hake stock, variability in yield and total yield in the fishery. Furthermore, the SRG recommends the development of area-specific objectives for these same three categories, noting that the MSE Technical Team also identified the need for more input on developing spatial performance metrics.**
4. **The SRG requests that the MSE evaluate a management procedure that incorporates the age-one index obtained from the acoustic/trawl survey.**
5. **The SRG recommends that the OM contain variability in the initialization and conditioning to represent reasonable uncertainty when the simulated projections begin.** This could be done by using the uncertainty in the parameters from the stock assessment model, as one example.
6. **The SRG recommends that the OM projections consider variability in weight-at-age and selectivity, possibly linking the two.**
7. **The SRG reviewed preliminary spatial results from the current iteration of the MSE, but notes that further work on the spatial consequences of the biology and fisheries is needed by the MSE Technical Team.**
8. **The SRG recommends an investigation of the movement parameterization in the OM in order to understand the consequences of the parameterization in each season.** For example, understanding how the movement parameters influence the spatial distribution of unfished spawning biomass and recruitment may be important to achieving management objectives.
9. The SRG emphasizes the following topics (not in rank order) for examination with the MSE:
    i. Climate change and its impact on Pacific Hake distribution, movements, and fisheries in each country; and
    ii. Modeling the spatial distribution and movements of fish of different ages to ensure that sufficient quantities of fish are present in each country to allow TACs to be taken.
10. **The SRG strongly supports the MSE process, which is valuable for strategically advancing Pacific Hake/Whiting stock assessment science and management. Following finalization of the NOAA technical MSE report, the SRG recommends scheduling separate dedicated discussions on next steps for the Pacific Hake MSE.**

Environmentally Driven Forecasts of Pacific Hake Distribution

The second year of a two-year research project conducted by Mike Malick, a post-doctoral scholar at the Northwest Fisheries Science Center, was reviewed by the SRG. The goal of the second year of this project was to evaluate the performance of 8-month lead time forecasts of Pacific hake during the seasonal period covered by the U.S. and Canadian summer acoustic/trawl surveys. An intended outcome of this research is to help inform parameterization of the two-area MSE operating model, which includes fish movement between U.S. and Canadian waters.

Data for these forecasts consisted of Pacific Hake presence/absence from six surveys conducted between 2009 and 2017, with temperature anomaly reforecasts at 250 m depth from the J-

SCOPE regional ocean forecast model, distance from the shelf-break (200 m depth), latitude and longitude as covariates of distribution. Four forecast models of Pacific Hake presence/absence were evaluated: (1) average spatial distribution using latitude and longitude as covariates of hake, (2) a generalized additive model (GAM) with shelf distance, latitude and longitude, and temperature at 250 m as covariates; (3) a boosted regression tree model including the same variables as model 2, and (4) ensemble mean of models 2 and 3.

The survey presence/absence dataset was split into training datasets consisting of five of six surveys and a test data set of the remaining year and then cross validation was applied to evaluate how well the models estimated from the training datasets were able to forecast the presence/absence of Pacific Hake in unobserved years. Model performance was measured by area under the curve (AUC) scores (0 = no skill, 1 = perfect skill), which ranged from 0.79 (Model 1) to 0.83 (Model 4). Based on these scores, the models all offer good predictions with similar forecasting skill. . There were consistent differences in the ability of the models to predict presence/absence in specific years, with each model able to predict 2009 and 2012 well, but performing less well when predicting 2017.

The final test of the forecast models was to compare predictions for August 2019 against survey estimates (the true distribution) for August 2019. All of the models performed relatively well in forecasting presence/absence, with AUC scores ranging from 0.73 (Model 2) to 0.84 (Model 3). Distance to shelf-break was a strong predictor of Pacific Hake presence/absence.

The spatial domain of the forecast models ranged from Oregon to southwest Vancouver Island and did not cover the spatial distribution of Pacific Hake estimated by the 2019 survey. This limitation is derived from the domain of the J-SCOPE model, which was used to forecast temperature anomalies. Expanding the forecast domain will require the development of a similar ocean forecast model for British Columbia and California, where age-1 fish predominately occur. These forecast models only predict the presence/absence of Pacific Hake. Such forecasts would be improved by the ability to predict age-specific biomass distribution, which reflects the differential effects of transport mechanisms on Pacific Hake as they grow older. Although a transport covariate is available from the J-SCOPE model for inclusion in the forecasts, the modeling spatial domain limits the utility of this covariate and the development of biomass-based forecasts.

The NW Fisheries Science Center is supporting two postdoctoral scholars who are conducting research of interest to Pacific Hake modeling. One of these projects is using data collected during surveys to estimate the abundance and distribution of euphausiids, and to investigate relationships between euphausiid and hake distributions, as observed during surveys. The second project, which began during the past year, will focus on identifying environmental factors that are linked to hake recruitment success. If such relationships can be quantified, as they have been for Sablefish (*Anoplopoma fimbria*) and Petrale Sole (*Eopsetta jordani*) along the U.S. west coast, they may be incorporated into future MSE testing and/or the management assessment models.

Recommendations

1. The SRG commends the MSE Working Group (AP, JMC, and MSE Technical Team) for the planned coordination between the Acoustics Team, other relevant FATE projects, and the

MSE project to ensure that priority data are collected and results used to inform the operating model.

2. **The SRG encourages continued research into the environmental drivers of Pacific Hake distribution and productivity.** The presentation at this SRG meeting was informative in terms of forecasting the presence/absence of Pacific Hake from Oregon to southern BC. The limited spatial domain is related to the J-SCOPE and will require development of a similar model for the British Columbia and California coasts to move forward with this forecasting approach. **Further, the SRG encourages ongoing research to forecast biomass distribution, which captures age-specific differences in movement, because these forecasts are likely to be more informative to the MSE process and fishery managers than presence/absence forecasts.** The SRG also notes that estimates of euphausiid (*Euphausia pacifica* and *Thysanoessa spinifera*) distribution could be inputs into the FATE model to improve predictions of Pacific Hake movement and abundance.

At-Sea Investigations Planned for Summer 2020

The SRG received an informative presentation on survey-related research planned for summer of 2020 by the Acoustics Team, including testing of the EK-80 broadband system, research on improving acoustic discrimination of species and better resolution of biomass layers observed during trawling. Progress on work using acoustic moorings in Canada was reported and collaborations with other groups on eDNA and modeling of euphausiid distribution and abundance and diet studies were described. Lastly, inter-vessel calibration work between the FSV *Bell M. Shimada* and the new Canadian vessel, CCGS *Sir John Franklin*, is planned to ensure compatibility between acoustic systems on the two vessels. **The SRG looks forward to reviewing the results of these projects at future meetings**. Here, we summarize some highlights.

EK80: Both the US and Canada are moving from Simrad EK60 echosounders to the new EK80 model, the current world standard. The new Canadian research vessel, CCGS *Sir John Franklin*, will come into service in 2020 and is equipped with the EK80, and the FSV *Bell M. Shimada* will upgrade to the EK80 as well. Efforts to improve species identification will focus on *in situ* target strength measurements of Pacific Hake, Rockfish (*Sebastes* spp.) and mesopelagic species, using the broadband capabilities of the EK80 system and better discrimination of Pacific Hake near the seabed to improve biomass estimates, aggregations and the frequency response (Sv) of a number of species to improve acoustic discrimination between Pacific Hake and Rockfish and identification and sizing of euphausiids. An inter-vessel calibration of the EK80 systems on the FSV *Bell M. Shimada* and the CCGS *Sir John Franklin* is also planned to ensure acoustic consistency between vessels.

Stereo cameras: Research is planned with stereo video and drop cameras to improve resolution of layers and species in layers when trawling (video) and to evaluate drop cameras as a tool to positively identify species prior to trawling, thus saving time by avoiding trawling on non-target species.

Moored acoustic systems: DFO has retrieved three moored upward-looking echosounders that had been placed along the west coast of Vancouver Island at depths of 300-400 m in Barkley Canyon, Clayquot Canyon and off Brooks Peninsula. These moorings consisted of three frequencies (70, 125, and 200 kHz) looking upward to the surface to provide high-time-

resolution views of organisms (from euphausiids through fish) that move over fixed areas through time. The goal of this research is to provide a better understanding of the timing and dynamics of hake migration along the west coast of Vancouver Island. Two years of data are now available and analysis is underway.

eDNA: Water samples were collected near Pacific Hake aggregations during the 2019 survey in U.S. waters for environmental-DNA (eDNA) analysis. This is the first time that these samples have been collected on the acoustic/trawl survey. These samples will be evaluated for evidence of hake presence and density, and eventually compared with acoustic and trawl data from the same location. If successful, this research may point to new methods of supplementing traditional survey information. The goal is to evaluate the utility of environmental DNA to detect and quantify Pacific Hake presence and abundance. Further samples are expected to be collected in the summer of 2020, perhaps at a finer spatial scale to add context to the 2019 results.

OptiO2 sensor: a submersible, optical instrument to measure dissolved oxygen may be tested on the FSV Bell M. Shimada on both the CTD and flow-through system to evaluate its endurance in marine water.

Drivers of euphausiid distribution: A project funded by the NOAA FATE program is underway with the goals of characterizing and understanding euphausiid distribution and the drivers of that distribution based on historical time series of euphausiid acoustic data (2003-2019), environmental data, and Pacific Hake distribution and abundance from acoustic data. The project is expected to develop a time series of euphausiid distribution and abundance from survey acoustic data for the 2003-2019 period and a euphausiid habitat model. These components will be used to evaluate euphausiid-Pacific Hake overlap and hotspots along the coast using bottom depth, distance to shelf break, chlorophyll-a, and temperature and temperature anomalies as covariates. Results from this project are intended to inform Pacific Hake distribution modelling and growth scenarios in the MSE process.

Diet: Stomach contents have been sampled from Pacific Hake routinely as part of the Canadian survey since the 1990s and as part of U.S. efforts since 2018. The goal of this work is to characterize diet at different ages, particularly euphausiid consumption, and use the findings as inputs to broader ecosystem models such as Atlantis.

Recommendations and Conclusions for At-Sea Investigations

1. Winter cruises were conducted in Jan-Feb 2016 and 2017 in part to examine whether a winter survey could efficiently estimate Pacific Hake biomass as the distribution of Pacific Hake was thought to be compressed into a smaller area in winter than summer. The winter survey results were also expected to address questions on the reproductive biology of Pacific Hake including skipped spawning, maturity schedule, and fecundity, which would be informative to the MSE process. **The SRG continues to recommend that the Acoustics Team complete the analyses of the winter cruise survey data.**
2. **The SRG supports the transition to the EK80 echosounders on the survey vessels in each country.**
3. The SRG looks forward to presentations on the results of research on stereo video cameras and drop cameras, moored echosounders, the drivers of euphausiid distribution and abundance, Pacific Hake diet analysis, and the utility of eDNA.

4. **The SRG commends the Acoustics Team for completing these items and other research that will ensure continuation of a high-quality survey into the future.**

Other SRG Recommendations

1. The SRG remains concerned about a meeting schedule with a short period between the end of the SRG meeting and the start of the JMC meeting. If a serious issue is identified, then there is insufficient time to re-run the assessment, revise the assessment document, and present updated management advice before the JMC meeting. **The SRG recommends maintaining a gap of at least one week between the two meetings to allow time for corrective actions if needed, and for the SRG to complete its work in a more considered manner.**
2. **The SRG recommends maintaining routine communication among all bodies (AP, JMC, SRG, JTC, Acoustics Team, MSE Working Group, MSE Technical Team) supporting the implementation of the Pacific Hake/Whiting Agreement, so that members of the SRG are updated about research and analysis priorities and concerns of the management and stakeholder communities.**
3. **The SRG also requests that when the JMC identifies areas on which it would like SRG input, it submit written requests to the SRG co-chairs at least two weeks before the SRG meeting to allow time for the SRG agenda to be adjusted appropriately, and for review by SRG members of any associated background materials.**
4. The SRG appreciates that for several years now, both the Acoustics Team and the JTC have presented explicit responses to previous SRG recommendations. **We request that this approach be continued indefinitely.**
5. **The SRG recommends that the JTC continue to provide electronic copies of the data and model files prior to the review meeting.**

ATTACHMENT 1

Joint US-Canada Scientific Review Group for Pacific Whiting

MEETING AGENDA

Graduate Seattle Hotel 4507
Brooklyn Avenue N.E.
Seattle, WA 98105 United
States

February 25-28, 2020

Tuesday, February 25, 2020 **Wright Ballroom**

09:00 Welcome and Introductions

09:15 Review and Approve Meeting Agenda (Chair)
- Review Terms of Reference for Assessments and Review Meeting
- Meeting report mechanics
- Assignment of reporting duties

09:30 Fisheries, Data, and Inputs Used in the 2020 Assessment (JTC)

- 2019 Fisheries Catch, Size, and Age-composition Data
  - Canadian Waters
  - U.S. Waters

10:30 ***Break***

10:45 Survey, Data and Inputs Used in the 2020 Assessment (JTC)
- Integrated acoustic-trawl survey results including Biomass Indices, Size, and Age-composition Data (Acoustics Team)

12:00 ***Lunch (on your own)***

13:00 2020 Pacific Hake/Whiting Assessment Modeling Approach (JTC)
- Methods, results and discussion
  - Parameterization of recruitment and/or estimating σ_R
  - Parameterization and estimation of time-varying selectivity
  - Initial data weightings for fishery and survey age-composition data
- Model performance and diagnostics: sensitivities and retrospectives
- Discussion

14:45 ***Break***

15:00 Review of Assessment Modelling approach continues

16:00 Public Comment

16:15 SRG discussion, develop list of requests for JTC, as needed

16:30 SRG work session
17:00 Adjourn for the day

Wednesday, February 26, 2020 **Quimby Room**

9:00 Discussion of previous day, follow-up questions, review results of assigned tasks, etc.

9:30 Review other 2019 SRG Stock Assessment Requests (JTC)

10:30 ***Break***

10:45 Management Outcomes of the 2020 Pacific Hake Assessment and discussion (JTC)

12:00 ***Lunch (on your own)***

13:00 Pacific Hake/Whiting Management Strategy Evaluation (MSE), including responses to 2019 SRG MSE Recommendations (Kristin Marshall, Nis Jacobsen, and JTC)

14:45 ***Break***

15:00 MSE Discussion continues

15:30 SRG Discussion, requests for additional information JTC, Acoustics Team & MSE, as needed

16:15 Public Comment

16:30 SRG work session

17:00 Adjourn for the day

Thursday, February 27, 2020 **Wright Ballroom**

09:00 Discussion of previous day, follow-up questions, review results of assigned tasks, etc.

09:30 Survey-related Research (Acoustics Team)
- Overview of 2020 summer research
- Saildrone
- Pacific Hake summer distribution and environmental drivers (Mike Malick)
- Other research

10:30 ***Break***

10:45 Review of 2019 SRG Survey Recommendations (Acoustics Team)

11:30 2021 Survey Design (Acoustics Team)

12:00 ***Lunch (on your own)***

13:00 Management Outcomes of the 2020 Pacific Hake Stock Assessment and discussion (JTC)

14:30 ***Break*** 14:45 Discussion of various topics

16:00 Public comment

16:30 SRG work session

17:00 Adjourn for the day

Friday, February 28, 2020 **Wright Ballroom**

09:00 Review of previous day, follow-up questions, etc.

09:30 SRG discussion continued of research needs for 2020 and longer-term
- Evaluation of base model and primary sources of uncertainty
- MSE methodology and approaches

10:00 Final SRG discussion, report review, requests for additional information, etc.

12:00 Distribution and review status of notes and draft SRG Report

13:00 Meeting Adjourn

ATTACHMENT 2

List of Participants

Name	Affiliation
Aaron Berger	NOAA Fisheries, JTC
Trevor Branch	University of Washington, SRG independent member
Al Carter	AP-USA appointee
Dezhang Chu	NOAA, NMFS, NWFSC, Acoustics Team
Jaclyn Cleary	PBS, DFO, SRG, Canadian appointee
Barren Carswell	Province of B.C.
Andrew M. Edwards	DFO, JTC
Arnie Fuglvog	Glacier Fish Company
Stephane Gauthier	DFO, Acoustics Team
Chris J. Grandin	DFO, JTC
Joe Greene	AP Canada
Trent Harthill	American Seafoods
Jim Hastie	NOAA, NMFS, NWFSC, SRG, Co-chair, US appointee
Allan Hicks	FAWI, SRG, US appointee
John Holmes	PBS, DFO, SRG, Co-chair, Canadian appointee
Mike Hyde	AP - USA
Nis Jacobsen	NOAA, NMFS, NWFSC, MSE Technical Team
Kelli Johnson	NOAA, NMFS, NWFSC, JTC
Steve Jonar	JMC-USA
Frank Lockhart	NOAA, NMFS, JMC
Shannon Mann	AP Advisor to SRG - Canadian appointee
Kristin Marshall	NOAA, NMFS, NWFSC
Alex McQuaw	Marathon Fisheries
Kristin McQuaw	UW Grad student, Manager Shoreside Coop
Stacey Miller	NOAA, NMFS, NWFSC
Mike Okoniewski	AP- USA
Sandy Parker-Stetter	NOAA, NMFS, NWFSC, Acoustics Team
Paul Ryall	DFO
Lori Steele	AP Advisor to the SRG-USA appointee
David Sampson	Oregon State University, SRG-independent member
Ian Taylor	NOAA, NMFS, NWFSC, MSE Technical Team
Rebecca Thomas	NOAA, NMFS, NWFSC, Acoustics Team
Vanessa Tuttle	NOAA, NMFS, NWFSC, At-Sea Observer Program
Dan Waldeck	PWCC, JMC-USA
Remote Attendees	
Corey Niles	WDFW
Julia Clemons	NOAA, NMFS, NWFSC
Rob Tadey	DFO
Cathleen Vestfals	NOAA Fisheries, Post-doc