Joint Canada - U.S.A. Scientific Review Group Report for 2022

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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 virtually via Google Meets, February 14-17, 2022 to review the draft stock assessment document prepared by the Canada/U.S.A. Joint Technical Committee (JTC), the coastwide acoustic survey conducted by both nations in 2021 progress on an MSE focused on Pacific Hake/Whiting (Pacific Hake), ecosystem drivers of recruitment research and acoustic trawl survey research. 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. Following the retirement of David Sampson, the SRG was short one independent member for its 2022 meeting and that situation should be addressed prior to the 2023 SRG meeting.

The SRG provides independent peer review of the JTC's work. The SRG is charged with:

1. Reviewing the stock assessment data and methods and survey methodologies used by the JTC;

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 Monday, February 14, 2022. Jim Hastie (SRG co-chair) welcomed attendees and after a round of introductions reviewed the SRG Terms of Reference, ground rules for a productive virtual meeting, and the proposed agenda (Attachment 1). The co-chairs then assigned reporting duties to each SRG member. It was noted that the SRG was expected to submit its report to the JMC by February 22, 2022, and that it would be posted to the website by February 23, 2022. Meeting participants represented the AP, JMC, JTC, Acoustics Team, MSE Technical Team, and stakeholders (Attachment 2). **Text highlighted in bold throughout this report represents requests from the SRG for more information, analysis, or guidance.**

Major Conclusions

The following points summarize the main findings of the SRG with respect to the 2022 stock assessment and acoustic survey research.

1. The structure of the 2022 assessment model is similar to the 2021 model. The main difference is the inclusion of the age-1 index, which provides information on year-class strength before it is observed in the fishery.

2. All runs in the 2022 model use a Bayesian sampler applied via the MCMC No-U-Turn Sampler (NUTS) to estimate parameter uncertainty, including the base-case model, bridging, sensitivity and retrospective analyses. The uncertainty measures in this assessment are based on the data, structure, and processes included in the base model. Thus, uncertainty in current stock status and projections is likely underestimated.

3. Additional data for the 2022 assessment include the new biomass estimate and age-composition data from the 2021 acoustic survey, fishery catch, age-composition data, and weight-at-age data for 2021 and minor changes to pre-2021 data. The addition of the age-1 index time series (1995-2021) is the main change in data streams relative to the 2021 assessment. The Canadian freezer-trawler fleet was subject to electronic monitoring in 2021, but there was no biological sampling because of staffing challenges for the observer program due to COVID-19. As a result, age data are not available from this fleet in 2020 and 2021. A limited number of samples (4) were collected from the Canadian shoreside fleet owing to a program change that led to a communications error. Only one of these samples was aged in time to be included in this assessment. The remainder will be aged and included in the 2023 assessment. **The SRG strongly encourages Canada to conduct biological sampling on all of its catch streams.**

4. The SRG considers the 2022 assessment report and appendices to represent the best available scientific information on Pacific Hake. The SRG appreciates the thoughtful responses of the JTC to its requests for analyses in the 2021 SRG report. The SRG also acknowledges the tremendous amount of work required to develop a report that is compliant with Section 508 of the Rehabilitation Act of 1973, which requires U.S. Federal agencies to make their electronic and information technology (EIT) accessible to people with disabilities.

5. The addition of the 2021 data and the addition of the age-1 index did not change the pattern of recruitment estimates but did change the estimates of recruitment in some years. The median estimate of 2014 recruitment increased by 0.4 billion fish (5% increase) while the median estimate of 2016 recruitment increased by 1.6 billion fish (33% increase) and the below average 2018 recruitment increased by 0.5 billion fish (272% increase), but remains below average. The 1980-year class (17.2 billion fish) is estimated to be the largest year class in this time-series, but the 2010-year class (also 17.2 billion fish) is estimated to be almost the exact same size (less than 1% difference). The 2014-year class size remains well above average at 9.3 billion fish (fifth highest in the time series) but is smaller than the 2010-year class. There is more certainty that the 2016-year class is above average and that the 2020-year class may be above average due to observations of both cohorts in the 2021 survey and fishery.

6. Over the last 25 years, it is unusual for this stock to be supported by multiple above-average cohorts simultaneously, however, the 2010, 2014, 2016, and 2020 cohorts are predicted to comprise 7%, 13%, 18%, and 32%, respectively, of the stock biomass at the start of 2022.

7. The base-case model estimates that median female spawning biomass at the beginning of 2022 is 1.171 million metric tons (Mt), with a 95% credible interval from 0.584 to 2.585 Mt. This estimate represents a spawning biomass that is 65% of the unfished equilibrium level (B_0), with a 95% credible interval of 31% to 135%. There is a 0% joint probability that the stock is both below $B_{40\%}$ at the beginning of 2022 and above a level of fishing intensity equivalent to the default harvest rate of $F_{40\%}$ in 2021.

8. Total exploitable stock biomass (age 2+, males and females) at the beginning of 2022 is estimated to be 3.347 Mt, with a 95% credible interval of 1.561 to 8.367 Mt.

9. The decision 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. Application of the default harvest policy corresponds to a catch of 715,643 t in 2022 and 586,146 t in 2023. Applying the default harvest policy ($F_{40\%}$ – calculated using average selectivity over the last 5 years) in 2022 and 2023 results in a 31% probability that the stock will be below $B_{40\%}$ at the beginning of 2024. The probability that fishing intensity is greater than $F_{40\%}$ in 2022 and 2023 when harvesting at these levels is less than 44%.

10. Under all examined catch levels less than 613,000 t, the probability of stock decline is less than 50% in 2023. The probability of stock decline is greater than 50% for all catch levels examined after 2023.

11. An acoustic survey was conducted from July 1 to September 21, 2021, proceeding north from Point Conception, CA, (34.5°N) to Dixon Entrance, BC (54°N). The 2021 survey was conducted by the NOAA R/V *Bell Shimada*, which surveyed from the southernmost point north to southwest Vancouver Island between July 1 and September 21 and the F/V *Nordic Pearl*, which was contracted to survey Canadian waters from southwest Vancouver Island to Dixon Entrance between August 21 and September 13. The 2021 survey estimated age 2+ biomass is 1.525 Mt (million tonnes), an 11% decrease from the 2019 survey biomass estimate of 1.718 Mt. Vessel and COVID-19 challenges resulted in about a 1 month gap and prolongation of survey operations along the west coast of Vancouver Island that may have influenced survey results, especially considering that the 2021 survey estimated the lowest hake biomass in Canadian waters in the acoustic survey time series. **The SRG concurs with the design approach for the 2021 survey, although the temporal gap surveying off Vancouver Island may confound interpretation of the results.**

12. An update on the Pacific Hake management strategy evaluation (MSE) was provided to the SRG. The SRG applauds the work of the MSE Technical Team members over the past year in model development and in addressing SRG comments pertaining to

documentation. This progress is especially noteworthy given the COVID-19 impacts on working conditions and the fact that the MSE Technical Team contains no individuals that are dedicated solely to advancing Pacific Hake MSE programming and application. The MSE Team is exploring important questions regarding environmental drivers of hake productivity and dynamic reference points that when resolved will advance the ability of this tool for providing strategic advice. **The SRG continues to support ongoing MSE development and progress on the 2022 workplan identified by the MSE Team.**

13. The SRG reviewed research on environmental influences on Pacific hake dynamics and distribution. **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 dynamics. The SRG believes that results of this research may improve stock assessment projections and be useful in refining the MSE operating model and in examining potential impacts of global climate change scenarios on the Pacific Hake stock.**

14. The JTC implemented decision-table revisions discussed at the 2021 SRG meeting that improve clarity in depicting the projected impact of the specified amounts of harvest on stock status at the beginning of the following year, along with 90% credible intervals for consistency with other reporting. **The SRG concurs with this decision because it improves the clarity and understanding regarding the projected impact of harvest on the stock. The SRG encourages the JTC to explore other ways of describing the likelihood of experiencing future stock declines or increases.**

15. The SRG appreciates the JTC's efforts to explore model sensitivity to the absence of biological data from the Canadian Freezer-Trawlers in 2020-21 fisheries. That analysis indicated an appreciable downward impact on estimated biomass from an extended reduction in available age data from Canadian fisheries. We note that planning is underway to avoid this situation in 2022. **The SRG underscores the importance of collecting age samples from these sectors in 2022.**

2022 Stock Assessment

Overview

The 2022 assessment uses the same 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, observations of survey age-composition from trawl samples taken during the survey, and an age-1 survey index that was added as a new data source in 2022. 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 in calculating annual fecundity, as well as catch and 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 since

the 2018 assessment model for the fixed parameter ($\Phi = 1.40$) that constrains 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 2021 assessment include the addition of 2021 fishery catch, age-composition, and weight-at-age data, and minor updates to pre-2021 fishery data. Sampling of catch from the Canadian freezer-trawler fishery did not occur in 2020 or 2021 due to precautions associated with the COVID-19 pandemic and thus 2020 and 2021 age-composition data are not available from this fishery. Few age samples are available from the 2021 Canadian shoreside fishery. Kriged results of age 2+ biomass and age composition from the 2021 acoustic-trawl survey were used in the 2022 assessment and an age-1 index of abundance was used in the base model for the first time.

The 2022 base model implements a Bayesian MCMC sampler (the no-U-turn sampler (NUTS) algorithm) to estimate parameter uncertainty. This algorithm provides the ability to conduct model estimation and all forecasts and sensitivity runs using the same approach, rather than having to switch between MCMC and maximum-likelihood estimators. The NUTS algorithm is preferred since it is a more effective sampler of parameter space and provides an improved description of the posterior distribution and parameter uncertainty, and speeds up the main model estimation, but other sensitivity and forecast runs take longer to complete than with a maximum-likelihood estimator. Cloud computing proved useful to conduct all the necessary runs in the short time available.

The 2022 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 the removal of the age-1 acoustic survey index (because it is now in the base assessment). Sensitivity runs were also conducted to illustrate the sensitivity of the 2022 assessment results to alternative data-weighting methods, flexibility of time-varying selectivity (Φ), and alternative parameterizations of time-varying selectivity. In response to the lack of age data from the Canadian Freezer-trawler fleet in 2020 and 2021, the JTC provided an analysis where all Canadian age data were removed from the model for years up to the present starting in 2008, 2018, 2019, and 2020. Results from the model with no Canadian Freezer-trawler age data from 2008 to 2021 were also presented. Without Canadian age data, the age compositions may be biased when aggregated across all fisheries because the Canadian fisheries tend to encounter older fish. Little difference was seen in results with a few years of missing age data, but biases in estimated spawning biomass were apparent when removing Canadian age data back to 2008. Continued lack of Canadian age data may affect future stock predictions.

It was noted during the 2021 SRG meeting that σ_R is an influential parameter, and the SRG encouraged further work. The JTC conducted sensitivity analyses for σ_R using the Woods Hole Assessment Model (WHAM), modelling recruitment deviations as a random effects time-varying parameter. Comparisons using alternative modelling platforms built in TMB (such as WHAM and State-Space Assessment Model) allow for estimation of random effects not currently possible in Stock Synthesis. In addition, it was noted that there is a long-term plan to replace Stock Synthesis with a new assessment package called FIMS that is currently in development. **The SRG supports continuing efforts to explore new recruitment**

parameterizations, including treating recruitment deviations as random effects, to better estimate σ_R.

The JTC outlined efforts to better simulate future recruitments, including using the age-1 index and environmental covariates and outputs of the ROMS model. Since Stock Synthesis cannot draw randomly from past observations or use mixing distributions, a variety of work-arounds were proposed. These include a stock-recruitment multiplier, mean recruitment taken from a user-defined time period, and a time-varying R_0 parameter.

The 2020-year class is estimated to be above average and will likely result in an increase in biomass in the next year. The 2018- and 2019-year classes are estimated to be below and near average, respectively. The 2021- and 2022-year classes have no information, but due to model conditions (i.e., the sum of recruitment deviations is not forced to be zero) these year-classes are slightly above zero. This approach may be reasonable for recent recruitment which has a positive effect on the projections. However, the assumption that the recruitment deviations do not sum to zero leads to a discrepancy between the projections and the calculated equilibrium reference points based on R_0. In response to a request during the 2022 SRG meeting, the JTC showed that the median estimate of R_0 is lower than average recruitment, and that the sum of the recruitment deviates is not 0 but is higher. These results point to a stock that is more productive than implied by the stock-recruitment curve and σ_R parameterization. **The SRG notes that since average recruitment is not similar to R_0 these results provide additional support for exploring the use of dynamic reference points in the stock assessment.**

SRG Recommendations and Conclusions for the Stock Assessment

The SRG thanks the JTC for its detailed responses to its 2021 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 SRG recommends exploring alternative methods to simulate recruitment in the projections. Although Stock Synthesis currently does not have the capability to characterize a different process other than the assumed lognormal distribution, improvements such as drawing from past observations or using a mixture distribution to simulate recruitment should be considered for modelling platforms in the future.**
3. Pacific Hake dynamics are highly variable even without fishing mortality. **The SRG applauds the efforts of the JTC and the MSE Working Group to add capabilities for specifying dynamic reference points within the assessment and MSE platforms, and encourage those groups to work together and develop a discussion of alternative reference points, including dynamic reference points, for future SRG consideration.**
4. 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 and analysis to improve understanding of the Pacific Hake reproductive cycle**.

5. **The SRG also recommends continuing to conduct the following sensitivities: steepness, natural mortality, σ_R, excluding the age-1 index, alternative standard deviations for time-varying selectivity, and down-weighting fishery age-composition data.**
6. Based on the preliminary results shown, previous assessments have correctly predicted an increase or decrease in recruitment and spawning biomass in subsequent years, although the projections are usually less definitive than the current base model results. Given that this analysis provides some confidence in the current expectations of continued stock decline, **the SRG recommends that the JTC continue to explore and refine this analysis for future assessments. The SRG encourages the JTC to explore, with the JMC and AP, the value of a threshold for specifying the probability of projected declines or increases of the stock in future assessments.**
7. 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).**
8. **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.
9. Uncertainty in weight-at-age is not accounted for in the stock assessment and a five-year average of recent observations is used for all years of the projections. **The SRG requests that the JTC explore alternative methods for forecasting weight-at-age and evaluate whether they can improve projections.**
10. The parameter weighting the acoustic survey age samples was often estimated near the upper bound of 1.0 and could not upweight the age samples. Investigations during the SRG meeting showed that the posterior distribution of the parameter may have some probability of upweighting the age samples from the base assessment inputs, although likely had little difference on stock assessment outcomes. **The SRG encourages the JTC to consider methods to determine the maximum input sample size for the survey age compositions. Previous work of Stewart and Hamel (2014) may be useful for this purpose.**
11. The use of high-performance computing (e.g., a dedicated server or cloud computing) allowed for the complete set of assessment results to be characterized using MCMC at a minimal cost. **The SRG recommends future use of high-performance computing to provide complete and thorough assessment results in a timely manner.**

12. The SRG appreciates the investigation of alternative model structures, including alternative modelling platforms. **The SRG encourages the JTC to continue these types of investigations.**

13. **The SRG appreciates the dedication and teamwork displayed by the JTC in producing the best available scientific information and advice on the Pacific Hake stock during the continuing COVID-19 pandemic.**

2021 Summer Acoustic Survey

Substantial logistical challenges were overcome in 2021 to complete the Ecosystem and Pacific Hake Acoustic Trawl Survey (hereafter "survey"). The survey started on June 27 with a two-vessel design with predominantly 10 nmi spacing using the NOAA R/V *Bell M. Shimada* and the CCGS *Sir John Franklin*. These vessels had not had their acoustics systems calibrated so an inter-vessel calibration study was included in the survey design. As a result of a mechanical issue, the *Sir John Franklin* was taken out of service for the remainder of the field season and Canada chartered the F/V *Nordic Pearl* to deliver several surveys, including the hake survey. On July 15, when the *Sir John Franklin* was taken out of service, transect spacing for the *Shimada* was changed to 20 nmi. It was changed back to 10 nmi when the *Nordic Pearl* came into service on August 6, re-establishing the two-ship design, but with the elimination of the inter-vessel calibration, since these vessels were calibrated against each other in 2017. Changes up to this point affected the survey south of Newport. On August 24, the *Shimada* needed to replace an engineer, resulting in the loss of 8 additional days at sea (12 days total for the *Shimada*). The survey was adjusted in that the *Shimada* had 3 transects removed off Washington, and the northern range of the *Shimada* was restricted to southern Vancouver Island. The *Nordic Pearl* design dropped the northernmost transect since it was in U.S. waters and an additional one off the west coast of Haida Gwaii. **The SRG notes the substantial challenges encountered during the 2021 survey and commends the survey team on overcoming the challenges and completing the survey.**

Results from the acoustic survey and associated midwater trawling show that few hake were observed on the west coast of Vancouver Island or further north. Most of the hake biomass observed during the survey (96.7%) occurred in U.S. waters. Hake sampled in Canada were larger fish, ranging from 40-60 cm and predominantly in the age-5+ group, whereas age-1 fish occurred from Point Conception north to around 50 nmi south of Newport, OR. The 2016, 2014, and 2017 age classes contributed most to the overall biomass, respectively. Hake were observed farther west and offshore compared to previous surveys, particularly on transects between Crescent City and Newport. Hake were observed on four transects in Canadian waters and the estimated biomass on these transects is the lowest estimate in Canadian waters in recent decades (1995-2021). While the Canadian Freezer Trawlers were able to achieve recent catch levels, the Canadian fresh fleet was not able to achieve levels comparable to previous years.

The SRG discussed the gap in time and delay in survey operations that occurred off Vancouver Island, and whether these factors contributed to the lesser amount of observed hake. The timing of the survey in that area was only off by about a week from recent surveys, but the overall completion of the survey was much later (late September) than usual

(around September 1), due to the Shimada's required days in port and the personnel delay. The SRG was not able to reach a firm conclusion regarding the influence of either factor on the acoustic hake biomass estimate.

High survey variance in Canada was noted by the SRG. It was suggested by the survey team that the high variance was due to many small and a few large aggregations being encountered, and not because of the gap in timing between the two vessels. The impact of this biomass pattern could have been exacerbated by the increased transect spacing and overall low biomass observed, especially in Canadian waters.

The 2021 index value is the fourth highest value in the time series. The majority (~58%) of the age-1 hake were mingled with adults, which has been more common over the last 4 survey years. This year's index demonstrates a similar geographic distribution to the 2011 index but the value is lower than 2011.

The 2021 survey used EK80 echosounders. It was recently determined that the EK80 has a linear signal response and therefore biomass estimates do not need correcting. However, the EK60 has a non-linear response, especially at lower received signals (e.g., backscatter at depth) and an empirical correction was developed and applied to the 2021 survey data. The Survey Team described a multiplex study in 2018 in which EK60, EK80, and corrected EK60 (called virtual or vEK80) estimates were compared and found that the EK60 estimates were approximately 6% higher than EK80 estimates of biomass. There was a 2% difference between vEK80 and EK80 estimates. A 6% difference between EK60 and vEK80 was also observed for the 2019 survey, and it was noted that age specific biomass estimates were comparably affected.

Given difficulties due to the pandemic, the overall 2021 survey biomass estimate derived from the 38 kHz was back-corrected to be compatible with the existing survey biomass time series which is based on EK60 data at 38 kHz. The Survey Team is planning to correct the 38 kHz biomass time series (2005, when the EK60 came into service on the survey, to 2019) to EK80 values when capacity and resources permit them to do so. It was noted that surveys from 1995 to 2003 were conducted using the EK500 echosounder. The EK500 exhibits a linear signal response pattern, similar to the EK80, and therefore does not need to be corrected.The Survey Team noted that the EK60 correction does not mean that fish were not detected, rather the correction is needed to account for loss of the backscatter energy in the electronics (which is converted to biomass) for species such as hake that are relatively deep in the water column. Applying the correction is also recommended for species such as krill or species that do not have a high target strength. Work to correct other frequencies collected during the survey is not as high a priority as the 38 kHz data.

Recommendations

1. **The SRG supports the planned future work of the Survey Team and recommends correcting the full EK60 38 kHz times series (2005-2019) to EK80 values.**

2. **The SRG appreciated the cruise report that the Survey Team provided in advance of this meeting, and requests the continuation of this practice for future surveys.**

Management Strategy Evaluation (MSE) and Supporting Analyses

The MSE Technical Team reviewed progress made in 2021 against three work plan priorities: (1) explore alternative management procedures that could meet the objectives of the JMC, (2) better understand the consequences of structural assumptions about movement and spatially explicit recruitment in the operating model, and (3) explore the robustness of management procedures to environmentally-driven variability in recruitment and climate-change driven changes in recruitment.

Extensive changes were made to the model code structure to improve speed and access. Following these updates, the Technical Team added perfect-information scenarios, generalized HCR and reference points code, undertook preliminary testing of operating model (OM) robustness to change in recruitment SD and began testing alternative F_{SPR} rules. A NOAA technical report was finalized in June 2021. The Technical Team will continue to develop technical documentation and transition the technical report to Rmarkdown (to facilitate annual updates). A manuscript examining climate driven scenarios was accepted in ICES JMS (Jacobsen et al.), the results of which suggest there is a higher risk of fishery closures in climate-induced movement scenarios.

The Technical Team continues to work towards adding the capability to calculate dynamic reference points in the OM and estimation model (EM), respectively, to allow investigation of management procedures using dynamic reference points in the future. Additionally, funds have been secured for one new postdoc for two years to continue OM development to investigate environmental influences on Pacific Hake dynamics and distribution, and the testing of climate change scenarios.

Recommendations for Next Steps in the MSE

The SRG continues to support the ongoing work of the MSE technical team, and agrees with the five major areas identified as priorities for future work. Specific recommendations related to these priorities are provided here.

1. **The SRG recommends testing resampling of recruitment by adding this option to the operating model in the MSE simulations, and testing the impact on the estimation model.**
2. MSE operating models are typically complex to allow for the simulation of many scenarios representing a wide range of uncertainty and must be conditioned to mimic the dynamics of the population. **The SRG suggests that the JTC consider alternative models to help understand the complex components of the existing conditioned OM and implement these alternative models if appropriate**. For example, a coastwide stock-recruitment relationship with coastwide recruitment apportioned to each area may better fit the limited knowledge of recruitment for Pacific Hake. This approach may also allow for a reduction in the number of seasons and still allow for fishing periods and a spawning/recruitment period in the operating model.

3. **The SRG encourages adding the capability to estimate dynamic reference points in the OM and EM, respectively, to allow investigation of management procedures using dynamic reference points in the future.**
4. **The SRG strongly supports the MSE process, which is valuable for strategically advancing Pacific Hake stock assessment science and management.**
5. The age-1 index provides information of the strength of recent year classes, providing improved projections. However, there are asymmetric risks to overpredicting or underpredicting the size of recent year classes. **The SRG recommends that MSE closed loop simulations be used to investigate the risk of overpredicting or underpredicting the magnitude of the year class due to the inclusion of the age-1 index.**

Ecosystem-related Research

Ecosystem Drivers of Pacific Hake Recruitment

The intention of new research linking ecosystem drivers of hake distribution and recruitment variability is to focus on using these relationships to improve management decisions. Several approaches were discussed: (1) testing the sensitivity of management procedures to future variability in environmental drivers that can be predicted by global climate models, (2) use of simulation-testing to evaluate utility of ecosystem drivers in the assessment model, and (3) investigating other mechanisms for combining ecosystem status information in the decision-making process.

The "environmental drivers" presentation covered empirical and modelling approaches to advancing ecosystem research for Pacific hake. One project used an empirical approach to investigating drivers of hake recruitment. Ecosystem conditions for adult females 'summer before spawning' and conditions during yolk-sac and first-feeding larval stages were related to Regional Ocean Modeling System (ROMS) using GLMs. The results identify ecosystem conditions impacting adult females (location of North Pacific Current bifurcation, eddy kinetic energy and age-2 herring biomass; all negative) and physical ocean conditions (longshore transport and day between storm events) impacting yolk-sac and first-feeding larval stages (also negative relationships). These findings may highlight ecosystem conditions that contribute to hake cohort strength. However, the direction of several of these relationships were opposite to hypothesized relationships and thus, further investigations are needed to aid interpretation. This work by Vestfals et al. has been summarized as a manuscript for Northwest Fisheries Science Centre internal review.

Modeling approaches for incorporating drivers of recruitment were considered in the context of the assessment and the MSE. It was acknowledged that each requires different sources of oceanographic data. For example, ROMS model outputs can be used to explain historical patterns in recruitment deviations but other modelling approaches are needed for projection models (e.g., ROMS projections, 2010-2100). In the assessment model context, initial explorations use ROMS time series (from recruitment drivers research, Vestfals et al.) as an index of recruitment deviations, with focus on impacts of including environmental drivers on age-0 and age-1 recruitment deviations. Research plans to extend this approach include: simulating environmental drivers that are increasingly correlated with baseline recruitment deviations, using dynamic factor analysis which combines key drivers into a single index to

achieve higher correlation, and exploring other assessment models that have more flexibility to incorporate environmental drivers (e.g., WHAM). Research approaches for the MSE process include adding in environmentally-driven recruitment capability to the operating model by partitioning variance into climate-driven variability and random variability. The goal is to expand the operating model to support hypothesis testing to examine "climate readiness" of hake MPs (e.g., are robust to climate impacts on recruitment, growth and/or distribution). Scenarios would be developed in collaboration with the MSE Technical Team.

Recommendations

The SRG continues to support research to improve understanding of linkages between the environment and hake distribution and recruitment variability, including ways this information can be used to improve management decisions. Specific recommendations related to the direction of this research are provided here.

1. The SRG is encouraged by the results of the research into environmental drivers of Pacific Hake recruitment shown during the presentation at this meeting and **the SRG supports the ongoing research to develop predictive relationships of Pacific Hake recruitment that can inform the stock assessment forecasts and MSE process.**
2. **The SRG encourages continued ecosystem-related research into the drivers of Pacific Hake distribution and productivity.** The J-SCOPE oceanographic forecasts provide a basis for improved in-year predictions of Pacific Hake distribution and abundance and be more informative to the MSE process and fishery managers than presence/absence forecasts.
3. **The SRG encourages the development of ecosystem indicators reporting for Pacific Hake as an important contextual supplement to the stock assessment information for decision-making and looks forward to further reporting at future SRG meetings.**

Survey Team Responses to 2021 SRG Recommendations

(Numbers reference items in the Survey "Recommendations and Conclusions" of the 2021 SRG Report)

1. A new Age-1 Index value was estimated from the 2021 survey and provided to the JTC. A manuscript regarding the Age-1 Index is being prepared.
2. Transects in Dixon Entrance were carried out across depth contour for the 2021 survey, consistent with survey designs in previous years.
3. The Survey Team provided the SRG with a draft processed report on the 2021 survey in advance of the review meeting.
4. Development of Terms of Reference for reporting on the survey and related research has been re-prioritized for 2022.
5. A new survey protocol document remains in preparation, though much of that information is included in the individual processed reports.

6. A new comparison of the spatial distributions of hake survey biomass and fishery catch in 2021 was presented to the SRG, for U.S. waters off Oregon and Washington. The Survey Team plans to update this to include the waters off Canada in time for the 2023 SRG meeting.

7. The Survey Team has adopted the SRG's recommendation to portray kriging uncertainty using the Standard Deviation instead of the Coefficient of Variation, and will continue to do so in the future.

8. The Survey Team reports quantitative uncertainty measures, where possible, and is conducting research to better understand the potential for biomass variability that is introduced through the human judgment that is involved in assigning age-compositions from hauls to unsampled backscatter. To this end, they have organized a trial in which an outside individual, who is familiar with acoustics, will make independent assignments, with subsequent comparison of the impact on overall biomass-at-age estimates.

9. An overview of the amount and percentage of adult hake backscatter that was found in extensions of planned transect distances was presented for the last four surveys. This type of summary will be a standard part of future survey reporting.

10. Research into hake reproduction and genetics continues, and results from some of this ongoing research may be available for discussion at the 2023 SRG meeting.

11. Despite a number of logistical challenges faced by the 2021 survey, the recommended 10-nm transect spacing was able to be preserved throughout most of the surveyed area.

Recommendations and Conclusions for 2022 Research and Future Surveys

1. **The SRG supports the array of research activities planned by the Survey Team for 2022 (inter-vessel calibration of the R/Vs *Bell Shimada* and *Sir John Franklin*, EK80 research to understand acoustic properties of fish, hake-mesopelagic community interactions, habitat associated with hake mixtures and rockfish aggregations, fine-scale hake migration and movements relative to vessels)**
2. The Survey Team provided a report of the 2021 survey in advance of the 2022 SRG meeting. **The SRG supports continued development of such reports.**
3. **The SRG Co-Chairs in consultation with the Survey Team, will develop a draft Terms of Reference for reporting operations and findings in advance of the next SRG meeting in 2023.**
4. **The SRG also looks forward to reviewing more complete documentation of survey methods and protocols and the history of changes in the survey at the 2023 SRG meeting.**
5. The SRG found the spatial analysis of survey and at-sea US commercial catch presented at its 2020 and 2022 meetings to be very informative, and **the SRG recommends continuing 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. Since the US at-sea sector primarily fished for Pacific Hake before and after the survey's**

presence off Oregon and Washington, SRG recommends enhancing this type of retrospective analysis with the addition of data from shoreside fishery logbooks, as well as the inclusion of fishery and survey activity off Canada, which it hopes to review in 2024.

6. **The SRG encourages the conversion of past acoustic survey EK-60 data to be comparable to results from the EK-80 echosounder at 38 kHz using appropriate conversion equations. The converted data would then be used to create a consistent time-series of hake biomass. The conversion of additional frequencies may be useful but is not a priority at this time.**
7. The SRG acknowledges that several key steps in the collection and analysis of the survey acoustic data involve human judgment, which complicates a comprehensive quantification of uncertainty associated with biomass estimates. However, **the SRG encourages the Survey Team to continue to make progress on quantifying uncertainty in biomass estimation.**
8. **The SRG continues to support the default use of 10-nm spacing for transects in the acoustic-trawl survey, based on observed spatial auto-correlation.**
9. The SRG received an overview of the National Marine Fisheries Service' upcoming US west coast "unified" acoustic survey planning efforts, including plans for a limited virtual workshop that will be held in late April. The presentation acknowledged the importance of input from Canada and the fishing industry in the development of a final strategy. **The SRG is hopeful that this collaborative planning process will lead to overall survey improvements for hake monitoring, while maintaining the exciting new work that the hake survey has been doing with respect to krill, ecosystem, and eDNA sampling in recent years.**
10. **The SRG commends the Survey Team, DFO, and NOAA for completing the 2021 hake survey, in the face of numerous COVID- and vessel-related challenges.**

Survey-Related Research

Saildrone Research

Saildrones were deployed in conjunction with the Pacific Hake survey conducted in 2019, collecting backscatter information in generally close proximity to the Shimada throughout the US portion of the survey. Comparison of backscatter measured by both sources found the Saildrone backscatter to be 28-29% less than that measured by the Shimada, both for the entire area and for the region of the coasts of Oregon and Washington. One comparison survey provides insufficient evidence to know if this level of backscatter difference would be consistent over multiple comparisons. Additionally, it remains unknown to what degree the availability of additional acoustic frequencies on Saildrones would reduce the backscatter difference.

A key uncertainty in the ability to conduct a Saildrone "survey", to replicate biomass estimates from surveys employing research vessels, is the question of how best to characterize the age-distribution of Saildrone backscatter, in the absence of research-vessel trawls. A preliminary estimate of the biomass off Oregon and Washington, using average age

compositions from the US at-sea Pacific Hake fleet produced a biomass estimate that was 26% less than that calculated using *Shimada* data.

Over the past year, a postdoc working with NWFSC survey and assessment staff, has conducted analysis of alternative methods for using age data from at-sea and shoreside sectors of the U.S. fishery and the NWFSC Bottom Trawl Survey to approximate location-specific age compositions derived from hauls in U.S. waters conducted by the *Shimada* during the 2019 hake survey. Alternative approaches for latitudinal stratification and clustering of ages and months were evaluated. Biomass estimates for clustered ages, derived using a modeled combination of these alternative data, were compared with results using age compositions derived from survey sampling aboard the *Shimada*.

In the most data-rich area, off Oregon and Washington, and for ages better represented in the fishery, this modeled approach holds considerable promise to inform the estimation of biomass using Saildrone acoustic backscatter, based on the 2019 comparison. In the next phase of this research, the same modeling approach and alternative data sources will be used to develop and compare alternative biomass estimates for age clusters in previous hake survey years. All of the data needed for this extension of the 2019 analysis have been assembled. The new work will focus on the consistency of performance over time, particularly in years when the population's age composition is very different from that in 2019.

Although the modeling of alternative sources of 2019 age compositions performed well in replicating survey hauls conducted off Oregon and Washington, where the ages present were better selected by the fishery and the bottom trawl survey, the approach was not able to reproduce catch compositions from central and southern California, which have a higher average contribution from young fish. In order for Saildrones to conduct a complete, independent survey, some alternative approach will be required to provide age-composition data to backscatter south of Cape Mendocino. Information from the most recent surveys and data for environmental drivers of recruitment might provide an alternative, however more study is needed on that potential. Another alternative might involve the use of a contracted vessel to conduct biological sampling in the vicinity of Saildrones throughout areas where age compositions are poorly informed by available alternatives.

eDNA Research

As part of the 2019 hake survey, nearly 2,000 eDNA water samples were collected at 186 locations between San Francisco and the Canadian border, during night operations aboard the *Shimada*. The samples were collected near the surface and at five additional depths ranging from 50 m to 500 m. Each sample was then filtered onboard as quickly as possible to preserve the integrity of the genetic material. Subsequent genetic screening for hake was conducted at the NWFSC.

The hake backscatter observed by the survey often portrays a patchy distribution of adults along the coast, and this is also reflected in the variability of the amount of hake DNA collected in the water samples, particularly at depths down to 300 m. Composite temperature maps of DNA abundance show more high areas than similar maps of survey biomass, but nearly all of the high survey biomass areas also have high DNA index values. When

aggregated to 1-degree latitudinal bins, there was a high positive correlation between these abundance metrics (R^2=0.87), although eDNA cannot provide age composition information.

In addition to capturing similar patterns of abundance variability, the eDNA sampling also revealed the presence of some hake DNA in over 90% of the water samples collected from all depths between San Francisco and Canada. Even though some of the collected genetic material may have been shed by sub-adults (although their contribution would be expected to be smaller north of San Francisco than south of it), this finding underscores the ubiquitous nature of hake in the ecosystem, which the acoustic survey protocols (with a focus on hake aggregations) are not as well-suited to document. Comparison of the cumulative distributions of abundance indicate that both sources of information locate the population centroid at 41.5°N during the survey period. However, cumulative eDNA abundance accumulates more rapidly south of Cape Mendocino (perhaps due to greater presence of 1-year-olds in that area), and the survey's biomass accumulates most rapidly just north of the Cape and between 43°N and 45°N, where large aggregations were observed.

Continued collection of eDNA samples occurred during the 2021 hake survey and is also planned for the 2023 survey. While eDNA appears to provide a potentially-valuable alternative measure of hake abundance, it is a relative measure. Consequently, the ability to draw useful insights regarding hake abundance and distribution for future science products is reliant on creating a time series of observations. Since samples must be processed swiftly following collection to preserve the genetic material, future collection of these samples is reliant upon ship space for the science staff and equipment to do the preservation while at sea. DNA samples have been retained in a frozen state by the NWFSC, and can be subjected to additional genomic assays in the future.

Recommendations

1. **Saildrone research:** The SRG received a presentation with results of research into alternative sources of age-composition information that could be combined with acoustic measurements of hake biomass derived from Saildrones in 2019. Ages from at-sea and shoreside sectors of the U.S. fishery and the NWFSC Bottom Trawl Survey were analyzed using a range of latitudinal stratification and clustering of ages and seasons. Biomass estimates using a modeled combination of these alternative data were compared with results using age compositions derived from survey sampling aboard the R/V Shimada. **The SRG encourages completion of research plans to extend the analysis of these alternative sources of hake age composition to prior acoustic survey years.**

2. **Saildrone research: Saildrones could provide a helpful supplement to standard survey methods if reliable sources of age-composition information can be identified for the entire survey area. Currently planned application of the analytical approach to earlier survey years will provide a more robust evaluation of the use of alternative data sources, however only with regard to U.S. waters. Ideally, additional research would examine the ability to replicate the age composition of hake survey hauls conducted off Canada, using available alternative data in that region. Additional paired deployments of Saildrones and research vessels are needed to determine whether differences observed in the strength of acoustic**

backscatter measured by these platforms and research vessels are consistent and easily correctable in other years or areas where R/V comparison values are not available.

3. The SRG found the comparison of survey and eDNA-based biomass estimates and distribution for the 2019 survey to be promising. Samples for eDNA analysis were also collected during the 2021 survey, and are planned for 2023, as well. **The SRG supports continued exploration of the potential uses of eDNA analysis as a supplement to traditional survey methods. Trial collections of eDNA have been conducted only in U.S. waters, but to achieve their greatest possible value, these collections would need to be expanded to include Canadian waters within the hake survey footprint.**

Other SRG Recommendations

1. **The SRG recommends maintaining the opportunity for report writing and potential revisions by scheduling a gap of at least one week between the SRG and JMC meetings.**
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 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 submits 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, the JTC, and the MSE Technical Team have presented explicit responses to previous SRG recommendations, and **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 as this is an efficient way to meet data requests made by the AP and others.**

6. The ability of the Survey Team to finalize the survey biomass estimate is dependent on the availability of age data from samples collected during the survey. In 2021, ageing of U.S. survey ages was completed by mid-October, but other priorities prevented the completion of Canadian survey age reading until the end of November. Given the hard deadlines for assessment review and management decisions, particularly with earlier 2022 SRG and JMC meetings, delays in the completion of age reading has a direct impact on the amount of time available to the JTC for model development and testing. Because the August-October period has fewer competing ageing priorities in the U.S., **the SRG urges NMFS and DFO to discuss ageing priorities prior to the start of future surveys. In circumstances where DFO is not confident that their survey age reading**

can be completed before November, the SRG encourages utilization of NMFS ageing capacity to expedite the reading of all survey age structures. Given the existing cap on hake ageing at the DFO lab, this would have the additional benefit of allowing more Canadian fishery ages to be read, when they are available.

Literature Cited

Stewart, I.J. and Hamel, O.S. 2014. Bootstrapping of sample sizes for length- or age-composition data used in stock assessments. Canadian Journal of Fisheries and Aquatic Sciences. 71(4): 581-588. https://doi.org/10.1139/cjfas-2013-0289

ATTACHMENT 1

Joint US-Canada Scientific Review Group for Pacific Hake/Whiting

MEETING AGENDA

Online Virtual Meeting

February 14-17, 2022

Monday, February 14, 2022
08:30 Early Log-in to resolve connection issues

09:00 **Welcome and Introductions**
- Resolve immediate connection/communication problems

09:15 **Review and Approve Meeting Agenda** (Chair)
- Review Terms of Reference for Assessments and Review Meeting
- Review operational priorities and Co-chair recommendations for the virtual format
- Meeting report mechanics
- Assignment of reporting duties
- Review procedures for resolving communication issues throughout the meeting

09:30 **2021 Integrated Ecosystem & Pacific Hake Acoustic-Trawl Survey** (Survey Team)
- Integrated acoustic-trawl survey results including Biomass Indices, Age-Composition Data (Acoustics Team)

10:45 Break

10:55 **Fisheries, Data, and Inputs Used in the 2022 Assessment** (JTC & Ind. Advisors)
- 2021 Fisheries Catch, Size, and Age Composition Data
  - Canadian Waters
  - U.S. Waters

11:40 **2022 Pacific Hake/Whiting Assessment Modeling** (JTC)
- Methods, results and discussion

12:30 Lunch

13:45 **2022 Pacific Hake/Whiting Assessment Modeling (cont.)** (JTC)
- Methods, results and discussion (continue, as necessary)
- Model performance and diagnostics: sensitivities and retrospectives
- Response to 2021 (or prior) SRG requests
- Forecasts and management implications

- Discussion

15:00 Break

15:15 **Public Comment**

15:30 **SRG discussion, develop list of requests for JTC,** ***as needed***

16:00 **Adjourn for the day**

Tuesday, February 15, 2022
08:45 Early Log-in

09:00 **Pacific hake/Whiting Management Strategy Evaluation (MSE) Update** (Kristin Marshall, JTC)
- Responses to 2021 SRG recommendations
- Update on MSE process & 2022 work plan
- SRG Discussion & Recommendations

10:30 Break

10:45 **Review responses to 2022 SRG Stock Assessment Requests** (JTC)
- SRG discussion, develop list of requests for JTC, as needed

12:00 Lunch

13:30 **Update on ecosystem drivers of recruitment research & next steps** (Marshall & Kiva Oken)

14:30 **Review responses to 2021 SRG Stock Assessment Requests (cont.)** (JTC)
- SRG discussion, develop list of requests for JTC, as needed

15:00 Break

15:15 **Review responses to 2021 SRG Stock Assessment Requests (cont.)** (JTC)
- SRG discussion, develop list of requests for JTC, as needed

15:35 Public Comment

15:15 **SRG Discussion**, as needed

15:30 Adjourn for the day
Wednesday, February 16, 2022
08:45 Early Log-in

09:00 **Pacific Hake Acoustic-Trawl Survey Research** (Survey Team)
- Saildrone research (Derek Bolser)
- Planned 2022 survey-related research
  - Canada & US
- Upcoming US West Coast 'unified' survey planning efforts (Julia Clemons)
- Ageing otoliths from the Canadian survey vessel (Hastie)
- eDNA (Ole Shelton)
- SRG Discussion & Recommendations

10:30 Break

10:45 **Review responses to 2021 SRG Stock Assessment Requests (cont.)** (JTC)
- Discussion of model finalization and management outcomes

12:00 Lunch

13:20 Review of SRG Assessment Recommendations & Research Priorities
- Updates on any other hake-related research projects (JTC/Survey)

14:20 Public Comment

Wednesday, February 16, 2022 (Cont.)

14:30 Break

14:45 **SRG Discussion & Work Session**
- Stock assessment model finalization and management outcomes (as needed)
- Finalize research needs/priorities for assessment, survey, and MSE
- Draft SRG report

15:30 Adjourn for the day

Thursday, February 17, 2022 (<u>if needed</u>)

08:45 Early Log-in

09:00 **SRG Work Session**

10:15 **Public Comment**
10:30 Break

10:50 **SRG Work Session** (as needed)

12:00 Lunch

13:30 **SRG Work Session** (as needed)

15:30 SRG Meeting Adjourn

ATTACHMENT 2

List of Participants, all days

Jim Hastie - SRG Co-chair NOAA, NMFS, NWFSC, US appointee
John Holmes - SRG Co-chair SRG, DFO, PBS, Canadian appointee

Allan Hicks - SRG, FAWI, US appointee
Jaclyn Cleary – SRG, DFO, PBS
Trevor Branch – SRG, University of Washington, independent member
Lori Steele – SRG, AP Advisor, USA appointee
Shannon Mann – SRG, AP Advisor, Canadian appointee

Aaron Berger – JTC, NOAA, NMFS, NWFSC
Andy Edwards – JTC, DFO, PBS
Chris Grandin – JTC, DFO, PBS
Kelli Johnson – JTC, NOAA, NMFS, NWFSC

Al Carter - AP
Andrew Shelton - NOAA, NMFS, NWFSC
Arne Fuglvog - Glacier Fish Co.
Beth Phillips - NOAA, NMFS, NWFSC
Bob Dooley - AP
Corey Niles - WDFW
Craig Russell - NOAA, NMFS, NWFSC
Dan Waldeck - JMC
Dave Smith - AP
Derek Bolser - NOAA, NMFS, NWFSC
Dezhang Chu - NOAA, NMFS, NWFSC, Acoustic Survey
Elizabeth Phillips - NOAA, NMFS, NWFSC
Felicia Cull - DFO, SP, IFP
Frank Lockhart - JMC
Galeeb Kachra - NOAA WCR
George Mukai - AP
Jennifer Shaw - DFO, FPS, NCR
Joe Bersch - AP
Julia Clemons - NOAA, NMFS, NWFSC, Acoustic Survey
Katie Pierson - ODFW/GMT
Kristin Marshall - NOAA, NMFS, NWFSC, MSE Team
Kristin McQuaw - US Shoreside Coop,
Mike Okonieski - AP
Owen Hamel - NOAA, NMFS, NWFSC
Rebecca Thomas - NOAA, NWFSC Acoustic Survey
Rob Tadey - DFO, FM, GMU
Stephane Gauthier - DFO, IOS, Acoustic Survey
Steve Joner - JMC

Trent Hartill - American Seafoods
Whitney Roberts - WDFW
Yvonne DeReynier - NOAA, NMFS, WCRO