DRAFT Joint Canada - U.S.A. Scientific Review Group Report for 2023

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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 at the Graduate Hotel, Seattle, February 7–10, 2023 to review the draft stock assessment document prepared by the Canada/U.S.A. Joint Technical Committee (JTC), planning for the coastwide acoustic survey to be conducted by both nations in 2023, preliminary planning for the proposed 2025 integrated survey, 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 and 2023 meetings. The United States has secured the services of a new member, who should be in place for the 2024 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 Tuesday, February 7, 2023. John Holmes (SRG co-chair) welcomed attendees and after a round of introductions reviewed the SRG Terms of Reference 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 20, 2023, and that it would be posted to the website by February 21, 2023. 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 2023 stock assessment and acoustic survey research.

1. The structure of the 2023 assessment model is similar to that of the 2022 model. All runs in the 2023 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 only on the data, structure, and processes included in the base model. Thus, uncertainty in current stock status and projections is likely underestimated.

2. Additional data for the 2023 assessment include new 2022 fishery catch, age-composition and weight-at-age data, and minor changes to pre-2022 data. The Canadian freezer-trawler fleet was subject to electronic monitoring in 2022 and a new biological sampling program delivered by freezer-trawl crews that required sampling of 50 fish from two tows per trip ($n = 100$ in total per trip). Biological samples are collected from the Canadian shoreside fleet by the dockside monitoring program.

3. The SRG considers the 2023 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 2022 SRG report.

4. The addition of the 2022 data did not change the pattern of recruitment estimates but did change the estimates of recruitment in some years. Importantly, the median estimate of the 2020 year-class is 6.2 billion fish higher than in the 2022 assessment (a 118% increase), confirming that this recruitment is well above average based on observations in the age-1 index and of age-2 fish in the fishery. The median estimate of 2014 recruitment decreased by 147 million fish (1.6%) and the median estimate of 2016 recruitment decreased by 44 million fish (<1%). Similarly, the below average 2017 recruitment decreased by 112 million fish (4%) and remains below average. The 2014 year-class size remains well above average at 9.2 billion fish (sixth highest in the time series) but is smaller than the 2010 year-class.

5. Since 2010, this stock has been supported by multiple above-average cohorts simultaneously: the 2010, 2014, 2016, 2017, and 2020 cohorts are predicted to comprise 3.5%, 6.6%, 9.5%, 6.5%, and 61.6% of the stock biomass, respectively, at the start of 2023.

6. The base-case model estimates that median female spawning biomass at the beginning of 2023 is 1.910 million metric tonnes (Mt), with a 95% credible interval from 0.757 to 5.610 Mt. This estimate represents a spawning biomass that is 104% of the unfished equilibrium level (B_0), with a wide 95% credible interval of 42% to 300%. There is a 0.1% joint probability that the stock is both below $B_{40\%}$ at the beginning of 2023 and above a level of fishing intensity equivalent to the default harvest rate of $F_{40\%}$ in 2022.

7. Total exploitable stock biomass (age 2+, males and females) at the beginning of 2023 is estimated to be 4.514 Mt, with a 95% credible interval of 1.753 to 13.669 Mt. This

estimate is a 35% increase relative to the 2022 median estimate, due largely to the big 2020 year-class.

8. 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. Application of the default harvest policy corresponds to a catch of 778,008 t in 2023 and 740,322 t in 2024. Applying the default harvest policy ($FSPR_{40\%}$ – calculated using average selectivity over the last 5 years) in 2023 and 2024 results in a 24% probability that the stock will be below $B_{40\%}$ at the beginning of 2025. The probability that fishing intensity is greater than $F_{40\%}$ in 2023 and 2024 when harvesting at these levels is less than 37%.

9. An acoustic survey is planned for June 18 to September 16, 2023, proceeding north from Point Conception, CA (34.5°N) to Dixon Entrance, BC (54°N). The survey will be conducted by the NOAA R/V *Bell M. Shimada* and the CCGS *Sir John Franklin*. Oceanographic and ecosystem data (e.g., eDNA, ADCP) will be collected during the survey in both countries following existing survey protocols. The Survey Team outlined plans to interleave vessel survey legs off Washington and Vancouver Island and contingency plans to address changes in schedule as the survey proceeds. **The SRG concurs with the design approach for the 2023 survey, although the temporal gap surveying off Vancouver Island may confound interpretation of the results. Continuing the oceanographic and ecosystem data time series data collection is a priority for the SRG because it contributes significantly to ongoing research to improve recruitment forecasts, to better understand drivers of distributional shifts, and many other projects important to the JMC's goals.**

10. The SRG noted the intention of NOAA to develop and implement an integrated West Coast pelagic survey by 2025 which would combine the Hake acoustic trawl survey and the coastal pelagic species acoustic survey. This work is still in the early planning stages, and **the SRG recommends that NOAA consider providing an opportunity for feedback and advice on the combined survey to ensure that it will provide the information required to support the joint management of the Pacific Hake/Whiting stock.**

11. 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, research supporting the MSE, and documentation plans. This progress is especially noteworthy given the fact that the MSE Technical Team contained no individuals dedicated solely to advancing Pacific Hake MSE programming and application in 2022. The MSE Team is exploring important questions regarding environmental drivers of Pacific Hake productivity, variability in weight-at-age, and dynamic reference points that when resolved will advance the ability of this tool for providing strategic advice. **The SRG supports the effort to hire a postdoctoral fellow dedicated to the MSE, ongoing MSE development, and progress on the 2023 workplan identified by the MSE Team.**

12. Preliminary results and potential uses of dynamic reference points were discussed. Dynamic unfished biomass (dynamic B_0) is a measure of the size that population would have attained given the variable recruitment success observed, but in the absence of fishing. Dynamic reference points provide a means of disentangling fishing effects on the stock from changes in productivity. **The SRG regards this approach as a promising innovation to assessing stock status and recommends that the JTC and the MSE Team continue this research.**

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, many of which are generated from the oceanographic and ecosystem data collected during the acoustic survey as currently implemented. 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 on Pacific Hake.**

14. **The SRG encourages analysis of catch distribution, biomass distribution and predictors based on environmental covariates that can explain the latitudinal distribution of Pacific Hake between Canada and the United States.**

15. **The SRG appreciates the valuable new research presented on maturity, diet, predation, cannibalism, and environmental drivers of recruitment, and supports continued research in these and other areas because the results of this research are expected improve our understanding Pacific Hake stock dynamics including spawning biomass, spatial shifts of the stock, and recruitment variations**

2023 Stock Assessment

Overview

The 2023 assessment continues with the same model structure used 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 1–6 is estimated for the fishery and ages 2–6 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, catch, and biomass. It 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 2022 assessment include the addition of 2022 fishery catch, age-composition, and

weight-at-age data, and minor updates to pre-2022 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, but biological sampling resumed again in 2022 with the assistance of industry. Thus, 2020 and 2021 age-composition data are not available from this fleet. Kriged results of age 2+ biomass and age composition from the 2021 acoustic-trawl survey were used in the 2023 assessment and the age-1 index of abundance was used in the base model.

As in 2022, the 2023 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. High performance multi-core computing resources were essential in conducting all the necessary runs given the short time available.

The 2023 assessment included the standard suite of sensitivity analyses requested by the SRG: alternative standard deviations of the priors for natural mortality, alternative values for steepness, alternative values for σ_R (a parameter limiting recruitment variability), and the removal of the age-1 acoustic survey index. Sensitivity runs were also conducted to illustrate the sensitivity of the 2023 assessment results to alternative data-weighting methods, flexibility of time-varying selectivity (Φ), and alternative parameterizations of time-varying selectivity.

The SRG has previously noted that σ_R is an influential parameter, and encourages further work by the JTC. 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, SSAM) allow for the 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 continues to investigate methods to better simulate future recruitments, including using the age-1 index and environmental covariates and outputs of the ROMS model. The 2020 year-class is estimated to be well above average in the 2023 assessment and is driving the increase in exploitable biomass and female spawning biomass in this assessment. The 2018 and 2019 year-classes are estimated to be below and near average, respectively. The 2021 year-class is estimated below average based on very limited fishery data, and is highly uncertain. The 2022 and 2023 year-classes have no information, but due to model assumptions (i.e., the sum of recruitment deviations is not forced to be zero) recruitment for these year-classes are slightly above R_0. 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 2022 recommendations and has several additional recommendations for future iterations of the Pacific Hake stock assessment. The recommendations below are shown in order of priority.

1. 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 estimating dynamic reference points within the assessment and MSE, and encourage those groups to jointly develop alternative reference points, including dynamic reference points, for future SRG consideration.**

2. **The SRG also recommends continuing sensitivities for steepness, natural mortality, σ_R, excluding the age-1 index, alternative standard deviations for time-varying selectivity, and using the McAllister-Ianelli method to weight fishery age-composition data.**

3. **The SRG recommends that the JTC include dynamic unfished spawning biomass in the 2024 assessment as a comparator with the equilibrium unfished spawning biomass used to provide management advice. The SRG also encourages the continued outreach regarding the use of dynamic reference points to stakeholders and managers, including identifying pros and cons of using dynamic unfished spawning biomass**

4. **The SRG recommends that the JTC explore alternative ways of estimating natural mortality to update the current approach in the model, which is based on methods from more than a decade ago, since newer methods are available. Information presented during the SRG meeting implies that natural mortality on age-2 Pacific Hake is higher than currently assumed in the assessment model and should be explored more fully.**

5. **The SRG encourages an analysis of catch and CPUE distribution for Canada and US that examines latitudinal shifts in fishing over time.**

6. **The SRG recommends continued work to collect ovary samples and data to develop a picture of the Pacific Hake reproductive cycle both seasonally, inter-annually and at the life-time scale based on histological and physiological measurements.** Given

the inter-annual variability in age-at-maturity, **the SRG recommends that the JTC explore ways to incorporate time-varying maturity in the stock assessment model.**

7. The SRG noted that the age-1 index did not include a value for 2001 because it was zero. Although this decision had negligible influence on the results because the estimate for 2000 recruitment was close to zero, the SRG noted that Stock Synthesis uses a lognormal likelihood which does not handle zero values. Given that future zero values are expected to have a bigger influence on the results in the short-term, **the SRG recommends that the JTC explore likelihood forms that can fit to very low index values from the age-1 survey (e.g., robust likelihood).** The SRG acknowledges that implementing new likelihoods will require changes to the Stock Synthesis platform.

8. Given the importance of the age-1 index in estimating the size of the age-classes entering the fishery, **the SRG recommends that the JTC implement updated age-1 index CVs, when they are provided by the Survey Team, in the stock assessment model.**

9. A new at-sea sampling program in the Canadian freezer-trawler fleet was implemented in 2022 involving vessel crews sampling 50 fish per tow from two tows per trip. **The SRG recommends that Canada consider sampling fewer fish from more tows to spread the sampling out and provide a more representative sample of fishery catches.**

10. **The SRG encourages the JTC to consider methods to determine the maximum input sample size for the age compositions** (e.g. Stewart and Hamel 2014).

11. The SRG notes that there have been multiple strong cohorts in the stock recently compared to earlier periods where there was only one strong cohort supporting the stock, including during the period of sample collection for the ageing error matrix that supports the assessment model. **Therefore, the SRG encourages the resumption of the ageing error study by the Committee of Age Reading Experts (CARE) using samples collected during the past decade.**

12. **The SRG supports the investigation of alternative selectivity functions, which may include a two-dimensional autoregressive (AR) approach, which may use information from the previous year and from adjacent year classes to predict selectivity.**

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.

Acoustic Survey

2023 Summer Acoustic Survey

The SRG received a briefing on the 2023 summer acoustic survey, planned for June 18 to September 16, 2023, conducted by the NOAA R/V *Bell M. Shimada* and the CCGS *Sir John Franklin*. The survey will begin at a randomly determined location near Point Conception (34.5°N) and proceed north to Dixon Entrance (54.5°N). Transects in U.S. waters and as far north as the northern end of Vancouver Island (50.5°N) will be spaced at 10 nmi intervals and extend from bottom depths 50 m offshore to 1500 m or until Pacific Hake are no longer detected. Transect spacing from the northern end of Vancouver Island (50.5°N) to Dixon

Entrance (54.5°N) will be spaced 20 nmi apart. Both vessels are equipped with EK-80 echosounders and five or six frequencies and use 38 kHz as the main frequency for detecting fish. An inter-vessel calibration of the R/V *Bell M. Shimada* and the CCGS *Sir John Franklin* was completed in the summer of 2022. Five survey legs are planned for the *Bell M. Shimada* covering U.S. waters except northern Washington and the northern half of the west coast of Vancouver Island. Two survey legs are planned for the *Sir John Franklin* covering the northern half of Washington, the northern half of Queen Charlotte Sound, Hecate Strait, Dixon Entrance and the west coast of Haida Gwaii. The interleaving of vessels in the survey plan may leave temporal gaps in coverage that the Survey Team worked hard to minimize. Survey operations are expected to occur during the day, including trawls for echogram validation and biological sampling of Pacific Hake. Nighttime operations on both vessels will focus on collecting oceanographic data (temperature, salinity, dissolved oxygen) and environmental DNA (eDNA). **The SRG supports and recognizes the efforts of the Survey Team to consult with industry and develop a survey design that is responsive to their concerns and potentially changing ocean conditions, while providing good coverage in support of the stock assessment.**

Integrated West Coast Pelagics Survey Planning

The Survey Team provided a presentation on the planning currently underway at the Northwest Fisheries Science Centre (NWFSC) and the Southwest Fisheries Science Centre (SWFSC) to integrate the Pacific Hake and coastal pelagic species (CPS) acoustic surveys by the Summer of 2025 as directed by NOAA leadership. This charge has international consequences since the 2003 Hake/Whiting Treaty identifies the acoustic survey as a key component for the assessment and sustainable management of the offshore Pacific Hake stock. The survey is currently conducted jointly with Canada, including with a Canadian vessel completing a portion of the survey in the U.S. and Canada. As part of the effort to standardize the survey, DFO has recently acquired an identical net to that currently used during the U.S. led portion of the Pacific Hake Survey. **The Treaty also states the SRG is charged with reviewing survey methodology and therefore is expected to review the data and associated analyses supporting the changes to the survey.**

The ambitious timeline proposed for implementing the new integrated pelagic survey may be insufficient for the NWFSC Survey Team to address some of the changes to the Hake Survey methodology, and it also does not appear to provide adequate time for the SRG to evaluate the new methodology as it applies to Pacific Hake. Important changes include a proposed switch to a new single net to fish both in the midwater during the day for Pacific Hake and at the surface at night for CPS without changing the rigging, and validation of Pacific Hake aggregation identification acoustically during the day with nighttime surface trawling. The SRG recognizes the NWFSC Survey team is understaffed and this additional heavy burden on the small team will further delay ongoing SRG requests.

The SRG recommends that the first step in the Integrated Survey process is to focus on maintaining the existing Hake Survey methods of acoustic data collection coupled with midwater trawling with an Aleutian Wing Trawl (AWT) during the day while encouraging collaboration between the NWFSC and the SWFSC on elements that are less likely to negatively impact either survey, such as shared acoustic data collected on the NOAA Ship(s). A measured approach to survey integration in 2025 is to build on the

success the SWFSC has had with biosampling by chartered trawlers at night in areas where CPS aggregations were identified during the day. The SRG proposes this approach as a logical step to developing an integrated survey while acknowledging the strong successes the two surveys have had individually. These two components (maintained daytime midwater trawling for Pacific Hake and night trawling for CPS by separate vessels) are a solid step forward for the proposed integrated survey and **the SRG recommends that NOAA support a more careful and cautious, modular approach to integration to avoid changes that could have long-term negative consequences to Pacific Hake stock assessment and management.** Even in the ideal case that a new survey is found to provide adequate coverage and biosampling, changes in biosampling could mean that there would be a break in the survey selectivity and greater uncertainty in the Pacific Hake assessment for several years, at the very least.

The SRG notes that the SWFSC has plans to incorporate nighttime surface trawling above Pacific Hake aggregations identified acoustically (and validated with daytime trawling) on the NOAA R/V *Lasker* and trawlers during the CPS Survey. This data is intended to provide a first step towards evaluating this alternative method for biosampling and compare it to the longstanding traditional trawling methods by the Hake Survey to see if nighttime surface trawling can provide additional data inputs into the Pacific Hake stock assessment, or as proposed by the SWFSC, would be able to replace the existing trawling methods. The SRG is concerned the nighttime surface trawling planned by the CPS Survey this summer may be of inadequate sample size to ascertain the value of this method which would ultimately eliminate the ground-truthing of acoustic aggregations, although if results are similar to those seen during the summer 2022 research as detailed earlier in the report, this may provide an adequate counterfactual. **While the SRG is willing to consider data-driven alternatives, they have serious concerns about the method, and requests NOAA leadership allow this investigative research to develop fully before supporting/proposing a major Hake Survey methodology change that will break the 28-year Pacific Hake time series**.

The SRG is also concerned regarding the expectation to begin integrated survey operations in Mexico due to recent developments in the past two years by the CPS Survey to partner with Mexico to survey some CPS species. In February 2016, after the SAKE Survey was conducted beginning in the Southern California Bight and to the north, it was concluded that adult Pacific Hake sampled south of Point Conception, California during the survey were from a different stock of Pacific Hake and this region should not be included in the base survey design for the Hake Survey. As such, the southern start of the Hake Survey for 2017 and going forward has been at Point Conception, California. Extending the base survey area to Baja California adds significant time during which Pacific Hake survey personnel are expected to participate in a portion of a survey that the current scientific evidence shows will not contain portions of the coast stock of Pacific Hake.

The SRG is also concerned that DFO's role and engagement in this on both Pacific Hake and CPS side has not been fully and jointly established by NOAA and DFO leadership. Of particular note, having identical nets and calibrated acoustics along with the current approach of having the U.S. vessel(s) survey portions of the west coast of Vancouver Island and the DFO vessel survey portions of Washington provides survey flexibility that makes a relatively synoptic Hake Survey possible. If the U.S. switches to a new net, this will complicate that

approach and also result in an inconsistent survey over time if one country or the other has to take over surveying the entire coast, as was the case in 2003 and 2015.

The SRG sees great value in maintaining the environmental sampling time series, including nighttime CTD rosette sampling of temperature, salinity and dissolved oxygen coincident with Pacific Hake abundance and distribution along with continuation of the eDNA sample collection. The CTD sampling results in subsurface temperature recordings that are not available from remote platforms (e.g. satellite products), and the co-collected environmental data underpin the relationships between Pacific Hake distribution and temperature that inform the J-SCOPE in-season Pacific Hake forecasts that have been presented to the SRG since 2019. Ongoing collection of subsurface environmental data is critical for model training and forecast development.

SRG Recommendations and Conclusions for Acoustic Survey

1. **The SRG requests that it be provided with the opportunity to review the proposed Integrated West Coast Pelagics survey design and protocols in order to provide input into the Hake components. The SRG strongly recommends engagement with outside experts in survey design and protocols as was done during the 2015 SRG meeting.**

2. **The SRG reiterates its recommendation that the Survey Team document and publish the survey design, methods and operational protocols, including trawl protocols in technical reports for each country and requests that the SRG have the opportunity to review the documents prior to entering the publication process in each agency.**

3. Given the importance of the age-1 index in estimating the size of the age-classes entering the fishery, **the SRG recommends that the Survey Team explore estimating the CV of age-1 index values and moving away from a fixed 0.5 minimum CV for all years**

4. **The SRG requests that the survey team provide regular updates on survey research and planning to all parties (SRG, JTC, JMC), so that the parties can provide feedback and direction on survey comparisons, proposed methodologies, and direction for next steps.**

Survey-Related Research

Summer 2022 Research Updates

Hake/rockfish habitat delineation, SASSI

The proportion of survey backscatter estimated to come from Pacific Hake/rockfish mixes ranges from 0-17% across years of the survey, with an average of 4%. Given the potential damage to the net from catching large amounts of rockfish, the option of using the Semi-Autonomous Strobed Stereo Imager (SASSI) in the net with an open cod-end may be advantageous. However, this requires being able to predict when rockfish is likely.

This research was undertaken to help determine if information on bottom habitat can help distinguish Pacific Hake from rockfish or rockfish/Pacific Hake mixes. Acoustic data from 17 trawls, 11 with Pacific Hake and 7 with rockfish present, were used as a training set to discriminate rockfish habitat based upon bottom hardness, (acoustic) first bottom length and bottom depth. Quadratic discriminant analysis was used for the classification model, minimizing cross-validation error. During July 22-August, 8, 2022, the *Shimada* surveyed three sets of paired transects two to three times each, conducting 28 open or closed cod-end trawls with the SASSI net camera. Habitat segments predicted to contain rockfish (a bit less than half of segments) during these transects were found to contain rockfish 66% of the time, while those predicted as "Pacific Hake" were found to contain rockfish only 5% of the time.

In 2023, this tool will be used to help determine Pacific Hake vs. rockfish habitat when judging acoustic data, while adding additional trawls to the data-training library. Future surveys may use this to help determine when to fish with an open cod-end. SASSI can provide both species identification and thus composition, and lengths. Continued eDNA collections will help address Pacific Hake/rockfish questions including diel patterns and relative abundance.

Inter-Vessel Calibration

From August 17-24, 2022, the *Shimada* and *Franklin* conducted an inter-vessel comparison of their acoustic data by conducting 33 side-by-side transects (within 800 m, commonly 500 m apart) and joint trawling. The *Shimada* conducted 4 daytime midwater trawls, while the *Franklin* conducted 7 daytime midwater trawls and 3 nighttime surface trawls. There was limited opportunity for trawling due to intermittent observation of fish and the presence of longline gear in portions of the survey area. Overall matches were generally good, and average ratio between backscatter for all water column and Pacific Hake aggregations backscatter between vessels was near 1.

Nighttime Trawling

The three nighttime surface trawls conducted during inter-vessel calibration were analysed to see if they indicated potential for collecting biological data for Pacific Hake by trawling near the surface at night. However, even the most productive of the three nighttime trawls only caught seven Pacific Hake over 20 minutes of trawling near 10 pm on August 18, 2022. In comparison, a 6.5 minute haul on acoustically observed Pacific Hake in the same area but at noon on that same day caught 751 Pacific Hake. The average individual weight of Pacific Hake was similar between the two tows.

Zooplankton Trawl Gear Comparison

On August 15-16, in collaboration with Oregon State University, the *Shimada* sampled along the Newport Hydrographic Line at stations 1, 3, 5, 10, 15, 20, 25, 35, 45, and 65 taking CTD, water samples, and using vertical, bongo, Methot and Isaacs-Kidd midwater trawl nets.

As part of this work, catches from the Methot and Isaacs-Kidd midwater trawl nets were compared. The latter can be deployed from the side of a research vessel and thus is much easier to deploy. The opening of the Isaacs-Kidd net is half the size (2.4 m^2) of the Methot

net, resulting in half the volume of water filtered, and it collected only 200 ml of zooplankton, which is substantially less than the Methot net (4,700 ml). Despite this difference, the Isaacs-Kidd net caught more larval fish (41 vs. 19) and similar length of krill compared to the Methot net.

Mesopelagic research

The *Sir John Franklin* worked along the West Coast of Vancouver Island to look in detail at the mesopelagic assemblage around Hake aggregations. There are many species, and these may affect backscatter of Pacific Hake, or Pacific Hake may disperse into the blue haze of mesopelagics. This work was to look at acoustic properties and trophic linkages. They were not able to find large Pacific Hake aggregations, just as was the case with the industry in this area. They were able to find Pacific Hake at the shelf break, a small carpet of fish could be seen acoustically that were not easily fishable.

Research with the University of Victoria resulted in barcoding of 260 mesopelagic specimens, including 9 families and 20 species. For some of these, they conducted metabarcoding on lipids and gut content for food web information. Some of these species had very high levels of lipid content (10-20%).

Saildrone Research

Two saildrones were deployed from August 27-October 3, 2021 to study offshore Pacific Hake and examine fine-scale movement patterns through paired transects off Cape Mendocino. A total of 29 transects were conducted across the two saildrones, with day and night sampling as far as 68 nmi offshore. The saildrones found Pacific Hake aggregations near the shelf break and had good acoustic coverage despite some weather-related attenuation.

More research is needed to see if saildrones can provide an annual index on their own, given the differences seen between the survey and saildrone values in 2019. In addition, compositional data will rely on fisheries if operating nearby in the same timeframe, or will need a sampling boat in other cases (e.g. off California). Larger saildrones, which could travel faster, would be useful for keeping up with the survey and providing additional but linked data.

SRG Recommendations and Conclusions for Survey-Related Research

1. The SRG notes that a successful acoustic intercalibration between the *Bell M. Shimada* and *Sir John Franklin* was completed in the summer of 2022. This result provides added confidence in the survey data collected by each vessel and the resulting age-1 recruitment index and age-2+ biomass index used in the assessment.

2. **The SRG encourages the Survey Team to continue research into the development and testing of tools, including habitat delineation machine learning, to make the classification of echograms with respect to Pacific Hake and other species mixes less subjective**.

3. The SRG recognizes the joint Survey team is understaffed, which has affected the ability of the Survey Team to address high priority SRG requests in a timely fashion. The extra burden placed on the NWFSC Survey Team by the Integrated Survey planning process is likely to be unsustainable. **The SRG encourages both agencies to commit to providing additional qualified staff to the Survey Team as soon as possible to avoid burnout by current members.**

4. The SRG was presented with preliminary research results from 2022 that show nighttime trawling for Pacific Hake was largely unsuccessful. **The SRG recommends the FEAT Survey team cooperate with the CPS survey team to research the implications of using nighttime-only Pacific Hake samples in estimating Pacific Hake biomass estimates. The SRG would like to see evidence that this approach to sampling Pacific Hake provides comparable data to the current daytime sampling protocol before it is incorporated into the survey protocol.**

5. **The SRG requests detailed documentation on the survey biomass index estimation algorithm**, including the kriging method, from the Applied Physics Laboratory at the University of Washington that are currently rewriting the code from Matlab to Python.

6. **The SRG encourages the integration of US and Canadian oceanographic data so that Pacific Hake models cover the full distribution of the species.**

Management Strategy Evaluation (MSE) and Supporting Analyses

The MSE Technical Team presented progress made in 2022 on the topics related to (1) recruitment, (2) growth and weight-at-age, and (3) dynamic reference points. These research topics will support the goals of the MSE including evaluating the performance of management procedures under alternative hypotheses about current and future environmental conditions.

A significant amount of work has been done to relate environmental variables with recruitment to answer questions about how recruitment and recruitment variability in the future may be similar or different from historical observations. The Technical Team plans to use ROMS projections for indicators (as well as other abiotic and biotic variables) identified as skillful for predicting recruitment, generating projections of an age-0 index, modifying the MSE operating model to incorporate alternative recruitment modelling approaches, and testing alternative methods for recruitment forecasting.

Variability in weight-at-age was examined using GAMMs to look at age, cohort, year, month, spatial, and spatiotemporal effects. Preliminary results show evidence of cohort, month, and year effects, as well as consistent spatial patterns. This research is to continue and be incorporated into the MSE operating model.

Dynamic reference points are being considered, realizing that there are alternative ways to calculate these values. For example, to determine stock status a moving window of dynamic unfished spawning biomass may be used, which could be the single year of interest or the average of a number of previous years. The Technical Team continues to work towards adding the capability to calculate dynamic reference points in the operating model (OM) and estimation model (EM), respectively, to investigate the utility of harvest control rules based

on dynamic reference points. The results of this investigation will inform decisions regarding the best methods to incorporate dynamic reference points into Pacific Hake management.

Additionally, a new postdoctoral fellow has been hired (19 months) to continue OM development and incorporate variability of growth into the MSE process.

Recommendations for the MSE

The SRG continues to support the MSE process, which is valuable for strategically advancing Pacific Hake stock assessment science and management and continues to support the ongoing work of the MSE technical team. Recommendations related to the MSE are shown in order of SRG priority below, pending input from the JMC.

1. **The SRG recommends adding the capability to estimate dynamic reference points in the OM and EM, respectively, and supports the investigation of management procedures using dynamic reference points in the future.**

2. One of the key questions for this fishery is how the proportion of fish in Canada and the US might change over time, and whether this needs to be taken into account in management. **The SRG recommends that the MSE should be used to test the impact on fisheries in each country of such changes.** This could be externally forced: for example, what would happen with three years in a row of high proportions in Canada; three years with low proportions in Canada; or a trend over time due to environmental change. It could also be internally based, using predictions from environmental factors, if strong predictive links can be shown.

3. **The SRG recommends using the MSE to compare the default 40-10 harvest control rule based on static B_0, to the same rule, but based on dynamic B_0 (either with 1-yr or 10-yr smoothing of B_0).**

4. To account for variability in weight-at-age, **the SRG supports the addition of more complex modelling of weight-at-age in the operating model**.

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.**

6. **The SRG requests documentation of the MSE operating model and results from 2023 before the 2024 meeting.**

Ecosystem- and Life-History-Related Research

Pacific Hake Recruitment Forecasts for Use in Management

A continuing area of research is how to predict recruitment from environmental information. One approach is to fit recruitment deviations using ecosystem indicators and ROMS ocean indicators, and the resulting relationships could be then included in stock assessments, risk tables and MSE analyses.

Ongoing simulation testing of a hypothetical index of recruitment in Pacific Hake stock assessment model suggests very strong correlations are needed to improve estimation, which makes a strong case for continuing the age-1 index and developing other direct measures of recruitment success.

Pacific Hake Diet Research

Pacific Hake diet data has been collected by the Survey Team every field season since 2005. Through 2018, this involved taking an average of 10 stomach samples per tow, from fish which also had otoliths removed for ageing, and these samples were analysed back on land. Since 2019, half of the stomachs taken were analysed at sea. Data has been stored in various media, and with non-standardized nomenclature. In 2020, thanks to additional time given the canceled field season, a database was developed, and the data cleaned up and standardized. Work has continued on standardization, database efficiency, and the addition of other data from the AFSC and DFO. Currently there are data from 4,276 stomachs from across the coast and ages 1-19 years, with an average of 600 stomachs per surveyed year.

By number, euphausiids dominate Pacific Hake diet, followed by fish, shrimp, myctophids, and cephalopods. By weight, younger Pacific Hake eat mostly krill, which make up a decreasing proportion of the diet (while remaining dominant) through age-5, while fish dominate the diet from age-8 or 9. Interannual variability in consumption patterns are likely due to a combination of prey availability and the age structure of the Pacific Hake population. Recent research found that in cool ocean years Pacific Hake co-occurred with krill 41% of the time, but this was only 17% in warm ocean years. Further work involves comparing relationships between Pacific Hake weight-at-age and Pacific Hake-krill co-occurrence.

Pacific Hake Multi-Species CEATTLE Model

The Climate-Enhanced Age-based model with Temperature-specific Trophic Linkages and Energetics (CEATTLE) multi-species catch-at-age model can look at time-varying mortality, climate drivers, bioenergetics, temperature-dependent growth, and cannibalism.

The model was based on parameters from 2020 Pacific Hake stock assessment, with natural mortality (M) partitioned into: residual mortality ($M1$) and predation mortality ($M2$). Predation mortality ($M2$) was calculated from the age composition of predators and derived from suitability coefficients, prey biomass, and consumption info, with temperature, predator body size, etc. affecting consumption rates. Pacific Hake stomach content information was used to estimate the amount of cannibalism. While the occurrence of Pacific Hake in Pacific Hake stomachs is low by number, Pacific Hake dominates by weight among fish eaten by Pacific Hake, comprising 15% by weight of the diet for age 10+ Pacific Hake. Cannibalism is mostly of age 1 and to a lesser extent age-2 Pacific Hake, and includes up to age-5 for older (> age-12) Pacific Hake consumers.

CEATTLE gives similar results to the 2020 Pacific Hake stock assessment with fixed $M1$ and no cannibalism, but when $M1$ is estimated, even without cannibalism, it finds a higher $M1$ (0.26) and larger population size. With cannibalism, the Pacific Hake population is larger, and $M1$ increases further, up to 0.32. Age-specific estimates of $M1$ plus $M2$ indicate higher values for young ages. Future steps include adding more trophic interactions, including krill as prey, and including other predators such as California Sea Lion.

<u>Pacific Hake Maturity Research</u>

Pacific Hake are indeterminate batch spawners with a protracted spawning season. Reproduction, including maturity and fecundity, is variable over years and space. Pacific Hake mature at a younger age south of Point Conception than they do to the north. Recent and ongoing research has confirmed the differences in age and length of maturity along the coast, and particularly south of Point Conception; elucidated seasonal spawning patterns; detailed interannual changes in maturity-at-age and -length, and related these to variable climatic events. Future research may compare maturity patterns of Pacific Hake off the U.S. West Coast and Canada, and investigate batch fecundity, including variation across space, age, and year.

Recommendations for Ecosystem- and Life-History-Related Research

The SRG supports research to improve understanding of linkages between the environment and Pacific Hake distribution and recruitment variability, including ways this information can be used to improve management decisions. Specific recommendations are provided here.

1. The SRG is encouraged by the results of the research into environmental drivers of Pacific Hake recruitment, and **the SRG supports the ongoing research to develop predictive relationships of Pacific Hake recruitment that can improve stock assessment forecasts and inform the 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.**

4. **The SRG encourages continued work on maturity and fecundity, including temporal and latitudinal variation.**

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 2023 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 Pacific 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.**

ATTACHMENT 1

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

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

February 7-10, 2023

AGENDA

Tuesday, February 7, 2023

08:30   Early login to resolve connection issues for virtual participants

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 2023 Assessment (JTC) 2022 Fisheries Catch, Size, and Age Composition Data
- Canadian Waters
- U.S. Waters

10:30   *Break*

10:45   2023 Pacific Hake Stock Assessment Methods, Results and discussion (JTC)

11:45   *Lunch (on your own)*

13:00   2023 Pacific Hake Assessment: Sensitivities and Retrospectives and discussion (JTC)

13:45   Review 2022 SRG Stock Assessment Requests (JTC)

14:15   Ecosystem conditions as related to recruitment strength (JTC)

14:45   *Break*

15:00   Management Outcomes of the 2023 Stock Assessment and discussion (JTC)

15:45   SRG discussion, develop list of requests for JTC, as needed

16:15   Public Comment

16:30   SRG Work Session

17:30   Adjourn for the day

Wednesday, February 8, 2023

08:45   Early login

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

10:00 Break

10:15   SRG Discussion, requests for additional information JTC as needed

10:45   Survey-related Research (Survey Team)
- 2022 summer research
- Overview of ongoing research projects

11:45 *Lunch (on your own)*

13:00   2023 Survey Design and Plans (Survey Team)

14:00   Review of 2022 SRG Survey Recommendations (Survey Team)

14:15   Discussion of structure exchange and ageing timeline

14:30 *Break*

14:45   Updates on 2025 Integrated West Coast Pelagic Survey planning (Survey Team)

15:15   SRG Discussion, requests for additional information JTC, Survey Team, as needed

16:00   Public Comment

16:30   SRG Work Session

17:00   Adjourn for the day

Thursday, February 9, 2023

08:45   Early login

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

10:00   MSE progress update, including responses to 2022 SRG Recommendations/JMC requests

10:45   Climate and ecosystem indicators for recruitment forecasts (Kristin Marshall)

11:00 *NWFSC seminar (Stephane Gauthier) and Lunch (on your own)*

12:30   SRG Discussion, requests for additional information from JTC, Survey Team, MSE as needed

13:00   Spatio-temporal maturity analysis update (Melissa Head)

13:30   Hake diet research (Alicia Billings and Beth Phillips)

14:00   Ceattle model update (Sophia Wasserman)

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 10, 2023

08:45   Early login

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

09:30   SRG discussion continued of research needs for 2023 and longer-term
- Evaluation of base model and primary sources of uncertainty
- MSE methodology and approaches

10:15   *Break*

10:30   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, all days

Owen Hamel - 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

Alicia Billings - NOAA, NMFS, NWFSC, Acoustic Survey
Julia Clemons - NOAA, NMFS, NWFSC, Acoustic Survey
Elizabeth Phillips - NOAA, NMFS, NWFSC, Acoustic Survey
Rebecca Thomas - NOAA, NWFSC Acoustic Survey
Stephane Gauthier - DFO, IOS, Acoustic Survey

Al Carter - AP
Andrew Shelton - NOAA, NMFS, NWFSC
Arne Fuglvog - Glacier Fish Co.
Bob Dooley - AP
Corey Niles - WDFW
Craig Russell - NOAA, NMFS, NWFSC
Dan Waldeck - JMC
Dave Smith - AP
Derek Bolser - NOAA, NMFS, NWFSC
Felicia Cull - DFO, SP, IFP
Frank Lockhart - JMC
Galeeb Kachra - NOAA WCR
George Mukai - AP
Haley Oleynik – University of British Columbia
Jennifer Shaw - DFO, FPS, NCR
Jim Hastie - NOAA, NMFS, NWFSC
Joe Bersch - AP
Kristin Marshall - NOAA, NMFS, NWFSC, MSE Team
Kristin McQuaw - US Shoreside Coop,
Maggie Sommer – NOAA WCR
Melissa Head – NOAA, NMFS, NWFSC
Mike Okoniewski - AP
Sophia Wassermann - University of Washington and NOAA affiliate

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