Joint Canada–U.S.A. Scientific Review Group Report for 2024

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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 Vancouver Island Conference Centre, Nanaimo, BC, February 6–9, 2024 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 2025, including 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. Although the United States has secured the services of a new independent member, contracting difficulties prevented the participation of this person at the 2024 SRG meeting, and thus only one independent member attended.

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 on Tuesday, February 6, 2024. 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 19, 2024, and that it would be posted to the website by February 20, 2024. 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 2024 stock assessment, acoustic survey, management strategy evaluation, and research.

1. The structure of the 2024 assessment model is similar to that of the 2023 model. All runs in the 2024 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 2024 assessment include a new age 2+ biomass estimate and age-composition data from the 2023 acoustic survey, a new age 1 index of relative abundance from the 2023 acoustic survey, fishery catch, age-composition data, and weight-at-age data for 2023, and minor changes to pre-2023 data (including removal of unsexed fish from the weight-at-age matrix).

3. Model-based estimates of both weight-at-age and maturity on an annual basis were developed for this assessment. Weight-at-age is based upon a model with fixed effects for sex, random effects for year and cohort, and a smoothed effect for age, in contrast to the empirical method used previously. The fecundity-at-age curve now varies across years based on temperature information (at 130 m).

4. The base-case model estimates that median female spawning biomass at the beginning of 2024 is 1.885 million metric tonnes (Mt), with a 95% credible interval from 0.853 to 4.828 Mt. This estimate represents a spawning biomass that is 99% of the unfished equilibrium level (B_0), but is highly uncertain with a wide 95% credible interval of 45% to 230%. There is a 0.2% joint probability that the stock is both below $B_{40\%}$ at the beginning of 2024 and above a level of fishing intensity equivalent to the default harvest rate of $F_{40\%}$ in 2023.

5. Total exploitable stock biomass (age 2+, males and females) at the beginning of 2024 is estimated to be 4.460 Mt, with a 95% credible interval of 2.022 to 11.288 Mt.

6. The 2024 assessment provides a positive picture of the stock but the SRG still has concerns about the status of the stock. Most importantly, the survey biomass estimate in 2023 was the third lowest in the time series, and catch utilizations were low in both countries, being only 52% for the U.S.A. and 14% for Canada. Additionally, the 2024 assessment is highly reliant on the 2020 and 2021 cohorts,estimating that spawning biomass at the beginning of 2024 is 1.885 Mt, which is roughly double the 2023 survey index of age-2+ biomass at 0.907 Mt. The magnitude of these cohorts is highly uncertain given only one and two years of age composition data are available, respectively, and they have been observed only in US waters at these young ages (age-2 and age-3 in 2023).

7. The SRG is also concerned that the proportion of fish in Canadian waters is at an all-time low with only 2.4% of survey biomass in Canadian waters in 2023 and catch attainment relative to the Canadian TAC being only 14.4% (an all-time low). The southern orientation of biomass in the survey affected biomass off Washington and Oregon as well,

resulting in an estimated biomass distribution far to the south of other years, with catch attainment relative to TAC in the US in 2023 (52.1%) being the second lowest in the past 30 years. Furthermore, predicted 2024 biomass is dominated by the young 2020 and 2021 cohorts, which are unlikely to show up in Canadian fishery catches (or surveys). Long-term trends in acoustic survey biomass show lower proportions of hake migrating into Canadian waters.

8. The addition of the 2023 data did not change the pattern of recruitment estimates but did change the estimates of recruitment in some years. The estimate of 2020 recruitment in last year's assessment was based on only two years of data and thus was highly uncertain; it suggested the cohort could potentially be huge (95% credible interval: 2.908-47.580 billion fish). With the extra year of data in this year's assessment, the 2020 cohort looks to be above average but not huge (95% interval 2.063-12.728 billion fish). The median has consequently fallen from 11.409 to 4.748 billion fish between the two assessments. The 2021 year-class is also estimated to be large, with 10.187 billion fish. The median estimate of 2014 recruitment decreased by 909 million fish (9.9%) and the median estimate of 2016 recruitment decreased by 736 million fish (11.5%). The 2014 year-class size remains well above average at 8.3 billion fish (seventh highest in the time series) but is smaller than the 2010 year-class.

9. Since 2010, this stock has been supported by multiple above-average cohorts simultaneously, but in 2024 it is predicted to be comprised mostly of the 2020 and 2021 cohorts, with 20% and 52% of the age 2+ stock biomass, respectively, at the start of 2024.

10. 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 747,588 t in 2024 and 772,111 t in 2025. Applying the default harvest policy ($FSPR_{40\%}$ — calculated using average selectivity over the last 5 years) in 2024 and 2025 results in a 16% probability that the stock will be below $B_{40\%}$ at the beginning of 2026. The probability that fishing intensity is greater than $F_{40\%}$ in 2024 and 2025 when harvesting at these levels is 37–39%.

11. The SRG considers the 2024 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 2023 SRG report, and during the 2024 SRG meeting.

12. The Joint US-Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey (ATS) survey was conducted between June 15 and September 12, 2023, proceeding north from Point Conception, CA (34.5°N) to Dixon Entrance, BC (54°N). The survey was conducted by the NOAA R/V *Bell M. Shimada* and the CCGS *Sir John Franklin*. Oceanographic and ecosystem data (e.g., eDNA, ADCP) were also collected during the survey in both countries following existing survey protocols. The SRG notes that the 2023 survey estimate of age 2+ biomass (0.907 Mt) is the third lowest in the time-series,

75% of the survey numbers were ages 2 and 3, and that only 2.4% of the estimated age 2+ biomass was in Canada.

13. Due to planned mid-life vessel refits, reducing vessel availability, NOAA is planning an integrated West Coast pelagic survey for 2025 and future years, which will combine the NWFSC Pacific Hake Ecosystem and Acoustic Trawl Survey and the SWFSC California Current Ecosystem Survey, or Coastal Pelagic Species survey. **The SRG requests a detailed plan to be presented to the SRG in a meeting planned for December 2024, to support the joint management of the Pacific Hake/Whiting stock in a comparable manner to the current hake acoustic/trawl survey, including biological sampling and eDNA collection that can be used for hake and its prey species.**

14. An update on the Pacific Hake management strategy evaluation (MSE) was provided to the SRG. **The SRG supports the effort to advance the MSE process, ongoing MSE development, and progress on the 2024 work plan identified by the MSE Team.**

15. **The SRG regards dynamic reference points as a promising innovation for assessing stock status and recommends that the JTC and the MSE Team continue this research.**

16. The SRG received updates on research on environmental influences on Pacific Hake dynamics and distribution. **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.**

17. **The SRG recommends as a high priority analysis of catch distribution, biomass distribution and predictors based on age, environmental covariates, and stock size that can explain the latitudinal distribution of Pacific Hake between Canada and the United States.**

2024 Stock Assessment

Overview

The 2024 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 (implemented in the base model since 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. In 2024, the JTC introduced a new model-based approach for developing the input matrix of weights-at-age, and new time-varying maturity ogives to better inform time-varying fecundity. These changes were investigated through the model bridging analysis, and are adopted into the 2024 base model.

A Bayesian approach is used for parameter estimation, with informative priors specified for natural mortality and spawner-recruit steepness. Changes in data from the 2023 assessment include the addition of 2023 fishery catch, age-composition, and weight-at-age data, minor updates to pre-2022 fishery data, and 2023 values for the age 1+ relative index (updated from a lognormal to Student's t distribution) and 2+ biomass index derived from the 2023 acoustic-trawl survey. Kriged results of age 2+ biomass, age composition, and the age-1 index from the 2023 acoustic-trawl survey were used in the base model for the 2024 assessment.

The 2024 assessment included the standard suite of sensitivity analyses requested by the SRG: higher standard deviations of the priors for natural mortality, an alternative prior distribution (mean and standard deviation) for natural mortality based on the Hamel (2015) and Hamel and Cope (2022) life history meta-analytic method, alternative values for steepness, alternative values for σ_R (a parameter limiting recruitment variability), the removal of the age-1 acoustic survey index, downweighting of fishery age-composition data, and alternative standard deviations for time-varying selectivity (Φ).

SRG Recommendations and Conclusions for the Stock Assessment

The SRG thanks the JTC for its detailed responses to its 2023 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. **The SRG recommends continuing sensitivities for steepness, natural mortality, σ_R, excluding the age-1 index, alternative standard deviations for time-varying selectivity, and down-weighting fishery age-composition data.**

2. **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, and particularly consider options which have age-based natural mortality.**

3. **The SRG encourages an analysis of catch and biomass distribution for Canada and US that examines latitudinal shifts in fishing over time, and tries to predict factors influencing these shifts.**

4. Pacific Hake dynamics are highly variable even without fishing mortality. **The SRG applauds the efforts of the JTC to estimate dynamic reference points, and encourages efforts by the MSE Technical Team to include dynamic reference points in the MSE process.**

5. **The SRG recommends continued work to collect ovary samples, with a focus on fecundity and functional maturity, as well as continued annual maturity analysis.**

6. On three occasions since 2009 (2011-12, 2016-17, 2023), stock assessments have predicted a rapid increase in biomass similar to that seen in the 2024 assessment, where this rapid increase was not visible in subsequent assessments. **The SRG recommends investigating what factors might be causing these shifts in biomass estimates and projections**.

7. **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, Hulson et al. 2023).

8. **The SRG has previously noted that σ_R is an influential parameter, and encourages further work by the JTC. The SRG supports continuing efforts to explore new recruitment parameterizations, including treating recruitment deviations as random effects, to better estimate σ_R.**

9. 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.

10. **The SRG recommends that the JMC review the decision tables and reconsider required harvest scenarios to reduce the number of similar and overlapping scenarios.**

11. The SRG noted that alternative structures of the assessment model have not been comprehensively examined since 2011 (e.g., multiple fleets and/or spatial model), and were informed that limited staffing and availability of the JTC inhibits these time-consuming analyses. **The SRG recommends examining structural assumptions of the stock assessment as time allows. More complex structural assumptions may utilize the data more thoroughly, explain different trends across areas and/or fleets, and estimate stock status more accurately, but simpler models may be more appropriate for determination of the TAC. The MSE can be used to determine best performing assessment models for management**.

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 Acoustic-Trawl Survey

Scientists from the Fishery Resource Analysis and Monitoring (FRAM) Division at the NWFSC and the Institute of Ocean Sciences and the Pacific Biological Station at DFO conducted the 2023 Joint US-Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey (ATS)aboard the NOAA Ship *Bell M. Shimada* and the Canadian Coast Guard Ship *Sir John Franklin*. The survey began at Point Conception, California and proceeded north along the west coast of the U.S. and Canada, surveying Queen Charlotte Sound, Hecate Strait, Dixon Entrance, and the west side of Haida Gwaii (surveyed from north to south). *Bell Shimada* surveyed the southern extent to mid-Washington starting June 27 and ending August 22. *Bell Shimada* completed leg 5 off northern Vancouver Island between August 28

and September 6. *Sir John Franklin* began surveying off mid Washington on August 16 and finished leg 1 on August 27 off Southern Vancouver Island. *Sir John Franklin* surveyed around Haida Gwaii from August 29 to September 10. *Bell Shimada* surveyed 85 transects and *Sir John Franklin* surveyed 31. There were very few days where both vessels were concurrently surveying. Survey protocols were the same as past surveys and trawling was conducted by each vessel to identify the backscatter observed by that vessel. There were 4 trawls associated with 13 acoustic regions (out of 282 regions) that were classified as hake mixed with other species, which made up 3.1% of the total unkriged biomass. Other sampling included deployment of CTDs, collection of eDNA, zooplankton, and harmful algae bloom (HAB) samples, and bongo net tows.

Hake backscatter was mostly observed south of Washington. The largest catch in weight from the entire survey was yellowtail rockfish (33.7%) with hake making up 32.1% and widow rockfish 16.3% of the entire survey catch. While hake comprised the largest survey catch in U.S. waters (10,761 kg), it was only the fourth largest survey catch in Canadian waters (409 kg), behind yellowtail rockfish, walleye pollock, and splitnose rockfish. Lengths of hake in U.S. waters ranged from 6 cm (age-0) to greater than 60 cm, while lengths observed in Canada were mainly between 43 and 60 cm. Average length generally increased with latitude. Compared to prior years, the hake backscatter was distributed to the south and a large amount of biomass extending offshore was observed near Cape Mendocino. The total estimate of hake biomass, using kriging, was 0.907 Mt with 97.6% in U.S. waters. The estimated kriged coefficient of variation (CV) was 8.61% and the North-South length scale estimated from kriging was the lowest in the time-series. The 2020 and 2021 year classes comprised the majority of the biomass, although the 2014 and 2016 year-classes were also present. An index for age-1 hake was also produced and was the 6th largest in the time-series.

HAB sampling occurred in two locations along the U.S. coast (south of Crescent City, CA and near Newport, OR). Warm water was observed along with observations of different harmful species. These areas were not associated with low densities of hake, but specific comparisons between hake biomass and HAB observations were not made.

The SRG was concerned with the low estimate of hake, especially in Canadian waters. The acoustic survey team noted that a lot of trawling was done to ensure that hake was identified when present. The biomass of hake estimated in Canada was 22,000 t and the catch in Canada for 2023 was 23,557 t. Catches in Canadian waters were high in May then declined throughout the summer, picking up slightly in August and September when the survey occurred in Canada. The SRG noted that a similar amount of hake was caught in Canada that was estimated in the survey (though note that catchability (q) of the survey is estimated in the assessment to be less than 1, such that the model estimates more hake than seen in the survey, even for fully selected age classes), but the fishery occurred over a longer period than the survey and hake are known to move between U.S. and Canadian waters within a year. Observations of trawls with no hake agreed with observations from the fishery. However, the fishery noted that in some places small amounts of hake could be caught in difficult-to-trawl locations. The SRG was interested in the estimated biomass-at-age from the survey compared to the catch-at-age from the fishery, and requested to see this comparison at the meeting.

<u>Planning for the 2025 Integrated West Coast Pelagics Survey</u>

The Survey Team provided a presentation on the planning currently underway at the Northwest Fisheries Science Center (NWFSC) and the Southwest Fisheries Science Center (SWFSC) to integrate the Pacific Hake and coastal pelagic species (CPS) acoustic surveys for summer 2025. This has international implications given the Hake/Whiting Treaty identifies the acoustic survey as a key component for the management of Pacific Hake. The survey team detailed a new Multi-Function Trawl net (MFT) that can conduct midwater trawling for hake and surface trawling for CPS, and planned 2024 summer experiments to compare this net with the AWT net currently used by both countries for the survey. **The SRG is charged with reviewing survey methodology and therefore expects to review the data and associated analyses supporting the changes to the survey well in advance of the survey commencing in 2025.**

The combination of daytime trawling for Hake with nighttime trawling for CPS species in 2025 has substantial implications for data collected during the survey. Currently this includes biological samples, oceanographic data, especially subsurface water temperatures and dissolved oxygen from CTD casts, and water samples for eDNA. Ongoing collection of subsurface environmental data is critical for model training and forecast development. **The SRG is concerned that the integrated survey may reduce or eliminate some of these key data, particularly the eDNA water samples, which are useful in developing a parallel long-term index of hake, their prey, and their predators.** In addition, the eDNA time series offers comprehensive coverage of latitude, distance from shore, and depth that can be used for a wide variety of other research projects such as marine mammal presence.

The SRG is concerned that the two weeks of comparative studies planned for the summer of 2024 will be insufficient to estimate the relative selectivity of the proposed MFT and AWT nets prior to the implementation of the Integrated West Coast Pelagics survey in 2025. Given the possible large changes moving to the integrated survey, the SRG is concerned that there could be long-term negative consequences to Pacific Hake stock assessment and management. **Therefore, the SRG recommends providing a vessel that has two net reels and can deploy both the MFT net and the AWT net for the initial survey in 2025.** This configuration will also allow for easy comparison of the existing and new multiple function trawl gear. Even in the ideal case that a new survey provides adequate coverage and biosampling, changes in biosampling could mean that there would be a break in the survey net selectivity and greater uncertainty in the Pacific Hake assessment for several years, at the very least.

The SRG is concerned about the additional time needed for Pacific Hake personnel on the survey south of Point Conception, where biological data show that the hake are different (earlier age at maturity), and any change in survey timing may affect comparability of the survey time series.

SRG Recommendations and Conclusions for the Acoustic Survey

The 2025 Integrated Survey may result in an appreciable change in the estimation of hake biomass compared to previous surveys, with potential downstream effects on management advice. The following recommendations are in order of SRG priority.

1. The SRG strongly recommends that the Integrated survey be conducted using a vessel with two net reels, to allow for the use of both the AWT and MFT gear types.

2. The MFT may have a different selectivity on age-1 hake than the AWT. As such, a longer-term comparison of the two nets is particularly important for the age-1 index time series.

3. The SRG is concerned that the integrated survey may reduce or eliminate collection of some key environmental data, particularly eDNA water samples, which are useful in developing a parallel long-term index of hake, their prey, and their predators. The SRG recommends that the Integrated Survey be provided with adequate resources to continue the collection of these data.

4. Given the advance time needed to make planning changes to this survey, the SRG recommends providing an opportunity well in advance (suggested in December 2024) to provide feedback on the plan for the Integrated Survey, as the February meeting may be too late for any recommendations to be implemented.

5. 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.

6. The SRG appreciates the availability of a draft summary of the 2023 Integrated Ecosystem and Acoustic Trawl Survey. The SRG recommends that the Survey Team continue to 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. The SRG asks that in future years, notifications are provided when draft and final documents are first available.

7. The SRG requests that the survey team continue to 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.

8. The SRG thanks the survey team for the documentation of the 2023 survey this year, and requests a written document outlining the plans for the 2025 Integrated Survey, available at the same time as the 2025 assessment (two weeks before the SRG meeting).

9. The SRG requested that the age-1 distribution plots include a summary of relevant environmental observations below each year, similar to how the age classes are displayed for the age 2+ distribution plots.

Survey-Related Research

Summer 2023 Research

Intraseasonal distribution and abundance of Pacific Hake

Madelynne Reifsteck, an undergraduate NOAA Hollings Scholar in 2023, presented her research on the intraseasonal movement and distribution of Pacific hake in the California current ecosystem. This analysis focused on analyzing the acoustic data from the 2019 hake survey, which runs from south to north beginning at Pt. Conception, and the CPS survey, which runs from north to south, beginning at Cape Scott, BC. In order to maximize the temporal contrast between surveys, Madelynne focused her analysis on the Pt. Conception to San Francisco area as the hake survey traversed this region in June and the CPS survey covered it in August. The analysis showed that: (1) there is a northward shift in abundance between June and August, with the highest abundances occurring south of Monterey Bay in June and being more evenly distributed as far north as San Francisco in August; and (2) the distance that hake distribute themselves from the shelf-break (200-m isobath) was noticeably tighter in the August data (no more than 20 km) relative to June (up to 50 km). It was noted that the acoustic data are collected and processed differently on these surveys, which probably limits the ability to develop a hake abundance index from the CPS survey data and may have contributed to the tighter distribution relative to the shelf-break in August. Biophysical and oceanographic hypotheses were suggested to explain these results. **The SRG supports the next steps to analyze the remaining transects for both surveys to compare movements and distribution over the entire geographic range of the coastal Pacific hake stock, to compare observations from the two surveys where they overlap in time and space, and to determine whether observed movements are correlated with Hake age, prey availability, climate and current shifts.**

Historical trawl temperature and depth analysis

The SRG reviewed some preliminary results from an analysis of trawl temperature and depth from the 2003 to 2023 surveys. Models were developed for gear temperature (the temperature in which a trawl is made based on year and latitude) and trawl depth (footrope depth as a function of year, latitude and gear temperature). While gear temperature is increasing slightly in succeeding years, there is no apparent link between temperature data from the survey trawls and the proportion of the Pacific hake stock in Canada by year. The depth model shows that trawls are being fished deeper over time, that trawl depths are shallower with increasing latitude, and that trawl depth is deeper with decreased gear temperature. Two potential explanations of these results are: (1) Hake are following the temperature contour down: trawls are getting deeper even though gear temperature is going up slightly, or (2) there are two behavioural paradigms: shallower "snake" hake and deeper "shelf-break" hake. **The SRG supports continuing work on this issue, including an analysis of isotherm depths relative to hake abundance and distribution.**

Additional preliminary analysis of upwelling and the proportion of hake in Canada was presented as a potential method of predicting the northern distribution of hake prior to the survey. The proportion of biomass in Canadian waters is related to age and the La Nina 3.4

climate anomaly. While the La Nina 3.4 anomaly relationship provides a prediction, it would likely be improved with knowledge of ages expected to be in Canada. **The SRG supports work developing tools such as these that can be used for survey planning and fishery planning in each country.**

Summer 2024 Planned Survey Research

Aleutian-Wing Trawl and Multi-Function Trawl net studies

Initial field trials to examine the performance of the new multiple function trawl net (MFT) developed for the Integrated West Coast Pelagic Survey were conducted on the NOAA ship *Reuben Lasker*, Dec 11-15, 2023. A total of 10 trawls with open cod-ends were conducted during this period (N=3 midwater trawls, N=7 surface trawls). While performance was considered promising for midwater trawling for hake, several issues were identified with respect to surface trawling for coastal pelagics species. The MFT net is expected to be implemented in the 2024 CPS survey in the California Current ecosystem. Additional work is needed on hake aggregations at different depths with a closed codend and comparative studies of the AWT net currently used on the survey and the new MFT net are planned for summer 2024 involving research vessels from both countries. Part of the intent of these studies is to begin developing selectivity curves for each net, which can then be used in estimating survey biomass. **The SRG supports comparative studies of the nets and the development of selectivity curves for the nets, but it is concerned that the two weeks planned for both vessels to conduct the trawl studies will not be sufficient to fully establish the selectivity of each net.**

Ongoing Survey Research Projects

Machine learning algorithms (convolutional neural networks) have been trialed to identify hake aggregations in the acoustic backscatter, with promising results. This technology has the potential to greatly reduce the processing time required to obtain abundance estimates, and to reduce subjectivity in the assignment of hake backscatter. **The SRG strongly supports the continuation and extension of this work.**

SRG Recommendations and Conclusions for Survey-Related Research

1. **The SRG strongly encourages the Joint Survey Team to continue research into the development and testing of machine learning tools to inform the classification of Pacific hake in echograms and make the assignment mixes less subjective**.

2. The SRG looks forward to the research on the multi-function trawl net (MFT) and supports the development of novel methods to ensure that daytime trawling for Pacific hake remains in the survey protocols. **The SRG recommends that in 2024 the Joint Survey Team continue to compare the performance and selection properties of the Aleutian wing trawl (AWT) net and MFT proposed for the integrated survey in order to calibrate the MFT with past Pacific hake acoustic-trawl surveys.**

3. **The SRG encourages the Survey Team to develop selectivity curves for the trawl nets used on past and future surveys and incorporate those selectivities into the**

age-1 index and age 2+ biomass index estimation process.

4. 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 Joint Survey Team by the Integrated Survey planning process is likely to be unsustainable. **The SRG encourages both agencies to commit to funding additional qualified staff to the Joint Survey Team as soon as possible to assist in the completion of survey projects and avoid burnout by current members.**

5. **The SRG encourages the continued collection and integration of US and Canadian oceanographic data (e.g., CTDs, eDNA, etc) so that analyses cover the full distribution of the coastal Pacific hake stock.**

6. **The SRG requests that the joint Survey Team provide survey age composition and biomass data by country as a routine output.**

7. The SRG appreciates the research done in 2023 by Madelynne Reifsteck, a Hollings scholar, and **encourages the continuation and extension to other years to better understand intraseasonal shifts in distribution of hake and potential implications for survey biomass estimation (both the age-1 index and age 2+ biomass).**

8. **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.

9. **The SRG supports continued research on the distribution and abundance of Pacific hake in survey research years, such as the research proposed off the west coast of Vancouver Island in 2024.**

10. **The SRG encourages continued research on hake distribution by depth and changes over time related to environmental observations.**

Management Strategy Evaluation (MSE) and Supporting Analyses

An update on the MSE process was provided to the SRG. This included a personnel update, overview of previous Pacific hake MSE work, a progress update and current work plan, and responses to 2023 SRG requests. A new postdoc began working on the MSE in November 2023, with 15-18 months of funding through OSU to test climate-robustness of Pacific hake fishery management. It may be possible to extend this position to investigate temperature-driven biomass distribution. The overview of past MSE work highlighted that a spatial operating model (OM) and MSE framework is in place, that the JMC specified goals for the MSE in 2018, and that there are objectives to use when evaluating management procedures.

The main goal of the Pacific hake MSE is to further evaluate the performance of the current and alternative hake/whiting management procedures under current and future environmental conditions, which was one of the goals set by the JMC in 2018. Additional priorities include investigating dynamic reference points, incorporating time-varying growth, and adding variability to the historical conditioned operating model (i.e. starting conditions). This work will occur in 2024 and 2025. Work has been completed on environmental drivers of

recruitment and time-varying growth, and the MSE Working Group will implement these concepts into the MSE OM.

Relating the distribution of age-0 hake and movement of all ages of hake to environmental and population variables is important for testing the climate-readiness of Pacific hake management. The distribution of age-0 Pacific hake may be driven by this environmental variable in the OM, or at a minimum the OM should incorporate variability in the proportion distributed to each area in each year. Furthermore, the SRG supports future work as in option 3 (movement driven by temperature) and recommends determining if movement could be based on age, the size of the stock, and temperature. Movement rates are confounded with age-0 distribution and these two should be investigated simultaneously.

Three options for developing climate scenarios were provided with increasing complexity of climate-driven growth and distribution. The SRG sees the benefits of each option and **supports Option 2 where growth and distribution shifts related to climate are informed by an ecosystem model, but encourages the MSE Technical Team to consider moving towards Option 3 where movement is driven more explicitly by temperature**.

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. The SRG recognizes the progress on modelling time-varying weight-at-age and understands the challenges addressing past SRG requests given the delay in funding a postdoc. Recommendations related to the MSE are shown in order of SRG priority.

1. The SRG discussed the importance of conditioning the OM to the most recent understanding of the stock dynamics and status, much of which is determined from the recent stock assessment. Therefore, given the updates and improvements in the 2024 stock assessment, **the SRG recommends conditioning the OM to be consistent with the 2024 stock assessment results and hypotheses.** This includes time-varying growth, time-varying maturity driven by a temperature covariate, and recent observations of a large percentage of age 2 and 3 fish in the population and a low acoustic survey biomass estimate. **Projections of biological processes (e.g., weight-at-age) in the OM should be random processes to incorporate time-varying properties.**

2. **The SRG recommends adding the capability to estimate dynamic reference points in the OM and estimation model (EM), respectively, and supports the investigation of management procedures using dynamic reference points in the future. This includes comparing the default 40-10 harvest control rule based on static B0 to the 40-10 rule based on dynamic B0 (either with 1-yr or 10-yr smoothing of B0).**

3. 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 of such changes on fisheries in each country.** 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. Ideally, this would be based on predictions from environmental factors if there are strong predictive links.

4. The movement and distribution of Pacific hake are confounded by age. **The SRG recommends investigating the potential to relate the distribution of age-0 recruits to environmental variables, possibly by examining the distribution of age-1 Pacific hake from acoustic survey and fishery observations.** The distribution of age-0 Pacific hake may be driven by this environmental variable in the OM, or at a minimum the OM should incorporate variability in the proportion distributed to each area in each year.

5. **The SRG supports future work as in option 3 (movement driven by temperature) and recommends determining if movement could be based on age, stock size, and temperature (or other environmental/physical drivers).** Movement rates are confounded with age-0 distribution and these two should be investigated simultaneously.

6. 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 the MSE be used to investigate the risk of overpredicting or underpredicting the magnitude of the year class due to the age-1 index.**

7. **The SRG requests documentation of the MSE operating model and results from 2024 to be distributed at the same time as the stock assessment (i.e. at least two weeks before the 2025 SRG meeting).**

8. **The SRG recommends that the MSE investigates simpler EMs (to be used as an assessment model) to guide management in some years (such as following years without surveys), which could ideally reduce assessment workloads in those years while providing similar advice.**

Other Research Related to Pacific Hake

Early indications of Pacific Hake recruitment

The SRG reviewed a presentation from Andrew Edwards on using NOAA's rockfish recruitment and ecosystem assessment survey (RREAS) data to provide early indications of age-0 Pacific Hake recruitment. The idea is based on the community ecology concept of size spectra, which characterise how a property of a community varies with body size. When the body sizes of all levels of a community are plotted against their abundance in the community, the slope of the relationship is an ecosystem indicator of stability. The slope of the line is called the size spectra exponent. External factors such as fishing can change the slope of the line.

A somewhat different use of this approach is proposed. Data on lengths of age-0 hake caught in the RREAS are plotted against counts for each length bin and a model is fitted to the descending limb from which the slope (size spectrum exponent) is estimated. The exponent is then plotted against estimates of recruitment from the stock assessment model to develop a relationship, which could be used to inform management advice. Operationalising this work is possible since length data from the survey become available in November prior to the stock assessment.

Select observations from the 2023 Hake Survey oceanography sampling

A total of 275 CTDs were conducted off of the NOAA Ship *Bell M. Shimada* and 74 off the CCGS *Sir John Franklin* during the 2023 survey on every other transect (20 nmi spacing). Core depths for sampling were the 50, 150, 300, 500, and 1500 m isobaths. Cool surface waters were observed off CA due to strong upwelling. There was a narrower upwelling band off OR and WA, where warmer surface waters were located. Higher surface salinity was observed in CA due to upwelling, with narrower upwelling bands off OR and WA, consistent with the temperature observations. Both salinity and temperature data are indicative of habitat compression off of OR and WA. Midwater hypoxia was detected off central WA, which coincides with a 'break' in hake backscatter during the survey. Bottom hypoxia was observed along most of OR and WA shelf.

2023 continued the trend of having a Marine Heat Wave every year since 2019, and this was followed by an El Nino event. Sampling for harmful algal blooms (HABs) found unusual phytoplankton communities, while krill relative abundance was the second lowest reported since 2007.

Fourier transform near infrared spectroscopy (FT-NIRS)

The SRG viewed an update on research on Fourier transform near infrared spectroscopy (FT-NIRS) of otoliths conducted by NWFSC scientists. FT-NIRS measures light absorbance signatures of otoliths and models how the infrared spectra relate to age with the goal of implementing this approach to ageing. The advantages of FT-NIRS relative to current traditional human age readers are speed and repeatability. After calibration, ageing speed increases by a factor of 10 compared to traditional age reads. Results for walleye pollock are promising with an R^2 value of ~0.9 (±1 year 67% of the time; Helser et al. 2019). It was noted that 2,852 ages from 2019 acoustic survey trawls will take about 12 working days to scan and estimate ages. **The SRG considers FT-NIRS a promising tool to support age reading requirements for the stock assessment and supports ongoing research to refine the approach as it applies to Pacific hake.**

Investigation of Bottom Trawl Survey Data

A collaborative DFO and NOAA project to compile 2003-2021 bottom trawl survey data on Pacific hake from California to Alaska and model hake distribution was reviewed by the SRG. This analysis is preliminary so conclusions are not available. However, the bottom trawl data appear to capture hake from the coastal stock and not inland stocks such as those in the Strait of Georgia and Puget Sound. A calculation of the centre of gravity of hake biomass off the contiguous U.S. (excluding Alaska and Canada) shows about 4 degrees of latitude variability across years, with the most southerly concentration in the 2012-2014 period, centered around 40º N. Trends in biomass in the bottom trawl and acoustic trawl surveys were complex and did not always align in easily interpretable ways. However, these analyses are preliminary and may improve with future modeling efforts.

Recommendations for Additional 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 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.** This includes the J-SCOPE oceanographic forecasts which provide a basis for improved in-year predictions of Pacific Hake distribution and abundance and may 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 fecundity at size and age, including temporal and latitudinal variation.**

Other SRG Recommendations

1. The SRG has been missing members for several years due to delays in finalizing appointments before the February meeting. These delays affected two key members in 2024 resulting in diminished expertise and capacity to deliver on the terms of reference of the SRG. **The SRG recommends that appointments and reappointments are made before summer in each year (ideally as soon as possible after nominations are made at the February/March JMC meeting), to allow for time to start the contract process in summer the year before the meeting occurs.**

2. **The SRG recommends appointing a fifth JTC member, as specified in the Treaty.** It will be important that this fifth JTC member has the skills and time to contribute substantially to the hake assessment and other analyses, especially since the MSE process will be transferred to the JTC in 2025, substantially increasing their workload.

3. The earlier meeting schedule this year was problematic for the SRG. The JTC requires until the end of January to produce the stock assessment. This year the meetings were scheduled earlier than usual led to suboptimal amount of time for the JTC to prepare and fully check the stock assessment, and for the SRG members to review all of the documentation prior to the SRG meeting, such that issues were discovered during the course of the meeting rather than during pre-meeting review. **Therefore, the SRG recommends discussions on meeting timing that allows for time to prepare the assessment, review the assessment, and present the SRG report with sufficient time for the JMC to use it in their decisions.**

4. **The SRG recommends maintaining routine communication among all bodies (AP, JMC, SRG, JTC, Joint Survey 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.**

5. **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.**

6. The SRG appreciates that for several years now, the Survey Team, the JTC, and the MSE Technical Team have presented explicit responses to previous SRG recommendations, and **request that this approach be continued indefinitely.**

7. **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.**

ATTACHMENT 1

Joint US-Canada Scientific Review Group for Pacific Whiting

DRAFT AGENDA

Vancouver Island Conference Centre, Nanaimo, BC

Online Webinar Meeting (Connection information at the end of the agenda)

February 6-9, 2024

<u>**Tuesday, February 6, 2024**</u>

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

09:30 **Review and Approve Meeting Agenda** (Chair)
  • Review Terms of Reference for Assessments and Review Meeting
  • Meeting report mechanics
  • Assignment of reporting duties
  • Review of meeting norms and expected behaviours
  • Review procedures for resolving communication issues throughout the meeting

09:45 **2023 Integrated Ecosystem & Pacific Hake Acoustic-Trawl Survey** (Survey Team)
  • Integrated acoustic-trawl survey results including Biomass Indices, Age-Composition Data

10:45 *[11:00-15]*   *Break*

11:00 [*11:15*] **Fisheries, Data, and Inputs Used in the 2024 Assessment** (JTC & AP Advisors)
  • 2023 Fisheries Catch, Size, and Age Composition Data
    ▫ Canadian Waters
    ▫ U.S. Waters

11:30 **Modeling of time-varying weight-at-age** - Andrea Odell, Kelli Johnson

12:00 **Modeling temporal and spatial trends in hake maturity-at-age** – Eric Ward

12:30   *Lunch*

13:45 *[2:00pm]*   **2024 Pacific Hake/Whiting Assessment Modeling** (JTC)
  • Methods, results and discussion
  • Model performance and diagnostics: sensitivities and retrospectives
  • Forecasts and management implications
  • Discussion

15:00 *Break [skipped]*

15:15 **2024 Pacific Hake/Whiting Assessment Modeling (cont.)** (JTC)

16:00 **Public Comment**

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

16:25 *Break*

16:35   **SRG Work Session**

17:00   *Adjourn for the day*

Wednesday, February 7, 2024

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

09:30   **Pacific hake/Whiting Management Strategy Evaluation (MSE) Update** (MSET, JTC)
  • Responses to SRG recommendations
  • Update on MSE process & 2024 work plan
  • SRG Discussion & Recommendations

10:30   *Break*

10:45   **Review responses to 2023 SRG Stock Assessment Recommendations** (JTC)
  • SRG discussion, develop list of requests for JTC, as needed

12:00   *Lunch*

13:30   **Update on ecosystem and life-history research**

14:30   **Investigating NOAA's Rockfish Recruitment and Ecosystem Assessment Survey data to provide early indications of Pacific Hake recruitment** – Andrew Edwards

15:00   *Break*

15:15   **Review responses to 2023 SRG Ecosystem and Life-History Research Recommendations** (JTC)
  • SRG discussion, develop list of requests for JTC, as needed

16:00   **Public Comment**

16:15   **SRG discussion,** requests for additional information JTC, Survey Team, and MSE, as needed

16:30   **SRG Work Session**

17:00   *Adjourn for the day*

Thursday, February 8, 2024

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

09:30   Integrated West Coast Pelagic Survey and **Pacific Hake Acoustic-Trawl Survey Research** (Survey Team)
  • Integrated West Coast Pelagics Survey updates and planned 2024 research
  • SRG Discussion & Recommendations

10:30   *Break*

10:45   Ongoing Research (Survey Team)

  ● Hollings project on hake movement and migration - Lasker & Shimada acoustics data (Maddie Reifsteck)
  ● Updates on Research & Collaborative Projects (Canada & US)

12:00   *Lunch*

13:30   **Review of 2023 SRG Survey Recommendations** (Survey Team)

13:45 **Updates on any other hake-related research projects** (JTC/Survey)

- Ocean Observations and Environmental Analyses (Survey Team)

15:00 *Break*

15:15 **SRG Discussion & Work Session**
- Stock assessment model finalization and management outcomes (as needed)
- Finalize research needs/priorities for assessment, survey, and MSE

16:00 **Public Comment**

16:15 **SRG discussion,** requests for additional information JTC, Survey Team, and MSE, as needed

16:30 **SRG Work Session**

17:00 *Adjourn for the day*

Friday, February 9, 2024

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

09:30 SRG discussion continued of research needs for 2024 and longer-term
- Evaluation of base model and primary sources of uncertainty
- MSE methodology and approaches

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

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

13:00 SRG *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, Canadian appointee
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

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
Chelsea Stanley - DFO, IOS, Acoustic Survey

Kristin Marshall - NOAA, NMFS, NWFSC, MSE Team
Maddie Reifsteck - NOAA Hollings Scholar, NWFSC

Sandra Curin Osario - NOAA affiliate, NWFSC
Bob Dooley - AP
Stephanie Johnson - NOAA GC
Frank Lockhart - JMC, NOAA WCR
Trent Hartill - American Seafoods
Jim Hastie - NOAA, NMFS, NWFSC
Corey Niles - WDFW
Mike Okoniewski - AP
John Pohl - NOAA, NFMS, NWFSC, Survey Team
Craig Russell - NOAA, NMFS, NWFSC
Colin Sayre - NOAA WCR, Treaty Coordinator
Steve Schut - DFO
Dave Smith - AP
Maggie Sommer - NOAA WCR
Eric Ward - NOAA, NMFS, NWFSC