Joint U.S.A. - Canada Scientific Review Group Report for 2021

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Introduction

Under the authority of the Agreement Between The Government of The United States of America and The Government of Canada on Pacific Hake/Whiting (hereafter referred to as "the Treaty"), the Scientific Review Group (SRG) met virtually via Webex, February 22-25, 2021 to review the draft stock assessment document prepared by the Canada/U.S.A. Joint Technical Committee (JTC), progress on an MSE focused on Pacific Hake/Whiting (Pacific Hake), and planning for the coastwide acoustic survey to be conducted by both nations in 2021. The SRG based its terms of reference on the language of the Treaty and on the Pacific Fishery Management Council's Stock Assessment and Review (STAR) terms of reference, which the Joint Management Committee (JMC) approved as the formal Terms of Reference for the SRG. The SRG is composed of two US, two Canadian, and two independent members designated by the JMC, based on recommendations from the Advisory Panel (AP), and two industry advisors from the AP.

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

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

2. Providing annually, by March 1 unless otherwise specified by the Joint Management Committee, a written technical report of the stock assessment and its scientific advice on annual potential yield; and

3. Performing other duties and functions as directed by the Joint Management Committee.

The SRG meeting convened at 09:00 Monday, February 22, 2021. John Holmes (SRG co-chair) welcomed attendees and after a round of introductions reviewed the SRG Terms of Reference, ground rules for a productive virtual meeting, and the proposed agenda (Attachment 1). The co-chairs then assigned reporting duties to each SRG member. It was noted that the SRG was expected to submit its report to the JMC by March 2, 2021 and that it would be posted to the website by March 3, 2021. Meeting participants represented the AP, JMC, JTC, Acoustics Team, MSE Technical Team, and stakeholders (Attachment 2). **Text highlighted in bold throughout this report indicate 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 2021 stock assessment and acoustic survey research.

1. The structure of the 2021 assessment model is similar to the 2020 model. The main difference is that the 2021 model uses a new and more efficient algorithm (the No-U-Turn Sampler—NUTS) for obtaining posterior samples that better characterizes the uncertainty in the model results. All model results, including sensitivity and retrospective analyses, are now based on posterior distributions rather than maximum likelihood estimates. One consequence of using NUTS is that projections and retrospective analysis take longer to run than previously, adding to the workload and planning that the JTC must undertake. The uncertainty measures in this assessment are based on the data, structure, and processes

included in the model. Thus, uncertainty in current stock status and projections is likely underestimated.

2. Additional data for the 2021 assessment include fishery catch, age-composition data, and weight-at-age data for 2020 plus minor updates to pre-2020 data. The Canadian At-Sea Observer program (ASOP) requirements on licenses to fish were lifted in 2020 because they were deemed to create a human health risk for at-sea observers and fishers and to constitute a public human health risk due to the coronavirus pandemic (COVID-19), and as a result, age data were not collected from the Canadian freezer-trawler feet in 2020.

3. The SRG considers the 2021 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 2020 SRG report. The SRG also acknowledges the tremendous amount of work that was involved in developing a draft document that is compliant with Section 508 of the Rehabilitation Act of 1973 which requires U.S. Federal agencies to make their electronic and information technology (EIT) accessible to people with disabilities. Additionally, this work allows for the rapid updating of the final document in Section 508-compliant form.

4. The 2020 data did not change the pattern of recruitment estimates but did change the estimates of recruitment in some years. The median estimate of 2014 recruitment decreased by 0.5 billion fish while the median estimate of 2016 recruitment increased to 4.8 billion fish, which is 6% higher than the estimate from the 2020 assessment model. The 2010 year class is the second highest in the time series (after that for 1980) and the 2014 year class size remains well above average at 8.9 billion fish (fifth highest in the time series) but smaller than the 2010 year class, which is estimated to be 16.1 billion fish. There is more certainty that the 2016 year class is above average and that the 2017 year class is about average due to observations of both cohorts in the 2019 survey and 2020 fishery.

5. It is unusual for this stock to be supported by multiple above average cohorts simultaneously as at this time. The 2010, 2014, 2016, and 2017 cohorts are predicted to comprise 14%, 25%, 24%, and 17%, respectively, of the stock biomass at the start of 2021.

6. The base-case model estimates that median female spawning biomass at the beginning of 2021 is 0.980 Mt, with a 95% credible interval from 0.404 to 2.388 Mt. This estimate represents a spawning biomass that is 59% of the unfished equilibrium level (B_0), with a 95% credible interval of 25% to 137%. There is a 1.7% probability that the stock is both below $B_{40\%}$ at the beginning of 2021 and also above a level of fishing intensity equivalent to the default harvest rate of $F_{40\%}$ in 2020.

7. Total exploitable stock biomass (age 2+, males and females) at the beginning of 2021 is estimated to be 1.610 Mt, with a 95% credible interval of 0.930 to 6.265 Mt.

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, B_0. The base-case model forecasts that catches of 565,191 t in 2021 and 427,836 t in 2022 could be achievable when fishing at the default harvest rate, $F_{40\%}$ (calculated using average selectivity over the last 5 years). Applying the default harvest rate in 2021 and 2022 results in a 55% probability that the stock will be below $B_{40\%}$ at the

beginning of 2023. There is a slightly greater than 50% chance that the fishing intensity would be greater than $F_{40\%}$ in 2021 and 2022 when harvesting at these levels, due to equilibrium assumptions in the assessment model.

9. Under all catch levels examined the stock is expected to decline for the next two years. In the absence of fishing, the probability that the stock will be below $B_{40\%}$ at the beginning of 2023 is 16%.

10. Including the age-1 index in the stock assessment leads to slightly more optimistic results, but continues to show that the stock will decline under all catch levels examined.

11. An acoustic survey is planned for the summer 2021. The design of the survey takes into account COVID-19 protocols for ship operations, available ship time in both Canada and the United States, and the need to conduct an inter-vessel calibration. Transect spacing is expected to be 10 nmi from Point Conception (34.5°N) to the north end of Vancouver Island (50.5°N) and 20 nmi spacing north of Vancouver Island to Dixon Entrance (54.5°N). To cover the entire survey area with the above constraints, the current plan includes a return to the 1500 m offshore limit protocol used in the pre-SaKe survey period (1995-2011), and also skipping every eighth transect from the starting point to the north end of Vancouver Island. The Survey Team outlined contingency plans to address the potential impacts of positive COVID-19 tests on the availability of either the Canadian or US survey vessels and changes in schedule as the survey proceeds. **The SRG concurs with this design approach for the 2021 survey.**

12. An update on the Pacific Hake management strategy evaluation (MSE) was provided to the SRG. The SRG applauds the work of the MSE Technical Team members over the past year in both the areas of model development and in addressing SRG comments pertaining to documentation. This progress is especially noteworthy given the COVID impacts on working conditions and the fact that the MSE Technical Team contains no individuals that are dedicated solely to advancing Pacific Hake MSE programming and application. The MSE Team is exploring important questions regarding the operating model and its behaviour that when resolved will advance this important tool for providing strategic advice. **The SRG continues to support ongoing MSE development and progress on the workplan identified by the MSE Team for 2021.**

13. The SRG reviewed plans for and results of research on environmental influences on Pacific Hake dynamics and distribution. **The SRG supports the continuation of this work and anticipates further improvements in forecasting skill with the introduction of transport covariates and other covariates of stock dynamics. The SRG believes that results of this kind of research are useful in refining the MSE operating model and in examining potential impacts of global climate change scenarios on the Pacific Hake stock.**

14. The SRG considered revisions to the decision tables in the stock assessment that depict fishing intensity for several catch streams and the associated impacts on the stock in terms of depletion (spawning biomass relative to B_0) for those catch streams. One main change was implemented: relative spawning biomass was projected forward for three years from 2021 instead of two years and the relative biomass values shown in each row now reflect the projected impact of the specified amount of harvest on stock status at the beginning of the following year. Additionally, the 25% and 75% intervals have been removed from both tables, leaving the median along with the 5% and 95% values from the distributions that

define the 90% credible intervals. **The SRG believes that the resulting decision tables are clearer and easier to understand and recommends that the JMC review these tables along with the standard decision tables, and provide feedback to the SRG and JTC as to its preference during the March 15-17, 2021 JMC Meeting. These alternative decision tables are presented in Appendix B of the JTC Stock Assessment document.**

2021 Stock Assessment

Overview

The 2021 assessment uses the same model structure as used in assessments since 2014. The model begins in 1966, and catches are modeled as being taken by a single coast-wide fleet. The model is informed by catch and age-composition observations from the fishery, an age 2+ biomass index from the acoustic/trawl survey, and observations of survey age-composition from trawl samples taken during the survey. Age-specific selectivity for ages 1 to 6 is estimated for the fishery and ages 2 to 6 for the survey, with constrained annual variation allowed in fishery selection up to age 6. The base model uses a matrix of empirical (observed) weights-at-age in calculating annual fecundity, as well as catch and biomass, and continues the approach, first applied in the 2018 assessment, of using Dirichlet-multinomial likelihoods to estimate the weighting of the age-composition data. The model also uses the same input value used since the 2018 assessment model for the fixed parameter ($\Phi = 1.40$) that constrains the year-to-year variation in fishery selection parameters. A Bayesian approach is used for parameter estimation, with informative priors specified for natural mortality and spawner-recruit steepness. Changes from the 2020 assessment include the addition of 2020 fishery catch, age-composition, and weight-at-age data, and minor updates to pre-2020 fishery data. Sampling of catch from the Canadian freezer-trawler fishery did not occur in 2020 due to precautions associated with the COVID-19 pandemic and thus 2020 age-composition data are not available from this fishery.

The 2021 base model implements a Bayesian MCMC sampler (the no-U-turn sampler (NUTS) algorithm) to estimate parameter uncertainty in place of the random walk Metropolis-Hastings MCMC algorithm used in the 2020 base model and previous base models. 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. Investigation of the posterior distribution illustrated that the NUTS algorithm provided better coverage of the parameter space than the random-walk Metropolis-Hastings algorithm used previously. While the NUTS algorithm speeds up the main model estimation, other sensitivity and forecast runs take longer to complete than when using a maximum-likelihood estimator. Nevertheless, 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.

The 2021 assessment included the suite of sensitivity analyses that the SRG has requested as a standard package: alternative standard deviations of the priors for natural mortality, alternative values for steepness, alternative values for sigmaR (σ_R, a parameter limiting recruitment variability), and inclusion of the age-1 acoustic survey index. Sensitivity runs were also conducted to illustrate the sensitivity of the 2021 assessment results to alternative data-weighting methods, flexibility of time-varying selectivity (Φ), and alternative parameterizations of time-varying selectivity. The JTC provided a sensitivity run using the random-walk Metropolis-

Hastings algorithm, as an alternative to the NUTS MCMC implementation used in the base model. In response to the lack of age data from the Canadian Freezer-trawler fleet in 2020, the JTC provided a sensitivity run in which the age data from this fleet were also removed from 2019 with little effect on the results. It was also noted that this fleet's fishing behavior was similar to that in prior years, providing confidence that 2020 age data were likely similar to previous years.

SRG Recommendations and Conclusions for the Stock Assessment

The SRG thanks the JTC for its detailed responses to its 2020 recommendations and has several additional recommendations for future iterations of the Pacific Hake stock assessment.

1. **The SRG notes that σ_R is an influential parameter and that determining the choice of σ_R remains a challenge and encourages the JTC to continue to work on the issue.**
2. **The SRG recommends exploring alternative methods to simulate recruitment in the projections, such as drawing from past observations or using a mixture distribution, to characterize a different process than the assumed lognormal distribution.**
3. **The SRG requests that the JTC consider developing a decision table in the next assessment with recruitment fixed at the median and mean levels to assess the resulting impact on stock depletion.**
4. Pacific Hake dynamics are highly variable even without fishing mortality. **The SRG encourages the JTC (and MSE technical team) to continue investigating the usefulness of dynamic reference points in the management of Pacific Hake.**
5. The SRG encourages work to develop a picture of the Pacific Hake reproductive cycle both seasonally and at the life-time scale based on histological and physiological measurements. In addition, the SRG notes that Canadian samples and those from the winter research cruises should be included in the maturity analysis. **The SRG encourages continued sampling and analysis to improve understanding of the Pacific Hake reproductive cycle**.
4. **The SRG strongly supports the ongoing genetic analyses to determine whether there are genetic differences between Pacific Hake from the area south of Point Conception and coastal regions to the north.**
5. **The SRG also recommends continuing to conduct the following sensitivities: steepness, natural mortality, σ_R, alternative standard deviations for time-varying selectivity, and down-weighting fishery age-composition data.**
6. **The SRG encourages the JTC to include a complete reproduction of the executive summary incorporating the age-1 index in the next assessment and, if time permits, the retrospective analyses.**
7. Based on the preliminary results shown, previous assessments have 'correctly' projected an increase or decrease in recruitment and spawning biomass in subsequent years, although the projections are usually less definitive than the current base model results. Given that this analysis provides some confidence in the current expectations of continued stock decline, **the SRG recommends that the JTC continue to explore and refine this analysis for future assessments.**

8. The SRG notes that there are currently multiple strong cohorts in the stock where previously there was only one strong cohort during the period of sample collection for the ageing error matrix that supports the assessment model. **Based on this observation, the SRG recommends that an ageing error study using samples collected during the past decade be conducted in conjunction with the Committee of Age Reading Experts (CARE).**

9. **The SRG recommends that historical sources of data be investigated to determine whether they can be used to supplement the weight-at-age matrix**, including unaged otolith samples (and associated data) from the 1970s that may be available in the Burke Museum in Seattle.

10. **If biological data cannot be collected by any fleet in 2021, the SRG encourages the JTC to explore model sensitivity to that absence. We commend the JTC for their foresight in investigating the impact of the lack of 2020 Canadian freezer-trawler age data in this year's assessment.**

11. Uncertainty in weight-at-age is not accounted for in the stock assessment and a five-year average of recent observations is used for all years of the projections. **The SRG requests that the JTC explore alternative methods for forecasting weight-at-age and evaluate whether they can improve projections.**

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

Management Strategy Evaluation (MSE) and Supporting Analyses

The SRG received an updated draft technical report on the MSE, a draft progress update on the MSE, and a presentation from the MSE Technical Team which provided an overview of the implementation of a MSE process for Pacific Hake.

Over the past year, the MSE Technical Team has worked to articulate goals for the next phase of the MSE, which include updating objectives, exploring alternative management procedures, better understanding structural assumptions in the operating model, and supporting the JTC with ongoing research needs for the stock assessment. A work plan was developed in 2020 to help meet these goals, with planned work to be undertaken by the MSE Technical Team, including the coordinator (Kristin Marshall, NOAA), Aaron Berger (NOAA), Chris Grandin (DFO), and Ian Taylor (NOAA). In addition, the MSE Technical Team continued to engage with the JMC in 2020 to better define the objectives and performance metrics that will be used to evaluate alternative simulation results, including spatial objectives and performance metrics linked to the distribution of TAC and catch among countries. Considerable work was undertaken over the past year to improve the flexibility of the code for adding new scenarios. The code is now structured into an R-package with automated code testing and integrated plotting functions. These updates will support rapid MSE analyses in the future. Work has continued on defining useful objectives and performance metrics to evaluate the simulation results. Area- specific objectives and performance metrics are being considered and discussed with the JMC.

The MSE closed-loop simulation model consists of (1) an operating model (OM) which describes hypotheses of the "true" population and spatial dynamics of Pacific Hake, and (2) a

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

The OM currently includes four seasons and two areas (Canada and the US), with movement between areas depending on the age of fish and season. Seasonal movement patterns are fixed over time. The MSE technical team is investigating recruitment and other options to improve the conditioning and tuning to unfished spawning biomass.

One goal for the MSE focuses on providing each country with the opportunity to attain their allocation of the TAC as specified in the treaty. The specific objective and performance metrics that will be used to evaluate MP performance relative to this goal are still being determined, but the MSE technical team is exploring attainment scenarios that allow the impact of each country's fishery to be assessed relative to this goal, both within a year and over multiple years. These scenarios include estimating the effect of partial attainment in each country on attainment in the other country, and are currently in progress.

The MSE Technical Team identified five areas of ongoing and future work. These areas include: 1) resolving recruitment and movement implications, 2) simulating attainment scenarios, 3) implementing uncertainty in historical simulated trajectories (i.e. initial conditions), 4) developing and testing new management procedures, and 5) incorporating environmentally-driven scenarios.

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

Recommendations for Next Steps in the MSE

1. **The SRG encourages continued development and editing of the technical document**. The technical document should be a standalone document to which MSE results presented in separate documents can be linked to a specific version of the technical document.
2. MSE operating models are typically complex to allow for the simulation of many scenarios representing a wide range of uncertainty and must be conditioned to mimic the dynamics of the population. **The SRG suggests that the JTC consider simpler models to help understand the complex components of the existing conditioned OM and implement these simpler models if appropriate**. For example, a coastwide stock-recruitment relationship with coastwide recruitment apportioned to each area may better fit the limited knowledge of recruitment for Pacific Hake. This approach may also allow for a reduction in the number of seasons and still allow for fishing periods and a spawning/recruitment period in the operating model.
3. **The SRG encourages adding the capability to calculate/estimate dynamic reference points in the OM and EM, respectively, to allow investigation of management procedures using dynamic reference points in the future.**

4. **The SRG encourages the MSE Technical Team to continue working with the JMC and AP members to define and clarify goals and objectives.**
5. **The SRG strongly supports the MSE process, which is valuable for strategically advancing Pacific Hake stock assessment science and management.**

Ecosystem-related research

Ecosystem Drivers of Pacific Hake Recruitment

The NW Fisheries Science Center is supporting a postdoctoral scholar conducting research on stage-specific drivers of Pacific Hake recruitment to inform the stock assessment and management strategy evaluation. The research is focusing on predictive relationships between recruitment deviations estimated by the stock assessment model and oceanographic variables derived from a Regional Ocean Modeling System (ROMS), predator (California sea lion pup index, Arrowtooth flounder biomass and age-1 Pacific Hake biomass), prey (age-2 Pacific herring biomass, age-0/1 Pacific Hake biomass, zooplankton/euphausiid abundance), and large-scale climate (PDO, ENSO, NPGO, spring transition date, bifurcation index, storm and calm indices) indices as predictor variables. Results so far show a negative relationship between recruitment and the location of the North Pacific Current bifurcation during the adult female preconditioning stage, a negative relationship to calm periods and both positive and negative influences of days between storm events (quadratic relationship) during the first-feeding larval stage, and a negative relationship between age-1 and age-0 Pacific Hake, suggesting predation or competition. The preliminary conclusion based on these findings is that cohort strength appears to be established between the early larval and age-0 juvenile stage and female Pacific Hake preconditioning stage is an important determinant of cohort strength. These results are, however, limited by the temporal and spatial extent of the ROMS model (1980-2010 and 31-47°N). Work is continuing to extend the analysis to recent years, and to develop quantitative linkages to inform the stock assessment and MSE process.

Related Ecosystem Research

A new database has been developed to house biological, trawl, and sensor data taken during the Pacific Hake survey, including lab analysis results from diet and histology samples. Data from the 2005 to 2019 surveys and diets have been uploaded. The updating of histological data, as well as the inclusion of metadata and diet records collected in Canada, are planned. The collection of these data within a single database will enhance the ability to conduct spatial-temporal analysis of Pacific Hake diets.

Several of these types of analyses are planned or underway. One project involves the estimation of euphausiid distribution/abundance and mapping their spatial overlap with Pacific Hake, while related work is investigating the spatial and growth response of Pacific Hake to krill availability. Work is also underway to improve the acoustic classification of euphausiids. Two new modeling efforts involving Pacific Hake and krill that are promising in terms of improving understanding of Pacific Hake population dynamics and distribution: (1) this effort is integrating data on Pacific Hake and krill into the California Current's Atlantis ecosystem model, which will facilitate investigation of larger-scale influences of krill abundance and distribution on Pacific Hake, and (2) the second modeling effort is planning the development of a Pacific Hake multispecies model (along the lines of the CEATTLE model for Bering Sea Pollock (Holsman et al. 2016), that will

include Pacific Hake and krill. These two modeling projects will be pursued with the assistance of postdoctoral scholars.

The SRG also received a presentation on building an "ecosystem indicator" report for Pacific Hake to provide supplemental information and context for management decision-making. A pilot set of Pacific Hake-focused ecosystem indicators from the U.S.A. of system productivity, recruitment drivers, Pacific Hake distribution, prey abundance and condition, predation pressure/mortality, bycatch, and socio-economic considerations was discussed. More than one indicator is available in some of these themes and some of the indicators may be derived from Pacific Hake research currently underway and supported by the SRG such as drivers of recruitment, and forecasting biomass distribution and abundance based on temperature. Several ways to present this kind of information, including a stoplight approach and other synthetic figures, were discussed with no clear favourite emerging from this initial exposure. Expanding this work into Canada would ensure robust utility of this kind of information for decision-makers in both countries.

Recommendations

1. The SRG is encouraged by the initial results of this research into environmental drivers of Pacific Hake recruitment shown during the presentation at this meeting and **the SRG supports the ongoing research to develop predictive relationships of Pacific Hake recruitment that can inform the stock assessment forecasts and MSE process.**
2. **The SRG encourages continued ecosystem-related research into the drivers of Pacific Hake distribution and productivity.** The SRG notes that forecasts of euphausiid (*Euphausia pacifica* and *Thysanoessa spinifera*) distribution and abundance could improve predictions of Pacific Hake movement 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.

2021 Summer Acoustic Survey

The SRG received a briefing on the 2021 summer acoustic survey, which is planned for June 27 to September 24. The design of the 2021 survey is greatly affected by health and safety precautions related to the continuing COVID-19 pandemic, limitations in available United States ship time, and the need to integrate inter-vessel calibration (IVC) between the NOAA Ship *Bell M. Shimada* (Shimada) and CCG Ship *Sir John Franklin* (Franklin) into the survey timeframe, since an IVC was not completed in 2020, due to the COVID-19 pandemic. Activity aboard the Shimada is restricted to a total of 75 days at sea (DAS), as well as a cap on the start-to-Newport stretch (Legs 1and 2) of 45 days and a required 16-day port stay in Newport before starting the final portion of the Shimada survey effort, Leg 3 (Figure 1).

As in previous years, the survey will begin in the US at a randomly-determined location near Point Conception (34.5°N) and will use primarily 10-nm spacing between transects from Point Conception to the northern end of the West coast of Vancouver Island (50.5°N) and 20-nmi spaced transects from the northern end of Vancouver Island to Dixon Entrance, (54.5°N). The

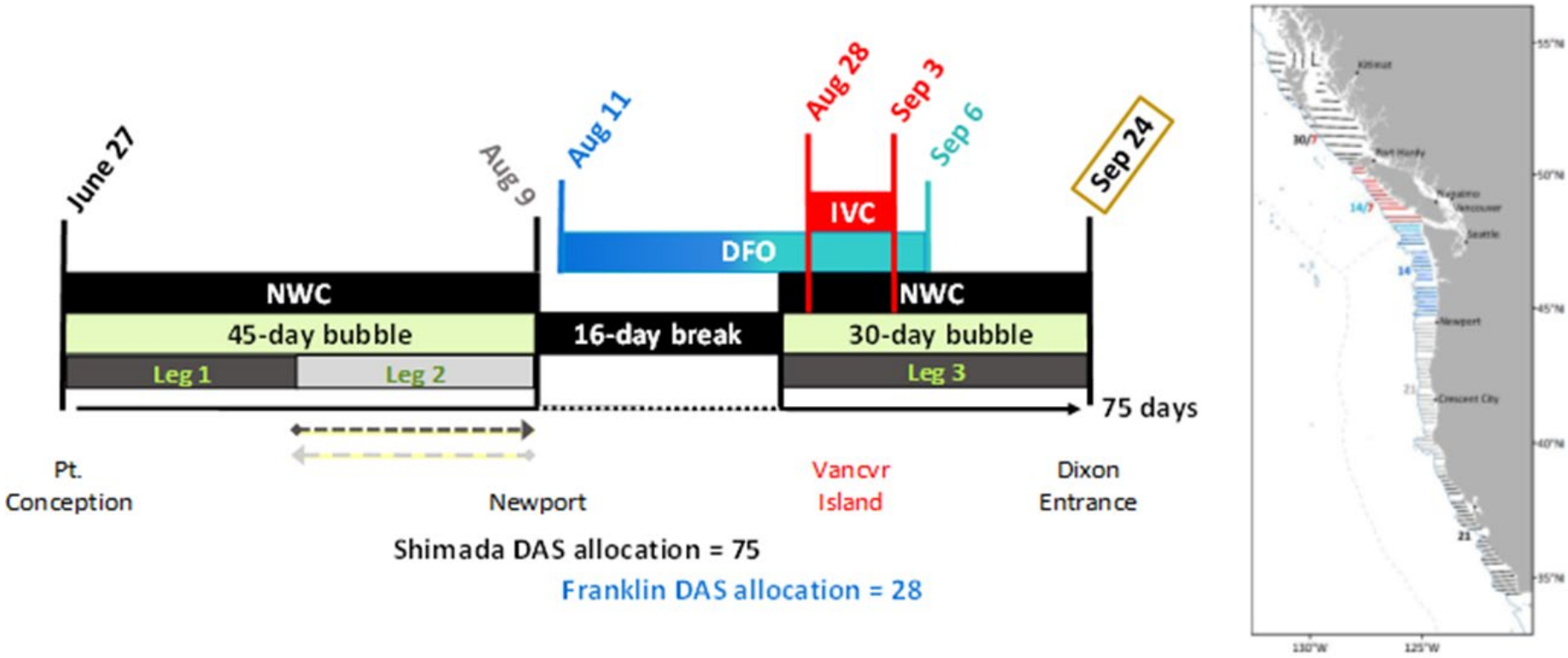

Figure 1. Summer 2021 acoustic survey planned spatial coverage (right panel) by the Shimada (grey transects), the Franklin (blue transects) and both vessels (red transects) and timing of the survey Legs delivered by each vessel.

US survey effort on the Shimada will proceed north to cover the survey area up to Newport, Oregon, before the Shimada is in port for a required 16-day port stay (Figure 1). The Canadian effort on the Franklin will begin on August 11 off Newport, Oregon, and will continue to the northern end of Washington. The two vessels will meet to jointly cover the survey area off the West coast of Vancouver Island, while conducting the IVC between August 28 and September 3. The Franklin will conclude survey activities on September 6, while the Shimada will cover the remaining survey area north of Vancouver Island to Dixon Entrance.

To cover the traditional latitudinal extent of the US-Canada survey and complete the IVC within the Shimada's 75 DAS and the Franklin's 28 DAS allocations, two survey changes are planned, in addition to the exchange of normally surveyed regions. First, rather than extending all transects to at least 35 nm or 1,500 m, whichever is greater, as has been the case since 2012, transects will extend from 50 m inshore to a depth of 1,500 m offshore, and will continue beyond that only if Pacific Hake sign is present at the offshore end of the transect, as was the protocol in the pre-SaKe period from 1995 to 2011. If a transect is extended due to Pacific Hake sign, then the following transect to the north will begin at roughly the same isobath as the previous transect, unless Pacific Hake sign is present when that point is reached. If there is Pacific Hake sign, then the research vessel will travel due west along that latitude until there is no more Pacific Hake acoustic sign. That point will mark the offshore starting point of the ensuing shoreward transect. Analysis of data from the five surveys which have been conducted since 2012 suggests that minimal backscatter will be missed, relative to the recent 35-nm protocol (an average of less than 2% annually).

However, based on average encounters with Pacific Hake sign in previous years, this first change in protocol will not be sufficient to complete the survey in 75 days, if all weather days are used. Consequently, the US survey also plans to skip every 8th transect of the 10-nm spacing design, to achieve full coverage of the survey area given the DAS allocations for both vessels. The Survey Team will employ the protocol for restoring skipped transects established in 2019 to survey some of the skipped transects north of San Francisco, if possible.

The scientific crew serving on Leg 1 of the US Survey will shelter-in-place (SIP) in Newport, Oregon, for 7 days prior to the ship's departure and will be tested for COVID on day 4 or 5 of the SIP. Once the SIP is complete and negative COVID test results have been received, they will be permitted to board the vessel. Leg 1 will begin with a calibration off Newport, Oregon, unless the calibration was successfully completed during the Pacific Hake Gear Trials, June 6-9. Leg one will then transit to the vicinity of Pt. Conception and conduct the survey northward to roughly 39°N. From that point the Shimada will travel to Newport, OR, to pick up the crew for the second leg, who will have been sheltering in place for 7 days prior to the ship's arrival. Following the exchange of scientists, the Shimada will head south, and resume surveying at the next transect northward from the conclusion of Leg 1. All science and vessel crew members will be tested for COVID prior to boarding either vessel. The Franklin will conduct its work in two legs, with a science crew change around the time of the transition between its survey work off the US and the start of the IVC off the west coast of Vancouver Island.

Both the Shimada and Franklin will rely on EK80 scientific echosounders for the first time as part of survey activities, although they have been extensively tested and calibrated to the former EK60 models. Also new this year, the DFO cruise will be deploying an Aleutian wing trawl net for sampling Pacific Hake that has the same specifications as the net that has been used by the US survey.

Acoustics Team Responses to previous SRG Recommendations

(Numbers reference items in the Survey "Recommendations and Conclusions" of the 2020 SRG Report)

1. A time series of Age-1 Pacific Hake Index values was provided to the JTC for exploration as part of this year's assessment. Key results from assessment model runs that include the Age-1 Index are provided in Appendix G of the 2021 Assessment document.

2,5. The Acoustics Team provided a document with guidelines/protocols decision rules for determining when trawling is conducted, throughout the survey. This will be part of a more comprehensive document covering protocols and methods that they hope to provide in advance of next year's SRG meeting.

3. The Acoustics Team reviewed backscatter patterns in the vicinity of Dixon Entrance for all surveys. Given the association of higher amounts of backscatter in some years with depth contours that have a greater east-west orientation in that area, the Team believes that the historical (more north-south) orientation of transects across those depth contours should be maintained.

4. The Acoustics Team plans to have a report summarizing the 2021 survey available in advance for SRG review in 2022.

6. The SRG was provided with an informative series of plots that illustrated the distribution of US at-sea commercial fishing effort and CPUE with the area covered by that year's survey transects and survey CPUE. Only small amounts of low-CPUE fishery effort were observed seaward of survey transect, noting that the US at-sea fishery commonly occurs before and after the survey is active in those regions.

8. The Team provided a side-by-side comparison illustrating the kriged SD of the survey biomass estimate, as well as the CV.

9. The process of trying to estimate all sources of uncertainty associated with the development of a biomass estimate is a complex issue. The Acoustics Team noted that some sources of uncertainty, such as target strength, are more straightforward to quantify. However, other elements of the data-capture and analysis processes, such as mark identification and determining when to trawl, involve subjective judgments that greatly complicate developing an overall measure of uncertainty for the biomass estimates.

10. The Acoustics Team presented estimates of the amount of biomass that was observed as part of transect extensions during the 2019 survey.

    Planned research on Pacific Hake reproduction and genetics was slowed by COVID precautions in place throughout the past year, however, it is hoped that greater progress in both areas can be made over the next year.

Recommendations and Conclusions for the 2021 Survey

1. **The SRG recommends the continued surveying and analysis of Age-1 Pacific Hake for further consideration of inclusion in the annual Pacific Hake assessment and the MSE process.**

2. **The SRG supports the continued use of previous transect orientations, across depth contours, in the vicinity of Dixon Entrance in future surveys**.

3. The Acoustics Team indicated its intention to provide a report of the 2021 survey in advance of the 2022 SRG meeting. **The SRG supports this effort and looks forward to reviewing the report.**
4. **The SRG in consultation with the Acoustics Team, will develop a Terms of Reference for this reporting in advance of the next SRG meeting in 2022.**
5. **The SRG also looks forward to reviewing a more complete documentation of survey methods and protocols and the history of changes in the survey at the 2022 SRG meeting.**
6. The SRG found this year's spatial analysis of survey and at-sea US commercial catch to be very informative, and **the SRG recommends continuing this kind of analysis on a regular basis to ensure that the survey is achieving its goal of covering the entire summer range of Pacific Hake. Since the US at-sea sector primarily fished for Pacific Hake before and after the survey's presence off Oregon and Washington, SRG recommends enhancing this type of retrospective analysis with the addition of data from shoreside fishery logbooks, as well as the inclusion of fishery and survey activity off Canada, which it would hope to review in 2023.**
7. **The SRG recommends continued presentation of the kriged SD in describing future survey results. The SRG recommends that the Acoustics Team report the kriging SD on maps of kriged biomass rather than kriging CV for consistency and ease of interpretation across the entire range.**
8. The SRG acknowledges that several key steps in the collection and analysis of the survey's data involve human judgment, which complicates a comprehensive quantification of uncertainty associated with biomass estimates. However, **the SRG encourages the Acoustic Team to report uncertainty where it can be quantified and continue research into methods for quantifying uncertainty in other elements that are critical to biomass estimation.**
9. **The SRG requests that the Acoustics Team provide an estimate of Pacific Hake biomass in the transect extensions of the 2019 and previous surveys at the 2021 SRG meeting.**
10. **SRG supports continued research on Pacific Hake reproduction and genetics.**
11. To complete the survey within the allocated DAS, maintaining the recent 35-nm offshore transect distance would necessitate dropping every 4th transect of the base 10-nm design, from Pt. Conception through Vancouver Island. **The SRG believes that would constitute an unwarranted sacrifice of acoustic and trawl sampling opportunities in depths where Pacific Hake are most frequently encountered.**
12. The SRG commends the Acoustic Team, DFO, and NOAA for developing protocols for the 2021 survey that prioritize the health and safety of all survey participants and their families. Since tests will be administered within a short window before scheduled departures, the SRG notes that these periods will represent key points of vulnerability, where planned schedules could be disrupted by positive COVID test results. Contingency plans have been developed to provide for covering the entire survey area, but even with those, the ability to achieve the planned survey densities is premised on the avoidance of last-minute positive test results.

Survey-Related Research

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

A key uncertainty in the ability of a saildrone "survey" to replicate biomass estimates from surveys employing research vessels is the question of how best to characterize the age-distribution of saildrone backscatter, in the absence of research-vessel trawls. A preliminary estimate of the biomass off Oregon and Washington, using average age compositions from the US at-sea Pacific Hake fleet produced a biomass estimate that was 26% less than that calculated using Shimada data. This was close to the backscatter relationship for that area, suggesting that the overriding difference in the estimates was due to the much lower backscatter total of the saildrones.

Work is underway to compile all sources of existing survey and fishery biological data for Pacific Hake collected since 2003. Age compositions derived from alternative fishery and survey sources will then be compared with those derived from Pacific Hake survey sampling. Pacific Hake otoliths from the bottom trawl survey have not been used in the assessment, and as a result, have not previously been prioritized for age determination, given limited resources. Among these unaged bottom trawl survey, samples from Acoustic Survey years will be prioritized for ageing, beginning with those collected during the most recent Pacific Hake survey years. Once these data have been compiled, a recently-hired postdoc at the NWFSC will focus on identifying the best approach for developing age-composition data that can be used to develop biomass estimates along with saildrone backscatter (in the absence of research sampling). This research will evaluate the importance of spatial-temporal proximity of composition and backscatter collection to the ability to approximate overall and age-specific biomass estimates developed using traditional vessel-based survey data.

The 2021 survey will be the first survey completed with the next generation Simrad EK-80 multiplexing sonar system. The survey team is investigating procedures to transform historical EK-60 data to the EK-80 data format and with then determine whether a reanalysis of the survey time series is necessary. Code has been developed within Echoview (sonar analysis software) and a Python script to accomplish the transformation. A preliminary run on 2019 data resulted in a 6.9% difference in backscatter, potentially because the EK-60 exhibits a non-linear response at deeper depths that the EK-80 does not. A further test on transforming 2018 EK-60 data to EK-80 will be completed later in 2021 and a decision on the necessity of reanalyzing all acoustic data will be made based on these results. Target strength research continues to be a priority for the Survey Team as target strength is a primary source of quantifiable uncertainty in the survey process. Two methods have been developed for this research: (1) conduct target strength measurements on the individual Pacific Hake on the edge of schools detected during trawl operations in 2012 and 2015-2019 (n = 57 trawls). Target strength is a measure of the acoustic reflectivity of an individual fish and can only be measured in-situ on isolated fish; during survey operations when echo integration is used to estimate back-scatter, it is not possible to estimate

target strength. The target strength-length relationship estimated from these data is similar to the published relationship; and (2) in-situ target strength measurements derived from a drop transducer system (DAISY) lowered to the depth of the fish. Canada has completed refurbishing the DAISY system with 38, 70 and 200 kHz transducers connected to EK-80 general purpose transceivers in a pressure casing now rated for 1,500 m depths. The goal is to develop target strength relationships for Pacific Hake at the depths that they inhabit, rather than closer to the surface as in existing published relationships.

Three acoustic moorings were deployed off the west coast of Vancouver Island from 2017 to 2019. These moorings have been recovered and analysis of their acoustic data is complete. The moorings provide time series of Pacific Hake and other pelagic species abundance phenology at these sites. Work is underway to investigate patterns of temporal autocorrelation and structure between sites to develop a more comprehensive model of Pacific Hake migration. These results will be linked to commercial catch data (particularly data from around mooring sites) to evaluate correspondence between backscatter and in-season patterns of catch. This analysis may be supplemented by the collection of echosounder data from industry vessels.

A pilot project attempting to develop ways in which backscatter and composition data from fishery participants could contribute to improved understanding of Pacific Hake abundance and distribution was described. The goal is to put external hard drives on industry vessels in the US and Canada to record echosounder data during fishing operations. This project builds off a successful project in the Bering Sea Pollock fishery and Survey Team members have been in touch with Steve Barbeaux, who oversees the Pollock program at the AFSC. Data from industry sources could be an adjunct in survey years, but it is less clear how it would be used in non-survey years, which would lack data from the southern coast.

Lastly, there is an ongoing need for better resolution of layers observed acoustically and identification of species in those layers. The Survey Team have developed a stereo camera for mounting on the trawl for this purpose and will test it at seas in the summer of 2021 using it during trawl operations on aggregations identified by the EK-80. The objectives of these tests are to collect stereo camera images of hake, hake mix and rockfish to determine whether the images can be used to identify layers and species within layers, and whether the stereo camera can be used to make length measurements. Stereo camera species identification and visual length measurements will be ground-truthed against catches in the codend of the trawls.

Recommendations

1. **The SRG recommends continuing the evaluation of the Saildrone performance and, if there is acceptable compatibility, then the development of approaches to address the collection of species and biological data with which to interpret the Saildrone backscatter data** as these results will inform the implementation of Saildrone technology to supplement the existing vessel-based survey approach.
2. The Survey Team described several promising lines of research to improve the delivery, analysis and reporting of acoustic survey results. **The SRG recommends that the Acoustics Team continue to explore and refine these options and their implications for the survey and survey results, and the SRG looks forward to reviewing their findings at future meetings.**

Other SRG Recommendations

1. The SRG appreciated the gap between the 2021 SRG and JMC meetings as it provided opportunity for the SRG to complete the writing and revision process of its report in a considered manner and allowed the JTC to .revise the assessment document, where necessary and present updated management advice before the JMC meeting. **The SRG recommends maintaining the opportunity for report writing and potential revisions by scheduling a gap of at least one week between the two 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. **We request that this approach be continued indefinitely.**
5. **The SRG recommends that the JTC continue to provide electronic copies of the data and model files prior to the review meeting as this is an efficient way to meet data requests made by the AP and others.**
6. The ability of the Acoustics Team to finalize the survey biomass estimate is dependent on the availability of age data from samples collected during the survey. Commonly, determination of all ages from each survey has not been completed until November, sometimes late November. Given the hard deadlines for assessment review and management decisions, this timing has a direct impact on the amount of time available to the JTC for model development and testing. **The SRG encourages NMFS and DFO to review age-reading priorities during the August-October period, to see if opportunities exist for expediting hake survey age reading.**

Literature Cited

Holsman, K.K., Ianelli, J., Aydin, K., Punt, A.E. and Moffitt, E.A. 2016. A comparison of fisheries biological reference points estimated from temperature-specific multi-species and single-species climate-enhanced stock assessment models. Deep Sea Research Part II: Topical Studies in Oceanography 134: 360-378.

ATTACHMENT 1

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

Online Webex Meeting

February 22-25, 2021

Agenda

Monday, February 22, 2021

08:30 Early Log-in to resolve connection issues

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

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

09:40 Fisheries, Data, and Inputs Used in the 2021 Assessment (JTC)
- 2020 Fisheries Catch, Size, and Age Composition Data
- Canadian Waters
- U.S. Waters

10:40 Break

11:00 2021 Pacific Hake/Whiting Assessment Modeling (JTC)
- Methods, results and discussion

12:00 Lunch

13:20 2021 Pacific Hake/Whiting Assessment Modeling (JTC)
- Methods, results and discussion (continue, as necessary)
- Model performance and diagnostics: sensitivities and retrospectives
- Response to 2020 SRG requests
- Forecasts and management implications
- Discussion

14:30 Break

14:45 Public Comment

15:00 SRG discussion, develop list of requests for JTC, *as needed*

15:30 Adjourn for the day

Tuesday, February 23, 2021

08:45 Early Log-in

09:00 Pacific hake/Whiting Management Strategy Evaluation (MSE) Update (Kristin Marshall, JTC)

- Responses to 2020 SRG recommendations
- Update on MSE process (2021 work plan, further developing objectives and performance metrics, and requests from JMC)
- Update on software development and testing
- SRG Discussion & Recommendations

10:30 Break

10:50 Update on research related to ecosystem drivers of recruitment (Cathleen Vestfals)

12:00 Lunch

13:30 Review responses to 2021 SRG Stock Assessment Requests (JTC)

- SRG discussion, develop list of requests for JTC

14:15 Break

14:30 Review responses to 2021 SRG Stock Assessment Requests (JTC) (cont.)

- SRG discussion, develop list of requests for JTC

15:00 Public Comment

15:15 SRG Discussion

15:30 Adjourn for the day

Wednesday, February 24, 2021

08:45 Early Log-in

09:00 Review planning for the 2021 Integrated Ecosystem & Pacific Hake Acoustic-Trawl Survey (Survey Team)

- SRG requests from 2020
- 2021 survey design
- Update on survey-related research
- Upcoming West Coast unified survey planning efforts

11:00 Break

11:15 Review results of 2021 SRG Stock Assessment Requests (JTC) (cont.)

- Discussion of model finalization and management outcomes

12:00 Lunch

13:20 Review of SRG Assessment Recommendations & Research Priorities
- Ecosystem Based Fishery Management metrics (Aaron Berger and Kristin Marshall)
- Update on other hake-related research projects (JTC)

14:20 Public Comment

14:30 Break

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

15:30 Adjourn for the day

Thursday, February 25, 2021

08:45 Early Log-in

09:00 SRG Work Session

10:15 Public Comment

10:30 Break

10:50 SRG Work Session (as needed)

12:00 Lunch

13:30 SRG Work Session (as needed)
- Final SRG discussion, report review, requests for additional information, etc.
- Distribution and review status of notes and draft SRG Report

15:30 SRG Meeting Adjourn

ATTACHMENT 2

List of Participants, all days

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

Allan Hicks - SRG, FAWI, US appointee
David Sampson – SRG, Oregon State University (Emeritus), independent member
Kendra Holt – SRG, DFO, IOS
Trevor Branch – SRG, University of Washington, independent member
Lori Steele – SRG, AP Advisor, USA appointee
Shannon Mann – SRG, AP Advisor, Canadian appointee

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

Al Carter - AP
Andi Stephens - NOAA, NMFS, NWFSC
Arne Fuglvog - Glacier Fish Co.
Barron Carswell - JMC
Beth Phillips - NOAA, NMFS, NWFSC
Bob Dooley - AP
Caren Barcelo - NOAA, NMFS, NWFSC
Cathleen Vestfals -- NOAA, NMFS, NWFSC
Chelsea Stanley - DFO, IOS, Acoustic Survey
Christian Heath - ODFW
Corey Niles - WDFW
Craig Russell - NOAA, NMFS, NWFSC
Dan Waldeck - JMC
Dave Smith - AP
Derek Bolse - NOAA, NMFS, NWFSC
Dezhang Chu - NOAA, NMFS, NWFSC, Acoustic Survey
Dierdre Finn - DFO, FM
Frank Lockhart - JMC
Galeeb Kachra - NOAA WCR
George Mukai - AP
Haley Oleynik - NOAA Sea Grant Knauss Fellow
Ian Tayor - NOAA, NMFS, MSE Team
Joe Bersch - AP
John Pohl - NOAA, NMFS, NWFSC, Acoustic Survey
Julia Clemons - NOAA, NMFS, NWFSC, Acoustic Survey
Katie Pierson - ODFW/GMT
Kristin Marshall - NOAA, NMFS, NWFSC, MSE Team

Kristin McQuaw - US Shoreside Coop,
Kevin Romanin - Government of British Columbia, Canada
Lynn Mattes - ODFW
Mike Okonieski - AP
Owen Hamel - NOAA, NMFS, NWFSC
Piera Carpi - IPHC
Rebecca Thomas - NOAA, NWFSC Acoustic Survey
Sarah Nayani - AP
Stephane Gauthier - DFO, IOS, Acoustic Survey
Stephen de Blois - NOAA, NMFS, NWFSC, Acoustic Survey
Steve Joner - JMC
Steve Martell - Sea State
Susan Chambers - WCSPA
Trent Hartill - American Seafoods
Whitney Roberts - WDFW