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Proceedings of the Pacific Regional Peer Review on Stock Assessment and Management Advice for BC Pacific Herring: 2013 Status and 2014 Forecast

September 4-6, 2013
Nanaimo, British Columbia

Chairperson: John Holmes
Editor: John Holmes

Fisheries and Oceans Canada
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Nanaimo, BC V9T 6N7

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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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http://www.dfo-mpo.gc.ca/csas-sccs/
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SUMMARY

These Proceedings summarize the relevant discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO), Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting on 4-6 September 2013 at the Pacific Biological Station in Nanaimo, B.C. Two working papers were presented for peer review. The first working paper reviewed recruitment forecasting methodologies and assessed their consistency with the DFO policy "*Fishery Decision-making Incorporating the Precautionary Approach*" and the second working paper assessed the current status of the five major and two minor herring stocks in BC in 2013 and forecasted pre-fishery biomass for 2014 by stock area. A draft Science Advisory Report was developed to provide science advice regarding recruitment forecasting compliance with the Decision-making policy and probabilistic statements concerning harvest options for each major and minor herring stock in BC.

Staff from DFO Ecosystems and Oceans Science and Ecosystems and Fisheries Management Sectors, and external participants from First Nations, commercial and recreational fishing sectors, environmental non-governmental organizations, and academia contributed to the meeting in person or remotely via webinar.

The conclusions and guidance resulting from this review are provided in the form of one Science Advisory Report (SAR) to Fisheries Management to inform the application of the BC herring management framework and the development of the 2014 Integrated Fisheries Management Plan (IFMP).

The Science Advisory Report and two supporting Research Documents will be made publicly available on the CSAS Science Advisory Schedule.

Compte rendu de la réunion d'examen par les pairs de la région du Pacifique sur l'Évaluation des stocks et conseils de gestion pour la pêche au hareng du Pacifique en Colombie-Britannique : évaluation de 2013 et prévisions pour 2014

SOMMAIRE

Le présent compte rendu résume l'essentiel des discussions et conclusions de la réunion régionale d'examen par des pairs de Pêches et Océans Canada (MPO) et du Secrétariat canadien de consultation scientifique (SCCS) qui s'est tenue du 4 au 6 septembre 2013 à la station biologique du Pacifique de Nanaimo, en Colombie-Britannique. Deux documents de travail ont été soumis à l'examen par les pairs. Le premier document de travail porte sur les méthodologies utilisées pour prévoir le recrutement et évalue leur conformité au « *cadre décisionnel pour les pêches intégrant l'approche de précaution* » du MPO; le second document de travail est une évaluation de l'état actuel des cinq stocks principaux et des deux stocks secondaires de hareng en Colombie-Britannique en 2013 ainsi que des prévisions de la biomasse avant la pêche pour 2014, par zone de stock. Un avis scientifique préliminaire a été élaboré en vue de la rédaction de l'avis scientifique officiel à fournir sur la conformité des prévisions de recrutement par rapport à la politique de prise de décision et sur les hypothèses probabilistes concernant les options de prélèvement pour chaque stock de hareng principal et secondaire en Colombie-Britannique.

Les employés du secteur des Sciences des écosystèmes et des océans et du secteur de la Gestion des écosystèmes et des pêches du MPO ainsi que des participants provenant des Premières Nations, d'organisations non gouvernementales de l'environnement, des secteurs des pêches commerciale et récréative et du milieu universitaire ont collaboré à la réunion soit en personne, soit à distance par webinaire.

Les conclusions et les conseils découlant de cet examen ont été présentés sous la forme d'un avis scientifique destiné à la Gestion des pêches, qui servira à orienter l'application du cadre de gestion du hareng de la Colombie-Britannique et l'élaboration du plan de gestion intégrée des pêches (PGIP) pour 2014.

L'avis scientifique et deux documents de recherche à l'appui seront rendus publics dans le calendrier des avis scientifiques du SCCS.

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS), Regional Peer Review (RPR) meeting was held on 4-6 September 2013 at the Pacific Biological Station in Nanaimo to review recruitment forecasting methodologies and their compliance with DFO's policy "*Fisheries Decision-Making Incorporating the Precautionary Approach*" and to assess the current status of the five major and two minor Pacific Herring (*Clupea pallasi*) stocks in British Columbia in 2013 and pre-fishery biomass forecasts for each stock in 2014*.*

The Terms of Reference (TOR) for the science review (Appendix A) were developed in response to a request for advice from DFO Ecosystems and Fisheries Management. Notification of the science review and conditions for participation were sent to representatives with relevant expertise within DFO Pacific Region and representatives from First Nations, the Government of British Columbia, commercial and recreational fishing sectors, environmental non-governmental organizations, and academia. Thirty-nine individuals participated in the review (Appendix B).

The meeting Chair, John Holmes, welcomed participants and invited them to introduce themselves and give their affiliation. He then reviewed the role of CSAS in the provision of peer-reviewed advice, and gave a general overview of the CSAS process. The Chair discussed the role of participants, the purpose of the various RPR publications (Science Advisory Report, Proceedings, and Research Document), and the definition and process around achieving consensus decisions and advice, noting that the meeting was a science review and not a consultation. It was confirmed with participants that all had received copies of the Terms of Reference, working papers , and the meeting agenda prior to the meeting.

The Chair reviewed the Agenda (Appendix C) and the Terms of Reference for the meeting, highlighting the objectives and identifying Linnea Flostrand and Matthew Thompson as Rapporteurs.

The following working papers (WP) were prepared for the RPR (summaries are provided in Appendix D):

Status of BC Pacific Herring (*Clupea pallasi*) stocks in 2013 and forecasts for 2014 by Jaclyn Cleary, Nathan Taylor, and Vivian Haist. (CSAP WP2013-P46);

Review of Recruitment Forecasting Methodologies for British Columbia Herring Stocks by Rob Kronlund, Jennifer Boldt, Nathan Taylor, and Jaclyn Cleary. (CSAP WP2013-P71).

All participants were invited to join in the discussion and to contribute knowledge to the process, with the goal of delivering scientifically defensible conclusions and advice. Participants were reminded that everyone at the meeting had equal standing and that they were expected to contribute to the review process with information or questions relevant to the paper being discussed.

Written reviews of the working papers were provided by Dr. Andrew Cooper (SFU), Sue Grant (DFO), and Dr. Andrew Edwards (DFO) (Appendix E). The goal of soliciting these reviews was to inform, but not limit, discussion by participants attending the RPR meeting. Copies of the written reviews were circulated to participants prior to the meeting.

The conclusions and advice resulting from this review are provided in the form of a Science Advisory Report (SAR) to Fisheries Management to inform the application of the BC Pacific Herring management framework and the development of the 2014 Integrated Fisheries Management Plan (IFMP) for BC Pacific Herring stocks. The Science Advisory Report and the two supporting Research Documents will be made publicly available on the CSAS Science Advisory Schedule.

HERRING SCIENCE OVERVIEW

Nathan Taylor provided an overview of the state of BC Pacific Herring science to identify where changes are occurring and where these changes fit within the Herring assessment and management framework. Pacific Herring management procedures and the many underlying steps were described. He noted that the harvest control rule (HCR) used to manage Pacific Herring stocks in BC is intended to achieve a balance between yield, inter-annual variability in yield, and the frequency of area closures. Actual and potential changes in Herring science were described under the categories of data, modeling, and the state-of-nature. In the data category, Nathan noted that DFO can no longer afford to fund annual dive surveys, which provide the spawn index data, the primary biomass index for BC Pacific Herring stocks. The fate of this survey beyond 2014 is unknown, but an evaluation of the impact of reduced survey frequency on stock assessment results in underway. He also noted that the spawn index has been corrected to take into account inconsistencies in lead line markings. The model used to conduct BC Pacific Herring stock assessments was developed and reviewed in 2011. In 2013, a thorough review of the code turned up a number of bugs and issues with the way certain processes were defined and coded (e.g., exploitation rate)and these issues have been fixed in the present version of the model. This code review is an ongoing feature of the assessment process. Lastly, it was noted that the state-of-nature is changing as illustrated by declines in size-at-age within all major stocks that have been occurring for at least 20 years and recent declines in model-estimated natural mortality rates. Both of these changes are persistent and appropriate ways to deal with them must be found. Averages over time are currently used for predictive purposes.

REVIEW OF BC PACIFIC HERRING RECRUITMENT FORECASTING METHODOLOGIES

Working Paper:	Review of Recruitment Forecasting Methodologies for British Columbia Herring Stocks by Rob Kronlund, Jennifer Boldt, Nathan Taylor, and Jaclyn Cleary. WP2013-P71.
Rapporteur:	Matthew Thompson
Presenter(s):	Rob Kronlund and Jennifer Boldt

PRESENTATION OF WORKING PAPER

Rob Kronlund began by reviewing the context in which advice on BC Pacific Herring stocks was provided in the past, the DFO Decision-making policy framework components, and the request for science advice in 2013 to identify risks associated with harvesting. The role of recruitment forecasts in harvest advice was described and then the method used to define the Poor-Average-Good (PAG) categories of recruitment and the decision rules to choose an appropriate category of recruitment for a given year were explained as they applied to the Haida Gwaii (HG), Prince Rupert District (PRD), and Central Coast (CC) Herring stocks.

A question was asked concerning Figures 5-8 in the WP and whether the fixed cut-off values from 1996 to 2011 were used to define the PAG categories and it was noted that the cut-off figures from old documents were used.

Clarification was requested concerning the spawning biomass histograms from the integrated statistical catch-at-age model (ISCAM) shown in Figure 3 of the WP. The authors explained that Figure 3 graphically represents the steps followed to forecast biomass in a stock based on draws from a joint posterior density distribution. They noted that the PAG category definitions are altered on each draw and that Figure 3 shows the results of one draw. This figure is specific to the HG stock. Recruitment variability is different in other stocks so the values and histograms will change.

The rules for forecasting the recruitment category to assign in Year *T+1* were reviewed for the HG, PRD, and CC stocks and it was noted that the PAG value was determined by recent decision rule outcomes in Years *T* and *T-1* and stock status. Discussion focused on the application of the decision rules and highlighted two points: marginal effects and lag effects. It was pointed out by the authors that absolute recruitment estimates near the thresholds (cut-off values) for each PAG category could be inflated or understated, depending on whether the values were marginally over or under the threshold value between categories. Stocks just above the threshold are unlikely to produce the historical average recruitment of the category because spawning biomass is below the level that produced average recruits historically and because declining size-at-age in all stocks means that it may not be possible to achieve levels of biomass per recruit observed historically. Since the recruitment forecasts are based on means for the entire time series, lag effects are introduced due to the inclusion of historical recruitment values that do not reflect current conditions.

The authors were asked whether the past PAG assignment used for Year *T-1* and *T* was updated retrospectively each year in their analysis. They indicated that they did not retrospectively update the recruitment categories. Discussion of this question continued and it became clear that there was no consistent understanding among meeting participants, many of whom were involved in previous stock assessment meetings, concerning the application of the decision rules for determining the PAG category of recruitment. PAG category assignments appear to have been upgraded and downgraded in the past based on decisions made at stock assessment meetings that were not fully described, which impedes our ability to retrospectively analyze recruitment forecasts. Based on the decision rules as written, it was pointed out that achieving a Good forecast was a rare event. Meeting participants noted that it is important to document what was done in the past to clarify issues surrounding recruitment forecasts and the forecasting process. It was recommended that the authors look into past advisory tables to determine what was done operationally, particularly a summary table in either the 2009 or 2010 Proceedings document. If the methodology cannot be clarified, then it should be reported in the Research Document.

Recruitment forecasting for the west coast of Vancouver Island (WCVI) and Strait of Georgia (SOG) stocks differs from the other major stocks and was described by Jennifer Boldt. She noted that the observed proportion of age-2+ Herring in a summer trawl survey on the west coast of Vancouver Island is used to predict the number of age-3 fish expected in year *T+1* and that this alternative estimate (to the assessment model forecast of numbers of age-3 fish in year *T+1)* is used to assign the appropriate PAG category for forecasted recruitment. Length frequency histograms are constructed for each tow retrospectively; and tows consisting of age-2+ fish or younger based on peaks in the length frequency data or tows < 100 kg are excluded from the analysis. The remaining tows are weighted by CPUE to estimate the proportion of age 2+ Herring in the summer trawl survey and a logit regression is used to predict the proportion of age 3+ Herring estimated by the statistical catch-at-age model based on the observed proportion of age 2+ fish in the summer trawl surveys. Concerns about the reliability of CPUE data were noted owing to the difficulty in estimating tow duration (effort). Clarification was sought about the meaning of the red triangle symbol in Figure 14 of the WP. These symbols represent tows that were excluded from the analysis because they consisted of immature fish. The assumptions on p. 51 of the WP were also reviewed.

The authors note that recruitment forecasting methodologies using the PAG categorization are inconsistent with the stock-recruitment assumption in the ISCAM used to assess Pacific Herring stocks in BC and DFOs Decision-Making Framework (DMF) Policy. They also showed that the

ISCAM can estimate quantities that are sensible in light of apparent ongoing changes in stock productivity and that these estimates are consistent with the DMF policy. They concluded that ISCAM forecasts of age-3 fish should be used going forward but also recommend closed-loop simulation to evaluate the performance of the management procedure used for Pacific Herring.

Following the presentation of this paper, there was agreement among meeting participants with the primary conclusion: the PAG forecasts should be discontinued and replaced with the ISCAM forecasts of age-3 fish in Year *T+1*.

WRITTEN REVIEWS

Andrew Cooper

The reviewer started off by stating that he agrees with the conclusions of the authors. He noted that the WP lays out a clear case to move to model-based forecasts of age-3 fish. The current method using PAG categorization does not encompass the full range of uncertainty in recruitment forecasts and forces trade-offs between variability in yield and conservation to be considered in an unusual place – external to the model. He noted that the model-based approach to forecasting age-3 fish is clearer and more transparent.

The reviewer noted a disconnect between stock size and recruitment in Figure 17 of the WP. Average recruitment occurs over a large range of spawning biomass, which would produce consistently similar forecasts with the PAG approach. His point was that this method is relatively insensitive to changes in stock productivity captured in this figure.

The reviewer requested a schematic diagram in the revised paper showing how recruitment forecasts are produced. This request was thought to be useful by meeting participants but questions were raised about the necessity of including the flow-chart in the revised WP given that it recommends discontinuing the PAG approach and using model estimated recruitment forecasts. Meeting participants decided that the inclusion of a flow-chart documenting recruitment forecasting merited inclusion in the revised WP.

The reviewer questioned the strength of the signal in estimates of recruitment of age-2+ fish, wondering about the reliability and accuracy of these data. He also noted that the model estimates of recruitment are based on commercial fishery samples of age-2 fish and questioned the reliability of the model forecasts as well. It was recommended that the authors add some discussion concerning forecast reliability to the general discussion of the WP.

Sue Grant

The reviewer agreed with the authors that the PAG approach to recruitment forecasting is problematic and was concerned about understanding alternative approaches. She asked whether we want to discontinue using the PAG approach before understanding the alternative and noted that often comparisons between existing and newer methods are completed to provide support/confidence that the proposed alternative is better than the existing approach. The reviewer considers the PAG categorization to be a conservative approach and wondered whether the 2014 stock assessment decision tables would be less precautionary because they aren't being used. In response it was noted that the decision tables simply convey harvest information relative to the harvest control rule probabilistically, they are neither more nor less precautionary than the PAG approach. The precautionary approach is applied when FAM and stakeholders use the tables to make harvesting decisions.

There was some discussion among participants about assessing the performance of the model-based forecasts of recruitment. It was noted that the PAG methodology was never formally evaluated and that a retrospective analysis may not be possible. Meeting participants agreed that they would rather see work go into close-loop simulation to develop a set of conservation and yield outputs as a way to evaluate the performance of this method. The WP authors noted that they do not claim the model-based recruitment forecasts are accurate, only that these forecasts capture and transmit the uncertainty in the estimates much better than the PAG method and in compliance with DFO's DMF policy.

The reviewer noted that the current PAG approach to recruitment forecasting is a "naive" model that is not informed by the underlying population dynamics. In contrast, the ISCAM is biologically based, is linked to spawning biomass, and directly provides information on recruitment. The PAG model seems to break this population feedback loop and forces trade-offs between conservation and yield to occur at an odd location in the overall framework. The reviewer observed that for some Fraser River sockeye stock return forecasts, a naive model performs better than a biological model if there is substantial uncertainty in the biological model. The reviewer questioned whether the historical PAG approach with the full range of uncertainty incorporated into it would it perform any differently than the ISCAM? After some discussion, there was agreement that the likely answer to the question is "no". The reviewer noted that she agrees with the conclusions of the authors, i.e., that the PAG approach to recruitment forecasting should be discontinued in favour or recruitment forecasts by the ISCAM because the PAG approach does not capture the true range of uncertainty in these forecasts.

The reviewer observed that she was puzzled by the fact that the PAG forecasts were conducted using Bayesian approaches, yet the advice provided to managers was not presented probabilistically even though the information was available to categorize risk for decision making. She agrees with the recommendation in the WP that uncertainty be included in the provision of Science Advice to Fisheries Management in the form of probability-based decision tables. She also suggests presenting the cut-off point (0.25 SB_0) probabilistically since there is uncertainty in the estimate of this benchmark.

GENERAL DISCUSSION

Both the reviewers and meeting participants agreed to accept the WP with some revisions that were communicated directly to the authors by the reviewers. Most of these revisions are minor and editorial in nature. There was a recommendation to look through previous proceedings documents in order to clarify the decision rules used to assign recruitment to a PAG category as accurately as possible. Since no one was certain where these rules were described, the authors agreed to put a reasonable amount of time into this task but will not hold up the revision process if the information is not readily available.

One of the reviewers requested a flow chart describing how recruitment forecasts are produced using the PAG approach. There was discussion on the benefits to the paper of including this diagram since it was noted that it would be time consuming to produce. It was concluded that it would be nice to have the flow chart but not necessary in the revised working paper.

There was a brief discussion of the implications for the 2014 stock assessment of rejecting the recruitment forecasting WP. It was noted that the stock assessment is a stand-alone WP that would be reviewed on its own merits.

CONCLUSIONS

Meeting participants concluded that using trawl survey data to forecast recruitment in two stocks (WCVI, SOG) and the categorization of model-reconstructed recruits (as poor/ average/good categories) applied to all Pacific Herring stocks as described in the working paper was not scientifically defensible and that it does not capture the uncertainty in recruitment forecasts and subsequent risks to BC Pacific Herring stocks.

RECOMMENDATIONS AND ADVICE

It is recommended that the statistical catch-at-age assessment model be used to derive recruitment forecasts and estimate the probability of breaching thresholds or achieving desirable outcomes for BC Pacific Herring stocks and fisheries. Since no alternatives to the model-based recruitment forecasts were evaluated at this meeting, an evaluation of the drivers of age-3 recruitment forecasts produced by the assessment model is also recommended.

REVIEW OF BC PACIFIC HERRING STOCK ASSESSMENT AND MANAGEMENT ADVICE

Working Paper:	Status of BC Pacific Herring (Clupea pallasi) stocks in 2013 and forecasts for 2014 by Jaclyn Cleary, Nathan Taylor, and Vivian Haist. WP2013-P46
Rappoteur:	Linnea Flostrand
Presenter(s):	Jaclyn Cleary

PRESENTATION OF WORKING PAPER

The authors circulated additional outputs from the assessment model, including tables showing estimates of SB_0, depletion, and marginal posterior density (MPD) estimates of projected spawning biomass in 2014 given 0 catch and contributions by age 3 and 4 and older fish (see Appendix F), as well as time series plots of spawn index results and spawn survey length, width and egg layer estimates from survey data.

The lead author briefly reviewed sources of data (commercial catch, biological catch samples and spawn surveys) for the assessment and data issues (resolved and unresolved). She noted that the criteria used to select representative samples for aging in each area were resolved and that the proportion-at-age tables were revised. In contrast, the weight-at-age matrices have some missing years and have not been updated yet because a suitable revision method has not been determined. An important change is the implementation of an adjustment for shrinkage in lead lines used for spawn surveys from 2003 to 2013. This adjustment results in an estimated 15% increase in spawn width during these years. The authors also clarified that mortality (F + M) in the model occurs over the year rather than at the beginning or end of the year.

The structure of the model, including its long term evolution and recent updates, model phases and steps that occur throughout a model year, and how uncertainty is captured and propagated to results were described by the lead author. Summaries of the data and assessment model time series results were presented by stock area and 2014 biomass projections based on 0 catch and current catch streams were provided in decision tables. It was clarified that the decision tables in the WP are based on estimates of SB_0 calculated over the historical time series rather than dynamic SB_0. Dynamic SB_0 estimates use the average weight-at-age and mortality for the last 5 years only. Outstanding issues and possible medium and long term work plans and goals were also described by the lead author.

After describing the main assumptions of the assessment model, the author noted that uncertainty associated with the lead line adjustment to the spawn survey index was not propagated through to the results – the lead line data were used with no error. Other unaccounted for structural uncertainties and error within the model include random walk mortality estimates and issues with modeling instantaneous mortality throughout year.

The authors noted that in conversations with Dr. Steve Martell, the developer of ISCAM, it was revealed that he had discovered an error in the calculation of MSY-based estimates in previous assessments. They noted that since the harvest control rule (HCR) and management decisions were not based on MSY-related quantities, conclusions and harvest advice from past assessments was unaffected by the calculation error.

In response to a question, the authors indicated that the assessment model was initialized in 1951 by estimating initial year class abundance after applying fishing to each stock.

Clarity was sought on an apparent mismatch between the 2014 projection results for the HG stock and 2013 age 2 composition in 2013 catch samples. Few age 2 fish were found in the 2013 catch samples but an increase in recruitment is forecast for 2014 relative to 2013. The authors responded that the recruitment forecast is influenced by how well the model is fitted to the spawn index data as well as deviations from the stock recruitment relationship for that year. A more detailed response is found in the general discussion section of these Proceedings.

The authors described the procedures for producing projections (future biomass forecasts) and reviewed the forecasts for 2014. It was noted that the previous forecasting methodology used only terminal year estimates of M and that projections in the present model are based on the average of the last 5-years. Using a multi-year average dampens the influence of trends in M on the projections, but it also compresses the true uncertainty in these projections. It was noted that some uncertainty intervals for 2013 spawner biomass estimates are similar in magnitude to 2014 projections, in part reflecting the contribution of greater uncertainty in estimates of recent years for characterizing cohorts.

It was clarified that the 10% target commercial harvest rate for minor stock areas (instead of 20%) is based on the fact that there are fewer historical observations in those areas (mostly spawn when available) compared to the major areas that are surveyed more regularly than the minor areas.

A brief description was requested and provided on how past models account for spawn-on-kelp (SOK) mortality. Past assessment models assumed a constant mortality per license, allocation or escapement. Although SOK data are available, the current model does not account for SOK removals. Appropriately accounting for SOK fisheries has been repeatedly noted as a concern in recent CSAS BC Pacific Herring assessment reviews.

Concern was expressed that the Herring cut-off (0.25 SB_0) is treated as a limit reference point. In response, it was noted that the cut-offs is not considered a reference point and that the definition of suitable reference points for Pacific Herring should be at least a medium term priority for Science.

WRITTEN REVIEW

Andrew Edwards

Overall the reviewer concluded the paper’s methods, results and advice are appropriate. He made several inquiries and thoroughly outlined many ways to help clarify aspects of the model and modeling process during revisions. The reviewer re-iterated many points made in his written review but only some of the points were elaborated on or addressed during the meeting (briefly included below).

The reviewer questioned whether stocks that are closed for fishing should be assessed annually along with other stocks. The question was raised in the context of workload since the Pacific Herring assessment amounts to seven separate stock assessments. Future scheduling of

Herring assessments remains an open question at the moment since it was not discussed in the WP or at CSAS meetings.

The reviewer noted that the Executive Summary was nearly as long as the assessment document. In response, the authors indicated that the format of the Executive Summary was new and that it probably will not be continued in the future.

The Markov Chain-Monte Carlo (MCMC) trace plots look reasonable for all stocks except for Area 27, where it appears that the chain should be run for longer to achieve stationarity. The authors re-ran the MCMC procedure for a longer period and reported that it converged and produced reasonable values, indicating that the probabilities in the decision table were correctly calculated for Area 27. There were minimal changes to the decision tables.

The assessment assumes time-varying natural mortality (M) and models it as a random walk process. It was noted that the random walk process documented in the WP (which is biased) is inconsistent with the structure and parameterization of this process in the model code, where the reviewer confirmed that it is implemented as a cubic spline. The reviewer requested that the rationalization and motivation for assuming time-varying M be explained in the revised assessment document. This justification is considered especially important since the resulting estimated natural mortalities have been declining in most stocks in recent years while estimated spawning biomasses have been increasing. The authors agreed to look into the effect of the random walk process and code used in model (related to a possible source of bias for estimating mortality). They also reported that previous assessments applied a long-term average M and that at some point, it was decided based on biological indicators (fewer older fish observed in catches, increased predation assumptions), that implementing time-varying M was a more appropriate approach.

The reviewer noted several instances in which the model process descriptions in the WP were inadequate or appeared to be wrong. He worked with the authors before the meeting and was able to confirm that in the cases he checked, the model was correctly coded. The authors agreed to improve the documentation of the model and model processes in the revised WP. The authors also committed to incorporating the editorial comments of the reviewer in the final document, particularly with respect to equation notation, statistical descriptions, etc.

The revised text should note that some data on food, social and ceremonial (FSC) fisheries are collected but the format of these data is not conducive to including them in the assessment model.

The authors stated that the red line in the WP described as the 5-year running average of estimated recruits in Figure 10, was in fact a 10-year average that was mistakenly labeled and will be corrected.

Regarding the confounding effects of lead line shrinkage (or no shrinkage) in the spawn survey index time series, it was also noted that past assessments have not characterized egg layer and density error in surface or SCUBA spawn survey data used to derive the spawn index and as a result some uncertainty is not captured in the models.

The basis for pooling age classes and pooling of minimum proportions was described as being linked to recent work (reviewed in June 2012). The reviewer stated that he is collaborating on a project testing different assumptions on this matter and could communicate future findings with the authors.

GENERAL DISCUSSION

Concerns were raised about discrepancies between model projections (forecast recruitment) and observed catch sample compositions (of age 2 fish) in the previous year, with specific reference to the HG stock. There was some discussion about unknown variability in maturity schedules between and within regions and some steps were suggested to test model output sensitivity to varying maturity ogives. These types of sensitivity tests were suggested for all northern stocks (HG, PR and CC), and an initial or main test that was suggested was to set 0% maturity for age 2 and continue with 90% maturity for age 3 and evaluate the impact on forecasts and decision tables.

It was stated that there is insufficient information to either confirm or improve currently modeled maturity schedules for BC Herring stocks. There was some discussion as to what information could be compiled to provide insights into the variability of maturity schedules, such as variability related to latitudinal gradients or two sex models. It was noted that the available maturity data may be biased because they are from fish sampled during the spawning season (on the spawning grounds) or in areas where fish are staging during migrations to spawning grounds and these fish are likely predisposed to having segregated from other components of the population that are on a different maturity schedule. It was suggested that future work could include a literature search on (Pacific) Herring maturity schedules that includes stocks outside BC (e.g., California, Alaska, etc.).

The question of data quality and the impacts of possible changes in methods or sampling bias on time series trends was discussed. It was suggested that the estimates of egg layers and egg size parameters, which affect fecundity in the model (eggs/gram female spawner), have uncertainty that is not captured in the model. A reference to possible bias or changes in fish weights due to sample access (from plants after brining versus fresh or frozen) was made and it was suggested that length-at-age may be a more robust metric of size. In response, it was noted that no sampling changes have occurred in the last 20 years and yet trends in size-at-age are apparent during this time. No recommendations on this topic were made.

Concern was expressed that using 5-year averages of recent M and weight-at-age for projection purposes will dampen any trends and compress uncertainty associated with forecasts produced by the assessment model. It was suggested that a multi-year average may be suitable if there are years lacking survey data, including the use of a shorter averaging period (e.g., 2 or 3 year averages). There was consensus among meeting participants in recommending that the Herring Technical Working Group evaluate the impacts of alternative methods of estimating terminal year quantities on biomass forecasts, including measures of uncertainty to include with these estimates.

There was concern about the risk of fishing down Herring stocks as a result of continuing to use $0.25B_0$ as a fishery cut-off. Since $0.25SB_0$ is a commercial cut-off and not a limit reference point, the issue isn't that SB_0 is wrongly estimated but that the ongoing use of this cut-off may introduce risks that management might wish to avoid if there was awareness of those risks. Recently, Herring SARs have included wording about unknown uncertainty or cautionary trends to try to outline these kinds of concerns. It was asked whether there are other metrics (e.g., descriptions of trends) that could be used in decision tables to help decision makers (e.g., probability of stocks increasing or decreasing from past or current estimates). It was suggested that a future investigation could consider the lowest historical biomass estimate in the time series from which a stock rebuilt as a candidate Lower Reference Point, but there are problems with using relative states and there is unknown scaling for absolute amounts. There was consensus that participants support the DFO precautionary policy on reference points.

The lack of accounting for mortality in SOK fisheries in the assessment was discussed. The authors indicated that some assessment models over the last 15+ years accounted for SOK removals by assuming a constant fishing mortality by licence, allocation, and spawner escapement. The current assessment model assumed there was no SOK mortality because these estimates required too many unknown and confounding assumptions related to unsubstantiated conversion factors, variability in ponding practises, incompatible data formats, incomplete records, etc.. From a precautionary standpoint, leaving out a potential source of fishing mortality is a more serious flaw in the assessment than estimating possible SOK escapement from surviving fish. As a starting point, a crude sensitivity test could be done based on whatever fishery history is available and by assigning high and low mortality bounds to these activities. There was consensus among participants in recommending that, despite the issues identified in this discussion, compiling the best available information and attempting to account for SOK-related fishing mortality (and escapement) in the assessment, whether for sensitivity tests or using derived estimates, should be a high priority research objective. This recommendation has been repeated in several of the recent CSAS Pacific Herring reviews, but there has been little progress to date. Although the issues are complex, the lack of progress is related to lack of resources for scientific observations and the compilation of information in formats that are compatible for making estimates. It was suggested that an outline of the desired data format could be given to the service provider to help improve data collection in the 2014 season.

There was some discussion concerning the lack of information on incidental mortality. Explicit examples of mortality from other Herring fisheries were provided (Herring gillnet and seine fisheries, test fisheries, SOK capture). Some work in characterizing incidental gillnet mortality was done (Hay et al. 1986) but several attributes of this fishery have changed since that work was completed, including the implementation of pool fisheries and the use of smaller net sizes. No studies have been conducted to quantify Herring mortality in these fisheries. In addition, it was mentioned that past work aimed at estimating incidental mortality in non-Herring fisheries concluded that overall levels of Herring mortality were relatively low. As an aside, it was noted that information on incidental mortality is often included in the SAR in text on ecosystem considerations. There are fishery catch records for minor fin fish, SOK and Special Use, Food and Bait, with some means of tracking to biological catch sample data, but data in these records are not all in the same locations or formats. There was consensus that very little is known concerning the sources and magnitudes of incidental mortality of Herring in other fisheries and it was recommended that the available information and data should be compiled to document research on the issue, the results of that research, and the types of data and information needed to complete an evaluation of the significance of incidental Herring mortality. Meeting participants also recommended that it should be noted in the revised 2013 assessment paper (and future assessments) that Food, Social, and Ceremonial Herring fisheries occur and that information is collected on these fisheries.

The issue of lead line measurement error affecting the quality of spawn index measurements was discussed. Some points related to the degree of confounding and how more information is needed to scope the problem. One idea is to consider how another index (spawn habitat index) or measurement (surface surveys) could be used to calibrate the spawn index. It was noted that the spawn index has no units. Uncertainty in the spawn index estimates is not propagated through the assessment and it is unclear how to quantify sampling variability (e.g., CVs). The assessment authors invited feedback from meeting participants on how to proceed for future assessments. Meeting participants recommended that a working group be formed to document sampling and gear issues in the different areas over time. This working group could advise on how best to proceed for future spawn index estimation (assessment modeling and field work) once the documentation process is completed. Then the Herring TWG would aim to characterize uncertainty associated with the issue in future assessments (e.g., 2014 if possible).

Structural uncertainty in the assessment model associated with the modeling of fishing and natural mortality were discussed. Meeting participants recommended partitioning fishing mortality (F) and natural mortality (M) throughout the model year relative to when the bulk of fishing removals occur. If this approach cannot be incorporated easily into the ISCAM model for BC Herring, then other model packages that model mortality in this way were suggested. It was noted that the assumption of time varying natural mortality (i.e., between years) is not common in stock assessment modeling. The use of a closed-loop simulation to provide insights into estimates of M was also discussed. It was recommended that closed-loop simulations be conducted to compare the effects of different structural assumptions for M (fixed, time-varying) on other model parameter estimates and estimates of management quantities (e.g., SB_0, current SB, recruitment). This work can be conducted one stock at a time.

Meeting participants endorsed the ISCAM model estimates of current (2013) biomass and 2014 forecast biomass and catch decision tables in the WP. Although participants strongly supported the recommendation to stop using past recruitment forecasting methods (as recommended by the Kronlund et al. WP), it was noted that no alternatives beyond the assessment model forecasts were presented for consideration. Some suggestions for future work were mentioned. For example, juvenile survey data in the SOG from ~ 1990 to present and in the CC from ~2002 to 2011 are available and could be considered for future work. It was also suggested that the performance of the Beverton-Holt stock-recruitment model be compared when informed and not informed by other model information (age samples) to ascertain what aspects of the data are driving model forecasts.

One of the authors commented that medium to long term assessment goals already identified before this meeting (e.g., as next steps) are to use closed-loop simulation to investigate the current HCR versus other management procedures, the impact of alternative spawn index survey frequency on informing model, and the impacts of trends in natural mortality on model performance.

CONCLUSIONS

The Chair circulated some draft summary points based on updating the format of material presented in the 2012 Herring SAR as an aid to focusing meeting participants on identifying the key advisory information and supporting tables and figures in the SAR. It was explained that the 2014 forecasts and metrics included in decision tables were prepared based on the requests from Fishery Managers. It was decided that Table 1 in the SAR would be an update of the past 5 years of known landed commercial catch by area, Table 2 would have new estimates of SB_0 and 0.25 SB_0, and that there would be a third table showing the 2014 projections, marginal probability density (MPD) and 90% intervals for age 3 and age 4+ contributions to spawning biomass, assuming 0 catch. Meeting participants agreed that tables summarizing probabilistic performance metrics should be included in the 2013 SAR, which will be novel for Pacific Herring. The metrics are based on the historical harvest control rules (Table 1 below). The range, scale and intervals of catch streams for each year will vary and it was proposed that all ranges in catch streams should encompass the metrics of U2014’ =20% for major stocks and U2014’=10% for minor stocks, and MPDs relating explicitly to those harvest rates should be included for reference purposes.

Table 1. Probabilistic decision table metrics.

Metric	Description
P(SB_{2014} < 0.25SB_0)	Probability the forecast spawning biomass (for a given catch level) is below cutoff (0.25SB_0)
Median ratio (SB_{2014} / 0.25SB_0)	Median ratio of forecast spawning biomass (for a given catch level) to 0.25SB_0. When ratio=1, SB_{2014} = 0.25SB_0; when ratio=2, SB_{2014} = 2* (0.25SB_0); when ratio=0.5, SB_{2014} = ½ (0.25SB_0)
P(U'_{2014} > 20%)	Probability the realized harvest rate (for a given catch level) is greater than the target harvest rate of 20% (major stocks)
P(U'_{2014} > 10%)	Probability the realized harvest rate (for a given catch level) is greater than the target harvest rate of 10% (minor stocks)
Median (U'_{2014})	Median realized harvest rate for a given catch level (magnitude of U'_{2014})

Bullet points were developed for each major and minor stock area describing recent commercial fishing history, estimated spawning biomass in 2013, recent trends in spawning biomass, and the projected spawning biomass in 2014 given zero catch. Additional caveats were drafted concerning the perception that estimates of the number of age-3 fish in HG, PR and 2W for 2014 appear to be highly uncertain. Meeting participants decided that the forecasted range in 2014 recruitment by age 3 and age 4 and older fish should be reported along with estimated spawning biomass in 2014.

Key conclusions noted for the SAR are:

The PAG recruitment forecasting approach is not scientifically defensible and it does not capture the uncertainty in recruitment forecasts and subsequent risks to BC Pacific Herring stocks. It should not be used for forecasting purposes in the future.

The 2013 spawning biomass and forecast of the 2014 spawning biomass were assessed using an integrated statistical catch-at-age model (ISCAM, “the assessment model”). Advice for each Pacific Herring stock is presented in probabilistic decision tables showing predicted status in 2014 given a range of constant catches relative to target harvest rates and performance metrics relating directly to the existing herring harvest control rule.

Recruitment and natural mortality are considered to be the most important processes determining the productivity of British Columbia herring populations. Natural mortality may be decreasing in all of the major and minor stock areas, except Area 2W, but the reasons for these changes (biological, model-related) are not clear at present and should be investigated.

RECOMMENDATIONS AND ADVICE

It is recommended that the assessment model be used to forecast recruitment in 2014 and to estimate the probability of breaching thresholds or achieving desirable outcomes for BC Pacific Herring stocks and fisheries.

There was consensus to accept the assessment working paper. The reviewer suggested several key revisions to improve the clarity of the model descriptions and the authors agreed to make changes accordingly. Also, an additional sensitivity test using different maturity ogives was recommended for inclusion in the revised working paper.

There was consensus to endorse the results for the 2013 spawning biomass estimates and 2014 forecasts of spawning biomass from the updated Herring integrated statistical catch-at-age model (ISCAM).

There was consensus that the advice for each BC Pacific Herring stock be presented in probabilistic decision tables showing predicted status in 2014 given a range of constant catches relative to target harvest rates and performance metrics relating directly to the existing Herring harvest control rule (HCR).

The following future work is recommended:

- Closed loop simulation to investigate varying survey sampling frequency, alternative management procedures, on assessment model performance;
- Compare the performance of the stock-recruitment model when informed and not informed by other information (age samples) to ascertain what aspects of the data are driving model forecasts of recruitment; and
- Incorporating fishery mortality not captured presently in ISCAM (SOK, etc.)

ACKNOWLEDGEMENTS

The Chair thanks the reviewers, Andrew Cooper, Sue Grant and Andrew Edwards for their thought-provoking reviews of the working papers and all of the participants for their constructive engagement in the science review process at this meeting. Matthew Thompson and Linnea Flostrand are thanked for their rapporteuring skills and excellent notes. The assistance of Marilyn Hargreaves in providing meeting logistics support is greatly appreciated.

REFERENCES

Hay, D.E., Cooke, K.D. and Gissing, C.V. 1986. Experimental studies of Pacific herring gillnets. Fish Res. 4: 191-211.

APPENDIX A: TERMS OF REFERENCE

Stock Assessment and Management Advice for BC Pacific Herring: 2013 Status and 2014 Forecast

Regional Peer Review – Pacific Region

September 4-6, 2013
Nanaimo, BC

Chairperson: John Holmes

Context

Pacific herring is a pelagic species inhabiting inshore and offshore waters of the North Pacific from California to the Beaufort Sea. Herring annually migrate between feeding and spawning areas. Commercial fishing for British Columbia herring stocks is managed based on five major and two minor stock management areas consisting of Haida Gwaii (Area 2E), Prince Rupert District, Central Coast, Strait of Georgia, and West Coast of Vancouver Island (WCVI). The two minor herring stock management areas are Haida Gwaii Area 2W and WCVI Area 27.

The assessment of current Pacific herring abundance and forecasts have been generated annually since the late-1980s for each of the five major and two minor stocks in British Columbia, with a statistical catch–age-model used coastwide since 2006. The model is fitted to commercial catch, proportions-at-age and fishery-independent survey data (spawn index) to estimate reference points and generate 1-year forecasts of spawning biomass (Martell et al, 2012; DFO 2013).

Fisheries and Oceans Canada (DFO) Pacific Fisheries Management Branch has requested that DFO Pacific Science Branch assess the status of B.C. herring stocks in 2013 and provide projections of potential herring abundance in 2014 and the consequences of a range of potential harvests to inform the development of the 2014 Integrated Fisheries Management Plan (IFMP). In addition, DFO Science Branch has requested that DFO Pacific Science Branch evaluate recruitment forecasting methodologies for B.C. herring stocks. This CSAS Regional Peer Review (RPR) is a scientific review of the assessment and projections undertaken in response to this request.

Objectives

Guided by the DFO *Fishery Decision-making Framework Incorporating the Precautionary Approach* (DFO 2009) under *the Sustainable Fisheries Framework*, RPR participants will review the following working papers and provide advice on the objectives listed below:

Stock Assessment and Management Advice for the British Columbia Herring Stocks: 2013 Assessment and 2014 Forecasts – CSAP Working Paper 2013-P46. Jaclyn Cleary, Nathan Taylor, Vivian Haist.

1. Present trends in herring biomass, depletion, and recruitment for each major and minor stocks;
2. Assess the current status of Pacific Herring for each of the five major and two minor stocks relative to 25% B_0; and,
3. Evaluate the consequences of different total allowable catch levels against probabilistic metrics to accommodate uncertainty in the advice. Results will be presented in the form of decision tables.

Review of Recruitment Forecasting Methodologies for British Columbia Herring Stocks – CSAP Working Paper 2013-P71. Rob Kronlund and Jennifer Boldt.

1. Evaluate the existing recruitment forecasting methodologies for validity of sampling and analytical approaches and for consistency with the DFO policy "A fishery decision-making framework incorporating the Precautionary Approach" (DFO 2009) requirement to consider uncertainty in decision making.

Expected publications

- CSAS Proceedings (1)
- CSAS Science Advisory Report (1)
- CSAS Research Document (2)

Participation

- DFO Science Branch
- DFO Fisheries Management Branch
- BC Provincial government representation
- Commercial and recreational fishing interests
- First Nations organizations
- Non-government organizations
- Academia

References Cited and Additional Information

DFO. 2009. A fishery decision-making framework incorporating the Precautionary Approach.

DFO. 2012a. A review of the Pacific herring assessment framework and stock assessment and management advice for Pacific herring 2011 status and 2012 forecasts, September 7-9, 2011. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2011/062.

DFO 2012b. Proceedings on the Regional Peer Review of the Evaluation of Data and Model Assumptions on the Calculation of Management Parameters using the Pacific Herring Assessment Model (ISCAM); June 27 & 28, 2012. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2012/043.

DFO 2013. Regional Advisory Meeting on the review of the Stock Assessment and Management Advice for the British Columbia Pacific Herring Stocks: 2012 Status and 2013 Forecasts; September 5 & 6, 2012. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2013/009.

Martell, S.J., Schweigert, J.F., Haist, V., and Cleary, J.S. 2012. Moving towards the sustainable fisheries framework for Pacific herring: data, models, and alternative assumptions; Stock Assessment and Management Advice for the British Columbia Pacific Herring Stocks: 2011 Assessment and 2012 Forecasts. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/136. xii + 151 p.

APPENDIX B: PARTICIPANTS

Last Name	First Name	Affiliation
DFO		
Boldt	Jennifer	Science
Boutillier	Jim	Science
Brown	Laura	Science
Cleary	Jaclyn	Science
Edwards	Andrew	Science
Evanson	Melissa	Science
Flostrand	Linnea	Science
Fort	Charles	Science
Grant	Sue	Science
Hall	Peter	Fisheries Management
Hargreaves	Marilyn	Science
Hay	Doug	DFO Scientist Emeritus
Holmes	John	Science
Kanno	Roger	Fisheries Management
Kronlund	Rob	Science
McCarter	Bruce	Science
Midgley	Peter	Science
Mijacika	Lisa	Fisheries Management
Rutherford	Dennis	Science
Schweigert	Jake	DFO Scientist Emeritus
Spence	Brenda	Fisheries Management
Taylor	Nathan	Science
Thompson	Matthew	Science
External		
Brown	Gus	Heiltsuk Tribal Council
Chalmers	Dennis	BC Ministry of Fisheries
Dorner	Brigitte	Hakaii Network
Gladstone	Keith	Heiltsuk Tribal Council
Haist	Vivian	Haist Consulting
Hamer	Lorena	Herring Conservation and Research Society
Hessing-Lewis	Margot	Simon Fraser University Herring School
Hrabok	Christa	A-Tiegay Fisheries Society
Jones	Russ	Council of Haida Nation
Keeling	Brittney	Simon Fraser University Herring School
Lane	Jim	Nuu-chah-nulth Tribal Council
Moody	Reg	Heiltsuk First Nation
Morley	Rob	Canadian Fishing Company
Rooper	Chris	National Marine Fisheries Service, USA
Safarik	Ed	Herring Conservation and Research Society
Starr	Paul	Consultant for Herring Conservation and Research Society

APPENDIX C: AGENDA

Stock Assessment and Management Advice for BC Pacific Herring: 2013 Status and 2014 Forecast

September 4-6, 2013

Pacific Biological Station
3190 Hammond Bay Road, Nanaimo, BC, V9T 6N7

Chairperson: John Holmes

Wednesday September 4 – Day 1

Time	Subject	Presenter
09:00	Welcome and Introductions	John Holmes
09:15	Review Agenda and Housekeeping Items	John Holmes
09:25	CSAS Overview and Meeting Procedures	John Holmes
09:35	Review Terms of Reference	John Holmes
09:45	Herring Science Overview	Nathan Taylor
10:15	***Break***	
10:30	Discussion of Herring Science	All Participants
11:00	Presentation: "Review of Recruitment Forecasting Methodologies for British Columbia Herring"	Rob Kronlund
12:00	***Lunch***	
13:00	Reviewer Comments and Authors Responses	Andrew Cooper/Sue Grant
14:30	***Break***	
14:45	Discussion of Recruitment Forecasting Methods	All Participants
15:45	Finalize conclusions and advice	All Participants
16:30	***Adjournment***	

Thursday September 5 – Day 2

Time	Subject	Presenter
09:00	Introductions & Housekeeping	John Holmes
09:15	Review Day 1 and Agenda for Day 2	John Holmes
09:30	Presentation: "Stock Assessment and Management Advice for the British Columbia Herring Stocks: 2013 Assessment and 2014 Forecasts"	Jaclyn Cleary
10:30	***Break***	
10:45	Reviewer Comments and Authors Responses	Andrew Edwards
11:15	Discussion of Results and Advice by Stock: HG, PRD, CC, SOG, WCVI, 2W, 27	All Participants
12:00	***Lunch***	
13:00	Discussion of Results and Advice by Stock Continued	All Participants
14:30	***Break***	
14:45	Finalize conclusions and advice by stock	All Participants
16:30	***Adjournment***	

Friday September 6 – Day 3

Time	Subject	Presenter
09:00	Introductions & Housekeeping	John Holmes
09:15	Review Days 1 & 2 and Agenda for Day 3	John Holmes
09:30	Science Advisory Report (draft will be circulated) Develop Consensus on: • Key results, conclusions and recommendations • Uncertainties • Ecosystem Considerations • Advice for Management , including Decision Tables • Recommendations for future work • Other	All Participants
10:30	***Break***	
10:45	Science Advisory Report Discussion Continued	All Participants

Time	Subject	Presenter
12:00	***Lunch Break***	
13:00	Finalize (Draft) Science Advisory Report	All Participants
14:00	Wrap-up, next steps, other business	All Participants
14:30	***Adjournment***	

APPENDIX D: SUMMARY OF THE WORKING PAPERS

REVIEW OF BC PACIFIC HERRING RECRUITMENT FORECASTING METHODOLOGIES

The five major, and two minor, stocks of Pacific Herring have been managed using defined fishery management including a harvest control rule since the 1980s. However, stock assessment model outputs have not been the only information source used when applying the harvest control rule. The forecast of pre-fishery biomass that was input to the harvest control rule was not solely a function of the prediction from the statistical catch-at-age model. Instead, model predictions of the numbers of fish recruiting to the pre-fishery biomass were replaced with one of three alternative values intended to better reflect the putative strength of incoming year class. For three of the major stocks, the selection of the preferred alternative used to calculate the potential harvest used decision rules that depended on the status of the stock relative to a threshold where fishing is curtailed and the strength of the incoming year class over the last two years. The remaining two major stocks used auxiliary data collected post-stock assessment from a summer trawl survey to identify the preferred alternative and consequently a potential harvest.

Following the development of these forecasting methodologies, fishery decision-making policy emerged in 2009 that explicitly requires reference points, a harvest strategy and evaluation of uncertainty and risk. This analysis reviewed the Pacific Herring forecasting methodologies and found that the categorization of model-reconstructed recruits to the pre-fishery biomass was inconsistent with the assumptions of the stock-recruitment parameterization of the assessment model and could produce a distorted perception of both forecast stock size and uncertainty. Decision rules applied to three of the stocks, originally motivated by a desire to provide options to decision-makers, do not communicate the trade-offs between conservation and yield considerations inherent in fishery management decisions; an alternative is to use the assessment model to produce probabilistic statements regarding the risks of breaching thresholds or achieving desirable outcomes for the stock and fishery are in keeping with policy goals. Application of the trawl survey data is hampered by issues related to unknown mixtures of Pacific Herring stocks in the survey area and use of these data external to the assessment model fits. However, the long history of data collection, quantitative assessment and application of a harvest control rule to Pacific Herring management provides a strong base for the development of closed-loop simulation approaches to evaluating management procedure performance.

BC PACIFIC HERRING STOCK ASSESSMENT AND MANAGEMENT ADVICE

Herring stock abundance in BC waters was assessed for 2013 and forecasts were made for 2014 using the integrated statistical catch-age model (ISCAM) developed in 2011. BC herring stocks are managed as five major and two minor stock areas and science advice is provided on the same scale. Commercial catch and survey information collected in each area and all biological data on spawn deposition, size and age composition of spawning stocks were used to determine current abundance and forecast future abundance levels. This working paper provides a summary of current stock status in 2013 and forecasts of abundance in 2014 for each stock area as well as probabilistic management advice on harvest options using performance metrics based on the existing herring Harvest Control Rule (HCR). A number of unresolved issues, major uncertainties, research and data needs were identified by the Technical Working Group and are summarized in this report.

APPENDIX E: WRITTEN REVIEWS

BC PACIFIC HERRING RECRUITMENT FORECASTING METHODOLOGIES

Andrew Cooper

The authors should be commended for what must have been an herculean task of not only figuring out how past decisions have been made but documenting it in a way that makes it relatively understandable for those unfamiliar with the process. According to the Terms of Reference, the goal of the report is to:

Evaluate the existing recruitment forecasting methodologies for validity of sampling and analytical approaches and for consistency with the DFO policy "A fishery decision---making framework incorporating the Precautionary Approach" (DFO 2009) requirement to consider uncertainty in decision making.

Given the time and resources available for this, the authors did an impeccable job. A large portion of the report is dedicated to explaining how the current system operates. I have to admit, despite reading the section numerous times, there are still aspects of the process I do not completely understand. In some cases I am not sure why it is done a certain way, but in others I am not sure what specifically is done. Rather than go into the minute details here, I simply hope we can discuss them more thoroughly at the meeting. The didactic diagrams such as Figures 2 and 4 were very helpful, but it would have been nice to see simplified versions of these figures combined with the information in Tables 3 and 6, along with the steps for age--length key, etc. to produce a single flow chart that depicts the entire process (probably separately for the HG, CC and PRD stocks and the SOG and WCVI stocks). Granted, it would be extremely difficult to produce a readable version on a single printed page, but a scalable electronic supplement would have definitely helped.

As suggested in an email by Dr. John Holmes, I will not delve into specific points of agreement and disagreement but will rather focus on my key points. My primary point is that I completely agree with the authors' conclusion that DFO should move away from the current Poor- Average-Good approach which attempts to combine the stock assessment output with external information to develop an estimate of spawning biomass (which is then input into a control rule) to a more model-based prediction of spawning biomass that is then fed directly into a control rule that allows managers to assess the trade-offs between conservation and yield. A model-based approach as described by the authors would not only make the process far more transparent, it would also be more directly in line with the intent of the requirement of the DFO policy "*A fishery decision-making framework incorporating the Precautionary Approach*" (DFO 2009) to consider uncertainty in decision making. I also agree with the authors' concerns about using the La Perouse survey data to predict age-3 recruitment for the SOC and WCVI stocks as well as their recommendation that further work needs to be performed if that approach is to be considered reliable.

Finally, I agree with the authors' final statements that their critique of the current management system and their recommended changes does not imply that "…the factors that lead to fishery closures were under management control, or that a different outcome would have occurred when applying an alternative management procedure." While the authors did not comment on this, it was interesting to notice that the spawner-recruit curves for all the stocks are actually quite flat over the range of observed stock sizes (Figure 17). This implies that using the long-term average recruitment to estimate future recruitment would not likely differ too markedly from assuming a deterministic result from the estimated spawner-recruit curve. This is not to say that the PAG-estimated recruitment accurately captured the temporal dynamics of the residuals from the estimated spawner-recruit curve as one would hope (we are actually given very little information about which of the PAG states have been chosen when), but it does somewhat lessen the problem of the PAG estimates being disconnected from the estimated stock size, one of the key issues discussed in the report.

Sue Grant

Terms of Reference:

As described in the Request for Science advice: "Is the method for Pacific Herring recruitment forecasting currently in use by DFO Science compliant with the Department Sustainable Fisheries Framework and the Precautionary Approach"; "If the [forecast] method used results in biases then the Management decisions taken re: TAC could a) result in stocks entering into or remaining in the Critical Zone (TAC too high) or b) result in loss of possible revenue for the fisheries (TAC too low).

As described in the TOR: "Evaluate the existing recruitment forecasting methodologies for validity of sampling and analytical approaches for consistency with DFO's Decision Making Framework (DMF) requirements to consider uncertainty in decision-making.

Priorities of CSAS Subcommittee during 2012 Assessment (Cleary et al. 2013 in review): Given the significance of recruitment to herring stock productivity, an evaluation of current recruitment forecasting methods and comparisons with other sources of data (herring purse seine surveys) and other modeling approaches warrant further research.

Key clauses in DMF that applies to the Science Advice as it applies to the current paper: #3: 'the need to take into account uncertainty and risk when developing reference points and developing and implementing decision rules'

Is the purpose of the working paper clearly stated?

Overall: at a high level agree that the purpose is described;

- **Title:** The paper is titled 'Review of forecasting methods for Pacific Herring', which is a big piece of what the paper is covering (i.e. a review of methods). However, I would have thought the detailed current forecasts methods would have been well documented in previous publications and could have been referenced for the current paper. If this is not the case, then the detail would be required for readers to understand the evaluation and is important to document for transparency. The title, however, might be narrowed to set up the reader more effectively in regards to the papers objective: e.g. 'A review of Pacific Herring forecast methods in the context of DFO's Decision Making Framework'.
- **Introduction:** As described in the paper's introduction: 'The purpose of this document is to focus on how uncertainty is represented in the [current] forecasts, which in part rely on factors external to the SCA model, and to assess the degree to which methodologies assist compliance with the DMF'. The introduction provides a list of what the paper will cover, which largely is described as a review of the current and historical forecast methods, and also includes a review of the Pacific Herring Harvest Control Rule (HCR) and DFO's Decision Making Framework (DMF). The final item listed in the introduction is linked to the Science request, listed as to 'summarize and discuss the problems incurred at selected steps of the forecast methodologies and assess how well the approaches align with DMF policy requirements'. So it is important (from the perspective of clarity on the paper's purpose) that both the title and introduction clearly describe the goals as two-fold since they each roughly divide the paper in half: 1) detailed documentation of all

current forecast methods for transparency purposes; and 2) provide an evaluation of the current forecast methods in the context of the DMF.

Broad comments on the current forecast approach (not specific to the current paper)

- The use of the term 'decision rules' is used both in the context of HCR and the current forecast process is confusing; I recommend an alternative name for the categorical forecast process used to select P/A/G categories, such as 'selection criteria' (although perhaps a moot point if the forecast approach in the future, as recommended by authors, diverges from the current approach); it is confusing to see the term 'decision rules' used for very different purposes (i.e. Science versus Management purposes);
- A succinct, clear and consistent way of describing the current method's use of both SCA forecasts for age-4+ and SCA age-3 numbers based on the entire time series, and broken into three categories would be helpful. Different papers describe the methods differently and in ways that do not always align correctly with what is actually done; the detailed methods descriptions in the current paper, however, were well done and provided a very clear and detailed understanding of the current methods;
- part of my confusion initially regarding current forecast methods (prior to reading detailed description of methods in current paper) came from the use of Poor, Average and Good Categories presented in all tables of DFO's Science Advice (e.g. Table 1 of current paper). Initially I thought that all the uncertainty in the SCA model derived forecasts for all ages were split into three categories (based on the 0.33 and 0.66 percentile of biomass across the entire time series). Then if there was informative auxiliary information, this could be used to provide science advice regarding expectations for the T+1 biomass to be either P/A or G. Instead, I think this use of the word Poor, Average, Good and the Science Advice provided to date has been misleading, implying different states of nature (different conditions contributing to T+1 ages 3+ survival and recruitment), when in fact it is just describing the distribution of Low, Medium, or High age-3 abundances across the historical time series; the Low, Medium or High characterization only reflects age-3 recruitment forecasts and not other ages (this latter point I believe has been made by the authors);
- it was a puzzle that the current forecasts were conducted using Bayesian approaches, yet the Science advice provided to managers was not presented probabilistically as described by the authors; the information was available and important to categorize risk (conservation and fisheries) that would have assisted in decision making; the cut-off point as well is estimated with uncertainty, and that should have been presented as well;

Higher Level Editorial Comments (details provided to authors embedded in word file).

- **Introduction:** provides background for the current forecast and the HCR, but does not provide sufficient context for why this evaluation is required. For example, it may be that the details on the historical and current forecast methods have been poorly documented until now and that that this current paper's documentation of detailed methods is an important piece for transparency and evaluation. It may also be that the methods to identify age-3 Poor, Average, Good Recruits has not been previously evaluated for bias/precision. In addition, it may also be that the 'forecast decision rules' to select Poor, Average, Recruits, have not been evaluated in the context of bias. What is the risk to the absence of this paper's evaluations and advice for Fisheries Managers from the context of conservation and sustainable use? All of this would have been helpful in the introduction to set the stage regarding why this paper is important. Other items to include in the introduction is the broad approach you used to evaluate the work, and the key findings (the punch-lines/recommendations).

- **Context Section:** this provides some of the rationale for the purpose of this paper, of which some of the high level points could be included in the introduction, so reader has a high level perspective on why this paper is being written; need to provide more emphasis on how this context, particularly linked to the HCR, is important to consider from this paper's evaluations perspective; this is an important section to really focus the reader on the issue related to the current paper;
- **'Chronology of Forecast Methods' and ' METHODS' section:** for clarity it might be helpful to keep 'Chronology of…' in the 'CONTEXT' section and move 'METHODS' to an Appendix, since these methods are not the methods of the current paper's evaluation approach, but rather documentation of the methods of the current forecast approach (used up to 2012). If the current methods have not previously been documented in this level of detail, then this current methods section is very important for transparency and evaluation of the current forecast approach. I recommend the official METHODs section of the paper just include the methods of the current evaluation.
- **Results and Discussion:** there are a few figures/tables (results of the current paper's evaluation) that are misplaced (lost) in the current methods section that could be moved into this section; this would ensure these results are not buried in the review of the current methods such as Figures 2-3 and Table 4. An overview paragraph of the key conclusions and recommendations should be provided at the start so that the synthesis of your conclusions are not lost; this should be repeated in the introduction at a high level and also the abstract to emphasize your findings; there are so many scattered conclusions and results throughout this large section that distilling it all down and having a big picture view of it all is currently a challenge.

Are the data and methods adequate to support conclusions and explained in sufficient detail to properly evaluate the conclusions?

Key conclusion is to use SCA model output for all forecasts, including age-3;

1. The authors recommend the use of SCA model forecasts for all age-classes in subsequent years, a change from previous year's forecasts which replaced the age-3 SCA derived forecasts with alternatives based on past average returns of age-3 fish;
2. The authors also recommend presenting biomass forecasts probabilistically as Science Advice moving forward to frame out risk to managers (conservation risk and fishing yield risk); this has been possible in previous forecasts, although not presented as Science Advice in decision tables (e.g. Table 1 of current report), so was not previously compliant with the DMF; including probabilistic advice as recommended by authors will in part address compliance of the Science Advice to the DMF; *moving forward, although outside the scope of the current paper, I would recommend presenting the cut-off point (0.25 B_0) probabilistically as well since there is uncertainty in this benchmark; the risk in presenting the cut-off point as a single value is exacerbated by the lack of an upper benchmark (and/or a buffer around the cut-off point), as per the DMF, to trigger management action in periods of biomass declines prior to reaching the cut-off;*
3. The authors further recommend, as the "[o]nly ways to develop a management procedure that is robust to the true range of uncertainty in stock status and future projections is through feedback simulations"

Rationale for this recommendation;

- Key analyses/figures that support the authors' conclusions against the use of the current forecast methods include bias in the current forecast approach that arises from the use of historical average returns of age-3 fish (estimated using Bayesian methods) and categorizing these returns into three categories (designated Poor, Average, and Good); the authors use Figure 4 to demonstrate how relatively infrequent high abundances can skew the means (step 3.4) in the three categories (particularly in the Good category). Since this bias affects total biomass forecasts, this can for example result in increased conservation risk, particularly if Good categories (currently biased high) are selected for management purposes, and the biomass represented by the median of these distributions is close to the cut-off point (0.25 Bo);
- I agree the authors presented sufficient results to support the biased means in each category, however, it is not clear to me, why if the data are lognormally distributed, geometric means were not used in step 3.4 of the current methods, which would have resolved some of these issues; if this alternative approach was used risk would have been lower, particularly in the Good categories, when the median (step 3.7) of the distribution of geometric means (step 3.4) were used instead of arithmetic means; the current bias in forecast category means is exacerbated given the cutoff point is currently presented as a single value in the Science Advice, and that there is no upper benchmark to trigger management actions to respond to biomass decreases from the upper benchmark to the lower (cutoff point) benchmark (narrow cautious zone of the DMF, as presented in Cleary & Schweigert 2011);
- Further, the authors demonstrate in these Figures (4-9) how the mean abundances in these three categories used in the forecast will lag past abundances, which would be a particular issue if current abundances diverge significantly from past abundances in either direction (implications to both conservation and fisheries, depending on the direction the current abundances diverge from the past);
- I think the risk in the lag bias is not as high as the selection of the 'wrong' category; in Figure (5-9) I generally do not see huge inter-annual changes in the mean values of the categories and likely these distributions will largely overlap between years, particularly in light of recommendations to present the forecast probabilistically; so the more important issues to be emphasized are those associated with the following: (1) partitioning of past returns into three categories, and then using the median (time T) biomass comparison with the median cutoff (and in some cases also past category assignments in year T and T-1) to select one of the forecast categories for fisheries management; this selection process does not consider the probability distributions of the biomass at time T and the cutoff, for example almost half the biomass distribution at time T could be below the cutoff, and yet a 'Good' category would be selected if the median is only slightly above the median cutoff (the authors make this point); this is all particularly important given the current HCR is largely an on/off switch, defined largely by the cutoff, so either a buffer to the benchmark is required or, as identified in DFO's DMF an upper reference point is required to taper off fishing as biomass decreases (currently the cautious zone described in the DMF is narrow for Pacific Herring Management as per Cleary & Schweigert 2011); (2) through the selection of one of the three categories using 'selection criteria' further introduces risk given the data based on figures 15-17 show that recruitment is not necessarily autocorrelated (as the authors mention), so it does not follow that if the previous two years were Good or Poor or Average, that the Y+1 will necessarily be the same; as a result the selection of a particular category, even probabilistically, will introduce bias in the advice and underestimates uncertainty;

- The authors state that “[i]n regards to the ‘decision rules’ used for HG, CC, and PRD stocks used to choose between the Poor, Average or Good median values in the forecast tables (e.g. Table 1), the authors conclude that there is ‘no reason a priori to expect that such rules would be superior to model-based forecasts.; agreed, but authors need to really emphasize all the issues with assigning these categories as per some points in the previous bullet; I think this is the key point to make, above and beyond biases and lags in the means used;
- the selection approach for WCVI and SOG stocks, in contrast, uses survey data to assign categories, and for this the authors also recommend against using La Perouse survey to predict age-3 recruitment(s) to the spawning stock biomasses of WCVI and SOG stocks is that several stocks mix in the survey area; the reason that stock mixing invalidates the utility of these survey data for predicting age-3 recruits to the spawning stock biomass is that in any given year, the relative proportion of each stock is unknown.
- Other key analyses that support the argument against the categorical current forecasts are they underestimates uncertainty as presented in Figure 3 and Figure 10 to 13; The authors conclude that “[t]he posterior distributions of numbers at age-3 from each of the Poor and Average categories, and sometimes the Good categories are much narrower than would be obtained using the full marginal posterior distribution of the numbers at-age 3 from the SCA model. This compression is propagated to the…forecast biomass”
- I do not see this in all cases (e.g. not the case for SOG or WCVI, and not the case for almost all Good categories, associated with higher uncertainty likely given the use of arithmetic means); there is a lot of overlap in the distribution between categories and SCA; this narrowing of distributions is even less apparent when looking at the total biomass forecast distributions; however, I do agree with authors that in the cases where the distribution is quite small in a selected P/A/G category, and if this probabilistic information is used (as recommended by authors) moving forward, the use of the category would underestimate risk as presented to managers;
- the authors recommend the SCA model since it explicitly considers the most up-to-date information on growth, spawning stock biomass, natural and fishing mortality. In addition it can be updated to address autocorrelation if required. Also it takes into consideration the stock-recruitment relationship;
- I agree with the authors, that the current approach of breaking the age-3 forecast into three categories and selecting one for the HCR is likely not appropriate. At the very least moving forward, if the age-3 forecast is replaced with returns (i.e. current methods), the entire return distribution should be used (rather than breaking up the return distribution into three categories); retrospectively, given uncertainty in the SCA model it is possible that this naïve model might perform better than the biological one (we see this for certain stocks in our Fraser Sockeye models); however, there are many other arguments the authors make towards using the CSA model (replacing model derived age-3 forecasts with medians, even of the entire distribution, results in a loss of information; SCA model predicts expected recruitment; etc.) that support the use of the CSA model over the naïve model;
- The authors recommend that characterization of uncertainty should be provided in the Science Advice to Fisheries Management to align with the DMF (i.e. inclusion of uncertainty in Science advice) and DFO’s Sustainable Fisheries Framework (i.e. ensuring conservation and sustainable use objectives are used in decision making); the authors conclude that the “current approach meets the DMF policy to characterize

uncertainty to the extent possible for the stock reconstruction but has not been consistently applied to quantify the risks to achieving desirable future outcomes for the stock and fishery." This is being resolved through the inclusion of quantification of risk in the upcoming forecast paper (as per Clearly et al. 2013 in review); As authors describe, using past single values for the forecast previously (up to 2012) represented risk that a stock might be overfished, given that although the median of the selected distribution fell above the cutoff (0.25 Bo), half the distribution might actually be falling below.

- I would agree with authors that the inclusion of uncertainty in the provision of Science Advice to Fisheries Management should be recommended for subsequent stock status evaluations; it is unclear why, if current forecasts were cast in a Bayesian framework, the forecast distribution relative to objectives (or simply the distribution alone) was not presented previously; it would be important for managers to make decisions with a clear understanding of conservation and fisheries risks, in order to make informed decisions (as recommended by authors and used in Clearly et al. (2013 in review); I would also suggest the risk in not presenting the forecasts probabilistically is further exacerbated by only the median cutoff (lower reference) point only being presented (not the distribution), and the lack of an upper reference point to reduce fishing if biomass started decreasing towards the lower benchmark);

BC PACIFIC HERRING STOCK ASSESSMENT AND MANAGEMENT ADVICE

Andrew Edwards

General Comments

Assessing seven independent stocks using a Bayesian age-structured model is a formidable undertaking. Tasks include processing of data, running the computational models and writing up the Working Paper, each of which is non-trivial and time-consuming. There are only about six weeks between availability of Pacific Herring survey data and the submission deadline for the Working Paper. The authors have done a commendable job in completing the work on time, though I feel that the very short timeline is the reason for several of the issues that I identify below.

The main component of the advice is the decision tables. Such an approach is appropriate since it makes good use of the estimated uncertainties from the model, and allows managers to make informed decisions given their objectives. It is also more consistent with the DFO Precautionary Approach than I understand previous advice might have been. As described on p44 of the main text, the metrics reported were agreed upon by the Technical Working Group and Fisheries Management.

Several previous inconsistencies (such as queries for extracting biological data for proportions-at-age matrices and input of the maturity ogive) have been documented and fixed. Having a Technical Working Group who had time to look at the code has clearly proved beneficial.

I have some general comments, followed by detailed comments.

1. Given that some areas are currently closed to fishing (e.g. Haida Gwaii since 2004), I wonder whether every stock really needs to be fully assessed every year.

Reducing the workload on the authors would give them more time to focus on the open areas. Closed areas could perhaps be assessed every other year. This would give the authors time to deliver a more polished document that is easier to read and includes an abstract, consistent page numbering, correct Table of Contents, completed references, equation symbols defined after each equations, etc. Although each of these alone is relatively minor, cumulatively they result in the Working Paper being much harder to understand than it needs to be. Additional time would then also be available for the authors to read through and properly edit the full document before submission (many minor errors/typos would have easily been picked up). While errors can be fixed for the finalised Research Document, it would obviously be preferable to have had them fixed for the submitted version (making it easier for meeting participants, including reviewers). An abstract in particular would give a useful overview.

The final Research Document could then be submitted more quickly after revisions, freeing up some time to work towards preparing for the following year's assessment. I realise that the model and format of advice has changed in recent years, but hope, and anticipate, that the annual assessment can work towards a standard format, with some of the computations and writing using an automated approach that would actually reduce the summer workload.

2. Below I outline in detail numerous problems and errors with the model description. However, I have gone through some of the ADMB source code with the two lead authors to check a few examples where the model equations are incorrect in the working paper. I found that the code itself does appear to be correct and makes sensible calculations. For example, the second line of equation (27) in Table 2 of the Technical Description Appendix is missing the term that propagates individuals into the plus-age class – see (1) below. However, in the ADMB code the relevant line of code does include the missing term. Thus, while the write-up of equations needs substantial correcting, the code may indeed be consistent and plausible (and hence the results are reasonable).

Furthermore, page 6 of the main text states that the Technical Working Group did a thorough review of the model code, lending further confidence that the code is consistent. I realise that sometimes modellers can find it easier to write and understand models in code form rather than mathematically, and so the code is thought of as the 'model' rather than the equations. Having the equations correct (in the past) might have helped avoid some of the earlier inconsistencies that have now had to be documented and corrected (e.g. page 27 of main text and, in particular, the projected catch for year $T+1$, page 28), and I hope that clarifying the equations will avoid the need for such corrections in the future. This would also clarify several questions that arise due to confusion over the model.

3. I have not previously used time-dependent mortality in similar models, and feel that this part of the model in particular needs further explanation and motivation (see below). Especially since the resulting estimated natural mortalities have generally been declining for all stocks in recent years (Figure 12, p39 of main text) while estimated spawning biomasses have been increasing (Figure 8, p35). It's hard to understand what is driving what, and justification for the time-varying mortality might help know what is reasonable. Also, the random walk for the natural mortality gives a biased random walk, such that the mortality is expected to exponentially increase over time (see below); this needs some justifying.
4. The MCMC trace plots are given in Appendix D and look reasonable for all stocks (such that the probabilities in the decision tables are correctly calculated), except for Area 27. For Area 27 the first values for log.m are clearly not representative of the final posterior distribution, suggesting that the chain should be run for longer to achieve stationarity.

Regarding the questions asked of reviewers:

Is the purpose of the working paper clearly stated?

The start of the Executive Summary explains the output, but a more general statement of the assessment would be useful (and would presumably appear in an abstract). Having the results in an abstract would also be useful, and could be based on a condensed version of the text on p32-33 of the main text.

Are the data and methods adequate to support the conclusions?

An age-structured population model is used in a Bayesian context. This is appropriate given the data available and allows formalisation of uncertainty in the resulting advice. The data and methods seem adequate to support the conclusions (which are essentially the decision tables).

Are the data and methods explained in sufficient detail to properly evaluate the conclusions?

The equations are not sufficiently explained (see below), though the parts of computer code that were checked do appear to be correct. The data are generally explained in sufficient detail, though it should be stated somewhere early on that 'Spawn index' is actually an index of spawning biomass (not of spawn). Not being familiar with Herring data/terminology, I'd originally interpreted it as an estimate of spawn, providing information on mature fish in two years time.

If the document presents advice to decision-makers, are the recommendations provided in a usable form, and does the advice reflect the uncertainty in the data, analysis or process?

Yes, the decision tables are usable, their format has been agreed upon by Fisheries Management, and they reflect uncertainty in the model output by giving probabilities. Though it should be noted (at least in the Science Advisory Report) that the uncertainties in the tables reflect only the Bayesian uncertainties of the specified model (rather than, say, uncertainties in model structure or related to data collection).

Can you suggest additional areas of research that are needed to improve our assessment abilities?

A clearly written model would clarify many issues. The time-varying natural mortality could be investigated, as its justification and implication are not obvious. Several areas of research are already outlined in the Working Paper.

The rest of this review is divided up by sections of the Working Paper. There are further extensive minor editorial issues/typos that can be given separately to the authors.

Executive Summary

In my opinion, the Executive Summary has ended up being somewhat long (for a summary), and not being familiar with the fishery or model I had to read the main text first. I would suggest that, in future, the material here could form the Results section of the main text, with a note early in the main text advising that interested parties (managers, industry, First Nations etc.) could jump to that section to see the main results. This would avoid some material being repeated (in the Executive Summary and main text) and shorten the document. The current length is too long to easily become the Science Advisory Report (which is essentially an Executive Summary that omits details of the model/data etc.).

p3, Catches. Is there any rough estimate of the FSC and recreational catch – is it essentially negligible?

p5, 'The current (2013) median posterior spawning biomass is estimated to be 80% of the estimated unfished equilibrium level (SB_0) with 90% credibility intervals...'. This description implies that the median of SB_{2013} is 80% of the median of SB_0, which is not what should be calculated. A correct statement would be 'the estimated median of the posterior of the ratio

SB_{2013}/SB_0 is 80%'. The latter is actually what it says in Table b, and so I trust that the calculations are done correctly, just not accurately described in the text (and for other stocks and pages 32-33 of the main text).

Also, given that distributions of quantities are estimated, more care (accuracy) needs to be taken with phrases such as '... the spawning stock biomass has been increasing since 2009'. This should either be given a probability (calculated as the proportion of MCMC draws for which this statement holds), or more simply, state that the *median* spawning stock biomass has been increasing since 2009. Though actually Table b shows this to be true since 2008. Similarly, for PRD compare text on p13 with Table b on p14, and for WCVI.

A personal preference is to avoid the word 'Depletion', since it's the opposite of what's being calculated (SB_t/SB_0 is what the stock has been depleted to, not how much it's been depleted). This has caused confusion in previous (non-Herring) CSAP meetings.

p5, Figure b: the legend circle for 'Dive' should be a triangle (it is correct in figures in main text).

p7, Figure e: Clarify what the red line is a five-year running average of (presumably medians), and over which five years (the preceding ones?). And it doesn't look to be correctly calculated – it's flat from 1960-1963 yet the recruitments have increased. This is most clearly seen in the PRD Figure e, page 15, over the same period.

p8: it's not clear to me what is meant by 'fishing mortality rates are not comparable across gear types', since they are being plotted on the same graph in Figure g. And in Figure g caption, add that the fishing rates are averages of age-specific values (if that is what is being shown).

p9, paragraph 2: it would be simpler to replace $T + 1$ by 2014 – just say 'spawning biomass in 2014, SB_{2014}', especially since T hasn't been defined. Similarly in Table f: Prob(below cutoff in 2014), or Prob(biomass in 2014 below cutoff).

Many of the above comments refer to the other stocks, giving the identical formatting.

Main Text

page 12, (1): U' needs defining. And are all biomasses here supposed to be spawning stock biomasses? The comparison of B_{T+1} with $0.25SB_0$ implies that the biomasses are similarly defined, but then there is no need for the mixed notation (and the definition given for B_{T+1} should be more explicit).

p12: final line – the efforts to ensure consistency in input data is commended, and should avoid the previous inconsistencies that are discussed.

p14: in Table 2, are the two different shades of tickmarks indicative of anything?

p16. The lead-line shrinkage issue is unfortunate and it's good that a sensitivity test was done showing the impact on the results (page 47).

p17, (3): the 10^{-5} converts 1,000s eggs to tonnes (assuming 100 eggs per gramme of spawning fish), but the explanation given is incorrect (since $10^{-5} \neq 100 \times 1,000,000$, as stated). The 10^{-5} is the factor to convert 1,000s of eggs into tonnes of spawning fish, done by multiplying by 1,000 (to get number of eggs), dividing by 100 (to get grammes of fish, assuming 100 eggs/g) and dividing by 1,000,000 (to get tonnes), which does result in multiplying by 10^{-5}. Also, L and W should be defined, I_t is the spawning index *in year* t, and EggDensity also depends on t.

p17, Table 3: I wonder if it might be possible to calculate uncertainties for the annual spawn indices, and include them in the model run (in future assessments)?

p23, top. I don't fully understand the age incrementing, but I think if the definition of the start of a model year is clarified (see below), this would help to ensure consistency. Since the start of the 'biological' year is July 1st (Appendix F), I think the incrementing makes sense, but could be better explained. Though I don't see why 'Herring aged prior to 1985' would be age-adjusted, if in that period Herring were aged with a July 1st birthday.

p26, Figure 5. It might be helpful (in future) to distinguish the missing years (for which the recent five-year averages are used) from true data, for example by filled circles. Or at least mention in the text how many years have missing data.

p27: these inconsistencies seem to have been satisfactorily addressed.

p28: the previously-used formulation (4) further seems unsatisfactory in that it ignores age-2 fish, which, as Figure 6 shows, can be spawning (and thus caught in the fishery).

p29: the table of issues to address is useful for documenting which issues should be prioritised, and if and when they might be addressed given the resources available.

p32, para 1: the convergence properties of the MCMC runs should be briefly mentioned here (given in Appendix D). Also, for the future, the lowess lines in the trace plots (Appendix D) are not that informative – maybe cumulative medians would be more useful.

p32, para 2: remove 'median' from first sentence. For Figures 7, 11 and 13 why are the MPD values used rather than the medians (though Figure 11 caption says MLEs)? And Figure 7 says 'total biomass', but this is a slightly inaccurate term given that age-1s are not included.

p32, para 3: 'as reported' should be 'than reported'?

p41. Section 3.4.1 has no text, and Figure 14 is not referred to in the text. And in the Figure 14 caption, rather than the blue curve being the Beverton-Holt curve 'fitted to these data', isn't it plotted using the MLEs of its parameters, which are estimated by the full model? And why are MLEs used rather than MPD's or medians of posteriors?

p42, penultimate para: an equation for $SB^*_{o,t}$ would be helpful here, in particular to clarify why t appears here (is it the recent five-year averages are taken from t to $t - 4$ years?). And in Table 5, p43, presumably t is set to 2013.

p44, (6): presumably Na should be $N_{T+1,a}$, which comes from (27) in Appendix F (and includes the fishing effort in year $T + 1$, which is varied to create the constant catches for the decision tables). It should be clarified why (6) is not simply (24) from Appendix F with $t = T + 1$.

p47, final sentence. I wouldn't quite call the effect of the width-estimate sensitivity run 'negligible', since the median depletion values change by $\sim$ 10% for three of the stocks (Table 12).

p53, Table 13: the changes for this sensitivity test (medians of depletion) are $>$ 20% for HG, CC, and SOG, and so maybe more comment is needed. For HG and CC the change results in a higher SB_{2013}/SB_0. Presumably there is more confidence in the data presented for the base case run (and main results) than for the sensitivity test.

p55, Table 14: Just to note that caution should be taken in interpreting the SB_t/SB_0 column, since the values in a column cannot be compared to each other (because they compare different years of SB_t). A useful comparison (for future assessments) might be to give the value of SB_{2003}/SB_0, as calculated using the data up to each year 2003, 2004, ..., 2013. This would show the influence of each new year of data.

p56. There is no p56!

p57. Unresolved problems. Resolving some of the model issues, particularly the timing of natural and fishing mortality, would simplify and clarify the model explanation.

p57. Research needs. Feedback simulation would indeed be useful to develop a robust management procedure. This would require clearly defined management objectives. And regarding my earlier thoughts about the need to evaluate every stock every year, it sounds like lack of funding for surveys may force this to happen anyway.

Appendix F: 'Technical Description of ISCAM'

It would be useful to have a list of assumptions of the model, and maybe a statement somewhere as to how many parameters are estimated by the model. After the first paragraph, the text jumps to talking about weight-at-age and equation (5), without much context.

The model description is lacking in several places, and the notation is not sufficiently explained to make it clear what the model is doing. I realise that some of the notation etc. was determined in earlier assessments, but in my opinion it needs clarifying. One example is that k is used three times to mean different things.

It would seem to be more logical to have Table 3 as the first table, rather than after the two that have equations (because the equations can't be understood without the definitions in Table 3). For example, the second paragraph on page 1 gives m_a from age $a = 2$, but the reader does not yet know why age 1 is being ignored. So I would suggest first explaining the notation, and then walking the reader through the equations.

Also, the time-dependent model (Table 2) should probably come before the steady-state version (Table 1), since the steady-state version should presumably be derivable from the time-dependent model, though it is not clear why the notation is so different in the steady-state version and what the real purpose of the steady-state model is.

What follows first refers to the three tables, and then to the text.

Table 3

Table 3 gives a list of symbols of parameters and variables used in the model, but it is woefully incomplete. For example, equation (10) has six parameters, of which only one (M) appears in Table 3. There are at least 20 symbols that are not defined: $t_0, F_e, B_0, l_a, l_\infty, v_a, \imath_a, \phi_E$ etc., $s_0, \nu_{k,a}, T_k, V_{k,t}, \lambda_{k,t}, \epsilon_{k,t}, R_t, M_t, w_a, \dot{a}, \dot{\gamma}$.

Further problems with Table 3 are:

t – is this considered to go 1,2,... or 1951, 1952, ...? Either way it should be stated, and be consistent in the equations (e.g. (18) and (20) use both ways).

n – presumably should be n_k, since it depends on the gear type.

$w_{t,a}, C_{k,t}$ and $N_{t,a}$ – units need to be given. If $w_{t,a}$ is in kg, and $C_{k,t}$ in tonnes, then $N_{t,a}$ must be number of individuals as 1,000s so that (26) is consistent, and not just 'the number of individuals'.

M – I think M is a 'constant natural mortality rate used in the steady-state equations', and that there should presumably also be M_t, which would be the 'instantaneous natural mortality rate *in year* t used in the time-dependent model', according to (20). And in (14) it should therefore be M_t not M.

$\ddot{R} - \bar{R}$ is the average from year $\acute{t}$ to T, but $\ddot{R}$ is the average over what?

γ_k – maybe 'influences slope of...' as it's not technically the slope.

$\hat{a}_k$ – 'age at 50% selectivity *for gear* k'. And could drop the $\hat{}$, since elsewhere that seems to represent the estimated value of something, e.g. (35).

$F_{k,t}$ (the strange F) – .... for gear k in year t

$\ddot{\omega}_a$ – age-$\acute{a}$ should be age-a, to agree with (17)? And over the values $a > \acute{a}$?

SB_t – it's very confusing (and poor practice) in equations when two letters (SB) are used in a variable name, especially when B_t is also used. This should be considered to be changed in future assessments (SB occurs throughout the assessment, so would be tedious to change now). And give units (tonnes?).

B_t – 'total biomass', but age-1s are not included, since 2 is the first age considered, so 'total' is misleading. Give units. And '... in year t'. Also, on page 8 B_0 is defined as the unfished spawning stock biomass, which is inconsistent with the definition given here.

$f_{a,t}$ – fecundity at age a *in year* t. Also, write as $f_{t,a}$ to be consistent with other notation such as $N_{t,a}$ (where t always comes first). As it stands, $N_{3,2}$ and $f_{3,2}$, for example, would correspond to different years.

Table 1

Caption: 'unequal vulnerability-at-age', is this just 'age-specific vulnerability', which would be consistent with the rest of the sentence?

There needs to be some context (in the text) to explain the second sentence of the caption about M and w_a depending on the time period specified – reconstructions and projections are not mentioned in the text. It is not clear what is going on.

(1): $\hat{a}$ and $\hat{\gamma}$ should be $\hat{a}_k$ and $\hat{\gamma}_k$ since they depend on the fishery? And F_e is not defined anywhere – I think it means equilibrium fishing (though subscripts elsewhere generally represent indices).

(2): Does Φ contain fixed parameters? I don't see $\dot{a}$ and $\dot{\gamma}$ anywhere. And a here seems to be the weight-length coefficient in (4), but a represents age in (3), (5) and elsewhere, so use another letter.

(5): presumably $v_{a,k}$?

(6), (7): these should presumably be equivalent when F_e = 0 in (7), but there is a factor e^{-M} missing/extra for $a = A$. And $a > 1$ should really be $1 < a < A$. And should these depend on fishery k? Maybe there's an assumption about a single fishery instead.

(8), (9), (10): Presumably these should just sum to A instead of ∞. And ϕ_q does not seem to be discussed anywhere else (it just appears in (13)), though the text does mention (10) as referring to the per-recruit yield to the fishery.

(8): presumably $f_a = m_a w_a$.

Table 2

(14): $\{\omega t\}_{t=1}^{t=T}$ should be $\{\omega t\}_{t=t'}^{t=T}$ }, and $\{\phi t\}_{t=2}^{t=T}$ should be $\{\phi t\}_{t=t'+1}^{t=T}$, as mentioned earlier (or redefine T).

(17)-(21): The heading says 'Initial states ($t=\acute{t}$)', but (18) says $\acute{t} \leq t \leq T$ and (20) says $t > 1$, so something is incorrect. And (17) and (18) give two different answers for $N_{\acute{t},\acute{a}}$.

And shouldn't there be an initial value given for $SB_{\acute{t}-1}$, since it would be needed to calculate $R_{\acute{t}+1}$ from (29); I think there are similar quantities that also need to be initially specified.

(25): $v_{k,t,a}$ presumably should be $v_{k,a}$.

(26): as previous line, and w_a presumably should be $w_{t,a}$.

(27): This is really the crux of the model (individuals become one year older each year or they die). The first equation should be for $\acute{a} < a < A$, not just $\acute{a} < a$. The second equation, for $a = A$, seems to missing a term, and should be something like:

$$N_{t,A} = N_{t-1,A}\exp(-Z_{t-1,A}) + N_{t-1,A-1}\exp(-Z_{t-1,A-1}) \quad (1)$$

otherwise the individuals $N_{t-1,A-1}$ will not contribute to any $N_{t,a}$, and none could enter the plus-age class. As noted above, the correct formulation does appear in the ADMB code.

Also, there seems to be no equation for $N_{t,\acute{a}}$, i.e. two-year old fish. Presumably it should be $N_{t,\acute{a}} = R_t$, which in turn depends on the spawning biomass two years prior, as given by (29).

(28): I'm not sure what this calculation for U' is used for (and should it be U' and $N_{T,a}f_{a,T}$?). I think (28) should be equivalent to (5) on p28 of the main text, although (24) here has no natural mortality term.

Main text of appendix F: 'technical description of ISCAM'

page 1. The third paragraph discusses survivorship etc., but it is not clear what the steady-state model is being used for. And the equations are hard to follow without first giving definitions of the parameters and variables. And I can't see how the first equation simplifies to (12).

"We further assume that 100% ...., and that the start of each biological year is July-1st". This should be expanded to make clear. So for year t, if $t = 2012$ does this cover the time from July 1st 2012 to June 30th 2013? And is $N_{t,a}$ the number of age-a fish at the *start* of year t, i.e. July 1st 2012? It is hard to confirm the order in which events are assumed to occur (fishing, mortality, spawning etc.).

page 1, final sentence says "recruitment in years before year $\acute{t}$ are given by eq. 17", but (17) is valid for $t = \acute{t}$. I agree that if not assuming an unfished equilibrium at the start then the earlier recruitments need to be specified/estimated, but it is not clear how this was done. I think maybe only a few indexing terms are given incorrectly (and it might all make sense if corrected), but it is hard to tell.

page 3, line 1: should 'eq. 17' be (18) or (29)? It's confusing, because equations (17)-(21) are under the heading 'Initial states ($t = \acute{t}$)', but non-initial times are being talked about.

para. 4. If F_t (presumably $F_{k,t}$) is assumed to be zero sometimes then, from (21), $\text{F}_{k,t} = \ln F_{k,t}$ will be undefined in such cases. So what happens?

para. 5. There is no justification given for the random walk process for natural mortality. And I find the random walk used somewhat problematic. It is given as (20):

$$M_t = M_{t-1}\exp(\varphi_t), \quad t > 1, \varphi_t \sim N(0, \sigma_M). \quad (2)$$

[Note that $t > 1$ should be $t > \acute{t}$, and that the initial value $M_{\acute{t}}$ needs to be specified/estimated – checking the code the prior on log $M_{\acute{t}}$ is N(-0.8, 0.4), and $\sigma_M = 0.1$ is fixed].

The trouble with this formulation is that the expected value E[M_t] is always increasing over time (replacing $\acute{t}$ by 1 for simplicity here):

$$E[M_t] = E[M_1 e^{\varphi t} e^{\varphi t\text{-}1} \cdots e^{\varphi t2}] \quad (3)$$

$$= M_1 E[e] E[e^{\varphi t\text{-}1}] \cdots E[e^{\varphi t2}] \quad (4)$$

$$= M_1 e^{\sigma^2_M/2} e^{\sigma^2_M/2} \cdots e^{\sigma^2_M/2} \quad (5)$$

$$= M_1 \left(e^{\sigma^2_M/2}\right)^{t-1} \quad (6)$$

which increases exponentially as time goes by. Thus, this is a biased random walk, rather than one who's expected value would always be the original M_1. (The concept is related to why as stated after (37), there is a bias-correction term in (29)). This seems a biologically unrealistic assumption, and so needs justification. Is it intended that natural mortality should increase over time? If so, then it should be bounded at some point. In random walks in other contexts with which I am familiar (e.g. animal movement models), it is more usual to see the random component added to the previous value, rather than the multiplicative aspect seen here. That would be the case here if taking ln of (3), but this still leads to a biased random walk of lnM_t (and since M_t occurs in the model as e^{-M_t}, this doesn't help). Also, on page 8 it says 'as estimates of natural mortality rates trend upwards, estimates of B_0 [actually SB_0] decrease', so this issue deserves understanding.

I suspect that the estimated values of ϕt would not be normally distributed around 0, as they would have to offset the inherent bias of the random walk. [Though I checked these with the two main authors for one stock, and while there was autocorrelation the mean was still essentially 0].

The idea that natural mortality should increase over time may be somewhat justified by the statement (and references) on page 10 of the main text that populations of predators have increased over time, though more explanation is warranted. And it may be driving the model output somewhat – e.g. for WCVI (Exec. Summ., p37-39) the increasing in median spawning biomass is accompanied (caused?) by a decrease in natural mortality from a historic high to almost a historic low.

para 7. The fact that recruitment is to age-2 needs to be explained up front somewhere. And this seems to repeat what is on page 1, so can maybe be shortened or removed. Certainly, the text 'and κ = ...' onwards can be removed, as the formulation for the Ricker model is not really relevant here (and similarly for (40)).

page 6. After (30), the reason for two values for σ_C needs more explanation. And n_k after (31) should presumably be T_k.

last paragraph: 'where $\rho\vartheta$ is the proportion of the total error that is associated with observation errors', but page 5 says ρ is the 'fraction of the total variance associated with observation error' – are these statements compatible? If so, consistency of terminology is needed.

page 7, paragraph 2: having the weights for the post-1988 data being twice as precise as for the early data makes sense given the comments in the main text. But does it matter that values of 1 and 2 were chosen, instead of, say, 0.5 and 1?

page 8, para 1. The pooling of age classes could do with a bit more explanation. Presumably it is only done for the likelihood calculations. And in the penultimate line, 'In the case of $\dot{p}$ = 0, the pooling of the adjacent age-class still occurs...' seems to contradict the preceding text.

(37): I can't see the meaning of ω_t, and how it really relates to δ_t, though I think this will become clearer with the aforementioned clarification of notation and definitions.

page 9: para 4. Note that the convergence penalties are not documented.
pages 9 and 10: maybe tables for the constraints and priors would be simpler.

page 10, Survey priors. If the MLE is being used for the q's, then why would a prior need to be specified? And it's unclear why the MLE is being used instead of the MPD or the Bayesian results.

APPENDIX F: UPDATED SPAWNING BIOMASS PROJECTIONS

Table Appendix F-1. Updated spawning biomass projections for 2014 and estimated contributions by age 3 and 4 and older fish circulated during the RPR Meeting.

	Percent contribution by age-class (based on MPD)		Projected spawning biomass (SB_{2014}) given zero catch		
Stock	**age-3**	**age 4-and-older**	**5th percentile**	**Median**	**95th percentile**
HG	39%	54%	12,270	26,260	58,540
PRD	72%	25%	19,750	44,840	109,500
CC	21%	69%	13,230	23,370	41,210
SOG	36%	52%	73,260	123,300	206,000
WCVI	29%	52%	11,880	21,770	39,360
Area 2W	40%	58%	1,520	4,427	11,760
Area 27	17%	71%	520	1,011	2,000