Fisheries and Oceans Canada | Pêches et Océans Canada
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Canadian Science Advisory Secretariat (CSAS)

Proceedings Series 2022/015

Pacific Region

Proceedings of the Pacific regional peer review on the Stock Assessment and Management Advice for BC Pacific Herring: 2017 status and forecast for 2018

Meeting dates: October 17-18, 2017
Location: Nanaimo, British Columbia

Chairperson: John Neilson
Rapporteur: Linnea Flostrand

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Pacific Biological Station
3190 Hammond Bay Road
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May 2022

Canada

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.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

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

ISSN 1701-1280
ISBN 978-0-660-42553-5 Cat. No. Fs70-4/2022-015E-PDF

Correct citation for this publication:

DFO. 2022. Proceedings of the Pacific regional peer review on the Stock Assessment and Management Advice for BC Pacific Herring: 2017 status and forecast for 2018; October 17-18, 2017. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2022/015.

Aussi disponible en français :

MPO. 2022. Compte rendu de l’examen par les pairs de la région du Pacifique sur avis relatifs à l’évaluation et à la gestion des stocks de harengs du Pacifique en Colombie-Britannique : état en 2017 et prévisions pour 2018; du 17 au 18 octobre 2017. Secr. can. des avis sci. du MPO. Compte rendu 2022/015.

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SUMMARY

Fisheries Management Branch annually requests science advice regarding the status of Pacific Herring stocks in British Columbia (BC) and harvest options following the current harvest control rule and using decision tables. Fisheries and Oceans Canada (DFO) Pacific Region is also engaged in a concurrent multi-year process to renew the management framework for Pacific Herring, which includes simulation evaluation of harvest control rules (i.e. through management strategy evaluation, MSE). Until the MSE process and analyses have been completed, BC Pacific Herring stock assessment continues to be based on two previously endorsed configurations of the current stock assessment model (AM1 and AM2). New to the 2017 assessment is the estimation of stock productivity, and estimation of the current stock status relative to the limit reference point of $0.30SB_0$, which was reviewed and approved in early 2017 (DFO 2017).

These proceedings summarize the discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting of October 17-18, 2017 held in Nanaimo, British Columbia (BC) to review the Working Paper titled “Stock assessment for Pacific Herring (*Clupea pallasii*) in British Columbia in 2017 and forecast for 2018”.

In-person and web-based participation included individuals from DFO Science and Fisheries and Aquatic Management Sectors staff; and external participants from First Nations organizations, the commercial fishing sector, academia, the U.S. National Oceanic and Atmospheric Administration, Alaska Department of Fish and Game, and the private sector.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report (SAR) to help inform on DFO fishery management of BC Pacific Herring. The Science Advisory Report and supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat website.

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) meeting was held on October 17-18, 2017 at the Pacific Biological Station in Nanaimo to review the Working Paper (WP) titled "*Stock assessment for Pacific Herring (*Clupea pallasii*) in British Columbia in 2017 and forecast for 2018*".

The Terms of Reference (TOR) for the RPR (Appendix A) were developed in response to a request for advice from DFO Fisheries Management. Notification of the RPR meeting and conditions for participation were sent to representatives with the relevant expertise from DFO, First Nations, Alaska Department of Fish and Game, commercial and recreational fishing sectors, environmental non-government organizations, and academia.

The following WP was prepared and made available to meeting participants prior to the meeting (abstract can be found in Appendix B):

Cleary, J.S., Hawkshaw, S., Grinnell, M.H., and Grandin, C. Stock assessment for Pacific Herring (*Clupea pallasii*) in British Columbia in 2017 and forecast for 2018. CSAS Working Paper 2017PEL01.

The meeting Chair, John Neilson, welcomed participants, reviewed the role of CSAS in the provision of peer-reviewed science advice, and gave a general overview of the CSAS process. Group introductions were made each day with Linnea Flostrand identified as the rapporteur. The Chair discussed the role of participants, the purpose of the resulting CSAS publications (Science Advisory Report, Proceedings, and Research Document), and the definition and process for achieving consensus around advice. The Chair reviewed the TOR and Agenda (Appendix C) and confirmed that copies of the TOR, WP, and Agenda were distributed to participants prior to the meeting.

In total, 37 people participated in the RPR (Appendix D). The participants were invited to engage fully in the discussion and to contribute knowledge to the process, with the goal of delivering scientifically defensible conclusions and advice. The room was equipped with microphones to allow for remote participation by web-based attendees, and in-person attendees were reminded to address comments and questions so they can be heard online. Participants were informed that Dr. Rabindra Singh (DFO, Maritimes Region) and Dr. Jason Cope of the U.S. National Oceanic and Atmospheric Administration (NOAA, Fisheries, Northwest Fisheries Science Centre) were asked before the meeting to prepare written reviews which were circulated to participants prior to the meeting (e.g. Appendices E and F). All references to figures and tables relate to those of the Working Paper (WP) unless otherwise stated.

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report (SAR) to Fisheries and Aquaculture Management to inform Pacific Herring fishery planning. The SAR and supporting research document will be made publicly available on the Canadian Science Advisory Secretariat website.

PRESENTATION OF WORKING PAPER

Working Paper: Cleary, J.S., Hawkshaw, S., Grinnell, M.H., and Grandin, C. *Stock assessment for Pacific Herring (Clupea pallasii) in British Columbia in 2017 and forecast for 2018*. CSAS Working Paper 2017PEL01.

Rapporteur: Linnea Flostrand

Presenter: Jaclyn Cleary

The Science presentation included a thorough overview and detailed description of the below topics:

- the terms of reference and context that guided the development of the WP;
- the input data (catch by fishing gear, fish weight, fish age, spawn survey index);
- stock assessment bridging and sensitivity analyses
  - partitioning error and variance parameters (observation and process error),
  - time varying natural mortality,
  - varying priors values (means and boundaries) on spawn survey catchability parameters q1 and q2, and
  - varying maturity at age to equal seine roe fishery selectivity ogive;
- concepts related to biological reference points and operational control points and the DFO precautionary approach (DFO 2009), including the mentioning of candidate upper stock references (USR) that could be considered in future work;
- differences between the two base case model configurations (AM1 and AM2)
  - a reference was made to information in Table A1 in DFO 2016 (Appendix G), and
  - retrospective spawning biomass time series plots for each were shown;
- major area stock assessment time series plots of posterior model fits to: spawn survey index, age-2 recruitment, instantaneous natural mortality (M), spawning biomass reconstructions, and production analyses;
- major area stock assessment results of: 2017 spawning biomass (SB_{2017}) relative to the limit reference point (LRP) of 0.3SB_0, projected 2018 spawning biomass (without catch), and relative contribution of fish aged 3 and aged 4-10;
- the use of probabilistic catch decision tables for the provision of advice; and
- future research requirements and recommendations:
  - simulation testing of management procedures,
  - quantify mortality and removed spawn (SOK),
  - investigate appropriateness of sock-specific maturity ogive,
  - potential for stock specific prior distribution on q, and
  - quantify uncertainty (annual variance estimates) in the spawn index .

Responses to points of clarification and questions that arose during the presentation is summarized below.

The author explained why two of the Terms of Reference objectives were not met. Spawn-on-kelp (SOK) fishery data for estimating fishery mortality is not yet ready for inclusion into assessment models but a working group has been tasked with considering how to characterize mortality. For the minor stock areas (2W and 27), spawn surveys observations and biological data were not collected in both areas in 2017 and incomplete time series compromise abilities to assess these stock.

To clarify the nature of herring roe fisheries, the author explained that a large component of the catches are from seine and gillnet roe fisheries that target ripe but unspawned fish and that the timing and locations of the roe fishery are planned to maximize roe quality.

The author described how cohorts can be tracked in time series plots of proportion-at-age by area (Figures 5 and 102 and 111) and she illustrated how cohorts appear more punctuated in areas like the Haida Gwaii (HG) versus the Strait of Georgia (SOG) and West Coast Vancouver Island (WCVI). Possible reasons for the difficulty in detecting cohorts in the age data of southern stocks may be related to faster and more variable growth and greater ageing error from reading annuli in scale.

A declining weight at age trend until 2010 was shown for all major areas (Figure 4) and that, depending on the stock, since 2010 the trends have shown increases and/ or leveled off.

It was clarified that 5-year running average weight-at-age estimates shown in Figure 4 were not used in the assessment but are included to communicate the trends and that mean weight-at-age by year and area are what are used in the assessment. However, five-year average weight-at-age and five-year average model estimates of natural mortality are used in the one-year projection of herring biomass.

For the bridging analysis, the reason for changing model code and platform was explained in terms of seeking a way to have more efficient and flexible computational coding for current and future assessment work. The steps in the bridging analysis were to seek and identify inconsistencies between versions (V0, V1, and V2) and make improvements with changing the model code structure and methods from the 2016 assessment. The variance structure was updated to be based on total precision to improve estimation and to follow the correct errors-in-variables approach. It was explained that two base case models (AM1 and AM2) used for the major stocks had the same parameter settings as those used in the 2016 assessment (DFO 2016).

Based on results of the sensitivity analyses on the q priors where changes to the bounds of the q prior standard deviation didn't affect directional changes in biomass estimates of all major areas similarly, the authors recommended to keep the standard deviation for the q prior for AM1 the same as used in the 2016 assessment (DFO 2016). The author's recommendation was endorsed by participants.

Background for the reason to test changing the maturity ogive to match the selectivity of the seine roe selectivity was explained in terms of investigating a potential cause linked unreasonably high estimates of reference points related to fishing mortality (F_{MSY}), identified in previous reviews (e.g. DFO 2017). The current work showed that changing the maturity ogive reduced the estimates of fishing mortality reference points somewhat but that the estimates still appear unusually high.

The author explained that production analyses were included in the stock assessment because estimates of biomass alone are not fully informative for describing the status of a stock to consider if a stock has been growing or not. Information from productivity trends can also be associated with the probability of a stock being at or near a LRP level for projecting purposes.

PRESENTATION OF WRITTEN REVIEWS

Dr. Rabindra Singh (DFO, Maritimes Region) and Dr. Jason Cope (NOAA Fisheries, Northwest Fisheries Science Centre) provided reviews of the Working Paper in written and oral presentation formats. Both reviewers commended the authors for a well written and presented WP. Both reviewers reiterated information included in their written reviews and where applicable, responses from authors were noted and are described below.

DR. RABINDRA SINGH (DFO, MARITIMES REGION)

The reviewer asked for clarification on why gillnet caught fish are excluded from the calculation of average weight-at-age. The lead author explained that gillnet catch data are accounted for in the model and that gillnet caught numbers at age data are used to estimate selectivity but that mean weight at age information from gillnet samples are not used to characterize mature spawner weight at age on a stock level due to the gear's size selectivity. Seine caught biological catch sample data alone (from roe seine fisheries and test fisheries) are used because seine gear is unselective to fish size. It was recognized that the behavior of seine fisheries can introduce biases by seeking to set on fish of desired sizes. The author explained that seine test fishing effort has a wider range in time and space than the commercial fishery and aims to have unselective behaviour. It was explained that assessment modeling keeps information from winter fisheries separate from roe fisheries to try to reduce biases from different fishery motivations but the assessment doesn't model motivation of the fisheries.

Clarification was provided to the reviewer on the spawn index as being two separate time series (no overlap) by area based on the type of dominant spawn survey undertaken to characterize spawn events which assessment modeling fits separately.

The reviewer asked about the low sample size for the HG reported on page 16. The author responded by confirming that the number of samples for the HG stock has been relatively low in recent years compared to earlier years and other areas. The author explained that although there have been commercial fishery closures in over 10 years in the HG that a seine test fishing charter has been working the area with the same captain and boat and that in 2017 the charter crew found it hard to locate and access schools to sample.

The reviewer commented on the reduced weight-at-age trends shown for the stocks stating that similar trends observed for herring and other species on the east coast. He pointed out that when a population has smaller size at age, the number of fish per unit weight increases so more fish are required to sustain biomass and catch levels. It was also noted that gear size selectivity can remove the genetically larger or faster growing individuals in a population thus causing smaller individuals to have more importance in contributing to recruitment. Authors explained the possibility of changes in size-at-age trends as being ecosystem driven, as similar trends in size-at-age have been seen in Pacific hake and salmon stocks.

DR. JASON COPE (NOAA FISHERIES, NORTHWEST FISHERIES SCIENCE CENTRE)

The reviewer started by explaining that his review points are meant as constructive feedback and not necessarily meant for revisions of the current WP and he leaves it to the authors and others to decide what feedback to use and when, how and where to use it.

He asked about the inclusion of information in section 1.7 relating to reference points and harvest control rules in a stock assessment because, based on experience, this type of information is not typically in an assessment research document. He asked about the 20% harvest rate and the fixed cutoff. The author acknowledged that information on legacy practices may be confusing for someone outside of the DFO Pacific Herring process and explained that Pacific herring stock assessment analysts have been asked to include this type of information into research documents, largely because there has been no other place to document this information. She explained that a 20% harvest rate came about from 1983 simulation work published in 1988 that estimated a 20% harvest rate as one that maximized SOG yield and adhered to other desired performance metrics such as reduced closures. She also explained that recent simulations suggest that stocks don't respond as well as earlier expected to a 20% harvest rate in part due to varying stock productivity. It was also explained that authors have been asked to report AM1 results for each major stock area with respect to a cutoff of 0.25SB0, and to report AM2 results with respect to fixed cutoffs determined in 1996. The 1996 fixed cutoff amounts were first established after a series of years after 1986 when the cutoff was updated every 1-3 years and when stock area boundaries and assessment methods were changing. In 2011/2012 when AM1 was developed and incorporated into the stock assessment process with q2 estimated, other model changes and trends such as changes in mean weight-at-age, it didn't make sense to use the 1996 fixed cutoffs so AM1 estimates of 0.25SB0 were used instead. There was agreement that 1-2 sentences on each of these topics would be useful when revising the WP.

The reviewer asked to what degree is catch from other fishery sources not being included in the model. Is it worth hypothesizing in scenarios to characterize uncertainty and sensitivity at different levels? The author responded that Food, Social, and Ceremonial (FSC) and recreational catches are negligible when compared with seine and gillnet fishery catches.

It was clarified that age compositions are fitted in the model and it was asked if ageing error is accounted for. The authors explained that double ageing by two age readers occurs for up to 10% of scale data by year used in the assessment process, and if there is poor ageing agreement, additional double ageing occurs. For northern stocks, reconciling annuli from winter growth is generally clearer but for southern stocks, challenges reconciling ages 2 or 3, and 3 or 4 have come up, believed to be due to faster growth in these areas. The reviewer suggested that the research document could include wording to acknowledge or describe that ageing error does exist and efforts are taken to reconcile the error outside of the model. He further suggested that future work could be considered to account for ageing error within the model.

It was also asked why the WP stated age adjustments happened to age data before 1985. The author explained that the ageing conventions changed from a January to July birthday that year. The reviewer suggested that some wording explaining this may be helpful to readers and if this may affect modeling then sensitivity runs should be done to test this.

The author sought clarification that authors were inputting matrices of weight-at-age data and asked whether weight-at-age data are fully integrated into model. The author responded that the model is fitted to a matrix of average weights-at-age for ages 2:10+, from 1951-2017, and that weight-at-age is averaged for the seine-caught fish only (excluding fish caught using gillnet gear). The reviewer asked if fits to age composition data were looked at and if they could be included in the document as diagnostics to account for uncertainty. The author said yes they do look at these data but have not included them to reduce to bulk to document; thus, they are interested in suggestions for a concise way to present this information. The reviewer proposed the use of 1: 1 (observed: expected) plots.

The reviewer asked about uncertainty associated with the spawn survey indices (e.g. error bars) as it appears the uncertainty is not added to the model. The author explained that efforts are underway to explore ways to characterize variance within and between spawn survey sites (e.g., transect bootstrapping). It was clarified for the reviewer that 0.38 is assigned to represent the average of the overall variance of spawn survey observation error across years and is a multiplier that gives the dive survey greater weight in the likelihood function. It was also explained by an author that sensitivity runs are being considered to test variance assumptions and these issues have already been identified by authors and others for future work. Specific feedback from the reviewer at a later time to assist DFO analysts with this would be welcome.

The reviewer asked why growth parameters from Fish Base were reported in the document and sought clarification for whether age was estimated through a growth model. It was explained that no growth model is used and empirical observation of age-at-length and age-at-weight are used. Because of this, it was agreed that no reference to Fish Base parameters are required in the report.

Regarding LnR0, the reviewer suggested not using a negative lower bound, which authors and the reviewer perceived as a simple adjustment.

Regarding M, the reviewer sought clarity on the origin of this value and suggested more information in the report to explain the source of the value and putting the fixed M values on the plots. The reviewer also suggested future work be done to test the sensitivity of varying M.

The reviewer asked is it biologically possible for the variability in natural mortality to increase two fold over a relatively short part of the time series (e.g. from 0.1 to 0.6 in 10-20 years). The reviewer suggested that it may be useful to consider some hybrid between time varying and fixed M if time varying M estimates are questionable. An author explained that the variability in M may be realistic due to changes in the predator community and trophic interactions but acknowledged that variability in M may also be accounting for too much of the model variance. The reviewer suggested that some wording in the report on this would be useful to capture this uncertainty.

The reviewer suggested the inclusion of total likelihoods from different sensitivity model runs in the report and the lead author acknowledged that this could easily be done.

In response to the reviewer’s written review, the authors revised information in Table 48 to reduce redundancy related to reporting information both in terms of q1 and a2 and surface and spawn survey periods.

The reviewer commented that fixing q2 to 1 for AM2 is making it the most informative prior possible and questioned why authors would flag the uncertainty in AM1 q2 priors over AM2 q2=1. Authors agreed with and acknowledged the reviewers point.

The reviewer suggested that several other future work sensitivity analyses could help evaluate some of the assumptions and uncertainty associated with the assessment models and authors responded that they agree and will seek specific feedback from the reviewer outside of the meeting.

GENERAL DISCUSSION

General discussion was focused on topics related to input data informing the stock assessment modeling, stock assessment assumptions and analyses, assessment results and output, uncertainties and information gaps, ecosystem considerations and developing conclusions and future work recommendations in association with developing a Science Advisory report (SAR).

INPUT DATA

A participant made the following comments related to biological hypotheses or trends not being considered or accounted for in the stock assessment:

- there could be notable differences in sex specific age-at-maturity and /or fishery selectivity by stock and across stocks that is not characterized because data from both sexes are combined in the assessment;
- sex ratios can vary by fish size;

- there may be a tendency for males to be relatively larger than females;
- with climate change, maturity may be happening at younger ages (i.e. leftward trend in maturity ogives);
- there may be information from past fecundity studies to estimate uncertainty associated with assumed fecundity; and,
- the assessment's maturity ogive may be questionable.

As a response, it was noted that all of this is possible; however with regards to sex ratios, it was explained that seine catch samples generally show 50:50 sex ratios. The lead author requested that available information to inform on improving maturity ogives be provided to her outside of the meeting.

It was asked if age data from catch sampling of different fisheries have been looked at to see if there are systematic differences in ages between sample sources for a given year. It was explained that in recent years the relative amounts from winter fisheries compared to roe fisheries has increased and so has the number of samples taken from the winter fisheries. The lead author said that this has been looked at and that age distributions from seine caught winter fisheries appear similar to age distributions from seine caught fish during the spawning season but no investigation beyond that has been done and added that no adjustments are made to any biological sample data to account for different sampling times.

It was asked what fishery independent age information is available for representing all fish in a stock, such as to inform on maturity schedules and catchability. The lead author explained that other than the seine test fishing program which aims to span a stock's spawning season, fishery independent samples taken outside of the spawning season are confounded by mixed stock issues and samples have too much uncertainty to assign fish to a stock area. It was acknowledged that if representative stock specific samples could be collected outside of the spawning season, the information could be used to get better estimates of maturity schedules.

It was asked why cohorts as seen in age composition plots for the southern stocks are less punctuated compared to northern stocks? One explanation is that there may be more ageing error due to faster growth in the southern stocks.

The comment was made that in the HG, SOK can be the major part of the catch and that the WP does not clearly describe this. An author suggested that a revision to the WP could be a reference to the recently drafted technical report by Schweigert et al. (2018, reporting on available SOK information) and that some background information on the SOK fishery in HG can be included to the report.

It was asked if uncertainty from misreporting catch by stock area during the reduction fishery era is accounted for. The lead author responded that the assessment doesn't account for catch uncertainty by era, as there is no information to help tease out how and where the misreporting may have occurred. She noted some sensitivity tests were conducted in 2012 to consider effects from varying historical catch assignments but that no other work has been done.

A revision suggestion was made to have figures showing catch by stock and year to also be disaggregated by fishery type. Authors acknowledged this could easily be done (except for SOK).

STOCK ASSESSMENT MODELING

A request was made to have a reference to Table A.1 from the 2016 assessment (DFO 2016) included in a WP revision to summarize main differences between AM1 and AM2 (Appendix G of current proceedings), and there was agreement on this.

It was pointed out that some of the WP modeling outputs were only presented for AM2 (e.g. figure of spawner-recruit relationships, posterior distributions of leading parameters etc., Figures 30-35). An author responded that results for AM1 will be added during revisions.

Spawn survey index and spawn survey scaling parameters (q)

With regards to the q priors for AM1 and AM2, it was explained that the posterior estimates of q closely reflect the priors and since AM2 q2 is fixed at 1, it makes modeling behaviour more rigid with less variability in scale compared to allowing q2 to vary such as for AM1. As a result, AM1 appears less stable but is actually more sensitive to representing input data and model assumptions.

For all major stocks except the Prince Rupert District (PRD), sensitivity analyses showed that the posterior estimates of q mirror the prior estimates for both AM1 and AM2 but it is still unclear if data would support that conclusion. It was noted that the next step would be to use simulation with a known q to explore where modeling effects on estimating q posterior estimates come from.

It was pointed out that median posterior estimates of q1 and q2 between AM1 and AM2 are most similar for the PRD stock.

It was asked what information was used to inform on q prior for AM1. The lead author explained that for the 2011 assessment (i.e. Appendix C of Martell et al 2012) information from independent studies was considered, these studies were based on information related to characterising egg loss from: repeat surveys; sampling bias from time lags between spawn and survey days, effects from predation and waves. She further noted that no directed studies have been conducted to directly estimate the proportions of spawn sites observed through surveys.

As a point of clarification it was asked if sensitivity analyses were also done for prior probability distributions on the spawn survey parameters (q1 and q2) for AM2, the answer to which was no, only for AM1.

It was confirmed that the median posterior value of q1 and q2 for AM2 can exceed 1.0 (i.e. SOG). The lead author clarified that this is not to be interpreted as a maximum estimate resulting from the dive survey observations but is largely due to increases in the bounds of the prior.

It was suggested that a better WP conclusion would be to state that q priors for both AM1 and AM2 have considerable effect, as it is not just applicable to q2 with AM2. There was agreement on this point.

It was stated that variability in q between years may be linked to variability in stock size and spawn density. For example, q may be lower when a stock is at a higher biomass or spawning density. These sorts of relationships have not been considered in the assessment and the source of the variability is different from potential uncertainty and biases associated with spawn survey observations. A future work suggestion was made to investigate the putative ecosystem interaction of increased relative predation rates on spawn sites with lighter egg densities than heavier densities. It was suggested that this could be done by modeling a numerical response (associated with both egg layers and total eggs) versus a functional response.

Stock status and production

With regards to Figures 18-27, a participant noted that the leading edge of the low productivity – low biomass states for HG is closer to the LRP value of 0.3SB0 than for WCVI. It was stated that because the DFO Precautionary Approach states that LRP levels should be avoided with high probability that a LRP of 0.3SB0 makes sense for the WCVI stock but a larger LRP should be used for the HG stock.

An author explained that until acceptable probabilities are defined and tested through simulation, the utility of the LRP alone cannot be evaluated and whether 0.3SB is precautionary enough for the HG cannot be determined. In the meantime, the assessment provides decision tables with probabilities with respect to 0.3SB0 for different catch levels for managers to consider.

It was asked why the lower 20% of the spawning biomass estimates are shaded in grey in Figures 18-27 (panel a) and if done somewhat arbitrarily, then it may be better to not shade any estimates. There was agreement on this suggestion. It was also noted that the y-axis scale for Figure 24 (panel a) is not large enough to show the estimate of SB0 and authors agreed to address this (e.g. to edit figure or caption in a revision).

A request was made to revise the abstract to include comparisons of SB2017 with 0.25SB0 (for AM1) and SB2017 with fixed cut-off values (for AM2) for the major stocks (in addition to being compared with 0.3SB0).

There was discussion on the dynamics of stock productivity associated with providing fishery advice. It was asked why in Section 1.7, the DFO Precautionary Approach advises the use of long time series for determining reference points. Why not use shorter time series to represent more recent periods? Using longer time series representing higher production periods will likely lead to curtailed fishing opportunities. In response to this it was explained that longer time periods are deemed important to represent variability in stock production for considering reference limits and exploring estimates of B0 over time is informative but for providing fishery advice. However in terms of evaluating risk, clear fishery management objectives need to be determined first to evaluate outcomes though simulation.

A comment was made that given reduced size-at-age seen in other stocks in the Atlantic and Pacific Oceans and effects of climate change, productivity changes may prove to be unidirectional. If assumptions associated with stock dynamics are static over time, then fishing opportunities may be missed. In response to this, it was stated that there are questions (uncertainty) about the types of impacts fisheries have, as even small catches can have impacts on stocks.

It was explained that DFO now has an Ecosystem Science Division and there are interests to include ecosystem considerations in Science advice. However, it was noted that there will still be difficulties assessing if and how stock responses are ecosystem driven.

There was discussion on variability in size-at-age. It was noted that there are differences in size-at-age between Alaska and BC herring stocks which could be explored. It was noted that it is important to recognize that small fish can still be relatively productive (salmon stocks support this). Currently WP authors are using the 5-year average weight-at-age for biomass projections, and this assumption could be explored through sensitivity tests or simulation work.

In association with recognizing genetic homogeneity across Pacific herring stocks, someone suggested it would be curious to see how production trends appear if stock information was aggregated into northern (HG, PRD, Central Coast (CC)) and southern (WCVI and SOG) groupings.

Recruitment and maturity

Regarding the use of the maturity ogive in recruitment forecasting, a participant questioned the effect of having the same maturity schedule for all stocks when different trends in age compositions are apparent. It was asked that if samples from southern stocks (such as the SOG) tend to see more younger fish (i.e. age 2) compared to northern stocks (i.e., HG), then are more age 3 fish forecasted for southern stocks compared to northern stocks? An author referred to the number of age 2 recruits estimated for the SOG in 2017 and the high degree of uncertainty associated with the estimate. She explained that information for forecasting is also coming from a stock specific Stock-Recruit (SR) relationship, which also has a high degree of uncertainty. Both of these sources of uncertainty are propagated into age 3 forecasts.

It was noted that information from the SOG juvenile herring seine survey could be considered to see if there is consistency with assessment model estimates of SOG recruitment.

A suggestion was made to format the annual points in the Spawner-Recruit plots (i.e. Figure 30) the same as done for years represented in Figures 18-27 (panel b).

Minor stocks

There was discussion on the information gaps and role of providing science advice related to the minor stocks (Areas 2W and 27). If these areas are not being fished, and if sampling and surveys are not being regularly conducted in these areas (due to remoteness, unpredictable spawning behaviour and timing, and associated science costs) it was asked if they should be included in the assessment report. It was recognized that there is considerable uncertainty associated with the monitoring of these stocks but support was shown by Fishery Management and Science representatives to continue assessing these areas to collect information that may be advisory for addressing fishery interests as well as ecosystem monitoring. There was consensus for the authors to revise the assessment document to include time series plots and estimates for the spawn survey index and catch for Areas 2W and 27 for years observed (but catch-age model output will not be generated).

DECISION TABLES AND OTHER CONSIDERATIONS

It was clarified that decision table output were revised from values originally reported in the WP with respect to evaluating against the LRP. It was noted that for the SOG, probabilities changed considerably and were more optimistic.

It was asked if different fishing pressures on the stocks are taken into account when setting catch limits. An author responded that catch tables show projections which include 0 catch and it is up to Fishery Managers (outside of this meeting) to make decisions on setting limits.

There was discussion as to how and where to include additional information from First Nations perspectives to advise fishery managers in association with DFO stock assessment advice. It was explained that the 2015 and 2016 Science Responses (DFO 2015a and DFO 2016) summary information provided by non DFO contributors as part of the Herring Technical Working Group and was included to represent on the grounds observations from First Nations' perspectives. It was explained that this independent information is useful for considering information gaps, consistencies and inconsistencies with the DFO stock assessment advice. A request was made to have the 2017 WP and/or the SAR reference or acknowledge additional sources of information, possibly in the provision of an internet link. It was explained that unlike the 2015 and 2016 SR processes, the current RPR and resulting documents are based on information reported in the WP and presented at the review meeting in following with the meeting's TOR objectives. It was explained that advice cannot be provided on information not included in the review process. Some participants stated they thought that there should be some flexibility in the RPR process to include other sources of information associated with science advice to Fishery Managers.

SCIENCE ADVISORY REPORT

The role and format of a Science Advisory Report (SAR) as a product of a peer review process was explained as were the time lines and steps for drafting, revising and submitting the SAR, Proceedings, and Research Document.

To guide discussion for drafting the 2017 SAR, recently published SARs on Pacific Herring were referred to (DFO 2015b and DFO 2017). The Chair reminded the room to seek non-technical wording to facilitate understanding from readers of different backgrounds. There was discussion on what information should be included in the SAR related to summary points, description of assessment work and findings, associated figures and tables, ecosystem considerations, conclusions, recommended future work, and uncertainty. Notes pertaining to the below topics were drafted to guide the development of summary points relevant to all stocks.

- Introductory/background information on stocks and form of provisional advice.
- Bridging analysis- a brief description on the role and outcomes of bridging analysis.
- Sensitivity analyses- what was done and why (details and key merits and concerns of AM1 and AM2 to be explained in more detail assessment section of SAR)
- Sensitivity analyses alone are insufficient for understanding the complex interplay between *q* and management parameters, and resolution between AM2 and AM1 parameterization of *q* will require simulation-evaluation.
- This is the first year of using a LRP in advice and resulting from a February 2017 review-parallel Fishery Management herring renewal efforts to determine objectives, risk probabilities etc., through simulation studies.
- Comparison of trends in weight-age between stocks and similarities/ differences in survey index between stock.
- SOK mortality and TOR objective not yet addressed (work still underway).

Using the HG as an example, detailed bullet points were drafted as a guide to determine the type and format of summary information to include for all major stocks. For the purposes of drafting and tracking the types of information, information was grouped into subsections (e.g. Stock assessment and data, Stock productivity and recruitment, estimated stock status relative to biological reference points, projected spawning biomass in 2018 and spawning biomass related to harvest control rule (HCR). For each of the minor stocks, the key pieces of information to report on (as available) were trends in recent fishing activity, the spawn index and age compositions.

For determining which figures to include in the SAR, there was consensus on time series plots for the major stock areas showing trends in: the spawn survey index and scaled spawn survey data estimates; natural mortality; age-2 recruits; spawning biomass and catch; production and production rates. For determining which tables to include in the SAR, there was consensus on tables summarizing posterior medians and 90% credibility intervals for a suite of reference points (i.e. WP tables 13-17) by major stock area, and probabilistic decision tables by major stock area. Fishery Managers stated they would like information for both AM1 and AM2, recognizing it makes for a lengthy SAR.

Topics identified for inclusion under the “Sources of Uncertainty” section included:

- Processes determining productivity (e.g. factors affecting recruitment, natural mortality, growth)
- Stock structure and the assumption of discrete stocks
- Models AM1 and AM2 differ in the priors used to estimate q1 and q2.
- Below average sample sizes for biological samples (HG).
- SOK mortality and egg loss.

Other suggestions made for drafting the SAR:

- Describe 2017 recruitment trends of the major stocks in terms of trends in age-2 abundance, rather than as points with respect to a Spawner- Recruit relationship.
- Include reference to Table A.1 DFO 2016 which summarizes differences between AM1 and AM2 (included in Appendix G herein).
- Include time series plots showing catch by gear, year and area, as per WP revision request.
- Address differences in y-axis scales (biomass) in figures for different stocks.
- Include posterior density distributions plots that are similar to WP Figure 29 but representing SB2018 projections (for AM1 and AM2) given 0 catch assumption in 2018 and include lines for 0.25SB and the fixed cutoffs for AM1 and AM2 results, respectively. Suggestion was also made to revise WP to include this information into Research Document.
- 2018 catch projections and decision table columns metrics for evaluating against harvest rates (e.g. P(u > 10% etc) to be left to Fishery Management input with authors.
- In decision tables for AM1, remove columns relative to 1996 fixed cutoffs or put NAs (not applicable) or dashes in cells below column headings.
- To populate the "Ecosystem Considerations' section, relevant information from past SARs can be referred to and reiterated (i.e. DFO 2015b, DFO 2017).

CONCLUSIONS

The key conclusions resulting from consensus during the regional peer review process, and which will be captured in the SAR, relate to:

- The Working Paper was accepted subject to identified revisions, which were the inclusion of additional information characterizing minor stocks and the inclusion of corrected information pertaining to the decision tables. Other revision suggestions (mostly editorial), were left up to the authors and Chair to determine whether and how they be included.
- Spawning biomass in 2017 (SB_{2017}) and pre-fishery forecast spawning biomass for 2018 (SB_{2018}) were assessed using the most up-to-date version of the integrated statistical catch-at-age model (ISCAM or "the assessment model"). Two base cases were implemented and endorsed for use in the assessment: AM2 and AM1, differing in the treatment of spawn survey scaling coefficients (q_1, q_2).
- It was determined that sensitivity analyses alone were insufficient for understanding the complex interplay between *q* and management parameters, and resolution between AM2 and AM1 parameterization of *q;* therefore additional simulation-evaluation is required.
- Advice for each Pacific Herring stock is presented in probabilistic decision tables showing predicted status in 2018 given a range of constant catches relative to the limit reference

point (LRP) of $0.30SB_0$, the commercial fishery cut-offs (AM2 only), and target harvest rates of 10% and 20%.

- This is the first year including a LRP in advice (resulting from a February 2017 review) and DFO Pacific Region is also engaged in a concurrent multi-year process to renew the management framework for Pacific Herring, which includes the development of fishery management objectives and simulation evaluation of harvest control rules.

Recommendations for future work:

- Simulation-testing of management procedures (for all fisheries).
- Quantify mortality and removed spawn from all fisheries (e.g. SOK).
- Quantify uncertainty in the spawn index (annual estimates of variance and biases)
- Investigate potential for stock-specific prior distribution on q, and potential for year-to-year variability in q
- Investigate appropriateness of stock-specific maturity ogive
- Investigate patterns of M in terms of biological realism

ACKNOWLEDGEMENTS

We appreciate the time contributed to the RPR process by all participants. In particular, we thank the reviewers, Dr. Rabindra Singh and Dr. Jason Cope, for their time and expertise. We also thank John Neilson as Chair of the meeting and Linnea Flostrand as the Rapporteur.

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APPENDIX A: TERMS OF REFERENCE

STOCK ASSESSMENT AND MANAGEMENT ADVICE FOR BC PACIFIC HERRING: 2017 STATUS AND 2018 FORECAST

Regional Peer Review Process – Pacific Region

October 17-18, 2017
Nanaimo, BC

Chairperson: Dr. John Neilson

Context

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

The assessment of current Pacific Herring abundance and forecasts has been completed annually since the late-1980s for each of the five major and two minor stocks in British Columbia. Since 2006, the assessment has utilized an integrated statistical catch-age model fitted to commercial catch, proportions-at-age and a fishery-independent survey of herring egg deposition (spawn index) to estimate biomass and recruitment, and to generate 1-year forecasts of spawning biomass (Martell et al, 2012; DFO 2013). Martell et al. (2012) introduced two revisions to the management procedure (MP): model-estimated fishery cutoff values, and model-estimated q (catchability) for the dive survey. This modified MP is termed “AM1”. Since the introduction of AM1, concerns have been raised regarding application of this MP relative to the previous MP (AM2: fixed cutoffs and the assumption that q=1 for the dive survey), as well as the potential implications of the model for fisheries management (e.g., higher estimates of spawning abundance in some areas under AM1 and potential to open fisheries at lower biomass levels than under the previous Management Procedure, AM2).

In 2015 and 2016 herring stocks were assessed using both AM1 and AM2 parameterizations of the integrated statistical catch-age model, and Science Responses included outputs from both model cases. The 2016 Science Response also included a table developed by the Herring Technical Working Group that describes the main attributes and limitations of AM1 and AM2, intended to address concerns arising both from previous CSAS processes about implementation of each approach. Although both MPs have been peer-reviewed through CSAS and both have been provided as science advice for Pacific Herring in previous years, identifying MPs robust to uncertainties in parameters such as q (catchability) requires dedicated simulation-evaluation analysis, which is part of the multi-year renewal of the management framework (Pacific Herring Renewal) initiative. DFO has committed to Pacific Herring Renewal to address a range of challenges facing the fishery. Science work to support this initiative includes two streams: the Operational and Strategic Streams. For the Strategic Stream, a management strategy evaluation (MSE) process is underway to conduct simulation-testing of alternative MPs to identify a procedure that is compliant with DFO’s Fishery Decision-Making Framework Incorporating the Precautionary Approach (the PA framework) (DFO 2009) and characterize trade-offs among conservation, economic and socio-cultural objectives. Until results from these analyses are available, Pacific Herring stocks will continue to be assessed using the current stock assessment model. For 2017, results from both AM1 and AM2 model configurations will be provided as science advice.

A spawning biomass-based Limit Reference Point (LRP) of $0.3B_0$ was recommended for the major Pacific Herring stocks during a CSAS Regional Peer Review, February 7-8, 2017. This recommendation was based on results of production analyses and is consistent with international best practice recommendations (DFO 2017). In addition to the annual assessment and forecast, Fisheries Management (DFO) has requested updated advice from DFO Science on the current biomass and status of Pacific Herring relative to the recently established LRP.

The assessment, and advice arising from this Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR), will be used to support the development of the 2017/18 Integrated Fisheries Management Plan (IFMP).

Objectives

The following working paper will be reviewed and will provide the basis for discussion and advice on the specific objectives outlined below:

Cleary, J.S., Hawkshaw, S., Grinnell, M . Stock assessment for Pacific Herring (*Clupea harengus*) in British Columbia in 2017 and forecast for 2018. CSAP Working Paper 2017PEL01.

Guided by the DFO Sustainable Fisheries Framework, the following objectives for this assessment have been established:

1. Present data and assessment model updates:
    a. Present modifications and updates to integrated statistical catch-age model equations and its AD Model Builder code. Investigate comparisons between old and new model code using a bridging analysis.
    b. Present herring spawn-on-kelp (SOK) fishery data and methods for including SOK data as input data for each stock area.
    c. Present parameterization of maturity and fishery selectivity ogives and investigate interactions between these and other model-estimated parameters.
2. Assess the current status of Pacific Herring for the five major stocks using the integrated statistical catch-age model.
3. Present trends in Pacific Herring biomass, depletion, and recruitment for each major stock; including trends in biomass for each major stock relative to the LRP.
4. For the minor stock areas, present stock status updates using available spawn survey data and biological samples.
5. Evaluate the consequences (including potential risk of exceeding harvest rates prescribed by both modelling approaches) of different total allowable catch levels for 2018 against probabilistic metrics to accommodate uncertainty in the advice.

Expected publication

- Science Advisory Report
- Research Document
- Proceedings

Expected Participation

- DFO Science and Fisheries Management

- First Nations and Commercial Harvesters Technical Experts

References Cited and Additional Information

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APPENDIX B: WORKING PAPER SUMMARY

This document presents a stock assessment for Pacific Herring (*Clupea pallasi*) in British Columbia using data current to 2017. Results of the work are intended to serve as advice over the short term to fishery managers and stakeholders on current stock status and likely impacts of different harvest options. An updated platform of the integrated combined-sex statistical catch-at-age model (ISCAM) was applied independently to each of the 5 major stock areas and tuned to fishery-independent spawn index data, annual estimates of commercial catch since 1951, and age composition data from the commercial fishery and from the test fishery charter program. Comprehensive stock assessments were done for five major stock areas: Haida Gwaii (HG), Prince Rupert District (PRD), Central Coast (CC), Strait of Georgia (SoG), and West Coast of Vancouver Island (WCVI). Results are summarized as stock reconstructions, status of spawning stock in 2017, and projected spawning biomass in 2018.

The model estimated stock-recruitment parameters, time-varying natural mortality, catchability coefficients for the survey time series, and selectivity parameters for the commercial fishery and those survey series for which age data are available. Median posterior estimates and 90% credible intervals of spawning biomass, recruitment, time-varying natural mortality, and unfished equilibrium spawning biomass are presented for AM2 and AM1 model parameterizations. Unfished equilibrium spawning biomass (SB0) is the main biological reference point used for Pacific Herring and it is estimated from a Beverton-Holt stock-recruitment relationship (parameterized within the assessment model) fitted to longterm average trends in weight at age and natural mortality. One-year projections of spawning biomass 2018 were performed for each major stock area over a range of constant catches to estimate probabilities that spawning biomass and harvest rate metrics are below and above control points historically used in the management of Pacific Herring, as specified in the herring harvest control rule. This assessment also includes presentation of current stock status and projected stock status in 2018 relative to a Limit Reference Point of 0.3SB0.

Some assessment results by stock area are briefly listed below.

Haida Gwaii: There is declining trend in spawning stock biomass since 2013 and in most years since 2000, including 2017, the WCVI stock has been in a low productivity low biomass state. Both AM2 and AM1 models estimate SB2017 to be below the LRP of 0.3SB0 with greater than a 50% probability.

Prince Rupert District: Since the mid-1990s, the PRD stock is characterized by two periods of consistent and stable biomass: 1996-2003 and 2006-2017. Based on a comparison of median estimates, both AM2 and AM1 models estimate SB2017 to be above the LRP of 0.3 · SB0 with greater than a 50% probability and less than a 95% probability.

Central Coast: The survey index increased from 2012 – 2016 and declined from 2016 to 2017. AM2 and AM1 base case assessments estimate an increasing trend in spawning stock biomass since 2012. Based on a comparison of median estimates, both AM2 and AM1 models estimate SB2017 to be above the LRP of 0.3SB0 with greater than a 95% probability.

Strait of Georgia: The survey index increased from 2013 – 2016 and declined from 2016 to 2017. AM2 and AM1 base case assessments estimate an increasing trend in spawning stock biomass since 2010. Based on a comparison of median estimates, both AM2 and AM1 models estimate SB2017 to be above the LRP of 0.3SB0 by greater than 95% probability.

West Coast Vancouver Island: Since 2005 the WCVI stock has been in a prolonged low productivity low biomass state, increasing in 2016 and then declining in 2017. At these low biomass levels, the WCVI stock is characterized by seemingly abrupt differences in year-to-year survey biomass. AM2 and AM1 base case assessments estimate a decline in spawning stock biomass from 2016 to 2017. Based on a comparison of median estimates, both AM2 and AM1 models estimate SB2017 to be above the LRP of 0.3SB0, by greater than 50% probability but less than 95% probability.

APPENDIX C: AGENDA

Canadian Science Advisory Secretariat

Centre for Science Advice Pacific

Regional Peer Review Meeting (RPR)

Stock Assessment and Management Advice for BC Pacific Herring: 2017 Status and 2018 Forecast

October 17-18, 2017

Pacific Biological Station, Nanaimo BC

Chair: Dr. John Neilson

DAY 1 – Tuesday, October 17

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping CSAS Overview and Procedures	Chair
0915	Review Terms of Reference	Chair
0930	Presentation of Working Paper	Jaclyn Cleary
1015	***Break***	
1030	Presentation of working paper cont'd	Jaclyn Cleary
1100	Overview Written Reviews Rabindra Singh and Jason Cope	Rabindra Singh & Jason Cope
1200	***Lunch Break***	
1300	Discussion from written reviews	RPR Participants
1330	Identification of Key Issues for Group Discussion	RPR Participants
1445	***Break***	
1500	Discussion & Resolution of Technical Issues	RPR Participants
1630	Discussion & Resolution of Results & Conclusions	RPR Participants
1700	Adjourn for the Day	

DAY 2 - Wednesday, October 18

Time	Subject	Presenter
0830	Introductions Review Agenda & Housekeeping Review Status of Day 1	Chair
0845	Carry forward outstanding issues from Day 1	RPR Participants
1030	***Break***	
1050	Develop Consensus on Paper Acceptability & Agreed-upon Revisions	RPR Participants
1115	*Science Advisory Report (SAR)* Develop consensus on the following for inclusion: • Context • Sources of Uncertainty	RPR Participants
1200	***Lunch Break***	
1300	*Science Advisory Report (SAR)* • Results & Conclusions • Additional advice to Management (as warranted) • Required tables/figures	RPR Participants
1445	***Break***	
1500	Next Steps – Chair to review • SAR review/approval process and timelines • Research Document & Proceedings timelines • Other follow-up or commitments (*as necessary)*	Chair/CSAS
1545	Other Business arising from the review	Chair & Participants
1600	***Adjourn meeting***	

APPENDIX D: MEETING PARTICIPANTS

Last Name	First Name	Affiliation
Benchetrit	Jose	DFO Science, National Headquarters
Benson	Ashleen	Landmark Fisheries Consultant
Boldt	Jennifer	DFO Science
Bukta	Christine	DFO Fisheries Management
Cass	Al	Herring Industry Advisory Board
Chalmers	Dennis	Province of British Columbia
Chavez	Lais	Haida Nation
Christensen	Lisa	DFO Science, Centre for Science Advice Pacific
Cleary	Jaclyn	DFO Science
Cope	Jason	National Oceanic and Atmospheric Administration
Daniel	Kristen	DFO Science
Dennis-Bohm	Hilari	DFO Science
Dorner	Brigitte	Heiltsuk Nation
Dressel	Sherri	Alaska Department of Fish and Game
Flostrand	Linnea	DFO Science
Forrest	Robyn	DFO Science
Fredrickson	Nicole	Island Marine Aquatic Working Group
Galligos	Cathy	Tla'amin First Nation
Goruk	Andrea	DFO Fisheries Management
Grinnell	Matt	DFO Science
Groves	Steven	DFO Fisheries Management- North Coast
Hall	Peter	DFO Fisheries Management
Hawkshaw	Sarah	DFO Science
Hay	Doug	DFO Scientist Emeritus
Jones	Russ	Council of Haida Nation - Haida Fisheries Program
Kanno	Roger	DFO, Fisheries Management
MacDougall	Lesley	DFO Science, Centre for Science Advice Pacific
McGreer	Madeleine	Central Coast Indigenous Resource Alliance
Neilson	John	DFO Scientist Emeritus
Ormond	Chad	South Island Nations
Rusel	Christa	A'Tlegay Fisheries Society
Schweigert	Jake	DFO Scientist Emeritus
Singh	Rabindra	DFO Science, Maritimes
Spence	Brenda	DFO Fisheries Management -South Coast
Starr	Paul	Herring Industry Advisory Board
Thomas	Greg	Herring Conservation and Research Society
White	Penny	North Coast Skeena FN Stewardship Society

APPENDIX E: WORKING PAPER REVIEW – RABINDRA SINGH

Reviewer: Dr. Rabindra Singh (DFO, Maritimes Regions, St Andrews, New Brunskwick)

Working Paper 2017PEL01: Stock assessment for pacific Herring (*Clupea pallasi*) in British Columbia in 2017 and forecast for 2018

Thanks for the opportunity to review this working paper on Pacific Herring assessment. This is my first detailed look at Pacific herring. My comments would not be focused on the models, since that it not my area of expertise. The purpose of the paper is stated clearly. The authors have put a lot of effort in producing the model s and model outputs.

On page 13, the authors state that "Gillnet caught fish are excluded from the calculation of average weight-at-age." It was not obvious to me why this was done. I realize that gillnets are size selective but I am not sure why the data on weight-at-age would be excluded. It would obviously be better to use as much of the data available to calculate the average weight-at-age. Perhaps the authors could include an explanation in document.

I am not sure what the situation is like in the Pacific but here in the Maritimes, we have found that the purse seine fleet are able to be selective in the size of the herring that is caught. That is, they can make a decision on whether the captured fish are too small and release their catch if needed. The other issue is that some seiners actually target smaller herring because these smaller fish are used in the canning process. I wondered if this is a consideration in the Pacific fishery.

It is good to see the authors attempt to summarize some reasons for the decline in the weight-at-age in all the stocks. It is something that is also observed in the Maritimes herring stocks. This decline, as the authors, describe has implication for stock biomass and harvest levels since more numbers of fish are being taken now to achieve the similar biomass levels in the past. As the authors indicated, there is no one simple explanation and a combination of factors may cause this decline. Fishing effects caused by gear selectivity, results in removal of larger individuals and this could result in smaller individuals becoming more important in contributing to recruitment. Since growth rate is an inherited characteristic then this results in decreased weight-at-age. As the authors recommended, this decline should be investigated and the results considered in future stock assessments.

On page 14, the authors state that for the abundance index, the surface survey index and the dive survey index were combined into a single index. I am not familiar enough with the methods used in each index but I assume that the data can be combined as done by the authors. A surface survey seems to be quite different from a dive survey.

On Page 15 (Haida Gwaii), the number of samples was much lower than from other areas with 8 samples (about 800 fish total). Is this the result of no/little fishing activity? And, given the samples sizes used in the other areas, was this sufficient?

The advice provided on each of the stocks does indicate the uncertainty in the analyses. There has obviously been a lot of work done on the Pacific stocks and it is fortunate that models exist to conduct stock projections.

APPENDIX F: WORKING PAPER REVIEW – JASON COPE

Reviewer: Dr. Jason Cope (NOAA, Northwest Fisheries Science Centre, Seattle, Washington)

Working Paper 2017PEL01: Stock assessment for pacific Herring (*Clupea pallasi*) in British Columbia in 2017 and forecast for 2018

This stock assessment uses a statistical catch-at-age model in a Bayesian framework to model 5 separate sub stocks of Pacific herring (*Clupea harengus*) in British Columbian waters. The model contains removal histories for some, but not all, of the fisheries, spawning surveys from two time periods (distinguished by the sample mode), and age compositions. Average weight at age is also used to allow difference over time to be incorporated into the calculation of biomass. Two base cases are retained, delineated by the treatment of the index catchabilities and the control rule. Below are comments and suggestions in response to different sections of the document that are hopefully useful in improving the current version of the working paper. Major action items are **bolded**. A few editorial comments are also included at the end.

REFERENCE POINTS

In general, it is curious that most of section 1.7 comes across as the reference points for Pacific herring as being not well defined. Defining the reference points would be out of the scope of a stock assessment. Additionally, it seems troubling to do a stock assessment without some way to interpret it for management measures (i.e., reference points and control rules). All of this discussion in the text makes it confusing to actually know what is being applied in this assessment. **Should this section be shortened or excluded from this document?**

For what seems to be the most current harvest control rule, the authors provide a good overview of the harvest control rule (mostly a constant rate with a steep threshold below the limit referent point), particularly on the current and future reference points. One thing that is not discussed is where the 0.2 harvest rate comes from. That rate is implicitly tied to the productivity of the stock. **It would be useful to add some description on where this value comes from, and some talk on how well it matches the implied productivity used in the stock assessment.**

ASSESSMENT HISTORY

It is not clear what is meant by “estimated fishery cut-offs ” and fishery cut-offs being fixed to 1996 values. **Does the former refer to derived values from AM1 of the current stock status of 0.25 biomass? And is it total or spawning biomass? For the latter, do 1996 estimates refer to a model done in 1996 (the Schweigert et al. 1997 model)? Was that what was used all the way up to 2011?** There is a fare bit of historical decisions that seem still relevant now, but with little documentation other than going back into the historical documents. **Is it reasonable to add some documentation of these historical decisions?**

AVAILABLE DATA

Removals (1951-2017) modelled as 3 fleets, 1 post-egg fishery (“other fisheries”) and 2 egg fisheries separated by gear type (“seine” and gillnet”). Removals do not currently include SOK, FSC or recreational fisheries. **Some indication of the magnitude of these fisheries needs to be included in order to gauge whether sensitivities to excluding these fisheries is critical for understanding uncertainty in model derived outputs for management.** Specifically, removals directly affect the absolute scale of the population, and thus the recommended catch. While I understand there are no times series of measures for these fisheries, there must be a way to get a ballpark magnitude. If not, I am not sure how one could suggest the stock assessment is giving useful catch-based management advice. **Hypothesized catches and their affects should be understood, including the need for future research on the topic.**

The lack of description of each fishery also makes it difficult to evaluate what it is doing, thus providing a basic understanding of selectivity. **Addition details on how the fisheries are conducted would be useful.**

Biological compositions

Regarding the ageing of sampled fish, is there any ageing error? If so, is that ignored or treated in the model; was it considered as a model specification sensitivity? And what does it mean that pre-1985 ages have been "age-adjusted"?

Weight at age: it seems the protocol is to get an average vector of weight at age, which is then applied to the numbers to get biomass. This would seem to de-couple weight and length if growth is kept constant. **Was such an assumption looked at?** It is possible to use weight at age directly and bypass age-length relationships to avoid this issue.

Spawning indices

I did not notice a description of the uncertainty associated with these indices. **What uncertainty was used in the model, and how was it calculated? Was there any additional variance estimated in the model?**

BIOLOGICAL PARAMETERS

Growth: **Why is growth taken from FishBase and not estimated within the model? Or why is the weight at age data not fit internal to the model? There seems to be no reason these should be fixed parameters given the available data. And no sensitivity is explored to the assumption of growth?**

PARAMETER PRIORS

$\ln R_0$: why would the lower bound be below 0?

Natural mortality (*M*): **This is such an important parameter, I think it worth stating where the mean value comes from, and not just from the last assessment.** It is not uncommon to have an assessment carry over poorly-derived values for *M*. One cannot tell the source of this value other than to keep going back into assessments until you find one that states its origin.

The time varying nature of natural mortality need more explanation. For the HG stock, the estimates are hard to believe (a 3-fold change in *M*). The others seems to be more reasonable, and seems to make less difference than just estimating a constant *M*. Would not a constant *M*, while an abstraction, be more parsimonious? It is stated that there were convergence issues with constant *M*, but that is not explained, so cannot be evaluated. See also the next section for why the "better fit" of the time-varying *M* scenario may or may not be true.

SENSITIVITY ANALYSES

One general comment about the sensitivity analyses is **the need to report the total likelihood changes across the different model runs**. While looking at fits is one thing, knowing what the likelihood change is particularly useful, and will allow a better capacity to evaluate whether changing specifications really improves the integrated fit over all data and parameters. For instance, it is argued that the fits to the index are better when M is time-varying, but that is not uncommon when adding more parameters. How much of a better fit would be indicated by the AIC values. And just because it fits the index better, does not mean it fits other data better. So having the overall likelihoods to compare is needed.

PRIOR PROBABILITY FOR CATCHABILTIES

It seems odd that the AM1 model is being criticized for its prior probabilities when $q_2 = 1$ in AM2.

Table 48 seems to have a typo, as q_1 should only have a value listed for the surface survey, and q_2 for the dive survey only. The table shows surface and dive surveys have a value for both q_1 and q_2. **Table 48 should really only have one line for each prior distribution, as q_1 and q_2 are by definition affiliated with a particular survey. That would greatly simplify the table (same goes for Table 2).**

BASE MODEL

I do not see great evidence to keep the AM2 model. See my comments above about retaining the time-varying *M*.

It would be valuable to include likelihood profiles over parameters *M*, *h* and R_0. It is currently hard to tell how much information is contained in the model for those parameters.

The model output plots need to show the uncertainty around the indices of abundance and the estimated abundance. Very hard to interpret without knowing how much error is in (and thus how the model is weighting) the surveys.

ASSUMPTIONS AND UNCERTAINTY

More sensitivities could be used to investigate further model specification uncertainty (i.e, beyond within-model uncertainty). Different values of mean M, steepness, and growth are just a few. While the Bayesian approach does integrate over the prior uncertainty, it does not account for bias. The model specification sensitivities would offer that insight.

EDITS

*last line, page 8: “were” instead of “we are”

*line three in section 1.8: “… re-structuring of various model components…”

*The explanation of SOK appears after its first use (both on page 11). Make sure the first usage also has the acronym explanation.

APPENDIX G: HISTORY AND IDENTIFIED LIMITATIONS OF AM1 AND AM2 MODELLING APPROACHES FOR BC HERRING STOCKS

From Table A.1 (DFO 2016).

<table>
<tr><th>Issue</th><th>AM1 (q estimated)</th><th>AM2 (q = 1)</th></tr>
<tr><td>Assessment model reliability</td><td colspan="2">• Modelling results reflect only the structural assumptions specified in the model and weights assigned to the various data components.
• As is often the case with stock assessments, there are unresolved issues around potential sampling biases in data and there is potential for model misspecification (estimation biases resulting from omitting relevant explanatory variables);
• Consequently, there may be biases and errors in model estimates that are not detectable through model diagnostics; this introduces uncertainties about the true state of nature that are not captured by the probabilities in the decision tables;
• Estimates of uncertainty shown in the decision tables should be considered minimum estimates.</td></tr>
<tr><td>Herring spawn surveys</td><td colspan="2">• The annual spawn survey program is intended to survey all major herring spawns in each stock area. It is recognized that eggs are lost to predation prior to being measured and that the spawn survey does not measure all herring spawns (e.g., some early/ late spawns may be missed).</td></tr>
<tr><td rowspan="2">Spawn survey scaling parameter (q)</td><td>• Estimates q_1 for the surface survey time series (1951-1987) with a prior;
• Estimates q_2 for the dive survey time series (1988-2016) with a prior;
• Estimating q_2 introduces an additional parameter into the model to represent estimated average survey efficiency for the dive survey period.
• The survey estimates are scaled by 1/q to represent total spawning biomass.
• q_1 and q_2 are estimated independently for each area as part of the model fitting process, using a prior based on: assumptions about non-detection of spawn, independent studies on egg loss prior to spawn surveys, days between spawn deposition and survey, and bias in mean egg density (Martell et al. 2012);
• The same survey prior is used for both q_1 and q_2 in all stock areas;
• In 2016, the estimate of q_2 is similar to the prior value of ~0.5 for all areas except Prince Rupert where it is 0.9.</td><td>• Estimate q_1 for the surface survey time series (1951-1987) as free parameter;
• Fixes q_2 for the dive survey time series (1988-2016) at 1.0;
• The q_2=1.0 assumption assumes the survey observes all spawn, and that no eggs are lost to predation;
• In AM2, the herring spawn index is considered a minimum estimate of spawning abundance.</td></tr>
<tr><td colspan="2">• Both AM1 and AM2 assume no change in relative survey efficiency over time (i.e., q_1 stays the same from 1951-1987; q_1 stays the same from 1988-2016).</td></tr>
<tr><td>Perception of spawning biomass estimates</td><td>• The scaling of spawn survey biomass estimates in AM1 produces higher biomass estimates and higher catches given the same HCR than for AM2 using the same set of input data.</td><td>• By definition, time series of spawning biomass estimates appears consistent with perceptions based on observations, influenced by long-term use of AM2-type models.</td></tr>
</table>

<table>
<tr><th>Issue</th><th>AM1 (q estimated)</th><th>AM2 (q = 1)</th></tr>
<tr><td></td><td>• Biomass estimates produced by AM1 may appear inflated and inconsistent with perceptions created by long-term use of AM2-type models.</td><td></td></tr>
<tr><td>unfished biomass, SB_0</td><td colspan="2">• SB_0 estimates are directly proportional to weight-at-age and inversely proportional to natural mortality (M), so that given the same unfished recruitment (in numbers) the estimated unfished biomass declines with both reduced weight-at-age and increased M.
• Model estimates of SB_0 change as a result of the changing weight-at-age and changing M, thus there is no single estimate of SB_0 available to inform the HCR without making additional assumptions in AM1 about which values of M and weight-at-age to use.
• Similarly, fixed cut-offs in AM2 are conditional on assumptions about M and weight-at-age made in the 1996 assessment.</td></tr>
<tr><td>operation of harvest control rule (HCR)</td><td>• HCR developed in the 1980s has not been simulation-tested with current AM1 model parameterization. Specifically: estimation of q_1, q_2 (with informative priors), changes in weight-at-age, and estimation of time variant natural mortality;
• Application of fixed cut-offs (estimated in 1996) in the HCR is not relevant/ appropriate for AM1;
• Application of $0.25SB_0$ as a commercial fishing cut-off in the HCR may not be appropriate for AM1 given changes in model structure, weight-at-age, and natural mortality;
• The harvest rate component of the HCR (10% or 20%) is the same as for the HCR developed in the 1980s. Consequently the catch level advice using AM1 will be high relative to AM2 because the underlying biomass will be relatively larger than the biomass expected when the rule was evaluated, due to a different assumption about q_2.</td><td>• HCR developed in the 1980s has not been simulation tested in conjunction with current AM2 model parameterization. Specifically: estimation of q_1 (surface survey), changes in weight-at-age, and estimation of time variant natural mortality;
• Application of fixed cut-offs (estimated in 1996) in the HCR may not be appropriate for AM2 given changes in model structure, changes in weight-at-age, and estimation of time variant natural mortality;
• Application of $0.25SB_0$ as a commercial fishing cut-off in the HCR may not be appropriate for AM2 given changes in model structure, weight-at-age, and natural mortality.</td></tr>
<tr><td>probability levels in decision tables</td><td colspan="2">• Decision tables express the mathematical probability of biomass falling below the cut-off and exceeding the target harvest rate;
• Probability levels in the decision tables do not fully communicate risk to the stocks, because metrics from the HCRs have not been evaluated against objectives using current model formulations.</td></tr>
</table>