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Proceedings of the Pacific Regional Peer Review on the Determination of Escapement and Exploitation Rate Benchmarks for the Three Georgia Strait Southern BC Coho Management Units

November 4-5, 2014 & April 14, 2015
Nanaimo, BC

Chairperson: Mary Thiess
Editor: Julia Bradshaw

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Science Branch
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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.

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SUMMARY

These Proceedings summarize relevant discussions and key conclusions that resulted from the CSAS Regional Peer Review meeting of November 4-5, 2014 held in Nanaimo, British Columbia to review the working paper titled, “Habitat-based Benchmarks for Coho Salmon in Georgia Strait Mainland, Georgia Strait Vancouver Island and Lower Fraser Management Units”. A follow-up review meeting was held on April 14, 2015.

In-person and web-based participants included current and retired DFO Science and Fisheries Management staff, members of the Pacific Salmon Commission Coho Technical Committee, environmental non-governmental organizations and biological consultants with expertise on relevant Coho Salmon conservation units, stock assessment and fisheries management models.

The working paper presented the results of a habitat-based Coho Salmon carrying capacity model, along with a Bayesian stock-recruit analysis. This regression model, based on empirical data, was presented as a novel method for providing science-based recommendations for escapement and exploitation rate benchmarks for Coho Salmon in the five Lower Fraser and East Vancouver Island-Georgia Strait Coho conservation units (CUs). Additional meeting objectives were: to provide advice on methods to combine CU benchmarks into management unit (MU) benchmarks and to identify gaps in data and uncertainties. Note that no assessment of status for either the CUs or MUs was intended to be part of this work.

The conclusions and advice resulting from this RPR process will be provided in the form of a Science Advisory Report, and will be used to inform the ongoing development of WSP benchmarks, assessment of WSP status at the CU level and MU-level management reference points. The Science Advisory Report and supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) Website.

Compte rendu de l'examen par les pairs de la Région du Pacifique sur la détermination des indices de référence de l'échappée et du taux d'exploitation pour les trois unités de gestion du saumon coho du détroit de Georgie, dans le sud de la Colombie-Britannique

SOMMAIRE

Le présent compte rendu résume les principales discussions et conclusions qui découlent de la réunion régionale d'examen par les pairs du Secrétariat canadien de consultation scientifique qui a eu lieu les 4 et 5 novembre 2014, à Nanaimo, en Colombie-Britannique, et qui avait pour but d'examiner le document de travail intitulé « Habitat-based Benchmarks for Coho Salmon in Georgia Strait Mainland, Georgia Strait Vancouver Island and Lower Fraser Management Units ». Une réunion de suivi a eu lieu le 14 avril 2015.

Les participants en personne et via Web comprenaient des employés actuels et anciens des secteurs des Sciences et de la Gestion des pêches du MPO, des membres du Comité technique sur le saumon coho de la Commission du saumon du Pacifique, des organisations non gouvernementales de l'environnement et des experts-conseils spécialistes des évaluations des stocks, des modèles de gestion des pêches et des unités de conservation du saumon coho pertinentes.

Le document de travail présente les résultats d'un modèle de la capacité biotique du saumon coho fondé sur l'habitat, ainsi qu'une analyse bayésienne stock-recrue. Ce modèle de régression, fondé sur des données empiriques, a été présenté comme une nouvelle méthode pour fournir des recommandations de nature scientifique au sujet des points de référence pour les échappées et le taux d'exploitation du saumon coho dans les cinq unités de conservation (UC) du cours inférieur du fleuve Fraser et de la côte est de l'île de Vancouver ainsi que le détroit de Georgie. Les autres objectifs de la réunion étaient les suivants : fournir des conseils sur les méthodes de combinaison des points de référence des UC en points de référence pour les unités de gestion (UG) et cerner les lacunes dans les données ainsi que les incertitudes. Il est à noter que ces travaux ne comportaient aucune évaluation de l'état de ces UC ou UG.

Les conclusions et l'avis découlant de ce processus régional d'examen par les pairs seront présentés sous la forme d'un avis scientifique, et seront utilisés pour guider l'élaboration continue des points de référence pour la PSS ainsi que l'évaluation de l'état de la PSS au niveau des points de référence des UC et des UG. L'avis scientifique et le document de recherche à l'appui seront rendus publics sur le site Web du calendrier des avis scientifiques du Secrétariat canadien de consultation scientifique.

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INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS), Regional Peer Review (RPR) meeting was held on November 4-5, 2014 at the Vancouver Island Convention Centre in Nanaimo to review the development of escapement and exploitation benchmarks for Coho Salmon management in Georgia Strait Mainland, Georgia Strait Vancouver Island and Lower Fraser management units.

The Terms of Reference (TOR) for the science review (Appendix A) were developed in response to a request for advice from Management. Notifications of the science review and conditions for participation were sent to representatives with relevant expertise from DFO, First Nations, commercial and recreational fishing sectors, environmental non-governmental organizations and academia.

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

> Habitat-based Escapement Benchmarks for Coho Salmon in Georgia Strait Mainland, Georgia Strait Vancouver Island and Lower Fraser Management Units. (CSAP WP 2014/15SAL013)

The meeting Chair, Mary Thiess, welcomed participants, 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. Everyone was invited to participate fully in the discussion and to contribute knowledge to the process, with the goal of delivering scientifically defensible conclusions and advice. It was confirmed with participants that all had received copies of the Terms of Reference and working paper prior to the meeting.

The Chair reviewed the Agenda (Appendix C) and the Terms of Reference for the meeting, highlighting the objectives that had been set for this RPR process. The Chair then reviewed the ground rules and process for exchange, reminding participants that the meeting was a science review and not a consultation. The room was equipped with microphones to allow remote participation by web-based attendees, and in-person attendees were reminded to address comments and questions so they could be heard by those online.

Members were reminded that everyone at the meeting had equal standing as participants and they were expected to contribute to the review process if they had information or questions relevant to the paper being discussed. In total, 38 people participated in the initial RPR and 19 participated in the follow-up review meeting (Appendix D). Julia Bradshaw was identified as the Rapporteur at both meetings.

Participants were informed that Dr. Mara Zimmerman and Ms. Carrie Cook-Tabor had been asked before the meeting to provide detailed written reviews for the working paper to provide a starting point for discussions at the peer-review meeting. Participants were provided with copies of the written reviews in advance of the meeting (Appendix E).

The conclusions and advice resulting from this review will be provided in the form of a Science Advisory Report to inform the ongoing development of WSP benchmarks, assessment of WSP status at the CU level and MU-level management reference points. The Science Advisory Report and supporting Research Document will be made publicly available on the Canadian Science Advisory Secretariat (CSAS) website.

PRESENTATION OF WORKING PAPER

Working Paper: Habitat-based Escapement Benchmarks for Coho Salmon in Georgia Strait Mainland, Georgia Strait Vancouver Island and Lower Fraser Management Units. CSAP WP2014/15SAL013

Rapporteur: Julia C. Bradshaw

Presenter: Cameron A.J. Noble

There are currently no biological benchmarks to aid Coho fisheries management for the 5 Coho Salmon Conservation Units (CUs) in southern BC: Georgia Strait Mainland (GSM), East Coast Vancouver Island-Georgia Strait (EVI-GS), Howe Sound-Burrard Inlet (HS-BI), Lower Fraser River (LFR) and Lillooet River (LILL). Note that for Pacific Salmon Treaty work, the CUs are grouped into three Management Units (MUs): Georgia Strait – Mainland, Georgia Strait – Vancouver Island and Lower Fraser River. A habitat-capacity model combined with stock-recruit and stock-smolt analyses were used to develop informative, science-based benchmarks.

Incomplete data sets complicate the analysis and therefore the authors suggest presenting managers with a range of values rather than an average. The most useful benchmark as a result of this analysis is the maximum sustainable harvest rate (U_{msy}) rather than a benchmark based on abundances, which are uncertain. The models produce reasonable agreement with the estimates of recruitment data for GSM, EVI-GS and LFR. LFR and HS-BI are much less productive than other CUs; in fact, HS-BI has such low productivity, it cannot be exploited according to this model's prediction.

PRESENTATION OF WRITTEN REVIEWS

Dr. Mara Zimmerman and Ms. Carrie Cook-Tabor provided written reviews of the working paper (Appendix E). Dr. Zimmerman presented her review broken down into categories. A summary of the review according to these categories follows.

COHO PRODUCTION MODEL

Gradient selection is an important consideration for Coho Salmon habitat as the density of fish found in 6-8% gradients is much less than in 2-4% gradients. Quality of habitat should be included as a metric (e.g., intrinsic potential habitat model), as well as an assessment of the freshwater conditions. There are data concerns with the length of the time series used in the analysis. It may not be long enough to predict future smolt capacity. Is there reason to believe that the CUs are fundamentally different from one another? More justification was needed for the selection of model 1 over model 2.

COHO-SPAWNERS AT FULL SEEDING

There was concern that egg-smolt survival is density-dependent. As a result, freshwater survival rates may be more relevant. It was suggested that the effect of female body size on fecundity should be assessed in the paper. Pre-spawn mortality should also be taken into consideration as it could influence the full seeding of the habitat. There is doubt that these systems are fully seeded, which is an assumption in the WP. More of the details included in the author's WP presentation (such as the smolt back calculations, where the marine survival rates come from and how they influence the results) should be included in the WP.

STOCK-RECRUIT ANALYSIS

More emphasis needs to be placed on exercising caution when interpreting the results from the WP.

BENCHMARK SELECTION

There are several worthwhile options for benchmarks. A more clear rationale is warranted for the selection of U_{msy} over others than is given in the WP. How can this benchmark be used to assign stock status? How do we relate this to the PST requirements for an abundance benchmark?

Participating by phone, Ms. Cook-Tabor then presented her review, highlighting key points to consider. It was pointed out that the conditions represented by the data used in the analysis may or may not be reflective of current or future conditions. Dr. Zimmerman's comments regarding the level of seeding were seconded. Ms. Cook-Tabor questioned if there was a way to tighten up the baseline data.

GENERAL DISCUSSION

The general discussion of the WP focused on a few overarching themes which will be summarized below. These include data deficiencies, parameters of the habitat model, the indicator approach, issues with the stock-recruit analysis, level of habitat seeding, additional sensitivity analysis, resulting benchmarks and advice to management.

DATA DEFICIENCIES

Many data sets for Coho Salmon are considered data deficient. New sources of data were identified that could be added to the analysis (smolt production from the Alouette and Cheakamus rivers, BC hydro monitoring, data from the Upper Capilano, data from hatcheries and possibly from mark-recapture studies). The authors are expecting to receive this data from various sources identified in the meeting. Fecundity and sex ratio data should be added as well as the length-fecundity relationship. Some of the stream length data should be verified, especially in the case of Salmon River. Side channel spawning habitat can be important for some Coho Salmon populations and perhaps should be included, especially if these restorative habitats are common in one or all of the CUs. Infilling of data should be done. This should be a straightforward application of an existing infilling algorithm and the methodology has already been peer-reviewed in a previous CSAS process[1]. The bootstrap method could be used to represent the uncertainty in the data, rather than just a mean.

PARAMETERS OF THE HABITAT MODEL

A measure of stream gradient should be layered into the habitat model. Is stream length really the only important variable (in agreement with Bradford et al. 1997)? For stream order, are we sure we are not missing important ephemeral habitat by not including first order streams? Is

[1] Brown, G.S., Baillie, S,J., Bailey, R.E., Candy, J.R., Holt, C.A., Parken, C.K., Pestal, G.P., Thiess, M.E., and Willis, D.M. . Pre-COSEWIC review of southern British Columbia Chinook salmon (*Oncorhynchus tshawytsca*) conservation units, Part II: Data, analysis and synthesis. Canadian Science Advisory Secretariat (CSAS) Working Paper 2013/14 P67.

there a way to include a measure of habitat quality and not just quantity? Some measures of quality would need to be directly measured, but you can use GIS to get at the intrinsic potential of a habitat.

THE INDICATOR APPROACH

Are indicator streams an appropriate approach to take in this analysis, rather than a broad aggregate of streams within a CU? It would allow a tighter feedback loop as we will be measuring the escapement in these systems. There are 13 or 14 streams with relatively good data. Some participants felt that the habitat-based approach is better if you are doing a broad-based escapement program which you can use to compare against your model. Is there a reason to think that the indicator streams are not representative of the region as a whole? The authors did not feel that the indicators for LFR and GSM are indicative of the entire CU. The recommendation is to develop a hierarchy in the modeling of these systems, whereby if you have good data for a particular region use it as an input for the model. If you do not have good data, you must rely on data from an aggregate of streams that you assume is representative of the region you are modelling.

STOCK-RECRUIT ANALYSIS

Are the stock-recruit numbers lining up with historic values? As a proof of principles, the authors should take the numbers, simulate the history and see how the escapement predictions line up with what we've seen in the past. Is the stock-recruit analysis supported by data for all the CUs (i.e., for HS-BI, the data is very thin)?

HABITAT SEEDING

There were several concerns expressed throughout the meeting about the validity of the authors' assumption that the available data is from fully-seeded systems. The model assumes that spawners are not limiting, but that may not be the case in all systems. The authors explain that the asymptote from the stock-recruit analysis gives you an average, not a maximum at full seeding. A sensitivity analysis should be done to test this assumption, whereby the systems that you expect are not fully seeded could be removed and see how that affects the analysis. Alternatively, one could specifically plot only the systems that are known to be not fully seeded and compare.

SENSITIVITY ANALYSIS

The sensitivity analysis should be more inclusive. Sensitivity of the model to variation in fecundity and smolt productivity should be added. A figure should be added that portrays the variability in smolts/km. Is there more information about fecundity and size? (e.g., in the 1990s, there was a large drop in productivity that had more to do with a decrease in body size affecting fecundity). Hatchery information could be used to get at this? There is US data that could be used to get at the general relationship between size and fecundity.

BENCHMARKS

Several alternative benchmarks were explored through the discussion. Exploitation rate to maximum sustainable yield (U_{msy}) was chosen by the authors as the most reliable benchmark. One of the key ideas to emerge from the discussion is the potential use of marine survival and productivity as a proxy for stock status. This model allows for a new mechanism to evaluate harvest rates against a range of marine survivals. It was cautioned that marine survival on its

own should not be used to determine exploitation rate without some other measure of abundance.

SUMMARY OF REQUIRED REVISIONS

A list of revisions to be undertaken was provided to the authors following the regional peer review meeting. Note these were in addition to items raised by the formal reviewers.

PROCESS TO REVIEW MANDATORY UPDATES TO WORKING PAPER

There was consensus that the methodology used in the paper is sound. Consensus could not be reached on the model results due to deficiencies in the data inputs and parameterization of the habitat model. The meeting participants agreed to accept the paper with major revisions, which will be re-evaluated at a follow-up review meeting. A draft SAR was distributed to participants but not discussed further at this time.

The group acknowledged that in order to accept the results of this working paper, a follow-up review would be necessary to assess critical modifications and additions to the stock recruit model assessments and simulation analysis sections of the paper.

The group agreed that a revised working document would be provided early in 2015 followed by a virtual meeting to review the updates. The revised paper will be distributed to participants in advance of the follow-up meeting. A draft SAR will also be sent to participants in advance to facilitate its development during the follow-up meeting.

SUBSEQUENT REVIEW OF REVISED WORKING PAPER

OVERVIEW

The authors presented their revised results from the habitat and stock-recruit models using an updated data set of Type-IV or better data quality from 1990 and onwards. Updated smolt per spawner productivity was highly variable between streams. Issues with data quality remain and as a result, a range of exploitation marks should be presented to managers. The stock-recruit curves are heavily influenced by marine survival rates and the sensitivity analysis should be shifted to a lower marine survival to reflect current estimated marine survival rates. U_{msy} is the recommended benchmark and should be presented over a range of plausible marine survival rates, including confidence intervals. This model could be used to identify possible indicator streams. Participants agree to accept the paper with the revisions discussed herein.

PRESENTATION OF THE REVISED WORKING PAPER

Additional data from DFO and non-DFO sources (i.e., BC Hydro) were added. The habitat analysis was broadened to include stream order 1 and a gradient up to 8%. The total accessible habitat was found to be very sensitive to stream order, especially in the low-lying Boundary Bay CU, but not to stream gradient. Several streams were ground-truthed, but there some variability remains in a few of the accessible stream lengths (i.e., Salmon River).

Smolt data was added for Cheakamus and Allouet from BC Hydro. Capilano, Cultus Lake and Quinsam smolt data were excluded because of their hatchery predominance. As part of the sensitivity analysis, the authors paired high quality DFO spawner and smolt data to back-calculate the number of spawners using only empirically measured data (i.e., no infilling). (Note: “high quality” was defined as having an estimate quality ranking of Type-IV or better in the new Salmon Escapement Database System (nuSEDS).) The resulting productivity was highly variable and averaged 38 smolts per km. In contrast, Korman and Tompkins (2014) found an

average of 105 smolts per km, albeit during a period of low stock size and likely higher productivity.

Stock-recruit curves were re-analysed for GSM and GS-EVI CUs (LFR and LILL did not meet data standards) using data from 1990 and later. Hatchery components were removed with direction from Salmon Enhancement Program (SEP) staff. Indicator streams were chosen based on escapement record with Type-IV or better and used to infill the other streams with missing data to estimate the number of spawners. Black Creek was used to determine the number of recruits and all Coho were assumed to be 3 years old. The analysis produced a very weak pattern for the smolt data; however, the habitat based capacities line up well.

As in the original working paper, both the Beverton-Holt (BH) and Logistic Hockey Stick (LHS) models were used to fit the adult stock-recruit and smolt stock-recruit data. The BH model produces U_{msy} estimates that are well above what would be expected from a good data set and may result in unrealistic harvest rates. The smolt stock-recruit curves are very dependent on estimated marine survival rates. The authors recommend using harvest rate to achieve maximum sustainable yield (U_{msy}) as a benchmark. Given data concerns, it is the most implementable benchmark because it relies on the initial slope of the curve, which is less affected by variability in the data. The maximum sustainable harvest rate for GSM is approximately 40%, and 30% for EVI. It was noted that the low end of the credible limit for average U_{msy} is slightly higher than the current harvest rate (i.e., current harvest rate is nowhere near the average U_{msy} generated by the model).

DISCUSSION

Several issues concerning data quality and resulting uncertainty in the outputs were discussed. There were concerns about the data sources used to obtain the smolts per spawner estimates, particularly with the two streams representing extremes in productivity, Quinsam and Simms. The habitat is fundamentally different across the CUs of interest and warrants a CU-specific approach to modelling and decision-making. Including stream order 1 may be more relevant for the low-lying Boundary Bay CU than for EVI and GSM because of their differing geographical features. Perhaps more relevant is the impact of low snow pack and droughts (e.g., like this past fall) which may further limit accessibility to smaller (order 1) streams. The phase of the PDO has been shown to make a difference to stream accessibility by Coho in the BC Interior region.

The range of marine survival rates included in the sensitivity analysis (2.5 to 10%) is thought to be unrealistically high. The authors will include a 1% marine survival rate and remove the 10% level in the revised working paper.

Participants noted that at low marine survival, sex ratios are known to change dramatically (higher survival rates for males than females) . The smolts per spawner ratio should be much more conservative than this model would suggest. Should we account for differences in sex ratio at varying marine survival rates?

The authors cautioned against using the habitat model for management advice on a stream-by-stream basis rather than for the CU aggregate. The regional data set was used to drive the productivity model and any uncertainty will be amplified on an individual basis. An indicator stream, however, could be used as an estimate of scale for abundance. In the absence of stream-specific information for an indicator, the habitat model could be used to provide an interim target.

Hatchery marine survivals are used as a proxy for wild marine survival, but they may not be comparable. Exploitation rates and behaviour of hatchery fish are also different than wild fish.

Goldstream, in particular, has a very high exploitation rate that may not be applicable to other streams/areas. Because of this, the authors were advised to use a stratified weighted average marine survival across systems.

The definition of benchmark in the working paper should be clarified. The habitat-based model outputs are fed into the stock-recruit model. These outputs help determine a benchmark, which is U_{msy}.

There was concern that the suggested U_{msy} is unrealistically high. A range of harvest rates should be presented including the 95% confidence limits, rather than just an average. These Coho populations may not be able to sustain a 30% harvest rate.

All participants agreed to accept the revised working paper with further revisions as discussed in this meeting.

FINAL LIST OF REVISIONS

Following the subsequent review meeting, a final list of minor revisions was provided to the authors for incorporation into the research document prior to publication.

RECOMMENDATIONS & ADVICE

- The paper was accepted with minor revisions at the April 14, 2015 follow-up review meeting.
- Recommended future work includes the development of a hierarchy of decision rules across multiple models depending on the breadth of (and confidence in) the input data.
- Two models (a Habitat Model and a Stock Recruit Model) were presented for the purpose of providing biological benchmarks for escapement. In addition, the Stock Recruit Model is capable of providing biological benchmarks for exploitation rates. In all, four metrics (habitat-based spawners, U_{msy}, S_{gen}, S_{msy}) were provided for CUs and MUs of southern BC Coho Salmon, though not all metrics could be calculated for all CUs and MUs. (TOR Objective 1)
- Habitat-based capacity estimates (average smolts and required spawners to produce average smolts) are intended to provide a starting point to assess biological status of CUs and MUs. Additional Coho-specific work to establish WSP biological benchmarks informed by the results from this model will be needed (e.g., similar to existing benchmarks for other species of Pacific salmon).
- Allowable exploitation rate estimates (assuming specific levels of marine survival) were generated by the Stock Recruit Model. These results are not inconsistent with the regional analysis undertaken by Korman and Tompkins (2014), which showed similar rates using high-quality published data obtained at a different spatial scale.
- At this time, there are no MUs for which all of the component CU exploitation rate benchmarks could be calculated. Therefore, no advice was generated on methods to appropriately combine CU-level exploitation rate benchmarks into compatible MU benchmarks (TOR Objective 2).
- For CUs that lack sufficient data to calculate benchmarks, analysis using the high-quality regional data set, similar to Korman and Tompkins (2014), is recommended.
- There are varying degrees of uncertainty associated with many of the inputs to both models presented here, leading to high uncertainty in the model outputs. Caution should be exercised when interpreting or applying these results.

- A number of key assumptions and uncertainties in the data and methods were identified and evaluated through sensitivity analyses. In particular, the models are sensitive to the definition of "accessible habitat", and care must be exercised when setting this model input. Note that within any given watershed, the quantity of accessible habitat (based on a pre-determined definition) can vary from season to season (differentially affecting smolts and spawners), and/or from year to year (e.g., some Order 1 streams may dry up completely in some years or seasons, but not in others).
- The methods presented here are suitable for developing biological benchmarks for escapement and exploitation rates for both Management Units and Conservation Units, provided they can be supported with sufficient data (sufficient in quantity and quality). In order to provide science-based exploitation rate benchmarks for all CUs and MUs of southern BC Coho Salmon, thorough review of nuSEDS escapement data for Area 13 and the LFR, HS-BI and LILL CUs is necessary to ascertain its quality and suitability for analysis. Further evaluation of the potential for stock recruit analyses of these CUs and their component MUs will not be possible until such a review is complete.
- In order to provide a consistent analytic approach for establishing biological benchmarks across all populations of Pacific salmon, it is recommended that these methods (i.e., using habitat-based escapement estimates to provide prior information to stock-recruit analyses) be incorporated into the growing suite of analytic "tools".
- Regardless of the approach used to develop biological escapement benchmarks, specific streams (i.e., indicator streams) will need to be identified (and prioritized) for consistent, annual escapement work to ensure there are an appropriate number of indicators in each CU to produce reliable escapement estimates.
- There is a continued need for data assembly and quality review in DFO databases (e.g., NuSEDS) and other data holdings that have not been compiled or archived (e.g., grey literature). Further, steps to improve discoverability of all datasets will facilitate work in this area in the future.

ACKNOWLEDGEMENTS

The Chair thanks the authors of the Research Document for producing a valuable document in a timely fashion, the reviewers for their conscientious evaluations, the meeting participants for constructive input, Julia Bradshaw for her excellent work as rapporteur resulting in these proceedings, and finally the CSAS office for assistance coordinating the meeting and producing final reports.

REFERENCES

Bradford, M. J., G. C. Taylor, and J. A. Allan. 1997. Empirical review of coho salmon smolt abundance and the prediction of smolt production at the regional level. Transactions of the American Fisheries Society 126(1):49-64.

Korman, J., and A. Tompkins. 2014. Estimating regional distributions of freshwater stock productivity, carrying capacity, and sustainable harvest rates for Coho Salmon using a hierarchical Bayesian modelling. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/089. vii + 53 p.

APPENDIX A: TERMS OF REFERENCE

Determination of Escapement and Exploitation Rate Benchmarks for the Three Georgia Strait Southern BC Coho Management Units

Regional Peer Review Process – Pacific Region

November 4-5, 2014
Nanaimo, BC

Chairperson: Mary Thiess

Context

The Pacific Salmon Treaty (PST) identifies four Southern BC inside management units (MU): Interior Fraser (including Thompson), Lower Fraser, Strait of Georgia Mainland, and Strait of Georgia Vancouver Island. The objective of the bilateral Canada/US Coho Salmon management plan is to constrain total fishery exploitation to enable MUs to produce Maximum Sustainable Harvest (MSH) over the long term, while maintaining the genetic and ecological diversity of the component populations and to improve long-term prospects for sustaining healthy fisheries in both countries. The PST requires the development and documented derivation of the escapement goal or exploitation rate that achieves MSH; and exploitation rates for 3 status categories, Low, Moderate and Abundant for each MU.

In addition to the above PST obligations, and as part of implementing Strategy 1 of the Wild Salmon Policy (WSP), Fisheries and Oceans Canada (DFO) is required to identify biological benchmarks to assess the status of WSP Conservation Units (CU's) for Pacific salmon (PST MU's are comprised of multiple CU's). WSP Benchmarks have not been established for any Southern BC Coho CUs at this time.

An analysis, funded by the Southern Endowment Fund of the PST, to provide science-based recommendations for escapement and exploitation benchmarks for the Strait of Georgia Mainland and Strait of Georgia Vancouver Island CU's and MU's has been undertaken by LGL Ltd of Sidney, BC and Ecometric Research of Vancouver BC. This analysis utilizes a habitat-based Coho carrying capacity model, originally developed for the Nass River watershed (Bocking and Peacock 2004), along with a Bayesian stock-recruit analysis (Korman and Tompkins 2014a, 2014b) focused first at the CU level. Specific advice and recommendations for methods to appropriately combine CU level exploitation rate benchmarks into compatible MU exploitation benchmarks will also be provided. An assessment of status for the CU's and MU's will not be completed as part of this work.

Fisheries Management Branch has requested that Science Branch provide advice on the WSP and PST obligations for the Lower Fraser River, Georgia Strait-Mainland and Georgia Strait-Vancouver Island CU's and MU's. Results of the assessment, and advice arising from this Regional Peer Review process, will be used to inform the ongoing development of WSP benchmarks, assessments of WSP status at the CU level and management reference points.

Objectives

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

Noble, C., B.Bocking and J.Korman. Habitat based Escapement and Exploitation Rate Benchmarks for Georgia Strait Mainland, Georgia Strait Vancouver Island and Lower Fraser River Management Units. CSAP Working Paper 2014/15SAL013.

The specific objectives of this review are to:

1. Develop biologically-based benchmarks for escapement and exploitation rate for Strait of Georgia Mainland,Strait of Georgia Vancouver Island and Lower Fraser River MU's and their component CU's.
2. Provide Specific advice and recommendations for methods to appropriately combine CU level exploitation rate benchmarks into compatible MU benchmarks.
3. Examine and identify uncertainties in the data and methods.

Expected Publications

- Science Advisory Report
- Proceedings
- Research Document(s)

Participation

- Fisheries and Oceans Canada (DFO) (Science, Fisheries Management, and Salmonid Enhancement Program)
- First Nations
- Commercial and Recreational Fishing Representatives
- Environmental Non-government Organizations
- Academia

References

Bocking, B. and D. Peacock. 2004. Habitat-based production goals for coho salmon in Fisheries and Oceans Statistical Area 3. DFO. Can. Sci. Advis. Sec. Res. Doc. 2004/129. vii +77pp.

Fisheries and Oceans Canada. 2005. Canada's Policy for Conservation of Wild Pacific Salmon. Fisheries and Oceans Canada, Vancouver, BC. 34 pp.

Grant, S.C.H., MacDonald, B.L., Cone, T.E., Holt, C.A., Cass, A., Porszt, E.J., Hume, J.M.B., and Pon, L.B. 2011. Evaluation of uncertainty in Fraser Sockeye (*Oncorhynchus nerka*) Wild Salmon Policy status using abundance and trends in abundance metrics. DFO. Can. Sci. Advis. Sec. Res. Doc. 2011/087. viii + 183 pp.

Holt, C.A. 2009a. Evaluation of benchmarks for Conservation Units in Canada's Wild Salmon Policy: technical documentation. DFO. Can. Sci. Advis. Sec. Res. Doc. 2009/059. xii + 50 pp.

Holt, C.A., Cass, A., Holtby, B., and Riddell, B. 2009b. Indicators of status and benchmarks for Conservation Units in Canada's Wild Salmon Policy. DFO. Can. Sci. Advis. Sec. Res. Doc. 2009/058. vii + 74 pp.

Korman, J and Tompkins, A. 2014a. Comparison of the Fishery and Conservation Performance of Fixed- and Abundance-Based Exploitation Regimes for Coho Salmon in Southern British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/090.

Korman, J. & Tompkins, A. 2014b. Estimating Regional Distributions of Freshwater Stock Productivity, Carrying Capacity, and Sustainable Harvest Rates for Coho Salmon Using a Hierarchical Bayesian Modelling. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/089.

APPENDIX B: ABSTRACT OF WORKING PAPER

Identifying biological reference points or benchmarks for management of Coho Salmon is a critical component of the Wild Salmon Policy, and key to sustainable fishery management; yet data and budget restrictions limit the use of traditional stock recruit methods to identify benchmarks. Here, we combine a habitat-based model and Bayesian stock-recruit and stock-smolt analysis to estimate average CU smolt production and the number of spawners required to achieve this, as well as stock productivity parameters and three potential benchmarks Umsy, Smsy and Sgen for wild (non-enhanced) Coho Salmon populations. Stock recruit analyses were conducted using both Beverton Holt (BH) and Logistic Hockey Stick (LHS) models and spawner-to-smolt and spawner-to-recruit data sets. Stream length accessible to Coho Salmon was determined from terrain resource inventory maps (TRIM) using GIS and maps at 1:20,000 scale. Stream order, gradient and known barriers were used to define the accessible length of stream. The number of smolts per kilometer was derived using a log-linear predictive regression of smolt yield and stream length for 22 streams within the CUs of interest. Average estimated smolt production and the number of spawners required to produce the average number of smolts for each CU were calculated respectively as 1,603,226 and 49,422 (ECVI-GS); 395,603 and 11,968 (GSM); 751,868 and 22,784 (HS-BI); 1,484,479 and 46,005 (LFR); 910,977 and 27,605 (LILL); and 608,082 and 18,427 (BB). Estimated average smolt production and spawners for each MU were calculated respectively as 1,147,471 and 34,752 (GSM); 3,003,538 and 92,037 (LFR); and 1,603,226 and 49,422 (GS-VI). Results of the habitat model are dependent on the amount of habitat available, particularly as it applies to stream order, and to the number of smolts produced per spawner. The Logistic Hockey Stick stock-recruit model estimates that at an assumed future marine survival rate of 2.5%, harvest rates of approximately 35-40% will produce MSY for ECVI-GS and GSM CUs, however, at 1.0% survival, harvest rates to produce MSY drop to between 1-4% for ECVI-GS and GSM CUs, a level more in line with current management practices. While we model, and provide, estimates of Sgen and Smsy, we abstain from recommending them due to implementation challenges due to the fact that escapement isn't monitored completely to determine if the benchmark was met and because it requires a reliable pre-season forecast of abundance to determine how much catch to take to end up at Sgen or Smsy. The results of the stock-recruit analysis are highly dependent on marine survival estimates. Data deficiencies prevented stock recruit analyses to be completed on all other CUs, which resulted in no stock recruit analysis conducted on the GSM and LFR MUs.

APPENDIX C: AGENDA

Canadian Science Advisory Secretariat

Centre for Science Advice Pacific

Regional Peer Review Meeting (RPR)

Determination of Escapement and Exploitation Rate Benchmarks for the Two Georgia Strait Southern BC Coho MU's

November 4-5, 2014

Vancouver Island Conference Centre
Nanaimo, BC

Chair: Mary Thiess

DAY 1 - Tuesday, November 4th

Time	Subject	Presenter
1300	Introductions Review Agenda & Housekeeping CSAS Overview and Procedures	Mary Thiess
1315	Review Terms of Reference	Mary Thiess
1330	Presentation of Working Paper	Author
1430	Questions & Points of Clarification	RPR Participants
1445	***Break***	
1500	Overview of Written Reviews	Chair, Reviewers & Authors
1600	Identification of Key Issues for Group Discussion: • Technical Issues • Results & Conclusions	RPR Participants
1645	Develop Plan for Day 2 Discussions	Mary Thiess
1700	***Adjourn for the Day***	

DAY 2 - WEDNESDAY, November 5th

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping Review Status of Day 1 Distribute draft Science Advisory Report (SAR)	Mary Thiess
0915	Discussion & Resolution of Technical Issues	RPR Participants
1030	***Break***	
1045	Discussion & Resolution of Results & Conclusions	RPR Participants
1145	Develop Consensus on Paper Acceptability & Agreed-upon Revisions	RPR Participants
1200	***Lunch Break***	
1300	<u>Develop the SAR</u> Establish consensus on the following: • Sources of Uncertainty • Results & Conclusions • Additional advice to Management (as warranted)	RPR Participants
1430	***Break***	
1450	Continue Working on SAR	RPR Participants
1600	Next Steps – Chair to outline: • SAR review/approval process and timelines • Timelines for other documents • Other follow-up or commitments required	RPR Participants
1645	Concluding Remarks • Summarize other business arising from the review	Chair & RPR Participants
1700	***Adjourn meeting***	

APPENDIX D: PARTICIPANTS

November 4-5, 2014

Last Name	First Name	Affiliation
Bailey	Richard	DFO Science Fraser River.
Baillie	Steve	DFO Science South Coast
Blackbourn	Dave	Former DFO Science, retired
Bocking	Bob	LGL Ltd
Bradshaw	Julia	DFO Science
Campbell	Kelsey	A'Tlegay Fisheries Society
Cook-Tabor	Carrie	U.S. Fish & Wildlife Service
Decker	Scott	DFO Science South Coast
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Staley	Mike	Fraser River Aboriginal Fisheries Sec.
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Van Will	Pieter	DFO Science South Coast
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Whitehouse	Timber	DFO Science Fraser River

Last Name	First Name	Affiliation
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Zimmerman	Mara	Washington Department of Fish and Wildlife

April 14, 2015

Last Name	First Name	Affiliation
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Baillie	Steve	DFO Science South Coast
Bocking	Bob	LGL Ltd
Bradshaw	Julia	DFO Science
Cook-Tabor	Carrie	U.S. Fish & Wildlife Service
Grout	Jeff	DFO Fisheries Management
Kakowaki	Ronald	DFO Fisheries Management
Korman	Josh	UBC Fisheries Centre
Lynch	Cheryl	DFO Salmon Enhancement Program
Noble	Cameron	LGL Ltd
Ormond	Chad	Qullhanumutsun
Parken	Chuck	DFO Science Fraser River
Patten	Bruce	DFO Science Salmon and Freshwater Ecosystems
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Thiess	Mary	DFO Science Salmon and Freshwater Ecosystems
Van Will	Pieter	DFO Science South Coast
Tompkins	Arlene	DFO Science Salmon and Freshwater Ecosystems
Weitkamp	Laurie	National Marine Fisheries Service

APPENDIX E: WORKING PAPER REVIEWS

Date: 29 October 2014

Reviewer: Mara Zimmerman, Washington Department of Fish and Wildlife

CSAS Working Paper: 2014/15SAL013

Working Paper Title: Habitat-based Escapement Benchmarks for Coho Salmon in Georgia Strait Mainland, Georgia Strait Vancouver Island and Lower Fraser Management Units. CSAP WP2014/15SAL013

Authors: C. Noble, J. Korman and R. Bocking

I appreciate the opportunity to review the working paper on the development of benchmarks for Coho Salmon in southern British Columbia. The geographic scope of the working paper included five Conservation Units which are aggregated into three Management Units in the Pacific Salmon Treaty. Analyses in the working paper were conducted at the level of the Conservation Unit.

The authors use two different approaches to develop benchmarks for coho salmon in southern British Columbia. The first approach, a Coho Production Model, produced estimates of smolt capacity and spawner levels required to fully seed the watershed. The second approach, a Spawner-Recruit Model, produced estimates under three marine survival scenarios for U_{msy} (optimum harvest rate for maximum sustainable yield), S_{msy} (spawner abundance at maximum sustainable yield), and S_{gen} (spawners that would result in recovery to S_{msy} within one generation in the absence of directed fishing). The authors conclude that spawner escapement benchmarks should be selected from Coho Production Model results and that harvest benchmarks (U_{msy}), dependent on marine survival rate, should be selected from the Spawner-Recruit Model results. The authors developed their conclusions based on solid rationale, albeit limited data. In this memo, I offer the following critique and suggestions for improvement to the working paper. I have organized by comments according to four major themes in the working paper: (1) Coho Production Model, (2) Coho Spawners at Full Seeding, (3) Stock-Recruit Analyses, and (4) Benchmark Selection.

1) Coho Production Model

- **Use of stream distance to predict smolt capacity:** The Coho Production Model assumes that smolt capacity of a watershed is primarily determined by stream length, an assumption that is supported by previous analyses when considering smolt capacity at a regional scale (Bradford et al. 1997). The authors further state that over-winter habitat, downstream of the upper-most extent of spawning distribution, is likely the limiting factor in freshwater. Although I agree with the decision to use stream distance as a suitable predictor of coho smolt capacity, there are several additional papers worth discussing as they bear on the potential for basin geomorphology (Sharma and Hilborn 2001) and summer habitat (Beecher et al. 2010 - see Fig. 2) to contribute to smolt capacity of a given watershed. The authors own data suggest that smolt/km may be fundamentally different among watersheds. For example, average smolt/km are lower for Georgia Strait Mainland CU than East Vancouver Island. As I am not familiar with the watersheds, I do not know whether the different in smolt density is merely due to the study streams in question or whether the geomorphology of the GSM watersheds is fundamentally different (higher gradient?) than East Vancouver Island. According to the sensitivity analysis included in this working paper, the GSM CU watersheds appear to have more high gradient segments than EVI CU watersheds (Table 7), consistent

with the concept that smolt density is affected by watershed geomorphology as well as stream distance. The potential for this type of bias should be discussed.

- **Estimation of stream length of coho bearing habitat**: The estimates of smolt productive capacity are particularly sensitive to parameters used to estimate stream length such as stream order and gradient. The authors did a thorough job of discussing the rationale for the parameters they selected and citing literature and observations that formed the basis for their selections. An additional citation should be included in this discussion of modeling coho spawner distribution (Fransen et al. 2006).
- **Historical mean smolt data as reflective of future smolt productive capacity:** The proposed benchmarks are contingent on the relevance of existing smolt data to future scenarios. Among the reasons that this might not be the case are (1) if watersheds are not currently fully seeded due to chronically low marine survival since the late 1980s, (2) if freshwater habitat conditions are predicted to improve or degrade in the future. These issues should be discussed more thoroughly. Of particular concern is whether the smolt counts represent a time period that the watersheds are fully seeded with spawners. Although the time periods for the smolt data are not given, the data set lengths are variable suggesting that some of the data must limited to recent years only (following decline in SoG marine survival) while other data span a longer time frame (high and low SoG marine survival). If low marine survival in the Strait of Georgia has resulted in spawner abundance below a full seeding level, than smolt counts from these years underestimate the capacity of the watershed. Two potential ways to defend the use of existing smolt data would be to show spawner-smolt relationships (where available) or to demonstrate that smolt production over time has not decreased in the low marine survival years (Black Creek or Quinsam).
- **Applying measured smolt densities to modeled stream habitat:** The authors assume that the calculated smolts/km from study streams are applicable to non-monitored systems regardless of the distribution of habitat gradients in these watersheds. The authors acknowledge that the highest densities of coho occur at the lowest gradients, consistent with published literature (e.g., Sharma and Hilborn 2001). Thus there is a potential bias in the final estimated smolt productive capacity if some watersheds are higher gradient than others. Indeed the authors show that some CUs are more sensitive to gradient cut-offs than others (Table 7). While this assumption may cause some bias in the estimate of smolt productive capacity, the sensitivity analysis indicates that this bias is minimal compared to the inclusion/exclusion of streams according to stream order. The potential bias should be discussed, but unless empirical adjustments associated with stream gradients exist, additional modifications to the existing model are probably not warranted.
- **Two models compared:** The authors use two different models to predict smolt productive capacity at the CU level. Model 1 is a predictive regression model that describes the relationship between stream km and average smolt production from 14 watersheds. Model 2 uses smolt densities from monitored population within each CU expanded to the stream distance available in the entire CU. The authors clearly favor the results of Model 1, but the rationale for this preference needs to be better described in the text.

2) Coho Spawners at Full Seeding

- **Freshwater survival**: The conversion of smolt productive capacity to spawners at full seeding is particularly sensitive to the assumed survival from egg to smolt (Table X). The overall egg-to-smolt survival used to convert smolt productive capacity to spawners is approximately 4%, a rate consistent with that seen in US wild coho population data sets that I work with. Although the survival rates and their sources are provided, it is unclear whether the authors considered spawner densities associated with the survival estimates they are

selected. Freshwater survival of all life stages might be expected to decrease as a function of increasing spawner densities. The appropriate freshwater survival to use to calculate full seeding would occur at low spawner densities prior to the onset of density-dependence. I recommend adding a few sentences explaining how the survival data were obtained and how/whether density-dependent effects were considered when selecting these values.

- **Fecundity:** The conversion of smolt productive capacity to spawners at full seeding is contingent on estimates of fecundity. The authors state that there is minimal information on fecundity and then select 2,500 eggs/female which is a published literature value based on studies published in the 1950s (Sandercock 1991). As fecundity is known to be a function of female body size, the authors need to include some description of trends in body size of wild female coho salmon in the present years as compared to a half century ago. Has body size changed under the low marine survival period? How might this affect fecundity? Even if there is no direct data that can be used to change the selected fecundity value, this issue and its potential bias on the estimates discussed (e.g., if female body size has decreased more spawners are needed for a given smolt capacity).

3) Stock-Recruit Analyses

- **Smolt data calculations:** The stock-recruit analysis was the most difficult part of this working paper to assess because the data used for the calculations were not provided and the methods used to derive these data were not provided. What were the spawner escapement estimates and how were they calculated (were any estimates “in-filled”)? What were the exploitation rate estimates and how were they calculated? What were the marine survival rates used to back-calculate smolt production and what was the justification for using these particular marine survival rates? What are the potential uncertainties or bias in these data sets?

- **Spawner-recruit analyses:** The benchmark values resulting from the spawner-recruit analyses differ from those resulting from the spawner-smolt analysis. While the authors make an important point that the benchmarks developed from the spawner-recruit analysis are only appropriate for the current marine regime, the basis for this conclusion is unclear as it appears that data used for this analysis occurs over at least two marine survival regimes. The text would benefit from more strongly emphasizing caution regarding use of the results from the spawner-recruit analysis given the differences in marine survival observed over the data set used to conduct this analysis.

- **Spawner-smolt analyses:** The authors do a good job of explaining how spawner-smolt analysis can be used to calculate benchmarks under different marine survival conditions. However, an assumption inherent to this approach should also be discussed. The authors fail to mention that their approach assumes that freshwater conditions remain constant between the marine survival periods. If freshwater habitat has changed notably over the course of the dataset or is projected to change in any of these CUs, this additional complexity should also be considered when using the results of these analyses to develop management benchmarks.

4) Benchmark Selection

- **Use of spawners at full seeding as a benchmark:** The authors recommend the spawner calculations from the Coho Production Model be used as a spawner escapement benchmark. However, additional explanation is needed to understand why the authors prefer this metric over the Smsy (spawners at maximum sustainable yield) metric from the Stock-Recruit analysis. The text should include a comparison of the values of these two metrics and should defend the rationale for selecting one metric over another.

- **Use of Umsy as a benchmark:** The authors argue that Umsy (optimum harvest rate for maximum sustainable yield) is a useful benchmark. I find myself confused as to how this harvest metric would be useful as a benchmark and think that the concept should be more completely explained in the working paper. For example, Umsy is a useful benchmark to plan fisheries (contingent on accurate marine survival indicator) but I don't see how it is useful to evaluate stock status because the fisheries would presumably be manipulated to meet this benchmark. Perhaps the intended use of this metric as a benchmark would be that a lower Umsy value is reflective of lower marine survival rates (low productivity) and a higher Umsy is reflective of higher marine survival rates (high productivity).
- **Habitat based capacity vs. S-R model capacity:** The estimate of watershed capacity based on the Coho Production Model (habitat based) was consistently lower than that based on the Spawner-Recruit model. Although the authors state that the Coho Production Model capacity is more likely to be accurate, a more detailed rationale for this comparison is needed that incorporates potential sources of bias inherent in both methods. What does this difference mean? How likely is this result due to inaccurate data in spawner-recruit analysis (recruitment, marine survival)? How likely is this result due to sensitivities of the habitat model?

References

Beecher, H. A., B. A. Caldwell, A. B. DeMond, D. Seiler, and S. N. Boessow. 2010. An empirical assessment of PHABSIM using long-term monitoring of coho salmon smolt production in Bingham Creek, Washington. North American Journal of Fisheries Management 30:1529-1543.

Bradford, M. J., G. C. Taylor, and J. A. Allan. 1997. Empirical review of Coho salmon smolt abundance and the prediction of smolt production at the regional level. Transactions of the American Fisheries Society 126(1):49-64.

Fransen, B. R., S. D. Duke, L. G. McWethy, J. K. Walter, and R. E. Bilby. 2006. A logistic regression model for predicting the upstream extent of fish occurrence based on geographic information systems data. North American Journal of Fisheries Management 26:960-975.

Sandercock, F. K. 1991. Life history of coho salmon (*Oncorhynchus kisutch*). Pages 395-446 *in* C. Groot, and L. Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver, BC.

Sharma, R., and R. Hilborn. 2001. Empirical relationships between watershed characteristics and coho salmon (*Oncorhynchus kisutch*) smolt abundance in 14 western Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58:1453-1463.

Reviewer: Ms. Carrie Cook-Tabor, U.S. Fish & Wildlife Service

Ms. Cook-Tabor provided her review verbally in the review meeting.