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Proceedings of the Regional Peer Review on the West Coast Vancouver Island Chinook Salmon Escapement Estimation and Stock Aggregation Procedures

June 18 – 20, 2013
Nanaimo B.C.

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Foreword

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

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SUMMARY

These Proceedings summarize the discussions and key conclusions from the Fisheries and Oceans Canada (DFO), Canadian Science Advisory Secretariat (CSAS) Regional Advisory meeting conducted on June 18th to 20th, 2013, at the Vancouver Island Conference Centre in Nanaimo, B.C. The workshop objectives were

1) to evaluate the escapement estimation methodology used to evaluate the abundance of West Coast Vancouver Island (WCVI) Chinook index stocks relative to escapement targets; and,
2) to recommend methods for estimating an annual aggregate escapement or appropriate surrogate for the entire WCVI Chinook management unit. Participants included biologists, scientists and academics with relevant experience from DFO and other interested agencies.

A working paper on the methodology used to estimate escapement of WCVI index stocks was reviewed as part of objective 1. The summary of the working paper, the reviews and the main points for the review discussions are summarized in these Proceedings. Participants and reviewers recommended that more work be conducted, including further model development, sensitively analysis and calibration with empirical data. The paper was not accepted in its current form.

To meet objective 2, the methods for estimating the aggregate abundance of WCVI Chinook were evaluated in small group sessions. The group process, report-outs and discussions are summarized in these proceedings. Participants found that the current index method is appropriate for WCVI Chinook, but that improvements could be made by incorporating elements from the other methods evaluated (i.e., GRTS, habitat-based method and CWT/GSI/Scale method).

Recommendations for improvements to the escapement estimation of WCVI Chinook are described here and also summarized in a Science Advisory Report that resulted from the meeting. In addition, these Proceedings include the background materials prepared for the workshop and written contributions by presenters.

Compte rendu de l’examen régional par des pairs sur les procédures d'estimation des échappées de saumon quinnat de la côte ouest de l'île de Vancouver et de regroupement des stocks

SOMMAIRE

Le présent compte rendu résume les discussions et les conclusions principales de la réunion de consultation scientifique régionale du Secrétariat canadien de consultation scientifique (SCCS) de Pêches et Océans Canada (MPO) qui a eu lieu du 18 au 20 juin 2013 au Vancouver Island Conference Centre de Nanaimo, en Colombie-Britannique. Les objectifs de l'atelier étaient les suivants :

1) évaluer la méthode d'estimation des échappées employée pour évaluer l'abondance des stocks indicateurs de saumon quinnat de la côte ouest de l’île de Vancouver (COIV) par rapport aux objectifs d'échappées;
2) recommander des méthodes d'estimation des échappées globales annuelles ou un substitut approprié pour l'ensemble de la zone de gestion du saumon quinnat de la COIV. Parmi les participants, on comptait des biologistes, des scientifiques et des universitaires versés en la matière, provenant du MPO et d'autres organismes intéressés.

Dans le cadre du premier objectif, les participants ont examiné un document de travail sur la méthode utilisée pour estimer les échappées des stocks indicateurs de la COIV. Un résumé de ce document de travail, des examens et des points saillants des discussions à ce sujet est donné dans le présent compte rendu. Les participants et les examinateurs ont recommandé que davantage de travaux soient réalisés, notamment sur l'élaboration avancée des modèles, l'analyse de sensibilité et la calibration en fonction de données empiriques. La version actuelle du document n'a pas été acceptée.

Dans le cadre du deuxième objectif, les participants, séparés en petits groupes, ont évalué les méthodes d'estimation de l'abondance globale du saumon quinnat de la COIV. Le processus des groupes, les rapports et les discussions sont résumés dans le présent compte rendu. Les participants ont déterminé que la méthode actuelle d'indice est adéquate pour le saumon quinnat de la COIV, mais ils ont remarqué que des améliorations sont possibles si l'on intègre certains éléments des autres méthodes évaluées (c.-à-d. méthode d'échantillonnage stratifié par tessellation aléatoire généralisée, méthode fondée sur l'habitat et méthode d'identification génétique des stocks, des micromarques magnétisées codées [MMC] et des échelles).

Les recommandations concernant les améliorations à apporter à la méthode d'évaluation des échappées de saumon quinnat de la COIV sont détaillées dans le présent document; elles sont également résumées dans un avis scientifique issu de la réunion. Le présent compte rendu comprend également les documents d'information préparés pour l'atelier et les contributions écrites des présentateurs.

INTRODUCTION

A Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) meeting was held on June 18th-20th, 2013 at the Vancouver Island Conference Centre in Nanaimo to: 1) evaluate the escapement estimation methodology used to evaluate the abundance of WCVI index stocks relative to escapement targets; and, 2) recommend methods for estimating an annual aggregate escapement or appropriate surrogate for the entire management unit.

The Terms of Reference (TOR) for the regional peer review (Appendix A) were developed as part of ongoing work to improve the WCVI Chinook assessment framework. The working paper and workshop were part of a Pacific Salmon Treaty (PST) Sentinel Stocks Program (SSP) project to scientifically review and evaluate the methods for estimating WCVI Chinook escapements. Notifications of the science review and conditions for participation were sent to biologists, scientists and academics with relevant experience from DFO and other interested agencies.

The first part of the workshop (day 1 / TOR objective 1) was a peer review of the escapement surveys and estimation methodologies for Chinook in individual rivers on WCVI. The review was based on the working paper:

Evaluation of escapement monitoring program and escapement estimates for WCVI Chinook (Oncorhynchus tshawytscha) extensive indicator stocks by D. Dobson, M. Labelle, D. McHugh, and E. Porszt. (CSAP Working Paper, 104pp.)

The day 1 review and discussion provided context for the second part of the workshop (days 2 and 3 / TOR objective 2) which was to evaluate methods for estimating aggregate abundance of WCVI Chinook. In other words, taking the escapement estimates for individual streams and expanding to give an estimate of the total escapement (or index of escapement) for the WCVI aggregate. An estimate of aggregate escapement is a requirement for the Pacific Salmon Treaty (PST) as well as for domestic management and reporting. River-based methods for estimating the aggregate abundance, including the current index system, were considered, as well as fishery-based methods described below.

A significant amount of work was done in preparation for the second part of the workshop. First, a questionnaire was prepared and distributed to a number of organizations to learn more about methods used to estimate the aggregate abundance across the Pacific US and Canada regions. Next, the questionnaire results were compiled and methods assessed in terms of suitability for estimating the aggregate abundance of WCVI Chinook. The summarized questionnaire results are shown in Appendix G. The four methods deemed most suitable for WCVI Chinook based on questionnaire results were discussed in detail at the workshop. Experts on each of the methods gave presentations which were followed by discussion in small groups. The workshop was designed so that the format of the questionnaire, presentations and small group discussions were aligned with each other and the objectives in the TOR.

A workshop binder was prepared for each of the participants. Binders contained the workshop agenda, the TOR, a list of acronyms, a participants list, the working paper reviews, the questionnaire results, the four presentations on aggregate estimation methodologies, the evaluation criteria for aggregate estimation methods, and information on Nanaimo.

The original workshop agenda is contained in Appendix B. It should be noted that issues identified on day 1 resurfaced as obstacles to some of the discussion on day 2, and so the agenda was adjusted on day 3 to focus mainly on these issues and the resulting science advice.

These proceedings have been broken down according to parts 1 and 2 of the workshop with background and supporting documentation shown in the appendices. The highlights from the additional discussion on day 3 are given in these proceedings. There were 36 participants who contributed to the process. Rapporteurs for the workshop were Stephanie King and Stefanie Miller.

The conclusions and advice resulting from this review will be provided in the form of Science Advisory Reports to Fisheries and Aquaculture management to inform salmon assessment planning for the above-noted stocks. The four Science Advisory Reports and two supporting Research Documents will be made publicly available on the CSAS Science Advisory Schedule.

WORKSHOP SUMMARY PART 1 – WCVI CHINOOK SALMON ESCAPEMENT ESTIMATION

Welcome and introduction to the RPR process

The meeting Chair, Marilyn Hargreaves, 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, working papers, and working paper reviews.

The Chair reviewed the Agenda (Appendix B) and the Terms of Reference (Appendix A) for the meeting and highlighted the objectives. The Chair then reviewed the ground rules and process for exchange, reminding participants that the meeting was a science review and not a consultation.

Members were reminded that everyone at the meeting had equal standing as participants and that they were expected to contribute to the review process if they had information or questions relevant to the paper being discussed.

Participants were informed that Josh Korman, Dan Rawding and Kim Hyatt had been asked before the meeting to provide detailed written reviews for the working paper to assist everyone attending the peer-review meeting (Appendices D, E and F respectively). Participants were provided with copies of the written reviews.

Overview of the working paper

Diana Dobson gave an overview of the working paper including context, a description of the study area and population, the extensive indicator stock datasets and the models for making escapement estimates. The stated objective of the working paper was to evaluate the survey methodology used to estimate WCVI Chinook escapement for extensive indicator stocks and review the resulting estimates in order to provide the basis for evaluating:

- the method used to estimate escapement using periodic visual survey data
- the quantification of uncertainty in the estimates
- the potential for bias in the survey procedure
- clarity in the description of survey and sampling protocols

There are a number of management objectives that require annual estimates of escapement. The Pacific Salmon Treaty uses escapement data to forecast production and evaluate stock status. DFO’s Wild Salmon Policy uses surveys to evaluate the status of conservation units. The data are also used to manage and evaluate terminal fisheries in the WCVI areas. The escapement estimates receive increased attention due to concern over low abundance, and the issue is complicated further by declining resources for the assessment program. In light of the management objectives and difficulties surrounding the assessment there is a pressing need to establish solid sampling and survey protocols with estimates of uncertainty.

The current extensive indicator monitoring program was established in 1995 with the objective of establishing consistent survey and analytical methods to estimate escapement for WCVI

Chinook indicators. A visual survey method is used where snorkel teams count the number of fish in the known spawning areas. Surveys are scheduled every seven to ten days, although weather and water conditions often impeded this schedule.

Following work by Irvine et al. (1992), the analytical methods were based on the trapezoidal Area-Under-the-Curve (AUC) method to generate escapement estimates; however, the parameter assumptions (observer efficiency, survey life) were not directly measured. Observer efficiency (OE) was based on the judgment of the survey crews based on survey conditions. The survey life generally fell within the range of five to twenty days documented in the literature for residence times for Chinook in B.C. and Washington State. A review of the data suggests that the escapement estimates may be biased low due to reporting peak counts only.

The working paper describes the re-analysis of these data using two methods that allow for incorporation of uncertainty in the escapement estimates; a revised AUC model and a Maximum Likelihood Estimation (MLE) model. The revised AUC builds uncertainty into the parameter assumptions through Monte Carlo sampling of OE and SL parameter distributions. Alternatively, the MLE model fits existing data to a run timing model and estimates key parameters through a likelihood approach. The time series data were also assessed using a Principal Component Analysis (PCA) for similarities in parameters between systems, but the results did not suggest obvious stratification of systems based on conditions related to AUC parameters.

Diana Dobson discussed the issues related to observer efficiency (OE), survey life (SL) which were compared to tagging studies and the model results. The survey life assumptions used for AUC analysis for the reported data appear to be reasonable. Crews reported observer efficiencies were likely too high based on both observer efficiencies that were measured (through tagging studies) and estimated (through the likelihood approach). There was a high degree of variation in estimated observer efficiency among survey dates and evidence of deterioration in OE conditions over the duration of the survey. Horizontal visibility and discharge rate were measured at the start of each survey by field crews. The relationship between OE and the ratio of horizontal visibility and discharge (HV/Q) shows a positive correlation for several WCVI rivers; however, the relationship was not consistent among years.

Marc Labelle described the MLE model that was applied in more detail, including discussing the parameters, data input, and adjustments made to the model based on the distribution of the returns. He argued the main benefit of the MLE approach is the ability to generate confidence bounds and use prior information. The model can be further developed to deal with other uncertainties in migration timing – i.e., bi-modality, and differential mortality associated with arrival timing.

Written reviews

The written reviews by Josh Korman, Dan Rawding and Kim Hyatt are given in Appendix D. These were provided to participants prior to the meeting. Each reviewer was asked to present the main points from their review. Kim Hyatt was unable to attend the meeting and Chuck Parken spoke to the review on his behalf. Below is a summary of the Author's response and additional discussion for each of the reviews.

Review #1 – Main points and Authors' response

Josh Korman (Ecometric Research Inc.) gave an overview of his written review. The full review is provided in Appendix D. The main issues noted were related to the assumptions made for OE and SL.

The authors agreed with the reviewers comments that the SL and OE parameters are important, and that OE estimates are likely too generous. The OE estimates are only used in the start simulation. They commented that the model could accommodate variable stream life (i.e., longer at the beginning of the run and shorter at the end of the run), but they thought there needed to be more investigation to show evidence of this. The authors agreed that it would be useful to calibrate the parameters with fence or Didson counts.

In response to the reviewer's comments on the assumptions, the authors asked participants to think about and recommend how to deal with the assumptions. The authors agreed that dealing with the assumptions would likely change the conclusions around stock status. It was noted that the TOR didn't include anything about stock status.

The Authors offered clarification on why the outliers were removed and pointed to the trace documentation for more detail. One point made was that when chum show up the lower portion of the river the data are considered unreliable. The authors also noted that low escapement estimates are often associated with poor conditions so are expanded before applying the model.

The reviewer and participants discussed the organization of the paper and concluded that it would improve the flow of the paper if the model description was integrated into the main part of the paper instead of included as appendices. The authors agreed that the paper needed more organization and documentation.

The reviewer also noted the variability in the OE- HVQ relationships and suggested looking at just the discharge relationship with OE. It was also suggested that error bars be added to the OE estimates and that the axes for the OE-HVQ plots should be flipped. The reviewer noted the usefulness of linking river properties to other nearby rivers and suggested looking further into changes in river characteristics and the relationship with OE.

Review #2 – Main points and Authors' response

Dan Rawding (Oregon Department of Fish and Wildlife) gave a summary of his written review, and commented that many of the concerns were similar to those of the first reviewer. The full review is given in Appendix E.

The authors agreed with the reviewers suggestions about exploring the error structure more thoroughly, but noted that to explore different model structures would require more data. They remind participants that the working paper is a comparison of methods and they hope that the workshop will result in recommendations on how to proceed.

In response to the reviewers' recommendation to include the Burman MR data for comparison, the authors note concern that the Burman data may not be a better estimate.

Review #3 – Main points and Authors' response

Chuck Parken (DFO) highlighted the main points from Kim Hyatt's (DFO) written review. The reviewer's main concerns were with SL and OE, similar to the comments by the first two reviews. The full review is given in Appendix F.

Participants discussed the need to compare estimates and parameters with real measurements or independent estimates from other papers.

Comments on part 1 from invited participants

The second part of day 1 was spent discussing issues paper and the methodology in more detail. The following were comments and main points covered.

- Participants continued the discussion on looking at past surveys using other methods for evaluation and comparison. Recent work (Clark 2013, unpublished report) assessed the estimates from past work with WCVI streams and found that many of the estimates have a CV of <15%. There was some debate about how these estimates compare to the paper's model estimates. One participant commented that the ML estimates were substantially lower than the past MR estimates. Another participant suggested they were similar.
- One participant noted that straying is a major issue for some WCVI streams.
- The group agreed that a more detailed description of the survey and sampling protocols is needed.
- One participant noted that the importance in identifying the management questions that the working paper addresses (i.e., bias doesn't matter for trend analysis). From a CSAP perspective the paper is meant to be a technical document that focuses on the science questions rather than management questions. However, it was later noted that the PST has specific management goals around uncertainty and that an effort should be made to estimate actual numbers rather than trends.
- There was some debate about the use of self-evaluation for OE estimates. Some participants felt that the use of this method should be rejected. Other participants thought that the self-evaluation is useful, particularly for WCVI where there are a lot of small streams that are easier to survey. The self-evaluation provides the analyst with an observation of how the survey conditions change through time. However, if there is no actual count of the number of fish then there is no way to calibrate the self-evaluation based estimate.
- Several participants suggested a more detailed assessment of the various sources of uncertainty and bias. Is the uncertainty associated with the timing of the peak, the run timing trajectory, or something else? SL appears to be a bigger issue than OE.
- Participants recommended that more time be spent assessing the robustness of the model. For example, how do small changes in the parameters change the results or what happens when the peak/start/end is missed?
- It was also suggested to do more work with environmental parameters and identify groups of systems that behave in a similar ways.

Day 1 Conclusions

The paper was not accepted in its current form. There was group consensus that the paper was an important step in clarifying and improving the WCVI Chinook escapement estimation program, but that the paper needed substantial reorganization and the model needed more work, including sensitivity analysis and calibration with empirical data. After this work is done the paper should come back for review.

WORKSHOP SUMMARY PART 2 – WCVI CHINOOK SALMON STOCK AGGREGATION PROCEDURES

Overview of Part 2 – Methods and working groups

The second part of the workshop scaled up from escapement estimates for individual systems to estimates for the entire WCVI aggregate. The objective was to evaluate the current method plus three additional methods for estimating the annual aggregate of WCVI Chinook.

Chuck Parken gave context for the aggregate discussion by reviewing the PST and CTC model requirements and summarizing the model stock groups from the Canada and United States (Appendix H).

Diana Dobson described the current index method used to estimate the aggregate escapement of WCVI Chinook. Three other presentations on methods for estimating aggregate abundance used in other regions included:

- GRTS as used in Oregon, presented by Julie Firman (ODFW)
- GSI/CWT/Scale method, presented by Josh Korman (Ecometric)
- Nass Habitat method, presented by Robert Bocking (LGL Limited)

These methods were chosen for their potential application for WCVI Chinook based on the pre-workshop questionnaire results (Appendix G) and expert consultation. Each presenter provided a written summary of their presentation which is included below. Following J. Korman's presentation on the GSI/CWT/Scale method, Dave Bernard shared a few comments and slides based on a similar fishery based methodology used in the Gulf of Alaska.

The presentations were used to provide a foundation for group discussion. During the presentations, participants were asked to consider the strengths and weaknesses of the current method and three additional methods. They were provided with the following questions to help guide their evaluation of each method:

- What are the survey protocols used to estimate the aggregate abundance (ie. the monitoring design)?
- What are the sampling protocols used to estimate the aggregate abundance (ie. the response design)?
- How do you expand to give an estimate of the aggregate abundance?
- Does the method for estimating the aggregate abundance give an estimate of uncertainty? Is it acceptable?
- What are the assumptions and limitations of the method?
- Is there bias in the method? Where does it come from?
- How well does the method perform with respect to changes in funding and resources?

Method #1: Index method for estimating aggregate abundance of WCVI Chinook

Contributed by Diana Dobson, DFO

WCVI Indicator Stream Index Method

Overview of the aggregate

WCVI Chinook are a PST stock group, or "driver stock" in the CTC Chinook model. They are also a Regional Management Unit for Canadian domestic management purposes. The assessment unit is the group of Chinook populations that originate from rivers of the west coast of Vancouver Island (WCVI), corresponding to DFO statistical areas 20 to 27. For Canadian domestic purposes, there are 3 biologically and genetically similar populations referred to as Conservation Units (CUs) on the WCVI from about 100 streams.

Chinook in this assessment unit are "ocean type", smolting shortly after emergence (typically at 30 to 90 days). They spend about 5 to 6 months in near shore habitat before migrating marine areas off Southeast Alaska and north to rear. They typically mature between 2 to 6 years of age with age 3 to 5 as the predominant age classes. There is some variation in predominant age of return and migration timing among populations within the unit; the more northerly populations return to the terminal area about 4 to 6 weeks earlier than more southerly populations. Similarly, peak spawning is about 1 week earlier for the more northerly populations. The timing of when Chinook re-enter freshwater habitat for spawning is largely dependent on stream flows. Typically, migration occurs during fall 'freshets' as low-water conditions prevail during the period (mid July to mid September) when they return to terminal areas.

WCVI is an isolated, mountainous and relatively un-populated area. Many survey sites are not accessible by road or only accessible by rough road or boat. One of the key geographical features on WCVI is the series of large Inlets (or Sounds) along the coast-line. Chinook are typically limited to the first order mainstem as the tributaries off the mainstem are typically too high gradient, narrow and short to support Chinook spawners.

Precipitation levels on WCVI can be very high and river flows ‘flashy’. On the other hand, during periods of drought, river flows can be very low. Land use practices, such as logging, contribute to increased discharge rates in WCVI rivers as there is less capacity for water retention in heavily forested watersheds. Chinook typically pool in near-shore habitat until a freshet. For some watersheds, discharge rates are moderated by upstream lakes. For larger watersheds, discharge rates are typically sufficient not to impede migration to freshwater - i.e the fish will not hold so long in near-shore habitat. Features of the upstream habitat also influence the turbidity of the systems. Some of the systems supporting Chinook populations are relatively turbid as a result of upstream influences, such as lakes.

Monitoring design

The survey design is both knowledge based and convenience based. The key factors in determining which populations are surveyed are size of populations (i.e. for the most part, the larger populations are surveyed), representation (i.e. this is an effort to conduct surveys throughout the assessment unit – within each inlet or DFO Statistical Area), management requirements (i.e. some systems require information to manage specific terminal fisheries) and convenience (i.e. some systems are surveyed because of their location and ease of access, some systems are surveyed because of participation of partners - e.g. First Nations or hatchery staff). About 15-18 populations are surveyed for spawner abundance annually in order to assess the status of individual stocks and stocks within management units (e.g. WCVI, CUs, etc.).

Sampling methodology for individual survey components (response design)

Spawners are counted visually by survey crews that swim down the river. Crews typically consist of three observers swimming mainstem left, center and right. The crews survey what is known to be the accessible length of the river to Chinook spawners. Surveys are usually constrained to the main-stem of the rivers. Most of the tributaries do not contain significant amounts of Chinook spawning habitat.

The objective is to survey each river weekly, ideally with a periodicity of 5 days, for a total of 6 to 8 surveys over the spawning season. An additional objective is to survey near the beginning and end of the spawning period in order to establish "0" counts. Estimates are derived by expanding the counts using Area Under the Curve (AUC) techniques and a maximum likelihood model.

Potential sources of bias relate to incorrect assumptions about "observer efficiency" and "survey life", and if there are few or infrequent visual surveys. Another potential source of bias is whether or not the entire accessible length surveyed - although this can be dealt with through good estimates of "survey life" (i.e. as opposed to "stream life"). Another source of bias is applying the survey methodology on those systems with an abundance of other salmon species spawning concurrently where there is the potential for species mis-identification. There is also potential bias when discerning species contribution to a group of fish in a spawning location. Size of spawning population may also contribute to bias - i.e. small populations may be hard to count when fish are rare, estimation error is introduced when counting large populations.

One of the key limitations of the method as applied to WCVI systems is dealing with the impact of precipitation on survey conditions. Major precipitation events are often correlated with migration from marine to freshwater, particularly after drought conditions. However, major precipitation events can make the river inaccessible to surveys (either due to safety concern or turbidity). When the events are prolonged, resulting low survey number and infrequent surveys will contribute to greater uncertainty and/or bias in the estimates.

The method for estimating the aggregate abundance (inference design)

The aggregate index of abundance is simply the summed escapement estimates of the indicator stocks with terminal catch. The objectives of the assessment program are to annually estimate the spawning abundance of a portion of the spawning populations within the assessment unit. The trends in abundance observed in these populations are used to index the status of other populations within the assessment unit. The populations that are assessed (including hatcheries) are estimated to represent about 90% or more of the total production.

Reporting programs are in place for all terminal fisheries, including commercial, recreational and First Nation (aboriginal). There are some gaps in fishery monitoring and/or reporting. For instance, the WCVI Creel survey does not operate outside the June to September period - however, effort and impacts are considered very low outside this period. There is also some First Nation catch that is either not monitored and/or reported. For the most part, this level of catch is considered very low. Although, there may be a few instances for which near-terminal First Nation catch accounts for a relatively large portion of a single system terminal return.

The hatchery and wild contribution are not estimated separately, although spawning abundance of those rivers supporting major hatchery populations are separate (e.g. Conuma, Somass (RCH) and Nitnat). Many of the index Chinook populations receive some level of enhancement. In many cases, the spawning population is sampled for hatchery marks (e.g. thermally marked otoliths) to get an idea of the hatchery contribution.

The assumptions with this method for estimating the aggregate are that 1) the index stocks represent the entire assessment unit (i.e. patterns of mortality, survival rate), and 2) the index stocks (+ hatchery stocks) represent a very large portion (e.g. 85 to 95%) of the total production. A potential source of bias in the estimate is that the index stocks are not representative of the other populations within the assessment unit. Additionally, because the estimate is an "index of abundance", the index is inherently low relative to the overall abundance. The uncertainty of the aggregate estimate has not been quantified.

The number of populations surveyed depends on funding and, in some cases, partnerships.

The method is fairly flexible to variations in resources from the point of view that the number of indicator systems can readily be decreased. Issues would of course arise from whether or not the indicators are suitably representative of non-surveyed populations. From the point of view of applying the "aggregate" (sum) estimate, in forecast models adjustments could be made to scale for relatively large populations that are no longer surveyed.

Method #2: A GRTS design with Rotating Panels for Estimating Total Abundance of Oregon Coastal Coho

Contributed by Julie Firman, ODFW

Introduction

The Oregon Department of Fish and Wildlife (ODFW) uses a design-based estimator to assess the population abundance of natural- and hatchery-origin coho spawners and temporal trends in abundance. The sample is selected using a Generalized Random Tessellation Stratified (GRTS) design (Stevens, 1997; Stevens & Olsen, 1999; Stevens & Olsen, 2000, Stevens & Olsen, 2002). The availability of pairwise joint inclusion probabilities allows the Horvitz-Thompson (HT) estimator with its associated variance estimator to be applied (Horvitz and Thompson, 1952). The design also includes a rotating panel design to bolster trend detection (Stevens 2002).

These abundance estimates and derived metrics (productivity, distribution, trend, and persistence) are used to evaluate listing status under the United States Endangered Species Act (ESA) and monitor progress toward conservation goals. Abundance estimates are also used to forecast returns and set harvest limits.

The Oregon Coast Coho Evolutionarily Significant Unit (ESU) encompasses Oregon coastal watersheds from the Necanicum River in the north to the Sixes River in the south. It is comprised of a total of 56 historical populations. Thirteen populations are identified as functionally independent, eight as potentially independent, and 35 as dependent populations which are too small to sustain themselves and regularly rely on strays from larger adjacent populations.

Coho have high fidelity to a 3-year life history with a low rate of jacks. They return to the spawning grounds in the fall and winter (late October to late February in Oregon, with peak spawning in November and December). The only terminal fisheries on this stock are in-river recreational fisheries in selected rivers. Which rivers will have recreational fisheries is determined based on forecasted returns. Out of 21 independent populations, between 5 and 13 experienced harvest in a given year with total exploitation rates for terminal harvest ranging from 1% to 3%. Harvest has only been reinstated in recent years as populations have increased. For many years previous to this there were no terminal fisheries on any segment of the stock.

The Oregon Coastal Province is underlain primarily by marine sandstones and shales or basaltic volcanic rocks. Mountains dominate the area except for interior river valleys and a few locations where there is a prominent coastal plain. Elevations range from 0 to 1,250 m, though most coho salmon habitat occurs in low gradient reaches at lower elevations. The climate is temperate maritime with mild, wet winters and warm, dry summers. Most of the current forestland is in relatively young seral stands, and the larger river valleys have been cleared for agriculture. About one-third of the land is publicly managed, and the remainder is owned privately. Close to 90%of the stream reaches that have the highest potential to produce coho salmon occur on private lands. Logging, channelization, road building, and conversion of forested lands to agriculture has left reaches that historically supported coho salmon with a scarcity of large wood, a lack of conifers, lessened connectivity with off-channel alcoves and flood plains, and excess accumulations of fine sediment and gravels. For streams that drain the Coast Range flow is dependent on rainfall. Following heavy rains that are common in the fall and winter in this region, stream flow is high and rivers are turbid. There are a total of 8,433 miles of coho spawning habitat in the Oregon Coastal Coho ESU. Independent populations vary from 32 miles of spawning habitat to 273 miles of spawning habitat. The presence of logging roads through much of the area makes most stream reaches accessible for weekly visits.

Sampling methodology for survey sites (Response Design)

Surveyors visit sites weekly to walk the stream bank upstream and make visual counts of spawning salmon. If visibility or flow are high enough that surveyors cannot see to the bottom of riffles, the count is not included in the estimate. Sites where surveyors are unable to make counts for a period longer than eleven days (the average survey life) are excluded from the sample. Fixed estimates of Survey Life (SL) are used to calculate an Area-Under-the-Curve (AUC) estimate for each site and to adjust this estimate for Observer Efficiency (OE). These assumptions could introduce positive or negative bias to the estimates.

Survey design for sampling the aggregate (Spatial and Temporal Designs)

A spatially-balanced statistical sample (GRTS) is taken of the entire frame to which we wish to make inference. All sites have an equal probability of inclusion. Because stratification results in a lower sample size in each stratum vs. the whole, there have to be very strong differences between strata in order for stratification to improve the confidence of the estimate. In our case there were no strata for which differences were that strong. Since stratification would have decreased the confidence of our estimates we did not stratify. Four panels from the rotating panel design are used each year: 1 panel of sites that are sampled every year, 1 panel of sites that are sampled every 3 years, 1 panel of sites that are sampled every 9 years, and one panel of sites that are sampled only once. Sites are equally apportioned to each panel.

The method for estimating the aggregate abundance (Inference Design)

To obtain the abundance estimate the AUC estimates at sites are divided by the stream length sampled for the site and then multiplied by the sample weight (weight = stream length in sampling frame / number of sites). This is an unbiased estimator that provides for direct estimation of the entire area of inference. The variance estimate is calculated using the Horvitz-Thompson estimator. All populations are sampled. Estimates are made for 21 independent populations, 3 dependent-population groups, 5 groups of 3-6 independent populations, and for the entire Evolutionarily Significant Unit (ESU). This method is very flexible to accommodate different levels of effort. Samples can be intensified or made less dense without compromising the spatial balance of the sample or the method of inference.

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Method #3: Estimating Escapement of Chinook Returning to the West Coast of Vancouver Island Using CWT Recoveries and Genetic Stock Identification Data

Contributed by Chuck Parken, DFO, Josh Korman, Ecometric, Michael Chamberlain, DFO, Ivan Winther, DFO, John Candy, DFO, Darlene Gillespie, DFO

Presented by J. Korman, Ecometric.

We developed a Bayesian model to estimate the escapement of an aggregate salmon stock based on Genetic Stock Identification (GSI) data and recoveries of coded wire tags (CWTs) from a hatchery indicator stock in distant fisheries and on the spawning grounds. We applied the model to estimate escapement from 2003 to 2006 for the South Thompson and West Coast of Vancouver Island (WCVI) ocean-type Chinook aggregates. In this presentation, we present results for WCVI only. With this approach, the catch for a large aggregate stock in a fishery is first calculated from the product of the total catch and the proportion of the catch comprised of the aggregate stock as determined by GSI data. Assuming the ratio of fish in the escapement to the number in the fishery is the same for indicator and wild aggregate stocks (i.e., the gorilla assumption), the escapement for the latter is determined by multiplying the catch of the aggregate in the fishery by the ratio of CWTs in the escapement to the CWTs in the fishery. This approach can also be used to estimate terminal run size for an aggregate stock using the number of CWTs in terminal fisheries instead of the CWTs in the escapement.

WCVI ocean-type aggregates are genetically distinctive from other aggregates in the Northern BC troll fishery. There were few CWT recoveries in the troll fishery for age 3 and 5 fish in most years leading to greater uncertainty in escapement estimates for these ages. The sample size for GSI assignments was generally large except for age 3 fish in most years. CWT recoveries in the terminal run were relatively large for WCVI for all ages and years.

The expected total terminal run for the WCVI aggregate ranged from 141,000 to 500,000 between 2003 and 2006. Uncertainty in total escapement estimates was reasonable, but CVs for the 2003 and 2004 terminal runs were high owing to low CWT recoveries in the NBC troll fishery (2003) combined with a low number of GSI assignments (2004).

This analysis has shown that it is possible to reliably estimate escapement for large aggregate salmon stock using a combination of data for genetic stock identifications, scale age identifications, and the stock and age identifications from the recovery of CWTs in distant fisheries and on the spawning grounds. Escapement estimates were relatively precise in cases where the number of CWT recoveries in distant and terminal fisheries (or escapement) and GSI assignments was adequate. Due to low CWT recoveries in the NBC troll fishery (and occasionally in the terminal run or escapement), CV's for most age-specific estimates of terminal run size or escapement for the WCVI aggregate between 2003 and 2006 were generally greater than the 0.15 PSC standard. However, the CV's for the total escapement across ages were generally at or very close to the PSC standard for in 2005 and 2006 for the WCVI aggregate. Some minor adjustments to these escapement estimates may occur based on additional analyses, and such changes would be reflected in estimates entered into the Fisheries and Oceans salmon escapement database.

Method #4: Estimating Aggregate Coho Abundance in the Nass Area

Contributed by RC Bocking, LGL Limited and Nisga'a Fish and Wildlife Department

Under the terms of the Nisga'a Final Agreement (NFA), Coho salmon returning to the Lower and Coastal Nass Area Coho Salmon Aggregate (LCNAA), which predominantly encompasses the Lower Nass and Portland Sound-Observatory Inlet-Portland Canal CUs, are managed as a single aggregate. The LCNAA escapement estimate is combined with a mark-recapture estimate for the Middle and Upper Nass Coho salmon Aggregate stock to calculate an overall Coho salmon escapement estimate for the Nass Area. This estimate is then combined with estimates of catch in marine fisheries (using CWT return data from the Zolzap Creek key stream project) and terminal fisheries to derive a total return to Canada (TRTC) for Nass Area Coho salmon. This TRTC estimate is then used for post-season fishery evaluations, population status review, and catch accounting under the provisions of the Nisga'a Final Agreement.

The Lower and Coastal Nass Area Coho Salmon Aggregate (LCNAA) consists of all Coho salmon bearing Nass River tributaries from Gitwinksihlkw westward (the Lower Nass) and all Coastal Coho salmon populations within the Nass Area as defined under the Nisga'a Final Agreement. Coho populations within the LCNAA are typical of most Coho populations in that juveniles spend 1 or 2 full years in freshwater and 2 summers at sea, returning to spawn as 3 or 4 year olds. Jacking is known to occur to varying degrees in the Aggregate populations. Little is known about the early marine behaviour of LCNAA Coho but harvest rates are known to be high in Alaskan fisheries and low in Canadian fisheries.

The Lower and Coastal Nass Area includes a wide diversity of rivers and habitats ranging from the highly sediment laden and glacially fed lower Nass River systems to high gradient and habitat limited coastal systems fed by primarily by surface run-off. The Lower Nass also has extensive sloughs and associated wetlands in its flood plain.

LCNAA Coho are harvested in terminal net and hook and line fisheries in PFMA 3 as well as in the lower Nass River gillnet fisheries conducted by the Nisga'a Nation. These Nass Area fisheries primarily focus on Sockeye salmon (and Chinook salmon in the case of Nisga'a FSC Fisheries) both of which return prior to the peak of LCNAA Coho salmon abundance. Terminal harvest rates on LCNAA Coho salmon are therefore thought to be modest. Some populations (eg. Tseax River and Kincolith River)are also subject to modest rod and reel fisheries in freshwater (both recreational and Nisga'a FSC).

Index systems within the LCNAA are surveyed each year using stream walks and/or snorkel surveys. Survey data are used to calculate AUC escapement estimates for index systems. Index stream escapement estimates are expanded to the LCNAA Aggregate estimate in proportion to total number of spawners in the LCNAA required to fully seed the available rearing habitat as described in the Area 3 Coho Habitat Model (Bocking and Peacock 2004). Escapement estimates are generated for at least three systems each year to expand to the Aggregate using the habitat capacity model. Ansedegan Creek and Diskangieq Creek have been surveyed in all years since implementation of the NFA in 2000. Ginlulak Creek and Salmon Cove Creek have been surveyed in some years depending on funding, and a mark-recapture estimate has been generated for Zolzap Creek in years when the Zolzap Creek wild Coho salmon smolt coded wire tagging program was operating. The total index estimate (sum of the index stream escapements) typically accounts for between 5% and 10% of the LCNAA Aggregate escapement.

For the index systems, standard reaches are surveyed which are known to be used by spawning Coho salmon and together represent the majority of spawning habitat in each system. Where not all of the known (based on watershed assessment studies conducted in the 1990s) spawning habitat is surveyed, estimates for surveyed reaches are expanded to account for un-surveyed reaches assuming a constant linear density of spawning fish.

For visually surveyed systems, stream walk and or snorkel surveys occur at a frequency of every 7-10 days. As many as seven surveys are attempted over the spawning period. Generally there is good success in getting appropriate survey conditions throughout the spawning period. Survey sections are relatively short and easily accessible. Surveys are divided into reaches, and crews estimate their own observer efficiency on a reach specific basis. AUC estimates are then derived using an AUC modeling tool in Microsoft Excel (AUCmonteMASTER2.04). This tool allows the modeling of variability in both observer efficiency and survey life using a Monte Carlo simulation. In general, observer efficiency is modeled on a per survey basis using a uniform distribution with minimum and maximum values bracketing the crew's estimated values. Survey life (spawner residence time) is modeled using a normal distribution around an estimated mean value with an estimated standard deviation. Maximum spawner residence time has been validated periodically but infrequently with tagging studies.

A few assumptions implicit in the approach to estimating aggregate Coho abundance in the Nass Area are:

- the spawning populations, including the index systems, within the aggregate co-vary in terms of survival rates and exploitations rates
- spawner returns to the index systems are proportional to the total number of spawners required to fully seed the available rearing habitat within the aggregate
- habitat not quantified by the habitat capacity model (mainstem Nass River sloughs and associated wetlands, small estuarine channels, etc.) do not provide year round rearing habitat to a significant number of Coho smolts and therefore do not contribute significantly to production, and therefore escapement

Format and instructions for the breakout sessions

Following the presentations on the four methods, participants were given instructions and materials for the breakout sessions. Participants were assigned to groups of four to six people so that each group had a range of experience in methods for estimating aggregate abundance and knowledge of the WCVI. Each group was asked to consider one method per breakout session (Table 1) so that each method was evaluated by three groups.

Table 1. Methods assigned to groups for breakout session #1 and #2. In each session groups discussed the assigned method for about 45 minutes

Group Name	Method assigned Session #1	Method assigned in Session #2
Juan de Fuca Strait (JdF)	WCVI Index method	GSI/CWT/Scale method
Barkley Sound (BS)	WCVI Index method	GSI/CWT/Scale method
Clayoquot Sound (CS)	WCVI Index method	GSI/CWT/Scale method
Nootka Sound (NS)	GRTS method	Habitat based method
Kyuquot Sound (KS)	GRTS method	Habitat based method
Quatsino Sound (QS)	GRTS method	Habitat based method

The groups were given two report-out sheets to help guide the discussion and evaluation of the assigned methodologies (Appendix I). Report-out sheet #1 asked the groups to base their discussion on two questions with respect to assessment criteria aligning to the TOR. Report out sheet #2 listed 9 desirable attributes of a method for estimating the aggregate abundance. Participants were asked rate the method for each of the desirable attributes based on responses in report-out sheet #1.

The groups were asked to assign a record keeper and spokesperson for each group. The role of the record keeper was to 1) track the salient points and conclusions of the discussion on report-out sheet #1 and #2, and 2) post results of the group consensus on the attributes on sheet #2. The role of the spokesperson was to 1) facilitate the group discussion, and 2) present the highlights from the discussion.

Summary of report-out sheets and discussion from breakout sessions

Each group was given about 5 minutes to report-out on their discussion. Report-outs were followed by a group discussion. It should be noted that participants generally agreed that issues identified on day 1 need to be resolved before successfully applying any of the river based methods. The results from report-out sheet #2 are summarized in figure 1.

WCVI Index Method

The groups Juan de Fuca (JdF), Barkley Sound (BS) and Clayoquot Sound (CS) discussed and reported out on the WCVI index method. The main points from the report-outs and following group discussion were as follows:

- The method is lacking a statistical sample design.
- The method is biased but ok for trend analysis.
- There are issues with tracking wild vs. hatchery stocks.
- For many smalls systems there is an unknown amount of enhancement, brood stock and straying.
- Another method should be used in addition to the current method.
- There needs to be an estimate of catch for all terminal fisheries who don’t estimate catch.
- Many wild stocks are not currently surveyed.
- There needs to be improved sampling at the Nitnat and Conuma hatcheries.
- The index could be expanded using GIS watershed mapping.

GRTS Method

The groups Nootka Sound (NS), Kyuquot Sound (KS), and Quatsino Sound (QS) discussed and reported-out on the GRTS method. The main points from the report-outs and following group discussion were as follows:

- The method allows a statistical framework that is unbiased and enables an estimate of precision, provided the issues with OE and SL are resolved.
- The spatial coverage is better compared to the status quo.
- Groups discussed stratifying the WCVI aggregate by Sounds, stream length and/or hatchery vs. non-hatchery streams.
- GRTS could be applied to either reaches or entire streams.
- The method is useful for conservation and for obtaining more information on systems not currently sampled.
- The method could be costly and that there are problems with access to some sites.
- The method could work well for sharing sampling with partner programs and is flexible in terms of fluctuations in funding.
- Additional programs are needed to get escapement by age and hatchery contribution.

CWT/GSI/Scale Method

The groups Juan de Fuca (JdF), Barkley Sound (BS) and Clayoquot Sound (CS) discussed and reported-out on the CWT/GSI/Scale method. The main points from the report-outs and following group discussion were as follows:

- The method has a lot of potential for use on WCVI with some modifications.
- There is uncertainty in some of the key assumptions, i.e., there may be problems in the difference in maturity age between CWT and wild stocks.
- Escapement estimates by age if the terminal fishery is sampled.
- The bias with the method is difficult to test, but is possible if the current sampling program is upgraded.
- Many small stocks will be missed.
- It would be important to include hatchery stocks besides Robertson Creek.
- There is variation between the terminal runs.
- The ratings in report-sheet #2 were different between the groups but on most points participants converged.

Habitat Method

The groups Nootka Sound (NS), Kyuquot Sound (KS), and Quatsino Sound (QS) discussed and reported-out on the habitat method. The main points from the report-outs and following group discussion were as follows:

- The method would give an estimate for un-surveyed rivers.
- The method requires a Chinook habitat model.

- Currently, the model does not have very good representation for small watersheds.
- There is a lot of variability on WCVI which the model doesn't account for and systems do not necessarily co-vary.
- The method is cost effective but would rely on a sound sampling design.
- The method does not account for enhanced vs. non- enhanced systems.
- The method could be used as a secondary method (ie. With GRTS to increase precision).

Watersheds change over time which could be an issue. **Desirable attributes**	WCVI Index method			GRTS method			CWT/GSI/Scale method			Habitat method		
	JdF	**BS**	**CS**	**NS**	**KS**	**QS**	**JdF**	**BS**	**CS**	**NS**	**KS**	**QS**
The method generates estimates of escapement by age	X	X	✓		X	✓	✓		X	X	X	
The method generates an estimate of the total escapement (all ages)	X	X		✓	✓	✓	✓				✓	✓
The method generates estimates of terminal run (escapement plus terminal catch) by age	X	X			X	X	✓			X	X	
The method generates an estimate of the total terminal run (all ages)	X	X			X	X	✓	✓			X	
The method generates a measure of precision (e.g. CV) for estimates of escapement or terminal run	X	X		✓		✓	✓	✓	✓			✓
The method's assumptions can be tested (e.g. via targeted research)		✓	X	✓		✓		✓	✓	✓	✓	✓
The method generates estimates that are unbiased (e.g. average error equals 0)	X	X		✓	✓				X		✓	
The method generates estimates that are suitable for trend analysis	✓	X	✓	✓	✓		✓	✓		✓	✓	✓
The method can produce separate estimates for hatchery and natural components	X	X	✓	X	X	✓	✓	✓	X	X	X	X

✓	The method achieves the desired attribute very well
	The method achieves the desired attribute moderately well
X	The method does NOT achieve the desired attribute

Figure 1. The results from report out sheet #2 summarized for all groups. Groups JdF, BS and CS reported out on the WCVI Index and the CWT/GSI/Scale methods, and NS, KS and QS reported out on the GRTS and Habitat based methods.

Following the group report-outs and discussion, individuals were asked to vote on the four methods. Each participant places a sticky note on the method they thought had the most and second most potential for estimating the aggregate abundance of WCVI Chinook. The majority of participants chose the current method as having the most potential, followed by the GSI/CWT/Scale method, the GRTS method, and lastly, by the habitat method (Figure 2, Table 2).

Figure 2. Visual representation of report-out sheet #2. From left to right the four posters are the Index Method, GRTS, Fishery Method, and Habitat-based Method. Pink, blue and orange stickys are replicated in figure 1. The yellow and dark blue stickies posted at the bottom of the posters show voting. Dark blue stickies are votes for the method with the most potential. Yellow stickies are votes for the method with the second most potential. Table 2 summarizes the votes

Table 2. Totalled votes for methods with the most and second most potential for estimating the aggregate abundance of WCVI Chinook.

	WCVI Index method	GRTS method	CWT/GSI/ Scale method	Habitat method
# votes for method with the most potential for use on WCVI	12.5	4.5	8	-
# of votes for method with the second most potential for use on WCVI	3	8	11	3

Part 2 Conclusions

The current method is suitable for estimating the aggregate abundance of WCVI Chinook with some improvements. Improvements might be in the form of incorporating elements from GRTS and the habitat based examples/methods, and should also allow for an estimate of uncertainty. The fishery-based method could also be used to compare with the current index method. The major caveat for the discussion on aggregate abundance is that the issue of bias identified for the individual stream escapement estimates need to be resolved before any of the river-based methods can be used successfully. Furthermore, the approach taken will depend on the scale and the specific management objective.

Plenary Discussion

After discussing individual stream surveys in part 1 of the workshop and methods for estimating the aggregate abundance in part 2 of the workshop, a plenary discussion was focused on bringing the main points from each part and giving direction for improving escapement assessment framework on the WCVI.

The work presented in the working paper and discussed at the workshop should be further developed and organized into three main documents:

> **Document #1:** A data report including all escapement data for WCVI Chinook and environmental data for WCVI streams
>
> **Document #2:** A research document describing year and stream specific escapement survey protocols and estimate methodologies
>
> **Document #3:** A framework for estimating the abundance of the aggregate including the sampling design and considering management obligations

The research document (document #2) should incorporate the revision and reorganization suggested by reviewers on Day 1 including:

- integrating the DFO & non-DFO survey data (including SSP and FN programs) to AUC & ML analysis
- integrating the ML & AUC model descriptions into the main part of the document
- expanding on sampling protocols description and include in appendices the Stream Inspection Logs (SILs) & supplemental information (NUSEDS)
- further development of the retrospective analysis and report (not assessment of status)

Furthermore, specific directions were suggested for the research document (document #2):

1. Develop bias correction factors:
    - Review of all other types of Mark-Recapture and Mark-Resight studies made on WCVI (including SSP and FN programs) and determine those of suitable quality to compare to AUC estimates. Specific suggestions were to use studies on the Burman and Gold Rivers.
    - Examine various bias correction techniques (performance/sensitivity evaluation).
    - Evaluate minimum population size (Min handled/observed to ML model estimates) and consider minimums within confidence intervals.
    - Evaluate other population abundance techniques (e.g. peak counts) against MR estimates.
2. Evaluate sensitivity of of AUC/ML model parameters to provide direction about future refinements:
    - How important are daily OE factors?
    - How important are annual SL estimates, or stream specific SL estimates?
    - Explore survey frequency requirements in terms of peak count and multiple peaks. Assess the potential for classification by system type/size.

3. Refine AUC data inputs:
    1. Examine Observer Efficiency :
        - Investigate HV/Q and other covariates (ie. Q alone, low water/arrival timing and tidal cycle – Burman data).
        - Review spatial and temporal variation at individual locations.
        - Review other WCVI studies on OE (ie. non-DFO, Burman 2012 and Kaouk 2011).
        - Investigate variability in due to crew experience.
        - Compare reported OE vs. measured OE or environmental covariates.
        - Consider implementing replicate swim/walk surveys.
    2. Examine Survey Life:
        - review of other studies (DFO and non-DFO) to conduct a meta-analysis to investigate relationship between system size/environmental conditions and SL
        - spatial temporal variation, etc - see above
        - sensitivity analysis with abundance

Specific directions were also suggested to develop the escapement assessment framework (document #3):

1. The individual stream escapement surveys are a fundamental part of aggregation and need to be improved.
2. Refine and document a statistical framework to define the criteria required for the framework and the best way to implement it.
3. Improve escapement estimation at Nitinat and Conuma.
4. Define clear objectives for the estimates: aggregate (PST) and CU (WSP), First Nations, domestic fisheries management.
5. Expand to the aggregate by considering incorporating elements other methods/examples to improve the current index method:
    - From the GRTS method:
        - Keep surveying at some/all existing sites but use stratification to compliment current method.
        - Stratify by CU, stream size, enhanced/wild, sound, population size
        - Incorporate rotating panels.
        - Investigate the issue of dropping sites through simulations to accommodate sampling logistics.
        - Assess GRTS as a way to incorporate non-DFO monitoring efforts (ie. First Nations) into the framework.
    - From the Habitat example:
        - Apply the current method after some review and validation of the model /assumptions.

    - Assess considerations with using this method for WCVI such as straying fish and changes in land use.
- From the fishery based method:
    - Apply fishery based method to compare with other aggregate methods.
    - Rigorously test the assumptions.
    - Use otoliths or other marks to determine hatchery contribution (aggregate or individual system scale).
    - Investigate model based on rearing practices.

6. Conduct a power analysis for the number of streams surveyed with stratification by their abundance.
7. Evaluate the protocols for collecting and utilizing ancillary data to refine the hatchery versus wild escapement components.

RECOMMENDATIONS

Review participants drafted recommendations and conclusions which have been developed into Science Advisory Report (SAR). Briefly, this review concluded that the current visual survey methodology to estimate stream escapement does not provide an estimate of uncertainty. Several sources of uncertainty and bias were identified for which participants suggested approaches for evaluating and correcting. An analysis to compare and verify the modeled estimates (AUC/MLE) of escapement with independent estimates of escapement from tagging or other studies was also recommended. Deficiencies were identified in the current visual survey method including the documentation of survey and sampling protocols. Incorporating environmental variables and conditions into the assessment was also suggested.

Several methods for estimating aggregate escapement were examined and compared to the current method. There is potential for improving the current method by incorporating elements from GRTS and the habitat based examples/methods to improve the current index method at various scales and objectives. It was also suggested that a fishery based method be used to compare with the current method. The approach taken will depend on the scale and the specific management objective.

The review participants recognized the importance and value of undertaking the recommended analyses to meet the objectives for the WCVI assessment program because of the applicability in the Pacific Northwest. Moving forward, three initiatives were recommended:

- Produce a data report documenting all available DFO survey data and environmental data.
- Produce a research document, based on the working paper, describing the visual survey escapement estimation methodology and recommended analyses for river and year specific escapement estimates for individual systems. Refinement of AUC/ML data inputs and further development of both the AUC and ML escapement estimation models is recommended.
- Develop and document a statistical design for the WCVI Chinook escapement assessment framework to estimate the WCVI aggregate abundance and CU status which includes an estimate of uncertainty.

ACKNOWLEGEMENTS

Key to the success of this workshop was the commitment and effort of the organizing committee comprised of Diana Dobson, Chuck Parken, Stephanie King, Diana McHugh, and David O'Brian. In particular, I would like especially like to recognize Stephanie King, who not only took a lead role in the overall coordination of the workshop, also prepared the questionnaires and documentation for the workshop, as well as rapporteuring and drafting the Science Advisory Report and these Proceedings. Stephanie was assisted in the rapporteuring duties by Stephanie Miller.

The Chair and organizers of the workshop would like to thank Josh Koman, Dan Rawding and Kim Hyatt for their time and helpful written reviews of the working paper presented on Day 1 and Josh Korman, Julie Firman and Robert Bocking for preparing both written summaries and presentation on the alternate methodologies evaluated on Days 2 and 3.

Special thanks are also due to Karen Learmonth, a local Nanaimo B.C. artist who generously created and donated the beautiful watercolor image of the Chinook Salmon that graced the workshop binders.

Last, but certainly not least, we thank the workshop's participants who played a key role revisiting the working paper presented on day 1 and engaging collaboratively on Days 2 and 3 for the evaluation and development of new idea and approached for producing better estimates of salmon escapements.

APPENDIX A – TERMS OF REFERENCE

West Coast Vancouver Island Chinook Salmon Escapement Estimation and Stock Aggregation Procedures

Regional Peer Review - Pacific Region

June 18, 19, 20, 2013
Nanaimo, BC

Chairperson: Marilyn Hargreaves

Organizers: Diana Dobson and Stephanie King

Context

As part of the implementation of the Chinook Salmon Annex of the Pacific Salmon Treaty (PST), Canada is required to assess the escapement of West Coast Vancouver Island (WCVI) PST index stocks relative to escapement goals annually. Canada is also required to assess the abundance for the entire WCVI Chinook Salmon management unit for input into the PST Chinook Salmon management model. Similar assessments of individual stocks and aggregate stock groupings are required to implement Canada's Wild Salmon Policy and meet other domestic management needs.

For the assessment of spawning abundance relative to escapement goals, periodic visual surveys are used to estimate escapement of WCVI Chinook Salmon index stocks. The application of this method has been evaluated and improved through recent studies funded under PST Sentinel Stocks Program. Similarly, alternative methods have been developed under the Sentinel Stocks Program to estimate aggregate abundance of management units. As a result of this recent work, a Canadian Science Advisory Secretariat (CSAS) Regional Peer Review will be held to: i) evaluate the escapement estimation methodology used to evaluate the abundance of WCVI index stocks relative to escapement targets; and, ii) recommend methods for estimating an annual aggregate escapement or appropriate surrogate for the entire management unit.

Objectives

1. To evaluate the visual survey methodology used to estimate WCVI Chinook Salmon escapement for index stocks.

   A working paper will be reviewed on day one and will provide the basis for evaluating:

   - The method to estimate escapement using periodic visual survey data;
   - The quantification of uncertainty;
   - The potential for bias in the survey procedure; and,
   - Clarity in the descriptions of the survey and sampling protocols.

2. Review and recommend methods suitable for estimating aggregate escapement (or an alternate index of production) for WCVI Chinook Salmon through a workshop approach.

   Presentations on various methods of estimating aggregate salmon escapement will be invited from contributors from other areas and jurisdictions. To evaluate the methods in the context of the WCVI situation, workshop participants will break-out into small groups representing a range of expertise and backgrounds. Each group will be asked to report on the following for each method.

The assumptions and limitations of the method;

- The potential for bias in the method;
- The survey and sampling protocols required to estimate of aggregate escapement;
- The method for estimating uncertainty; and,
- The performance of the method under various survey conditions, population or habitat characteristics, funding and resource levels.

Plenary sessions will be convened to discuss and recommend the method(s) most appropriate for achieving the objective of estimating aggregate escapement for WCVI Chinook Salmon escapement. Objective 2 will be addressed during days 2 and 3 of this review process.

Expected publications

- CSAS Science Advisory Report (1) providing a summary of the science advice resulting Objectives 1 and 2 of this peer review process.
- CSAS Research Document (1) describing the details of the survey methodology and estimation procedures to be used for estimating WCVI Chinook Salmon escapements.
- CSAS Proceedings summarizing the discussion and recommendations.

Participation

- DFO Science Branch
- Members of the Pacific Salmon Treaty, Chinook Technical Committee (PST) and Sentinel Stock Committee (PST)
- Representatives from the Alaska Department of Fish and Game, Oregon Department of Fish and Wildlife, the Washington Department of Fish and Wildlife, and the National Oceanic and Atmospheric Administration.
- Representatives from the Nuu-chah-nulth Tribal Council
- Academia

APPENDIX B – WORKSHOP AGENDA

West Coast Vancouver Island Chinook Salmon Escapement Estimation and Stock Aggregation Procedures

Workshop agenda

DAY ONE (JUNE 18) 8:30AM – 4:30PM		
TIME	**SESSION**	**LEAD / PROCESS**
8:30 – 9:00	Registration Meet & Greet	
9:00 – 9:15	Welcome, Introductions & Housekeeping	Marilyn Hargreaves
9:15 – 9:30	Overview CSAS Process	Marilyn Hargreaves
9:30 – 9:45	Review of the Terms of Reference Day 1	Marilyn Hargreaves & Diana Dobson
9:45 – 10:30	Presentation of Working Paper	Diana Dobson
10:30 – 10:45	Health Break	
10:45 – 11:15	Review #1 & Author's Responses	
11:15 – 11:45	Review #2 & Author's Responses	
11:45 – 12:00	Identification of Key Points for Group Discussion	Marilyn Hargreaves
12:00 – 1:00	Lunch *(not provided)*	
1:00 – 2:20	Group Review and Discussion of Working Paper	RPR Participants
2:20- 2:40	Health Break	
2:40 – 3:30	Group Review and Discussion of Working Paper	RPR Participants
3:30 - 4:15	Development of Conclusions and Recommendations	Plenary Discussion
4:15 - 4:30	Preparation for Day 2/3 and Wrap-up	Marilyn Hargreaves
4:30	Adjourn	

DAY 2 (JUNE 19) 8:30AM – 5:00PM		
TIME	**SESSION**	**LEAD / PROCESS**
8:30 – 9:00	Settling-in & Coffee *(tea and coffee provided)*	
9:00– 9:15	Introductions & Agenda Review	Marilyn Hargreaves
9:15 – 9:40	Purpose of Workshop and Review of the Terms of Reference for Days 2 & 3	Marilyn Hargreaves & Diana Dobson
9:40 – 9:55	Presentation – PST Backgrounder & Requirements	Chuck Parken
9:55 – 10:15	Presentation – Method #1 Current Method	Diana Dobson
10:15 – 10:30	Presentation – Method#2 GRTS	Julie Firman
10:30 – 10:50	Health Break *(tea and coffee provided)*	
10:50 – 11:10	Presentation – Method#3 Fishery Based	Josh Korman
11:10 – 11:30	Presentation – Method#4 Habitat Model	Bob Bocking
11:30 – 12:00	Preparation for Breakout Group Evaluation	

DAY 2 (JUNE 19)	**8:30AM – 5:00PM**	
TIME	**SESSION**	**LEAD / PROCESS**
12:00 – 1:00	Lunch *(not provided)*	
1:00 – 2:00	Breakout Group Discussion Methods 1 & 2	
2:00 – 2:40	Plenary Report Out	Group Spokesperson
2:40 – 3:00	Health Break	
3:00 – 4:00	Breakout Group Discussion Methods 3 & 4	
4:00 – 4:40	Plenary Report Out	Group Spokesperson
4:40 – 5:00	Wrapping Up & Preparation for Day	Marilyn Hargreaves
5:00	Adjourn	

Group dinner at the Dinghy Dock Pub on Protection Island: Ferry leaves Maffeo Sutton Park at 6:00 and 6:30pm

DAY 3 (JUNE 20)	**8:30AM – 3:00PM**	
TIME	**SESSION**	**LEAD / PROCESS**
8:30 – 9:00	Settling-in & Coffee	
9:00– 9:15	Welcome & Introductions	Marilyn Hargreaves
9:15 – 9:30	Day Two Recap & Establishing Objectives and Structure for Day 3	Marilyn Hargreaves
9:30 – 10:30	Discussion – Applying Methods to WCVI – What works, what doesn't and why?	Plenary Discussion
10:30 – 10:50	Health Break *(coffee & tea provided)*	
10:50 – 12:00	Discussion – Variations, combinations, new directions, issues not reconciled	Plenary Discussion
12:00 – 1:00	Lunch *(not provided)*	
1:00 – 2:30	Developing Conclusions and Advice for the Science Advisory Report	Plenary Discussion
2:30 - 3:00	Wrap Up	Workshop Organizers
3:00	Adjourn Workshop	

APPENDIX C – WORKSHOP PARTICIPANTS

Last Name	First Name	Affiliation	Role*	Attended June 18	Attended June 19	Attended June 20	GROUP
Organizers							
Dobson	Diana	DFO (CTC)	Q/P	Yes	Yes	Yes	Nootka Sound
King	Stephanie	Sea This Consulting		Yes	Yes	Yes	
Hargreaves	Marilyn	DFO		Yes	Yes	Yes	

Last Name	First Name	Affiliation	Role*	Attended June 18	Attended June 19	Attended June 20	GROUP
DFO Participants							
Bailey	Richard	DFO (CTC)	Q	Yes	Yes	Yes	Nootka Sound
Baxter	Bruce	DFO		Yes	Yes	Yes	Nootka Sound
Brown	Gayle	DFO (CTC)		Yes	No	No	
Grant	Sue	DFO		Yes	Yes	Yes	Quatsino Sound
Holt	Carrie	DFO		Yes	No	No	
Hyatt	Kim	DFO	R	No	No	No	
Irvine	James	DFO		Yes	No	No	
Labelle	Marc	DFO		Yes	Yes	Yes	Clayoquot Sound
Lewis	Dawn	DFO		Yes	Yes	Yes	Clayoquot Sound
Luedke	Wilf	DFO		Yes	Yes	Yes	Kyuquot Sound
Mahoney	Jason	DFO		Yes	Yes	No	Juan de Fuca
McHugh	Diana	DFO		Yes	Yes	Yes	Juan de Fuca
O'Brien	David	DFO		Yes	Yes	Yes	Juan de Fuca
Parken	Chuck	DFO	P	Yes	Yes	Yes	Quatsino Sound
Porszt	Erin	DFO		Yes	Yes	Yes	Barkley Sound
Sawada	Joel	DFO		Yes	Yes	No	Kyuquot Sound
Tompkins	Arlene	DFO		Yes	No	No	
Trouton	Nicole	DFO		Yes	Yes	No	Clayoquot Sound
Van Will	Pieter	DFO		Yes	Yes	Yes	Quatsino Sound
Velez-Espino	Antonio	DFO (CTC)		Yes	Yes	Yes	Barkley Sound
Winther	Ivan	DFO (CTC)	Q	Yes	Yes	Yes	Clayoquot Sound

Last Name	First Name	Affiliation	Role*	Attended June 18	Attended June 19	Attended June 20	GROUP
External Participants							
Bernard	Dave	DR Bernard Consulitng (CTC)	Q	Yes	Yes	Yes	Kyuquot Sound
Bocking	Bob	LGL	Q/P	Yes	Yes	Yes	Juan de Fuca
Carlile	John	ADFG (CTC)		Yes	Yes	Yes	Clayoquot Sound
Clark	John	ADFG (CTC)		Yes	Yes	Yes	Quatsino Sound
Dalton	Timothy	ODFW (CTC)		Yes	Yes	Yes	Barkley Sound
Dunlop	Roger	NTC		Yes	Yes	Yes	Barkley Sound
Evenson	Dani	ADFG (CTC)		Yes	Yes	Yes	Nootka Sound
Firman	Julie	ODFW	Q/P	Yes	Yes	Yes	Nootka Sound
Korman	Josh	Ecometric Research	P/R	Yes	Yes	Yes	Barkley Sound
Rawding	Dan	WDFW	Q/R	Yes	Yes	Yes	Juan de Fuca
Riggers	Brian	ODFW	Q	Yes	Yes	Yes	Kyuquot Sound
Schwarz	Carl	SFU		Yes	Yes	Yes	Quatsino Sound

*Roles: Q – completed questionnaire, P – Presenter, R – Reviewer

APPENDIX D – WRITTEN REVIEW #1

Date:	June-17-13
Reviewer:	Josh Korman, Ecometric Research
CSAS Working Paper:	2013/14 PXX
Working Paper Title:	Evaluation of escapement monitoring program and escapement estimates for WCVI Chinook (*Oncorhynchus tshawytscha*) extensive indicator stocks by Diana Dobson, Marc Labelle, Diana McHugh, and Erin Porst

Summary

I appreciate the opportunity to review this paper, and hope the comments below are helpful and will lead to improvements. This paper has some very useful elements but there are a few limitations in the analysis. There are also a few key conclusions and recommendations that are not well supported by the results.

The paper provides a very thorough synthesis of visual survey counts of Chinook from WCVI extensive indicator streams. It also provides an informative overview of trends hatchery production, and abundance, population status, and fishing impacts, albeit based on uncertain escapement estimates. A significant and painstaking effort was made to recover assumptions used to derive reported escapement estimates, and a revised escapement time series for extensive indicator streams is derived. A synthesis and analysis of more recent telemetry data from a smaller set of streams, used to derive observer efficiency and residence time, is also given. The report is an excellent synthesis.

The authors recommend reducing telemetry-based monitoring efforts required to estimate, as opposed to guess at, observer efficiency and residence time, which ultimately will lead to more accurate escapement estimates for a smaller set of streams. These data could potentially be used to provide more accurate expansions of raw count data from streams where such intensive techniques cannot be applied. Their rationale for reducing or eliminating future telemetry studies is that they are too expensive, and that their partners in stock assessment (First Nations?)do not have the expertise to conduct this work. They also support the recommendation based on the claim that extrapolating telemetry results to other years and streams would be highly uncertain due to high variability in observer efficiency and residence time among streams, and among years within streams. The paper provides no analysis to support this claim. The first two issues (cost, partners) are policy issues that should be considered by decision makers (not scientists) after a fair and thorough evaluation of the results are presented.

The authors suggest that more accurate escapement estimates are unlikely to change the basic conclusion regarding the status of WCVI fall Chinook. There is little support for this assertion as the analysis relies on highly uncertain professional judgement-based values for observer efficiency and survey life used to derive revised escapement estimates. The revised estimates are almost certainly too low. Observer efficiency values used are too high, and the analysis I think assumes that observer efficiency and survey life is constant over the run. It is likely that at least observer efficiency declines in the latter part of the run when river conditions. Thus, many of the annual escapement estimates are much closer to Smsy benchmarks than presented and that the status quo method overestimates the extent of conservation concern.

Key issues with analysis and interpretation are provided below

1. Methods for Some Aspects of Modelling Not Clear

I found it difficult to tell what was done for a few key aspects of the analysis and some clarification is required. There appear to be at least 3 methods used to estimate survey life from tagging data (p. 17), and 2 or 3 types of values are provided in Table 29. Given the limited and ambiguous text, and the uninformative caption for Table 29, it’s hard to tell what methods were actually used. The description for the AUC tag survey life estimate assumes all tags are seen on each swim, so very likely overestimates survey life. No guidance is given on which method provides the most reliable estimate of survey life.

I was also unclear about what estimates of observer efficiency and survey life were used for the MLE run timing model. In the main body of the text (p. 18) it states that uncertainty in observer efficiency was accounted for, however there are no statements about what data were used for this (perhaps the same as for revised trapezoidal?). In Appendix 2, which describes the MLE run timing model, it explicitly states that only uncertainty in stream life was accounted for (bottom of p. 15). In the end, I assumed that the highly suspect professional judgement-based observer efficiency (OE) values were used in some way for the MLE run timing model, which is a problem. Please clarify how uncertainty in OE was accounted for in the run-timing model.

The arguments regarding outlier removal (bottom of p. 29) seem very circular. Outliers (high expanded counts) were adjusted based on the suspect assumption that observer efficiency was constant across surveys. This seems strange, as a very low count could be due to very low efficiency, or visa-versa. Assuming a zero counts to anchor the run timing curve will underestimate the uncertainty in the escapement estimate, and will also likely result in the estimate being too low. An advantage of the MLE run timing model is that it will largely disregards outliers if they are uncertain (low efficiency) or inconsistent with run-timing assumptions inherent in normal or beta distribution models. It other cases the outliers will cause the MLE model to estimate greater uncertainty. This is preferred over what appears to be a somewhat arbitrary-circular logic approach to removal.

2. Logic Behind Main Analysis Problematic

A central objective of the report is to evaluate the extent of bias in historical estimates based on AUC or peak count methods that in part depend on professional judgement (PJ) -based estimates of survey life and observer efficiency. A logical way to evaluate the bias would be to compare status quo estimates based on PJ with those based on the MLE run timing model using data from specific streams and years where observer efficiency and survey life were actually measured based on radio telemetry, or above a weir where escapement is measured reliably. Thus one would compare the uncertain historical ‘status quo ‘estimates with more reliable estimates that have an objective and scientific basis. From what I can tell, the authors have compared the status quo estimates with those from the MLE run timing model, but both estimates are based on PJ values for observer efficiency and survey life. The only difference between the two types of estimates is that revised estimates are based on a smoothing function on the number of fish present (the MLE run timing model) while the other is a simple AUC computation. As both methods rely on the same highly uncertain observer efficiency and survey life values, they are both highly uncertain. I think this is why the historical and revised trapezoidal AUC estimates are very similar on average (Table 39). MLE run timing estimates are a bit higher because that smoothing model can allow peak abundance to exceed the peak expanded counts in years when surveys were not conducted near the peak of the run. The key point is that neither comparison is very informative, because they are all based on the same highly uncertain input data, and don’t account for potentially large biases associated with professional judgement guesses on observer efficiency and survey life, and the assumption that on average, OE is constant over the run.

3. Conclusions about Consistency of Observer Efficiency-HV/Q Not Supported

In the results and discussion sections, the authors conclude that the relationship between observer efficiency and the ratio of horizontal visibility to discharge (river conditions) is inconsistent among years within rivers. However, no statistical evaluation is provided to justify this statement. There looks to be some confusion on this issue as demonstrated by the fact that the dependent variable (observer efficiency) is placed on the x-axis in the key figure (Fig. 10). A logistic model predicting observer efficiency based on river conditions (HV/Q) should be fit to data from all years for each river using a poisson or binomial likelihood. This null model could then be compared to one where different curves are fit to each year, using a simple AIC analysis. Considering the scatter within years, which is not surprising given the sampling error in OE estimates (low sample sizes in Table 3), it is very likely that the AIC analysis would support use of a single OE-HV/Q relationship across years for Tranquil. Thus results for Marble and Leiner (only other rivers with more than one year of data) will be inconclusive as there looks to be low power to detect annual differences.

The claim that the OE-HV/Q relationship is not stationary across years within rivers is part of the rationale the authors use to recommend cutting back on future telemetry studies. This recommendation is not supported by the results as no formal comparisons across years within rivers, or across rivers was done. You don’t really have the data yet to make this conclusions.

4. Revised Escapement Estimates Unreliable, thus Conclusions about Stock Status are Unreliable

In my view, telemetry efforts need to be continued to obtain reliable observer efficiency estimates from multiple systems, and to develop relationships between those estimates and river conditions. These studies will likely be able to provide estimates of efficiency in years when telemetry data are not available (based on discharge) and even to other river systems. In the long run, a hierarchical model may be helpful in performing the some of these extrapolations. All that has been done in the current report is to use a run-timing model to reduce potential biases or interannual differences in escapement resulting from differences in survey timing and frequency. This is a useful step, but the analysis continues to rely on professional judgement-based estimates of survey life and observer efficiency. As well, from what I can tell, the revised estimates are based on a model that assumes that observer efficiency is constant over surveys in each year. In reality, it is likely that in at least some years, efficiency declines later in the run as river conditions deteriorate. Increases in discharge may bring late-run fish into the system, and this component of the run will be underestimated if on assumes observer efficiency does not decline with higher flow. These fish may also have lower residence time, which further increases the potential for negative bias in the escapement estimate. This limitation likely leads to large underestimates of escapement, and underestimation in the upper confidence bound.

The authors conclude that although escapement estimates they present may be biased low by 20-30%, the overall picture of stock status is OK (p. 27). There is no support for such a statement since they do not provide reliable estimates of escapement that use: 1) measured estimates of observer efficiency; and 2) decreasing observer efficiency and probably survey life, late in the run. These two issues could lead to increases in escapement well above the 20-30% figure that is cited. Such a correction would certainly push substantial parts of the annual escapement profiles into the confidence bound of Smsy in Figures 21-25, suggesting conservation concerns are much less compared to those derived in the paper.

5. Principle Components Analysis

The logic behind the PCA eludes me. I would think a multivariate technique like clustering or discriminant function analysis would be more useful than PCA, if the objective is to determine how rivers can be grouped based on physical characteristics thought to influence observer efficiency, survey life, or run timing. It's really hard to tell what use the PCA has in the report, but the authors suggest the results provide further evidence that there is not much utility to conducting additional telemetry work (bottom of p. 25).

6. commendations and Conclusions

I don't follow the logic behind some of the key recommendations from this report. The first one (p. 26) is to reduce efforts to reliably estimate escapement (via tagging) and reallocate that effort to estimating things like "impacts of terminal fisheries in WCVI areas outside DFO Statistical Area 23". I don't see how terminal harvesting impacts can be assessed in the absence of reliable escapement estimates. Aren't those escapement estimates needed to determine the harvest rate of these fisheries, or the productivity of the stocks targeted by these fisheries?

The recommendation that further telemetry studies will not be help improve escapement estimates is not supported by the analysis. The conclusion that the story regarding stock status will not change with improved escapement estimates is also not well supported. The rationale for these concerns is provided above.

APPENDIX E – WRITTEN REVIEW #2

Date: June 16, 2013 (Initial Draft)

Reviewer: Dan Rawding, WDFW

CSAS Working Paper: 2013/14 PXX

Working Paper Title: Evaluation of escapement monitoring program and escapement estimates for WCVI Chinook (*Oncorhynchus tshawytscha*) extensive indicator stocks by Diana Dobson, Marc Labelle, Diana McHugh, and Erin Porst

Thank you for the opportunity to review the WCVI escapement monitoring program by Dobson et al. (2013). In the terms of reference (TOR) for the WCVI Chinook Salmon escapement monitoring program, the purpose of the manuscript is "to evaluate the visual survey methodology used to estimate WCVI Chinook Salmon escapement for index stocks" by evaluating: 1) the method to estimate escapement using periodic visual survey data; 2) quantification of uncertainty; 3) potential for bias in the survey procedure; and 4) clarity in the descriptions of the survey and sampling protocols. These are re-stated again in the introduction section as the purpose of the paper. While the manuscript identifies the need for monitoring in the introduction, provides a description of the study area and populations, and provides the background for the monitoring program in the study population section, the manuscript deviates from the stated purpose and poor organizational structure makes it difficult for the reader to reach conclusions relative to the TOR. Important analytical details are missing from the paper and one is left to choose between trapezoidal or distribution-based Area-Under-the-Curve (AUC) models, which are in Appendix 2 and 3, and there are no statistical models provided to estimate observer efficiency (OE) and survey life (SL), yet estimates are provided in the report tables. There is a limited exploration of the bias in MLE-AUC in appendix 2 but there is no comparison of the bias and precision of the AUC method to the mark-recapture (MR) estimates on the Burman River. The uncertainty in the escapement estimates is reported in Tables 36-38 but there is limited discussion on why the escapement estimates and the uncertainty of those escapement estimates are different between AUC methods. The survey and sampling protocols are not well described. The authors then conduct a time series analysis relative to habitat based escapement goals, which is informative but beyond the scope of the paper. In summary, the methods and results sections do not adequately address: 1) the method to estimate escapement using periodic visual survey data; 2) quantification of uncertainty; 3) potential for bias in the survey procedure; and 4) clarity in the descriptions of the survey and sampling protocols.

Organizational Structure

The stated purpose of the paper is to evaluate the current AUC snorkel survey methodology. However, the paper insufficiently characterizes the method, sampling protocols, assumptions, possible bias, and uncertainty, with many of these important details being relegated to the appendices. If the purpose of the paper is to both define the method and its application to WCVI Chinook salmon populations, then the organizational structures presented in Schwarz et al. (1993), Adkison and Su (2001), and Korman et al. (2002) can be used as templates to improve the paper. These authors review the literature on the model variations available, develop and clearly define their statistical models including the probability distribution functions, and model assumptions. They use probability distributions to incorporate uncertainty in the model and use simulations to assess bias and accuracy of models when the assumptions are violated and/or to compare to other models. Schwarz et al. (1993) and Korman et al. (2002) described the protocols used to collect data, and apply their models to the collected data. It was informative to have the stock status assessment with the comparison of the recent escapement estimates to the habitat based escapement goals; however this is beyond the scope of the paper's purpose and should be placed in an appendix. In contrast, it is very distracting to have key elements of the paper (AUC models and simulations to assess bias) in the appendices; these elements should be more directly incorporated into the paper. Overall the report would benefit by integrating Labelle's work directly into the report rather than leaving it as a stand alone appendix.

Visual Survey Methodology

This paper does not provide an adequate statistical description of the visual methods used to estimate escapement. The methods in Labelle (2011) to estimate AUC escapement are the most complete but the authors need to provide more details on the methods associated with estimating survey life (SL) and observation efficiency (OE). It would be beneficial to break out the proposed AUC escapement method to estimate escapement into its components including the method used to estimate: 1) OE, 2) AUC, 3) SL, and the model that integrates the components. Having done this, the paper can focus on the study design, data collection, and statistical analysis for these components. The previous use of self-reported OE and professional opinion-based SL values in trapezoidal-AUC escapement estimates do not address the TOR objectives of quantifying uncertainty and bias in the estimates. Thus, incorporation of the OE and SL estimates collected between 2010 and 2012 would be an improvement over the previous estimates. However, rather than rely on these empirical estimates of SL and OE, the authors use uniform priors or bounds on OE and SL and have the AUC escapement models estimate these parameters. This approach is not well evaluated and has lead to some large differences between data and model estimates of OE (Table 33). Furthermore, Appendix 3 states that "ranges of the SL and OE distributions may be wrong", suggesting estimates of precision and bias may be misleading. The report would benefit from a more thoughtful assessment of the data and model based estimates of OE and SL. Given the short time frame, I have not been able to fully evaluate the AUC escapement approaches, but allowing the model to estimate OE and SL likely introduces issues of unknown consequence (e.g., weak identifiability and redundancy of the parameters Gimenez et al. 2009).

Spatial and Temporal Sampling Designs

The authors indicate they want to make inference at the population scale; therefore, the sampling universe for the population should be temporally and spatially defined. They state "Surveys begin at the upstream end of the known range of distribution (e.g. at a known velocity barrier or obstruction) and end in the estuary." For a spatial definition, it is not enough to indicate the upper extent of the distribution is known but methods like those by Fransen et al. (2006) can be used to determine the upper extent based on empirical data (surveys) or models. In this approach, surveys are conducted above the index area to ensure there are no observed fish outside of the index area. For example, in the 2012 monitoring program on the Burman River radio tagged fish were observed upstream of the known distribution (Roger Dunlop pers. comm.). The Burman River may be an isolated case but the paper would benefit from a discussion of how the known upper extent of distribution was determined in each system.

I could not find a definition for the temporal sampling frame in the paper. The authors state "The timing of reentry into freshwater habitat for spawning is largely dependent on stream flows. Typically, freshwater migration coincides with fall 'freshets' as low-water conditions prevail during the period (mid July to mid September) when they return to terminal areas." However, the data in Tables 10-25 suggest that in some years entry on some systems occurs as early as mid August and extends to late November. This is a 14 week period; a more accurate description of the temporal pattern for each system could be used to develop a more informed temporal sampling design. The authors address the lack of temporal coverage by assuming start or end dates based on professional opinion in the trapezoidal-AUC model or using distributions to address this in the MLE-AUC model.

Observation efficiency

Observer efficiency (OE) is the proportion of the total fish present in a reach that are observed. The authors need to provide a detailed description of their study design to estimate OE and include their variance equations. The authors used radio tags to obtain survey estimates of OE based on individual radio tags (Korman et al. 2002, Shardlow et al. 2007). Based on their study design, key assumptions are tagged and untagged fish are detected at the same rate (observers do not detect tagged fish at a higher or lower rate than untagged fish), the status of the radio tags is known (functioning or not), and the status of the fish is known (live and in survey area vs. other). Factors that may influence equal detectability include tag loss, less contrast between the fish and tag color as fish become more fungused, and newly tagged fish in the season may exhibit a different behavior (more likely to hold in pools because spawning may not take place until later) that may make cause spawning fish to be more or less likely to be detected. The authors should discuss how they met the equal detectability assumption in the report and describe the protocols for determining the status of radio tags and fish (Rawding 2011).

The authors focused on the ratio of horizontal visibility (HV) and discharge (Q) to obtain HV/Q to explain the variability in OE as identified by Korman et al. (2002). This relationship appears to work better in some systems than others. Figures 11 and 12, and Table 29 show that OE generally declines throughout the season. Although OE may be related to HV and/or Q (Figure 9), it may also be related to Chinook salmon behavior. For example, in the early season holding prior to spawning Chinook salmon often concentrate in pools, and if there is limited cover the pools, the observed efficiency may be high. Later in the season more Chinook salmon are spawning and they may be more difficult to observe in wider glides, tail outs and riffles with a few surveyors. For example, date or some other surrogate could be used to account for the changing proportion of fish observed holding in pools vs. spawning in shallows over the course of the season. Jones et al. (1998) found the accuracy and precision of fish present on a survey decreases as abundance increases. The total number of fish observed on each survey could be used as covariate to address the concern raised by Jones et al. (1998). A more comprehensive analysis of covariates to explain the variability in OE is warranted especially if there is no plan to empirically estimate OE for individual surveys in the future. One possible approach is to develop a thoughtful list of indicators for OE. For example, indicators such as stream width, number of surveyors, survey crew, habitat type, HV, Q, HV/Q, number of fish observed, and date could be analyzed using principal component or use maximum covariance analyses (Burke et al. 2013) to explore relationship between indicators. Repeating the same process for each of the other AUC escapement components (SL and arrival timing in the MLE-AUC model) may also prove beneficial.

Estimate of Fish Days (AUC)

The paper uses a trapezoidal and distribution based AUC models to estimate escapement. The distribution based method is not described in the paper but in Appendix 2. Since both methods were presented it is unclear which method is preferred. The statistical models should be defined within the paper, and not leave the reader to guess between methods. If both methods to estimates fish days are considered equal, this should be stated.

Survey Life

There are numerous methods to estimate stream life (Perrin and Irvine 1990; Parsons and Skalski 2009). However, survey life (SL), residence time, and stream life are usually defined differently (Bue et al. 1998, Hilborn el al. 1999, Labelle 2011) but the terms are sometimes used interchangeably. Therefore, it is important to state the definition of SL in the paper and rigorously use it. For example, in the 2012 the SSP executive summary report for the Burman River SL in the counting area was ~ 5 days with OE of 58% but Table 36 reports a SL of 15.8 days and an OE of 91%. These differences may be due in part to definitions and the methods used to estimate the parameters.

For estimating SL, the authors indicate “The average survey life for the study systems was estimated through the tag depletion curve of the radio tags. As well, the length of time each tag was active in the area provided an estimate of the average survey life of individual chinook. A third survey life estimate was estimated through the depletion curve based on re-sighting the external tags.” To meet the TOR, the equations and assumptions to estimate SL need to be included in the paper. The 2012 Burman River Chinook salmon radio tag data indicated that stream life was negatively correlated with entry (i.e. later entering fish had sorter stream life). If this is the case for other WCVI populations, a single tag depletion curve is not an appropriate method to analyze the data unless tagged fish are a random sample of all fish (Parsons and Skalski 2009). If there is not a random sample, Parsons and Skalski (2009) recommend the run should be stratified with fish sampled during each stratum and the strata estimates of SL be weighted proportional to the number of fish arriving during each time stratum. The second method used appears to be similar to the one used by Shardlow et al. (2007) to estimate residence based on radio tags. Because the time of tagging and death are known, individual stream life estimates can be estimated. Due to the negative relationship between survey life and entry date, an exponential decay or negative logistic function can be used to estimate survey life (Su et al. 2001; Korman et al. 2002). The third method proposed was a tag depletion curve based on visual tags, which is the same as method one except that it is based on batch releases of visual tags. If this method is used Bocking et al. (1988) suggested the tag counts be adjusted for OE. If the OE adjustment was done when using the visual tag depletion curve it was not mentioned in the methods.

The above methods estimate the time from tagging until the fish dies, which is not an estimate of SL. For the radio tagged fish there is a concern that all fish implanted with radio tags were not all tagged below the survey area. If this is the case the SL will be biased low. To adjust for this bias Korman et al. (2002) developed an adjustment factor for fish tagged within the survey area. Similar concerns exist for visual tags. Also the authors indicated that the apparent radio tagging mortality is high. Both tag loss and mortality will bias SL estimates. However, SSP executive summaries from the 2012 in the Burman and Harrison radio tagging studies indicated low tagging mortality. I encourage BC biologists involved in radio tagging to work together to identify possible causes and change protocols as needed to reduce tagging mortality.

AUC Escapement Model

Since two AUC escapement models were presented it was unclear which model was preferred. The trapezoidal-AUC model does not meet the TOR (see Appendix of this review) so this review focus on the MLE-AUC model. Labelle (2011) provides a review of the AUC methods based on a literature search to estimate fish days, but this review is not incorporated into the paper. If the authors support the review done by Labelle (2011), then summarizing this review as related to WCVI Chinook salmon would benefit the paper. There are some major considerations for AUC model choice: 1) state space (Korman et al. 2007), 2) arrival and departure models (Hilborn et al. 1999) or 3) observational models (Parken et al. 2003), and the use of 4) trapezoidal or 5) distribution based models to estimate fish days (English et al. 1992, Quinn and Gates 1997). Model choice will also depend on the quantity and quality of available data, the data needed for the model, and the number of parameters estimated by the model. Some specific factors for AUC models include 1) actual survey frequency especially near the peak count (Hill 1997), 2) the potential that the first and last counts are non-zeros (Bue et al. 1998, Hilborn et al. 1999), 3) analysis of data with few counts or when the peak is missed (Hilborn et al. 1999, Adkison and Su 2001), 4) use of prior information in data poor years (Hilborn et al. 1999, Su et al. 2001), and 5) the sensitivity of priors or bounds to the parameter estimates. Labelle considered many of these factors but the paper would benefit from the rationale used to select the MLE-AUC model.

Labelle's MLE-AUC model extended the concepts proposed by Hilborn et al. (1999) to include a normal mixture models to better account for pulse arrival of WCVI Chinook salmon on freshets, a log likelihood ratio function for fitting, using a Poisson distribution to estimate survival, and allowing the model to estimate OE based on constraining the bounds rather than supply the OE data or an informative distribution for OE (Hilborn et al. 1999). I do not understand Labelle's estimation of OE and SL. It appears that the maximum likelihood estimation (MLE) model is tying of find a single OE value using a constrained parameter, across all surveys within a year. If this is the case, the issues with weak identifiabiliy and redundancy of the parameters mentioned above should be explored. In addition, this approach ignores available empirical estimates of OE. The authors indicate OE is highly variable and fixed values across a year may not appropriate. Therefore, I recommend the model be structured to estimate OE from the data or a known non-uniform distribution based on the data (Hilborn et al. 1999). In addition, model should be structured to allow for the possibility for OE to vary with each survey. See comments below on how to estimate OE. Similar issues exist for SL as presented for OE and they should also be addressed.

Hilborn et al. (1999) evaluated different error structures and found the pseudo-Poisson error structure compared more favorably with the weir estimates. I have experienced some of the same issues raised by Labelle with the pseudo-Poisson error structure and his choice of error structure is reasonable. But it is unclear how sensitive WVCI Chinook salmon escapement estimates are to Labelle's choice of error structure. For example, Hilborn et al. (1999) did find that error structure affected estimates; therefore a comparison of abundance estimates using different error structures relative to the Burman River Chinook salmon MR estimates may be useful.

Labelle (2011) did not address model selection, specifically between normal and normal mixture models. Since Labelle's models are nested, likelihood ratio tests or various information criteria approaches (e.g., AIC; Burnham and Anderson 2002) could be used for model selection. It would be useful to determine the effect that an increasing amount of missing data has on the model selection (Ward 2008). Additionally, it would be beneficial to determine the sensitivity of the model to the priors or bounds used to constrain the parameters, especially since it is acknowledged in Appendix 3 that the uniform distribution may be wrong.

Protocols for data collection and sampling

The protocols for data collection provided in the report are: "The snorkel survey method involves a team of snorkel and dry-suit equipped personnel swimming down the river, and counting the fish observed. The counts are recorded every time the habitat type changes (usually every 10 m to 100 m) and are referenced to the counting section (i.e. 500m distance) and habitat type (e.g. pool, riffle, run). Surveys are scheduled every 7-10 days, although weather and water conditions often impact this scheduling. Surveys begin at the upstream end of the known range of distribution (e.g. at a known velocity barrier or obstruction) and end in the estuary."

See Thurow (1994) for an example for snorkeling protocols and Rawding and Cochran (2010) for application of these protocols to estimate adult steelhead abundance. Information missing from the protocols include: 1) the number of snorkelers per system, 2) horizontal visibility and stream width, or some estimate if snorkelers have sufficient visibility and coverage so that all salmon have the possibility of being observed, 3) configuration of snorkelers is called for in the study design (Thurow 1994 Figures 2 & 3), 4) type of QA/QC program to ensure snorkel protocols are being implemented, 4) protocols used to limit double counting of fish and uncounted fish swimming by snorkelers when recording counts, and 5) snorkel configurations used when visibility does not allow all fish to be observed. Other information that could be useful in the appendices would be a snorkeling manual if available and example datasheets or forms used in the survey. This is in addition to protocols needed for radio tagging and analysis for OE and SL mentioned above.

AUC Simulations to Address Bias and Precision

Simulations are used to test the accuracy and precision of models when the data are known , to assess the sensitivity of models to violations of key assumptions, and to develop study designs that achieve goals such as unbiased estimate and precision standards. For example, Adkison and Su (2001) used simulations to address the value of prior information (hierarchical models) to assess the accuracy and precision of AUC escapement estimates when most counts were conducted prior to the peak of spawning. Korman et al. (2002) used simulations to assess the effect of the decline of OE on the accuracy and precision of escapement estimates and if increasing survey frequency could mitigate for the decline in OE. Rawding (2011) used AUC swim methodology along with timer tags (Shardlow et al. 2007) to assess accuracy and precision for small Chinook salmon population (350 adults) to compare trapezoidal AUC to mark-recapture abundance estimates using Bayesian framework. In these simulations there were no non-zero counts, surveys were conducted every 7 days, the population was tagged at a15% and 30% rate, arrival models were normal and normal mixture models, SL was fixed at 14 days with CV of 6% and 15%, and OE was set at 40% and 80%. Labelle (2011) used simulations to assess the bias of estimates AUC estimates for WCVI Chinook populations assuming 500 or 2000 spawners, arrival models were normal and normal mixture models, a constant SL, and survey frequency of surveys (3,6,& 9 days), and OE of 0.8$\pm$0.05and 0.9$\pm$0.05. These papers demonstrate that simulations can be used to better understand bias, precision, effect sample size on precision, and violation of assumptions for AUC models.

I encourage the authors to extend the simulation framework used by Labelle to address the robustness of the AUC model they propose for use in monitoring WVCI Chinook salmon. Labelle's simulations only addressed bias and they should be extended to include precision, and include the recent information such as independent Burman MR estimates, along with OE and SL studies since his data set was limited to information prior to 2008. However, before simulations occur the authors should better summarize the available WCVI data to parameterize the model because accurate parameterization will lead to more realistic estimates of uncertainty. The a goal of Labelle's simulations was to provide advice on study designs, such as survey frequency, but I suggest testing the robustness of the AUC model more representative field conditions such as weeks of missed surveys, varying OE, declining SL, non-zero counts at the beginning and end of the season, and other encountered conditions.

Comparison of Estimates

There are concurrent estimates of Chinook salmon abundance based on MR and AUC methods in the Burman River. If both models meet their assumptions and AUC methods have unbiased estimates of OE and stream life, the both estimates should be similar. The MR estimates of abundance in the Burman are 2400, 3500, 5400, and 4100 adult Chinook salmon for years 2009-2012, respectively. Yet the AUC estimates from Table 36 are 1100, 1200, 1500, and 856 for the same years. The MR estimates are approximately 2 to 4 times greater than the AUC estimates, which is similar to differences reported by Clarke (2013) in a review of WCVI escapements. The report would benefit greatly by a structured comparison the MR and AUC models used on the Burman River, assumptions, and estimates in this basin, as it should provide valuable insight into the assumptions in the MR and AUC models, and how estimates of SL and OE affect the abundance estimates. This may lead to some critical areas of uncertainty in the application of AUC methodology to WCVI Chinook populations.

Summary

The authors have summarized and provided a much needed overview of the WCVI Chinook salmon monitoring program and the available data. They have proposed to incorporate uncertainty in AUC Chinook salmon estimates and not rely on expert opinion for a fixed estimate of SL and OE. They have applied their methods to assess stock status compared to habitat based goals and I commend them for their efforts. The authors still appear to depend on expert opinion for the uniform distribution of SL and OE in the trapezoidal-AUC model (Appendix to this review) and for OE in the MLE-AUC. Continuing to use expert opinion rather than data will make it impossible to meet the TOR. The manuscript lacks both the organizational structure and statistical design to adequately address the TOR and the stated purposes of the paper. Therefore, major revisions to the manuscript are required. The authors make an argument that it is challenging to monitor WCVI Chinook salmon using visual surveys due to the remoteness of many streams, the large number of populations, cost of monitoring individual populations, and the environmental conditions that make visual surveys difficult to implement. It seems like there is a missed opportunity in the discussion section to spend more time considering alternate methods. For example the authors note that funding for WCVI Chinook monitoring is declining, therefore they could explore more cost effective methods such as relationships between index peak counts and escapement with their current data or other approaches. Regardless, the manuscript and the current WVCI AUC monitoring program could be improved by a clearly defined sampling design along with its assumptions, protocols for data collection, a statistical AUC model that includes uncertainty in OE and SL based on data analysis and not AUC modeled parameters, and an assessment of the robustness of the model to assumption violations through simulations. Improvement to the proposed AUC methods to estimate escapement could be realized if covariates can be identified to reduce the variability in the estimates for arrival timing in the AUC model, OE, and SL. The use of transparent and comprehensive ecological (TRACE) modeling was innovative and improved this document. Its location in the appendices is appropriate; however the TRACE documentation could be more comprehensive.

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Review #2 Appendix. Evaluation of the trapezoidal-AUC model in Dobson et al. (2013)

Dobson et al. (2013) provided WCVI escapement estimates and there were often large difference between trapezoidal-AUC and MLE-AUC escapement estimates (Tables 36-38). In addition, tithe observer efficiency (OE) estimated from tagging data was always lower than the AUC model or expert opinion values (Table 33). The trapezoidal-AUC model is not well defined in the Dobson et al. (2013) but there is documentation in Appendix 3 - TRACE documentation of the proposed Extensive Escapement Estimation model-AUC component. Given the differences above, I thought a better understand of the trapezoidal-AUC would allow for the possible explanation between the discrepancies and possible insight into the AUC models used by Dobson et al. (2013).

The trapezoidal-AUC model is analyzed using **B**ayesian inference **U**sing **G**ibbs **S**ampling (BUGS) (Spiegelhalter et al. 2003). In Bayesian analysis the marginal posterior distribution ($\pi(\theta|Y)$) is proportional to the likelihood ($p(Y|\theta)$) times the prior distribution ($p(\theta)$), where Y are the data and θ are the parameters to be estimated (Gelman et al. 1995). A parameter is weakly identifiable when $\pi(\theta|Y) \approx p(\theta)$ (Gimenez et al. 2009). When this occurs, the inference about θ is mainly a result of the prior beliefs about the θ not the data collected. I explore this concept of weak identifability to understand how sensitivity of the escapement (ESC) estimates were to the choice of priors for survey life (SL) and OE in the trapezoidal-AUC model.

I re-coded the model in WinBUGS and called the code from R using R2WinBugs (Sturtz et al. 2005). The code is similar to the code listed in Appendix 3 except was adapted from Rawding (2011) and it added extra loops to evaluate the sensitivity of different priors and the relative bias of the ESC and SL estimates and bias of the OE estimate (Figure 1). I used data for a Lower Columbia River Chinook salmon population. In this dataset, the counts were of spawners, OE was assumed to be 100%, escapement was 813, and SL was estimated by dividing the AUC by the escapement (Parken et al. 2003). To understand the influence of priors, I assumed OE was 75% and multiplied the original observed counts by 75%. The first two uniform priors for OE were centered on the true OE (0.75), and included uniform priors of (0.5-1.0) and (0.6-0.9). The second set of uniform priors placed true OE (0.75) at the extremes of the prior (0.75-1.00) and (0.50-0.75). During this analysis the SL was a constant.

The sensitivity of the 4 different priors is shown for OE (Figure 1) and ESC (Figure 2). When the midpoint of the uniform distribution is the true OE, the estimates of OE are unbiased (0%) (top two graphs in Figures 1 and 2). For other cases (bottom two graphs in Figure 1 and 2) the relative bias is related to the difference in the midpoint of the uniform distribution and the true OE. The relative bias of OE was as expected 12.5% and -12.3% for priors 3 and 4, respectively. However, the bias in the ESC for these two conditions was greater than the bias for OE -14.3% and 19.7%, respectively. The uncertainty (credible interval) is a function of the width of the uniform distribution (top two graphs in Figures 1 and 2). When the OE is at the edge of the prior, the point estimate is not contained in the 95% credible interval (bottom two graphs in Figures 1 and 2). It should also be noted that because there is no data for OE and SL, the measure used for model selection in BUGS (Deviance Information Criteria, Spiegelhalter et al. 2003) cannot be monitored, thus model selection based on information criteria is impossible. This approach was repeated for SL when OE was a constant, and another approach was used allowing SL and OE vary based on different priors. The affects were the same as was observed for OE (results not reported).

The trapezoidal-AUC model listed in Appendix 3 and used for the analysis of WVCI estimates (Table 36-38 in Dobson et al. 2013) is an expert opinion model based on the subjective beliefs for OE and SL. There is no data used in the estimate of OE and SL in the model, the experts develop a uniform prior around their beliefs about the point estimate of OE and SL and its upper and lower bounds. In this model the posterior distribution equals the prior distribution ($\pi(\theta|Y) = p(\theta)$) because there is no data. Rather than have weak identifiability, the model actually has **no** identifiability, which is confirmed by the inability to monitor the DIC node for model selection.

Parsons and Skalski (2009) reviewed the AUC model based on Ames (1984) where OE estimates are subjectively made based on the professional opinion of observers. They indicated that when using these types of AUC models estimates of accuracy and precision are unknown, the direction of the bias is unknown, and therefore are not recommended for use. These same conclusions apply to the trapezoidal-AUC model in the Appendix 3. For the terms of reference (TOR) the trapezoidal-AUC model does not meet the first 3 evaluation criteria because: 1) it does not use OE and SL data; 2) uncertainty is not quantifiable because it depends on expert opinion; and 3) the bias in the estimates is unknown.

However, there are methods to use a trapezoidal-AUC to meet the TOR. For example, Rawding (2011) provided a framework to estimate Chinook salmon escapements based on annual radio tagging and snorkel surveys. Hilborn et al. (1999) developed a method to estimate the average of SL and OE and Korman et al. (2002, 2007) developed environmental covariates to estimates OE. Both of these approaches could be incorporated into the trapezoidal AUC framework proposed by Rawding (2011). Modification of the trapezoidal-AUC model in Parken et al. (2003) could also be explored if a non-Bayesian approach is preferred. Furthermore, OE and SL data are available for selected WVCI population (Dobson et al. 2103; McHugh and Dobson 2013, Roger Dunlop pers. comm.). I encourage DFO staff to consider these or other alternatives if they wish to pursue a trapezoidal-AUC model that meets the TOR.

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Figures

```
model{ # trapezoidal-AUC model to estimate salmon escapement
for (k in 1:prioirs) {
        OE[k]~dunif(OEmin[k],OEmax[k]) # subjective range for OE
        for (t in 1:survey){ CT[k,t] <- ct[k,t]/OE[k]} #adjust observed counts by OE
        #estimate AUC
        for (t in 1:(survey-1)){ auc[k,t] <- (day[k,t+1]-day[k,t]) *(CT[k,t]+CT[k,t+1]) * 0.5 }
        AUC[k] <- sum(auc[k, ])
        ESC[k] <- AUC[k]/SL} #estimate ESC
        # estimate relative bias for ESC and bias for OE
        For (k in 2:prioirs) {RB_ESC[k]<- (ESC[k]- ESC[1])/ESC[1]
                                B_OE[k]<- OE[k]-0.75 }
        } #end model
```

Figure 1. BUGS code for AUC model adapted from Rawding 2011. This is basically the same coded as in Appendix 3 except OE is the same for all surveys, where ct = the survey count, day = Julian day of the survey count, OE= observer efficiency set at 75%, SL = survey life at 5.4 days for spawning fish, AUC= the estimate of fish days, and ESC = the abundance or escapement estimate. In addition, there is a loop to evaluate the sensitivity of priors and estimate relative bias and bias of OE and ESC.

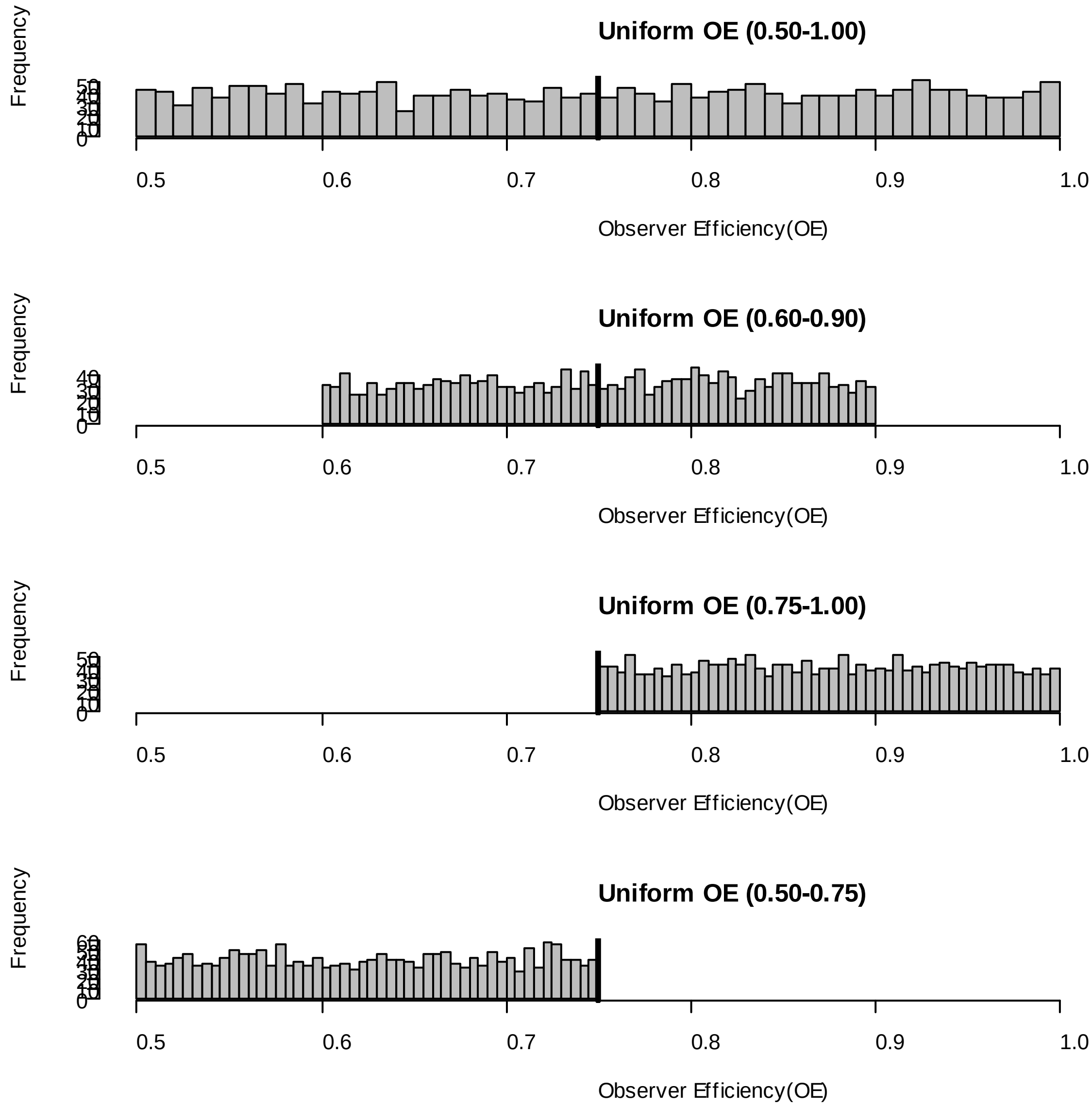

Figure 2. Posterior distribution for observer efficiency (OE) under 4 uniform priors for observer efficiency (OE) with a constant survey life. The true OE was 0.75 (solid black vertical line).

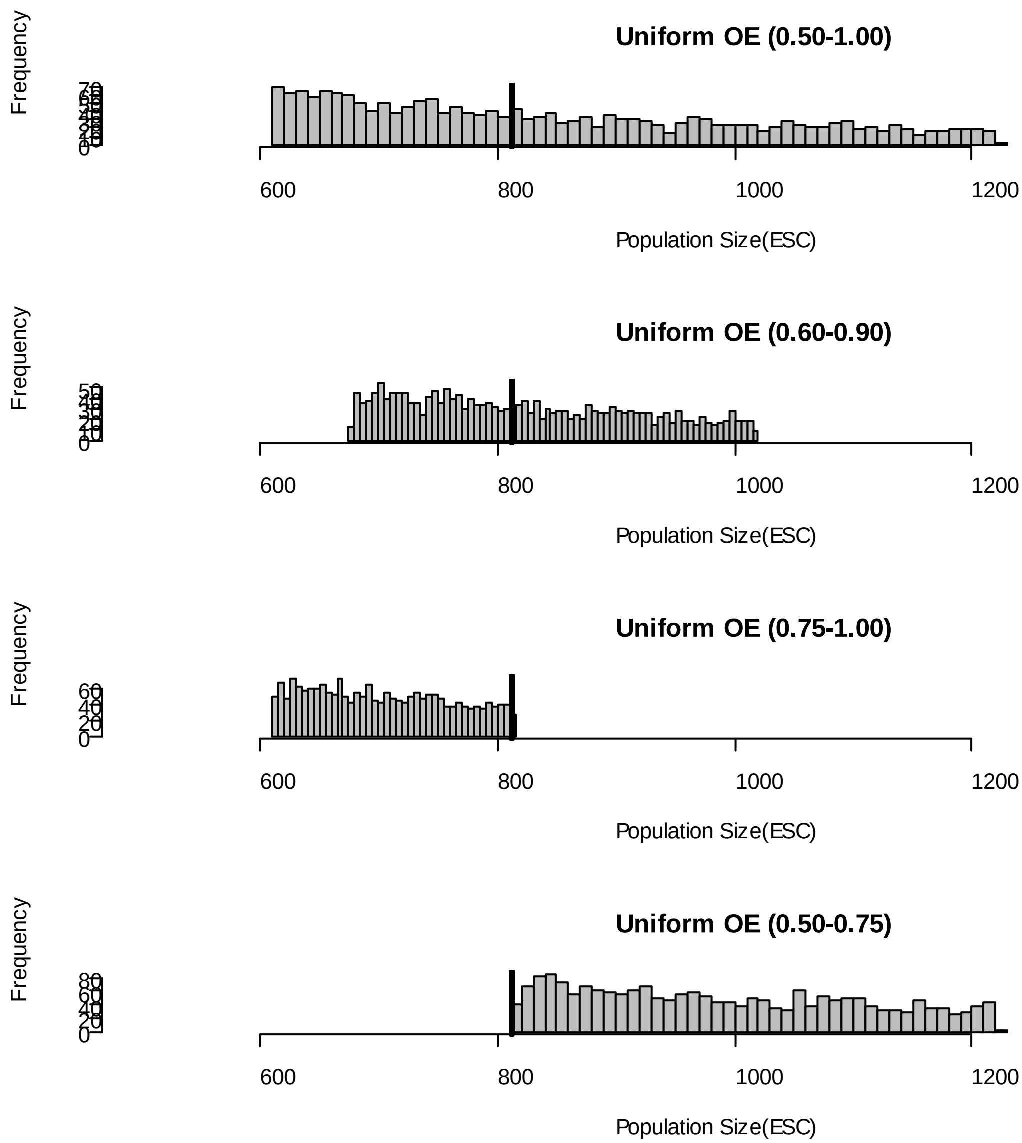

Figure 3. Posterior distribution for abundance (ESC) under different uniform priors for observer efficiency (OE) with a constant survey life. The true OE was 0.75 and true abundance was 813(solid black vertical line).

APPENDIX F – WRITTEN REVIEW #3

Date:	June 17, 2003.
Reviewer:	Dr. Kim Hyatt, DFO, Salmon and Freshwater Ecosystems Division
CSAS Working Paper:	2013/14 P57
Working Paper Title:	Evaluation of escapement monitoring program and escapement estimates for WCVI Chinook (Oncorhynchustshawytscha) extensive indicator stocks by Diana Dobson, Marc Labelle, Diana McHugh, and Erin Porst

General Overview Comments:
Key Focus and Conclusions:

The core of this working paper rests on the authors attempts to: (a) assemble raw survey data serving as the foundation for current escapement estimates of "sentinel" populations of WCVI Chinook salmon, (b) employ supplemental data sources to determine two key parameters used in escapement estimation, namely observer efficiency (OE) and survey life (SL) of field personnel and Chinook salmon respectively, (c) compare OEs and SLs from explicit data sources to the assumed values of OEs and SLs used in determining current escapement estimates, (d) conduct a reanalysis of raw survey data employing evidence-based OEs and SLs within a new AUC and maximum likelihood model to generate new sets of escapement estimates for the subject Chinook stocks and finally (e) draw conclusions as to whether previous advice re: status and trends of WCVI Chinook needs to be revised.

Let me say at the outset that I am supportive of the approach used in the paper and I believe the authors have largely accomplished what they set out to do as summarized succinctly in the results plotted in Figure 27. If one accepts several simplifying assumptions that the authors have been forced to make to get to this point, then their conclusion that the recent historic perspective that most WCVI Chinook (the exception being Marble) have declined and remain well below theirbenchmark S_{MSY} values is supportable. I generally agree with this summary assessment although I don't accept this without qualification (i.e. the data do not provide an unassailable basis for arriving at the main conclusions; see more detailed comments below). Further to this I suggest it would have been helpful to include a sensitivity component to the analysis regarding the extent to which the average OEs and SLs would have to be altered to bring most of the subject Chinook to or above their S_{MSY} benchmark values.

Other General Comments:

The abstract could be much more explicit about the actual findings as opposed to just providing a list of general outcomes. Further I'd focus the abstract on the core subjects of the paper noted above.

In general, the introductory portion of the paper rambles more than is necessary i.e. several pages of text must be read before one finally is able to identify the core purpose of the paper.. I understand the importance of providing general background on methods (escapement estimation) and subjects (Chinook salmon) that the substance of the paper will be developed around and I did learn a few things from this material. However, the core of the paper is about the development and application of OEs and SLs for re-analysis of escapement so it should not require 15 pages of introductory material before identifying this focus in the methods section starting on page 15.

The entire paper does require a careful edit and attention to provision of several key citations used in the text but not included in the list of references.

Detailed Comments:

Because determination and application of OEs and SLs are a key focus in this paper I've grouped comments on methods and results related to these in a series of "bullets" as follows:

- Page 16: Because OE and SL " parameters used in the trapezoidal AUC escapement estimates for WCVI extensive indicator stocks were not actively measured from year to year", then ,page 8., AUC estimates have used OEs based on subjective assessments of survey and river conditions even though in many instances there are few metadata to document what these were i.e. the expansions are based on subjective assessments of OEs.Having lots of experience with trying to do this myself, I simply have no confidence that defencible OEs can be generated this way.
- P. 17: the relationship between OE and the ratio of horizontal visibility and discharge (HV/Q) was explored as per Korman (2002). Detailed methods for how HV is determined should be provided in the methods as this variable appears to show some promise for influencing OE estimates. Although results provided on HV/Q appear to have some explanatory value they also exhibit unexplained variations. I've done some of this work in thefiled and note that HV will be influenced significantly by continuous changes in sub-surface illumination and turbidity that may change rapidly (i.e. within intervals of less than an hour) so measuring HV once at the beginning of a survey will be inadequate. Future attempts to generate these supplementary data should consider how to capture records of such variation to achieve greater analytical utility.
- Page 20: Although I have little confidence in the subjectively assessed OEs provided in Table 27, there is a cluster of low OEs in the 2003-2005 interval which suggests a year effect that may be associated with either survey crew (i.e. observers) or climate conditions. However, in the absence of supplementary observations its impossible to determine which or whether this is just a coincidental occurrence of low OEs.
- Page 21: The average SLs estimated through tagging studies were generally comparable with the assumed survey lives applied (as per Table 32) in the original AUC estimation. This conclusion appears to be supported but its important to clarify that this applies to averages generated across many surveys rather than determinations of empirical and subjective estimates generated on a survey by survey basis. The latter comparisons would be a more convincing basis for this comparison but obviously can't be at the current time given the nature of the source data. The other difficulty to be considered with respect to applying an all-year average and range for SLs is that this implicitly assumes that the hydrological and biological interactions controlling SLs have been and will remain stationary i.e. have a long term mean value with random year-to-year variation around the mean. Given the non-stationary nature of climate variation and change this assumption may be violated either during past intervals or future ones so this assumption must be verified as to its ongoing applicability.
- Page 21. The use of tagged animals and visual re-sightings of same has been used as the basis for verifying whether subjective OE estimates are biased. The authors conclude later that subjective OEs are biased high relative to empirically measured OEs. However, its important to note that OEs for detection of populations of fish are not the same parameter as OEs based on re-sightings of tagged fish. The latter are like looking for an albino blackbird in a flock i.e. what is the OE for detecting unusual targets in a background of more common

ones. The OE one really needs estimates for are at the population level i.e. what proportion of common targets do observers detect when these are distributed as a population in a complex landscape (or here river-scape). The only means of obtaining such OE parameter estimates is to conduct OE trials in river systems where apriori knowledge of the exact number of fish available for detection exists. The authors have substituted a different parameter as a proxy for the latter but this may well be problematic (i.e. the subjective OEs applied to populations are not the same as the measured OEs derived from a small set of tagged Chinook nested within a larger general population. May be the best they can do here, but “no cigar”!

- Page 25: The principal advice offered by this paper pertains to improving survey methods, analytical methods and documentation in the future such that the uncertainties that future analysts wrestle with are greatly reduced. The advice is that Chinook surveys be comprised of a minimum of 5 surveys per year with short (5-7 day) intervals between surveys. In short the authors are calling for surveys and analysis to be conducted to a standard and just as importantly that the observational data and analytical products are managed to a standard. Establishment of these standards is absolutely vital to improving the level ofresolution of our assessments such that we’re not constantly defending salmon escapement observations and estimates of questionable origin. This advice has been repeated in both specific cases and more generally as a broad regional issue on numerous occasions over the past 20 years. Apparently easier said than done!

I have a more extensive list of comments that might aid the authors in the finalization of this report but in the interest of focusing on just major comments will avoid listing them here. However, I’d be happy to meet with the authors to discuss these should they wish.

APPENDIX G - QUESTIONNAIRE RESULTS

In preparation for the workshop a questionnaire was sent out to biologists, scientists and academics to learn more about methods used to assess the abundance of aggregate stocks. These methods were considered in terms of suitability for assessing West Coast Vancouver Island (WCVI) Chinook Salmon.

Implementation of the PST Chinook management model requires the input of the annual abundance of driver stocks, including WCVI Chinook. Typically, abundance is indexed through an estimate of the terminal run size which includes terminal catch plus escapement. Two approaches for estimating abundance include 1) fishery-based methods which produce an estimate of the terminal run size and 2) river-based methods which produce an estimate of the escapement.

We use the term ‘aggregate’ to refer to the escapement or the terminal run-size of any unit (population or group of populations) that is used for management purposes. We use the term ‘abundance’ to refer to the estimates of escapement plus the terminal catch and/or the terminal run-size, although the terminal catch estimation methods are not reviewed in the questionnaire. Note that abundance may refer to the absolute abundance or an index of abundance.

The questions (table headings) and responses have been summarized into the following 5 tables:

1. Management requirements and the method used to estimate the aggregate abundance;
2. The survey design for the aggregate (ie. the monitoring design);
3. Sampling protocols for the survey components (ie. the response design);
4. Expansions and considerations for estimating the aggregate abundance (ie. the inference design);
5. Uncertainty, assumptions and bias associated with the method for estimating the aggregate abundance, and design flexibility.

Questionnaire participants were:

- Richard Bailey, DFO (CTC)
- David Bernard, ADFG (CTC)
- Robert Bocking, LGL
- Ethan Clemons, ODFW (CTC)
- Diana Dobson, DFO (CTC)
- Julie Firman, ODFW
- Daniel Rawding, WDFW (CTC)
- Brian Riggers, ODFW
- Ivan Winther, DFO (CTC)

MANY THANKS TO ALL OF THE QUESTIONNAIRE PARTICIPANTS FOR THEIR INTERESTING COMMENTS AND CONTRIBUTION TO THE WORKSHOP!

Table 1. Management requirements and the method used to estimate the aggregate abundance

Assessment Unit	How is the aggregate estimate used for management? (question #6)	Describe the method used to estimate or index the abundance of the aggregate (question #7):
SEAK Chinook (Transboundary and coastal rivers)	In-season and postseason management	Abundance is estimated for individual stocks from a capture-recapture program or from an expansion of counts from helicopter surveys.
Lower and Coastal Nass Area Coho Aggregate (LCNAA)	Used in the total return to Canada (TRTC) for Nass coho, for post-season fishery evaluations, for population status review, and for catch accounting under the provisions of the Nisga'a Final Agreement	Index stream escapement estimates are expanded to the Aggregate estimate in proportion to available habitat. Escapement estimates are combined with catch information and the Middle and Upper Nass River mark-recapture estimate to derive the TRTC for Nass Area Coho salmon
WCVI Chinook	Forecast production, evaluate performance of CTC models, harvest management.	The estimate is an aggregate index of abundance, which is simply the summed escapement estimates of the indicator stocks with terminal catch
Fraser River Chinook **Spring-Run 1.2; Spring-Run 1.3; Summer-Run 1.3; Summer-Run 0.3; Fraser Fall.**	PST Chinook model Domestic	1.2 springs: 1 m/r, 2 by aerial (heli) peak live, 2 by resistivity counter and 1 by multiple foot surveys 1.3 Springs. Mostly aerial peak live, a fe foot or float surveys 1.3 summers. 1 m/r, rest aerial peak live 0.3 summer. 1 m/r, rest aerial peak live Fraser fall. M/R
Lower Columbia River Chinook MU	Status, forecasting, and harvest management	There aggregate is composed of ~ 20 individual populations. There is an estimate of abundance of each population. The abundance for individual populations is typically estimated based on weirs, mark-recapture, mark-resight, AUC, redds, and peak count expansion although we have used genetic mark-recapture and sonar (DIDSON) for some populations.
Northern Oregon Coast (NOC) and Mid Oregon Coast (MOC) Chinook	NOC abundance (based on spawning escapement) is used in the PSC Chinook model harvest management and to represent the expected productivity for this aggregate. MOC is not used in the PSC Chinook model. Terminal management is currently primarily targeted at the basin level, not the aggregate.	A habitat expansion based method is used to expand from "standard" or normative survey index areas located throughout both aggregates to basin-wide estimates of escapement, which are summed and provide for an aggregated estimate of escapement.
Oregon Coastal Coho	The estimates feed viability criteria that have been identified to assess the status of Oregon Coastal Coho including abundance, productivity, persistence and diversity. They are also used to set harvest limits for sport fisheries.	Fishery-based estimates of harvest are added to river-based estimates of escapement to develop an estimate of total abundance.

Table 2. The survey design for the aggregate (ie. the monitoring design)

Assessment Unit	Describe the survey design for the aggregate estimate (question #8):	What are the survey components used in the survey design (question #9):	How many individual components are surveyed? With what frequency (question #10)?
SEAK Chinook (Transboundary and coastal rivers)	Abundance of Chinook salmon in SEAK estimated is estimated annually for each stock with a capture-recapture program or an expansion of counts from helicopter surveys based on past capture-recapture studies.	Most capture-recapture studies are "two-event" closed population studies with fish captured just above the mouth of the river, tagged, and released; and fish inspected for tags on the spawning grounds. For Helicopter surveys sections are selected because they consist of unobstructed, clear water.	C-R studies and/or spawning ground surveys are conducted annually for all 9 of the largest Chinook producing rivers
Lower and Coastal Nass Area Coho Aggregate (LCNAA)		The survey components used for the aggregate estimate are index streams. A complete census of spawners is conducted for the majority of known spawning habitat in each stream.	Escapement estimates are generated for at least three systems each year to prorate the habitat capacity model. Ansedegan Creek and Diskangieq Creek have been surveyed in all years since Treaty implementation in 2000. Ginlulak Creek and Salmon Cove Creek have been surveyed in some years depending on funding, and a mark-recapture estimate has been generated for Zolzap Creek in years where the Zolzap Creek wild Coho salmon smolt coded wire tagging program was operating.
WCVI Chinook	Knowledge based and convenience based. The factors determining which populations are surveyed are size, spatial representation, management requirements and convenience.	Individual spawning populations, which for the most part are associated with individual river systems.	15 to 18 populations/rivers surveyed annually
Fraser River Chinook **Spring-Run 1.2; Spring-Run 1.3; Summer-Run 1.3; Summer-Run 0.3; Fraser Fall.**	Time series of escapement estimates. Expanded to total returns using Fraser River Run REcon model	Stream by stream escapement, fishery catches in Fraser River	Annually survey a standard suite of streams, most fisheries
Lower Columbia River Chinook MU		individual populations	All populations (~20) are surveyed annually.

Assessment Unit	Describe the survey design for the aggregate estimate (question #8):	What are the survey components used in the survey design (question #9):	How many individual components are surveyed? With what frequency (question #10)?
Northern Oregon Coast (NOC) and Mid Oregon Coast (MOC) Chinook	"Historically-based", non-random surveys of spawning grounds. Peak counts of both live and dead fish are recorded during visual surveys of standardized areas are chosen to represent individual basin's escapement.	34 "standard" survey reaches in the NOC representing 7 major basins.	Fewer than 30 of the standard river reaches of these are currently routinely surveyed. Standard survey reaches range from 1 to 8 per basin. These surveys are conducted on a weekly basis every year.
Oregon Coastal Coho	We make Area Under the Curve estimates at sites selected in a GRTS design (stratified random).	We sample stream reaches that are approximately 1 mile long. Estimates are made for independent populations, strata (aggregates of several independent populations) and for the ESU.	We make estimates for 13 independent populations and 3 dependent population aggregates. The data are also used to make estimates for 5 strata and for the ESU as a whole.

Table 3. Sampling protocols for the survey components (ie. the response design)

Assessment Unit	Describe the sampling methodology (response design) of the individual survey components (question #18):	Describe the in-season sampling frequency of the survey components (question #19):	What are the potential sources for bias in application of the sampling methodology (question #20)?	What are the limitations of the sampling methodology in terms of survey conditions and requirements (question #21)?
SEAK Chinook (Transboundary and coastal rivers)	Streams are flown and peak count is used as an index of abundance. Expansion factors based on historical M-R surveys range from range from 1.5 to 5.4.	Streams are flown at least three times each year	For C-R: closed population, equal probabilities of capture, etc.	For C-R: flash flood severe enough to force the sampling crew to cease operations. For visual counts, problems with variation in turbidity, weather, etc. are reflected in the estimated variances for expansion factors
Lower and Coastal Nass Area Coho Aggregate (LCNAA)	Surveys are divided into reaches, and crews estimate their own observer efficiency on a reach specific basis. AUC estimates are then derived accounting for using an AUC modeling tool in excel (AUCmonteMASTER2.04) which allows variation in both observer efficiency and survey life to be modeled using a Monte Carlo simulation.	Every 7-10 days. As many as seven surveys are attempted over the spawning period.	Observer efficiency and survey life (spawner residence time).	Generally there is good success in getting appropriate survey conditions throughout the spawning period. Survey sections are relatively short and easily accessible

Assessment Unit	Describe the sampling methodology (response design) of the individual survey components (question #18):	Describe the in-season sampling frequency of the survey components (question #19):	What are the potential sources for bias in application of the sampling methodology (question #20)?	What are the limitations of the sampling methodology in terms of survey conditions and requirements (question #21)?
WCVI Chinook	Spawners are counted visually by survey crews (usually 3 people) that swim the length of the river accessible to Chinook spawners	Ideally every 5 days, with 6 to 8 surveys during the spawning period, and to have "0" counts near the beginning and end.	For AUC estimates: incorrect assumptions about observer efficiency, survey life, too few or infrequent surveys, if not all accessible sections of stream are surveyed, species mis-identification. Size of spawning population (harder to count fish in smaller populations, estimation error in larger populations)	Major precipitation events are often correlated with migration from marine to freshwater, particularly after drought conditions. However, major precipitation events can make the river inaccessible to surveys (either due to safety concern or turbidity). During prolonged events low survey number and infrequent surveys will contribute to greater uncertainty and/or bias in the estimates.
Fraser River Chinook **Spring-Run 1.2; Spring-Run 1.3; Summer-Run 1.3; Summer-Run 0.3; Fraser Fall.**	Mostly 2 or 3 overflight counts	depends on system, but usually 2 flights nr peak	OE is very high in low clear streams. Timing of flights is biggest issue mostly	Availability of heli and trained counters
Lower Columbia River Chinook MU	Many methods are used and the sampling protocols generally follow those of Johnson et al. (2007).	The scheduled sampling frequency for weirs and live tagging is daily. For recovery and spawning ground surveys the frequency is weekly.	Many methods are used. See Rawding and Rodgers (2013) for more details about bias associated with different methods.	Many methods are used. See Rawding and Rodgers (2013) for more details about the limitations associated with different methods. In general, representative tagging, recoveries, and spawning ground surveys are required. In addition, for visual surveys (mark-resight, PCE, AUC, and redds) water must be clear enough to observe fish, and water levels safe enough to survey.

Assessment Unit	Describe the sampling methodology (response design) of the individual survey components (question #18):	Describe the in-season sampling frequency of the survey components (question #19):	What are the potential sources for bias in application of the sampling methodology (question #20)?	What are the limitations of the sampling methodology in terms of survey conditions and requirements (question #21)?
Northern Oregon Coast (NOC) and Mid Oregon Coast (MOC) Chinook	Spawning ground survey of peak count per mile. The largest sum of live and dead chinook for a given survey on a given day.	Every 7 to 10 days if conditions warrant, ranging from September through January depending on the basin	Surveyor experience and same as the bias for the aggregate	Missed peak counts due to water/weather conditions, personnel or access issues.
Oregon Coastal Coho	Surveyors visit sites weekly to walk the stream bank and make visual counts of spawning salmon. If visibility or flow are high enough that surveyors cannot see to the bottom of riffles, the count is not included in the estimate. Sites where surveyors are unable to make counts for a period longer than two weeks are excluded from the sample.	Sites are visited roughly weekly throughout the season in which spawning occurs.	Observation efficiency, survey life and estimates of hatchery-wild proportions.	Surveyors must be able to see to the bottom of riffles for the count on that visit to be included in the AUC estimate. If flow or turbidly are too high the site is re-visited every couple of days until a valid count can be recorded.

Table 4. Expansions and considerations for estimating the aggregate abundance (ie. the inference design)

Assessment Unit	Do you account for the portion of the aggregate not surveyed? If so, how? If not, (ie. The aggregate estimate is an index of total abundance) what portion of the aggregate does the estimate represent? What is the basis of this assumption? (question #13)	Are hatchery and wild contribution estimated separately? How much of the aggregate is estimated to be from enhanced populations? (question #12)	Do you account for terminal/freshwater fisheries in your aggregate estimate? Describe: (question #14)
SEAK Chinook (Transboundary and coastal rivers)	In the case of helicopter surveys, counts are expanded according to factors derived from past comparisons with capture-recapture studies that did cover the entire aggregate. Almost all spawning occurs in 9 rivers.	Yes, CWTs are used to estimate the enhancement.	Yes. In river fisheries occur in Canada and are monitored by DFO and the First Nations. Commercial fisheries in US waters have catches tallied on fish tickets sport fisheries are surveyed. Catches from both types of marine fisheries are sampled extensively to recover CWTs and conduct GSI

Assessment Unit	Do you account for the portion of the aggregate not surveyed? If so, how? If not, (ie. The aggregate estimate is an index of total abundance) what portion of the aggregate does the estimate represent? What is the basis of this assumption? (question #13)	Are hatchery and wild contribution estimated separately? How much of the aggregate is estimated to be from enhanced populations? (question #12)	Do you account for terminal/freshwater fisheries in your aggregate estimate? Describe: (question #14)
Lower and Coastal Nass Area Coho Aggregate (LCNAA)	Standard reaches are surveyed which are known to be used by spawning Coho salmon and together represent the majority of spawning habitat in the system. Where not all spawning habitat is surveyed estimates for surveyed reaches are expanded to account for un-surveyed reaches assuming a constant linear density of spawning fish. Expansion to the aggregate is proportional to the available rearing habitat as per the Nass Coho Habitat Model (Bocking and Peacock 2004). The estimate (sum of the index stream escapements) typically accounts for between 5% and 10% of the aggregate.	No hatchery component exists	All escapement estimates assume that all fishery removals have already occurred. Some minor removals of fish that have already been enumerated may occur in some index systems (Zolzap and Diskangieq Creeks) but it is thought that these removals are minor.
WCVI Chinook	The objective of sampling is to estimate a portion of the spawning populations which represents about 90% of the total production (determined by historical records). There are 101 rivers with records of populations.	Not estimated separately. Spawning abundance of those rivers supporting major hatchery populations are separate. Many of the index chinook populations receive some level of enhancement. In many cases, the spawning population is sampled for hatchery marks, but no attempt is made to estimate the hatchery and wild component of the population separately.	Reporting programs are in place for all terminal fisheries, including commercial, recreational and First Nation (aboriginal). The WCVI Creel survey operates from Jun. to Sep. - effort and impacts are considered very low outside this period. There is also some First Nations catch that is either not monitored and/or reported, which is considered very low in most cases, but in some cases may account for a relatively large portion of a single system terminal return.
Fraser River Chinook **Spring-Run 1.2; Spring-Run 1.3; Summer-Run 1.3; Summer-Run 0.3; Fraser Fall.**	In-filling in run recon. model escapement time series	Yes for indicator streams, otherwise NO	Yes, as many as possible. For 3 of 5 Fraser aggregates, these ARE the principal fisheries

Assessment Unit	Do you account for the portion of the aggregate not surveyed? If so, how? If not, (ie. The aggregate estimate is an index of total abundance) what portion of the aggregate does the estimate represent? What is the basis of this assumption? (question #13)	Are hatchery and wild contribution estimated separately? How much of the aggregate is estimated to be from enhanced populations? (question #12)	Do you account for terminal/freshwater fisheries in your aggregate estimate? Describe: (question #14)
Lower Columbia River Chinook MU	The entire aggregate is surveyed so there is no need to expand for unsurveyed areas.	For each population, the proportion of hatchery origin spawners (pHOS) and natural origin spawners (pNOS) is estimated based on the mass mark. Typically the escapement estimate is multiplied by these proportions to estimate HOS and NOS. HOS have been observed in most in the aggregate but estimates of pHOS are generally higher in rivers with fall Chinook salmon hatcheries.	The methods we use to estimate abundance are designed to estimate escapement past the fishery, so there is no need to account for the terminal fisheries. However, terminal fisheries are monitored.
Northern Oregon Coast (NOC) and Mid Oregon Coast (MOC) Chinook	An estimate of that available habitat which is not surveyed is made and an aggregated survey density is apportioned to that estimated non-surveyed habitat and expanded accordingly. This accounts for about 18% of the available habitat within the NOC. This apportionment for non-surveyed areas does not currently occur for the MOC.	No separation of hatchery and wild contribution in the NOC aggregate estimation, but there is very little hachery contribution Higher proportion of hatchery contribution in the MOC, but there is no current method of separating estimates of hatchery or wild contribution.	No, the estimates provided to the model are specifically for spawning escapement.
Oregon Coastal Coho	We expand a representative sample (GRTS) to make an estimate of the total population size. The sample is expanded by the sample weight. The weight depends on the site density. Essentially we take the total length of the sampling frame and divide it by the number of sites sampled and multiply that value by the response at the site	There is little hatchery influence in this ESU. The number of natural-origin spawners and the number of hatchery-origin spawners is calculated via the hatchery-wild ratio observed for the population. We don’t have enough fin-mark recoveries at individual sites to estimate the number of hatchery and wild fish by site	Yes. Angler surveys are conducted on sport fisheries in rivers and these and FRAM estimates of ocean terminal fisheries are added to escapement estimates to generate a total aggregate estimate.

Table 5. Expansions and considerations for estimating the aggregate abundance (ie. the inference design) continued

Assessment Unit	Is the uncertainty in the aggregate estimate quantified? If so, what is the level of uncertainty associated with the aggregate estimate? (question #15)	What are the assumptions of the method for estimating the aggregate? (question #16)	What are the potential sources for bias in application of the method for estimating the aggregate? (question #17)	How flexible is the assessment method to variations in financial and human resources (ie. How do you deal with short-term and variable partnerships and projects)? (question #22)
SEAK Chinook (Transboundary and coastal rivers)	All estimates of abundance have reported estimated variances as per ADFG policy, including expansions from helicopter surveys	For Chinook salmon the assumptions are the same as for any capture-recapture study: closed population, equal probabilities of capture, etc	Any method will give biased results if the conditions for consistency are not met. All of Alaska's capture-recapture studies go through rigorous diagnostic testing to determine if conditions are met.	Some of this work goes back to the 1970s and has involved cooperation with First Nations and DFO. Until recently much of the work was supported by US federal monies in support of research on fish populations used by sport fishermen. With reductions in resources there would be fewer MR experiments.
Lower and Coastal Nass Area Coho Aggregate (LCNAA)	Not estimated	1. The spawning populations within the aggregate co-vary in terms of survival rates and exploitations rates. 2. Spawner returns are proportional to the total available rearing habitat within the aggregate. 3. The proportion of the population surveyed (index systems) is representative of differences in actual habitat capacity from predicted habitat capacity throughout the spawning systems used by the aggregate. 4. Habitat not quantified by the habitat capacity model (mainstem Nass River sloughs and associated wetlands, small estuarine channels, etc…) do not provide year round rearing habitat to a significant number of Coho smolts and therefore do not contribute significantly to production.	Biases could occur if any of the above assumptions is invalid. Biases could also occur due to biases in the Coho Habitat Model (e.g. over or underestimation of the available rearing habitat).	The LNCAA escapement enumeration program is a Core-funded activity within the Nisga'a Final Agreement and funded from the Lisims Trust fund. Nisga'a Nation is the sole entity implementing the work.

Assessment Unit	Is the uncertainty in the aggregate estimate quantified? If so, what is the level of uncertainty associated with the aggregate estimate? (question #15)	What are the assumptions of the method for estimating the aggregate? (question #16)	What are the potential sources for bias in application of the method for estimating the aggregate? (question #17)	How flexible is the assessment method to variations in financial and human resources (ie. How do you deal with short-term and variable partnerships and projects)? (question #22)
WCVI Chinook	The uncertainty of the aggregate estimate has not been quantified. The uncertainty of the individual spawning populations has not been quantified, although through recent work we are collecting data/developing models to describe the uncertainty of the estimates.	For the aggregate estimate: the assumption is that the 1) the index stocks represent the entire assessment unit (i.e. patterns of mortality, survival rate) and 2) the index stocks (+ hatchery stocks) represent a very large portion (e.g. 85 to 95%) of the total production.	For the aggregate index of abundance, a potential source of bias is that the index stocks are not representative of the other populations within the assessment unit. Note: because the estimate is an "index of abundance" - i.e. represents the sum of only index stocks + terminal catch + hatchery, the index is inherently low relative to the overall abundance.	Method is fairly flexible. The number of indicator systems can readily be decreased.
Fraser River Chinook **Spring-Run 1.2; Spring-Run 1.3; Summer-Run 1.3; Summer-Run 0.3; Fraser Fall.**	Not quantified	Lots in terms of run timing, equal vulnerability to fishing, accurate estimates of catch and escapement	Lots	Not flexible. Needs correctly timed flights. Covers 1/5 of land mass of Province in short period
Lower Columbia River Chinook MU	All individual tributary and population estimates have estimates of uncertainty. Our goal is to have CV of less than 15% but this target is not always achieved especially for small populations.	There are different assumptions associated with each method.	Violation of any of the assumptions with the method used could case bias in the estimate.	We have not had large variations in funding and resources. If these occurred we would likely used peak count expansions or AUC or GRTS surveys due to their lower cost. However, the uncertainty associated with the abundance estimate using these methods would increase.

Assessment Unit	Is the uncertainty in the aggregate estimate quantified? If so, what is the level of uncertainty associated with the aggregate estimate? (question #15)	What are the assumptions of the method for estimating the aggregate? (question #16)	What are the potential sources for bias in application of the method for estimating the aggregate? (question #17)	How flexible is the assessment method to variations in financial and human resources (ie. How do you deal with short-term and variable partnerships and projects)? (question #22)
Northern Oregon Coast (NOC) and Mid Oregon Coast (MOC) Chinook	The uncertainty for both the NOC and MOC estimates are not currently quantified. Although, habitat-based estimates are commonly within the confidence intervals of the concurrently derived M/R studies.	a. peak counts from standard surveys (index areas) are representative of the populations they are located within. b. There is a homogeneous relationship between peak count and the total number of fish. c. That these surveys may be appropriately expanded out to broader estimates of available habitat within the basin to account for estimates of total production. d. Survey conditions are relatively constant and can be broadly characterized as homogenous. e. Observer efficiency is constant over time, and is appropriately accounted for. f. Spawning life is constant through time, and is appropriately accounted for. g. Access to standardized surveys will be constant through time. h. That those areas which are surveyed for escapement at age are representative for those areas (and basins) which are not (age at maturity is homogeneous within the aggregate).	a. A violation of any of the assumptions. b. Landowner denial of access in an increasing proportion of those historically designated survey areas c. Surveys which are truncated (temporally) to a point at which the peak count is not actually observed.	Standard surveys are considered to be fairly stable as they are funded through federal base sources.
Oregon Coastal Coho	Yes. The variance observed in the GRTS sample is used to calculate confidence intervals around the estimate. Uncertainty for the ESU is below 15% of the estimate. For individual populations it can be greater than 30%.	For the AUC estimate at a site we assume that we have correctly estimated the detection probability and the time that individual fish spend on the spawning grounds (spawning life). For GRTS estimates we assume that we have correctly estimated the AUC and the hatchery-wild ratio, that all sites have an equal probability for selection for sampling, that selected sites provide an unbiased sample, and that we are accurate in assuming zero escapement for sites judged to be devoid of spawning habitat.	Over or under estimates of detection probability, spawning life, or hatchery fraction, or having sites that fall out of the sample due to landowner denial or physical inaccessibility result in a biased sample.	Our panel design has helped us to absorb restrictions in effort due to budget cuts. A decade of observations on annual panels and three-year panels allowed us to estimate values for three-year panel sites when we had to curtail our sampling effort.

APPENDIX H – PST BACKGROUND PRESENTATION

Use of Chinook Escapement or Terminal Run Estimates in PST Assessments

June 23
Chuck Parken

Outline

- Objectives
- Pacific Salmon Treaty (PST) Assessments
  - Escapement evaluations
  - Chinook model calibration
- Chinook model stock summaries
- Summary

Objectives

- Review key uses of escapement or terminal run data in the context of the annual PST assessment process for escapement indicator stocks & Chinook model stocks
- Improved understanding of the current WCVI data & how it compares to what it could be

Why so much attention for WCVI stock?

- Very large 'driver' stock
  - big part of catch in NBC & SEAK
- CDFO concerned poor status for decades
  - Canadian fisheries restricted since 1996
- Conservation of WCVI & other stocks were the basis for reductions under the 2009 PST Agreement
  - Sentinel Stocks Program with \$2M/yr to improve escapement estimates

Escapement Indicator Stocks

- What is an escapement indicator stock?
  - Each natural stock group has one or more locations where spawning escapement is monitored annually
  - Escapement indicator stocks are used to make inferences about the stock group as a whole

Escapement Evaluation

- Escapement is compared to an escapement objective each year
  - e.g. S_{MSY} or other biologically-based objective
  - Provides an insight about stock status
- Fisheries can have decision rules or obligations that depend on the outcome of the escapement evaluations for escapement indicator stocks & stock groups

WCVI Escapement Indicator Stocks: Current Approach

- Locations: Marble, Tashish, Artlish, Kaouk, Tahsis, Burman, Gold
  - Gold →dropped since mainly Robertson Hatchery strays
- Current methods
  - Accuracy:
    - Concerns about whether the method is demonstrably accurate
  - Precision:
    - No measures of precision generated

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Desired Approach for WCVI Escapement Indicator Stocks

- CTC has 2 data standards for estimating spawning escapement
  - Individual estimates of total spawning escapement for a stock should on average attain an estimated coefficient of variation of 15% or less
  - Specific estimates of escapement shall be delivered with demonstrably asymptotically accurate methods
    - i.e. methods that produce unbiased estimates

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Chinook Model Stocks

- What is a model stock?
  - Each model stock should represent one or more Chinook salmon stocks that share:
    - a common geography
    - life history
    - maturation schedule
    - patterns of ocean distribution
    - patterns of exploitation

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Chinook Model Stocks

- Chinook model uses terminal run or escapement data, along with other information, during the model calibration
- Model calibration estimates the cohort sizes, which are used to estimate Chinook abundance indices for fisheries
- Agencies use Chinook model information to develop annual fishing plans

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Escapement/Terminal Run Data Characteristics

1. Data for each age or the total for all ages
   - Age-specific data provides better representation of individual cohorts & fishery contributions
2. Escapement or terminal run can be an absolute abundance or relative abundance index
   - Absolute abundance measure
     - high accuracy (preferred)
   - Relative abundance index
     - Bias due to the escapement method used or because <100% of the area is surveyed

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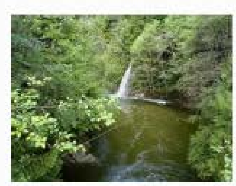
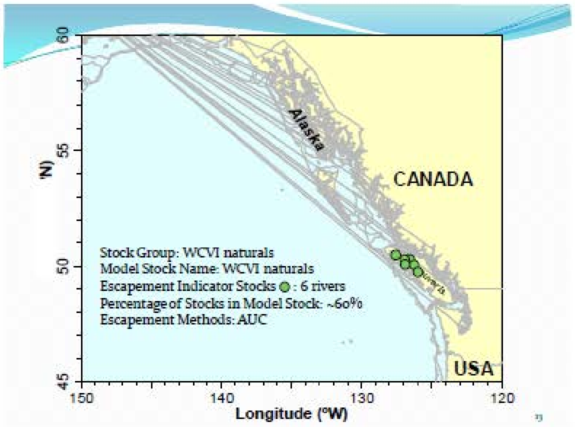
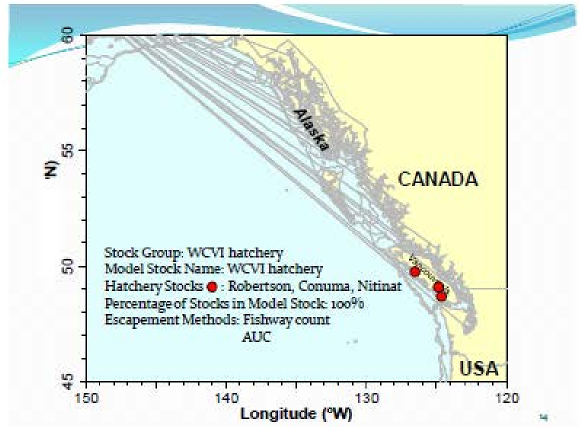
CTC Stock Group Summaries

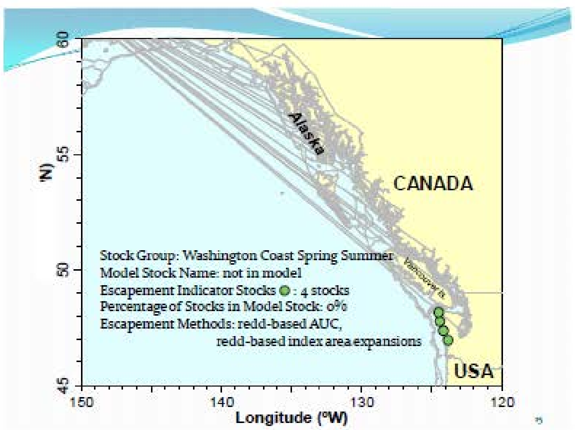
- 42 stock groups & 30 model stocks
- Coverage:
  - % of stock group locations included in the model stock
- Methods:
  - How are the escapements estimated?

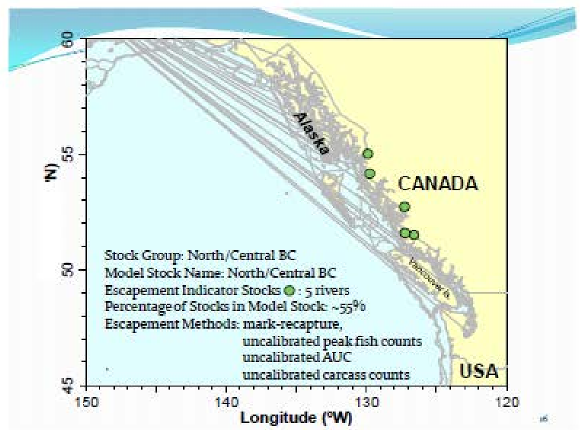


12

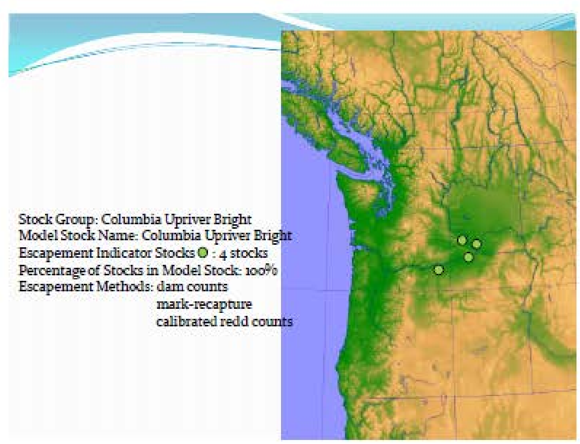

Alaska
CANADA
USA
Stock Group: WCVI naturals
Model Stock Name: WCVI naturals
Escapement Indicator Stocks : 6 rivers
Percentage of Stocks in Model Stock: ~60%
Escapement Methods: AUC
(°N)
60
55
50
45
150
140
130
120
Longitude (°W)


Alaska
CANADA
USA
Stock Group: WCVI hatchery
Model Stock Name: WCVI hatchery
Hatchery Stocks : Robertson, Conuma, Nitinat
Percentage of Stocks in Model Stock: 100%
Escapement Methods: Fishway count
AUC
(°N)
60
55
50
45
150
140
130
120
Longitude (°W)


Alaska
CANADA
Vancouver Is.
USA
Stock Group: Washington Coast Spring Summer
Model Stock Name: not in model
Escapement Indicator Stocks : 4 stocks
Percentage of Stocks in Model Stock: 0%
Escapement Methods: redd-based AUC,
redd-based index area expansions
(°N)
60
55
50
45
150
140
130
120
Longitude (°W)


Alaska
CANADA
Vancouver Is.
USA
Stock Group: North/Central BC
Model Stock Name: North/Central BC
Escapement Indicator Stocks : 5 rivers
Percentage of Stocks in Model Stock: ~55%
Escapement Methods: mark-recapture,
uncalibrated peak fish counts
uncalibrated AUC
uncalibrated carcass counts
(°N)
60
55
50
45
150
140
130
120
Longitude (°W)


Stock Group: North Oregon Coast
Model Stock Name: Oregon Coast
Escapement Indicator Stocks : 3 stocks
Percentage of Stocks in Model Stock: 100%
Escapement Methods: normative peak
count expansions


Stock Group: Columbia Upriver Bright
Model Stock Name: Columbia Upriver Bright
Escapement Indicator Stocks : 4 stocks
Percentage of Stocks in Model Stock: 100%
Escapement Methods: dam counts
mark-recapture
calibrated redd counts

CTC Stock Group Summaries: Coverage

Percentage of Stocks per Stock Group Included in CTC model	Number of Stock Groups
100%	21
75%-99%	5
50%-74%	6
25%-49%	2
0%	8
Total	42

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Escapement Data Quality

Type of Escapement	Number of Stock Groups
Absolute Abundance	16
Mix	11
Relative Abundance Indices	15
Total	42

Escapement Estimates	Number of Model Stocks
Age-specific	16
All Ages Combined	14
Total	30

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Summary

- Escapement indicator stocks & model stocks have different data quality requirements
  - →used for different objectives
- WCVI escapement indicator stocks
  - We should achieve the CTC data standards because of the value of WCVI stocks, their conservation status, & data are used for fishery obligations & stock status
- WCVI model stocks
  - We should be producing terminal run estimates that have high coverage & are unbiased, since data are used for fishery planning

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APPENDIX I – GROUP SESSION REPORT-OUT SHEETS

Sheet #1

Group Name: ______________________ Method:___________________________________

Record keeper: _____________________ Spokesperson: ____________________________

Breakout Group Report-out Sheet #1: Evaluation of the method for estimating the aggregate abundance for use on WCVI Chinook

Think about the following assessment criteria in your evaluation of the method for WCVI Chinook:

- Performance of method with respect to WCVI geography, populations or habitat
- Performance of method with respect to WCVI survey design
- Performance of method with respect to WCVI sampling protocols
- Assumptions and limitations
- Where does bias in the estimate come from?
- Does the method give an estimate of uncertainty
- Performance of method with respect to changes in funding and resources

Please write down the key points from your discussion on the following questions:

1. Describe why or why not you think this method is suitable given the existing survey and sampling protocols for WCVI Chinook? Would minor modifications make the existing survey and sampling protocols make the method work better? If so, please describe.

2. If the existing survey and sampling protocols for WCVI Chinook are not appropriate for the method you are considering, can you outline the key features of a monitoring program that would best suite this method (i.e. Where do you sample? How many sites? How often? How do you expand to the aggregate?).

Sheet #2

Group Name: ___________________________ Method: _______________________________

Record keeper: _________________________ Spokesperson: ________________________

Breakout Group Report-out Sheet #2: Desirable attributes of a method for estimating the aggregate abundance

Listed in the table below are 9 desirable attributes of a method for estimating the aggregate abundance. How well does the method you are evaluating achieve the desirable attributes for estimating the aggregate abundance of WCVI Chinook? Please put a checkmark in the box that describes how well the method achieves each of the desired attributes. If your group does not reach consensus on the ranking, please provide comments on the reverse.

Desirable Attributes for methods of estimating the aggregate abundance	The method achieves the desired attribute very well	The method achieves the desired attribute moderately well	The method does NOT achieve the desired attribute
The method generates estimates of escapement by age			
The method generates an estimate of the total escapement (all ages)			
The method generates estimates of terminal run (escapement plus terminal catch) by age			
The method generates an estimate of the total terminal run (all ages)			
The method generates a measure of precision (e.g. CV) for estimates of escapement or terminal run			
The method's assumptions can be tested (e.g. via targeted research)			
The method generates estimates that are unbiased (e.g. average error equals 0)			
The method generates estimates that are suitable for trend analysis			
The method can produce separate estimates for hatchery and natural components			