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Pacific Region

Canadian Science Advisory Secretariat
Science Advisory Report 2014/038

WEST COAST VANCOUVER ISLAND CHINOOK SALMON ESCAPEMENT ESTIMATION AND STOCK AGGREGATION PROCEDURES

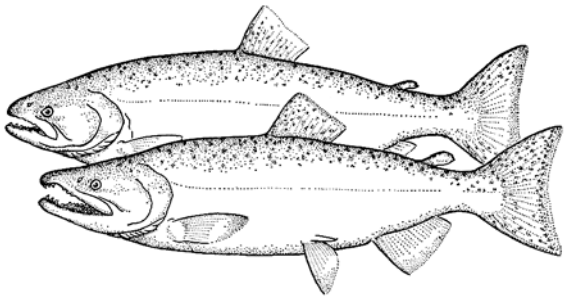

Image: Chinook Salmon (Oncorhynchus tshawytscha)

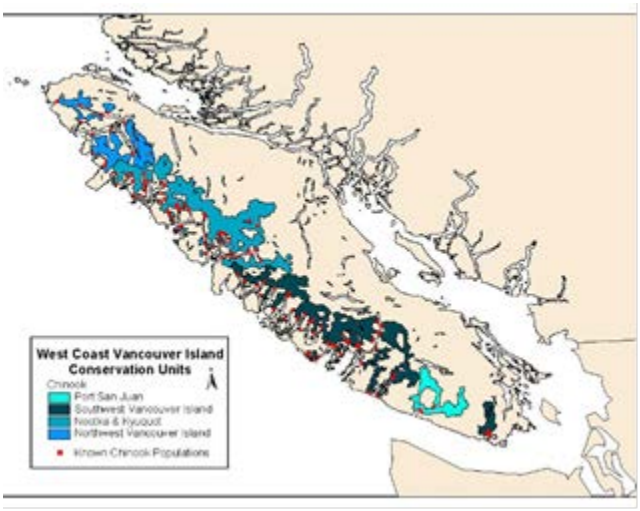

Figure 1. West Coast Vancouver Island Chinook Salmon Conservation Units and known spawning watersheds.

Context

Chinook salmon produced from the West Coast Vancouver Island (WCVI) make valuable and large contributions to fisheries ranging from the WCVI northward to South East Alaska. As part of the implementation of the Chinook Salmon Annex of the Pacific Salmon Treaty (PST), Canada is required to assess the escapement of 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 use in the Pacific Salmon Commission (PSC) 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 fishery management needs.

For the assessment of spawning abundance relative to escapement goals, periodic visual surveys are used to estimate escapement of WCVI Chinook Salmon extensive indicator stocks. The application of this method has been evaluated and improved through recent studies funded under PST Sentinel Stocks and Endowment Fund Programs. 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 was held to i) evaluate the escapement estimation methodology used to evaluate the abundance of WCVI extensive indicator stocks relative to escapement targets, and ii) recommend methods for estimating an annual aggregate escapement or appropriate surrogate for the entire management unit.

This Science Advisory Report is from the June 18-20, 2013, West Coast Vancouver Island Chinook Salmon Escapement Estimation and Stock Aggregation Procedures Regional Peer Review. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Canada is required to assess the escapement of West Coast Vancouver Island (WCVI) PST extensive indicator stocks relative to escapement goals annually and estimate the abundance for the entire WCVI Chinook salmon management unit as part of the implementation of the Chinook Salmon Annex of the Pacific Salmon Treaty (PST). Similar assessments of individual stocks and aggregate stock groupings are required to implement Canada's Wild Salmon Policy and meet other domestic management needs
- Periodic visual surveys are used to estimate escapement of WCVI Chinook salmon extensive indictor stocks. A Canadian Science Advisory Secretariat (CSAS) Regional Peer Review was held to i) evaluate the escapement estimation methodology used to evaluate the abundance of WCVI extensive indicator stocks relative to escapement targets, and ii) recommend methods for estimating an annual aggregate escapement or appropriate surrogate for the entire management unit.
- The periodic visual survey methodology was evaluated to assess the validity of the method considering biological, distributional and logistical factors specific to WCVI Chinook salmon, the ability of the methods to produce a measure of uncertainty and the potential for bias in the survey procedure.
- This review concluded that the current application of the method to estimate stream escapement does not provide estimates of uncertainty. Several sources of uncertainty and bias were identified, including the estimation of observer efficiency, survey life, the frequency of site visits and the identification of peak counts.
- Approaches for investigating the sensitivity of the estimates of escapement to these biases, as well as approaches for the evaluation of the bias and the development of correction factors were identified. Refinements of the Area-Under-the-Curve (AUC) and Maximum Likelihood (ML) estimation models, data inputs, and further development of both estimation models, as well as thorough documentation of protocols and analytical methods, are recommended.
- Given the further analysis and revisions required to provide advice on the validity of the current visual survey method, it was recommended that these initiatives be completed and the technical document resubmitted for peer review.
- Four methods of estimating aggregate salmon escapement were presented by contributors that have been used to assess Chinook and coho salmon in other spawning areas in B.C., as well as Alaska and Oregon. When these methods were evaluated by the scale and specific management objectives of WCVI Chinook salmon, elements of the Generalized Random Tessellation Stratified (GRTS) and the habitat based methods were identified that could improve the current WCVI methodology. It was also recommended that the fishery-based method be applied, giving an estimate of aggregate abundance independent of the visual escapement estimates, and results compared to the estimate based on visual surveys.

BACKGROUND

Estimates of escapement (i.e. the population that escaped harvest and returned to spawn in freshwater habitat) are a critical component of the stock assessment data that informs salmon management. These estimates are used to understand the productivity of the population, assess the stock status, establish harvest limits, forecast production, and evaluate harvest strategies. As part of the annual 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) Chinook salmon stocks in order to forecast production and evaluate stock status. Similar assessments of individual stocks are required to implement Canada's Wild Salmon Policy and meet other domestic fishery management needs, such as managing and evaluating terminal fisheries in the WCVI area.

Determining the status of a group of populations managed as a unit, such as WCVI Chinook salmon, involves the use of multiple assessment methods and data sources. For WCVI Chinook salmon, and most other BC salmon species, a system of 'intensive' and 'extensive' indicator stocks are used to assess stock status and fishery impacts and provide recommendations for harvest management. Intensive indicator stocks describe the marine distribution, exploitation and survival rate patterns for populations within a management unit that have a similar life history and distribution. Extensive indicator stocks provide a gauge of spawner distribution across the management unit, and are used to broadly monitor the conservation objective of maintaining heterogeneous stock structure and a wide spatial distribution to spread risk of spawning over a broad range of environmental conditions.

Since 1995, escapement estimates for the extensive indicator stocks monitored for WCVI Chinook were generated, for the most part, using periodic visual surveys of spawners expanded for observation efficiency and average 'survey life' (the period which Chinook are present in the survey area) of fish using the trapezoidal Area-Under-the-Curve (AUC) method. The use of the AUC method to date has not included an evaluation of the statistical uncertainty of the estimates and the application of the survey and analytical methods. As well, the assumptions used to apply the AUC method have not been documented.

The PST Sentinel Stocks Program (SSP) and Southern Endowment Fund Program provided funding to conduct studies to evaluate the application of the AUC method. In addition, alternative methods have been developed under the SSP to estimate aggregate abundance of management units. As a result of this recent work, a Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) was 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.

ASSESSMENT

WCVI Extensive Indicator Stock Survey Methodology

The current extensive indicator monitoring program was established with the objective of establishing consistent survey and analytical methods to estimate escapement for WCVI Chinook salmon indicators. On the WCVI, the periodic visual survey method involves snorkel teams counting the number of fish in the known spawning areas, typically from an upstream barrier or access point downstream to the tidal boundary. Surveys are ideally conducted every 5 days for a total of 6 to 8 surveys over the spawning season, although weather and water conditions often impede this schedule. About 15-18 streams 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.).

Starting in 1995, a trapezoidal AUC method was used to generate escapement estimates for individual populations; however, the parameters for observer efficiency and survey life were not measured but were imputed. The survey life (SL) appears to be reasonable when compared to values reported in the literature. However, observer efficiencies (OE) were based on crew self-evaluations, which are likely too high based on both OEs that were measured (through tagging studies) and estimated (through modelling). There is a high degree of variation in estimated OE among survey dates and evidence of deterioration in OE conditions over the duration of many

surveys. 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 appeared to vary among years.

Two methods were applied to the historical data to allow for the estimation of uncertainty in the escapement estimates; a revised AUC model and a Maximum Likelihood (ML) model. Principal components analysis was also used to evaluate the variation of physical parameters related to observer efficiency and survey life among survey systems, but the results did not suggest an obvious pattern that could be applied for survey stratification.

It was concluded that the assessment of the escapement estimation methodology used to evaluate the abundance of WCVI index stocks requires further analysis before a determination of its appropriateness for the intended application and confidence in the estimates of uncertainty can be confirmed. Several specific recommendations were made, including:

- Integrating all DFO and non-DFO WCVI Chinook salmon survey data into the re-analysis;
- Examination of the key assumptions OE and SL with the intention of developing bias correction techniques;
- Further development and documentation of the AUC and ML models, including sensitivity analysis, and;
- A retrospective analysis.

Finally, it was also recommended that a thorough description of the sampling protocols and models is completed to ensure consistency and transparency in the methods used to generate these estimates.

Estimating Aggregate Escapement

The current method for estimating the aggregate index of abundance is to sum the escapement estimates of the intensive and extensive indicator stocks with terminal catch. The trends in abundance observed in these populations are used to index the status of other populations within the assessment unit. While only 15-18 stocks of more than 100 Chinook bearing streams on WCVI are assessed, these populations (including hatcheries) are estimated to represent about 90% or more of the total production. If an annual escapement estimate is missing from one of the regular index stock, the value is estimated based on the average trend observation from other stocks.

The following four methods for estimating the aggregate abundance of WCVI Chinook salmon were evaluated at the workshop after participants were provided with an overview of each method:

1. WCVI Chinook Indicator Stream Index- Diana Dobson, DFO (The current index method used on WCVI Chinook salmon)
2. The Generalized Random Tessellation Stratified (GRTS) sampling design - Julie Firman, ODFW (The spatially-balanced statistical sampling design used to assess spawning abundance of Oregon coho salmon)
3. The fishery-based method – Josh Korman, Ecometric (The fishery-based method using Genetic Stock Identification (GSI), Coded Wire Tags (CWT) and scales with a Bayesian model to estimate terminal run size of WCVI Chinook salmon)

4. The habitat-based method –.Bob Bocking, LGL Limited (The habitat capacity model to expand survey data to estimate spawning abundance of coho salmon in areas of the Nass River)

Evaluation factors included:

- Assumptions and limitations of the method;
- Potential for bias in the method;
- Survey and sampling protocols required to estimate of aggregate escapement;
- Method for estimating uncertainty; and,
- Performance of the method under various survey conditions, population or habitat characteristics, funding and resource levels.

Individual participants rated the methods for i) most potential for use on WCVI Chinook salmon, and ii) second most potential for use on WCVI Chinook salmon. The results are shown in Table 1.

Table 1. Totalled votes for methods with the most, and second most, potential for estimating the aggregate spawning abundance of WCVI Chinook salmon.

	WCVI Index method	**GRTS method**	**Fishery-based 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

Participants agreed that there is potential for improving the current method to estimate escapement and produce aggregate escapement estimates by incorporating elements from GRTS and the habitat based methods. This assumes that issues of bias and estimation of uncertainty in the method to estimate individual escapements in index streams are resolved. Participants also agreed that the fishery based method could be used to compare with the current index method; although the fishery based method also has limitations.

Sources of Uncertainty

- The number of surveys in a stream per year affects precision and accuracy (i.e. low precision and accuracy expected with few and/or infrequent surveys);
- Imputing parameter values for survey life and observer efficiency affects accuracy;
- Misidentification of species during surveys affects accuracy (e.g. when many salmon species are present on spawning grounds);
- Limited spatial coverage of spawning grounds during surveys affects accuracy (i.e. when only a portion of the accessible spawning length used by the population is surveyed);
- Size of spawning population affects accuracy (i.e. small populations may be hard to count when fish are rare, whereas estimation error is introduced when counting large populations and high densities are observed).
- Sampling affects precision of the estimate of WCVI aggregate escapement.

CONCLUSIONS AND ADVICE

This CSAS Regional Peer Review process convened to i) evaluate the escapement estimation methodology used to assess the abundance of WCVI extensive indicator stocks and ii) recommend methods for estimating an annual aggregate escapement or appropriate surrogate for the entire management unit. Participants reviewed a technical document presented on the WCVI index stock survey methodology and, using an expert workshop format, proposed and evaluated multiple approaches for estimating the annual aggregate escapement of WCVI Chinook salmon. The conclusions and advice from these two undertakings are described below.

WCVI Extensive Indicator Stock Survey Methodology

The periodic visual survey methodology was evaluated to assess the validity of the method considering biological, distributional and logistical factors specific to WCVI Chinook salmon, the ability of the methods to produce a quantification of uncertainty and the potential for bias in the survey procedure. In addition, the descriptions of the survey and sampling protocol were evaluated for thoroughness and clarity.

Several sources of uncertainty and bias were identified, including the estimation of observer efficiency, survey life, the frequency of site visits, and where surveys coincided with the temporal peak of the abundance. Approaches for investigating the sensitivity of the estimates of escapement to these biases, as well as approaches for the evaluation of the bias and the development of correction factors were identified. Specifically, an analysis to compare and verify the modeled estimates (AUC/ML) of escapement with independent estimates of escapement from tagging or other studies was recommended. Refinements of the Area-Under-the-Curve and Maximum Likelihood estimation models, data inputs and further development of estimation models are also recommended.

Deficiencies were identified in the current visual survey method, including the clarity and detail in the documentation of survey and sampling protocols. Additionally, recommendations were made for the collection of additional data related to environmental variables and survey conditions that will assist in developing independent estimates of observer efficiency. There were also technical recommendations to use logistic regression to account for the precision of the observer efficiency measurements by considering the number of radio tagged fish available.

Given the further analysis and revisions required to provide advice on the validity of the current survey method, it was recommended that these be completed and the technical document resubmitted for peer review.

Estimating Aggregate Escapement

Presentations on various methods of estimating aggregate salmon escapement were made from contributors that assess Chinook and coho salmon abundance in other spawning areas in B.C. and Oregon. Peer review participants evaluated the methods in the context of WCVI Chinook salmon stocks in small break-out groups, each representing a range of expertise and backgrounds. Plenary discussion provided the opportunity to discuss and synthesize findings.

Participants advised that there is potential for improving the current method to estimate escapement and produce aggregate escapement estimates by incorporating elements from GRTS and the habitat-based methods. It was emphasized that the approach taken would depend on the scale and the specific management objective. It was also recommended that the fishery-based method be applied, giving an estimate of aggregate abundance independent of the visual escapement estimates, and results compared to the estimate based on visual

surveys. Evaluation of the each method's assumptions will be important for the comparison of estimates between methods.

Next Steps

The review participants recognized the importance and value of undertaking the evaluation of the visual survey method for estimating WCVI Chinook salmon stocks needed for domestic and international commitments. It was also highlighted that this evaluation and the further analyses recommended has broader applicability to other stocks and species in the Pacific Northwest.

Moving forward, three immediate initiatives are recommended:

1. Publication of the DFO and non-DFO WCVI Chinook salmon escapement survey data and environmental data.
2. Conducting the recommended analyses for river and year specific escapement estimates, as outlined to refine the visual survey escapement estimation methodology.
3. Using the discussion and considerations for improving the estimation of the aggregate abundance to develop and document a statistically-based design for the WCVI Chinook salmon escapement assessment framework which includes estimates of uncertainty.

SOURCES OF INFORMATION

This Science Advisory Report is from the June 18-20, 2013, West Coast Vancouver Island Chinook Salmon Escapement Estimation and Stock Aggregation Procedures Regional Peer Review. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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