Fraser Chinook Run Reconstruction Review

Executive Summary

1. Run Reconstruction has value as a tool to track catch and escapement trends in-river but the current procedure has some issues with assumptions and uncertainty. All fishery accounting models/tools have some level of uncertainty, which needs to be considered when using the outputs. Conclusions from the Run Reconstruction should appropriately consider the uncertainty for future fishery management plans.
2. Currently the Run Reconstruction has a substantial influence guiding fishery management, in particular Spring 4_2, Spring 5_2 and Summer 5_2 through the Fisheries Mortality index (FMI). These are the MUs that are managed at small percentage or index points of mortality. We feel the Run Reconstruction tracks large-scale changes and trends in mortality of each MU, but is not robust enough to identify small differences in mortality.
3. When comparing the Run Reconstruction outputs against potential source of uncertainty, we feel that uncertainties are likely large enough to influence the interpretation of the FMI when evaluating fishery management results for Spring 4_2, Spring 5_2 and Summer 5_2 against the current objectives. While it's likely that fishery mortalities have been reduced in the 2019-2023 period compared to the 2014-2018 base period, it's difficult to confidently quantify how much they have been reduced, whether the reduction is adequate to allow recovery and rebuilding and if priority for First Nations fisheries is being met.
4. This means that given the uncertainties it's not possible to confidently distinguish the relative impacts among sectors within a given year for Spring 4_2, Spring 5_2 and Summer 5_2 (for example, the 2022 Summer 5_2 FMI of 3.9% in the recreational fishery vs. 5.0% in First Nations fisheries). We also cannot say with confidence whether there is a difference in mortalities among years where estimates only vary by a few percentage points (for example, the Summer 5_2 total FMI of 10.2% in 2022 vs. 14.8% in 2021).
5. When developing fishery management objectives, the FSMB should consider other information equally to the FMI for MUs where management objectives are focused on conservation, and distribution of mortalities across limited fisheries (Spring 4_2, Spring 5_2 and Summer 5_2).
6. Uncertainties may be reduced and/or better understood by making improvements to the Run Reconstruction procedure, such as more and better escapement programs, external review as part of the annual process, re-developing the procedure in a probabilistic framework, and pairing with an in-season run size estimation program to validate results. It should be recognized that uncertainty will exist in Fraser salmon fisheries management data sources for the foreseeable future.

Background

1. The Fraser Chinook Run Reconstruction (RR) procedure is an accounting method used to determine run size at the mouth of the Fraser River for the five Fraser Chinook Management Units (MUs). The Run Reconstruction procedure was initially developed in 2005, with the associated paper authored in 2007 by English et al.
    a. The tool is a boxcar-type accounting method using weekly time steps that first uses escapement records for 84 Fraser Chinook spawning stocks, and sequentially

accounts for progressive losses downstream to the Fraser River mouth. Chinook fishery removals estimated via catch monitoring programs are assigned to one of several stocks that are expected to contribute to those fisheries, and account for the majority of fresh water fisheries in the Fraser River mainstem and tributaries down to Area 29 (First Nations, science/test, recreational, commercial).

   b. "Reliability of the run size estimates depends on the accuracy of the input data and validity of model assumptions" (see English et al. 2007). There is a need to determine the reliability of the input data and the model assumptions used in the most recent version of the RR procedure.
   c. There have been periodic updates to the RR procedure since 2007 (initial publication) by DFO Stock Assessment staff, but there has not been a rigorous peer-review of the changes made since then.
2. Some of the RR procedure limitations were partly investigated during the Chinook five year review (see Dobson et al. 2020) to identify potential areas of uncertainty and how it affects the outputs. For the five year review, estimates of marine Chinook fishery mortalities were added to the RR outputs, and this concept was later applied to compute the Fisheries Mortality Index (FMI) that has been used since 2021 to track fishery management performance annually. Considering the importance of the RR procedure in tracking Fisheries Management Performance, understanding the procedure's limitations and influence of those limitations on the interpretation of outputs is important.
3. Infilling for the RR is done to fill data gaps concerning stock-specific escapements and fishery removals. The infilled escapement inputs for the RR are produced using the average proportion a system makes up within a stock management unit applied to the applicable year's estimated escapement for the stock management unit. Escapement estimates have improved since 1979-1998 when the average number of streams within an MU that were infilled ranged from 26.5% to 35.3%, which accounted for an average of 0.4% to 43.8% of the total escapement estimate (and for many streams the escapements were altogether unknown). However, the reliability and accuracy of infilled records is not known with certainty despite the fact they could substantially influence the outputs. The current scope of infilling based on the RR input files since 1999 is summarized in Tables 1 and 2; of note:
   a. Up to 40% of Fraser Chinook streams within an MU (Spring 4_2 and Summer 5_2) are infilled in any given year, accounting for up to 31% of the total escapement within an MU (Summer 5_2).
   b. Summer 5_2 Chinook infilling averaged 19% (range 4%-40%) of streams, accounting for an average 14.2% (range 0.2%-30.7%) of the total escapement estimate for the MU.
4. Catch and effort monitoring programs produce the other required input to the RR procedure. The JTC has not yet reviewed available information on the reliability and completeness of the annual monitoring processes, however it is known that when data are lacking, some catch estimates have greater uncertainty or bias. There are also differences in the catch methodology and subsequent results depending on the fishery type (FSC, recreational, commercial, scientific/test), location, and annual resource availability.

Model Uncertainties

1. The RR is a largely deterministic procedure that provides no estimates of variance to gauge the reliability of various outputs. The use of probabilistic RR procedures is needed to provide estimates of uncertainty, which is currently not in part of the process.
2. There is a reliance on visual survey methods for most of the Fraser Chinook escapement programs, which may not fully cover known spawning areas or may have low accuracy depending on environmental features of the area. Climate change impacts to glacial systems are also reducing the ability to operate visual survey programs, which can result in additional need to infill if alternative methods are not able to be implemented. The proportion of fence counts (programs with close to 100% detection efficiency) for Fraser Chinook is very low (~1% of total escapement estimate). All escapement estimation methods produce estimates with differing levels of uncertainty that are not reported and/or accounted for when generating outputs using those data. Table 3 has a breakdown of the methods used in 2023 for escapement inputs to the RR procedure.
3. There is insufficient verification of the RR outputs, especially for tributary-specific escapements based on infilling and/or subject to survey deficiencies.
4. Regardless of data quality, escapement data inputs are considered as having equal weight. A probabilistic model can set data quality to be weighted so inputs with lower uncertainty are considered differently than inputs with high uncertainty.
5. Migration rates and residence time assumptions haven't been regularly verified or updated. Recent programs like the Big Bar monitoring program provide some usable information, however the program was limited in scope and specific to a migratory barrier, which could confound the results.
6. The RR procedure does not account for en-route mortality, except for certain discrete events subject to additional monitoring (e.g., Big Bar slide, Bonaparte Fishway collapse). As harmful environmental conditions become more prevalent, en-route mortality should be accounted for in the newer version of the RR procedure.
7. Catch data inputs for the RR should be further investigated. We acknowledge the presence of uncertainty and bias in catch monitoring inputs to influence the RR results.
    a. When focusing on Spring 4_2, Spring 5_2 and Summer 5_2 the total fishery mortality is low compared to the escapement, and likely a smaller influence on uncertainty than escapement data.
8. Release mortality from fisheries is not accounted for in the RR procedure.
9. Chinook salmon encountered in fisheries are considered as being equally vulnerable to capture. Gear restrictions that are now commonplace in Chinook fisheries affect the selectivity of some of the largest in-river Chinook fisheries, but changes in body size and stock specific vulnerability to fisheries is not considered.
10. The Chilliwack Summer 5_2 data is a component of uncertainty we have investigated in a separate memo (2024-06), and also applies here.

Interpretation of Uncertainty

1. FMI estimates based on the RR procedure outputs should consider the uncertainties mentioned above. It is plausible that the uncertainty is sufficient to seriously affect the interpretation of whether or not quantitative fishery management objectives for Spring 4_2,

Spring 5_2 and Summer 5_2 that focus on conservation, escapement and distribution of mortalities in limited fisheries have been met.

2. Determining whether a fishery management plan has met fishery objectives at low levels of mortality is confounded by the amount of uncertainty expected in the RR outputs, in particular for the Spring 4_2, Spring 5_2 and Summer 5_2 MUs.

Recommendations

1. When developing fishery management objectives, the RR should not be considered in isolation. The FSMB should consider other information equally for MUs where management objectives are focused on conservation, rebuilding and distribution of mortalities in limited fisheries (Spring 4_2, Spring 5_2 and Summer 5_2).
2. Address the key aspects of the RR uncertainties:
    a. Support escapement programs for Fraser Chinook with near 100% detection efficiency wherever possible (e.g., fence counts). Expand the use of mark-recapture escapement programs in areas where fence count operations are not possible or logistically unrealistic. Reduce the reliance on visual escapement programs. This is critical in particular for Chinook stocks that contribute to Spring 4_2, Spring 5_2 and Summer 5_2 MUs. JTC will continue to review with DFO Stock Assessment staff and develop recommendations for priority systems to improve.
    b. Inclusion of additional and more accurate and precise spawning surveys would help provide a much clearer picture of annual returns and the spawning stock composition of various Fraser Chinook populations (e.g. sex ratio, spawning success, condition, length/size).
    c. Escapement programs should be developed to produce estimates on infilled stocks and wherever possible eliminate the need for infilling.
3. External review of the annual operations that provide data input to the RR procedure, potentially through an FSMC technical process (JTC or JTWG). This should include external review of updated scalars or annual changes when proposed (e.g., migration rates and residence times).
4. Structured peer-review of the updated RR procedure that has been ported to R statistical software, which can be aided by fulsome documentation of what was updated, discrepancies between versions, description of the equations and infilling procedures used, and assumptions made. At minimum, JTC or members of the JTC are planning to review.
5. Explore developing a new RR procedure in a probabilistic framework to provide the ability to include quantitative metrics on uncertainty. Ensure new process can account for the magnitude of error associated with various catch and escapement estimates used.
    a. The FSMC-JTC has identified a Maximum Likelihood bio-statistical model used in Alaska for Bristol Bay Sockeye that could potentially make better use of all the data available to DFO, including estimates of stock contribution to various fisheries based on single nucleotide polymorphisms (SNPs) analysis of catch bio-samples (see Cunningham et al. 2017).
6. The updated RR could be paired with an in-season run size estimation program to provide additional annual data on run size and timing of MUs in addition to the benefits of in-season

information on Fraser Chinook. Both the RR and an in-season run size estimation program could benefit from the other program.

Tables

Table 1. Proportion of streams infilled in Management Unit

1979-1998	**Spring 4_2**	**Spring 5_2**	**Summer 5_2**	**Summer 4_1**	**Fall 4_1**
Average	26.5%	35.3%	30.0%	31.1%	33.3%
Minimum	0.0%	12.5%	16.0%	11.1%	0.0%
Maximum	40.0%	44.6%	52.0%	44.4%	66.7%
1999-2023					
Average	3.2%	14.7%	18.7%	10.2%	13.3%
Minimum	0.0%	7.1%	4.0%	0.0%	0.0%
Maximum	40.0%	25.0%	40.0%	33.3%	33.3%

Table 2. Proportion of total escapement estimate infilled in Management Unit

1979-1998	**Spring 4_2**	**Spring 5_2**	**Summer 5_2**	**Summer 4_1**	**Fall 4_1**
Average	5.5%	43.8%	7.4%	11.5%	0.4%
Minimum	0.0%	8.0%	0.5%	10.7%	0.0%
Maximum	32.6%	62.2%	14.0%	23.8%	0.7%
1999-2023					
Average	0.9%	9.2%	14.2%	3.5%	0.1%
Minimum	0.0%	3.9%	0.2%	0.0%	0.0%
Maximum	7.7%	23.8%	30.7%	10.8%	0.4%

Table 3. 2023 Summary of escapement counts by methods reported in the 2023 Fraser Chinook Run Reconstruction by MU.

	Fence (% total)	Mark-Recap. & Visual 5+ surveys (% total)	Visual <4 and Unknown/Other (% total)	*Total*
Spring 4_2	5,207 (46%)	4,482 (40%)	1,319 (14%)	*11,318*
Spring 5_2	1,940 (11%)	412 (2%)	14,968 (87%)	*17,320*
Summer 5_2	0 (0%)	7,310 (36%)	13,180 (64%)	*20,483*
Summer 4_1	0 (0%)	78,233 (12%)	563,012 (88%)	*641,245*
Fall 4_1	0 (0%)	146,498 (64%)	81,509 (36%)	*228,015*
Total	*7,156 (1%)*	*237,245 (26%)*	*673,979 (73%)*	*918,380*

References

Cunningham, C.J. T.A. Branch, T.H. Dann, M. Smith, J.E. Seeb, L.W. Seeb and R. Hilborn. (2017). A general model for salmon run reconstruction that accounts for interception and differences in availability to harvest. Can. Jour. Fish. Aquat. Sci. 75(1): 1-13. DOI:10.1139/cjfas-2016-0360.

Dobson, D., Holt, K. and Davis, B. 2020. A Technical Review of the Management Approach for Stream-Type Fraser River Chinook. DFO Can. Sci. Advis. Sec. Res. Doc. 2020/027. x + 280 p.

English, K., Bailey, R.E., Robichaud, D. 2007. Assessment of chinook salmon returns to the Fraser River watershed using run reconstruction techniques, 1982-04. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/020. x + 76 p.