Fisheries and Oceans Canada
Pêches et Océans Canada

Ecosystems and Oceans Science
Sciences des écosystèmes et des océans

Pacific Region

Canadian Science Advisory Secretariat
Science Advisory Report 2019/056

TECHNICAL REVIEW OF STREAM-TYPE FRASER RIVER CHINOOK MANAGEMENT APPROACH

Figure 1. Chinook Salmon adult spawning phase. (Photo credit: Fisheries and Oceans Canada.)

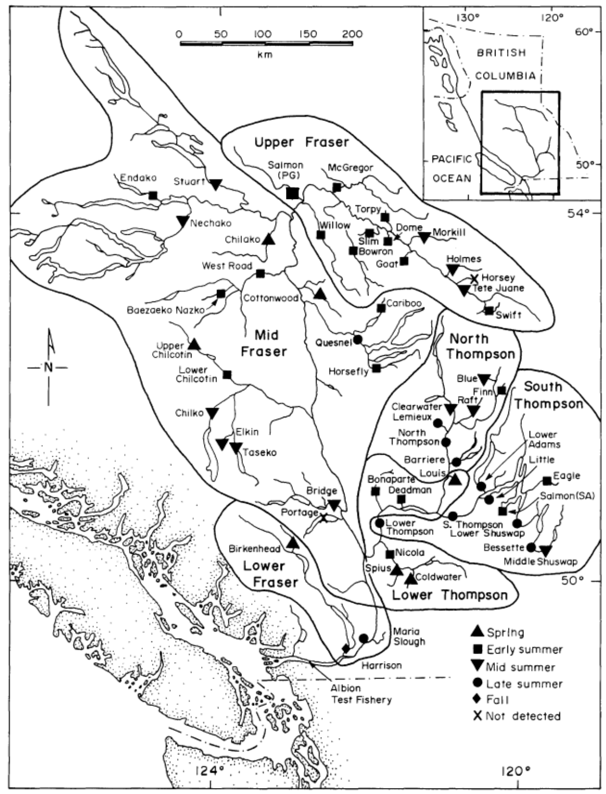

Figure 2. Locations of Chinook Salmon populations within six regional reporting groups in the Fraser River watershed, British Columbia, and their migration periods (Parken et al. 2008).

Context:

From 2008 to 2017, Fisheries and Oceans Canada (DFO) implemented a series of fisheries closures and restrictions to protect the three stream-type stock management units of Fraser River Chinook Salmon (Spring 4_2, Spring 5_2 and Summer 5_2). Initially aimed at protecting the Spring 4_2 stock management unit, the fisheries closures and restrictions were expanded in 2010 and again in 2012 to confer additional protections to the two remaining stock management units. DFO committed to reviewing the management approach after five years. For this purpose, a two-phase process was established to assess whether the approach had achieved its intended conservation and allocation objectives consistent with An Allocation Policy for Pacific Salmon *(1999).*

Under Phase 1 of the process (and the subject of this regional peer review), DFO Fisheries Management requested that DFO Science Branch complete a technical review of the data and methods available to assess fisheries impacts on stream-type Fraser River Chinook Salmon from all fishing sectors. The results of this review will be used to inform subsequent consultative discussions on DFO's *management approach for Fraser River stream-type Chinook Salmon under Phase 2 of the process (which is not part of this regional peer review).*

This Science Advisory Report is from the July 9-10, 2019 regional peer review on the Technical Review of Fraser River Chinook Management Approach. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Conservation concerns for three stream-type Fraser River Chinook Salmon Stock Management Units (SMUs; Spring 4_2, Spring 5_2 and Summer 5_2) led to implementation of a series of fisheries closures and restrictions that were initiated in 2008, then expanded in 2010 and again in 2012. The 2012 management measures were outlined in a letter written by the Regional Director General for DFO's Pacific Region to First Nations and stakeholder groups (referred to as the '2012 RD Directive').
- As part of the 2012 management measure implementation, a two-phase process was established to review DFO's management approach for stream-type Fraser River Chinook Salmon to determine whether the approach had achieved its intended conservation and allocation objectives consistent with *An Allocation Policy for Pacific Salmon* (1999). Phase 1 provides a technical review of the data and methods available to assess the fisheries impacts resulting from the management measures on stream-type Fraser River Chinook Salmon and is the subject of this review.
- Data were compiled from technical reports and Fraser-area stock assessment programs to examine trends in escapement, biological properties and annual exploitation rates. Fishery- and sector-specific exploitation rate indices for each SMU were estimated via two approaches for allocating fishery catch to SMU: the first approach used coded wire tag (CWT) data, and the second used an updated Run Reconstruction model supplemented with genetic stock identification (GSI) information for marine fisheries. The latter approach was used as a basis for evaluating management performance relative to management objectives taken from the 2012 RD Directive.
- A sensitivity analysis of the Run Reconstruction approach was conducted to investigate the potential effects of uncertainty in assumptions or systematic biases in data inputs on resulting estimates of management performance. An uncertainty analysis was used to demonstrate the extent to which the magnitude of uncertainty in data inputs and parameters affected the level of uncertainty in resulting model outputs.
- Results show that all three stream-type SMUs exhibited depressed escapement in recent years, and consistent declines over the last four years. There is also preliminary evidence of recent declines in size-at-age for some populations within SMUs which may, if the changes continue, affect selectivity of fisheries and the potential effectiveness of size-based management measures.
- Estimated fishery- and sector-specific exploitation rate indices based on the Run Reconstruction approach show that, while it is *possible* that overall reduction targets for exploitation rates on Spring and Summer 5_2 Chinook were met, considerable uncertainty in the input data and model assumptions precludes a definitive conclusion at this time. In particular, existing assumptions around fishing-related incidental mortality (FRIM) rates (that were used in this analysis) may underestimate the true impacts of FRIM, which could lead to an underestimation of total mortality.

- Results show that reductions to First Nations fisheries were likely higher than intended, while recreational and commercial reductions were likely lower than intended. However, results showed that when random error was introduced to input data and model parameters, measurement of the distribution of 'harvest impacts' (which includes both landed catch and fishing related incidental mortality) among sectors was highly uncertain, even for the low uncertainty scenario. This result was especially true for recreational and commercial sectors that relied on GSI sampling of marine catch composition.
- While the objectives of this process were deemed to have been met (as stated in the Terms of Reference), several items were identified as future work to improve subsequent iterations of these analyses. In particular, the need for a more rigorous assessment of fishery- and sector-specific FRIM impacts (identified during a previous Canadian Science Advisory Secretariat (CSAS) process) was highlighted, as was the need for an integrated modelling framework for estimating fishery-specific exploitation rates from both in-river and marine fisheries. Other areas for future investigation include: incorporating a cumulative effects approach to the sensitivity analyses (rather than assessing each factor singly); improved run timing information; further work to improve GSI baselines and stock identification to the SMU level; consistent annual sampling of fishery catch (for both CWT recoveries and GSI samples); and, a more comprehensive estimation of uncertainty around exploitation rate estimates, including stock assignment error when using GSI methods.
- It was recognized that this type of analysis would benefit from improved documentation and transparent availability of data and assessment methods, as well as routine publication of this information in citable sources and retrievable databases.

BACKGROUND

From 2008 to 2017, Fisheries and Oceans Canada implemented a series of fisheries closures and restrictions to protect the three stream-type stock management units of Fraser River Chinook Salmon (Spring 4_2, Spring 5_2 and Summer 5_2). Initially aimed at protecting the Spring 4_2 stock management unit, the fisheries closures and restrictions were expanded in 2010 and again in 2012 to confer additional protections to the two remaining stock management units. These measures affected fisheries in the Fraser River and throughout southern British Columbia, particularly in key migration corridors such as southwest Vancouver Island, Juan de Fuca and the Strait of Georgia. While harvest opportunities were reduced for all sectors including First Nation fisheries, the intent was to implement a management approach whereby the majority impact of the conservation measures would be borne by recreational and commercial fisheries.

Through this management approach, DFO attempted to reconcile multiple objectives; namely, how to meet conservation needs while prioritizing First Nation Food, Social, Ceremonial (FSC) access and still provide stability for other fisheries. The approach was documented in a letter written by the Regional Director for DFO's Pacific Region Fisheries Management Branch to First Nations and stakeholder groups. In the letter, DFO outlined management objectives related to the distribution of harvest reductions among sectors and committed to reviewing the approach after five years of implementation (referred to as the '2012 RD Directive'). A two-phase process was subsequently established to assess whether the approach has been achieving its intended conservation and allocation objectives consistent with An Allocation Policy for Pacific Salmon (1999)[1].

[1] Note: at time of writing, this policy is under review.

This report presents results of Phase 1 of the review process and were completed by a Joint Technical Working Group (JTWG), including biologists from Fraser River First Nation organizations and DFO. The JTWG focused the review on what was considered to be the primary purpose: to evaluate whether or not the management approach achieved the conservation and allocation objectives as set out in the 2012 RD Directive. The data, evaluations, and recommendations presented in this technical review are intended to inform Phase 2 of the review process.

ANALYSIS

Data relevant to the technical review was compiled along with comprehensive descriptions of key uncertainties associated with each data set. Fishery and sector-specific ‘harvest impacts’ (which includes both landed catch and fishing related incidental mortality) were estimated using available data and modelling tools. Sensitivity analyses were used to investigate the potential effects (magnitude and direction) of key sources of bias in both the input data and model assumptions on estimated harvest impacts. In addition, an uncertainty analysis was conducted to assess the impact of introducing variability to the input data and model parameters, where possible.

Data and Methods

Where available, detailed data on spawner abundances, marine survival, length-at-age, and age composition were obtained from stock assessment programs and presented in tabular and graphic formats to inform an evaluation of changes in escapement and biological properties. Fishery catch, release, effort, and stock composition data were also compiled to estimate catch and release mortalities at the Stock Management Unit (SMU) level. All fishery data and resulting SMU-level estimates were presented in tabular format.

Harvest impacts were quantified as fishery- and sector-specific exploitation rate indices (ERIs) based on a subset of Canadian fisheries for which data were available for most years between 2009 and 2018 (Table 1). Two approaches were used to derive ERIs. The first approach used coded wire tag (CWT) recovery data from indicator stocks compiled for the Pacific Salmon Commission Chinook Technical Committee’s Exploitation Rate Analysis (ERA), while the second approach combined the annual Fraser River Chinook Run Reconstruction Model (English et al. 2007) with GSI catch composition from marine fisheries. Release mortality and drop-off mortality were incorporated into ERIs for both the CWT and Run Reconstruction estimation approaches. In the CWT approach, release and drop-off mortality was accounted for using rates applied by the Pacific Salmon Commission’s Chinook Technical Committee, while in the Run Reconstruction approach, slightly different values obtained from a literature review were used. In both cases, estimates represented only short-term mortality. Medium and long term impacts were not represented.

The results of the Run Reconstruction approach were used to evaluate management outcomes relative to the objectives described in the 2012 RD Directive. Only the Run Reconstruction approach was used for this evaluation because there are no current CWT indicator stocks for either the Fraser Spring 5_2 or Summer 5_2 SMUs.

A Sensitivity Analysis was conducted on the Run Reconstruction approach to examine the extent to which systematic biases in input data or incorrect assumptions affected estimated quantities of interest. The JTWG identified 26 scenarios to represent key sources of uncertainty, or concerns, about the input data and/or assumptions used in the Run Reconstruction model (Table 2).

An Uncertainty Analysis was also conducted using Monte Carlo simulations to demonstrate the extent to which hypothetical levels of uncertainty in data inputs and parameters affected the level of uncertainty around estimated ERIs and performance measures related to the allocation of harvest reductions among sectors. Scenarios representing three levels of uncertainty (low, medium and high) were applied to each of the variables of interest.

Three metrics were used to assess the impacts of both the Sensitivity Analysis scenarios and Uncertainty Analysis on the estimated quantities of interest.

1. Annual SMU-level estimates of ERI;
2. The proportion of catch attributed to each fishery sector in recent years; and
3. Sector-specific estimates of the relative change in ERIs between the 2009-2011 period and recent Zone 1 years (2013, 2016, 2017), where Zone 1 is defined in the 2012 RD Directive.

This choice of metrics aligned with those used in the performance evaluation of the management objectives specified in the 2012 RD Directive.

Results

Trends in Biological Properties

Spawner abundances for all three stream-type Fraser River Chinook Salmon SMUs remain low. At an aggregate level, all three SMUs show depressed escapement in recent years compared to long-term averages and consistent declines over the last four years. Escapement levels in 2018 were the lowest since 1995 for all three SMUs (Figure 3).

For SMUs with size-at-age data for select component populations, there is preliminary evidence of recent declines in annual length-at-age measurements for some, but not all, populations. If a declining trend in length-at-age is confirmed, concerns will arise about the potential effect of these changes on stock productivity, the potential for reduced effectiveness of size-based management restrictions over time, and the potential impact of size-selective fisheries (i.e., ‘high-grading’ of catch).

Recent smolt-to-adult survival rates for the Nicola Spring 4_2 CWT indicator stock have been very low, averaging 1.3% over the last 5 brood years (Figure 4). Preliminary estimates of smolt-to-adult survival from the 2015 brood year—the most recent complete brood year estimate available—is 0.65%. Comparable smolt-to-adult survival rate estimates for the Spring 5_2 and Summer 5_2 Chinook SMUs are not presently available.

Trends in Exploitation Rate Indices

Data was available to support estimation of ERIs for indicator stocks from two SMUs using the CWT approach: the Spring 4_2 Nicola River indicator stock (1995 – 2018) and the Spring 5_2 Dome Creek indicator stock (1995 to1998, 2001 to 2003, and 2005). Consistent GSI sampling from marine fisheries started in 2009, which allowed estimation of ERIs using the Run Reconstruction approach for all three SMUs for the years 2009 – 2018. At the SMU level, ERIs estimated for the Spring 4_2 SMU using the Run Reconstruction approach showed similar patterns to these obtained using the CWT approach applied to the Nicola indicator stock, but were typically higher (Figure 5). A linear model fit to ERI estimates from the two methods produced an R^2 value of 0.59, indicating that the linear relationship explained 59% of the variation between the two methods. Comparisons between the two methods could not be made for the Spring 5_2 or Summer 5_2 SMUs.

Table 3 shows the time series of estimated ERIs by fishery sector for each of the three stream-type Fraser Chinook SMUs based on the Run Reconstruction approach. These estimates were used as a basis for evaluating management performance relative to the 2012 RD Directive.

Evaluation of the 2012 RD Directive Objectives

Management performance relative to objectives taken from the 2012 RD Directive are summarized as follows, where “Zone 1 years” are those in which the combined Spring 5_2 and Summer 5_2 return abundance to the Fraser River was expected to be less than 30,000. Note that the objectives listed here have been paraphrased; a complete description is available in Appendix A of the associated research document.

2012 RD Directive Objective 1: *When in Zone 1, reduce exploitation rates on Fraser River Spring 5_2 and Summer 5_2 Chinook by a minimum of 50% from the 50–60% exploitation rates in the early 2000s (resulting in an overall exploitation rate of less than 30%).*

Spring 5_2 and Summer 5_2 ERIs in recent Zone 1 years (2013, 2016, and 2017) were estimated to have decreased relative to the rates experienced by these SMUs prior to 2012 (Table 4). Based on an approximation of the degree to which the estimated ERIs represented total exploitation rates (using available CWT data from indicator stocks), it is possible that the Total ERs on these SMUs averaged less than 30% in Zone 1. Note that considerable uncertainty in the data inputs and assumptions required for this analysis prevent a definitive conclusion (e.g., it is quite plausible that the estimates for fishing related incidental mortality (FRIM) used in this assessment underestimate the full impact of FRIM over the medium and long term, ultimately leading to underestimation of exploitation rates).

2012 RD Directive Objective 2: *When in Zone 1, distribute the exploitation rate reductions such that the recreational and commercial sectors have a greater overall reduction than First Nations.*

Overall, this analysis suggests that Objective 2 was unlikely to have been achieved; however, considerable uncertainty exists in this conclusion. Reductions in harvest impacts on Spring 5_2 and Summer 5_2 Chinook for First Nations FSC fisheries were higher than those estimated for both recreational and commercial sectors (Table 4). Sensitivity analyses highlighted that measurement of sector-specific changes in exploitation rates such as these are highly uncertain, especially due to sampling variance associated with low GSI sample sizes. The recreational and commercial fisheries included in the ERI calculations had large uncertainty associated with them (owing to their small and variable impact). It was noted that aggregating the recreational and commercial fisheries to the same extent as the Fraser FSC fishery (which consists of at least 26 component FSC fisheries) would likely decrease the variance in ERI estimates associated with these fisheries.

2012 RD Directive Objective 3: *First Nations fishing for food, social and ceremonial purposes will have priority over other uses and will be provided the majority of the available fishery exploitation.*

For all three stream-type Fraser River Chinook Salmon SMUs, aggregated First Nations FSC fisheries took a larger proportion of total annual catch than recreational or commercial sectors, based on the Canadian fisheries included in the ERI estimates. Between 2012 and 2018, First Nations FSC fisheries took an average of 74.1% of Spring 4_2, 51.5% of Spring 5_2, and 40.6% of Summer 5_2 landed annual catch, respectively. Based on these estimates, it was noted that First Nations FSC fisheries only took the majority of the catch (defined as greater than 50% of the catch) for two of the three SMUs, suggesting that Objective 3 was not fully met.

2012 RD Directive Objective 4: *Increase the proportion of the Fraser River Spring 5_2 exploitation rate that is taken by the First Nations FSC fishery*.

The proportion of harvest impacts attributed to First Nations FSC fisheries remained relatively unchanged for Spring 4_2 Chinook between the three-year period prior to the implementation of the 2012 RD Directive (2009-2011) and after implementation (2012-2018); however, FSC fisheries accounted for a smaller portion of harvest impacts on Spring 5_2 and Summer 5_2 Chinook in recent years compared to the earlier time period, thus not meeting Objective 4. Sensitivity analyses on the impact of uncertainty on the distribution of harvest impacts among sectors highlight that these proportions are highly uncertain, even under the low variability scenario.

Sources of Uncertainty

In this analysis, parameterization of release mortality only included short-term impacts. As a result, the full impact of fishing-related incidental mortality (FRIM), including medium- and long-term mortality impacts, was not represented in either the base case or sensitivity scenario results. For example, the potential impact of water temperature on FRIM was omitted from the scenarios. Increasing fresh water temperatures has been identified as an exacerbating factor leading to increased FRIM rates (Patterson et al. 2017). While a full characterization of FRIM was identified as being beyond the scope of this review work, its exclusion does raise questions about the representativeness of the ERIs generated through this analysis. It is suspected that a more comprehensive representation of FRIM impacts in the analysis would lead to higher ERIs.

Sensitivity analyses based on the Run Reconstruction approach showed that, among on the range of scenarios considered (Table 2), results were most sensitive to:

- assumptions of equal fishery vulnerability of all SMUs within the Run Reconstruction model;
- peak spawning date;
- the abundance ratio used to split Spring 5_2 and Summer 5_2 catch composition estimates for Northern BC recreational and commercial fisheries;
- biases in escapement data (these data are typically biased low, but vary in magnitude among years); and
- high levels of en route mortality in a single year.

Note that the list of scenarios tested and values used to inform the model run were not empirically derived (e.g., through a literature search or a formal expert elicitation process). As such, the scenarios presented were intended to demonstrate examples of model sensitivity rather than an exhaustive analysis of all possible sources of bias and their relative impacts.

When random error was introduced to the Run Reconstruction model through the uncertainty analysis, estimates of management performance became highly uncertain, even for the low uncertainty scenario. This result was especially true for recreational and commercial sectors that relied on GSI sampling of marine catch composition. Uncertainty in run reconstruction data inputs and model assumptions also contributed to increased uncertainty in annual ERIs for in-river fisheries.

Uncertainty in GSI allocations of marine catch and releases to specific SMUs (including sub-legal releases) were omitted from the uncertainty analysis. This omission was identified as a key area for future investigation.

CONCLUSIONS AND ADVICE

While results from the Run Reconstruction analysis show that it is possible that overall reduction targets for exploitation rates on Spring 5_2 and Summer 5_2 Chinook were met, considerable uncertainty in available data, including estimates of FRIM, precludes a definitive conclusion at this time. Similarly, fine-scale objectives related to sector-specific exploitation rates and the allocation of impacts among sectors identified in the 2012 RD Directive cannot be effectively evaluated at this time given the data systems in place.

Establishing clearly-defined and measurable stock and fishery objectives for stream-type Fraser Chinook Salmon that represent desired management outcomes (e.g., rebuild stock to a given level over a specified time period) rather than a desired management response (e.g., reduce exploitation rates) is recommended. These “rebuilding”-type performance objectives could help guide future management responses and allow for more transparent evaluation of management performance.

Future Work

While the objectives this process were deemed to have been met (as stated in the terms of reference), several items were identified as future work to improve subsequent iterations of these analyses and are noted below.

Closed-loop feedback simulations, possibly within the context of a First Nation and stakeholder supported Management Strategy Evaluation (MSE), could be used to support rebuilding efforts for the stream-type Fraser River Chinook Salmon SMUs by providing insights into the impacts of various harvest strategies on the probability of achieving rebuilding goals.

More robust evaluations of fishery-specific impacts from both marine and freshwater fisheries could be developed through the use of an integrated forward stock-depletion model that uses maximum likelihood estimation to fit multiple datasets from both in-river and marine fisheries.

It is recommended that plans to analyze GSI samples collected at the Albion test fishery be fully supported along with the incorporation of this information into the Fraser Run Reconstruction model to inform annual run timing. Further work to improve GSI baselines and stock identification to the SMU level will help support the utility of consistent, annual GSI sampling in fisheries impacting stream-type Fraser River Chinook Salmon SMUs.

It is recommended that efforts be coordinated across all fisheries sectors to improve sampling rates and representativeness of catch, release and effort data (i.e., to improve quality of information obtained from both CWT recoveries and GSI sampling). For example, it was recommended that efforts to improve recreational fisheries catch, release and effort estimates be supported, such as through increased Creel surveys, and further development of logbook programs and the iREC survey. Additionally, collecting GSI samples from both retained and released catch could help determine if management measures such as slot size are effective in limiting retention of stocks of concern in all relevant fisheries.

Estimates of released catch and fishery-specific rates of fishing-related incidental mortality (FRIM) are highly uncertain for both marine and in-river fisheries. It is recommended that work be undertaken to apply the risk assessment approach developed by Patterson et al. (2017) to develop more detailed estimates of fishery-specific FRIM.

More comprehensive escapement monitoring (i.e., reduce the need for infilling of time series, surveying more stocks, increasing the number of accurate estimates, calibrating existing low precision time series, etc.) will improve confidence in escapement estimates and resulting estimates of harvest impacts via the Run Reconstruction Model. However, it is recommended that decisions about the level of effort afforded to increase escapement monitoring be made in the context of the level of precision needed to guide decision-making relative to management objectives.

The overall assessment and decision-making process for stream-type Fraser Chinook would benefit from improved documentation and transparency of data and assessment methods, as well as routine publication of this information in citable sources and retrievable databases (such as through the Government of Canada's Open Data Portal or the Pacific Salmon Foundation's Pacific Salmon Explorer). This work would also include well-defined responsibilities for data managers, as is intended through a regional data management strategy (currently in development).

It is recommended that a comprehensive review of available data be undertaken to identify priority areas for improvement within the decision-making context (i.e., to identify key data gaps and align them with the data needs of the management framework).

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SOURCES OF INFORMATION

This Science Advisory Report is from the July 9-10, 2019 regional peer review on the Technical Review of Fraser River Chinook Management Approach. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Chinook Technical Committee (CTC). 2018. Annual report of catch and escapement for 2016 membership of the Chinook Technical Committee. TCCHINOOK (18)-02.

Patterson, D.A., Robinson, K.A., Raby, G.D., Bass, A.L., Houtman, R., Hinch, S.G., and Cooke, S.J. 2017. Guidance to Derive and Update Fishing-Related Incidental Mortality Rates for Pacific Salmon. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/011. vii + 56 p.

APPENDIX A

Table 1. Fisheries included in the Exploitation Rate Indices. Fisheries excluded from the index include: Georgia Strait Recreational, Johnstone Strait Recreational, and all United States fisheries (i.e., all recreational, commercial and First Nations fisheries from Alaska, and Washington State).

Fishery Location	Fishery Name
In-River Fisheries	Fraser FSC
	Fraser Recreational
	Fraser Economic Opportunity (EO)
	Fraser Commercial (in-river portions of Area 29E (Gillnet) and Area 29B (Seine)
	Fraser Test Fisheries (Albion, Qualark)
Marine Fisheries	Juan de Fuca Recreational
	West Coast Vancouver Island Recreational
	Northern British Columbia Recreational
	West Coast Vancouver Island Commercial Troll
	Northern BC Commercial Troll
	T’aaq-wiihak

Table 2. Description of sensitivity analyses used to test concerns about potential biases in input data and model assumptions.

Concern	Test description	Sensitivity analysis name
Underestimation of releases from JDF recreational fishery due to assumption that the composition of released catch is equal to that of landed catch	Increase the number of releases from Spring 52 and Summer 52 MUs by 20% and 60%	Releases: JDF Rec 20 Releases: JDF Rec 60
Underestimation of releases from Fraser River commercial fisheries due to missing data	Increase the total mortality from Fraser River commercial fisheries by 10%	Total Mort: Fraser Comm
Underestimation of releases from Fraser River recreational fisheries due to missing data	Increase the total mortality from Fraser River recreational fisheries by 10%	Total Mort: Fraser Sport
Underestimation of released catch from Fraser River FSC fisheries due to missing data	Increase the total mortality from Fraser River FSC fisheries by 10%	Total Mort: Fraser FSC
Release mortality rates are highly uncertain. Values used in salmon IFMPs provide an alternative set of values to be considered.	Apply release mortality estimates from the salmon IFMP to all fisheries (see research document Table 10-7 for values)	Release Mortality: IFMP
The Run Reconstruction Model attributes in-river catches to individual spawning stocks based on fixed peak spawning dates that are held constant over time. Despite strong assumptions about peak spawn dates, there is considerable uncertainty around these values.	Move peak spawn date 7 days forward and 7 days backward for all spawning sites within a specified MU.	Spring 4.2 Timing Spring 5.2 Timing Summer 5.2 Timing
The duration of spawn timing, which is used in the Run Reconstruction Model to spread escapement over time, are fixed values that are held constant over time. Despite strong assumptions about spawning duration values, there is considerable uncertainty around these values.	Change spawn duration so that it is 10 days shorter or 10 days longer for all spawning sites within a specified MU.	Spring 4.2 Duration Spring 5.2 Duration Summer 5.2 Duration
Given concerns about declining body size, it is possible that age 4 fish from the Spring 42 MU have become less vulnerable to Fraser In-river fisheries in recent years	Reduce the percentage of Spring 42 abundance that is vulnerable to all in-river Fraser fisheries by 20%	Vulnerability: Spring 4.2

Concern	Test description	Sensitivity analysis name
Escapement estimates from the Summer 52 MU require more infilling of missing values than Spring 42 and Spring 52 MUs, which could potentially cause systematic biases in estimated escapements	Change escapement values for all Summer 52 stocks in the run reconstruction so that they are 20% higher or lower in all years	Escapement: Summer 5.2
Splits in catch composition between Spring 52 and Summer 52 MUs for Northern BC troll and NBC recreational fisheries are based on the annual ratio of return abundance to the Fraser River for these MUs, as estimated by the RR model. This assumption cause biases in estimated catch and releases	Change ratio of Spring 52 to Summer 52 abundance that is used to divide catch composition among these two MUs to be 20% higher or 20% lower in all years	NBC Abundance Ratio
In 2018, the fishway on Bonaparte River (Spring 42 MU) did not facilitate fish passage, resulting in an escapement estimate of 8 fish. It is uncertain whether fish that were unable to pass experienced en route mortality or moved to a nearby spawning site. The RR model cannot account for en route mortality, and therefore ER estimates may have been affected.	Increase Bonaparte escapement in 2018 to test the impact of en route mortality on exploitation rate estimates for co-migrating stocks. Two different Bonaparte escapement levels are tested: (i) 211 fish (Lo) and (ii) 1,970 fish (Hi).	Bonaparte 2018: PS Mort Low Bonaparte 2018: PS Mort High

Table 3. Time series of Run Reconstruction-based estimates of ERIs by fishery sector for each of the three stream-type Fraser Chinook SMUs. Highlighted rows (2013, 2016, 2017) show recent Zone 1 years.

Year	Spring 4_2				Spring 5_2				Summer 5_2			
	FN	Rec.	Comm.	Test	FN	Rec.	Comm.	Test	FN	Rec.	Comm.	Test
2009	30.88%	14.32%	3.27%	0.75%	20.86%	8.73%	3.96%	0.88%	12.48%	9.18%	3.92%	1.24%
2010	21.48%	1.65%	1.48%	1.24%	14.80%	3.13%	4.29%	1.34%	9.53%	3.44%	5.48%	1.18%
2011	28.37%	5.26%	1.90%	0.65%	20.64%	5.73%	3.97%	0.81%	22.22%	6.43%	4.84%	1.13%
2012	22.04%	3.27%	0.57%	0.52%	18.72%	8.61%	5.55%	0.59%	25.46%	8.65%	4.06%	1.10%
2013	11.56%	7.05%	0.05%	0.66%	8.52%	6.37%	2.98%	0.84%	6.48%	10.38%	2.77%	1.00%
2014	17.97%	2.35%	3.09%	0.74%	11.47%	6.26%	4.73%	1.04%	10.10%	5.15%	7.88%	1.12%
2015	15.76%	4.68%	3.91%	0.80%	8.97%	7.93%	3.44%	1.01%	5.39%	5.03%	2.93%	1.11%
2016	15.95%	4.92%	1.85%	0.63%	11.07%	4.34%	6.29%	0.88%	6.44%	11.40%	6.11%	1.38%
2017	17.11%	5.28%	1.56%	0.52%	10.41%	7.30%	8.18%	0.57%	7.30%	8.42%	9.57%	0.55%
2018	32.50%	3.86%	1.50%	0.78%	20.07%	6.69%	3.82%	1.01%	23.15%	6.60%	21.20%	1.00%

Table 4. Average change in the Run Reconstruction Model exploitation rate index (ERI) between the three years prior to the implementation of the RD Directive (2009 – 2011) and recent Zone 1 years (2013, 2016, 2017).

Sector	Spring 4_2	Spring 5_2	Summer 5_2
FSC	-44.7 %	-46.7 %	-54.3 %
Recreational	-18.7 %	2.4 %	58.5 %
Commercial	-47.9 %	42.8 %	29.6 %
Total	- 39.6 %	-24.0 %	-11.4 %

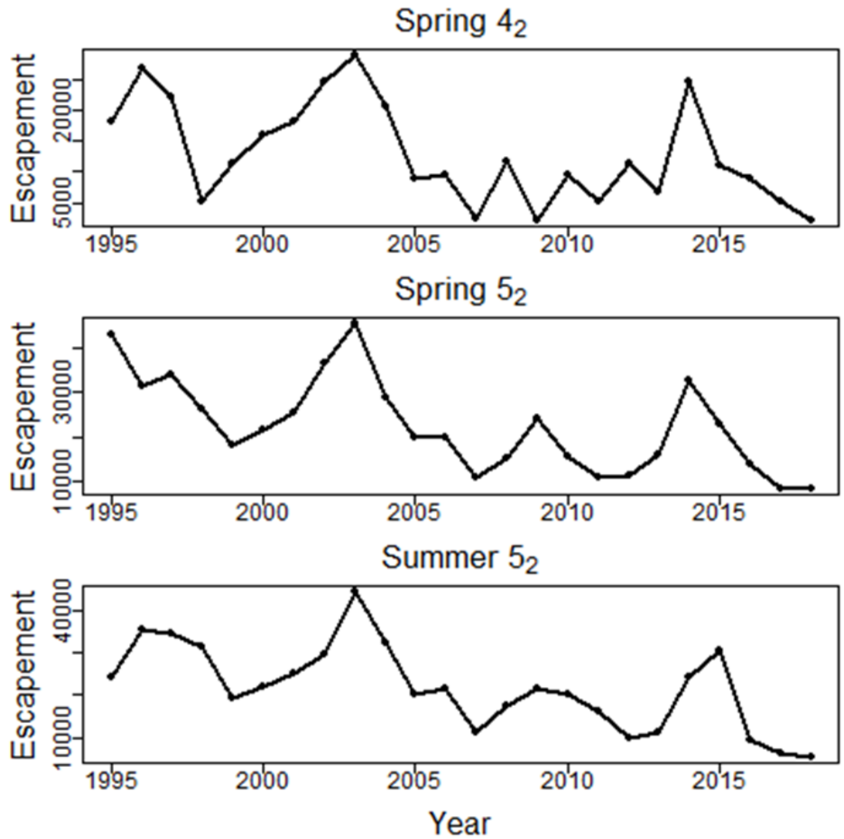

Figure 3. Escapement time series for Spring 4_2, Spring 5_2 and Summer 5_2 SMUs, respectively. Time series data is based on the data set compiled annually by the PSC Chinook Technical Committee (ref).

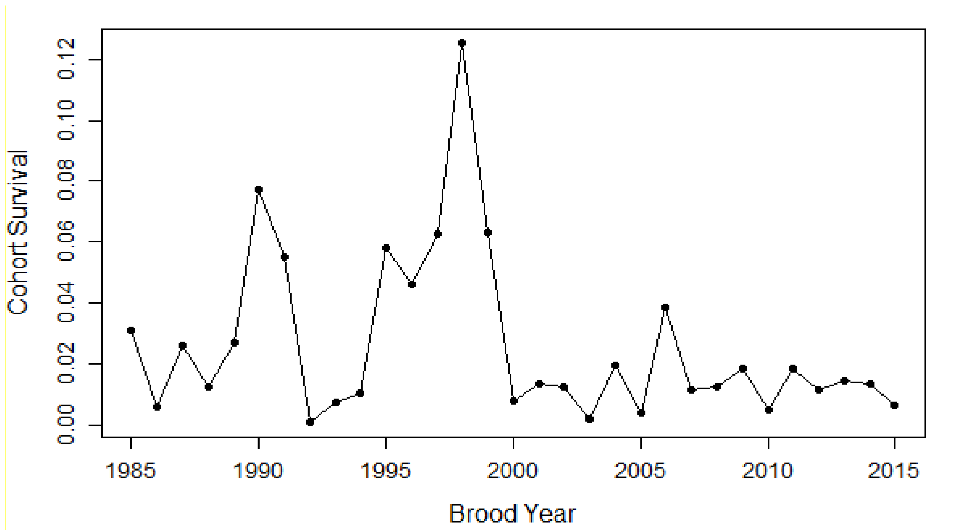

Figure 4. CWT-based estimates of cohort smolt-to-adult survival for Spring 4_2 Chinook (Nicola indicator stock), 1985–2015 brood years.

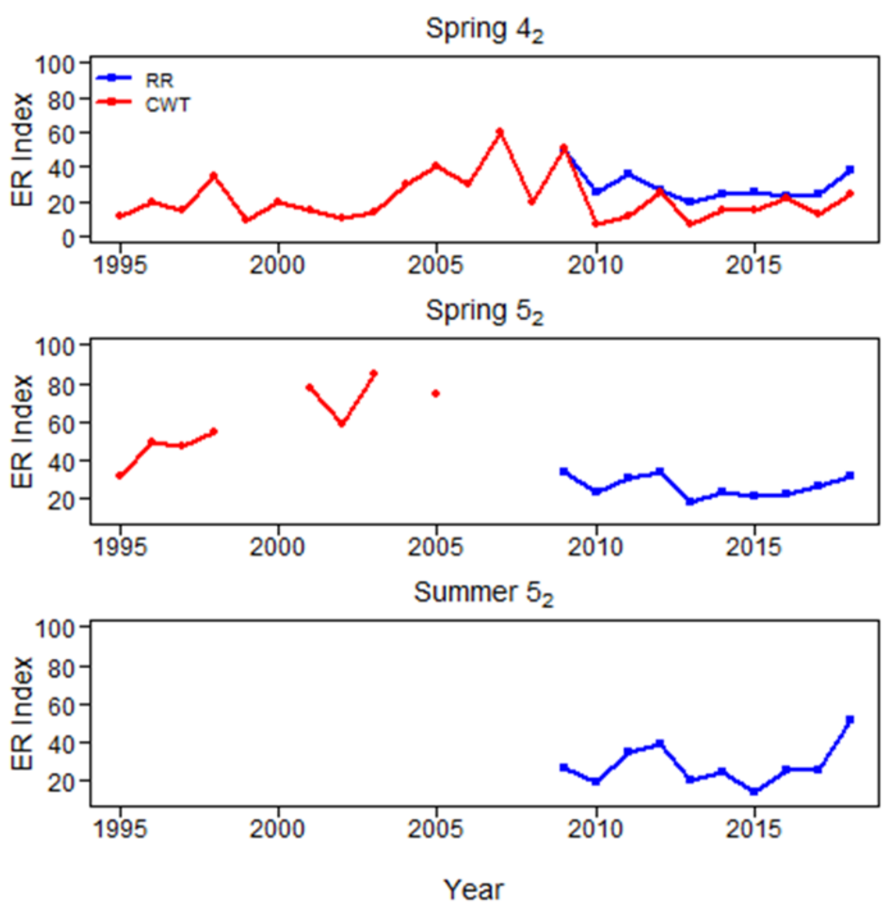

Figure 5. Exploitation rate indices for the three Fraser River stream-type Chinook SMUs developed using the Run Reconstruction Model and CWT approaches to ER Estimation.

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ISSN 1919-5087

Correct Citation for this Publication:

DFO. 2019. Technical Review of stream-type Fraser River Chinook Management Approach. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/056.

Aussi disponible en français :

MPO. 2019. Examen technique de la méthode de gestion du saumon quinnat du fleuve Fraser de type fluvial. Secr. can. de consult. sci. du MPO, Avis sci. 2019/056.