# Excerpt from Estimating Aggregate Coho Salmon Terminal Run and Escapement to the Lower Fraser Management Unit 2020

# Methods

## Distant Fishery Mark-recapture Estimation

The LFC terminal run () will be estimated using a variation of the two-sample Petersen mark-recapture method (Petersen 1896, Seber 1982, Schwarz and Taylor 1998) in an innovative way that uses a distant fishery and terminal escapements as the different components in Equation 1.



This method requires that random, representative samples of the Fraser Coho Salmon run be collected via an assessment fishery conducted during the LFC migration into the Lower Fraser River. The assessment fishery will occur downstream of the confluence with potentially abundant LFC spawning rivers (e.g. Pitt, Coquitlam, and Brunette rivers) in the main channel of the Fraser River where all the LFC migrating to upstream locations can be sampled with equal probability (i.e., in the proximity of New Westminster, B.C.). There are two very minor spawning systems, Musqueam and Byrne creeks, which are not anticipated to be part of the study design population because they enter the North Arm of the Fraser River downstream of New Westminster, BC. Details of the assessment fishery (sample sizes, timing, etc.) are provided in Section 2.2.

For the distant fishery mark-recapture estimation method (Equation 1), the ‘catch’ () will be the total number of LFC encountered in the assessment fishery, and the ‘recaptures’ () will be the number of ‘marks’ encountered in the assessment fishery (see Driver Stock Ratio method in PSCSSC 2018). Note that every Coho Salmon encountered in the assessment fishery will fall into one of seven groups (Table 1, Figure 1), and that specific stock components will be identified through DNA, CWT, or otolith samples. For the purposes of this analysis, ‘recaptures’ () will include Coho Salmon from the ‘clipped Nicoman Slough’ ( where AFC = adipose fin clipped), ‘clipped Chilliwack’ (), and ‘unclipped Lillooet’ () groups. All other LFC will be considered as unmarked with Coho Salmon identified as Interior Fraser Coho through genetics excluded from the catch. And the total catch () will be the sum of LFC Coho Salmon from five of seven groups (i.e. the total catch () will exclude clipped and unclipped IFC). It is important to note that all AFC Coho will be destructively sampled while adipose present Coho will be released alive.

Careful accounting of fish in the marked population () is required to produce a non-biased estimate because any loss of marks between marking and recovery would result in an underestimate of population size. In this design, the number of marked individuals in the population () will be determined from escapement and sampling of fisheries, as



Specifically, will be estimated as the total number of individuals originating from three groups (denoted by subscript ): Chilliwack or Nicomen Slough hatchery-origin, or wild Lillooet Coho. For each group, we will sum the total number of individuals that were caught in the assessment fishery () (except Lillooet because they will be live released), returned to each river as escapement (), or that were harvested in fisheries () in the area between the assessment fishery and the escapement location (e.g., the confluence of the Chilliwack and Fraser rivers); and then add them together to calculate (Equation 2). Catch data from DFO and Aboriginal Fisheries Strategy (AFS) catch monitoring will be used to represent fishery removals between the assessment fishery and spawning tributaries, and stock composition data from these removals will be used to estimate values of . (i.e., ; ; ). Escapement data for Nicomen Slough () and Lillooet River () Coho will come from separately funded Southern Boundary Fund projects (Appendix A and Appendix B), while this project will estimate the Chilliwack hatchery Coho escapement () through a passive mark-recapture approach (see section 2.3).

Figure 1. Estimated ratio of Coho Salmon encounters at the proposed Fraser River assessment fishery site. Based on recent Coho Salmon hatchery releases and the Decay Model.

### Assumptions

The distant fishery mark-recapture estimation method makes two key assumptions. The first is that the assessment fishery will collect a random sample of the entire LFC run for the year and that the stock components measured in the assessment fishery will be representative of the population components in proportion to their true abundance. Therefore, it is important to have a temporally wide enough sampling window to capture the full run-timing distribution. The second assumption is that the assessment fishery will encounter a stock composition of LFC that is reasonably similar to that depicted in Figure 1, which is based on recent Coho Salmon hatchery releases and the Decay Model (C. Parken, pers. comm. 2020) for stock composition. This second assumption is critical for ensuring that our study design methods are sound and that the assessment fishery will generate adequate sample sizes of our target catch (see Appendix D) to produce a target precision estimate of LFC escapement (see Appendix C).

There are also two factors of the distant fishery mark-recapture estimation method that require additional attention. The first factor is that the marked populations may behave differently from each other that results in a different probability of capture at the assessment fishery over the sampling window. We can account for this by using a stratified Petersen estimator (Schwarz and Taylor 1998, Bonner and Schwarz 2011). The stratified Petersen estimator allows for capture probabilities of each marked population to be estimated independently across different temporal periods where we could identify differences in run-timing of each population. Section 2.3, the Chilliwack Passive Mark-Recapture, also uses a stratified Petersen estimator and describes its assumptions and solutions in more detail. The second factor is that the input values that go into the estimator are not certain counts, they are estimates. The current stratified Petersen estimators do not have a way to incorporate variance in their inputs. We account for this variance by using a bootstrap method that creates iterations of the input data based on their individual variances (Appendix C). The bootstrap method propagates the uncertainty of each estimate to the system estimate in a similar way as Bayesian Monte-Carlo algorithms do. However, it was noted (C. Schwarz, pers. comm. 2020) that a full Bayesian framework may be necessary if sample sizes are small or if input value variance is high. Alternative methods are being considered and are under development that utilize Bayesian frameworks where input values have uncertainty (McElreath 2018).

### Sampling Logistics

To identify stock components within the assessment fishery for a given year, several types of stock identification methods will be used (Table 1). AFC fish will be sampled for DNA, otolith marks, and examined for a CWT (destructive sampling). Chilliwack and Inch Creek (in Nicomen Slough) hatcheries contribute substantial hatchery production of LFC with Inch Creek Coho being the current CWT indicator stock. Non-lethal DNA samples will be collected for any adipose present (unclipped) Coho Salmon encountered to allow for genetic stock identification (GSI) and to identify fish as IFC, Lillooet-origin LFC or non-Lilloeet LFC. Unclipped Coho Salmon will be placed in an onboard revival tank and released back to the river. Since Chilliwack Coho Salmon will not be CWT’d, they will be identified via parental-base tagging (PBT) for 2021 and by otolith marking from 2022 onward. We expect that the counts of the different stocks in the assessment fishery will have some error associated with them based on CWT loss, clip condition/natural degradation of adipose fins, uncertainty in GSI, and other observation error. Error in the counts will be accounted for in the bootstrap method (Appendix C).

Table 1. Expected Coho Salmon catch composition and sample methods from the proposed Fraser River assessment fishery. Expected Catch Components are also shown in Figure 1. 1Other refers to populations that are non Chilliwack, Nicomen, or Lillooet origin. 2IFC = Interior Fraser Coho.

| Coho Samples in Catch | Expected Catch Component | Lethal or Non-Lethal Sampling | Detection Method |
| --- | --- | --- | --- |
| unclipped non-Lillooet LFC | 18% | non-lethal | GSI (Genetic Stock Identification) |
| unclipped Lillooet River | 21% | non-lethal | GSI |
| clipped other1 LFC | 19% | lethal | clip condition and GSI |
| clipped Chilliwack River | 22% | lethal | clip condition and PBT (2021), otolith (2022 and forward) |
| clipped Nicomen Slough | 5% | lethal | clip condition and CWT |
| clipped IFC2 | 3% | lethal | clip condition and CWT/GSI |
| unclipped IFC | 11% | non-lethal | GSI |

### Summary

This study design brings information together from existing escapement programs (Nicomen Slough and Lillooet), infrastructure (hatcheries), and processes (CWT fishery sampling and data management, and otolith marking), and synthesizes them into an overarching objective. Additionally, this method incorporates direct information on natural stocks and mitigates some concerns about hatchery stocks being unrepresentative of natural stocks due to their differences in biological attributes (e.g., migration timing for hatchery fish can vary from natural stocks where hatchery brood collection practices are non-random, such as those that collect brood stock only from the early part of the migration). Details on the various components of the distant fishery mark-recapture method for estimating LFC escapement are found in Section 2.2 and in the appendices of this document.