Data Gap Research associated with the Recovery Potential Assessment of Summer run Chinook, Nanaimo River, British Columbia, Canada

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DATA GAP RESEARCH ASSOCIATED WITH THE RECOVERY POTENTIAL ASSESSMENT OF SUMMER RUN CHINOOK, NANAIMO RIVER, BRITISH COLUMBIA, CANADA

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Baillie, S.J. (Ed.) 2024. Data Gap Research associated with the Recovery Potential Assessment of summer run Chinook, Nanaimo River, British Columbia, Canada. Can. Manuscr. Rep. Fish. Aquat. Sci. 3280: vii + 159 p.

This publication is comprised of a series of project reports that were conducted to address data gaps in the habitat use and status of the Nanaimo Summer Chinook population. This population was assessed as Endangered by COSEWIC. A Recovery Potential Assessment is being developed using the information contained within this publication, as well as existing information.

RÉSUMÉ

Baillie, S.J. (Ed.) 2024. Data Gap Research associated with the Recovery Potential Assessment of summer run Chinook, Nanaimo River, British Columbia, Canada. Can. Manuscr. Rep. Fish. Aquat. Sci. 3280: vii + 159 p.

La présente publication regroupe une série de rapports sur des projets ayant été réalisés pour combler les lacunes dans les données sur l’état de la population de saumons chinooks d’été de la rivière Nanaimo et l’utilisation de son habitat. Le Comité sur la situation des espèces en péril au Canada a évalué cette population et l’a désignée « en voie de disparition ». Les renseignements contenus dans la publication, ainsi que d’autres renseignements existants sont actuellement utilisés dans le cadre de la réalisation d’une évaluation du potentiel de rétablissement.

Introduction

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) began to examine the Chinook Salmon (*Oncorhynchus tshawytscha)* populations of southern BC in 2011. In 2018 the first of two reports, covering the low enhanced or unenhanced Chinook populations, was published by COSEWIC. This was followed by the second report in 2020, which covered the enhanced Chinook populations. The Nanaimo Spring Chinook population (COSEWIC 2018) as well as the Nanaimo and Puntledge Summer populations (COSEWIC 2020) were assessed as ENDANGERED.

These designations triggered a response from Fisheries and Oceans Canada (DFO) in the form of a Recovery Potential Assessment (RPA); a process which provides scientific information on a species' status, threats to survival, and feasibility of recovery. The RPA informs the Minister of Fisheries, Oceans and the Canadian Coast Guard in their decision whether to list the population under the Species at Risk Act (SARA).

DFO has found evidence (i.e. similar run timing and genetics) to suggest that the Nanaimo River spring-run Chinook are not a unique population but a similar population to the Nanaimo River summer run Chinook salmon. The characteristics of these two Nanaimo populations were examined and the conclusion was that they could not be distinguished apart and should be treated as one population with two spawning locations (DFO 2023).

During the process of assembling information and risk assessments of Limiting Factors several data gaps were identified. Some of these gaps were fully or partially addressed by initiating projects and are presented in this document. Each project has been written and presented as individual studies, and several refer to other projects within this document.

This document is the result of collaboration of many researchers, both within Fisheries and Oceans Canada and from external agencies without whom the work could not be completed. Thanks to all those who reviewed and provided suggestions and corrections to the manuscript.

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The applied Risk Assessment Method for Salmon workshop

Steve Baillie[1], Isobel Pearsall[2], Nicolette Watson[1] and Jaclyn Boutillier[3]

Introduction

COSEWIC released two reports on the status of Chinook salmon (*Oncorhynchus tshawytscha)* in southern British Columbia in 2018 and 2020 (COSEWIC 2018, COSEWIC 2020). Among other populations, the Spring and Summer run Chinook Salmon in the Nanaimo River were assessed as Endangered. Subsequently Fisheries and Oceans Canada (DFO) was tasked with assembling a Recovery Potential Assessment (RPA) report. The purpose of this report is to provide information and data to the Species At Risk (SARA) program on the current and future potential status of the species.

The RPA is comprised of 22 elements covering 6 broad categories: Biology and Abundance, Habitat and Residence, Threats and Limiting Factors, Recovery Targets, Mitigation of Threats, and Allowable Harm assessment. This report describes the process used to understand the threats and limits to productivity and presents the results from that process.

DFO uses a holistic approach to understand the habitat and threats, referred to as the Risk Assessment Method for Salmon (RAMS). This method starts with assessing the life history of the salmon and breaks down the habitat requirements for each stage, known as Limiting Factors (LF). The existing data and knowledge for each LF are examined by a group of experts including First Nations, who rate each LF against a series of factors.

1. Spatial score: The proportion of habitat that is impacted by the Limiting Factor
2. Temporal score: The frequency at which the Limiting Factor is impacted

The scores from these two factors are combined to form the Exposure score.

3. Impact: The level of change caused by the Limiting Factor on the returning Adults

The Exposure score and Impact score are combined to assign the level of biological risk, from Low to Very High. This process is used for the current conditions ('next ten years') and the expected future conditions (30-50 years in the future).

The Risk score allows for identifying higher risk habitats and life history stages and therefore providing a direction on restoration or mitigation actions. The results of the technical expert process were presented to a larger group that were comprised of interested citizens, representatives of local industry, municipal, regional, provincial and federal governments. Each Limiting Factor result was presented, discussed and the scores either agreed upon or changed.

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Watershed Description

The Nanaimo River watershed is located on the east coast of Vancouver Island near the city of Nanaimo, and within the traditional territory of the Snuneymuxw First Nation. With its tributaries, the Nanaimo River drains a total area of approximately 830 km^2.

The Nanaimo River estuary is the largest on Vancouver Island, and the fifth largest in BC. In addition to the Nanaimo River, the Chase River and Beck (Hong Kong) Creek discharge into the west side of the Nanaimo River estuary, and Holden Creek discharges into the east side of the estuary (Bell and Kallman 1976).

The Nanaimo watershed connects a series of 4 lakes and 3 reservoirs. The annual flow distribution varies with precipitation, with high flows typical through the November to January period and low flows typical in the July through September period. Mean monthly flow ranges between 3.01m^3/s (July 1992) and 174 m^3/s (November 2009) (Butler et al. 2014). Below the lower Nanaimo River watershed lay several aquifers, which are a significant component of the flow in low-water years.

This watershed and estuary support a rich variety of organisms that are characteristic of southeastern Vancouver Island, with many species of mammals, birds, amphibians, and fish. It was once considered one of the most valuable and productive salmon and trout streams on Vancouver Island, supporting a host of fish species including Summer run Chinook which are the focus of this report.

Methods

Risk Assessment- Scoring Methodology

The following scoring methodology will be used to score and rank Limiting Factors impacting Nanaimo Summer run Chinook salmon. Periods assessed for scoring risk include: "current conditions – the next 10 years", and "future conditions – 30-50 years in the future". Carrying out the analysis over these two time periods allows us to examine how the impacts of various stressors are predicted to or could change under ongoing climate change.

Computation of Risk

The framework for this risk assessment is based on accepted methods from the Government of Canada Treasury Board (report in preparation) and Hobday et al. (2011). These have been adapted to salmon in watersheds by evaluating the biological risk to each life history stage. Biological risk is determined from two variables: Exposure and Impact. The term "exposure" is synonymous with the term "likelihood" which is used in some risk assessment methodologies, while the term "impact" is synonymous with the term "consequence". Figure 1 shows how biological risk increases as both exposure and impact increase. The Y axis, exposure, is the exposure of a particular life history stage to a particular stressor, and the X axis is the impact on that life history stage because of exposure to that stressor.

Biological risk is defined as the percent change in the abundance of Chinook returning to the river but should also consider changes in key biological characteristics such as age at maturity, sex composition, fecundity, and run timing of the Chinook population.

Scoring the “Exposure” Term

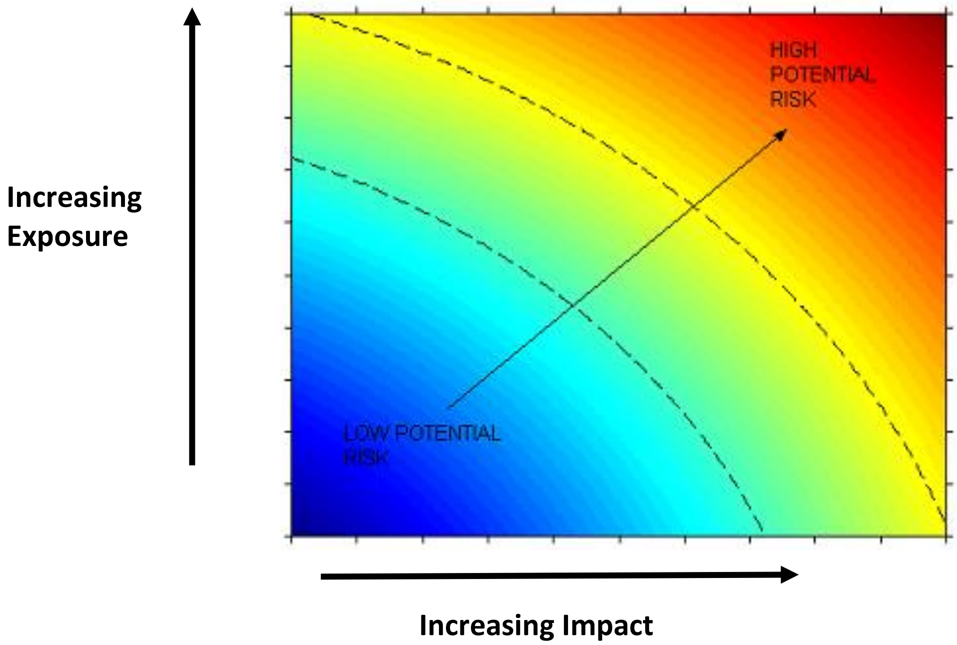

Figure 1. Graphic representation of estimating Risk from Exposure and Impact variables.

Exposure is based on combining 1) the spatial scale of the limiting factor, and 2) the temporal scale of the limiting factor. The methodology requires using expert opinion and/or knowledge to score each of these terms, and then discuss with others to develop a consensus value. Rationale and/or citation of existing data and/or reports should be documented.

Spatial Scale Score

Different LFs/stressors are rated in terms of the spatial scale of their effects. The spatial scale of impact is estimated as the percentage of the critical habitat required by a particular life history stage/or the percentage of the population itself that is impacted by the stressor (Table 1). A full rationale should be provided for this score. Critical habitat is any habitat that is necessary for the survival or recovery of Nanaimo Summer run Chinook.

Table 1. Spatial Impact Score Guide

Score	Single population (by life history stage)
Low (1)	Less than 10% of the critical habitat /population is impacted
Moderate (2)	10-20% of the critical habitat /population is impacted
Medium (3)	30-40% of the critical habitat /population is impacted
High (4)	50%-70% of the critical habitat /population is impacted
Very High (5)	80% or more of the critical habitat /population is impacted

Temporal Scale Score

The frequency at which an identified factor limits productivity of the species is called the “temporal score”. The 5 categories of temporal frequency are described in Table 2 below.

Table 2. Temporal Impact Score Guide

Score	Temporal Impact
Low (1)	Once per decade (Very rare)
Moderate (2)	Twice per decade (Occurs but uncommon)
Medium (3)	Three to four times per decade (Sometimes occurs)
High (4)	5-7 times per decade (Frequent)
Very High (5)	8 + times per decade (Continual)

Scoring the "Impact" The "impact" score is based on the expected magnitude of impact from the LF on the subsequent adult return. Chinook have a complex life history, with each stage susceptible to a myriad of factors which ultimately affect the number of adults returning to the river. To determine an impact score for Nanaimo Chinook we provide the following guide of current estimated mortalities in three key life phases.

Experts should be able to further delineate mortalities in these 3 phases based on available knowledge of limiting factors from this watershed or other stocks/watersheds (see Appendix A). This expert opinion will be used to assess potential contribution of each LF on mortality rates in one of the 3 life phases.

The impact scores related to change in subsequent return to river are shown in Table 3. Longer term change resulting from impacts on sex ratio, fecundity, age of maturity, size, etc. could be significant.

Participants are asked to provide an impact score for each LF, and then the group will agree on a score which will be entered into an Excel spreadsheet for that LF. Again, the full rationale for how a particular consensus score was derived must be provided. If there is disagreement amongst the experts, or if key information is lacking, the Hobday et al. (2011) method assigns the highest impact score to that stressor.

Table 3. Impact criteria to score potential risk

Level	Score	Description
Minor	1	Less than 10% decline in population returns
Moderate	2	11-20% decline in population returns
Major	3	21-30% decline in population returns
Severe	4	31-50% decline in population returns
Critical	5	50% + decline in population returns

Uncertainty/confidence levels in scores

There is always some level of uncertainty associated with predicting impacts of any stressor or limiting factor on fish or fish habitat. Uncertainty can arise from a lack of information, or could arise when predicting the effectiveness of new or innovative mitigation measures. In addition, there may be synergistic effects where two or more effects in combination express an effect greater than would have been expressed individually. These are difficult to identify and hence have the potential of being overlooked or underestimated. Acknowledging this uncertainty does not preclude making sound management decisions, but the uncertainty need to be described and taken into account at this risk assessment stage.

Thus, this risk assessment methodology requires that workshop participants provide confidence ratings for the risk scores that are produced from the Level 1 risk assessment. These ratings may be 1 (low confidence) or 2 (medium confidence) or 3 (high confidence) (Table 4).

Table 4. Confidence Scores

Confidence rating	Rationale
Low	• Data exist but are considered poor, or conflicting, or • No data exist, or • Substantial disagreement among experts
Med	• Data exist but some key gaps • Some disagreement between experts
High	• Data exist and are considered sound, or • Consensus between experts, or • Risk is constrained by logical consideration

Current and Future Trends

Workshop participants will also be asked to provide scores for the following:

Current Trend – Is this stressor currently increasing, decreasing or showing no trend? This will be scored between 1 (decreasing) and 5 (strongly increasing).

Future Trend – Is this stressor predicted to decrease, increase or remain the same in the future (50 years from present)? This will require workshop participants to discuss the predicted impacts of climate change. This will be scored between 1 (decreasing) and 5 (strongly increasing).

Results

Fifty Limiting Factors were identified which are listed in Appendix A along with the scoring and risk rating. The following Limiting Factors were identified as Very high Risk or High Risk to Chinook Salmon in the Nanaimo River Watershed:

Terminal Adult Migration and Spawning

LF2 (Limited or delayed spawner access), LF3 (Potential delays in upstream migration due to physical barriers), LF5 (Loss of safe migration route through lower river) and LF9 (Lack of high quality and quantity of spawning gravel) were rated as High, Very High, Very High and Very High current biological risk, respectively. All uncertainty ratings were considered as High Confidence levels.

The RAMS workshop recommended combining LF2 and LF3 because the factors were very similar in nature. The LFs were considered High Risk because of a possible low flow barrier at White Rapids Falls. While some work had been done previously to allow for easier migration past this point, there was no data available to understand what discharge levels were problematic for salmon migration. Observational data suggests that Chinook hold in the pool below this point, which exposes them to higher water temperatures and non-sanctioned fishing.

LF5 was considered Very High Risk because gravel accumulation in the lower river can result in shallow riffle habitat that may block upstream migration. The RAMS workshop suggested that this was more of a factor for the Fall run Chinook as they enter the river during August to September during the low water period and prior to fall rainfall events. Early-run Chinook enter the river during the February to July period, which normally has a higher water discharge.

LF9 was considered Very High Risk because changes in the spawning area below First Lake where most of the early Chinook spawn has substantial consequences. Although recent data was not available, observations from the Nanaimo River Hatchery staff, who use this area for brood stock collection, suggest that the volume of spawning gravel has decreased in recent years due to scour.

Freshwater Incubation and egg to fry survival

LF13 (High Suspended Sediment loads and reduced Dissolved Oxygen) and LF16 (More frequent and higher peak flows) were rated as High and Very High current biological risk, respectively. The uncertainty rating for LF13 was Low Confidence and for LF16 was High Confidence level.

LF13 was noted as Very High risk due to observed higher turbidity levels in the Harmac water withdrawal data, however no analysis was available on the spawning gravel composition or subgravel oxygen levels, resulting in a Low Confidence rating.

LF16 is similar to LF9 but the pressure of higher peak flows (and lower summer flows) are acting on the incubation and emergence of alevins from the gravel redds. Confidence was High based on the observations of the Nanaimo River Hatchery.

Freshwater Rearing from Fry to Smolt

LF23 (Inadequate in-stream complexity), LF24 (Increased stranding in off-channel areas), LF25 (High flows), and LF26 (Lack of food) were rated as High current biological risk, and LF29 (High levels of predation) was rated as Very High risk for this life stage. Confidence ratings were High, High, Low, Low and High, respectively.

LF23 was noted as High risk due to the lack of instream complexity such as low levels of pool/riffle habitats and high levels of glide, and a lack of Large Woody Debris. Confidence levels were High based pm information presented by the Habitat Status Report (HSR 2022).

LF24 was noted as High risk due to damaged off-channel habitat. The Nanaimo watershed does not have a lot of off channel areas however one side channel below the highway is becoming more isolated as gravel deposition accumulates. With less water in spring due to lower snow packs the discharge during migration decreases and juveniles may be isolated in off channel areas. Confidence levels in this LF were rated as High.

LF25 was noted as High risk due to increased exposure of juveniles to higher discharge events that result in increased turbidity, decreased channel stability and flushing downstream. Confidence level was Low due to a lack of information on residence time vs. peak flows, or rearing capacity.

LF26 was noted as High risk due to low productivity in cold water areas (above Second Lake), which impacts the yearling fry that rear in the area given that a larger smolt has a higher survival rate. There was much discussion regarding nutrient inputs and productivity, especially associated with logging activity. Confidence was rated as Low due to a lack of information on arthropod communities in the river.

LF29 was noted as Very High risk due to increased exposure to predators. Predation is a natural process however the changes in the habitat (lower flows during spring migration, decreased amounts of instream complexity) caused by anthropogenic activities has increased the exposure to predators. Confidence was rated as Moderate due to uncertainties in levels of predators.

Estuary Rearing

RAMS participants recommended dividing LF37 (Loss of estuary habitat) into riparian, intertidal and subtidal zones). LF33 (Lack of adequate food supply), LF37a (Loss of marine riparian habitat), LF37b (Loss of intertidal habitat), and LF37c (Loss of subtidal habitat) were rated as Very High biological risk, and LF38 (Decreased water quality due to ballast dumping, industrial discharge and sewage effluent) was rated as High biological risk. Confidence ratings were Low, High, Moderate, High and Low, respectively.

LF33 was noted as Very High due to changes in channelization which directs migrating juveniles to the east side of estuary where historic sewage discharge has occurred, and current log boom activities have altered the productivity. Current area of eelgrass habitat has decreased since early 2000's (Bonar and Zamora 2020). Confidence was Low due to unknown changes in productivity from decreasing the area of log storage leases, and ongoing changes to eelgrass beds.

LF37a was noted as Very High due to historic degradation of the riparian habitat from agricultural practices (diking and berm construction in intertidal areas) and channel changes that funnel Chinook to the urbanized west side and away from the productive natural forested east side. Confidence was rated as High due to known issues and the 1980's estuary work (Healey 1980).

LF37b was noted as Very High due to legacy effects from historic log storage leases across the intertidal flats from west to east. Over the last 2 decades the area leased has decreased significantly and recovery of benthic communities probably has started. Habitat issues such as bark and small woody debris will take many years to break down. Confidence was rated as Moderate due to unknown recovery rates.

LF37c was noted as Very High due to the loss of both eelgrass beds locally and kelp forests in near shore subtidal areas in Strait of Georgia. This habitat is important because estuary rearing fish congregate in this area during low tide. Confidence was rated as High because of documented losses to eelgrass and kelp forest habitats.

LF38 was noted as High due to historic and ongoing discharge from urban and agricultural sources. Bark and small woody debris from log booms were noted as industrial discharge as well. Confidence was rated as Low due to unknown levels of current discharge and shipping ballast dumping.

Marine Habitat

11 Limiting Factors are listed under this heading however only LF50 (Mortality due to fishing) was considered during the RAMS meeting. LF40-49 were later reviewed by DFO technical experts and included in this report.

LF50 was noted as High biological risk due to direct removal of adult Chinook from population prior to spawning activity. Confidence was rated as Moderate due to uncertain impacts from catch and release, underestimated catches and recent regulation changes. Chinook salmon are caught as bycatch in other fisheries, e.g. the hake fishery, and are underreported.

Potential Data Gap research and Recovery Measures

The RAMS process, in addition to identifying important habitat stressors that limit salmon productivity, also identified data gaps in existing knowledge and listed them in Appendix B.

Upslope Stabilization

Upslope instability results in sediment deposition and aggradation in key spawning areas. High turbidity events may lead to poor water quality conditions (i.e. lowered dissolved oxygen) during freshwater incubation. Restorative recommendations include the identification and containment of runoff debris, re-planting for long term slope stability and, where possible, road deactivation. Turbidity surveys should be conducted to determine inter gravel flow rates for salmonid redds.

Streamside Riparian Restoration

Loss of streamside vegetation may increase bank scour and erosion, leading to decreased channel stability and reduced energy dissipation in high-flow events. Streamside riparian plants stabilize thermal regimes and provide microhabitat for juvenile salmonids. Recommendations include identifying areas with inadequate riparian buffers and restoring natural riparian plant communities to mitigate bank erosion or channel instability.

Instream Complexity

Instream complexity forms and stabilizes pools and gravel bars, reduces instream erosion, and provides areas of refuge in high flow events. Recommendations include the installation of instream large woody debris and boulders to increase river complexity. Other options include beaver dam analogues and post assisted log structures.

Off-Channel Habitat and Connectivity

Off-channel areas provide refuge and rearing opportunities for juvenile salmonids as they are hydrologically stable habitats offering juvenile salmonids overwintering protection and access to food resources (i.e. aquatic insects and detritus). Recommendations include the identification of pre-existing off-channel habitat and suitable areas for the installation of new off-channel habitat. Prior to installation, monitoring efforts should include downstream fry trapping to determine distribution and residency.

Water Use

Lower spring & summer water levels negatively impact adult terminal migration by reducing allowable time for passage upstream to holding and spawning areas. Fish are particularly exposed to stressors and mortality in the Bore Hole.

Recommendations include the alteration of discharge patterns to overcome seasonal drought and loss of connectivity due to bedload aggradation. Surveys should include an annualized hydrograph of low-flow barrier areas (i.e. Bore Hole) as well as a flow-rate analysis for adequate upstream passage. Residency timing of high flow events should be considered.

Estuary rehabilitation and restoration

The Nanaimo River estuary functions as a critical habitat for salmonids for both terminal migration and juvenile rearing. This area has been significantly altered by historical and ongoing human-induced activities affecting the quality and quantity of marine riparian, intertidal and subtidal habitats.

In 2019, restoration initiatives were undertaken by the West Coast Conservation Land Management Program, supported by DFO's Resource Restoration Unit. This work included the removal of relic berms in the estuary. Other mitigations to human-impacted areas include the 2018 log storage lease agreement that reduces log boom storage areas to 10% of the former footprint.

In 2020, the Nature Trust of British Columbia implemented a 5-year project to conduct monitoring and research to assess estuary resilience to sea-level rise at various sites along Vancouver Island, including Nanaimo estuary.

Other ongoing work in the estuary includes marine mammal surveys conducted by Snuneymuxw First Nation, and juvenile abundance, distribution and residency surveys conducted by DFO.

Biodiversity surveys

To gain a better understanding of the biodiversity, abundance, distribution and interaction between species in the Nanaimo River watershed, the following monitoring is recommended:

- Benthic invertebrate surveys (indicator of estuarine health);
- Freshwater aquatic insects (indicator of watershed health);
- Predation surveys for Chinook salmon (e.g. seals, sea lions, mergansers, otters, etc.);
- Aquatic and riparian invasive species abundance and distribution.

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Appendix A – Limiting Factors Scores and Ratings

Limiting Factor	Life History Phase:	Ecosystem Unit:	Spatial	Temporal	Impact	Confidence	Current Risk	Future Risk
LF1 : Predation of adults in the estuary and lower river by pinnipeds	adult	estuary	4	4	3	H	Moderate	High
LF2 : Limited or delayed spawner access	adult	lower river	3	5	4	H	High	Very High
LF3 : Potential delays in upstream migration due to the physical barriers (natural or anthropogenic)	adult	lower river	4	5	5	H	Very High	Very High
LF4 : Aggradation creates a migration barrier in the lower river.	Adult	lower river	1	3	2	M	Very Low	Low
LF5 : Loss of safe migration route through the lower rivers due to channelization, loss of habitat complexity and instream cover features	adult	lower river	5	5	4	H	Very High	Very High
LF6 : High water temperatures in the lower river and estuary during the late summer/early fall migration period can increase migration mortality and sublethal stress.	Adult	lower river	2	5	3	H	Moderate	Very High
LF7 : Poor water quality conditions during migration period (low DO, coliform levels, deleterious substances)	adult	lower river	2	5	1	M	Very Low	Moderate
LF8 : Mortality due to unsanctioned fishing	adult	lower river	2	5	4	M	Moderate	Moderate
LF9 : Lack of high quality and quantity of spawning habitat	adult	lower river	4	5	5	H	Very High	Very High
LF10: Disturbance to natural spawning activity due to anthropogenic impacts	adult	upper river	2	4	1	M	Very Low	Moderate

Limiting Factor	Life History Phase:	Ecosystem Unit:	Spatial	Temporal	Impact	Confidence	Current Risk	Future Risk
LF11: Pre-spawn mortality due to disease	adult	upper river	1	1	1	M	Very Low	none/Unk
LF12: Mortality due to predation at spawning grounds	adult	upper river	1	1	1	M	Very Low	none/Unk
LF13: High suspended sediment loads and low DO that reduce egg to fry survival and emergence of alevins	egg – alevin	upper river	5	5	3	L	High	Very High
LF14: Non-optimal water temperatures that reduce fry survival by changing emergence time in relation to food availability	egg – alevin	upper river	3	3	3	M	Moderate	High
LF15: Lower low flows that dewater redds and reduce incubation survival	egg – alevin	upper river	1	1	1	M	Very Low	none/Unk
LF16: More frequent and higher peak flows over winter can scour/disturb redds	egg – alevin	upper river	5	5	5	H	Very High	Very High
LF18: Reduced egg to fry survival due to chum overspawn	egg – alevin	upper river	1	1	1	H	Very Low	none/Unk
LF19: Predation of eggs and alevins by fish (sculpins, trout) and birds (mergansers)	egg – alevin	upper river	3	5	2	M	Moderate	Moderate
LF20: Egg /alevin mortality due to redd disturbance by invasive or expanding endemic species (e.g. didymo)	egg – alevin	upper river	1	1	1	L	Very Low	none/Unk
LF21: Egg mortality due to redd disturbance by humans	egg – alevin	upper river	1	1	1	H	Very Low	none/Unk
LF22: Mortality or fitness impacts as a result of poor water quality (e.g. temperature, TSS, dissolved oxygen levels, pH, hardness, supersaturation)	fry	lower river	3	5	1	M	Low	Moderate

Limiting Factor	Life History Phase:	Ecosystem Unit:	Spatial	Temporal	Impact	Confidence	Current Risk	Future Risk
LF23: Mortality or fitness impacts as a result of inadequate in-stream complexity and riparian complexity	fry	lower river	5	5	3	H	High	Very High
LF24: Increased stranding in isolated off- channel habitat and tributaries can occur with rapid decreases in flow	fry	lower river	3	5	4	H	High	High
LF25: High flows impacting fry and smolts	fry	lower river	5	5	3	L	High	Very High
LF26: Mortality or fitness impacts as a result of lack of food	fry	lower river	4	4	4	L	High	Very High
LF27: Mortality or fitness impacts as a result of competition with Alien Invasive Species	fry	lower river	2	4	2	L	Low	Moderate
LF28: Mortality or fitness impacts as a result of competition, disease, interaction with other species/hatchery fry	fry	estuary	1	1	1	L	Very Low	none/Unk
LF29: Mortality as a result of high levels of predation	fry	lower river	5	5	4	M	Very High	Very High
LF30: Mortality or fitness impacts as a result of anthropogenic disturbance	fry	lower river	1	1	1	M	Very Low	Low
LF30.5 Aquifer drawdowns, direct mortality through pumping, domestic use	fry	lower river	5	5	1	M	Low	High
LF31: Mortality or fitness impacts as a result of disease	fry	lower river	1	1	1	L	Very Low	none/Unk
LF32: Mortality or fitness impacts as a result of hatchery introgression	fry	lower river	1	5	1	M	Very Low	none/Unk

Limiting Factor	Life History Phase:	Ecosystem Unit:	Spatial	Temporal	Impact	Confidence	Current Risk	Future Risk
LF33: Low early marine survival of Chinook fry and smolts in the estuary / nearshore marine due to the lack of adequate food supply (particularly in first 4 months of marine life) and reduced water quality	smolt	estuary	5	5	5	L	Very High	Very High
LF34: Predation of smolts in the lower river and estuary	smolt	estuary	2	4	3	L	Moderate	Moderate
LF35: Mortality of fry and smolts due to predation and competition from AIS	smolt	estuary	1	1	1	M	Very Low	Low
LF37a: Loss of good quality marine riparian habitat.	Smolt	estuary	4	5	4	H	Very High	Very High
LF37b: Loss of good quality intertidal habitat ie. Loss of natural abundance and composition of benthic communities, associated ecological communities.	Smolt	estuary	4	5	4	M	Very High	Very High
LF37c: Loss of good quality subtidal habitat ie. Loss of natural abundance and composition of benthic communities, eelgrass habitat, kelp forests and associated ecological communities.	Smolt	estuary	4	5	4	H	Very High	Very High
LF38: Reduced survival due to decreased water quality from ballast dumping, industrial discharge, and sewage effluent in the estuary.	Smolt	estuary	5	5	3	L	High	High

Limiting Factor	Life History Phase:	Ecosystem Unit:	Spatial	Temporal	Impact	Confidence	Current Risk	Future Risk
LF39: Mortality or reduced fitness as a result of direct anthropogenic interference, not covered by previous LFs.	Smolt	estuary	2	5	2	H	Low	Low
LF40: Low marine survival due to inadequate food supply (abundance or value)	adult	ocean	5	5	3	L	High	High
LF41: Low marine survival (<1%) in the Strait of Georgia due to low marine productivity, poor water quality, increase mean water temp	adult	ocean	4	2	2	L	Low	Moderate
LF42: Low marine survival as a result of competition for food	adult	ocean	1	1	1		Very Low	Very Low
LF43: Low marine survival due to high rate of predation by orcas, pinnipeds	adult	ocean	5	5	5	H	Very High	Very High
LF44: Low marine survival due to high rate of predation in nearshore environments	adult	ocean	Combined with LF43					
LF45: Mortality or fitness impacts as a result of competition with aquatic invasive species	adult	ocean	2	2	2	L	Very Low	None/Unk
LF46: Mortality due to impacts related to offshore habitat destruction	adult	ocean	2	5	1	M	Very Low	None/Unk
LF47: Mortality or sub-lethal effects as a result of pollutants	adult	ocean	4	5	2	L	Moderate	High
LF48: Mortality or fitness impacts as a result of disease	adult	ocean	1	1	1	L	Very Low	None/Unk
LF49: Mortality or fitness impacts as a result of HABS	adult	ocean	1	1	1	L	Very Low	None/Unk
LF50: Mortality due to fishing	adult	ocean	3	5	4	M	High	High

Appendix B – Limiting Factors comments from RAMS meeting

Limiting Factor	Summary Notes
LF1 : Predation of adults in the estuary and lower river by pinnipeds	• Pinniped population in Nanaimo Estuary; on average, 20 seals and 1-2 sea lions from November to December. Summer is a data gap (when Summer run migrating in). • Aside from log booms and haulouts, docks may serve as places for seals to loaf in the estuary. • Seals swim up the river to highway bridge and a family of river otters in the Borehole was observed preying on fall and summer run Chinook as they sat in the pool waiting to move upstream. During low flows at White Rapid Falls (WRF), fish are 'sitting ducks', an issue that will worsen in the future if hydrograph continues to shrink (Nanaimo River Hatchery). • Survey in the Puntledge (M. Sheng) found a resident population of 40-60 seals contributing to ~30% total mortality on terminal adult Chinook. There appeared to be a strong preference for females (hatchery broodstock has a ratio of 1:5 females: males). Habitualized seals use road crossing and lights to target fish; a learned behavior. • Similarly, NRH catches approximately 1:4 females to males for their brood stock suggesting a similar result of seal predation targeting females? However, a discrepancy noted as 50:50 sex ratio observed in Nanaimo River deadpitch surveys. • Feb to April, possible source of night light pollution around log booms and BC ferry terminal. If fish could migrate on dark side – might be better. Log boom storage was noted as being offshore, may not be as affected by light pollution? • Fair bit on interest from Snuneymuxw on the presence and pressure from seal/sea lion predation on salmon in the Nanaimo River. • Sea lion abundance appears to increase in winter; log booms ground at low tide so no longer provide haulout habitat. • Interestingly, because the log booms are now in bundles rather than flat rafts, they may provide complexity and refuge for fish. • Spring run fish trickling into the estuary over a period of time – not necessarily attracting large numbers of predators – seals may show greater response to fall run and chum that come in in larger numbers. • Recent story in Cowichan (year of log booms vs. no log booms) saw a big chunk of removals in the year with log booms.

Limiting Factor	Summary Notes
LF2 : Limited or delayed spawner access	• Issues for the end of the run- but this depend on when flows drop- this is getting earlier every year. Particularly low flows in May and June, but sometimes low flows can occur in late April. As spring hydrograph shrinks, population is squeezed for timing to get into the lakes above. • End of the Spring/Summer run is getting stuck at the Borehole – water is dropping earlier each year. • Hydrograph work done in the 90's found fish locked in at a specific flow (exact number unknown); results repetitive every year, with fall run unable to get up river during spring low flows; always a blockage at White Rapids Falls (WRF) with no passage until November rains come. • Without access at WRF, fish jumping at a rock wall; as a result, fishway was built. Fishway not currently being considered for maintenance/upgrade (SEP-RRU). Should consider history of anthropogenic solutions to natural problems (i.e. how long will mitigation effects last in changing climate). • According to Nanaimo River Hatchery, due to less snow pack and lower flows, blockage at the Borehole is the key issue. In 2019 ~100-200 fish holding out of a total of 500 – a big bottleneck (i.e. 40% trapped). Fish were seemingly able to pass the fishway at WRF, but were getting stuck at the Bore Hole. Increased flows in early August did lead to fish moving on; whether poached or able to make it up river is unknown. • Borehole deep and fly fishermen have seen them there in August – temperatures and stress will have an impact on fish and lead to fish kill • Habitat Status Report – regularly, minimum flow rates in the lower river are not being met (established to protect fish passage); should be a minimum of 3.9 m^3/s. Often not meeting this requirement May to September. There are increasing low flow events below 5 and 3 m^3/s. Expect declines of 60% watershed yield in the future, mostly over the summertime. Discharge flagged as a major issue in the lower river, impacting both summer run and fall run Chinook. • Harmac water plan established in the 90s for minimum flows (1.4 m^3/s) below Harmac's point of extraction was based on historic low flows in the river; and structured to provide augmented flow. Jump Creek is currently surplus. Releases from 4th Lake & Jump Creek are 1 day apart – additive. Concern that with growing population in the lower river significantly drawing water from Jump Creek which will worsen sustained flows if the storage is not there – will need to gradually increase pulse flows. • Jump Creek snowpack historical data accumulation into May. Recent data showed end snowpack accumulation advances several weeks. Pulse flows in May/June. Addition. Mitigate habitat modifications. • Drought trend is going to be earlier and more extreme. Areas like Haslam Creek have dried up completely in the summer due to well pumping.
LF3 : Potential delays in upstream migration due to the physical barriers (natural or anthropogenic)	• Consensus was to combine Limiting Factor 2 &3. • En route mortality and increased stressors are experienced by fish stuck at the Borehole and White Rapids Falls. These areas act as low flows barrier during upstream migration. • Most biologically productive side of estuary is east side, but fish currently moving through west side (i.e. industrial side). At high tide, all channels come into play; however, only west side channel is accessible at low tide. • Concern with fish only moving through one channel in the estuary creating a 'gauntlet' for predation.
LF4 : Aggradation creates a migration barrier in the lower river.	• Currently, adult spring run chinook are not affected by aggradation problems as they are moving through high water until April – June. • However, should still consider aggradation issues in summer drought conditions as adults migrate from holding in lake to river spawning grounds. • Accelerated flow regime, bedload movement and more intense spikes in flow are causing aggradation and simplifying in-river large woody debris. • Dam structures on the system moderate and mediate flow and gravel movement. • Fish don't challenge hot water, they move back to estuary or get up higher (if they can). • Chinook can migrate through shallow water, a couple of inches. • Lower river gravel bars increasing, estuary in south channel fork is diverting more water west. • Aggradation issues at Kelly's flats (just up from Firehouse Pool).

Limiting Factor	Summary Notes
LF5 : Loss of safe migration route through the lower rivers due to channelization, loss of habitat complexity and instream cover features	• Lack of habitat complexity is the key issue. • An increase in sediment distribution, reduction in riparian stands and loss of large woody debris play a fundamental role in refuge; adults will use these at different flow regimes. • Pool depth is an issue in June / July; not many deep pools for fish to hold in. • Lower section of river getting wider and shallower (supported by spatial and on-the-ground evidence), exposing fish to stressors from high temperatures, predation and poaching. • Spring/Summer run fish that can get up into the lakes before the decreased flows are safe; those that migrate during the end of the run may become stranded if water levels drop.
LF6 : High water temperatures in the lower river and estuary during the late summer/early fall migration period can increase migration mortality and sublethal stress.	• Likely less of an issue for spring/summer run Chinook entering early in season. • High water temperatures can have an impact on gametic fitness.
LF7 : Poor water quality conditions during migration period (low DO, coliform levels, deleterious substances)	• Spring/Summer run Chinook move quickly and can access the lake above so this should not be a particularly big issue for this population. • More of an impact downstream; upper river coliform is low. Coliform is an indicator of dangerous substances that grow in same conditions (water quality testing carried out by Snuneymuxw First Nation). • Sampling in the estuary found lots of farmland and septic systems flowing into the lower river. • Leaching from coal mining and raw sewage pouring into estuary for decades are significant legacy issues. Coastland leachate has been a problem in the past. • Duke Pt. sewage pipe broke last year and in Holden Creek and was running for months.
LF8 : Mortality due to unsanctioned fishing	• This is an issue for stranded spring/summer run fish at the Bore Hole. • Nanaimo River Hatchery found evidence of unsanctioned fishing (i.e. lots of triple hooks) particularly at the Borehole and highway. • Several people thought that poaching decreasing in the last few years, but may increase in future with a growing population in the lower Nanaimo River area. • Starting in September, lower sections – 1 through 3 – has seen a decrease in people coming out to fish in the last year or so. • Consensus that seals / river otter predation had a much more significant impact over poaching efforts. • Issue of poaching has been flagged with C&P for a number of years. • Unsanctioned fishing tends to cease during summer when the recreational swimmers are present. • Green Creek pool vulnerable to unsanctioned fishing, but its not covered here. No reports to date, but there may also be no one there to check?

Limiting Factor	Summary Notes
LF9 : Lack of high quality and quantity of spawning habitat	• Low availability of spawning habitat based on real sustained surveys was listed HIGH in Habitat Status report. Lots of documentation that areas have been damaged from road instability – extensive logging around that area. • Increased turbidity events observed; the capacity for the lakes acting as sediment sinks is unknown. • Nanaimo River Hatchery observed lots of space for spawning above the lakes (albeit not as accessible). • The habitat above Second Lake is thought to be underutilized due to colder temperatures flowing from Fourth Lake dam. • A major concern was raised with high quantity / quality spawning habitat being blown out by high flows. • In 2019, the spawning gravel at the outlet of First Lake blew out, leaving area with chest deep water and only basketball size boulders. This is the prime spawning habitat for summer run fish (80-100 or ~20-30% of run). • First Lake blow out expected to have come from high flow in nearby Deadwood Creek (an area with <30m riparian buffer and on-the-ground observations indicate less stability over time); channel appears to no longer be able to dissipate energy from high flow events. • Lake outlets are ideal place for spawners – most stable area. • According to Habitat Status Report, there is only 11.8km of upper river spawning grounds and 2km of that area is below the First Lake outlet. • Expected to worsen with changes in peak flows, leading to more blowouts in the future.
LF10: Disturbance to natural spawning activity due to anthropogenic impacts	• Impact will be higher in low flow years. • Summer recreational period (swimming, tubing, kayaking, etc.) may be disturbing fish. • There are a lot of people swimming in the lower river and population density is only increasing. • Based on telemetry work (M. Sheng), fish disturbed by these activities were moving back downstream or slowing migration, putting them at greater risk (i.e. poaching, predation, high temperature stressors). • Light standards can be regulated to require full cut off. Development is contained to urban containment boundary and regulations limit direct storm water infiltration into the river.
LF11: Pre-spawn mortality due to disease	• No issue with ich killing Summer run fish at the hatchery. • In past, significant fish death of summer run (10 out of 100) were witnessed, but disease lab was unable to determine cause – assumed a disease caused by warming water conditions (per. Comm. P. Preston).
LF12: Mortality due to predation at spawning grounds	• Not thought to be much of an issue. • A natural process. • Predation events (e.g. bears, trout, and other creatures) have not been noted by the hatchery staff.
LF13: High suspended sediment loads and low DO that reduce egg to fry survival and emergence of alevins	• Sediment flagged as an issue, but not dissolved oxygen. • Frequency of high turbidity events has increased in lower river; however, even with high turbidity, the level at which spawning gravel is being plugged up is unknown. • Low percolation from sediment / sand leads to low dissolved oxygen; need to avoid eggs being entombed from above. • Low confidence for this factor- we need more information on percolation in gravels in Nanaimo River. We have no information at all on intergravel flows, but we do know that turbidity has increased (data provided in Hab Status report, and graphs). • Need to consider the issue of sustainable forest management practices and privately used forest land to mitigate issues getting worse in future. Extreme flow events can increase scour. • Deadwood Creek comes in right at outlet of 1st Lake. Major sediment source; lake is dirty to its outlet when the rains come; therefore, outlets may provide less moderation of turbidity than expected.

Limiting Factor	Summary Notes
LF14: Non-optimal water temperatures that reduce fry survival by changing emergence time in relation to food availability	• Concerned of growth period being reduced due to shorter window between extreme cold and hot temps. • Water is cold above Second Lake, so not a concern there • Flashy hot / cold systems are related to lack of riparian. • Ideal 90-day rearing time with ideal temps (16°C) will become less and less as the window shortens. • Cold = slow development. If within phenotype of population to survive low temps – which has been the case for the yearlings – it might not be as bad with colder temps. Fish can adapt to lower productivity conditions (i.e. cold water coming out of Fourth Lake dam). • During the fall, Nanaimo River Hatchery is seeing natural temperatures throughout the incubation period. • Need to consider to what degree fish are fundamentally changing their whole suite of life history characteristics. • Warmer water causes eggs/alevins to develop faster, causing them to emerge earlier than they should. Timing with insect production is critical; if they emerge earlier, bugs may not be available. Probably not an issue above 2nd Lake, but might be an issue below 1st Lake as surface water from the lake infiltrates eggs and spawning areas. • Lake thermal dynamics; whatever normal temp. cycle is affecting downstream. Most stable is the reach above 2nd Lake. Should be two separate zones (above and below first lake) as this LF is more geared towards spawning population below 1st Lake.
LF15: Lower low flows that dewater redds and reduce incubation survival	• Fall of 2019 was fairly dry with little to no rain for ~ 1 month; however, the area in the upper river remains wetted where fish are spawning. • Generally, this is not considered an issue.
LF16: More frequent and higher peak flows over winter can scour/disturb redds	• There are more frequent and higher peak flows. • Historical logging practices and climate change contributing to flow regime change. • High flows can scour / disturb redds; leading to lower survival.
LF18: Reduced egg to fry survival due to chum overspawn	• Chum don't make it up to the ground in which the Spring/Summer run spawn; therefore, this is not an issue.
LF19: Predation of eggs and alevins by fish (sculpins, trout) and birds (mergansers)	• Predatory effects should be considered from a landscape level with more predation as a result of land alteration (resulting in higher vulnerability of Chinook due to lack of large woody debris, refuge etc.). • Cowichan River experienced a significant loss of tagged fish; 20-30% alone from brown trout. • However, need to consider that fish do serve as a food source and contribution to species that are preying on them. • Factors natural in origin, shift in species as function of change in the environment (indirectly related to anthropogenic impacts). Need to consider fishery regulatory policy vs. land management practices. • Research from Cowichan – monitored CK survival as fry released up Cowichan. By the time they reached the ocean (90-day fish), there was next to nothing left (predation – whether natural or invasive – raccoons, brown trout). In a different system, that would be high. Low water year saw a 90% decline – combination between ecosystem and predator pressure. • Eggs vs. alevins. Trout get into the fry; trout / sculpins aren't a factor once eggs are deposited, they are not affected by predation. • However, with less Chinook spawning and more trout spawning, they are outnumbered - greater effect on smaller population. • Tutty noted that this should be scored low but others disagreed.

Limiting Factor	Summary Notes
LF20: Egg /alevin mortality due to redd disturbance by invasive or expanding endemic species (e.g. didymo)	• Didymo not a factor in this population.
LF21: Egg mortality due to redd disturbance by humans	• Area that Spring/Summer run spawn are usually left alone in October. • No significant disturbances noted.
LF22: Mortality or fitness impacts as a result of poor water quality (e.g. temperature, TSS, dissolved oxygen levels, pH, hardness, supersaturation)	• Higher temperatures on outmigration concerning as juveniles have a long way to go. • When First Lake fills up, it is no longer supplying cold water which can impact downstream water temperatures. • Concerns raised with conforming life history strategies to one type (i.e. ocean or stream) and what the resulting loss could be. Suggested not an either or situation, but more of a factor of productivity in the first three months of life and that fish plasticity/adaptation should be considered. • The ocean-type summer run might be impacted by lower river high water temperatures and water quality issues (if they are rearing there). • Low impact is just an assumption – very little scientific process. • Fish stuck below Borehole may be at greater risk. • What about temperature in the lakes and effects on smolting? Is this an issue relative to survival, or is it a response from an organism to adapt for survival? It's in their genotype – both life histories (ocean type / stream type). • Climate change effects in future should be considered.
LF23: Mortality or fitness impacts as a result of inadequate in-stream complexity and riparian complexity	• Based on 5cm high resolution drone imagery in taken in upper river in 2019, there were only 2-10 pieces of LWD present per km (and zero in 2 reaches); suspect same situation downstream (Habitat Status Report) • High conversion to anthropogenic impacts in lower river and loss of riparian areas in upper river; overlap between spawning areas and riparian disturbance (Habitat Status Report). • Significant number of areas where logging or agricultural development occurred to within 30m of river bank (and in some cases, less than a 30m buffer exists). Very little mature conifer trees left in upper watershed. Upper river has very little cover. • Need for large woody debris is important, but how to maintain it with current peak flow conditions in the river doesn't seem feasible. Strategy would be creation off channel habitat out of energy zone. • Off channel habitat would need to be consistent with flow regime. • Issue in Cowichan was fish unable to set up territory in complexity along riverbank. Otoliths on adults coming back shown that those that could live and rear in river for 90days did better. How do you get a better smolt out of the river? Lower river remediation. • If fish can't set up real estate in upper river, they will move downstream, they will find food in estuary (there last and best chance).

Limiting Factor	Summary Notes
LF24: Increased stranding in isolated off-channel habitat and tributaries can occur with rapid decreases in flow	• Damage considered already done, but opportunities for rehabilitation exist. • At 50cms in other estuarine environments, all side channels connected; 7cms was inflection point where you start to lose side channels. Suspect similar values for Nanaimo. • Lots of rivers are downcutting and isolating floodplains- this is likely going to get worse in the future. • There are very few side channels available on Nanaimo River, possible rehabilitation potential for relic channels. • If fish given off channel habitat, they will use it. • Relic berms throughout lower river as a result of trying to reduce flooding in past farmland practices. Better chance of building off channels in upper river private land. • Issue of land use practices was flagged.• Very little off channel habitat in the upper and lower river- therefore this LF should not be too high of a concern given the lack of OC habitat. • However gravel bars do result in stranding issues and isolation of environments where only subsurface flows occur. • Key piece is off channel habitat. There is not much in upper river. In the lower river it's a high risk as we have channelized • Side channel below highway has now become isolated. That could be developed as possible rehab. Site. • Upper river tribs. Has a lot of gravel accumulation and infilling – could lead to stranding.
LF25: High flows impacting fry and smolts	• Low channel stability, increasing sediment, flushing by high flows, lack of LWD and side channels- so many interconnected issues. • Lowered confidence on this one as we do not really know how much this occurs and what the impacts are. We have a data gap around residency time and overlap with periods of peak flows. We also do not know the rearing capacity of the river. • This will have greater impacts on stream type Chinook. • Higher highs and lower lows; trend is happening every year. • With no refuge, fish getting flushed out of the system, resulting in immature smoltification and a decrease in adult returns. • Boulder, edge habitat and back eddies may provide refuge from high flows. • Need to consider how much production is being swept out at high flows. • Currently, process has a good handle on peak flows under old regime, but with impact of climate change, our understanding has decreased. Storm cells more tropical – high intensity and short term. With storm events increasing and changing, there is a need to plan accordingly. • DFO used to look at the lifespan of rehabilitated sites lasting for 25 years, that number is now thought to be cut in half.
LF26: Mortality or fitness impacts as a result of lack of food	• This limiting is associated with a bunch of other limiting factors already discussed, but also covers off nutrients. This is more towards ocean-type than stream-type as the population appears more stable in the upper river. • Fish adapt to cold water situation and low food (i.e. stream-type) • pH can cause a big fluctuation in insect population. • Annual steelhead rearing survival in Cowichan – food supply isn't a limiting factor. It is a different system, but has similar weather patterns, size of fry smolts. • Invertebrate surveys currently taking place on the Englishman. (Island Fly Fishers Association). • Lack of wetted vegetation = less insect population • In Cowichan, smolts leaving estuary around 70mm survived longer. Better strategy is to stay in-river longer so fish can grow, but it's also a matter of food availability in estuary at time of entry. • Fish going out later (i.e. a month later) at a bigger size do better; they are also taking advantage of a different habitat. • Logging activity causes increase in in-river nutrients over the short term (5 years). • Logging leads to bursts of plants that suck up phosphorus and cause decreased productivity due to poor nutrient load. • Nanaimo is much less productive than Cowichan; not a lot of complexity in the lower river. • Productivity in upper river differs around lake system than riverine system. • Unsure if nutrients provided in biofilm are being washed out by high flows.

Limiting Factor	Summary Notes
LF27: Mortality or fitness impacts as a result of competition with Alien Invasive Species	• Yellow perch, pumpkin seed, small mouth bass, largemouth bass, and American bull frog in Quennell Lake (Holden Creek area). • Low confidence on the scoring as not much is known about this. • Pumpkinseed in lower reaches may compete for food.
LF28: Mortality or fitness impacts as a result of competition, disease, interaction with other species/hatchery fry	• This has been identified as a data gap. It is unknown whether hatchery and wild fish are occupying different spaces both in-river and in the marine environment. • Nanaimo River Hatchery – once released, fry move downstream right away and out of the freshwater system; however, as fish are released into the lake, it is unknown how long the residency time is and where fish are occupying space. • Dick Nagtegaal's work saw that hatchery fry moved passed wild fry right away. • On the Cowichan River, hatchery and wild fish appear to use different strategies (not often viewed as occupying the same space). Hatchery fish move straight out to the estuary (already at size when released), resulting in a low level of overlap and interaction. • Peamouth Chub are present in the Nanaimo River watershed, competition may exist there.
LF29: Mortality as a result of high levels of predation	• Limiting factor should be related to low water flow (especially ocean-type smolts) as decreased water levels in the spring leave fry more exposed to predation pressures. • Need to consider shifting environmental factors – predators can align to changing conditions.' • In low water years, river is a predation gauntlet in Cowichan; 20-30% mortality in high water, 70% mortality in low water. • Ties to availability of riparian habitat; with refuge areas, fish have more of choice to move downstream when they want to, but currently the habitat is not there. • Window of rearing and smoltification is during the low drought cycle; without high turbid flows, there is no place for fish to take refuge. • More low flows in the future (under climate change) would lead to a higher impact posed by this Limiting Factor.
LF30: Mortality or fitness impacts as a result of anthropogenic disturbance	• Identified as more of an issue on the Cowichan River; swimmers and sun tan lotion, beer bottles, garbage etc. may have an impact on fish and aquatic insects.
LF30.5 Aquifer drawdowns, direct mortality through pumping, domestic use	• Currently, aquifer water being drawn down for mill purposes. The water flowing over the aquifer is cold at 10cfs; water that could be used to improve lower rearing conditions and could have a positive impact on smolt rearing. • Industrial effects of aquifers is slight for spring run; before pulp mill, lowest flow was 50cms. This is fundamental to the fall run facing high water temps; there is a need for groundwater wells (artesian wells) for water flow instead of lake runoff (which heats up in summer). • Temperatures in the lower river can reach sub-lethal to lethal summer temps (20-24°C in August) – modifications from aquifers to keep system temperatures in good condition. • For aquifers, there are licensed groundwater takings based on annual volumes. The Province of B.C. doesn't have records on a monthly basis (annual only). They are trying to get existing non-registered users to report. That way they can adjudicate new requests from a potentially fully allocated system. Groundwater level monitoring is taking place. Gap in information on the contribution of groundwater data to lower river stream flow. • Any new non-domestic water use needs to be licensed through the Province of B.C.
LF31: Mortality or fitness impacts as a result of disease	• A data gap – not a lot is known about mortality or fitness impacts as result of disease on the summer run population in the Nanaimo River.

Limiting Factor	Summary Notes
LF32: Mortality or fitness impacts as a result of hatchery introgression	• The recommended proportion of natural influence (PNI) of fish in an enhanced population should be 0.72 (DFO Science) – it is thought that the summer run population is at 0.6. • After two generations, hatchery origin is indistinguishable from fish spawning in the wild – stock appears similar enough to a wild stock. • Growing pool of evidence proving hatchery / wild genetic interaction is detrimental to viability of offspring in natural environment. • Behavioral impacts? • Suggestion that perhaps this limiting factor should also be reflected in the adult life history stage as well.
LF33: Low early marine survival of Chinook fry and smolts in the estuary / nearshore marine due to the lack of adequate food supply (particularly in first 4 months of marine life) and reduced water quality	• Most of the food availability is on the east side; however, flows direct juveniles towards urbanized west side of estuary from April to June. • Recent, reasonably significant adjustment (decrease) to the log storage area. • Channels potentially used during outmigration can be full of wind debris from log storage, covering the intertidal salt marsh benches used for feeding and refuge. • Currently an estimated 590,000m^2 of eelgrass in the estuary, compared to 2002 (field surveys) which estimated 1,300,000m^2. • Research done in Alaska does point out that estuaries can vary inter-annually from 10-50%. Proper eelgrass transplant techniques include core sampling to ensure the grounds are viable (i.e. impacts from fibre mat). • Sedge benches should also be considered as those areas can provide big sources of food for fish in the estuary. • Sea level rise will change dynamics of plants in the estuary as they have depth limitations; will start to move more uplands.
LF34: Predation of smolts in the lower river and estuary	• Not so much predation itself as that is a natural problem, but due to lack of refuge, other anthropogenic stressors, etc. • Recommendation to look at potential light sources assisting seal predation in-river at night. • Transition area between river and estuary especially needs attention as fish require that area for acclimatization. • Large woody debris is being cut up and removed from upper estuary which is concerning as it would be good areas for refuge. • Log booms provide refuge at high tide and are good stickleback habitat (source of food for juvenile salmonids); whether these booms are serving as a sink source for predation (i.e. bringing them all to the booms where seals wait to feed) is unknown. • Heron predation in Cowichan found 10% mortality caused by 90 birds. There are very little areas to protect these fish from bird predation. • Generally this is considered a data gap. • Mitigation should include refuge areas for fish. • With lack of wood on east side, refuge may not be as good as once thought. • Small population of seals can have a big impact on a small fish. • Time of year and other food source availability should be considered (i.e. seals will pass by salmon smolts near haulout on the way out to fish hake). • Moderate to high tides is when seals are using the log booms; when fish are most vulnerable, at low tide, seals are off into deeper water. We think there is an effect on the fish, but to what extent is unknown.
LF35: Mortality of fry and smolts due to predation and competition from AIS	• European green crab; DFO currently undertaking an active sampling program in Nanaimo. Movement of European Green Crab into Nanaimo is an inevitability. Regulatory standpoint – how do we fashion authorizations on how to deal with this? • currently not much information, but may be an increasing concern in the future

Limiting Factor	Summary Notes
LF37a: Loss of good quality marine riparian habitat.	• A meaningful critical habitat. • Full conversion of these habitats. Dredging maybe mitigated to move fish over to less disturbed right side (Jacks Point). • Salt marshes have historically been heavily impacted by farming practices; relic berms present (currently subject of rehabilitation through SEP-RRU unit). • If estuarine deposition isn't keeping up with sea rise, productivity decreases; already seeing sedges migrating into people's properties as sea level rises. • Although some areas are degraded, others are in good shape. Holden Channel has over 4km of mature forest riparian extending to Jack Point. • Invasive plants potentially contributing to part of the loss. • Large woody debris is no longer accessible in estuary of being replenished for refuge. • Need to ensure there are riparian refuge areas along the fringe; stands with legitimate growth that can contribute in a meaningful way.. • West side of estuary is heavily urbanized. • Need to consider access – fish are being routed to west side (industry), instead of mature coniferous forest on eastern side.
LF37b: Loss of good quality intertidal habitat i.e. Loss of natural abundance and composition of benthic communities, associated ecological communities.	• Ministry of Transportation and Highways had someone come out and look at the sediments on the west side of the estuary in the last 8 years- maybe look for this report? • High confidence in estuary aquatic plant refuge loss and lots of studies supporting the anoxic environment. • There appears to be stability and improvement in the benthic community (over the past 40 years) post log boom movements; as log boom shrinks, recovery continues. Ground-truthed (A. McNaughton). Log booms and clams are mutually exclusive (no clams found underneath booms); but higher density of copepods (Habitat Status Report)? • Habitat Status Report does not support benthic community improvement – lack of lit. to support this. Recovery of good habitat takes a long time following change to storage area to deeper water. • Other forms of impact beyond benthic communities (i.e. eelgrass); relic berms have a varying degree of impact. • Smaller channels on west side are accessible during certain tides; however, full of small woody debris from de-barking. • Log booms bottoming out cause impaction – will take a long time to recover.
LF37c: Loss of good quality subtidal habitat ie. Loss of natural abundance and composition of benthic communities, eelgrass habitat, kelp forests and associated ecological communities.	• Benthic mudflats need to be looked at as a food resource. As the tide drops, that is where fish take refuge. • Area is anoxic, not much showing up in net surveys in the mudflats. • Significant loss of eelgrass habitat noted over time. • Loss of kelp forests around the Strait of Georgia is a huge blow to habitat complexity and productivity.

Limiting Factor	Summary Notes
LF38: Reduced survival due to decreased water quality from ballast dumping, industrial discharge, and sewage effluent in the estuary.	• The Current status of estuary is thought to not be benefitting fish. • There is industrial runoff from agriculture in Holden Creek and runoff from impervious surfaces throughout urbanized areas surrounding estuary. • Bark from log booms can be thought of as industrial discharge. • Using history of estuary to come up with a long-term strategy. Need to be careful of moving footprint from one location to another if we undergo mitigation methods for current situation. • No discharge into the estuary; ballast may empty out from freighters, but rules unknown. • Consider LF less on point source, more on diffuse. • The Nature Trust (Tom Reid) is looking at estuary resilience, CTD monitoring, turbidity monitoring at Jack point, water quality profiles, plant productivity, understanding of water quality monitoring. Project goes from 2020 to 2025. • No evidence that federal quality guidelines have been exceeded, but very difficult to exceed those guidelines; increasing urbanization decreases biota. Whatever is in water will be absorbed into sediment. • Loose data on Ministry of Environment website. Soil sediment needs to be looked at in tandem – correlation between metals and fish. • Legacy of sewage. Harmac (?), coal tailings. Confidence in some aspects of contamination; uncertain of effect.
LF39: Mortality or reduced fitness as a result of direct anthropogenic interference, not covered by previous LFs.	• Some folks felt that any comments attributable to this limiting factor had already been covered by limiting factors focused on water quality in the estuary. • High urbanization and industry influence on the west side of the estuary. • Acknowledgement that the industry is aware of past practices and making efforts to shift (i.e. minimizing impacts of crop wash, decreased log boom storage, etc.). • Identified alternative log storage practices being carried out by others in the industry (e.g. direct-to-barge approach).
LF40: Low marine survival due to inadequate food supply (abundance or value)	Food availability occurs throughout the StGeo. Herring and Decapod larvae are major components. Unknown level of impact
LF41: Low marine survival (<1%) in the Strait of Georgia due to low marine productivity, poor water quality, increase mean water temp	Likely some areas are unaffected (mainland inlets). Not sure of the impact
LF42: Low marine survival as a result of competition for food	Same as LF40. Can't separate inadequate food supply with high levels of competition
LF43: Low marine survival due to high rate of predation by orcas, pinnipeds	Although RSKW prey on Chinook, most of these pods are in the southern part of the StGeo and Puget Sound. The Nanaimo Summer run Chinook population is known to be further north in the StGeo. Pinnipeds can be found throughout the StGeo however BKW have forced them to keep to haulouts. Seals and sealions are more likely to be found nearshore, due to BKW. Salmon sharks are an important predator on salmon in pelagic waters. Other predators such as other fish species will impact young salmon smolts. This is a natural process however what can be addressed is how anthropogenic activities have affected this relationship.

Limiting Factor	Summary Notes
LF44: Low marine survival due to high rate of predation in nearshore environments	Combined with LF43
LF45: Mortality or fitness impacts as a result of competition with aquatic invasive species	Unlikely to be a limiting factor
LF46: Mortality due to impacts related to offshore habitat destruction	No marine drilling in StGeo, but high level of boat traffic
LF47: Mortality or sub-lethal effects as a result of pollutants	Major sources of pollutants of treated sewage discharges from communities around the StGeo (population. 1M +), several pulp mills, Fraser River discharge from south central BC.
LF48: Mortality or fitness impacts as a result of disease	Unlikely to be a limiting factor
LF49: Mortality or fitness impacts as a result of HABS	Very localized algal blooms (Cowichan Bay)
LF50: Mortality due to fishing	• Need to look at Avid Anglers data. Approx. 5,000 DNA samples on Nanaimo Chinook out of the Strait of Georgia. • Losses as a result of catch and release may be underestimated. • Recent regulation changes lowered spatial scale. • No data on distribution of early run fish in marine environment. • Using Puntledge as a surrogate reduces confidence.

Nanaimo Estuary Marine Mammal Survey

Steve Baillie[4], Nicolette Watson[4] and Jaclyn Boutillier[5]

Figure 2. Nanaimo River Estuary, looking northwest.

Introduction

Estuaries are important habitats in the life history of salmon. As returning adults, salmon must assemble and move through estuaries before migrating upstream to holding and spawning areas. As juveniles, fry and smolts will migrate downstream from rearing areas to hold and feed in estuaries while their osmoregulatory system transforms to allow them to go from a freshwater environment to a saline environment. For this, estuaries must have adequate holding areas with refugia, clean water that is clear of contaminants, and adequate food supplies.

Marine mammals are known to predate on returning adult salmon (Bigg et al. 1990). Thomas et al. 2017 showed that both adults and juvenile salmonids are targeted by Pacific Harbour Seal (*Phoca vitulina richardii*) in the Strait of Georgia. They showed that prey species selection of adult salmon is related to abundance (targeting Chum and Pink salmon as the most abundant salmon species), and prey selection of juveniles is related to size, that is, the smolts of Chinook, Sockeye and Coho. The latter two species have yearling smolt life histories and Chinook are mostly sub-yearlings. In their analysis they differentiated the scat samples by DNA, then further divided the samples into juveniles and adults using hard structures but did not divide the juveniles into sub-yearlings and yearlings. Chinook were the most abundant salmonid in the samples from the Comox and Cowichan estuaries, while neither system have a yearling Chinook life history variant.

[4] South Coast Area, Fisheries and Oceans Canada, 65 Front Street, Nanaimo, BC, V9R 5H9
[5] Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, V9T 6N7

In addition, research on the Comox River[6] has shown that seals can become habituated to a riverine habitat, using anthropogenic devises (artificial lighting, channelized river, bridge shadow) to prey on migrating adult and juvenile salmon with high efficiency. In the Nanaimo River Estuary, a long history of sediment runoff have filled in holding pools, and log storage structures have been used by marine mammals as haul-out habitats.

Generally, seals will forage within 10-20 km of their favoured haul out locations (Ford 2014). Peterson et al. 2012, using satellite tags, found a mean distance between capture sites and over-water distances of 20.7 km (S.D. 31.4 km) with males ranging further (mean 24.2 km, S.D 34.3 km) than females (mean 6.5 km, S.D. 6.1 km) in their study in the San Juan Islands in the Strait of Georgia. Allegue et al. 2020 found lower than expected seal feeding behaviour in the Big Qualicum River estuary despite Coho and Chinook smolt releases of 384,000 and 3 million, respectively. They speculate that this may be due to the small size of the Chinook smolts and that the seals were targeting larger fish that were attracted to the abundance of the salmonid smolts.

There are several other haul out areas used by seals including the local islands (e.g. Newcastle, Protection, Hudson Rocks, Five Finger and Entrance Islands) as well as floating log booms in Northumberland Channel. The estuary based log booms provide a convenient base from which to initiate feeding activities in the estuary and likely contributes to predation of Summer run Chinook. In the absence of these log booms there are several alternative haul out locations within 20 kms.

The diet of seals is comprised of many species of fish and shellfish and the majority (75%) of prey is herring and hake with less than 5% from salmonids (Ford 2014). However, when Thomas et al. 2017 examined the scat remains from the Cowichan, Comox and Fraser River estuaries the results show that up to 65% of the daily consumption is comprised of salmonids in these specific habitats. The most frequent salmon species in the fall were Chum and Pink salmon, which are the most abundant salmonid species at this time. In contrast, the species composition of juvenile salmonids during the spring was Chinook, Coho and Sockeye which are less abundant that Pink or Chum juveniles, but much larger in size. Adult Chinook were detected in the estuary samples from April to November, with a large peak (15%) in September and a smaller peak (4.7%) in July, coinciding with the return of adults to their natal rivers (Figure 3).

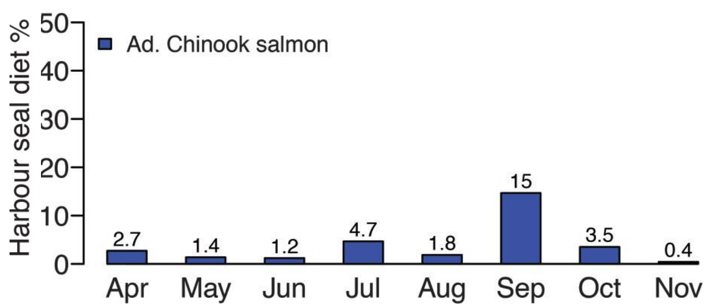

Figure 3. Seal diet composition, adult Chinook component. From Thomas et al. 2017, their Figure 3, in part.

In a similar study, unpublished data from the DFO Marine Mammal Section[7] suggest that within estuaries the proportion of salmonids in the seal's diet varies from year to year but have averaged lower than the data presented by Thomas et al. 2017. The highest salmonid component from estuary samples in the fall is Chum Salmon. The proportion of salmonids in the diet in the summer run estuary samples is very low, less than 5%.

[6] P. Olesiuk, Fisheries and Oceans Canada unpublished report
[7] S. Tucker, Fisheries and Oceans Canada, pers. comm.

While assembling background information for the RPA, the requirement for understanding the level of marine mammal activity in the estuary was identified therefore, with partnership with the Snuneymuxw First Nation (SFN), an assessment survey was initiated.

Goals of the assessment:

- Estimating the abundance of marine mammals in the estuary
- Monitoring fish feeding behaviour by the marine mammals
- Documenting the extent that the log booms were used by marine mammals

Methods

Marine mammal enumeration was conducted using an open herring skiff which allowed for maneuverability and access in varying tide levels. The vessel followed a serpentine course through the lower intertidal area so that the entire survey zone could be observed. Observational surveys were conducted periodically from 21-Oct-2019 through to 13-Sept-2021, covering the two-year period of the project.

Figure 4: Survey boundaries for the Nanaimo estuary marine mammal survey.

The survey area boundaries covered the extent of the mid to lower tidal sections of the estuary and were delineated by the mouth of freshwater inputs (i.e. Nanaimo River, Holden Creek, etc.), the Nanaimo Assembly wharf, the southern point of Protection Island and Jack Point (Figure 4).

For each survey, the date, start and end time, sea state, weather condition and visibility description were noted. A line was drawn on a survey map for each sample trip to indicate the direction, route of travel and extent of area surveyed.

For each sighting, a reference number was included on the map and corresponding information such as species, number of individuals, and behaviors were recorded. Surveys were conducted both with naked eyes and with use of binoculars. See Appendix C for a blank field data sheet example.

The behaviour descriptions were summarized into the following categories:

- On log booms
- In water
- Fishing
- Crabbing
- On land

Table 5. Number of Surveys conducted each month throughout study

Month	Number of surveys
Oct-19	2
Nov-19	9
Dec-19	4
Jan-20	1
Feb-20	2
Mar-20	4
Apr-20	5
May-20	7
Jun-20	9
Jul-20	6
Aug-20	5
Sep-20	7
Oct-20	4
Nov-20	5
Dec-20	10
Jan-21	2
Feb-21	2
Mar-21	3
Apr-21	2
May-21	2
Jun-21	2
Jul-21	2
Aug-21	2
Sep-21	1

In addition to Pacific Harbour Seals, other species observed were Steller Sea Lion (*Eumetopias jubatus*), California Sea Lion (*Zalophus californianus*), Northern River Otter (*Lontra canadensis*) and American Mink (*Neogale vison*). The latter two species are not classified as marine mammals however they are known to predate salmon in estuaries and therefore any observations were recorded.

Although the field crews endeavored to maintain sufficient distance from the observed animals to avoid altering their behaviour, it must be acknowledged that these animals often pause in their normal activities to scan for predators or observe any changes to their environment, including boat traffic. Behaviour such as fishing activity may have stopped prior to being observed by the field technicians and what was observed and recorded was 'in water'.

Each survey lasted between 1 and 4 ½ hours, and averaged 3 hours, 12 minutes. Regardless of the length of time, a similar area was observed on each trip. Frequency of surveys ranged between once per month up to 10 surveys per month (see Table 5). 98 surveys were carried out though the study period.

Results

Behaviour

2285 observations were made throughout the survey which have been summarized and presented in Table 6. The most frequent observed behaviour was the animals hauled out on log booms (61.8%), followed by being in water (36.1%), then actively fishing (1.6%), on land (0.4%), and crabbing (<0.1%). It is possible that the animals observed in the water may have been engaged in fishing behaviour and the presence of the observers altered their activity. Fishing behaviour was associated with actively diving and surfacing or consuming a fish. Pacific Harbour Seals comprised 90.4% of all observations, followed by Steller Sea Lion (4.8%), Northern River Otter (4.1%), California Sea Lion (0.5%) and American Mink (0.1%). Due to the high level of seal observations most of the analysis is based on the seal data.

Tidal cycle

Generally, surveys were undertaken between the mid-flooding stage and the mid-ebbing stage of the tidal cycle (Figure 5). The stage shown as *Mid level* is a situation where the tide was ebbing from a high

Table 6. Summary of marine mammal enumeration by species and behaviour.

	On log booms	In water	Fishing	Crabbing	On land
Harbour Seal	1327	718	15	0	0
California Sea Lion	3	7	2	0	0
Steller Sea Lion	6	83	20	0	0
River Otter	69	15	0	1	9
Mink	3	0	0	0	0

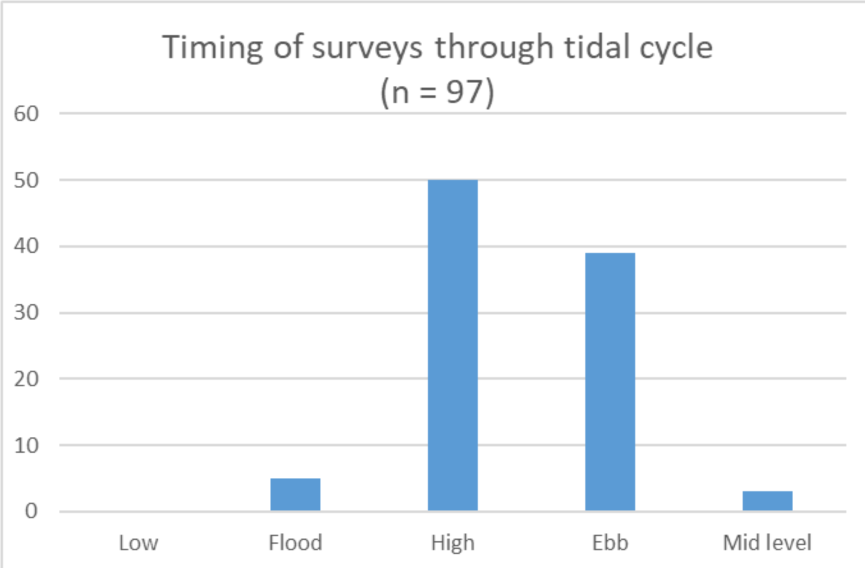

Figure 5. Tidal stage during surveys

point to a moderate low point with the resulting water level remaining constant for several hours. The lack of surveys during the low water segment of the tidal cycle prevents any analysis of marine mammal abundance and behaviours at these times. Physically, the log booms that are used for loafing behaviour are grounded at low tide with water present only in the river and tidal channels. Bigg et al. 1990 observed that in the Comox and Cowichan River estuaries seals moved to the shallow water areas at the edge of the estuary during the low water period of the tidal cycle and did not rest on the exposed intertidal gravels. We can infer that seals are following the same pattern in the Nanaimo estuary. Bigg et al. 1990 noted that these animals continued to conduct their daytime activities of fishing, slow swimming and resting in these areas.

Table 7 shows the mean number of observed seals by tidal stage across all surveys throughout the study. The number of seals were consistent for most of the stages of the tidal cycle that were surveyed except for the mid-level stage. The seals may have been moving out of the intertidal area at this tidal stage, as observed by Bigg et al. 1990.

Table 7. Average number of seals observed during different tidal stages.

Tidal cycle	# of surveys	Mean # Seals/survey
Flooding	5	20
High	50	22
Ebbing	39	22
Mid-level	3	8

Diurnal cycle

Observational surveys were only conducted during daylight hours. Surveys were conducted at various times through the daylight hours, depending on the tidal cycle. Although not evenly distributed, the diurnal coverage does allow for comparison of behaviours throughout the day (see Figure 6).

On Log Booms behaviour was more prominent in the mid-day to evening period, with *In water* behaviour dominate in the morning. As well, the majority of fishing behaviour was observed during this period. This suggests that when the seals are in the water they may be engaged in fishing behaviour as well.

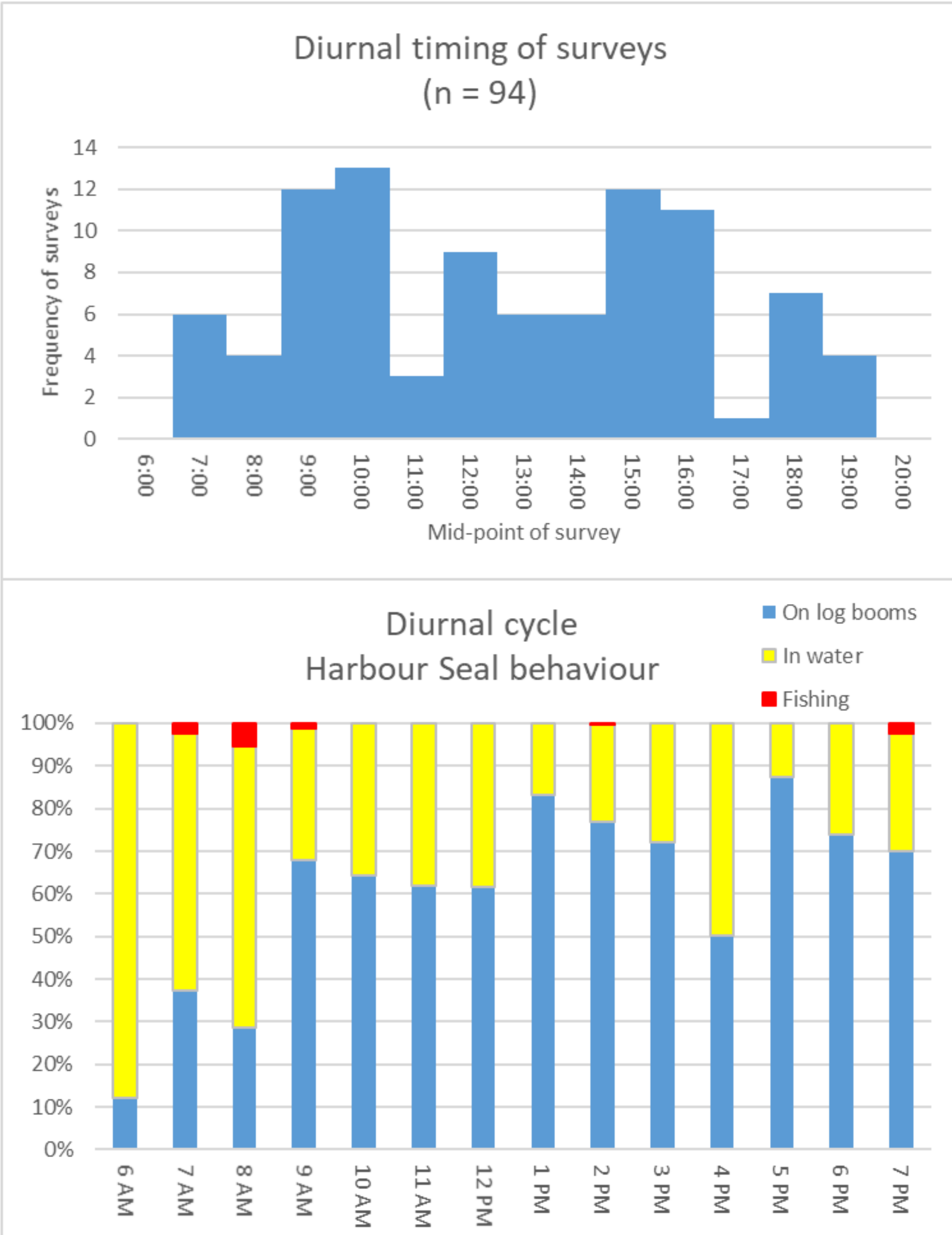

Figure 6. Timing of mid-point of individual surveys during the diurnal period, and a summary of the observed behaviour of seals through the diurnal period.

Annual Cycle

Figure 7 shows the number of animals observed throughout the year. The lower figure shows Pacific Harbour Seal only, and the upper figure shows the other four species. The year was divided into semi-monthly periods, and the data shows the average number of individuals observed per survey. Overlaid on these figures are the times when juvenile and adult salmon are present in the estuary. Steelhead trout were not added due to the low number of animals present. Regardless, they can be found migrating through the estuary from December until March with some adults (kelts) returning back to the ocean in April and May.

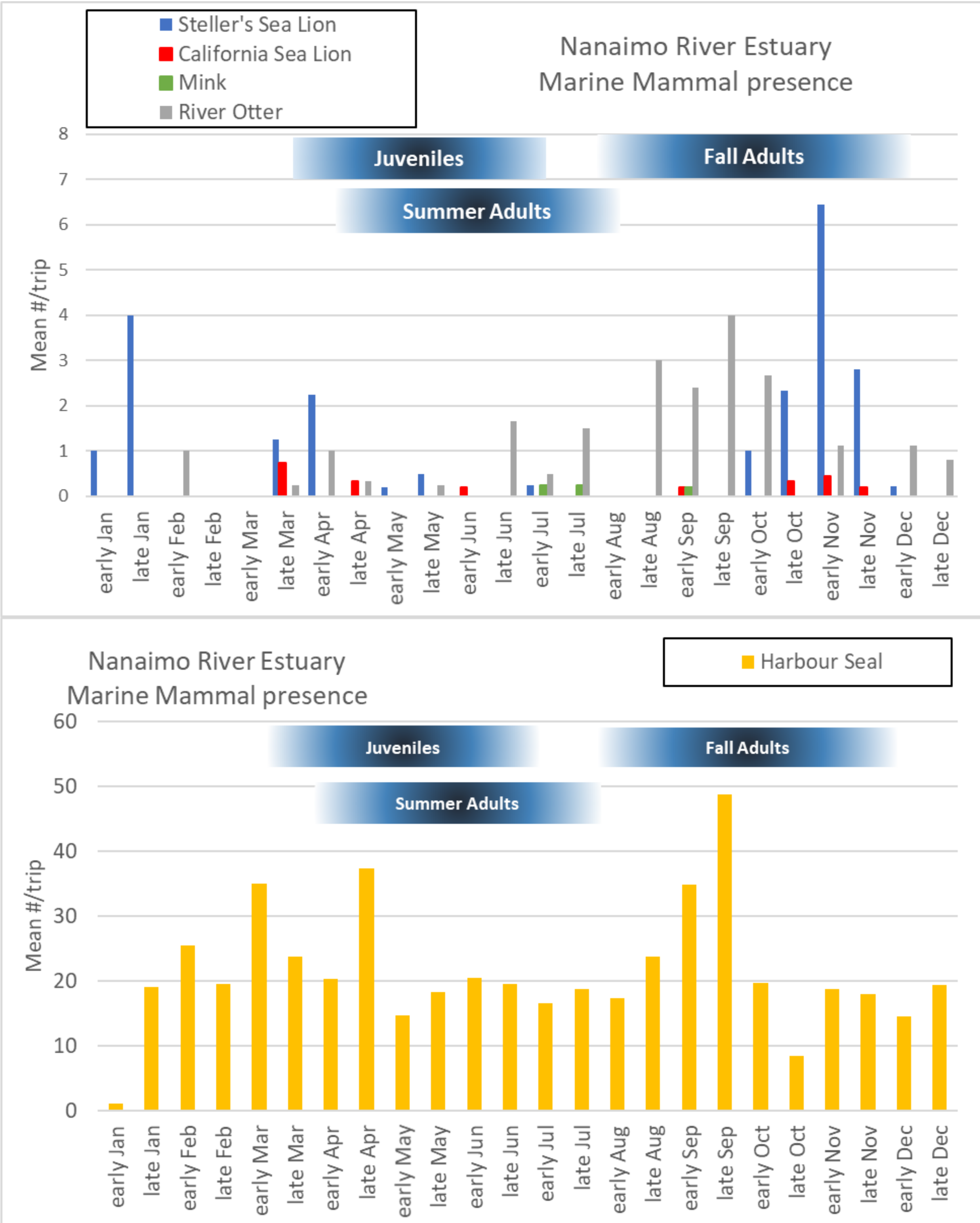

Figure 7. Abundance of marine mammals by semi-monthly period in the Nanaimo Estuary.

Pacific Harbour Seals were the most abundant of the marine mammals present in the estuary. There were consistently ~20 animals present throughout the year, with higher abundances in March-April, and September, coinciding with salmon smolt presence and Chinook and Chum adult presence, respectively.

The presence of Steller and California Sea Lions was more sporadic but were often observed in late March/April and again in September to January. Similar to Pacific Harbour Seals, these periods coincided with the presence of salmon smolts and adults.

Northern River Otters had a greater presence in the estuary during the summer and fall period. American Mink were seldom observed in the estuary.

Anthropogenic influences

The log booms are used by the seals as a haul out, but only during the high water period of the tidal cycle. During the low water period when Chinook would be most vulnerable to predation the log booms are either grounded or in the deep pools on the western side of the estuary and the seals likely move to offshore habitat.

Conclusions

Steller Sea Lions, California Sea Lions, Northern River Otters and American Mink were infrequently encountered in the Nanaimo Estuary so it is unlikely that they are a major predator on Summer run Chinook. All marine mammals were seen using the log booms in the estuary.

The most abundant marine mammal in the estuary is the Pacific Harbour Seal which can be found at all times of the day, during the mid to high periods of the tidal cycle and throughout the year. Approximately 20 seals can be observed on average at any given time during the higher levels of the tidal cycle. There are estimated to be 39,000 seals that reside in the Strait of Georgia, using up to 500 haul out locations including the log booms in the Nanaimo River Estuary. Seals tend to have a strong site fidelity to favoured haul out locations and the data from this study supports this observation.

Fishing behaviour was observed, but rarely. This may have been due to changes in seal behaviour caused by the presence of the observers, but based on information from other studies, we can assume that adult summer run Chinook could be as high as 4.7% of the seal's diet as shown by Thomas et al. 2017. Chinook smolts, especially yearling smolts may be part of the seals diet in the spring.

The anthropogenic influences in the estuary is limited to the presence of the log booms which are only utilized by seals during the high water period of the tidal cycle. During the low water period the seals likely behave normally and move to other haul-outs or forage in open water.

Based on the number of seals present, the low level that Chinook comprises in the seal diet, it is likely that this predator – prey relationship is a moderate or low risk to the Chinook population.

Figure 8. California sea lion feeding on salmon in Nanaimo River estuary, November 2019.

Acknowledgements

We would like to acknowledge the participation of the Snuneymuxw First Nation whose cooperation has made this project successful. Specifically, we thank Alfred Fraser, Wade Good, William Wyse for their expert boat and observation skills, and especially Juan Moreno for supervising the field activities and sharing his extensive knowledge of the Nanaimo River.

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Appendix C

Survey sheet used during 2019-21 Nanaimo estuary marine mammal survey.

Nanaimo River Estuary – Marine Mammal Survey Map

Date		**Surveyors(s)**	
Survey Start Time		**Survey End Time**	
Weather conditions (Check those that apply)	☐ Clear skies ☐ Overcast ☐ Rain (light/heavy) ☐ Snowing (light/heavy) ☐ Wind: (<10 km/h) (10 to 40 km/h) (40+ km/h)		
Visibility (Check those that apply)	☐ HIGH – (i.e. clear skies) ☐ LOW – (i.e. rainy, snow, fog)		
Sea State (Check those that apply)	☐ Flat ☐ Ripple ☐ Waves beginning to form ☐ White caps		

Instructions:
1) On the Survey Map, draw a line with directional arrows for route of travel;
2) Identify location of marine mammals and mark with a Reference Site #;
3) Complete details for each reference site in the Survey Table (back of page).

Log storage lease under 2017 proposed areas.

For each species found, use the following code:

Pacific Harbour Seal (*Phoca vitulina*) – Use code SEAL
Stellar Sea Lion (*Eumetopias jubatus*) – Use code STEL
River Otter (*Lutra canadensis pacifica*) – Use code OTTR
Mink (*Mustela vison*) – Use code MINK

Reference Site #	Species	Number Observed	Behavior (i.e. in water, haul-out, travelling, fishing, etc.)	Notes
Ex.	SEAL	5	*Hauled out on log booms*	n/a
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
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17				
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19				
20				

Additional Notes:

Enumeration and Run-timing of Chinook in the Lower Nanaimo River

Steve Baillie[8], Stewart Pearce[8], Nicolette Watson[8] and Andrew Campbell[8]

Figure 9. Chinook salmon migrating upstream on 9-May-2021

Introduction

The run timing of a salmon population is based on the specific month in which the peak rate of freshwater entry occurs. One of the data gaps that has been identified is the lack of run timing information for the early Chinook Salmon in the Nanaimo River. While there is extensive river swim enumeration data that could be used to provide insights into run timing, a more accurate run timing dataset would come from a fixed-point enumeration project in the lower reaches near tidewater.

> From Waples et al. (2004):
> *Adult run timing.* Adult run timing (time of peak entry into fresh water on the adult spawning migration) is the life history trait most commonly used to discriminate among and define salmon populations. All of the populations in the study could be characterized as belonging to one of four seasonal runs (peak run time of March–May, spring [S]; June–August, summer [SU]; September–November, fall [F]; December–February, winter [W]), which facilitated comparisons with the genetic data.

The record of early run Chinook Salmon in the Nanaimo River has been inconsistent in the run timing description, likely due to the lack of an assessment project that monitors the movement of this population(s) into the river. Two papers of note are Carl and Healey (1982) in which they describe three Chinook populations, corresponding to the three spawning locations and three different juvenile life histories, but used the term *Early* for the two upper populations and did not differentiate the timing. Holtby and Ciruna (2007) was the first paper that noted three run timing populations, but did not provide novel data to support this conclusion.

[8] South Coast Area, Fisheries and Oceans Canada, 65 Front Street, Nanaimo, BC, V9R 5H9

Early run Chinook are known to start entering the Nanaimo River between January and March, and continue through the spring and summer months. Figure 10 shows the average weekly swim counts of Chinook in three zones (Below White Rapids Falls, Below First Lake and Above Second Lake). Based on this data, the peak of migration of early run Chinook was determined to occur in June.

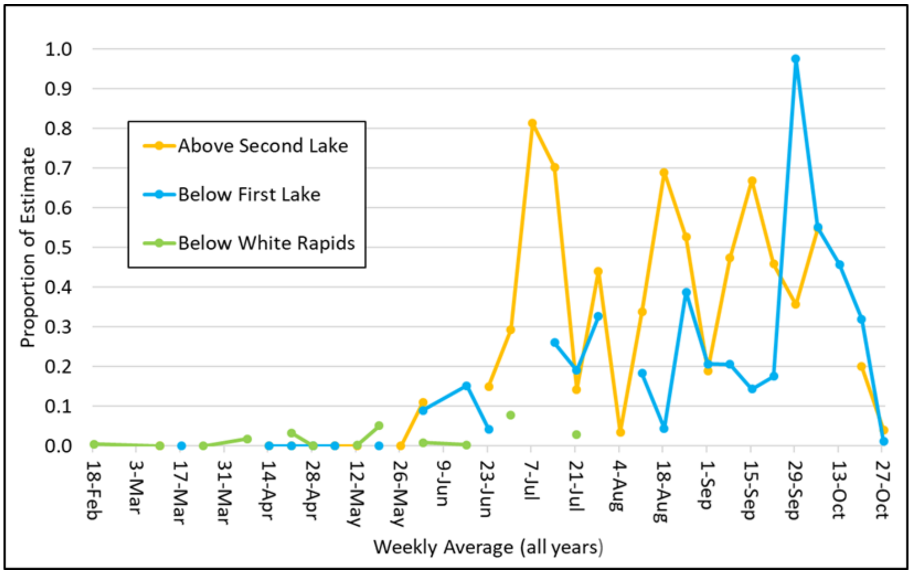

Figure 10. Average count by week of early run Chinook Salmon, Nanaimo River, 1979-2019.

Chinook that enter the river after 1-August are considered Fall Chinook, the majority of which enter the river in late September to early October. Both runs spawn in October to November; the Summer run Chinook in the mid river below First Lake and above Second Lake, and the Fall Chinook in the lower river below Highway 1. In addition, a winter Steelhead run is present in the Nanaimo River from December until May so the salmonids observed using the equipment cannot be assumed to be Summer run Chinook.

Methods

A Dual-frequency Identification Sonar (DIDSON) unit was installed in the lower Nanaimo River near the Duke Point Highway Bridge and started recording acoustic video on 12-February-2021. This location is normally used for Fall Chinook and Chum enumeration. The DIDSON recorded moving images from a wide range so complete coverage of the river cross-section was achieved, however species identification was not possible from the data. To provide species identification data three underwater video cameras were installed at this site and began operation on 7-April-2021. A subsample of the targets was captured but full coverage was not possible due to visibility limitations.

Data review was completed by technician Chantelle Johnny (Snuneymuwx FN). The output from this process was a daily count of all fish, associated with a subset of Chinook

Additional data was collected from the standard biweekly river swims starting on 22-January-2021. These were conducted by the BC Conservation Foundation until 13-May, and the Nanaimo River Hatchery after that date. The monitored reach includes the lower Nanaimo River from the Highway 1 bridge downstream to the Haslam Creek confluence (~2.3 km) and a spot check at the Borehole Pool, both known holding areas for adult salmonids.

Table 8. 2021 Nanaimo River Swim observations. Highway 1 downstream to Haslam Creek confluence, and Borehole

Date	STD	CK
22-Jan	0	0
11-Feb	1	0
3-Mar	0	0
19-Mar	0	1
24-Mar	3	4
16-Apr	3	24
13-May	5	64
28-May	0	33
30-Jun	0	70

Results

The following information was used to support the species composition estimates:

Steelhead Trout run timing is described as December to May, with a peak of migration in mid-March[9]. This information is based on extensive data sets from the neighboring Englishman and Cowichan Rivers.

Results of the swim surveys are shown in Table 8. The data showed zero Chinook in the observed reach prior to the 19-March-2021 swim, and zero Steelhead Trout were observed after the 13-May-2021 swim.

To separate the unknown target counts into Chinook and Steelhead, the study period was separated into 4 time periods:

1. 12-Feb-21 to 6-Mar-21DIDSON counts only, all targets assumed to be STD only
2. 7-Mar-21 to 6-Apr-21 DIDSON counts only, targets assumed to be both STD and CK
3. 7-Apr-21 to 31-May-21DIDSON counts and video ID, targets comprised of both STD and CK
4. 1-Jun-21 to 31-Jul-21 DIDSON counts and video ID, all targets assumed to be CK

Based on these assumptions, the unknown targets from the fourth period were assigned to Chinook. The unknown targets from the third period were divided simply by the proportion of known identified targets for this period. The targets from the first period were all assigned to Steelhead.

The targets from the second period were assigned using the following method. Using the known or assumed Steelhead target counts from 12-Feb to 6-Mar, and 7-Apr to 31-May, and an assumed mid-point of 15-March, a cumulative normal distribution was fitted to the data, solving for the standard deviation and the number of targets in the second period (Figure 11). The result of this process is an estimate of 36 Steelhead during the gap. Deducting this estimate from the target count of 59 leaves 23 Chinook for the period.

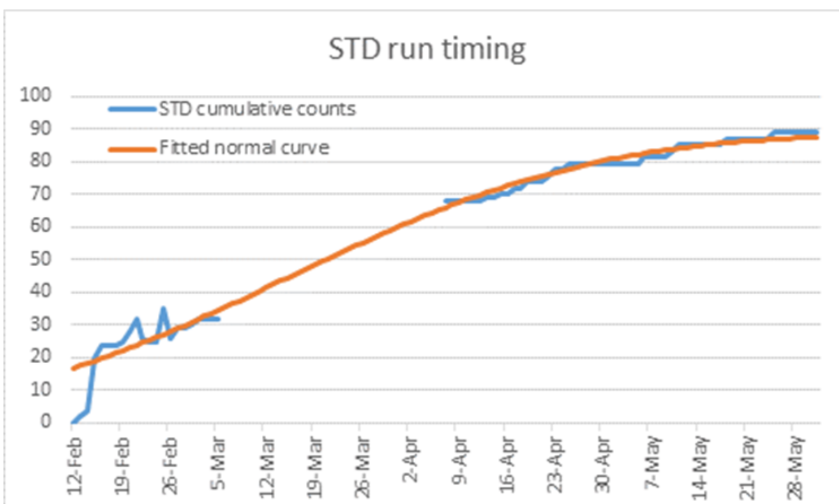

Figure 11. Resolved counts of Steelhead Trout, with fitted cumulative normal curve.

[9] M. McCulloch, BC Ministry of Forests, Lands, and Natural Resources, pers. comm.

Table 9. Summary of species count estimates by period.

	STD	CK
12-Feb to 5-Mar	32	0
6-Mar to 6-Apr	36	23
7-Apr to 31-May	22	266
post 31-May	0	703
total	90	992

Results from the DIDSON and Video review is shown in Appendix D. Table 9 summarizes the number of each species by period. Prior to 12-Feb there will have been additional Steelhead Trout migrating into the Nanaimo River however that information is not pertinent to this report.

Figure 12 shows the estimated weekly count of Chinook entering the Nanaimo River. As noted above, for the periods 2 and 3 in which both species occur, the unknown count for each day was assigned by the proportion of known identification observations for that period. This figure shows a mode during the early June period with 52% of the Chinook movement occurring during the period of 6-13 June.

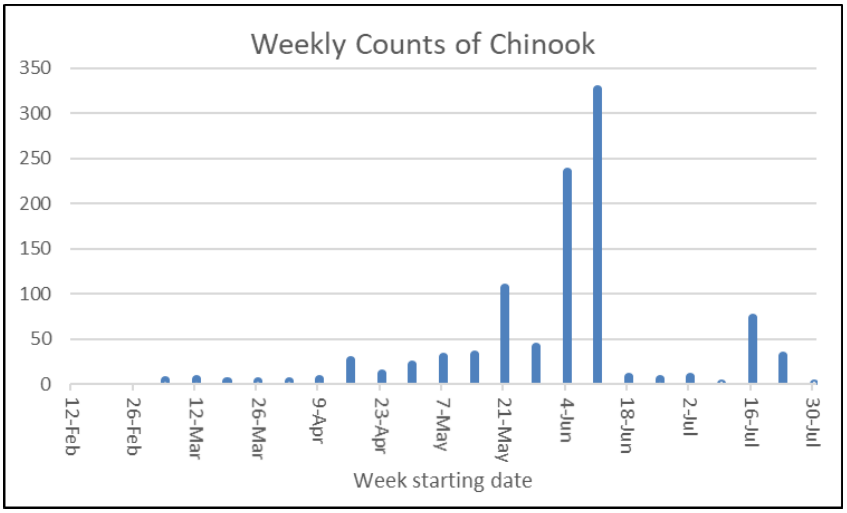

Figure 12. Weekly counts of Chinook Salmon, Nanaimo River, 2021

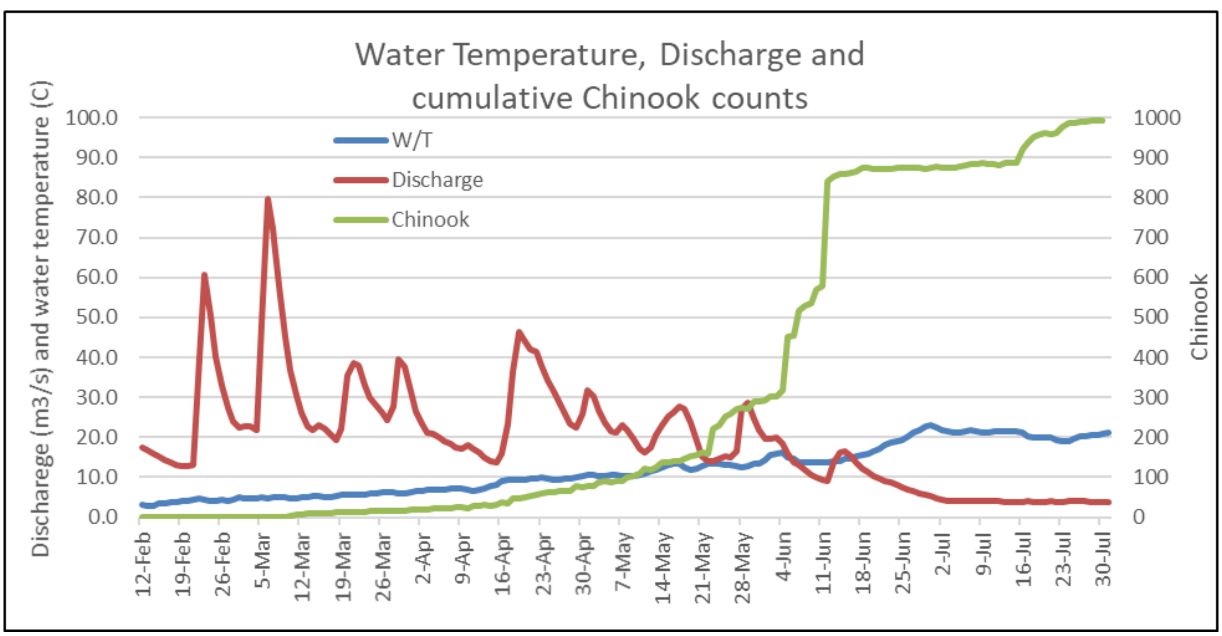

Figure 13. Cumulative Chinook counts, water temperature and discharge as measured at the Cassidy WSC station, 2021.

Figure 13 shows water temperature and discharge as measured at the Water Survey of Canada (WSC) station at Cassidy (Station # 08HB034). This station is located on the Nanaimo River near the Highway 1 crossing, approximately 7 km upstream from the DIDSON/Video site. Summer base flows of ~ 4.0 m^3/s and water temperatures of ~20^{O}C remained relatively constant from early July, with Chinook continuing to migrate upstream under these conditions.

Discussion

The data clearly shows a mode during the early June period, supporting the hypothesis that the early run of Chinook in the Nanaimo River has a peak freshwater entry in June, consistent with a Summer run timing designation (Waples et al. 2004).

While the data shows a mode in early June, there is also an increase in migration numbers in July. The July Chinook could be early Fall run Chinook or late Summer run Chinook and resolution would require DNA analysis of the individual fish. By convention, any Chinook entering the river after 31-July are assumed to be Fall run Chinook.

It would be difficult to identify a Spring-timed migration mode. The number of Chinook that spawn in the river upstream of Second Lake is less than 10 per year and it would be difficult for so few a number to form a mode, even if all targets can be satisfactorily identified. Regarding the data presented here, a lack of a mode could be an artifact of the methodology of assigning species (observed proportion applied to unknown ID counts and assuming any target prior to 6-March is a Steelhead).

Conclusion

The data presented in this report suggests that the majority of the early run Chinook in the Nanaimo River migrate upstream in early June which would denote this run as a Summer timed population.

References Cited

Carl, L.M., and Healey, M.C. 1984. Differences in enzyme frequency and body morphology among three juvenile life history types of Chinook salmon (*Oncorhynchus tshawytscha*) in Nanaimo River, British Columbia. Can J. Fish. Aquat. Sci 41: 1070–1077.

Holtby, L.B., and Ciruna, K.A. 2007. Conservation units for Pacific Salmon under the Wild Salmon Policy. Can. Sci. Advis. Sec. Res. Doc. 2007/070.

Waples, R.S., Teel, D.J., Myers, J.M. and Marshall, A.R. 2004. Life-history divergence in Chinook Salmon: historic contingency and parallel evolution. Evolution 58: 386–403.

Appendix D: Daily counts of DIDSON targets with species identification and assumed identification.

Positive value denote upstream migrating fish; negative values are downstream migrating fish.

12-Feb-2021 to 6-Apr-2021: DIDSON counts only

Date	Daily Total Counts	Unknown	Chinook		Steelhead	
			known	assumed	known	assumed
12-Feb-21	0	0	n/a	0	n/a	32
13-Feb-21	2	2	n/a		n/a	
14-Feb-21	2	2	n/a		n/a	
15-Feb-21	16	16	n/a		n/a	
16-Feb-21	4	4	n/a		n/a	
17-Feb-21	0	0	n/a		n/a	
18-Feb-21	0	0	n/a		n/a	
19-Feb-21	1	1	n/a		n/a	
20-Feb-21	3	3	n/a		n/a	
21-Feb-21	4	4	n/a		n/a	
22-Feb-21	-6	-6	n/a		n/a	
23-Feb-21	-1	-1	n/a		n/a	
24-Feb-21	0	0	n/a		n/a	
25-Feb-21	10	10	n/a		n/a	
26-Feb-21	-9	-9	n/a		n/a	
27-Feb-21	3	3	n/a		n/a	
28-Feb-21	0	0	n/a		n/a	
1-Mar-21	1	1	n/a		n/a	
2-Mar-21	2	2	n/a		n/a	
3-Mar-21	0	0	n/a		n/a	
4-Mar-21	0	0	n/a		n/a	
5-Mar-21	0	0	n/a		n/a	
6-Mar-21	0	0	n/a		n/a	
7-Mar-21	0	0	n/a	23	n/a	36
8-Mar-21	0	0	n/a		n/a	
9-Mar-21	2	2	n/a		n/a	
10-Mar-21	1	1	n/a		n/a	
11-Mar-21	9	9	n/a		n/a	
12-Mar-21	1	1	n/a		n/a	
13-Mar-21	6	6	n/a		n/a	
14-Mar-21	4	4	n/a		n/a	
15-Mar-21	4	4	n/a		n/a	
16-Mar-21	0	0	n/a		n/a	
17-Mar-21	1	1	n/a		n/a	
18-Mar-21	0	0	n/a		n/a	
19-Mar-21	3	3	n/a		n/a	

Date	Daily Total Counts	Unknown	Chinook known	Chinook assumed	Steelhead known	Steelhead assumed
20-Mar-21	1	1	n/a	See above	n/a	See above
21-Mar-21	-1	-1	n/a		n/a	
22-Mar-21	0	0	n/a		n/a	
23-Mar-21	2	2	n/a		n/a	
24-Mar-21	3	3	n/a		n/a	
25-Mar-21	1	1	n/a		n/a	
26-Mar-21	3	3	n/a		n/a	
27-Mar-21	0	0	n/a		n/a	
28-Mar-21	3	3	n/a		n/a	
29-Mar-21	-2	-2	n/a		n/a	
30-Mar-21	1	1	n/a		n/a	
31-Mar-21	1	1	n/a		n/a	
1-Apr-21	3	3	n/a		n/a	
2-Apr-21	3	3	n/a		n/a	
3-Apr-21	0	0	n/a		n/a	
4-Apr-21	1	1	n/a		n/a	
5-Apr-21	4	4	n/a		n/a	
6-Apr-21	5	5	n/a		n/a	

7-Apr-2021 to 31-Jul-2021: DIDSON counts and video identification

Date	Daily Total Counts	Unknown	Chinook known	Chinook assumed	Steelhead known	Steelhead assumed
7-Apr-21	-2	-2	0	120	0	10
8-Apr-21	0	0	0		0	
9-Apr-21	4	4	0		0	
10-Apr-21	0	-3	3		0	
11-Apr-21	-2	-2	0		0	
12-Apr-21	4	4	0		0	
13-Apr-21	3	1	1		1	
14-Apr-21	1	-1	2		0	
15-Apr-21	-2	-3	0		1	
16-Apr-21	4	3	1		0	
17-Apr-21	7	3	3		1	
18-Apr-21	-3	-3	0		0	
19-Apr-21	14	11	2		1	
20-Apr-21	2	2	0		0	
21-Apr-21	1	0	1		0	
22-Apr-21	7	6	0		1	
23-Apr-21	2	1	0		1	
24-Apr-21	3	3	0		0	
25-Apr-21	5	1	3		1	

Date	Daily Total Counts	Unknown	Chinook		Steelhead	
			known	assumed	known	assumed
26-Apr-21	2	1	1	See above	0	See above
27-Apr-21	2	1	1		0	
28-Apr-21	0	-1	1		0	
29-Apr-21	0	0	0		0	
30-Apr-21	11	5	6		0	
1-May-21	-2	-5	3		0	
2-May-21	2	1	1		0	
3-May-21	1	1	0		0	
4-May-21	9	2	7		0	
5-May-21	3	3	0		0	
6-May-21	0	-1	0		1	
7-May-21	1	0	1		0	
8-May-21	0	0	0		0	
9-May-21	10	5	5		0	
10-May-21	5	2	2		1	
11-May-21	9	7	1		1	
12-May-21	11	11	0		0	
13-May-21	-1	-1	0		0	
14-May-21	4	1	3		0	
15-May-21	13	12	1		0	
16-May-21	1	1	0		0	
17-May-21	4	3	1		0	
18-May-21	1	0	0		1	
19-May-21	6	6	0		0	
20-May-21	7	6	1		0	
21-May-21	2	0	2		0	
22-May-21	7	5	2		0	
23-May-21	-2	-2	0		0	
24-May-21	63	5	58		0	
25-May-21	9	5	3		1	
26-May-21	24	11	13		0	
27-May-21	7	1	6		0	
28-May-21	11	11	0		0	
29-May-21	4	3	1		0	
30-May-21	-3	-3	0		0	
31-May-21	19	9	10		0	
1-Jun-21	2	0	2	0	0	n/a
2-Jun-21	3	1	2	1	0	n/a
3-Jun-21	7	6	1	6	0	n/a
4-Jun-21	2	0	2	0	0	n/a
5-Jun-21	15	8	7	8	0	n/a
6-Jun-21	134	19	115	19	0	n/a

Date	Daily Total Counts	Unknown	Chinook		Steelhead	
			known	assumed	known	assumed
7-Jun-21	1	0	1	0	0	n/a
8-Jun-21	64	-2	66	-2	0	n/a
9-Jun-21	11	0	11	0	0	n/a
10-Jun-21	8	2	6	2	0	n/a
11-Jun-21	35	0	35	0	0	n/a
12-Jun-21	9	9	0	9	0	n/a
13-Jun-21	259	35	224	35	0	n/a
14-Jun-21	15	8	7	8	0	n/a
15-Jun-21	5	2	3	2	0	n/a
16-Jun-21	1	1	0	1	0	n/a
17-Jun-21	2	0	2	0	0	n/a
18-Jun-21	2	-1	3	-1	0	n/a
19-Jun-21	9	1	8	1	0	n/a
20-Jun-21	0	0	0	0	0	n/a
21-Jun-21	-2	-2	0	-2	0	n/a
22-Jun-21	0	0	0	0	0	n/a
23-Jun-21	0	0	0	0	0	n/a
24-Jun-21	-1	-1	0	-1	0	n/a
25-Jun-21	3	1	2	1	0	n/a
26-Jun-21	3	0	3	0	0	n/a
27-Jun-21	-2	-2	0	-2	0	n/a
28-Jun-21	0	0	0	0	0	n/a
29-Jun-21	-1	-1	0	-1	0	n/a
30-Jun-21	-3	-3	0	-3	0	n/a
1-Jul-21	6	6	0	6	0	n/a
2-Jul-21	1	1	0	1	0	n/a
3-Jul-21	-1	-1	0	-1	0	n/a
4-Jul-21	0	0	0	0	0	n/a
5-Jul-21	0	0	0	0	0	n/a
6-Jul-21	2	2	0	2	0	n/a
7-Jul-21	3	3	0	3	0	n/a
8-Jul-21	4	4	0	4	0	n/a
9-Jul-21	0	0	0	0	0	n/a
10-Jul-21	1	-1	2	-1	0	n/a
11-Jul-21	-1	-1	0	-1	0	n/a
12-Jul-21	-2	-2	0	-2	0	n/a
13-Jul-21	-2	-2	0	-2	0	n/a
14-Jul-21	5	5	0	5	0	n/a
15-Jul-21	0	0	0	0	0	n/a
16-Jul-21	1	1	0	1	0	n/a
17-Jul-21	35	35	0	35	0	n/a
18-Jul-21	15	15	0	15	0	n/a

Date	Daily Total Counts	Unknown	Chinook		Steelhead	
			known	assumed	known	assumed
19-Jul-21	15	15	0	15	0	n/a
20-Jul-21	5	4	1	4	0	n/a
21-Jul-21	4	0	4	0	0	n/a
22-Jul-21	-1	-2	1	-2	0	n/a
23-Jul-21	1	0	1	0	0	n/a
24-Jul-21	16	0	16	0	0	n/a
25-Jul-21	9	4	5	4	0	n/a
26-Jul-21	1	1	0	1	0	n/a
27-Jul-21	3	3	0	3	0	n/a
28-Jul-21	0	0	0	0	0	n/a
29-Jul-21	2	2	0	2	0	n/a
30-Jul-21	0	0	0	0	0	n/a
31-Jul-21	0	0	0	0	0	n/a
Total			**992**		**90**	

Understanding the discharge barrier at White Rapids Falls

Steve Baillie[10], Nicolette Watson[10], Stewart Pearce[10] and Andrew Campbell[10]

Introduction

During the pre-RAMS review of Limiting Factors (LF) held at DFO South Coast office (16-December-2019), the possibility of a migration barrier caused by low water levels at White Rapids Falls (WRF) was proposed as a Limiting Factor for Summer run Chinook productivity. At the RMAS meeting held at VIU (28-29 January 2020), the collective decision was a High rating for current biological risk and a Very High rating for future biological risk with high confidence score. The discharge level at which the WRF becomes a barrier was identified as a data gap.

Carter et al. 2003 states that White Rapids Falls is an historic obstacle to fish migration, noting that many salmon have been injured while attempting to jump the falls, causing pre-spawn mortality. This report further states that some restoration work, including blasting and the construction of a weir have improved fish passage but more work may be beneficial (Butler et al. 2014).

From Braniuk et al. (1993)

> *To assist fish passage, blasting work was undertaken by DFO at White Rapids Falls in the 1970s. Later in 1979, a small structure was placed at the upper falls to improve low flow passage conditions through a by-pass channel (SEP Community Project). In 1989, as part of the Nanaimo Regional Water Management Plan (NRWMP), strategic blasting of the lower falls and bypass channel was undertaken to improve passage. Some blasting of the upper falls by-pass channel was also undertaken to increase the discharge and improve passage conditions at minimum flow rates. In 1991, large numbers of the fall chinook were observed attempting to ascend White Rapids Falls after the pulse flow (see below) on Oct. 18, 1991. A significant portion of those fish presented with severe injuries. Several chinook were observed to successfully ascend through the Upper Falls By-Pass channel (pers. comm. R. Brahniuk, T. Gjernes, and B. Tutty, South Coast Division, Fisheries Branch, DFO). More work was undertaken by SEP in July of 1992 to increase bypass channel flow and improve passage conditions.*

Carter and Nagtegaal (1997) was the first in a series of annual manuscript reports on the DFO productivity study of Nanaimo Chinook. White Rapids Falls had been noted as an impediment to the migration of spring and fall Chinook during periods of low flow in that report. They state that after the blasting, physical alterations and a cement fishway was installed there was significantly easier passage for Chinook[11].

A fixed-point enumeration study was initiated in spring 2021 to examine the upstream movement of Chinook salmon adults above the White Rapids Falls area. There is very little holding habitat in the Nanaimo River above the falls until the confluence pool with the South Nanaimo River so any Chinook observed at the site are assumed to be moving from holding areas below the falls to the pools and lakes that are normally used.

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[10] South Coast Area, Fisheries and Oceans Canada, 65 Front Street, Nanaimo, BC, V9R 5H965

[11] Paul Preston, pers. comm.

If the White Rapids Falls is a low flow barrier historically, then this may have been the causal agent to develop early and late run timed groups. Fish would have been able to migrate past the barrier in the early summer before the summer drought flows started, and later migrating fish unable to get past this barrier at low flow and spawned downstream in a separate area.

A second habitat characteristic to consider as a causal agent is the water temperature. The Nanaimo River has several lakes in the upper watershed that develop thermoclines in the summer months with the warm surface water draining from First Lake into the river. Water temperatures can reach lethal levels in this area. Carter (2005) concluded that acceptable water temperatures for adult migration is 13-14^{O} C and that temperatures 19^{O} C to 23.9^{O} C is a barrier to migration. During the gravel sampling in August 2021, in the area below First Lake, the water temperature was 27^{O} C.

Methods

A Dual-Frequency Identification Sonar (DIDSON) unit was installed in the middle area of the Nanaimo River, approximately 21 km upstream of the lower DIDSON, and upstream of the suspected low flow barrier at White Rapids Falls (Figure 14). The unit was operated from 19-May-2021 until removal on 01-Sep-2021.

Data review was completed by technician Chantelle Johnny (Snuneymuwx FN). The output from this process is a daily count of targets, associated with a subset of targets identified to species level. Discharge and water temperature were recorded at the Water Survey of Canada station at Cassidy (Station # 08HB034) and averaged by day for comparison purposes.

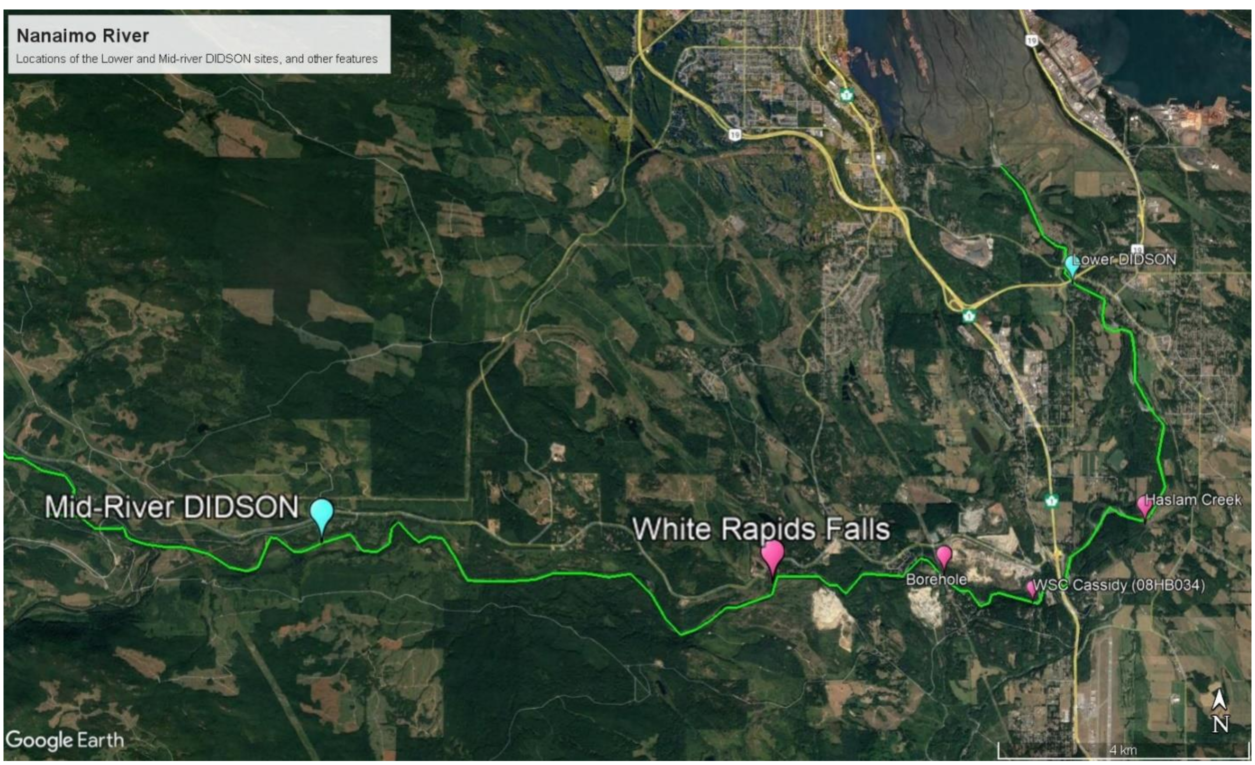

Figure 14. Map of Nanaimo River showing the locations of the DIDSON sites and other pertinent landmarks

In addition, river swim surveys were conducted bi-weekly by the BC Conservation Foundation (22-Jan-2021 to 28-May-2021) and the Nanaimo River Hatchery (30-Jun-2021 to end of season in October). The reach surveyed was the lower river from the Highway 1 bridge downstream to the Haslam Creek confluence (2.3 km distance), and a spot check at the Borehole pool, a known holding area that is located immediately downstream from the White Rapids Falls.

Results

Chinook adults started entering the Nanaimo River in mid-March-2021 with the first Chinook observed on 19-March-2021 on the river swims and it was located in the mainstem river between the Island Highway and the Halsam Creek confluence. Chinook continued entering the river through the summer with a peak of migration occurring in early June (Figure 15). The Summer run Chinook population was estimated to be approximately 992 (see chapter *Enumeration and Run-timing of Chinook in the Lower Nanaimo River*).

578 Chinook were enumerated at the mid-river station during the time the DIDSON was in operation. The peak count occurring on 8-July and continued at a decreasing but relatively high level until the DIDSON was removed on 1-September.

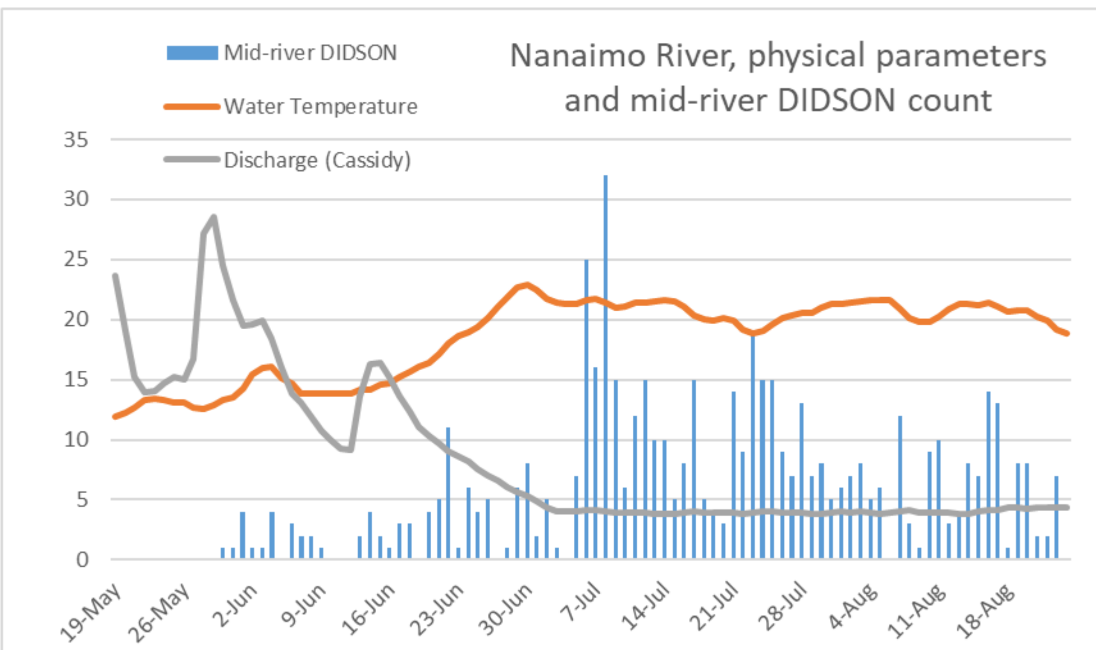

Figure 15. Mid-river daily counts of Chinook Adults, with daily average discharge and water temperature from the Cassidy Station.

Water discharge generally dropped through the spring and reached ~4 m^3/s on 3-Jul-2021 and remained there until the Fall storms brought water levels up again. Water temperature rose through the period, reaching a maximum daily average of 22.9^{O}C on 30-Jun-2021 and remained around 20 ^{O}C until the fall.

Figure 16 shows the estimated number of Chinook in the two surveyed reaches in the lower Nanaimo River. Chinook were observed initially on 19-March-2021, shortly after they were detected at the lower

DIDSON site. The peak count for the Haslam to Hwy 19 reach was 22 on 16-April-2021, and at the Borehole Pool the peak count was 26 on 28-May-2021, then a gap and a final count of 130 on 23-July-2021.

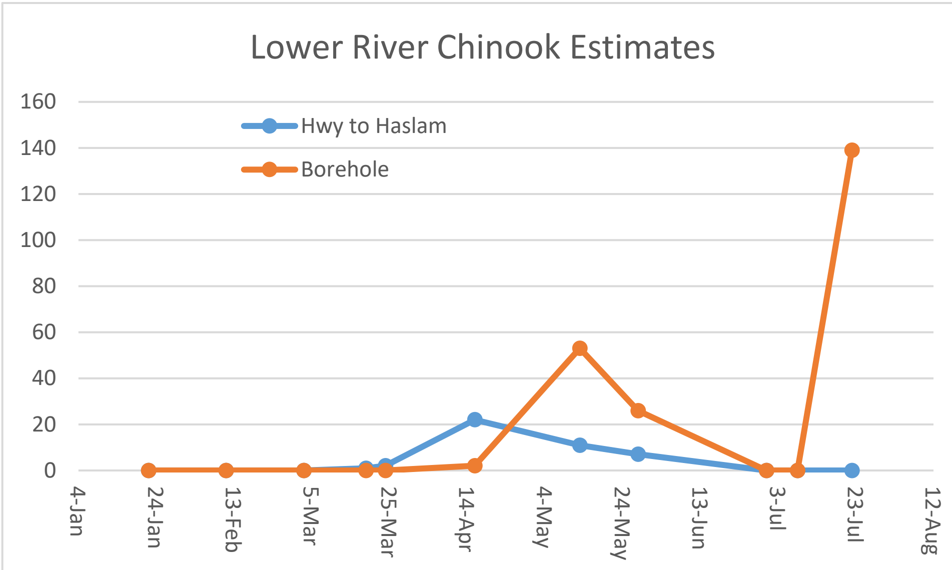

Figure 16. Abundance estimate of Chinook in the Borehole pool

Discussion

Although the mid-river DIDSON was not operating during the same period as the lower DIDSON, it was operating during the peak of migration (early June) as recorded by the lower unit. This peak did not occur in the upper unit until early July and daily enumerations continued at a relatively high rate for the next couple of months. This would suggest that the Chinook were holding between the two units in June and July.

The movement of Chinook detected at the mid-river DIDSON occurred during a period of low water discharge (4 m^3/s) and high water temperatures (+20^{O}C). This indicates: 1) that the White Rapids Falls is passable at summer low flow discharge levels, and; 2) the Chinook are able to withstand water temperatures that are higher than the normal range, at least for short periods of time.

The difference in timing between the two DIDSON stations suggests that the Chinook do not immediately migrate upstream to the holding areas in the South Fork confluence pool and Second Lake, but hold in various areas in the lower river. The Borehole pool is one such area however the low numbers of estimated Chinook from the river swim surveys indicate that Chinook hold in other areas as well. The Borehole is physically immediately downstream from the White Rapids Falls so this area would accumulate Chinook if the falls were a migration barrier. Another consideration is the level of human activity in this area, including swimming and non-sanctioned fishing activity. Both of these activities may discourage the Chinook from remaining in this pool.

Conclusion

The purpose of this project was to examine whether the White Rapids Falls is a low flow barrier to migration. The information collected suggests that the Falls is not a barrier and that Chinook are able to migrate past, even at high water temperatures which were thought to be a barrier to migration as well.

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Non-sanctioned Fishing Activity

Andrew Campbell[12] and Steve Baillie[12]

Introduction

Summer run Chinook enter the Nanaimo River between February and July and migrate upstream to holding areas where they remain until the fall. In September and October, Chinook move from the holding areas to the spawning gravels.

Through the warm months from June to September the surface waters of First and Second Lakes absorb thermal energy, resulting in water temperatures as high as 27°C which is far beyond the tolerable range for salmon (Carter 2005). The lakes drain into the Nanaimo River, drawing the hot surface waters so that in the summer months the water temperature in the river remains above lethal limits. These conditions limit the holding areas for Summer run Chinook salmon leaving them vulnerable to non-sanctioned fishing activity. Most of the Summer run Chinook hold in the deeper water of Second Lake where they remain below the thermocline, and the confluence pool with the South Nanaimo River. There are other pools where Summer run Chinook adults have been observed, particularly the Borehole area, downstream from the White Rapids Falls. It is at this location that non-sanctioned fishing activity is known to occur, based on reports from the stock assessment swim crews and anecdotal sources.

At the Nanaimo Summer run Chinook Risk Assessment meeting in January 2020, Non-sanctioned Fishing was noted as Limiting Factor 8 with the biological risk category determined as Moderate Risk. The level of Confidence for this assessment was Medium although the actual impact of this pressure was unknown. A project was proposed to monitor fishing activity covertly to understand the level of removals. DFO Stock Assessment installed trail cameras to monitor harvest of Chinook salmon from the Borehole on Nanaimo River in 2020 and 2021.

Regulations

Freshwater fishing is regulated by the BC Ministry of Forests, Lands, Natural Resources Operations and Rural Development. A booklet is published every two years that lists all the general, regional, and water specific regulations for all the freshwater areas throughout the province. The current booklet is in effect from 1-Apr-2023 to 31-Mar-2025. To fish legally the fisher must follow the Provincial regulations and licensing requirements, the Regional regulations for each specific region, the water-specific regulations that are listed in the booklet, and any in-season regulation changes that have been adopted since the booklet has been published. These changes are posted at www.gov.bc.ca/FishingRegulations. Salmon fishing, whether in marine waters or freshwater, is regulated by Fisheries and Oceans Canada.

The following is a selected set of the various regulations as they relate to the Chinook in the Nanaimo River. There are more detailed regulations listed in the booklet.

Provincial fishing restrictions on the Nanaimo River are as follows:

- Summer Closure: **No Fishing** in any stream in Management Units 1-1 to 1-6 from July 15 – Aug 31. *(Nanaimo River is in MU 1-5)*

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- **No Fishing** from power line crossing at "Bore Hole" upstream to fishing boundary signs at Boulder Creek. *(Comprises the holding areas between the Borehole pool, White Rapids Falls and upstream to Boulder Creek)*
- **No Fishing** from the Cedar Road Bridge upstream to approximately 400 m to the white square boundary signs near the Hwy 19 bridge, Sep 15 – Oct 30.
- **No Fishing** upstream of the Hwy 1 bridge Dec 1 - May 31.

Federal fishing restrictions on the Nanaimo River are as follows:

- **No Fishing** from power line crossing at "Bore Hole" upstream to fishing boundary signs at Boulder Creek, Jan 1 to Dec 31. *(Similar to provincial regulation)*
- **No Fishing** from the Cedar Road Bridge upstream to approximately 400 m to the white square boundary signs near the Hwy 19 bridge, Sep 15 – Oct 30. *(Similar to provincial regulation)*
- There is no allowable retention of Chinook on the Nanaimo River **at any time**.

In summary, provincial regulations prohibit all fishing in the Borehole area at any time of the year, and federal regulations prohibit retention of Chinook Salmon in the Nanaimo River at any time of the year.

Figure 17. Fisherman's image captured on North Side Trail camera.

Methods and Results

Motion activated and time-lapse cameras were placed along the trails leading down to each side of the river and in overhead vantages in order to get a overview of fishing activity. These cameras were installed in areas so that they could be undetected by trail users. The data from the cameras were collected periodically and reviewed.

Figure 18. Summer run Chinook salmon being removed from the Bore Hole by anglers, 26-May-2020.

2020 Monitoring

North Side-Trail Camera

A motion activated camera was installed on 13-February at the base of a tree approximately 20 m off the north side trail leading down to the Borehole (Figure 17). The first angler (a person carrying fishing equipment) was recorded on 17-February and the last on 8-July. In the 143 days between the first and last activity a total of 85 anglers were recorded on 52 days. Despite the amount of fishing activity only 3 fish were observed being carried out whole (Figure 18, red circle) but it is possible that more were transported in coolers or bags.

North Side Overhead Camera

A camera was installed high up on the north bank and set to take a photo every 10 minutes starting on 13-February. No fishing activity was observed on this camera due to image quality and vegetation which eventually obscured the view.

South Side Trail Camera

Figure 19. Fishing activity observed on South Side Trail Camera

This camera was installed on 9-April, two months after the other cameras were installed. Several attempts to install the camera had been made prior, but there were too many people to install the camera covertly. Only two people were observed fishing on this camera through to July (Figure 19).

South Side Overhead Camera

Figure 20. Fishing Activity observed on South Side upper Camera

A time-lapse overhead camera was installed on 13-February to observe fishing activity on both sides of the Borehole (Figure 20). The first fishing activity was observed on 19-February and the last on 19-June, a duration of 122 days. During this time a total of 55 anglers were observed fishing with activity noted on 30 days.

Summary

Both motion activated and time-lapse cameras were successful at confirming moderate to high fishing effort at the Borehole area. The first instance of fishing was recorded on 17-February and the last on 8-July, a duration of 143 days. Fishing activity was observed on 74 days (52%) with a minimum effort of 142 rod days.

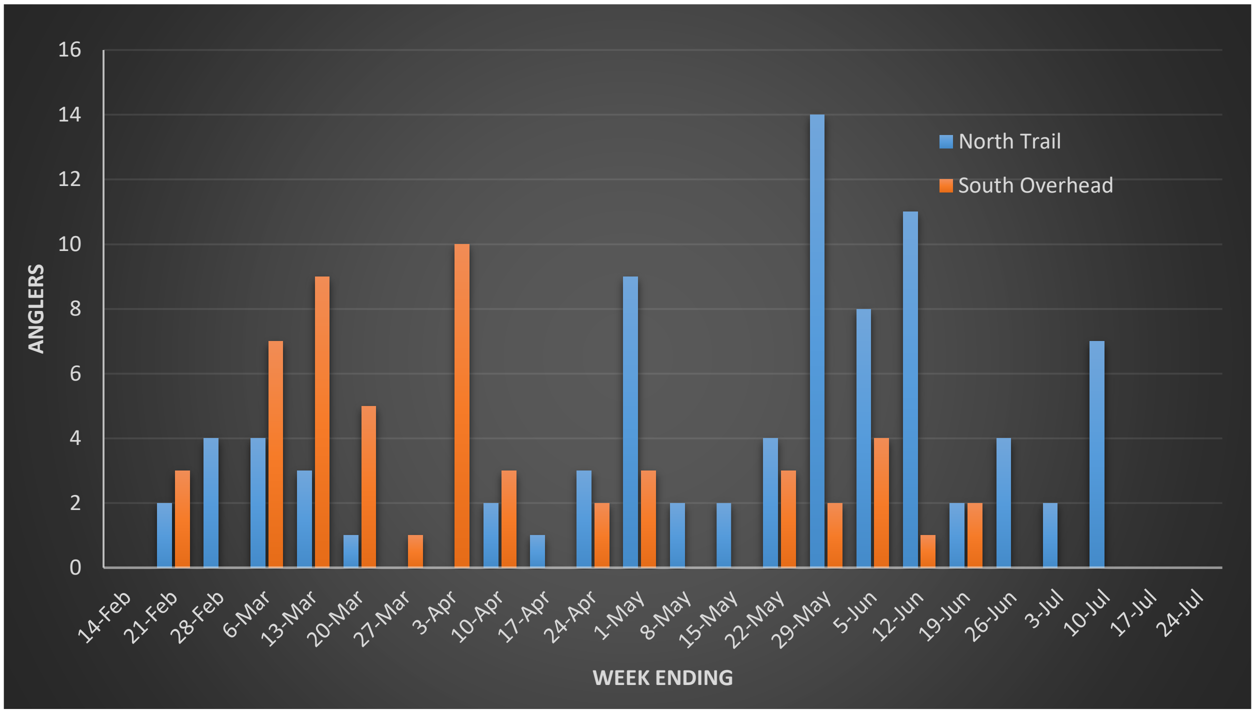

Figure 21. Summary of angler activity captured on the north trail and south overhead cameras, Nanaimo River Bore Hole, Spring 2020.

Anglers were recorded on 73 days on either the north trail (52 days) or south overhead (30 days) cameras with 9 days of activity on both (Figure 21). A simple expansion was derived from multiplying the number of active days on the north trail (52) by the percentage of days that both the south overhead and north trail cameras recorded angler activity (9/30). The expanded number of days with angler activity for the season was therefore 173. The average number of anglers observed on active days was 1.73 (1.83 on south overhead and 1.63 on north trail) producing an expanded effort of 300 rod days. 3 fish were observed to be harvested by 85 anglers on the north trail producing a minimum expanded harvest of 11 fish.

Spawner enumeration

In 2020, periodic swim surveys were used to estimate the escapement of Summer run Chinook in the Nanaimo River, prior to spawning activity. The highest estimate occurred on 10-July, with 470 estimated in the Borehole holding pool and 104 estimated in the South Fork holding pool for a total of 574. In addition, an unknown number of Chinook would have been holding in Second Lake.

When the Summer run Chinook were enumerated on the spawning grounds in September, 314 were estimated to spawn naturally and 64 were removed for brood stock by the Nanaimo River Hatchery, for a total of 378. This is a minimum estimate due to the unknown number that were holding in Second

Lake. The enumeration crews encountered pre-spawn mortalities rarely (2 on 30-Jul, none during the other 14 swims prior to 1-September. Carcasses may have been removed from the river by scavenging animals.

2021 Monitoring

In Spring 2021, DFO Stock Assessment installed 4 trail cameras to monitor harvest of Chinook salmon from the Borehole area. One camera was placed in the cliff on the south side of the river and set to take a picture every 10 minutes to capture a 'birds eye view' of fishing activity, this camera was in operation from early March until early August. Three cameras were placed on the north side of the Borehole, one along the trail to capture images of people walking with fish and fishing gear, and two near the riverbanks to capture people fishing.

North Side-Trail Cameras

A new location for the north side trail camera was required as the local climbing club constructed a trail right along it's previous location. A motion activated camera was installed on 3-March at the base of a

Figure 22. Image of fisherman captured on North Side Trail camera

tree approximately 5m off the north side trail leading down to the Borehole, unfortunately this camera was stolen some time between 27-March and 8-May. A new camera was installed approximately 50m up the trail. The first angler (a person carrying fishing equipment) was recorded on 25-March and the last on 11-July, there were the only 3 occurrences of anglers captured on this camera. In the 107 days between the first and last activity a total of 4 anglers were recorded on 3 days of fishing. No fish were observed in any instance of anglers captured on the North Side Trail camera. Of the other two North Side cameras, one was stolen after deployment and the other was vandalized with no pictures from this time period were recovered from these cameras.

South Side Overhead Camera

A time-lapse overhead camera was installed on 9-March and ran until 31-July to observe fishing activity on both sides of the Borehole (Figure 23). The first fishing activity was observed on 17-March and the last on 7-April, a duration of 22 days. During this time a total of 4 anglers were observed fishing with activity noted on 3 days.

Figure 23. Fishing activity captured on South Side upper camera.

Spawner enumeration

In 2021 a fixed point enumeration station was set up at the Duke Point Bridge crossing, using a Dual-frequency Identification Sonar unit (DIDSON). 992 Chinook were estimated to migrate upstream to all holding areas. During the fall spawning enumeration, 670 were estimated on the spawning ground plus 85 were removed for brood stock for a total of 755. The difference (992 – 755) of 237 were either lost to natural causes or non-sanctioned fishing activity.

Conclusions and Recommendations

Although the camera data resulted in a low number of observed Chinook removals from the Borehole pool, the amount of non-sanctioned fishing activity in this single location suggests a high likelihood of successful catches. The catch estimated by the data should be considered as a minimum as there was no expansion to account for Chinook that could not be seen by the cameras, or were taken from unmonitored areas.

The difference between the maximum observed escapement (2020) or the upstream migration (2021), and the estimate of spawning Chinook is attributed to natural mortality or non-sanctioned fishing. Given the low number of observed pre-spawn mortalities, it is possible that the majority of the 'missing' Chinook is due to non-sanctioned fishing activity.

The north side trail and south side overhead cameras produced consistent data while the others (south side trail, and the north side overhead) should be moved in future deployments. The north side trail camera captured the majority of fisherman but only three were observed with fish. At least one camera should be positioned closer to the water to better estimate the numbers of fish encountered by anglers. The number of anglers captured on the north side trail camera compared to those observed on the overhead cameras suggest that a significant amount of fishing activity occurs out of frame. Future studies could benefit from additional elevated cameras to observe fishing activity in the lower half of the main pool or further towards the head. More frequent trips to manage vegetation around the cameras would improve image quality while conducting trips early in the morning is recommended to avoid disclosing camera locations to trail users.

We recommend installing new signage to clearly display current regulations as a first step. Access points to the trails should be blocked to vehicles. Cameras should be re-installed on the north side trail and south side overhead locations for consistency while the others should be re-located as described above to investigate angler response. Patrols by enforcement staff (Provincial and Federal) may be warranted given the high probability of encountering fishing activity on any given day. Interviews would also provide clarity on the number of indigenous anglers fishing under food, social and ceremonial (FSC) permits.

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Spawning Gravel Quality

Steve Baillie[13], Andrew McNaughton[14], Steven Moore[14,] Karalea Filipovic[13] and Christina Czembor[15]

Introduction

At the RAMS meeting in January 2020, the Habitat Status Report (HSR 2022) presented the data from Hardie (2002) and concluded that the Indicator Risk Rating was High based on summary remarks by that report, and Burt et al. (2005). The conclusion from the RAMS discussion was that this Limiting Factor was rated as Very High Biological Risk, both now and in future outlook. Given the importance of spawning habitat to productivity, and the stated changes in quality since the 2001 data, a data project was identified to provide a more recent assessment. Further, because Hardie's work did not assess the subsurface particle sizes, this type of sampling would be included in a new assessment. C1 was defined as small to large gravel substrate, an undefined gradient, and high spawner densities. C2 was defined as either lower gradient and a higher composition of fine substrate, or a higher gradient and higher composition of cobble and boulder substrate, and medium density of spawners. Hardie only used surface observations to describe the gravel size which is representative of the subsurface composition of larger particle size, but does not represent the smaller particle sizes that are present (Kondolf and Mathias 2000). Staff from the Nanaimo River Hatchery have used the reach between First Lake and the Wolf Creek confluence for spawner enumeration of the Summer run Chinook. They have noted the decrease of suitable spawning gravel over time, which has accelerated since the mid 2010's.[16]

Kondolf and Mathias (2000) describes a methodology for assessing spawning gravel quality for salmonids, including methods and benchmarks. This project follows his procedures.

There are three aspects to gravel characteristics that are important to successful spawning activities:

1. Redd construction. Can the Chinook female construct the redd? The question here is whether the gravel particle composition has too many larger rocks that cannot be moved out of the redd area.
2. Egg incubation. Is there adequate subgravel water flow? If the water flow is too low, there will not be adequate oxygenated water and waste products will not be removed.
3. Fry emergence. The hatched fry require adequate interstitial space in order to emerge from the gravel redd. Too many finer particles will block this movement.

The solubility of oxygen in water is related to the temperature of that water. Generally, colder water is able to absorb a higher density of oxygen, so the data collected during the hot month of July (water temperature ~25^{O}C, oxygen solubility 8.1 mg/l) is not directly applicable to the November to February period when the eggs and alevins are within the gravel matrix of the redd. The mean temperature during this period is 5.1^{O}C, with a corresponding solubility of 12.4 mg/l oxygen. Solubility data taken from Wetzel (1975), referenced from Truesdale, Downing and Lowden, 1955.

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[16] Brian Banks, Nanaimo River Hatchery, 2775 Rugby Road, Nanaimo, V9X 1T2

Methods

Two assessments were conducted. First, 12 samples of gravel were removed from the target area (Figure 24), dried and partitioned using standard mesh screens. The samples were not randomly located, but were chosen based on accessibility and potential success of sampling. These samples were used to assess the particle composition of the gravel to a depth of 20 cm. The second method was to assess the particle size composition of the surface gravel along 21 transects, roughly 100 m apart, with three randomly selected 1 m^2 quadrats representing the Right, Centre and Left areas of each transect (Figure 25). These samples were used to assess the extent of potential spawning gravel in the target area.

Quality of spawning gravel: Egg Incubation and Fry Emergence

Egg incubation success was assessed by fractioning the sample into particle sizes and measuring the weight of all particles less than 1 mm in size and comparing this to the weight of all particles less than 25 mm in size. Kondolf and Mathias (2000) uses 12-14% as a benchmark for this metric, which is based on the gravel analysis that produces a 50% egg to hatch survival rate.

Figure 25. Gravel sample locations in Nanaimo River, downstream from First Lake

Figure 25. Gravel transect locations in Nanaimo River, downstream from First Lake

In addition, the oxygen level was measured at both the water surface and sub-gravel at 20 cm depth (Figure 27). The sub-gravel sample was extracted using a steel syringe style device, with the water ejected into a collapsed plastic bag. The oxygen probe was inserted into the bag with little or no introduced air and the measurement was taken immediately.

Emergence success was assessed by the same fractioning treatment, but using the proportion of particle sizes less than 6.25 mm out of the <25mm sample. The literature for the benchmark metric for Chinook is more variable with a range of 15-40% (Kondolf and Wolman 1993). For this study the median value (30%) was used for the green/amber benchmark and any samples over 40% were considered to be above the amber/red benchmark.

Figure 27. Taking subgravel water sample for oxygen measurement

Figure 26. McNeil gravel sampler

These metrics were based on gravel samples taken from actual redds, which will have had a portion of the finer material removed by the female Chinook. Since the samples in this study were not associated with a specific redd, an adjustment must be made to account for the cleaning behaviour of the female. Kondolf and Mathias (2000) reviewed literature that examined the difference in gravel composition between redds and surrounding unaltered gravel and was able to estimate an adjustment value to apply to samples. For the <1mm component, the adjustment is 67%, meaning 67% of the weight of particles that are less than 1 mm will remain after redd construction. For the <6.25 mm component, the adjustment value is 58%.

Gravel core samples were collected using a McNeil Sampler (Figure 26) in the main spawning area for Summer run Chinook. All particles within the sampler core were removed to a 5 gallon bucket, along with the turbid water in the sampler core. Site selection was based on appropriate spawning locations as described by Nanaimo River Hatchery staff.

Each sample was oven dried and sieved into component particles, then each component was weighed to provide a particle distribution (See Fig. 28 For examples). The X-axis represents the particle size (logarithmic scale) and the Y-axis represents the proportion of the total sample dry weight. The blue line represents the proportion of the sample that is smaller than the value of the corresponding X-axis. For example, the third point from the left on the lower figure represents 81.9% of the sample, by dry weight, is less than 25 mm diameter.

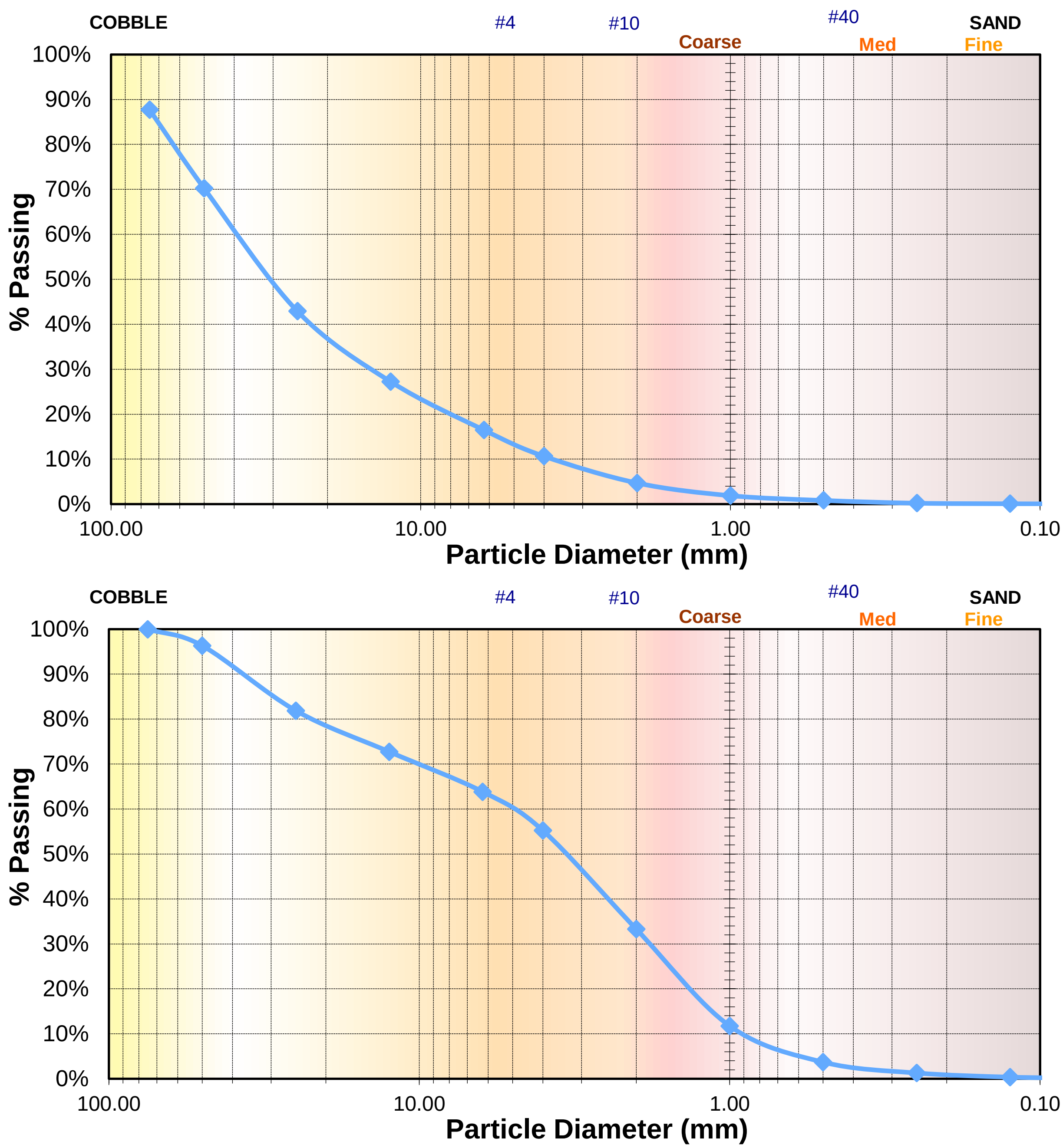

Figure 28. Particle size distribution for samples GR1 (upper) and GR12 (lower).

The sieving was completed using a Ro-Tap Tyler model RX-30 unit, designed to process four Tyler sieves at a time. Each set of four sieves was shaken for exactly 5 minutes.

Benchmarks for oxygen levels are low. Silver et al. (1963) found through laboratory experiments on different oxygen and flow rates, that Chinook eggs were able to survive at oxygen levels above 1.6 mg/l (levels assessed were 1.6, 2.5, 3.9, 8.0 and 11.7 mg/l) and water flow did not affect survival rate (velocities assessed were approximately 90, 580 and 1300 cm/hr). This suggests a oxygen level benchmark of 2.5 mg/l for egg survival.

Extent of Suitable Spawning Gravel

21 cross transects were established between the outlet of First Lake and the confluence of Wolf Creek, approximately 100 m apart. 3 sites were randomly chosen along each transect. At each site, the composition of the surface particles were determined by estimating the proportion of area within a 1 m^2 quadrat, using < 2 mm, 2-16 mm, 16-64 mm, 64-256 mm, and > 256 mm particle size classes (Moore and McNaughton 2023). The data from each sample location was arranged in a cumulative particle size, similar to the gravel core samples but based on percentage of composition.

In order to provide the specific metrics from these samples to compare to benchmarks, each set of sample data was interpolated using an MS Excel routine (https://exceloffthegrid.com/interpolate-values-using-the-forecast-function/, accessed 24-May-2023). This routine was used to estimate the cumulative proportion for a given particle size, or alternatively, to estimate the particle size at a given cumulative proportion.

The sample results were compared against benchmarks. Emergence Success, similar to the gravel composition samples, used the cumulative particle composition that is less than 6.25mm, expressed as a proportion of the cumulative particle composition that is less than 25mm. Again, a value of < 30% was considered adequate (Green), 30-40% was marginal (amber) and >40% was poor (red).

To measure whether there are too many large rocks for the female during redd construction, the particle size at the 50th percentile (D50) was compared to the largest size particle that could be moved by a Chinook Female. This size is estimated by taking 10% of the average fork length of female adults (690 mm) and using that as a benchmark (69 mm) (Kondolf and Mathias 2000). If the D50 of the sample was greater than the benchmark, then redd construction would be considered difficult for the female.

In addition, the geometric mean (dg) was compared to a range of measured Chinook spawning habitats (Kondolf and Wolman 1993). Anything within the 95% range was considered as adequate (green), outside this range but within the observed values was considered as marginal (amber) and outside the observed range was considered as poor (red).

Results

Egg Incubation

The size fractions for the twelve samples are shown in Appendix E. The data shows the dry weight of all the particles from each sieve (retained in grams), the proportion of the particle weight from each sieve of the total weight of the sample (retained percentage), and the summed weight of all the particles that passed through each sieve (Passed percentage).

From this data, the weight of the sample that passed the 25mm sieve is used as a baseline for comparing to the fraction that passed the 1 mm sieve and the 6.25mm sieve.

Of the twelve gravel samples, 11 had <1mm component of less than 14%, and GR8 was larger than 14% (see Table 10, Figure 29). This result indicates that most of the areas sampled would have adequate sub-gravel water flow for egg incubation. Since GR8 was slightly above 14%, it was coded amber.

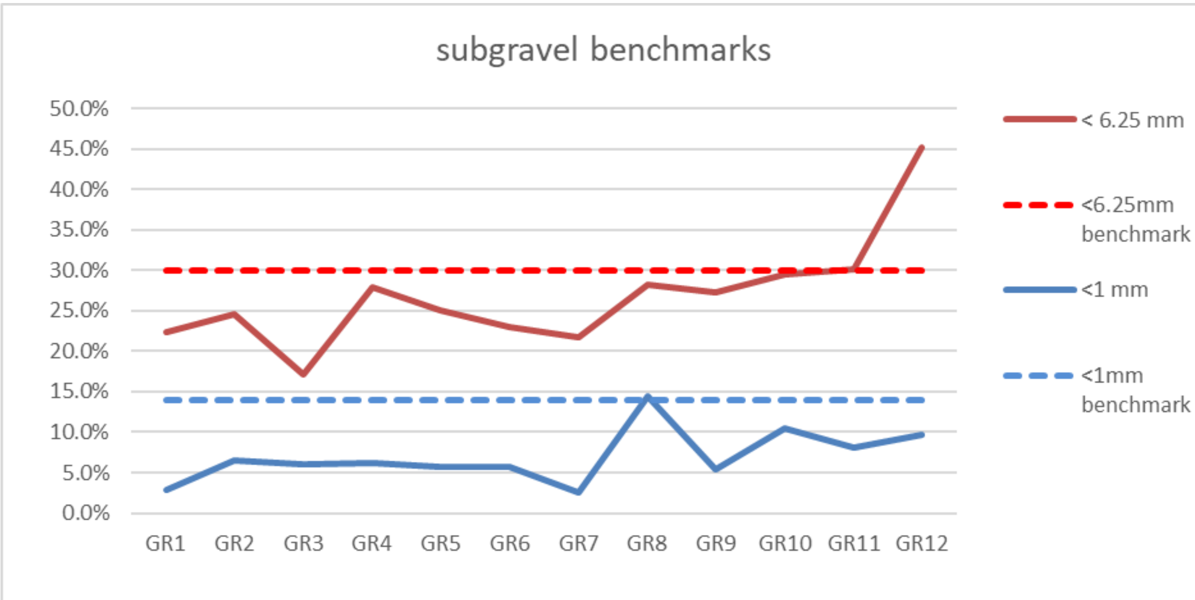

Figure 29. Values of <1mm and <6.25mm component for all gravel samples, and benchmark levels. GR1 and GR2 are closest to First Lake, GR12 is furthest downstream, near the Wolf Creek confluence.

Alevin emergence

Similarly, of the twelve gravel samples, 11 had <6.25mm component of less than 30%, and GR12 was greater than 40%. This result indicates that most of the areas sampled would have adequate interstitial space for alevins to emerge from the gravel redd. Since GR12 was higher than the 40% level, it was coded red.

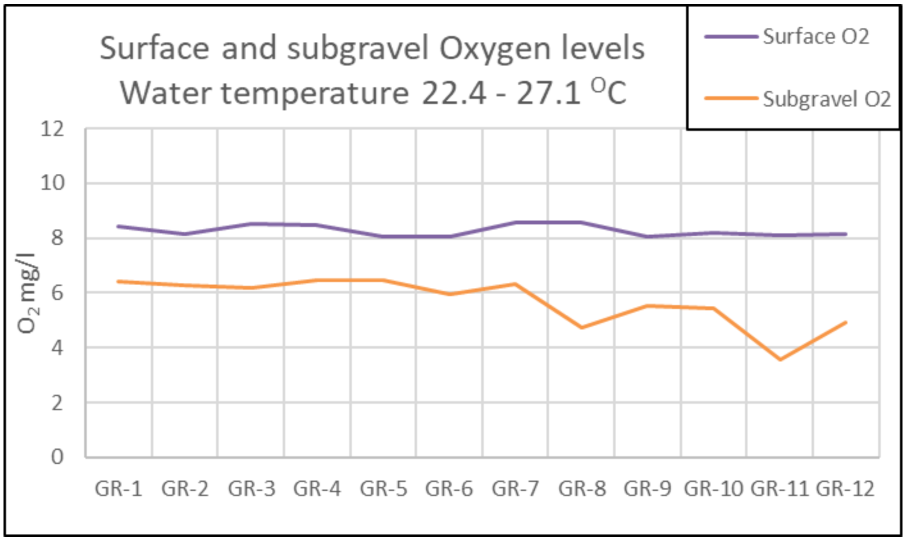

Figure 30. Water surface and sub-gravel oxygen levels.

Oxygen levels

The water temperature on the surface was consistent across all samples, with a mean of 25.6°C (range: 22.4-27.1°C). The oxygen level observed on the water surface was also consistent with a mean of 8.3 mg/l (range: 8.1 – 8.6 mg/l). During the incubation period from November to February, the average water temperature at the Cassidy station is 5.1°C (range 4.2 – 6.3 (2004/2005 - 2006/2007, 2011/2012 - 2018/2019)) which has an oxygen saturation level of 12.4 mg/l.

The sub-gravel oxygen level (mean 5.7 mg/l, range 4.7 – 6.5 mg/l) was approximately 2-4 mg/l less than the associated surface water oxygen level. During the winter months, with a possible oxygen level of approximately 12 mg/l, the sub-gravel oxygen could be similarly higher than the observed data. Both the observed values and the predicted values during egg incubation exceed the benchmark of 2.5 mg/l that is necessary for the viability of eggs (Figure 30).

Table 10. Proportion of the target component by weight from the <25mm gravel sample. The two categories are the sizes associated with egg survival (<1mm) and emergence success (<6.25mm). The original data represents the measured weight component, and the transformed data is adjusted to account for the changes caused by the female Chinook during redd construction.

Sample	<1 mm		< 6.25 mm	
	original	transformed	original	transformed
GR1	4.4%	2.9%	38.4%	22.3%
GR2	9.7%	6.5%	42.4%	24.6%
GR3	9.0%	6.0%	29.6%	17.2%
GR4	9.3%	6.2%	48.0%	27.9%
GR5	8.5%	5.7%	43.3%	25.1%
GR6	8.5%	5.7%	39.6%	23.0%
GR7	3.7%	2.5%	37.5%	21.8%
GR8	21.5%	14.4%	48.8%	28.3%
GR9	7.9%	5.3%	47.1%	27.3%
GR10	15.6%	10.4%	50.8%	29.5%
GR11	12.1%	8.1%	51.8%	30.1%
GR12	14.3%	9.6%	78.0%	45.2%

Extent of Suitable Spawning Gravel

The figures shown in this section are a schematic representation of the Nanaimo River below First Lake. The left hand side (Transect #1) is near the confluence with Deadwood Creek and is closest to the outlet of First Lake. The right hand side (Transect 21) is near the confluence with Wolf Creek, approximately 2 kilometers downstream from First Lake (Figure 25). The top row of cells represent samples taken on the left hand side of the river, looking downstream. Similarly, the centre row of cells represent the samples from the central area of the river, and the bottom row of cells represent the samples on the right side of the river, looking downstream.

Gravel samples GR1 to GR3 were located between Transect 1 and 2, GR4 was on Transect 3, GR5 was on Transect 8, GR6 and GR7 were between Transect 9 and 10, GR8 and GR9 were between Transect 11 and 12, GR 10 was just downstream from Transect 12, GR11 was between Transect 14 and 15, and GR12 was between Transect 20 and 21.

Redd Construction

We used the benchmark metric of the particle size of the D50 level (50th percentile) and compared it to the maximum size particle that a Nanaimo Summer run Chinook female can move (69mm). Below this size is considered adequate, and above this size is poor (red) (Figure 31).

Ability to build redds																					
Transect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Left	64.0	40.0	296.7	1.0	34.0	48.0	9.0	52.0	1.0	192.0	41.8	41.8	1.0	347.5	347.5	296.7	91.4	347.5	228.6	256.0	256.0
Centre	118.9	296.7	50.3	128.0	48.0	16.0	64.0	64.0	8.0	296.7	37.8	40.0	8.6	36.6	347.5	12.5	28.0	43.4	256.0	256.0	192.0
Right	64.0	278.2	33.9	37.8	40.0	118.9	44.8	52.0	16.0	96.0	24.8	34.0	40.0	34.5	208.0	1.0	3.8	48.0	52.0	32.0	140.8

Figure 31. Sample values for mean particle size (D50).

40 of 63 samples (63%) were considered as adequate (green) for redd construction.

Particle composition

We used the geometric mean (dg) of particle size for each sample, calculated as (D16*D84)^$^{0.5}$, and compared the result to the range of geometric means as reported in Kondolf and Wolman (1993). This reference listed results from 44 studies of Chinook spawning gravel composition. Dg values within the 95% range were considered to be adequate (green), and outside this value range as marginal (amber), and above or below the highest and lowest values, respectively, as poor (red) (Figure 32).

Geometric Mean particle size																					
Transect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Left	67.2	32.5	149.2	0.4	30.8	56.5	0.5	64.6	1.2	110.6	41.4	41.4	0.1	313.3	304.0	51.9	40.4	284.4	149.9	79.7	133.8
Centre	80.3	149.2	43.6	84.8	38.2	1.2	67.2	67.2	0.6	149.2	31.5	36.3	6.5	27.1	304.0	1.6	1.9	53.7	171.2	2.1	110.6
Right	34.7	148.2	25.6	32.8	34.4	80.3	44.5	64.6	0.8	60.6	0.7	23.8	35.4	0.8	134.3	0.3	0.4	36.7	51.4	1.9	2.0

Figure 32. Sample values for geometric mean (dg).

For 19 of 63 samples (30%) indicated adequate spawning gravel, 4 samples (6%) indicated marginal spawning gravel (amber), and 40 samples (63%) indicated poor spawning gravel (red).

Alevin emergence

We used the benchmark metric of the proportion of <6.25mm particle size to the <25mm particle size components. As noted previously the 'stoplight' zones were <0.30 (green), 0.30-0.40 (amber) and >0.40 (red) (Figure 33).

Alevin swim up space																					
Transect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Left	0.25	0.21	0.28	0.85	0.33	0.21	0.46	0.09	0.92	0.47	0.30	0.30	1.00	0.10	0.78	0.52	0.48	0.65	0.00	0.30	0.17
Centre	0.58	0.28	0.35	0.47	0.35	0.60	0.17	0.17	0.60	0.19	0.31	0.24	0.37	0.29	0.00	0.52	0.57	0.25	0.22	0.62	0.22
Right	0.48	0.28	0.22	0.25	0.18	0.47	0.25	0.14	0.51	0.34	0.50	0.37	0.34	0.58	0.84	1.00	0.65	0.45	0.36	0.58	0.78

Figure 33. Sample values for D_{16}/D_{25} (proportion of sample less than 16th percentile divided by proportion of sample less than 84th percentile).

26 of 63 samples (41%) were considered adequate for alevin movement, 10 samples (16%) were marginal and 27 (43%) were poor. This result should not be considered on its own since a sample that is comprised of large particles would be adequate for alevin movement, but poor for redd construction.

Moore and McNaughton (2023) compared the size composition of the samples to standardized spawning gravel components of ≤ 5% fines (< 2mm), ≥ 70% large gravel (2-16mm), ≤ 15% cobbles (16-64mm) and ≤ 5% boulders (>64mm). The analysis from this report showed that three samples met this criteria (TR3 right, TR5 right and TR14 center).

Alternatively, the Supply Creek gravel project (Puntledge River, 2020) proposed using a coarser composition for the Summer run Chinook spawning area (15% by volume 12.5-25 mm, 15% 25-50 mm, 30% 50-75 mm, 30% 75-100 mm, and 10% >100 mm). This composition was designed with the local flow and gradient conditions so that the downstream movement of material was minimized[17].

Adequate spawning gravel																					
Transect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Left	4	6	2	2	5	5	2	4	2	0	6	6	2	2	0	2	2	0	2	1	2
Centre	0	2	5	0	5	2	4	4	2	2	5	6	3	6	2	2	2	5	2	0	2
Right	4	2	6	6	6	0	6	4	2	2	2	5	5	2	0	2	2	4	4	2	0

Figure 34. Summed results of 3 spawning gravel analyses, where Adequate = 2, Marginal = 1, Poor = 0.

Combining the results from the three gravel quality assessments (redd construction, particle composition and alevin emergence), 9 samples (14%) were shown to have suitable spawning gravel while the other 54 samples had marginal or poor spawning gravel (see Figure 34). Among these 9 samples are the three samples identified by Moore and McNaughton (2023).

Summary

The results from the gravel samples show that most samples were suitable for egg development and alevin migration. These samples were not randomly located, however, the results show that there is some suitable spawning gravel in select locations.

The results from the surface composition samples show that there is limited suitable spawning gravel available in the spawning reach. Using 'back of the napkin' calculation (2000 m length X 31 m average

[17] Mel Sheng, pers. comm.

width X 14% adequate spawning gravel) suggests 8680 m^2 adequate spawning gravel, which is a decrease of 29% from the 12233 m^2 estimated by Hardie in 2002.

Anecdotal information and gravel composition assessment suggest that the volume of adequate spawning gravel has decreased over time, indicating that a potential restoration activity is required to stabilize the watershed hydrology and associated movement of bedload material and/or augment spawning gravels to return this habitat component to historic levels. In addition, protection of existing and added spawning gravels must be included in any restorative activity.

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Appendix E: Results from gravel sample sieving (grams)

Retained (grams) is the dry weight of particles from each sieve, Retained (%) is the proportion of the particles by weight from each sieve of the total, and Passing (%) is the proportion of the sample that has passed through that particular sieve, i.e. the proportion by weight that is smaller than the sieve size.

	GR1		
Sieve opening (mm)	retained (gms)	retained (%)	Passing (%)
75.00	1835	12.3%	87.7%
50.00	2598	17.5%	70.2%
25.00	4064	27.3%	42.9%
12.50	2330	15.7%	27.2%
6.25	1599	10.7%	16.5%
4.00	867	5.8%	10.6%
2.00	887	6.0%	4.7%
1.00	417	2.8%	1.9%
0.50	159	1.1%	0.8%
0.25	91	0.6%	0.2%
0.125	18	0.1%	0.1%
0.063	7	0.05%	0.03%
Pan	4.5	0.03%	0.00%
Total	14876.5	100%	

	GR2		
Sieve opening (mm)	retained (gms)	retained (%)	Passing (%)
75.00	2008	11.1%	88.9%
50.00	2122	11.7%	77.2%
25.00	3881	21.4%	55.8%
12.50	3537	19.5%	36.2%
6.25	2274	12.6%	23.7%
4.00	1027	5.7%	18.0%
2.00	1137	6.3%	11.7%
1.00	1135	6.3%	5.4%
0.50	797	4.4%	1.0%
0.25	162	0.9%	0.1%
0.125	15	0.1%	0.1%
0.063	6	0.03%	0.02%
Pan	4	0.02%	0.00%
Total	18105	100%	

	GR3		
Sieve opening (mm)	retained (gms)	retained (%)	Passing (%)
75.00	6630	44.8%	55.2%
50.00	2131	14.4%	40.8%
25.00	3162	21.4%	19.5%
12.50	1315	8.9%	10.6%
6.25	713	4.8%	5.8%
4.00	308	2.1%	3.7%
2.00	201	1.4%	2.3%
1.00	85	0.6%	1.7%
0.50	100	0.7%	1.1%
0.25	112	0.8%	0.3%
0.125	25	0.2%	0.1%
0.063	9	0.06%	0.08%
Pan	12	0.08%	0.00%
Total	14803	100%	

	GR4		
Sieve opening (mm)	retained (gms)	retained (%)	Passing (%)
75.00	0	0.0%	100.0%
50.00	3298	15.9%	84.1%
25.00	5896	28.4%	55.7%
12.50	3566	17.2%	38.5%
6.25	2431	11.7%	26.7%
4.00	1318	6.4%	20.4%
2.00	1656	8.0%	12.4%
1.00	1497	7.2%	5.2%
0.50	789	3.8%	1.4%
0.25	225	1.1%	0.3%
0.125	40	0.2%	0.1%
0.063	11	0.05%	0.03%
Pan	6	0.03%	0.00%
Total	20733	100%	

	GR5		
Sieve opening (mm)	retained (gms)	retained (%)	Passing (%)
75.00	0	0.0%	100.0%
50.00	1808	12.6%	87.4%
25.00	5440	37.8%	49.6%
12.50	2210	15.4%	34.2%
6.25	1830	12.7%	21.5%
4.00	1163	8.1%	13.4%
2.00	1013	7.0%	6.3%
1.00	302	2.1%	4.2%
0.50	213	1.5%	2.7%
0.25	260	1.8%	0.9%
0.125	96	0.7%	0.3%
0.063	23	0.16%	0.10%
Pan	15	0.10%	0.00%
Total	14373	100%	

	GR6		
Sieve opening (mm)	retained (gms)	retained (%)	Passing (%)
75.00	0	0.0%	100.0%
50.00	3732	26.4%	73.6%
25.00	3936	27.8%	45.8%
12.50	2566	18.1%	27.6%
6.25	1341	9.5%	18.1%
4.00	707	5.0%	13.1%
2.00	774	5.5%	7.7%
1.00	530	3.7%	3.9%
0.50	267	1.9%	2.0%
0.25	185	1.3%	0.7%
0.125	70	0.5%	0.2%
0.063	17	0.12%	0.09%
Pan	13	0.09%	0.00%
Total	14138	100%	

Appendix E (cont.)

	GR7		
Sieve opening (mm)	retained (gms)	retained (%)	Passing (%)
75.00	2893	22.8%	77.2%
50.00	2636	20.8%	56.4%
25.00	2989	23.6%	32.8%
12.50	1686	13.3%	19.4%
6.25	907	7.2%	12.3%
4.00	507	4.0%	8.3%
2.00	586	4.6%	3.7%
1.00	309	2.4%	1.2%
0.50	92	0.7%	0.5%
0.25	41	0.3%	0.2%
0.125	12	0.1%	0.1%
0.063	5	0.04%	0.03%
Pan	4	0.03%	0.00%
Total	12667	100%	

	GR8		
Sieve opening (mm)	retained (gms)	retained (%)	Passing (%)
75.00	1270	6.7%	93.3%
50.00	2913	15.5%	77.8%
25.00	4468	23.7%	54.1%
12.50	3025	16.1%	38.0%
6.25	2198	11.7%	26.4%
4.00	975	5.2%	21.2%
2.00	847	4.5%	16.7%
1.00	962	5.1%	11.6%
0.50	1607	8.5%	3.1%
0.25	504	2.7%	0.4%
0.125	59	0.3%	0.1%
0.063	11	0.06%	0.03%
Pan	6	0.03%	0.00%
Total	18845	100%	

	GR9		
Sieve opening (mm)	retained (gms)	retained (%)	Passing (%)
75.00	2423	13.1%	86.9%
50.00	3965	21.5%	65.4%
25.00	3203	17.3%	48.1%
12.50	2727	14.8%	33.4%
6.25	1977	10.7%	22.7%
4.00	1031	5.6%	17.1%
2.00	1311	7.1%	10.0%
1.00	1140	6.2%	3.8%
0.50	484	2.6%	1.2%
0.25	163	0.9%	0.3%
0.125	37	0.2%	0.1%
0.063	13	0.07%	0.05%
Pan	9	0.05%	0.00%
Total	18483	100%	

	GR10		
Sieve opening (mm)	retained (gms)	retained (%)	Passing (%)
75.00	0	0.0%	100.0%
50.00	2672	18.0%	82.0%
25.00	2555	17.2%	64.8%
12.50	2626	17.7%	47.1%
6.25	2100	14.2%	32.9%
4.00	1064	7.2%	25.7%
2.00	1105	7.4%	18.3%
1.00	1218	8.2%	10.1%
0.50	1244	8.4%	1.7%
0.25	222	1.5%	0.2%
0.125	15	0.1%	0.1%
0.063	8	0.05%	0.05%
Pan	7	0.05%	0.00%
Total	14836	100%	

	GR11		
Sieve opening (mm)	retained (gms)	retained (%)	Passing (%)
75.00	0	0.0%	100.0%
50.00	2405	15.7%	84.3%
25.00	2430	15.8%	68.5%
12.50	2866	18.7%	49.8%
6.25	2198	14.3%	35.5%
4.00	1117	7.3%	28.2%
2.00	1416	9.2%	19.0%
1.00	1637	10.7%	8.3%
0.50	1037	6.8%	1.6%
0.25	203	1.3%	0.2%
0.125	21	0.1%	0.1%
0.063	8	0.05%	0.04%
Pan	6	0.04%	0.00%
Total	15344	100%	

	GR12		
Sieve opening (mm)	retained (gms)	retained (%)	Passing (%)
75.00	0	0.0%	100.0%
50.00	628	3.7%	96.3%
25.00	2459	14.4%	81.9%
12.50	1558	9.1%	72.7%
6.25	1515	8.9%	63.8%
4.00	1468	8.6%	55.2%
2.00	3738	21.9%	33.3%
1.00	3672	21.5%	11.7%
0.50	1372	8.1%	3.7%
0.25	412	2.4%	1.3%
0.125	156	0.9%	0.4%
0.063	43	0.25%	0.11%
Pan	19	0.11%	0.00%
Total	17040	100%	

Aquatic Insect status in Nanaimo Summer run Chinook rearing areas

Steve Baillie[18] and Rosie Barlak[19]

Purpose

The aquatic benthic community is an important source of food for juvenile salmon, including Summer run Chinook Salmon (*Oncorhynchus tshawytscha*). Both Delayed Migrant fry and Yearling fry rear in freshwater for up to three months or one year, respectively, during which any remnant yolk nutrition will have been used up and alternative food sources will be found. In his review of Chinook Salmon, Healey (1991) presented information from various sources on commonly targeted groups of invertebrates as food. Although the composition of diet varied between studies, generally, larval and adult aquatic insects, terrestrial insects, amphipods and *Cladocera* are commonly consumed. Within the *Insecta* Class, the *Diptera* (mostly *Chironomidae*), *Ephemeroptera, Plectoptera*, and *Trichoptera* are important components. The mixture of aquatic and terrestrial origin of food organisms indicates that the juvenile salmon were feeding both within the water column and at the surface of the river.

Aquatic benthic invertebrates have a variety of life histories. Most have an annual cycle of egg – larvae – adult but others can cycle several times per year, or take several years to complete one generation. Similarly, reproduction and egg generation can take place at different times. Some species exhibit extended egg hatch periods resulting in multiple sizes within a cohort. Hynes (1970) proposed an annual cycle of biomass and abundance of freshwater aquatic benthic communities, taking these variables into account (Figure 35). This summary figure shows a low abundance in late Spring that subsequently increases as eggs hatch and growth takes place, through to late Autumn when species have matured and are reproducing. The abundance declines from that point as adult mortality sets in and later hatching species mature.

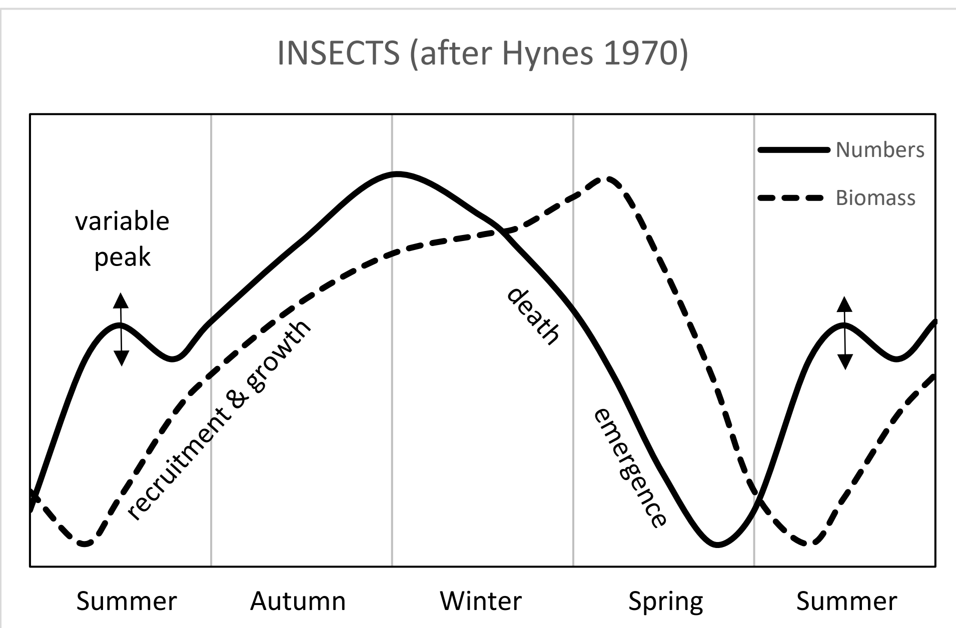

Figure 35. A schematic presentation of seasonal fluctuations in number and biomass of invertebrates in streams dominated by insects (Hynes 1970, Figure XIV, 5).

[18] South Coast Area, Fisheries and Oceans Canada, 65 Front Street, Nanaimo, BC, V9R 5H9
[19] Environmental Protection Division, BC Ministry of Environment and Climate Change Strategy, 2080-A Labieux Road, Nanaimo, BC, V9T 6J9

Reece and Richardson (1998) found that in the coastal BC sites the abundance was lowest during the Spring and increased to a peak in Summer that resulted from egg hatching thus, late spring and summer was more important to benthic organism recruitment than suggested by Haynes (1970). This coincides with the 'variable peak' that Hynes showed in the figure however Reece and Richardson found this peak much higher and more important in the coastal samples in their study.

Water temperature affects the species composition of the benthic community although generalizations are difficult to formulate. Although colder water regimes usually have fewer, longer-lived species, many exceptions can be found suggesting that temperature is not the only process affecting the benthic community. Even within a species, differences in temperature tolerances are common in different streams (Hynes 1970). The timing of adult emergence varies with the water temperature in the preceding months with earlier timing in warmer habitats (Ide 1940).

Baulch et al. (2005) found in a temperature manipulated experiment the epilithon (surface biofilm) increased photosynthesis when exposed to warmer temperatures however changes to the composition of the invertebrate community were small. In other *in situ* studies increased temperature within a water system caused changes in the makeup of the benthic communities. As result, some are locally extirpated from the warmer waters while new species appear and some are unaffected (Hynes 1970).

A data gap was identified during the RAMS process on the availability and abundance of aquatic insects (Limiting Factor 26: Mortality or fitness impacts as a result of lack of food). In order to address this data gap an assessment project was initiated.

Methods

Within the Nanaimo River Watershed, there are several habitats that are important for juvenile rearing so these areas were targeted for sampling. The site selection, sampling protocol and data analysis was conducted using the Canadian Aquatic Biomonitoring Network (CABIN) protocols, a national standardized program that provides a consistent, scientifically defensible approach using benthic macroinvertebrate communities to assess freshwater ecosystems. Data are collected by certified samplers following standard field methods and analyzed using Environment and Climate Change Canada's (ECCC) laboratory protocols, which ensures the consistency and quality of data (Environment Canada 2012; Environment Canada 2014). All data are stored in the CABIN database, which is managed by ECCC.

Reference Groups

CABIN promotes a study design called the Reference Condition Approach (RCA) that uses data from numerous reference sites (i.e., minimally affected by human activities) to build Reference Group models that characterize the natural range of variation in benthic macroinvertebrate communities (Reynoldson et al. 1995). CABIN models are available on the ECCC website and are accessible for those that have completed the appropriate level of CABIN training and certification. Test sites (i.e., potentially impacted sites) can be analyzed using these models to determine if the benthic community is similar to the Reference Groups. If the benthic community at the test site is different, it is assumed to have been influenced by human activities or other stressors.

There are four Reference Groups from the Vancouver Island 2021 model (Somers et al. 2021) that are used as baselines for comparing to the data from the sample sites. The specific Reference Group is selected by comparing 9 habitat variables from the Reference Groups to the sample, and the Reference Group with the best fit is used for the benthic comparison.

To compare the sample against a Reference Group, three vectors are used. Each vector is comprised of the relative abundance of all benthic organisms with each vector having a different weighting by taxa. Each pair of Reference Group vectors (Vector 1 vs Vector 2, Vector 1 vs. Vector 3, Vector 2 vs. Vector 3) are plotted with probability ellipses (Table 11) producing three sets of ellipses. The probability of degree of divergence of the sample value is calculated for each vector pairing with the most divergent value used to represent the sample (See Vector Plots in Appendix F for examples).

Table 11. Decision values for Reference ellipses

Category	**Description (probability)**
Similar to Reference	Within the 90% confidence ellipse
Mildly Divergent	Within the 90% and 99% confidence ellipses
Divergent	Within the 99% and 99.9% confidence ellipses
Highly Divergent	Outside the 99.9% confidence ellipses

In addition, water chemistry samples were taken at each location, with the results shown in Appendix G.

Sample Sites

In the Nanaimo River, four habitat types were selected for sampling, with two sample sites in each habitat. These habitats are used by juvenile Summer run Chinook for rearing:

- **Above Second Lake, tributaries (Figure 36)**: This habitat represents an accessible river area that is not influenced by the cold water outflow from Fourth Lake. The two sites were located on Green Creek (NAL-NAN-05), and the mainstem above the Fourth Lake outflow (NAL-NAN-06).
- **Above Second Lake, mainstem (Figure 36)**: This habitat represents an accessible river area that is influenced by the cold water outflow from Fourth Lake. The two sites are located on the mainstem at 200m (NAL-NAN-08) and 2 km (NAL-NAN-07) downstream from the Fourth Lake outflow.
- **Below First Lake, mainstem (Figure 37)**: Two sites were established in the spawning and rearing area below First Lake. The water temperature here is influenced by the surface water from First Lake. These were located 50m upstream of the Wolf Creek confluence (NAL-NAN-01) and near the confluence with South Forks creek (NAL-NAN-02).
- **Below Highway, mainstem (Figure 38)**: Two sites were established in the lower Nanaimo River, where the Fall run spawns and rears, and through which the Summer run migrates when smolting. These were located within the Nanaimo River Regional Park (NAL-NAN-04) and at the end of Hemer Road (NAL-NAN-09).

An additional site was included on Haslam Creek (Figure 38), immediately upstream of Highway 19A (NAL-NAN-03). This is a previously defined location that was sampled by the field crew as a CABIN reference site. This site is unlikely to be important for Summer run Chinook Salmon rearing.

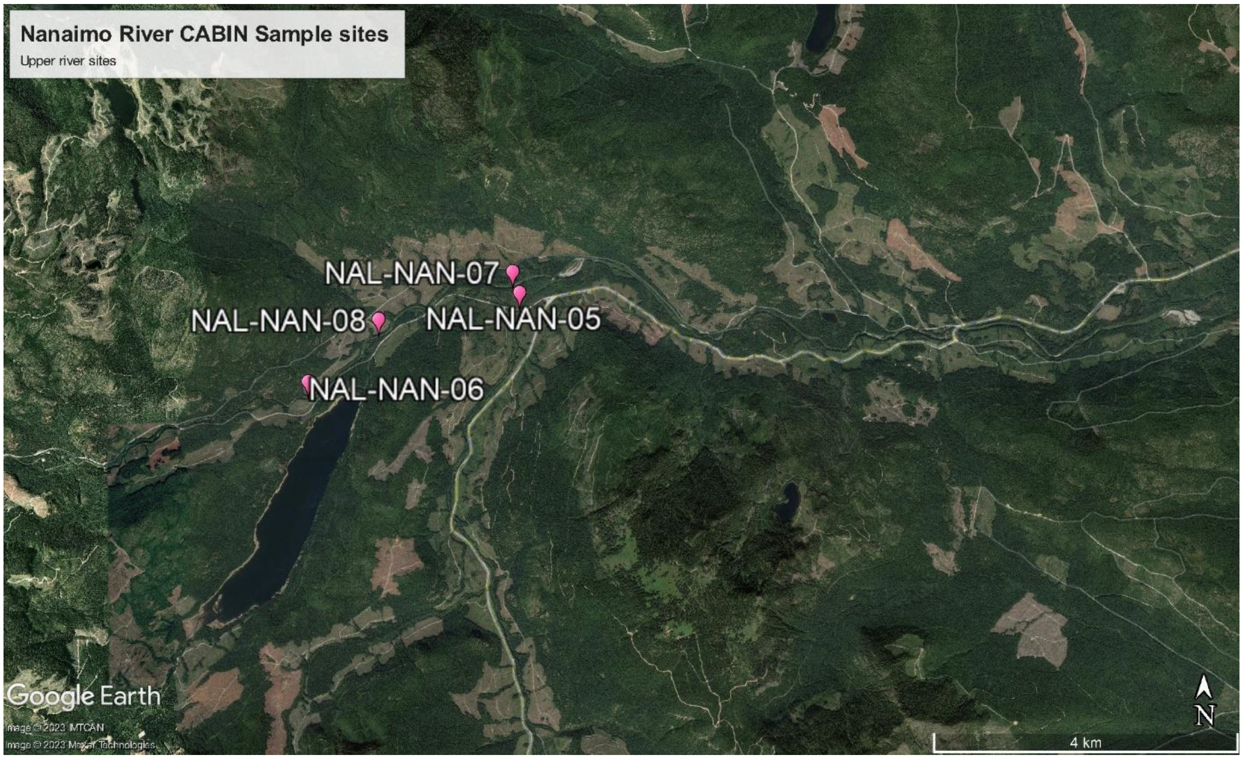

Figure 37. Sample locations in the upper Nanaimo River

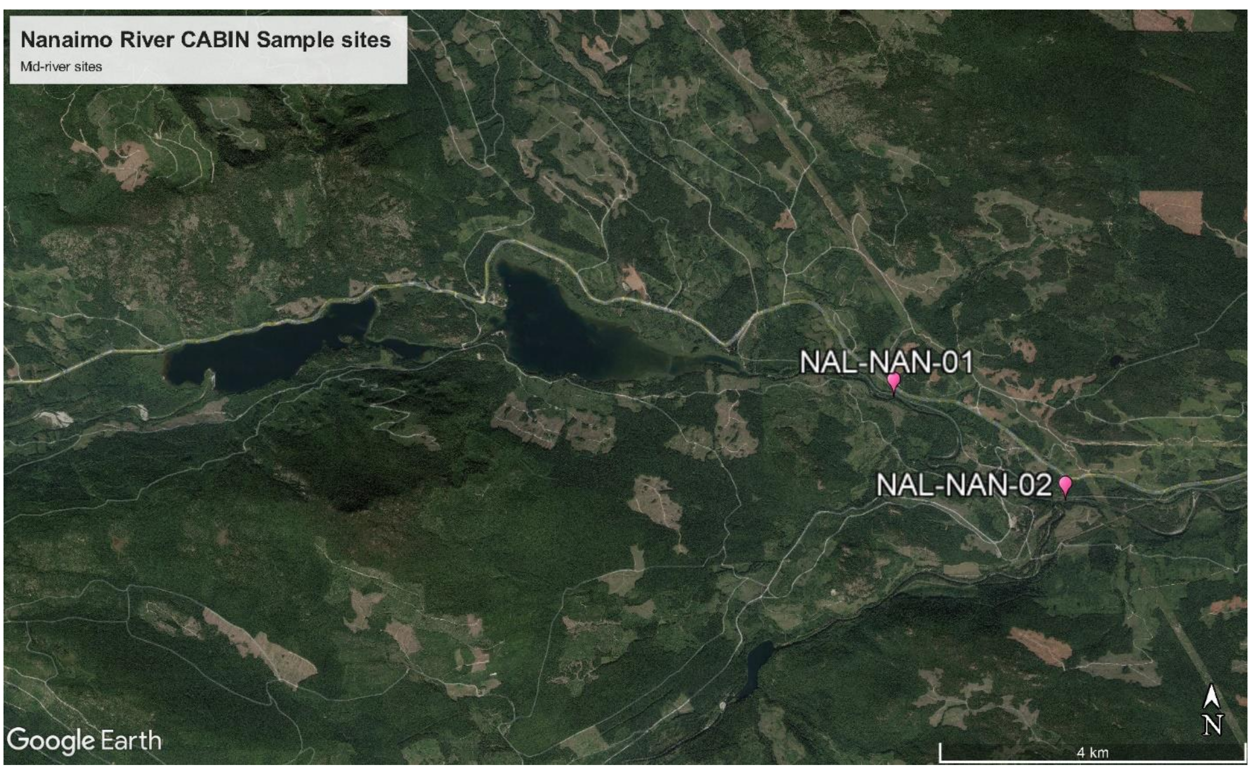

Figure 36. Sample locations in the middle Nanaimo River

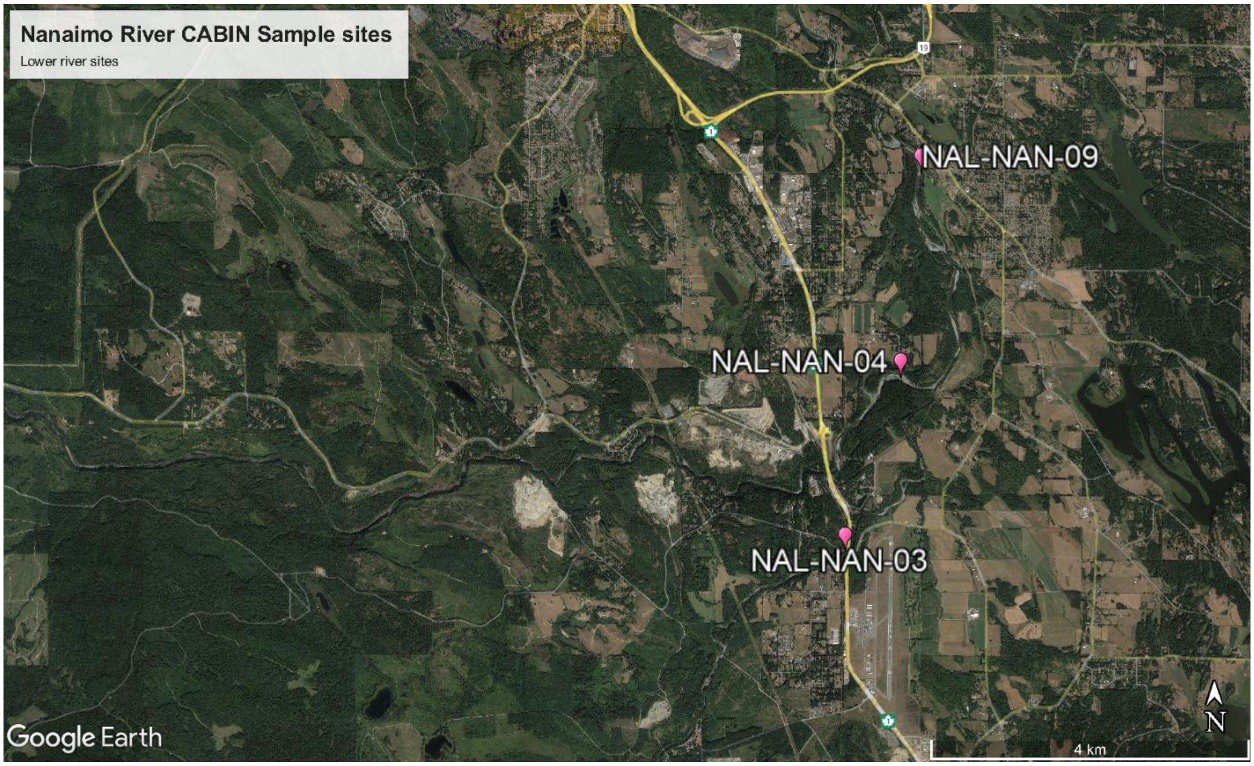

Figure 38. Sample locations in the lower Nanaimo River

Results

Samples NAL-NAN-7 and NAL-NAN-08 (both Mainstem above Second Lake) used Reference Group 4. Sample NAL-NAN-03 (Haslam Creek) used Reference Group 2. All other samples used Reference Group 3.

The Reference Group comparison results (Table 12) show that most of the samples are similar to or mildly divergent from their reference group suggesting that these samples come from areas of the river that are similar to undisturbed sites. The one sample that was highly divergent from the reference group was Site NAL-NAN-02, located below First Lake, immediately downstream from the confluence with the South Nanaimo Tributary. This result suggests that there was a stressor that influenced the benthic community in this location.

Looking at some of the metrics (Table 13) that can be derived from the data from this sample, the value for *% Ephemeroptera that are Baetidae* is above the 95% confidence interval of the reference group. The Ephemeroptera (mayflies) Order itself is sensitive to pollution however the *Baetidae* Family is tolerant so if this Family comprises a large component of the Order that suggests the presence of organic pollutants as a stressor (Czerniawska-Kusza 2005).

A second metric, *Percentage of 2 dominant taxa*, has a sample value that is above the 95% confidence interval. This indicates a low level of diversity of taxa in the sample. This lack of diversity within the benthic community is suggestive of poor benthic community health (Plafkin et al. 1989).

Table 12. Reference Group selection and vector results.

Group	Sample Site	Ref. Group	Vector 1 vs 2	Vector 1 vs 3	Vector 2 vs 3	Overall
Above 2nd Lake, Trib	NAL-NAN-06-above 4th Lake conf.	3	R	R	R	R
	NAL-NAN-05-Green Creek	3	R	R	R	R
Above 2nd Lake, Main	NAL-NAN-08-0.2 km d/s 4th Lake conf.	4	MD	MD	R	MD
	NAL-NAN-07-2.0 km d/s 4th Lake conf.	4	R	R	R	R
Below 1st Lake, Main	NAL-NAN-01-near Wolf Creek	3	MD	R	MD	MD
	NAL-NAN-02-South Nanaimo conf.	3	HD	D	R	HD
Below Highway, Main	NAL-NAN-04-RDN Park	3	R	R	R	R
	NAL-NAN-09-Hemer Road	3	MD	MD	MD	MD
Lower River, Trib	NAL-NAN-03-Haslam Creek	2	MD	R	MD	MD

Code	Comparison Result
R	Similar to reference
MD	Mildly divergent from reference
D	Divergent from reference
HD	Highly divergent from reference

Table 13. Statistical metrics from Sample NAL-NAN-02. The sample value, reference mean and standard deviation, and Z-score are shown. The highlighted Z-scores show the values that are outside the 95% confidence limit.

Metric	Sample Value	Reference Mean	Reference Std Dev	Z score
% *Chironomidae*	15.1%	19.9%	15.4	-0.31
% *Ephemeroptera* that are *Baetidae*	86.4%	22.6%	20.5	3.10
% of 2 dominant taxa	77.6%	52.7%	11.4	2.19
Coleoptera taxa	0	0.4	0.5	-0.80
Diptera taxa	4	3.4	1.3	0.48
Ephemeroptera taxa	4	4.1	0.8	-0.15
EPT taxa (no)	8	11.4	2.0	-1.68
Plecoptera taxa	2	3.8	0.8	-2.35
Simpson's Evenness	0	0.3	0.1	-1.39
Total Abundance	155	1525.0	1020.1	-1.34
Total No. of Taxa	17	20.6	4.3	-0.83
Trichoptera taxa	2	3.5	1.4	-1.02

Although the sample value for *Total Abundance* (155 organisms) was within the 95% confidence interval it was much lower than the reference group mean of 1525 (S.D. 1020) and was the lowest value among the nine samples. This low abundance of benthic organisms is suggestive of environmental stressors in the area (Resh and Jackson 1993).

Site NAL-NAN-2 is far from urban development or sewage outfalls. The surrounding area and upstream has been logged periodically over the last 150 years however this is common to all sample sites, so this activity is unlikely to affect this specific site only. The site is downstream from First Lake and is subject to highly elevated water temperatures (>25^{O}C) in the summer however so is the Wolf Creek, Main sample site which was considered only Mildly Divergent. In looking at the water chemistry results, only the Dissolved Organic Carbon (above) and Molybdenum (above) were outside the 95% interval as measured at the other sample sites.

Conclusions

The purpose of this project was to examine the benthic communities to assess whether this Limiting Factor would be able to support the productivity of juvenile Chinook or whether they may be a biological risk. The sampling sites were located in salmon rearing areas.

8 of the 9 sample sites were shown to have benthic communities comparable to undisturbed references and could be considered to have little or no impact from stressors. The ninth sample site was found to be Highly Divergent from the reference group which suggests a stressor is impacting the benthic community in this location. The water temperature and prior logging impacts are similar to other sample sites so these attributes are unlikely to be stressors. The water chemistry information was inconclusive for the source of this impact.

Warmer water temperatures due to Climate Change may result in changes in the composition of the benthic community however specifically changes in species and abundance will depend on the tolerances of the present community. Warmer waters can result in earlier adult emergence and reproduction which might coincide with earlier Chinook fry emergence.

Overall, the benthic communities should be able to support rearing juvenile Chinook Salmon. No explanation was found for the Highly Divergent site which suggests further assessment work is warranted.

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Appendices

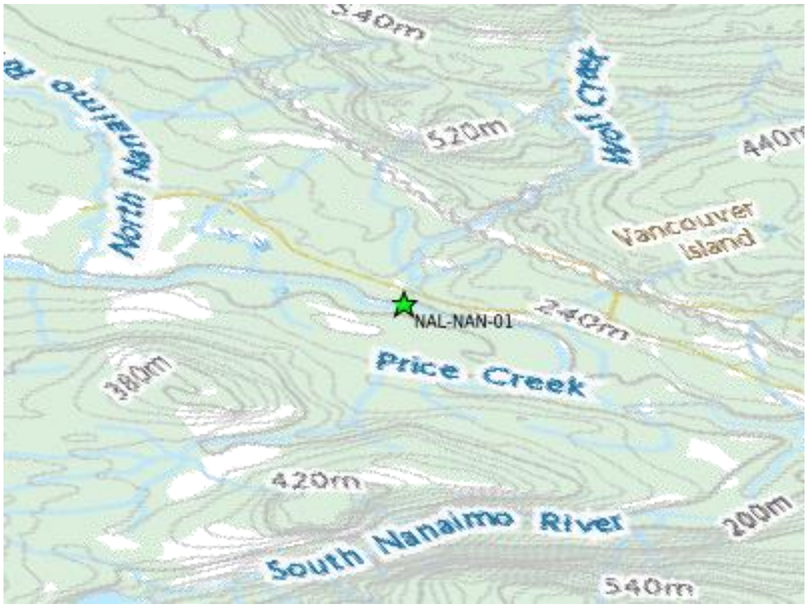
Appendix F – CABIN results

The following reports are a printout from the CABIN database for each of the samples. Each report consists of:

- Site Description, that includes:
    - Tombstone data for the sample location,
    - Rough topographic map showing the location of the sample site,
    - An photographic image of the sample site,
- The CABIN Assessment Results, consisting of:
    - The Reference Model Summary including physical model variables that are used to select which of the Reference Groups to use and the Probability of Group Membership for each of the Reference Groups, with the highest probability indicating which to use to assess the benthic community,
    - The last row on the table shows the result of the assessment,
    - The vector ordination for most divergent vector pair of the three pairs. This figure shows the four ellipse confidence areas, the plot of the reference sites (green dots) and the plot of the sample (blue dot with label)
- Sample information, and
- The benthic Community Structure, identified to Family and enumerated.

Site Description

Study Name	BC MOE-Vancouver Island Region
Site	NAL-NAN-01
Sampling Date	Aug 31 2020
Know Your Watershed Basin	South Central Vancouver Island
Province / Territory	British Columbia
Terrestrial Ecological Classification	Pacific Maritime EcoZone Eastern Vancouver Island EcoRegion
Coordinates (decimal degrees)	49.08911 N, 124.10731 W
Altitude	203
Local Basin Name	Nanaimo River 50m u/s of Wolf Creek
	Nanaimo River
Stream Order	5



Location map

Looking upstream

Cabin Assessment Results

Reference Model Summary				
Model	Vancouver Island 2021			
Analysis Date	April 21, 2023			
Taxonomic Level	Family			
Predictive Model Variables	Altitude DegreeDays ElevationMax ElevationMin Precip08_AUG stream order StreamLength Volcanic Width-BankFull			

Reference Groups	**1**	**2**	**3**	**4**
Number of Reference Sites	27	14	23	24
Group Error Rate	32.1%	40.0%	46.4%	28.9%
Overall Model Error Rate	35.8%			
Probability of Group Membership	0.7%	14.7%	83.7%	1.0%
CABIN Assessment of NAL-NAN-01 on Aug 31, 2020	Mildly Divergent			

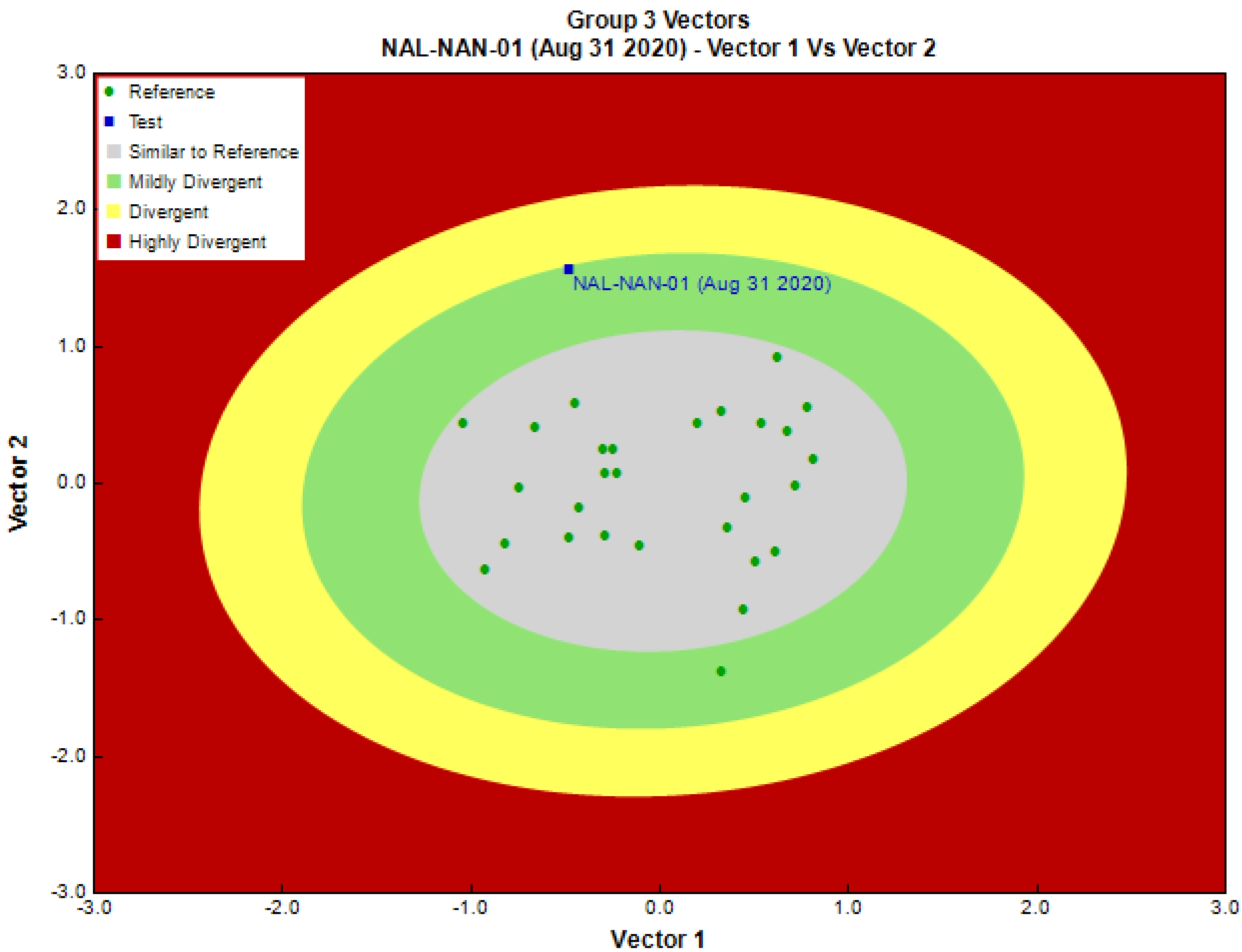


Figure 3. CABIN ordination assessment of the test site with the predicted group of reference sites. Each axis represents the relative abundance of the entire benthic invertebrate community with different organisms weighted differently on each axis.

Sample Information

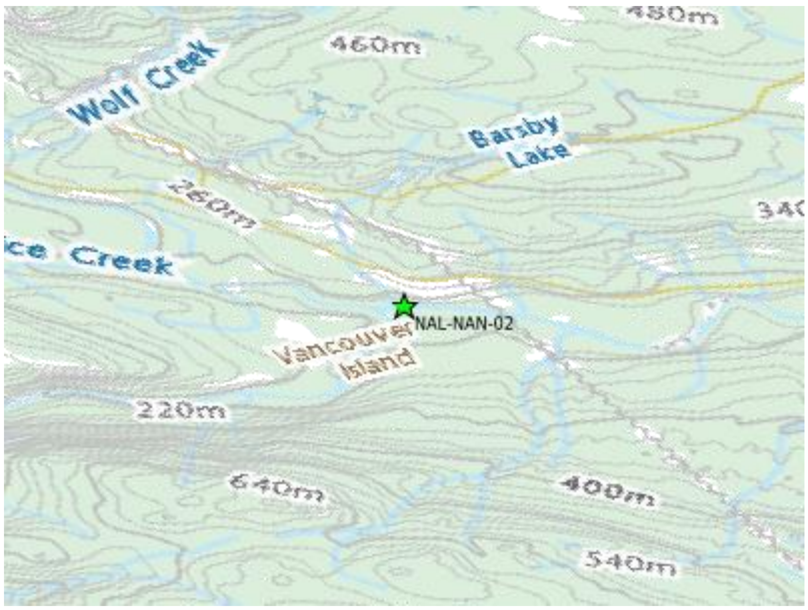
Sampling Device	Kick Net
Mesh Size	400
Sampling Time	3
Taxonomist	Adam Bliss, CRI
	-
Sub-Sample Proportion	50/100

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
Annelida	Clitellata	Opisthopora	Lumbricidae	2	4.0
		Tubificida	Naididae	77	154.0
Arthropoda	Arachnida	Trombidiformes	Lebertiidae	1	2.0
			Sperchontidae	2	4.0
			Torrenticolidae	6	12.0
	Insecta	Coleoptera	Elmidae	8	16.0
			Hydrophilidae	1	2.0
		Diptera	Ceratopogonidae	1	2.0
			Chironomidae	22	44.0
			Simuliidae	12	24.0
			Tipulidae	1	2.0
		Ephemeroptera	Baetidae	27	54.0
			Heptageniidae	42	84.0
		Plecoptera	Chloroperlidae	1	2.0
			Nemouridae	2	4.0
		Trichoptera	Unk.	1	2.0
			Hydropsychidae	66	132.0
			Hydroptilidae	1	2.0
			Leptoceridae	2	4.0
			Philopotamidae	23	46.0
Mollusca	Gastropoda	Basommatophora	Planorbidae	9	18.0
Total				307	614.0

Site Description

Study Name	BC MOE-Vancouver Island Region
Site	NAL-NAN-02
Sampling Date	Aug 31 2020
Know Your Watershed Basin	Southern Vancouver Island
Province / Territory	British Columbia
Terrestrial Ecological Classification	Pacific Maritime EcoZone Eastern Vancouver Island EcoRegion
Coordinates (decimal degrees)	49.07690 N, 124.07647 W
Altitude	170
Local Basin Name	Nanaimo River d/s of confluence w South fork
	Nanaimo River
Stream Order	5



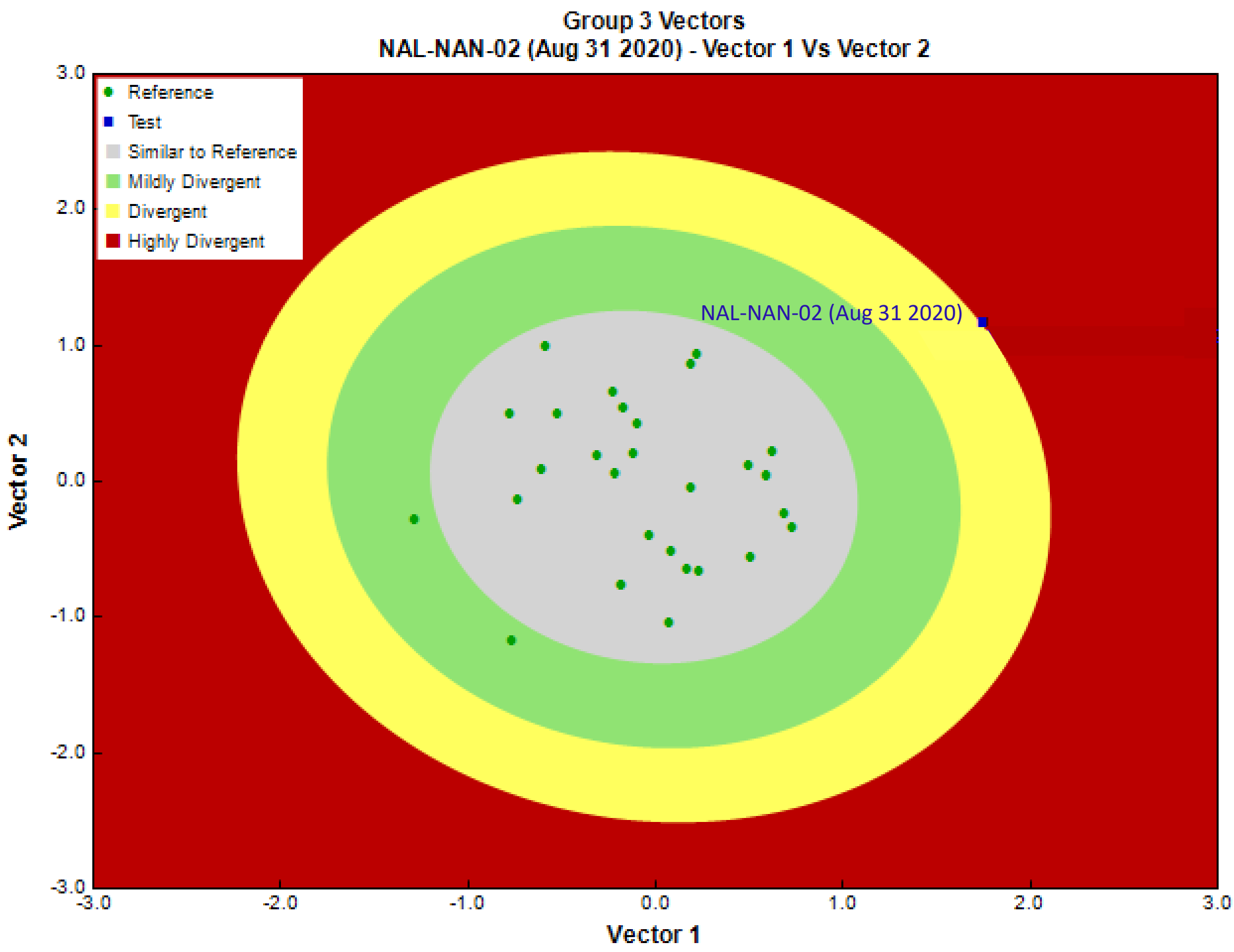
Location map

Looking upstream

Cabin Assessment Results

Reference Model Summary	
Model	Vancouver Island 2021
Analysis Date	April 21, 2023
Taxonomic Level	Family
Predictive Model Variables	Altitude DegreeDays ElevationMax ElevationMin Precip08_AUG stream order StreamLength Volcanic Width-BankFull

Reference Groups	**1**	**2**	**3**	**4**
Number of Reference Sites	27	14	23	24
Group Error Rate	32.1%	40.0%	46.4%	28.9%
Overall Model Error Rate	35.8%			
Probability of Group Membership	0.0%	10.5%	89.5%	0.0%
CABIN Assessment of NAL-NAN-02 on Aug 31, 2020	Highly Divergent			



Sample Information

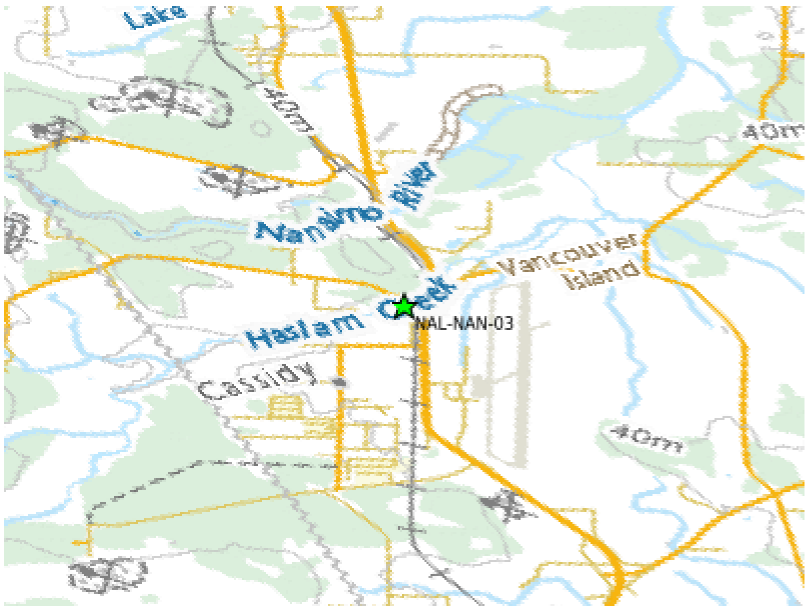
Sampling Device	Kick Net
Mesh Size	400
Sampling Time	3
Taxonomist	Trish Unknown (Biologica), Biologica Environmental Services
	-
Sub-Sample Proportion	100/100

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
Annelida	Clitellata	Opisthopora	Lumbricidae	1	1.0
		Tubificida	Naididae	3	3.0
Arthropoda	Arachnida	Trombidiformes	Aturidae	1	1.0
			Sperchontidae	1	1.0
			Torrenticolidae	1	1.0
	Insecta	Diptera	Ceratopogonidae	1	1.0
			Chironomidae	23	23.0
			Simuliidae	1	1.0
			Tipulidae	1	1.0
		Ephemeroptera	Unk.	2	2.0
			Baetidae	95	95.0
			Ephemerellidae	4	4.0
			Heptageniidae	9	9.0
			Leptophlebiidae	2	2.0
		Plecoptera	Nemouridae	3	3.0
			Perlodidae	1	1.0
		Trichoptera	Unk.	1	1.0
			Hydroptilidae	4	4.0
			Rhyacophilidae	1	1.0
Total				155	155.0

Site Description

Study Name	BC MOE-Vancouver Island Region
Site	NAL-NAN-03
Sampling Date	Aug 31 2020
Know Your Watershed Basin	South Central Vancouver Island
Province / Territory	British Columbia
Terrestrial Ecological Classification	Pacific Maritime EcoZone Eastern Vancouver Island EcoRegion
Coordinates (decimal degrees)	49.06141 N, 123.87884 W
Altitude	32
Local Basin Name	Haslam Creek @ Hwy
	Nanaimo River
Stream Order	3



Location map


Looking upstream

Cabin Assessment Results

Reference Model Summary	
Model	Vancouver Island 2021
Analysis Date	April 21, 2023
Taxonomic Level	Family
Predictive Model Variables	Altitude DegreeDays ElevationMax ElevationMin Precip08_AUG stream order StreamLength Volcanic Width-BankFull

Reference Groups	**1**	**2**	**3**	**4**
Number of Reference Sites	27	14	23	24
Group Error Rate	32.1%	40.0%	46.4%	28.9%
Overall Model Error Rate	35.8%			
Probability of Group Membership	2.2%	70.9%	18.8%	8.1%
CABIN Assessment of NAL-NAN-03 on Aug 31, 2020	Mildly Divergent			

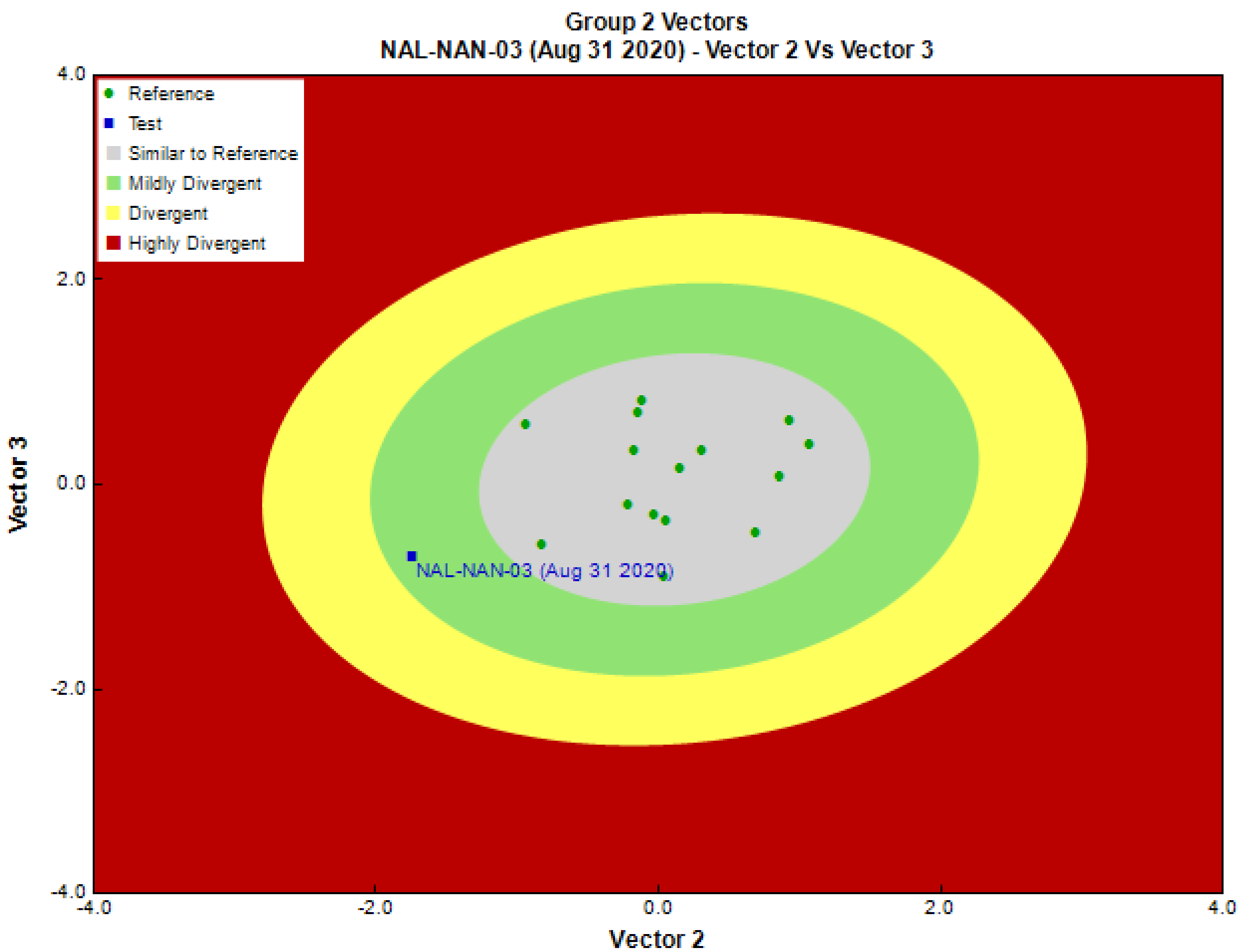


Figure 3. CABIN ordination assessment of the test site with the predicted group of reference sites. Each axis represents the relative abundance of the entire benthic invertebrate community with different organisms weighted differently on each axis.

Sample Information

Sampling Device	Kick Net
Mesh Size	400
Sampling Time	3
Taxonomist	Tara Unknown (Biologica), Biologica Environmental Services
	-
Sub-Sample Proportion	5/100

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
Annelida	Clitellata	Tubificida	Naididae	3	60.0
Arthropoda	Arachnida	Trombidiformes	Unk.	7	140.0
			Hygrobatidae	5	100.0
			Lebertiidae	2	40.0
			Limnesiidae	1	20.0
			Sperchontidae	3	60.0
			Torrenticolidae	143	2,860.0
	Insecta	Coleoptera	Elmidae	8	160.0
			Hydrophilidae	1	20.0
		Diptera	Unk.	1	20.0
			Ceratopogonidae	2	40.0
			Chironomidae	165	3,300.0
			Simuliidae	3	60.0
			Tipulidae	1	20.0
		Ephemeroptera	Ameletidae	2	40.0
			Baetidae	13	260.0
			Ephemerellidae	2	40.0
			Heptageniidae	1	20.0
			Leptophlebiidae	4	80.0
		Plecoptera	Chloroperlidae	18	360.0
		Trichoptera	Lepidostomatidae	2	40.0
Total				387	7,740.0

Site Description

Study Name	BC MOE-Vancouver Island Region
Site	NAL-NAN-04
Sampling Date	Aug 31 2020
Know Your Watershed Basin	South Central Vancouver Island
Province / Territory	British Columbia
Terrestrial Ecological Classification	Pacific Maritime EcoZone Eastern Vancouver Island EcoRegion
Coordinates (decimal degrees)	49.08164 N, 123.86793 W
Altitude	13
Local Basin Name	Nanaimo River @ lower RDN park
	Nanaimo River
Stream Order	5

Location map

No site image found

Cabin Assessment Results

Reference Model Summary	
Model	Vancouver Island 2021
Analysis Date	April 21, 2023
Taxonomic Level	Family
Predictive Model Variables	Altitude DegreeDays ElevationMax ElevationMin Precip08_AUG stream order StreamLength Volcanic Width-BankFull

Reference Groups	**1**	**2**	**3**	**4**
Number of Reference Sites	27	14	23	24
Group Error Rate	32.1%	40.0%	46.4%	28.9%
Overall Model Error Rate	35.8%			
Probability of Group Membership	0.0%	20.9%	79.1%	0.0%
CABIN Assessment of NAL-NAN-04 on Aug 31, 2020	Similar to Reference			

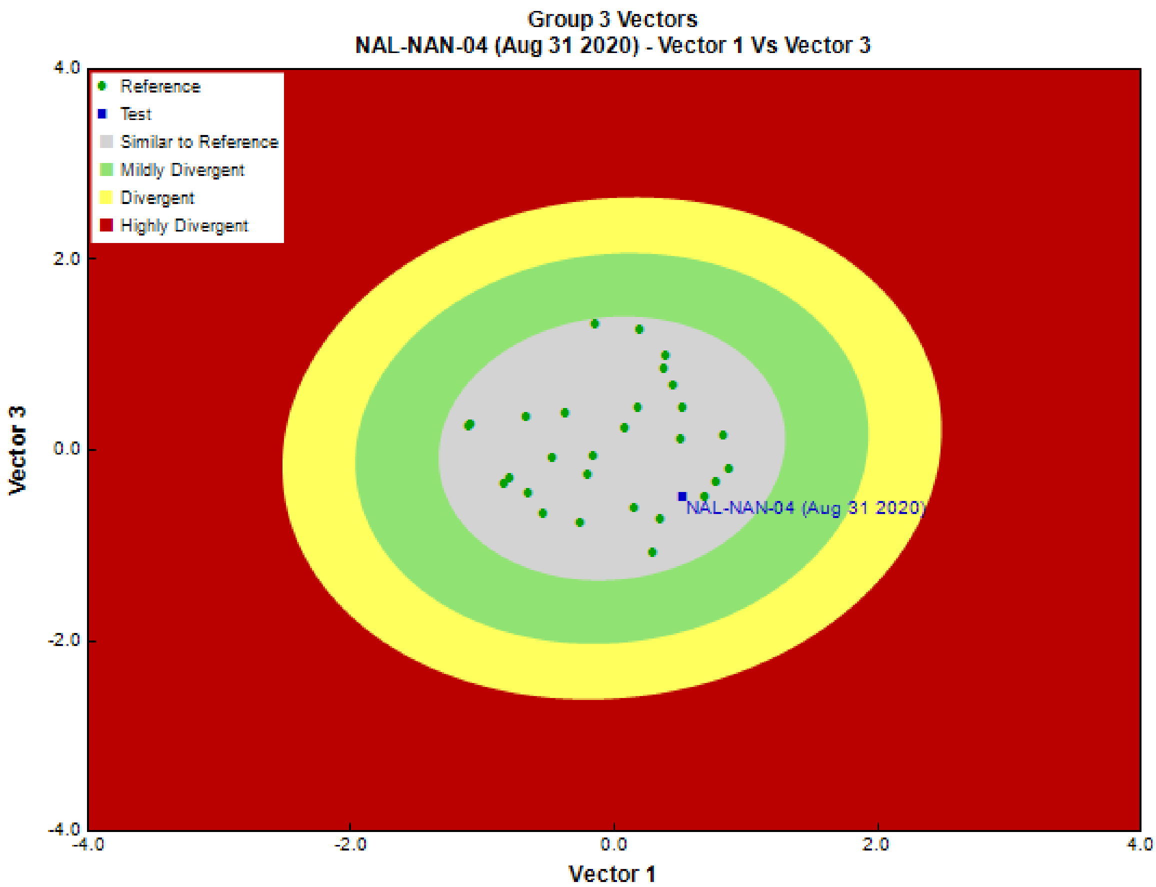


Figure 3. CABIN ordination assessment of the test site with the predicted group of reference sites. Each axis represents the relative abundance of the entire benthic invertebrate community with different organisms weighted differently on each axis.

Sample Information

Sampling Device	Kick Net
Mesh Size	400
Sampling Time	3
Taxonomist	Tara Unknown (Biologica), Biologica Environmental Services
	-
Sub-Sample Proportion	15/100

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
Annelida	Clitellata	Opisthopora	Lumbricidae	3	20.0
		Tubificida	Naididae	12	80.0
Arthropoda	Arachnida	Trombidiformes	Unk.	6	40.0
			Aturidae	4	26.6
			Feltriidae	1	6.7
			Halacaridae	1	6.7
			Lebertiidae	4	26.7
			Sperchontidae	2	13.3
			Torrenticolidae	25	166.7
	Insecta	Coleoptera	Elmidae	6	40.0
			Hydrophilidae	1	6.7
		Diptera	Unk.	2	13.3
			Chironomidae	107	713.4
			Dixidae	1	6.7
			Empididae	2	13.3
			Simuliidae	10	66.7
			Tipulidae	2	13.3
		Ephemeroptera	Baetidae	60	400.0
			Ephemerellidae	3	20.0
			Heptageniidae	29	193.3
		Plecoptera	Nemouridae	9	60.0
			Perlodidae	1	6.7
		Trichoptera	Hydropsychidae	6	40.0
			Philopotamidae	3	20.0
Mollusca	Gastropoda	Basommatophora	Planorbidae	2	13.3
Total				302	2,013.4

Site Description

Study Name	BC MOE-Vancouver Island Region
Site	NAL-NAN-05
Sampling Date	Aug 31 2020
Know Your Watershed Basin	South Central Vancouver Island
Province / Territory	British Columbia
Terrestrial Ecological Classification	Pacific Maritime EcoZone Eastern Vancouver Island EcoRegion
Coordinates (decimal degrees)	49.08611 N, 124.37531 W
Altitude	274
Local Basin Name	Green Creek 600m u/s of Nanaimo River
	Nanaimo River
Stream Order	4

Location map

Looking upstream

Cabin Assessment Results

Reference Model Summary	
Model	Vancouver Island 2021
Analysis Date	April 21, 2023
Taxonomic Level	Family
Predictive Model Variables	Altitude DegreeDays ElevationMax ElevationMin Precip08_AUG stream order StreamLength Volcanic Width-BankFull

Reference Groups	**1**	**2**	**3**	**4**
Number of Reference Sites	27	14	23	24
Group Error Rate	32.1%	40.0%	46.4%	28.9%
Overall Model Error Rate	35.8 %			
Probability of Group Membership	15.7%	7.6%	42.0%	34.7%
CABIN Assessment of NAL-NAN-05 on Aug 31, 2020	Similar to Reference			

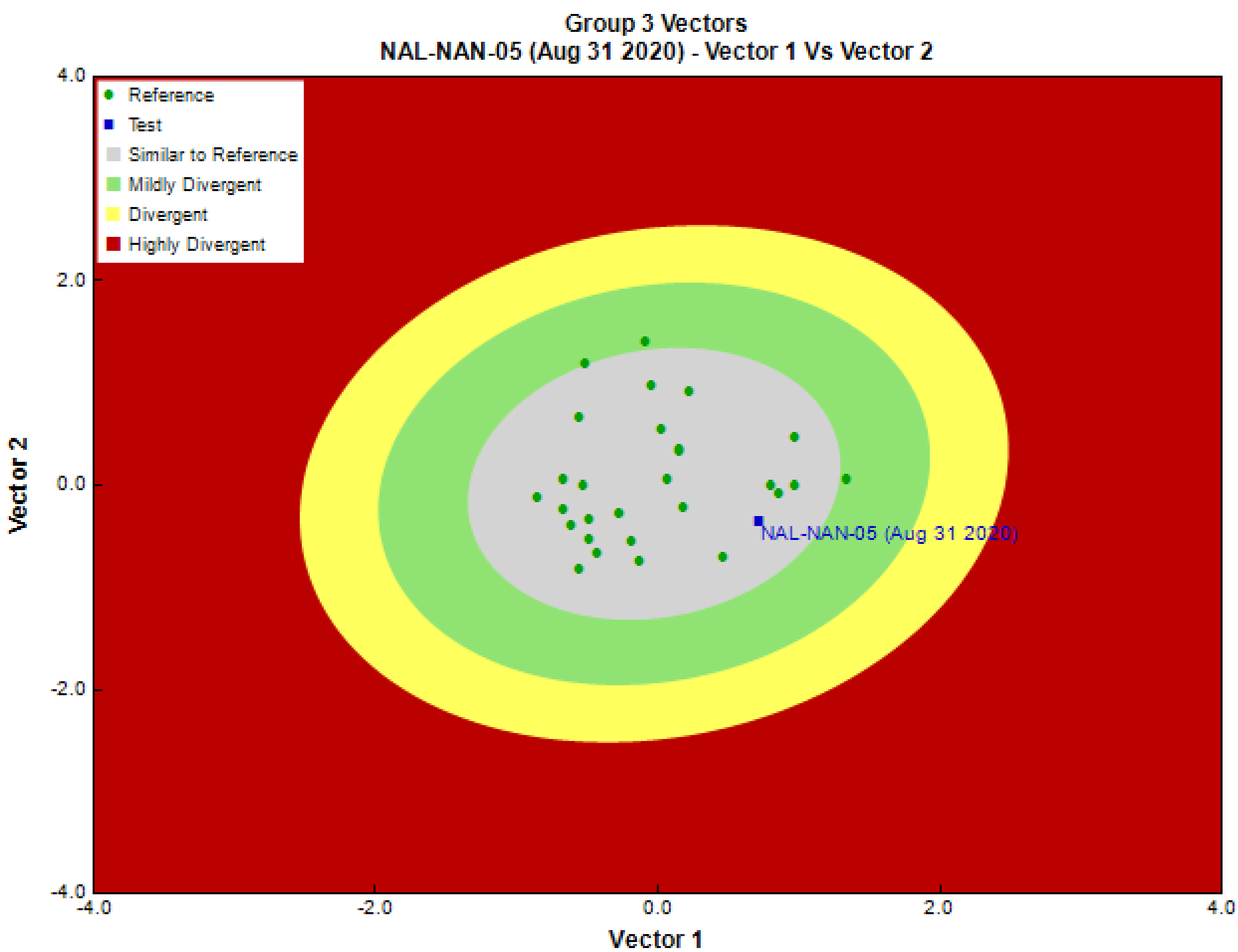


Figure 3. CABIN ordination assessment of the test site with the predicted group of reference sites. Each axis represents the relative abundance of the entire benthic invertebrate community with different organisms weighted differently on each axis.

Sample Information

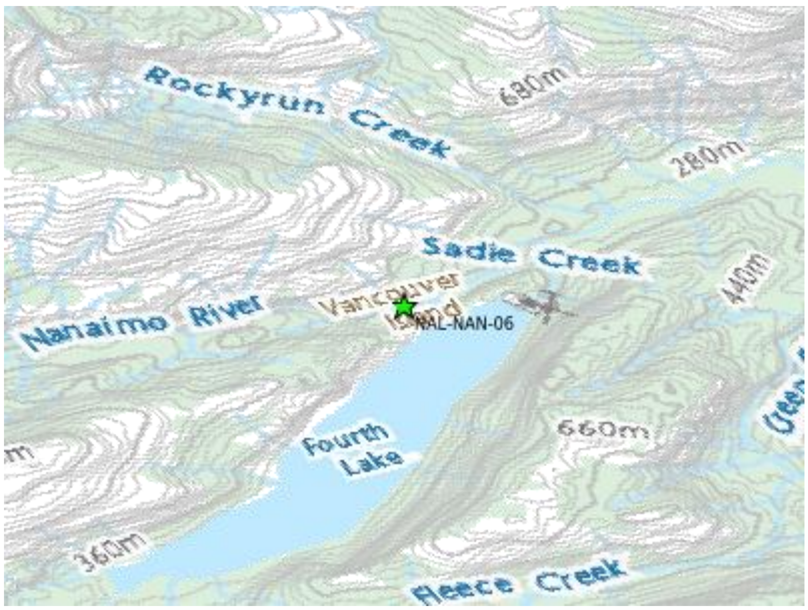
Sampling Device	Kick Net
Mesh Size	400
Sampling Time	3
Taxonomist	Trish Unknown (Biologica), Biologica Environmental Services
	-
Sub-Sample Proportion	14/100

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
Arthropoda	Arachnida	Trombidiformes	Hydryphantidae	2	14.3
			Hygrobatidae	1	7.1
			Lebertiidae	4	28.6
			Torrenticolidae	88	628.6
	Insecta	Coleoptera	Elmidae	42	300.0
			Hydrophilidae	4	28.6
		Diptera	Chironomidae	52	371.2
			Dixidae	1	7.1
			Tipulidae	8	57.2
		Ephemeroptera	Ameletidae	4	28.6
			Baetidae	25	178.5
			Ephemerellidae	2	14.3
			Heptageniidae	56	400.0
		Plecoptera	Chloroperlidae	10	71.5
			Perlodidae	2	14.3
		Trichoptera	Unk.	1	7.1
			Brachycentridae	2	14.3
			Glossosomatidae	1	7.1
			Hydropsychidae	1	7.1
			Lepidostomatidae	5	35.7
			Limnephilidae	1	7.1
Total				312	2,228.3

Site Description

Study Name	BC MOE-Vancouver Island Region
Site	NAL-NAN-06
Sampling Date	Aug 31 2020
Know Your Watershed Basin	South Central Vancouver Island
Province / Territory	British Columbia
Terrestrial Ecological Classification	Pacific Maritime EcoZone Eastern Vancouver Island EcoRegion
Coordinates (decimal degrees)	49.07635 N, 124.41348 W
Altitude	297
Local Basin Name	Nanaimo River 1km u/s of confluence w Fourth Lake outlet
	Nanaimo River
Stream Order	3



Location map

Looking upstream

Cabin Assessment Results

Reference Model Summary	
Model	Vancouver Island 2021
Analysis Date	April 21, 2023
Taxonomic Level	Family
Predictive Model Variables	Altitude DegreeDays ElevationMax ElevationMin Precip08_AUG stream order StreamLength Volcanic Width-BankFull

Reference Groups	**1**	**2**	**3**	**4**
Number of Reference Sites	27	14	23	24
Group Error Rate	32.1%	40.0%	46.4%	28.9%
Overall Model Error Rate	35.8%			
Probability of Group Membership	22.2%	13.1%	35.0%	29.7%
CABIN Assessment of NAL-NAN-06 on Aug 31, 2020	Similar to Reference			

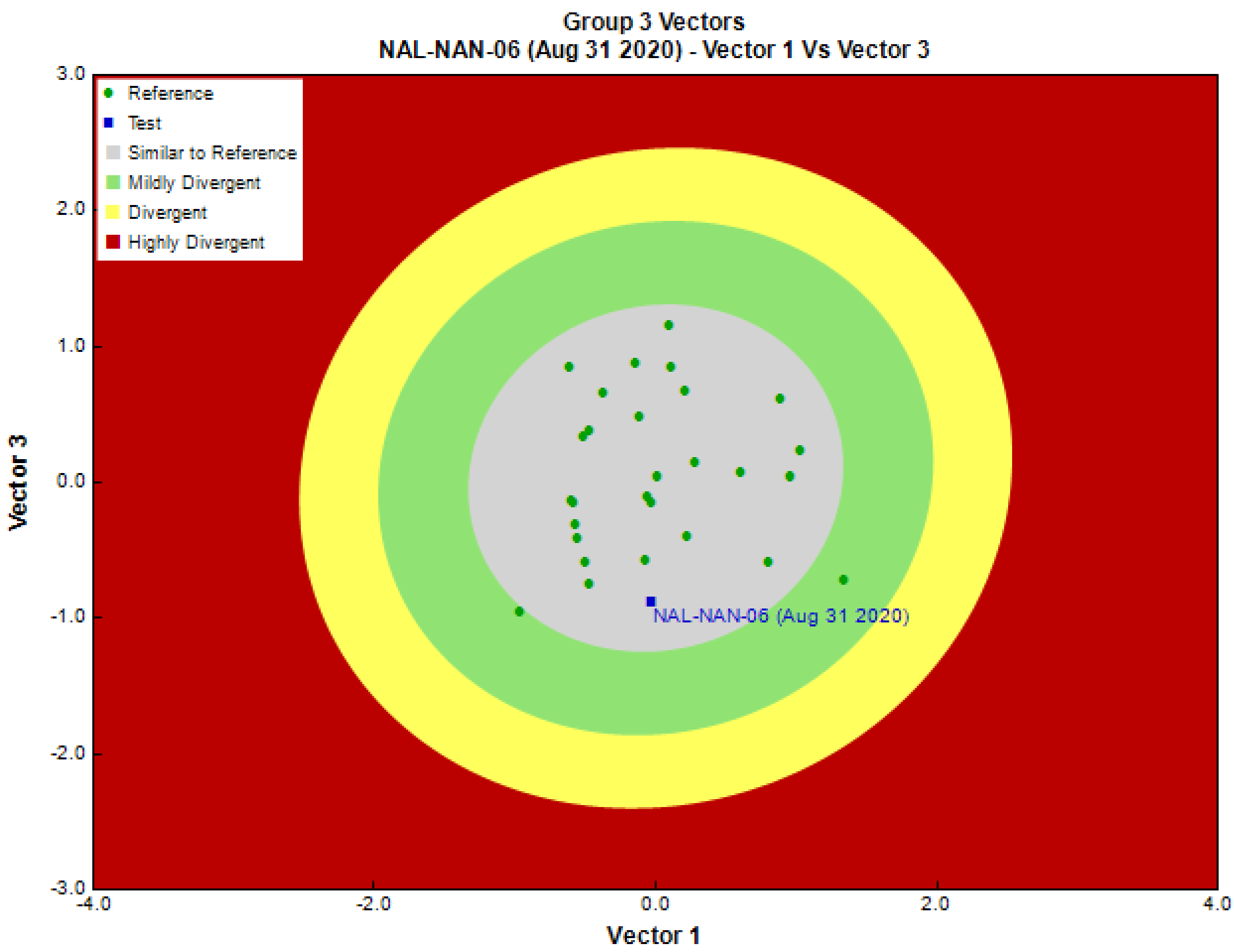


Figure 3. CABIN ordination assessment of the test site with the predicted group of reference sites. Each axis represents the relative abundance of the entire benthic invertebrate community with different organisms weighted differently on each axis.

Sample Information

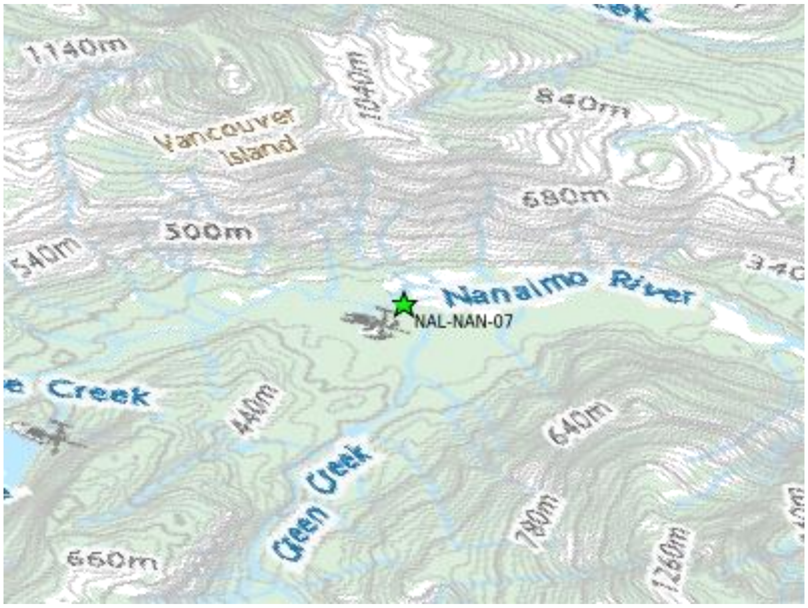
Sampling Device	Kick Net
Mesh Size	400
Sampling Time	3
Taxonomist	Trish Unknown (Biologica), Biologica Environmental Services
	-
Sub-Sample Proportion	30/100

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
Annelida	Clitellata		Enchytraeidae	1	3.3
		Lumbriculida	Lumbriculidae	1	3.3
Arthropoda	Arachnida	Trombidiformes	Unk.	1	3.3
			Hydryphantidae	3	10.0
			Hygrobatidae	3	10.0
			Lebertiidae	2	6.6
			Pionidae	1	3.3
			Torrenticolidae	74	246.7
	Insecta	Coleoptera	Elmidae	45	150.0
			Hydrophilidae	8	26.7
		Diptera	Ceratopogonidae	4	13.3
			Chironomidae	78	260.1
			Tabanidae	2	6.7
			Tipulidae	2	6.7
		Ephemeroptera	Baetidae	23	76.6
			Ephemerellidae	1	3.3
			Heptageniidae	30	100.0
		Plecoptera	Chloroperlidae	11	36.7
			Nemouridae	7	23.3
			Perlidae	7	23.3
			Perlodidae	1	3.3
		Trichoptera	Unk.	2	6.7
			Glossosomatidae	3	10.0
			Hydropsychidae	13	43.3
			Leptoceridae	5	16.7
			Polycentropodidae	1	3.3
Total				329	1,096.5

Site Description

Study Name	BC MOE-Vancouver Island Region
Site	NAL-NAN-07
Sampling Date	Aug 31 2020
Know Your Watershed Basin	South Central Vancouver Island
Province / Territory	British Columbia
Terrestrial Ecological Classification	Pacific Maritime EcoZone Eastern Vancouver Island EcoRegion
Coordinates (decimal degrees)	49.08957 N, 124.37678 W
Altitude	278
Local Basin Name	Nanaimo River 2km d/s of Fourth Lake
	Nanaimo River
Stream Order	5



Location map


Looking upstream

Cabin Assessment Results

Reference Model Summary	
Model	Vancouver Island 2021
Analysis Date	April 21, 2023
Taxonomic Level	Family
Predictive Model Variables	Altitude DegreeDays ElevationMax ElevationMin Precip08_AUG stream order StreamLength Volcanic Width-BankFull

Reference Groups	**1**	**2**	**3**	**4**
Number of Reference Sites	27	14	23	24
Group Error Rate	32.1%	40.0%	46.4%	28.9%
Overall Model Error Rate	35.8%			
Probability of Group Membership	3.3%	2.6%	7.9%	86.3%
CABIN Assessment of NAL-NAN-07 on Aug 31, 2020	Similar to Reference			

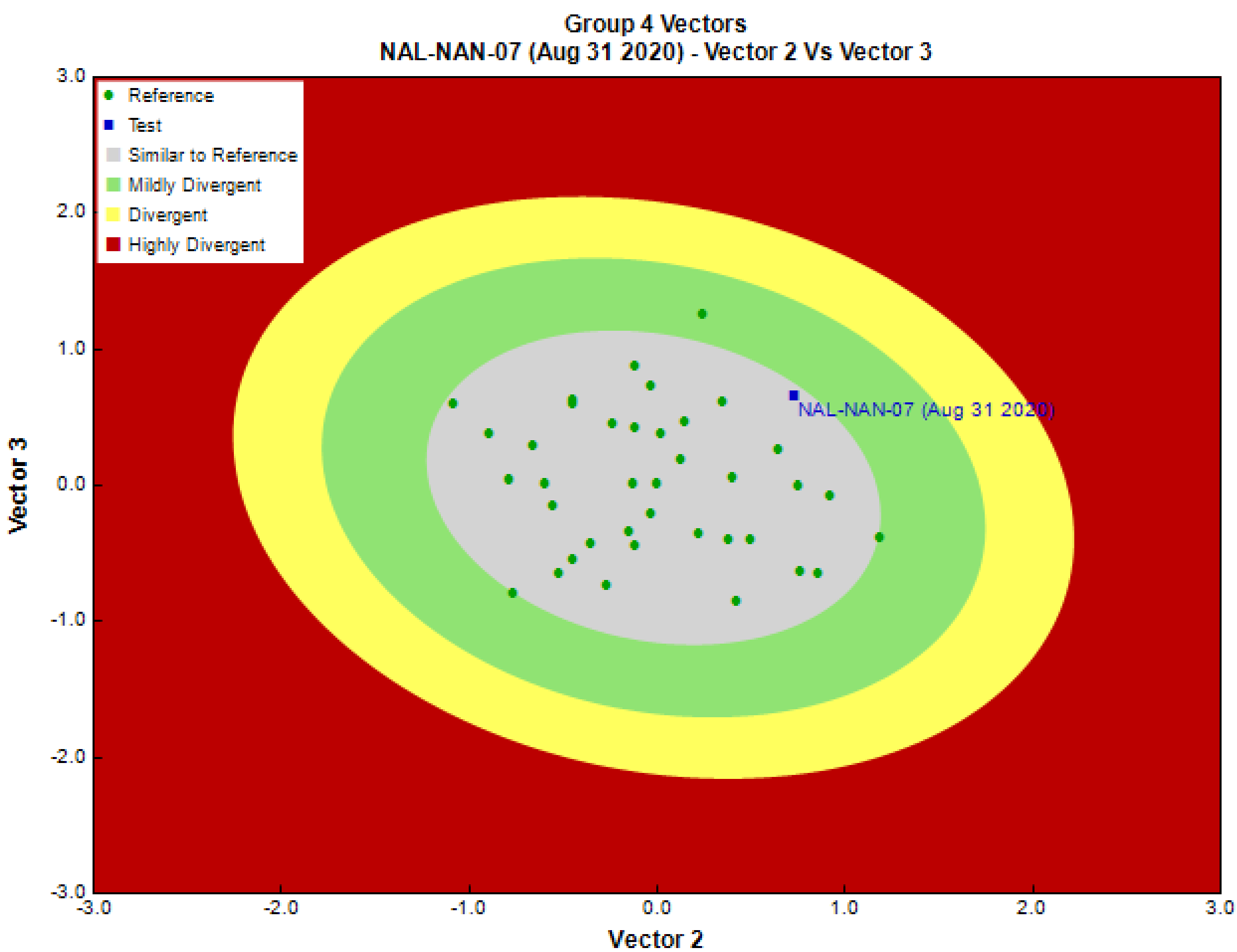


Figure 3. CABIN ordination assessment of the test site with the predicted group of reference sites. Each axis represents the relative abundance of the entire benthic invertebrate community with different organisms weighted differently on each axis.

Sample Information

Sampling Device	Kick Net
Mesh Size	400
Sampling Time	3
Taxonomist	Tara Unknown (Biologica), Biologica Environmental Services
	-
Sub-Sample Proportion	9/100

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
Arthropoda	Arachnida	Trombidiformes	Torrenticolidae	4	44.4
	Collembola	Collembola	Isotomidae	1	11.1
	Insecta	Diptera	Chironomidae	136	1,511.0
			Simuliidae	8	88.9
		Ephemeroptera	Unk.	1	11.1
			Ameletidae	1	11.1
			Baetidae	55	611.1
			Ephemerellidae	8	88.9
			Heptageniidae	21	233.3
		Lepidoptera	Unk.	1	11.1
		Plecoptera	Chloroperlidae	15	166.6
			Nemouridae	18	200.0
			Perlodidae	4	44.4
		Trichoptera	Glossosomatidae	22	244.4
			Hydropsychidae	2	22.2
			Hydroptilidae	1	11.1
			Lepidostomatidae	1	11.1
			Rhyacophilidae	1	11.1
Cnidaria	Hydrozoa	Anthoathecatae	Hydridae	1	11.1
Total				301	3,344.0

Site Description

Study Name	BC MOE-Vancouver Island Region
Site	NAL-NAN-08
Sampling Date	Aug 31 2020
Know Your Watershed Basin	South Central Vancouver Island
Province / Territory	British Columbia
Terrestrial Ecological Classification	Pacific Maritime EcoZone Eastern Vancouver Island EcoRegion
Coordinates (decimal degrees)	49.08355 N, 124.40089 W
Altitude	277
Local Basin Name	Nanaimo River 200m d/s of Fourth Lake
	Nanaimo River
Stream Order	4

Location map

Looking upstream

Cabin Assessment Results

Reference Model Summary	
Model	Vancouver Island 2021
Analysis Date	April 21, 2023
Taxonomic Level	Family
Predictive Model Variables	Altitude DegreeDays ElevationMax ElevationMin Precip08_AUG stream order StreamLength Volcanic Width-BankFull

Reference Groups	**1**	**2**	**3**	**4**
Number of Reference Sites	27	14	23	24
Group Error Rate	32.1%	40.0%	46.4%	28.9%
Overall Model Error Rate	35.8%			
Probability of Group Membership	9.9%	9.3%	25.7%	55.1%
CABIN Assessment of NAL-NAN-08 on Aug 31, 2020	Mildly Divergent			

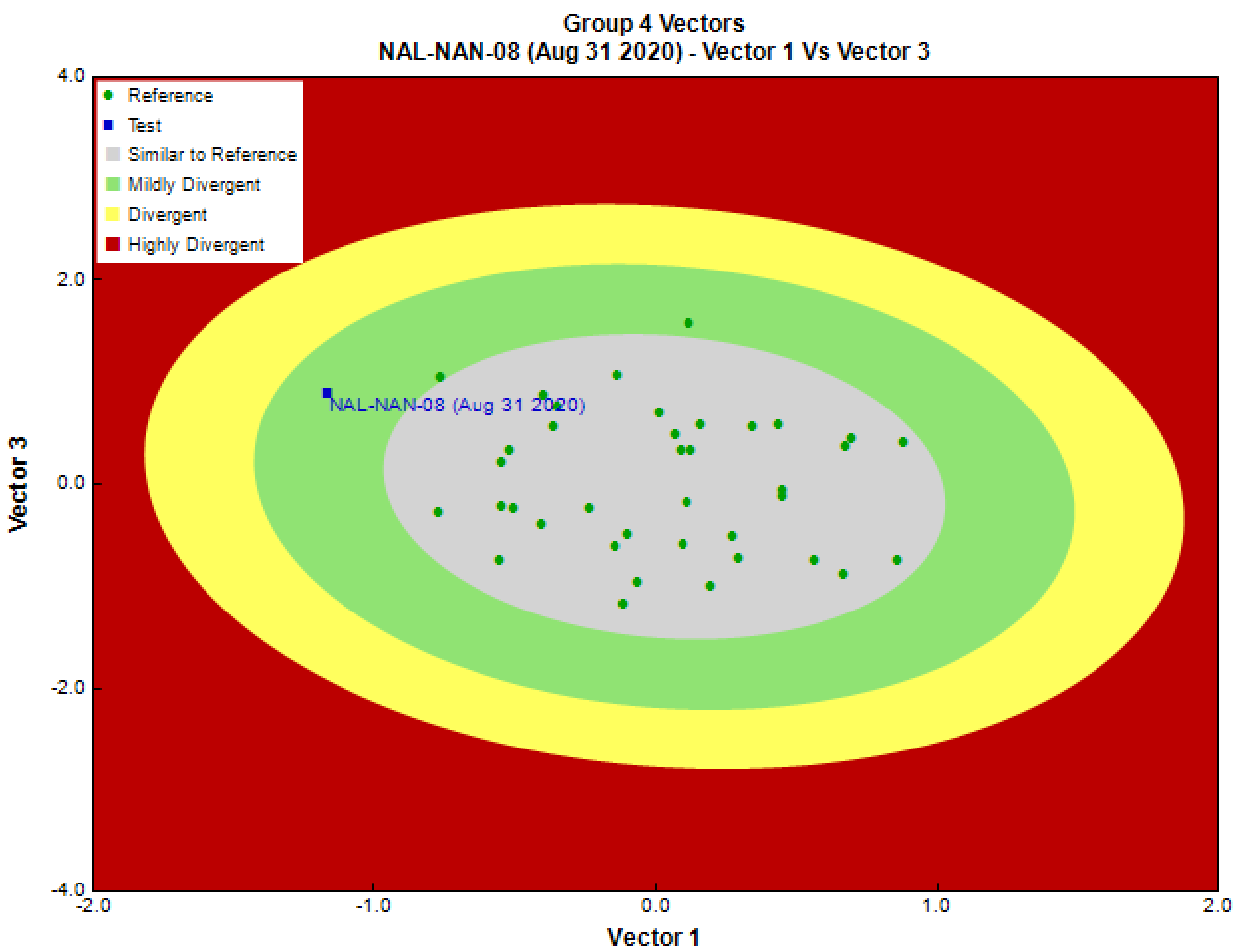


Figure 3. CABIN ordination assessment of the test site with the predicted group of reference sites. Each axis represents the relative abundance of the entire benthic invertebrate community with different organisms weighted differently on each axis.

Sample Information

Sampling Device	Kick Net
Mesh Size	400
Sampling Time	3
Taxonomist	Trish Unknown (Biologica), Biologica Environmental Services
	-
Sub-Sample Proportion	100/100

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
Annelida	Clitellata	Lumbriculida	Lumbriculidae	2	2.0
Arthropoda	Arachnida	Trombidiformes	Hydryphantidae	6	6.0
			Lebertiidae	1	1.0
			Pionidae	4	4.0
			Stygothrombiidae	1	1.0
			Torrenticolidae	27	27.0
	Insecta	Coleoptera	Elmidae	6	6.0
			Hydrophilidae	3	3.0
		Diptera	Ceratopogonidae	1	1.0
			Chironomidae	104	104.0
			Empididae	2	2.0
			Simuliidae	9	9.0
			Tipulidae	7	7.0
		Ephemeroptera	Ameletidae	3	3.0
			Baetidae	83	83.0
			Ephemerellidae	1	1.0
			Heptageniidae	47	47.0
		Plecoptera	Chloroperlidae	98	98.0
			Nemouridae	5	5.0
			Perlidae	2	2.0
			Perlodidae	13	13.0
		Trichoptera	Unk.	1	1.0
			Glossosomatidae	27	27.0
			Hydropsychidae	13	13.0
			Limnephilidae	1	1.0
			Rhyacophilidae	3	3.0
Total				470	470.0

Site Description

Study Name	BC MOE-Vancouver Island Region
Site	NAL-NAN-09
Sampling Date	Sep 01 2020
Know Your Watershed Basin	South Central Vancouver Island
Province / Territory	British Columbia
Terrestrial Ecological Classification	Pacific Maritime EcoZone Eastern Vancouver Island EcoRegion
Coordinates (decimal degrees)	49.10466 N, 123.86503 W
Altitude	5
Local Basin Name	Nanaimo River @ end of Hemer Rd
	Nanaimo River
Stream Order	5

Location map

Looking upstream

Cabin Assessment Results

Reference Model Summary	
Model	Vancouver Island 2021
Analysis Date	April 21, 2023
Taxonomic Level	Family
Predictive Model Variables	Altitude DegreeDays ElevationMax ElevationMin Precip08_AUG stream order StreamLength Volcanic Width-BankFull

Reference Groups	**1**	**2**	**3**	**4**
Number of Reference Sites	27	14	23	24
Group Error Rate	32.1%	40.0%	46.4%	28.9%
Overall Model Error Rate	35.8%			
Probability of Group Membership	0.0%	19.2%	80.8%	0.0%
CABIN Assessment of NAL-NAN-09 on Sep 01, 2020	Mildly Divergent			

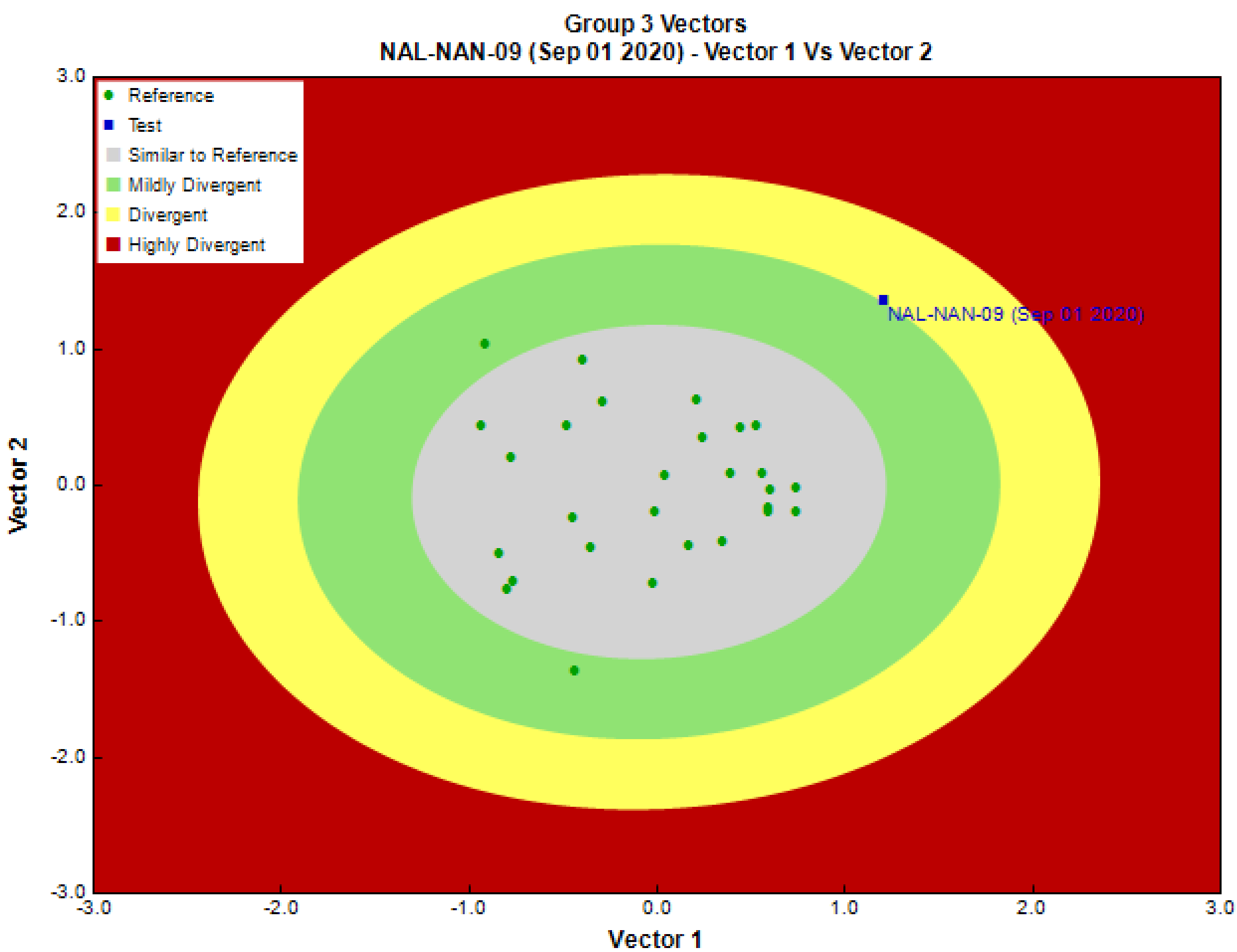


Figure 3. CABIN ordination assessment of the test site with the predicted group of reference sites. Each axis represents the relative abundance of the entire benthic invertebrate community with different organisms weighted differently on each axis.

Sample Information

Sampling Device	Kick Net
Mesh Size	400
Sampling Time	3
Taxonomist	Trish Unknown (Biologica), Biologica Environmental Services
	-
Sub-Sample Proportion	100/100

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
Annelida	Clitellata	Unk.	Unk.	1	1.0
		Lumbriculida	Lumbriculidae	49	49.0
		Tubificida	Naididae	56	56.0
Arthropoda	Arachnida	Sarcoptiformes	Unk.	42	42.0
			Hydrozetidae	7	7.0
		Trombidiformes	Unk.	14	14.0
			Aturidae	4	4.0
			Halacaridae	1	1.0
			Hygrobatidae	4	4.0
			Lebertiidae	3	3.0
			Limnesiidae	30	30.0
			Pionidae	5	5.0
			Torrenticolidae	95	95.0
	Insecta	Coleoptera	Elmidae	1	1.0
		Diptera	Ceratopogonidae	48	48.0
			Chironomidae	34	34.0
		Ephemeroptera	Baetidae	3	3.0
		Plecoptera	Nemouridae	1	1.0
		Trichoptera	Unk.	1	1.0
			Hydropsychidae	1	1.0
			Hydroptilidae	11	11.0
Chordata	Unk.	Unk.	Unk.	1	1.0
Mollusca	Gastropoda	Basommatophora	Planorbidae	3	3.0
Total				415	415.0

Appendix G – Water Chemistry

	Area		Trib, Above Second lake		Main, Above Second lake		Main, below First Lake		Main, below Hwy 19A		Trib, below Hwy 19A
	Location		Mainstem above Fourth Lake	Green Creek	Main, Above Second lake	~2km d/s Fourth lake	Confluence Wolf Creek	Confluence South Forks	RDN park	Hemer Road	Haslam Creek
	Site #		E320951	E320952	E320953	E320954	E320955	E320956	E320971	E320972	E299174
Field Tests (Water)	Threshold	Unit									
Conductivity, Client Supplied	2.0	uS/cm	n/a	n/a	n/a	n/a	45.4	47.6	53.4	n/a	109
Diss. Oxygen, Client Supplied	0.010	mg/L	n/a	n/a	n/a	n/a	9.05	9.71	10.26	n/a	11.24
Temperature, Client Supplied	-50	C	n/a	n/a	n/a	n/a	18.5	17.5	19.1	n/a	16.8
Physical Tests (Water)	Threshold	Unit									
Conductivity	2.0	uS/cm	71.0	85.7	32.5	32.9	45.6	46.6	53.2	52.8	112
Hardness (as CaCO3) - HTC	0.50	mg/L	25.1	32.3	13.1	13.3	17.5	17.1	18.4	18.6	35.8
Total Suspended Solids	3.0	mg/L	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Total Dissolved Solids	13	mg/L	39	52	21	23	37	37	48	31	76
Turbidity	0.10	NTU	0.10	0.10	0.28	0.20	0.22	0.22	0.18	0.15	0.15
Anions and Nutrients (Water)	Threshold	Unit									
Alkalinity, Total (as CaCO3)	1.0	mg/L	22.5	27.9	12.3	11.9	15.7	15.5	16.0	16.6	28.9
Ammonia, Total (as N)	0.0050	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bromide (Br)	0.050	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	0.50	mg/L	6.42	7.32	1.55	1.62	2.67	3.08	4.26	4.45	11.4
Fluoride (F)	0.010	mg/L	0.013	0.022	<0.010	<0.010	0.011	<0.010	0.011	0.013	0.016
Nitrate and Nitrite (as N)	0.0032	mg/L	0.0663	0.0826	0.0266	0.0292	<0.0032	0.0205	0.0131	0.0131	0.0302
Nitrate (as N)	0.0030	mg/L	0.0663	0.0826	0.0266	0.0292	<0.0030	0.0205	0.0131	0.0131	0.0302
Nitrite (as N)	0.0010	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Total Nitrogen	0.030	mg/L	0.120	0.139	0.089	0.094	0.096	0.098	0.086	0.089	0.094
Orthophosphate-Dissolved (as P)	0.0010	mg/L	<0.0010	0.0025	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0012	<0.0010
Phosphorus (P)-Total Dissolved	0.0020	mg/L	<0.0020	0.0038	<0.0020	<0.0020	0.0024	0.0021	<0.0020	<0.0020	0.0024
Phosphorus (P)-Total	0.0020	mg/L	<0.0020	0.0034	0.0022	0.0026	<0.0020	0.0069	<0.0020	0.0033	<0.0020
Sulfate (SO4)	0.30	mg/L	1.78	2.22	0.63	0.76	0.92	0.92	1.06	1.15	5.30
Organic / Inorganic Carbon (Water)	Threshold	Unit									
Dissolved Inorganic Carbon	0.50	mg/L	5.41	6.59	3.24	3.10	4.24	3.93	4.03	4.50	6.85
Dissolved Organic Carbon	0.50	mg/L	1.69	1.42	2.50	2.31	2.03	1.95	1.89	3.41	1.45
Total Metals (Undigested) (Water)	Threshold	Unit									
Aluminum (Al)-Total	0.00050	mg/L	0.0173	0.0165	0.0299	0.0263	0.0147	0.0143	0.0167	0.0105	0.00576
Antimony (Sb)-Total	0.000020	mg/L	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	0.000042
Arsenic (As)-Total	0.000020	mg/L	0.000117	0.000098	0.000051	0.000051	0.000097	0.000163	0.000120	0.000139	0.000204
Barium (Ba)-Total	0.000020	mg/L	0.0181	0.00715	0.00364	0.00387	0.00487	0.00503	0.00523	0.00637	0.0145
Beryllium (Be)-Total	0.000010	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Bismuth (Bi)-Total	0.0000050	mg/L	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Boron (B)-Total	0.0050	mg/L	0.0117	0.0207	0.0069	0.0076	0.0112	0.0105	0.0117	0.0136	0.0142
Cadmium (Cd)-Total	0.0000050	mg/L	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Calcium (Ca)-Total	0.010	mg/L	8.84	11.7	4.68	4.72	6.12	5.91	6.37	6.37	11.1
Chromium (Cr)-Total	0.00010	mg/L	<0.00010	<0.00010	0.00014	0.00013	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Cobalt (Co)-Total	0.0000050	mg/L	0.0000152	0.0000134	0.0000291	0.0000211	0.0000116	0.0000125	0.0000123	0.0000112	0.0000206
Copper (Cu)-Total	0.000050	mg/L	0.000358	0.000410	0.000359	0.000352	0.000361	0.000353	0.000355	0.000323	0.000655
Iron (Fe)-Total	0.0010	mg/L	0.0025	0.0027	0.0419	0.0329	0.0281	0.0670	0.0285	0.0271	0.0099
Lead (Pb)-Total	0.0000050	mg/L	<0.0000050	0.0000058	<0.0000050	<0.0000050	0.0000119	<0.0000050	0.0000082	<0.0000050	<0.0000050
Lithium (Li)-Total	0.00050	mg/L	0.00163	0.00082	<0.00050	<0.00050	<0.00050	<0.00050	0.00051	0.00051	0.00062
Magnesium (Mg)-Total	0.010	mg/L	0.737	0.750	0.349	0.366	0.538	0.558	0.606	0.660	1.95
Manganese (Mn)-Total	0.000050	mg/L	0.000387	0.000453	0.00962	0.00609	0.00362	0.00231	0.00117	0.00194	0.00120
Molybdenum (Mo)-Total	0.000050	mg/L	0.000050	0.000285	<0.000050	<0.000050	0.000118	0.000124	0.000114	0.000119	0.000137
Nickel (Ni)-Total	0.000050	mg/L	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000155
Potassium (K)-Total	0.020	mg/L	0.120	0.270	0.090	0.092	0.116	0.117	0.130	0.150	0.303
Selenium (Se)-Total	0.000040	mg/L	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040	<0.000040	0.000047	<0.000040	<0.000040
Silicon (Si)-Total	0.050	mg/L	1.76	2.38	0.999	1.06	1.57	1.72	1.68	1.78	4.07
Silver (Ag)-Total	0.0000050	mg/L	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Sodium (Na)-Total	0.020	mg/L	3.20	3.60	1.03	1.06	1.76	2.08	2.71	2.67	6.58
Strontium (Sr)-Total	0.000050	mg/L	0.0484	0.0515	0.0143	0.0150	0.0220	0.0238	0.0256	0.0284	0.0511
Thallium (Tl)-Total	0.0000020	mg/L	<0.0000020	<0.0000020	<0.0000020	<0.0000020	<0.0000020	<0.0000020	<0.0000020	<0.0000020	<0.0000020
Tin (Sn)-Total	0.000050	mg/L	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Uranium (U)-Total	0.0000020	mg/L	0.0000133	0.0000047	0.0000074	0.0000078	0.0000058	0.0000061	0.0000041	0.0000041	<0.0000020
Vanadium (V)-Total	0.00020	mg/L	0.00026	0.00039	<0.00020	<0.00020	<0.00020	0.00022	0.00026	0.00024	0.00046
Zinc (Zn)-Total	0.00020	mg/L	0.00022	0.00028	<0.00020	0.00036	0.00021	<0.00020	0.00053	<0.00020	0.00042

Preliminary Investigation of Habitat Use, Relative Abundance and Size of Juvenile Nanaimo River Chinook Salmon

Jeramy Damborg[20]

Disclaimer: This report references three ecotypes: a Spring run-timing population, a Summer and a Fall. At the time of writing the Chinook that use the spawning areas in the Nanaimo River above Second Lake were referred to as the Spring run. Subsequently, the data associated with the two early runs ('Spring' and 'Summer') were examined and no differences between the two spawning populations were found so the 'Spring' spawning area was included in the Summer run Chinook Conservation Unit (DFO 2023).

Abstract

The British Columbia Conservation Foundation (BCCF) and the Nanaimo River Stewardship Society (NRSS) were contracted by Fisheries and Oceans Canada, South Coast Area Salmon Stock Assessment to complete a brief field program to investigate relative abundances of three known ecotypes of Chinook salmon (*Oncorhynchus tshawytscha*) juveniles at various locations on the Nanaimo River, B.C. The main intent of the project was to compare these findings from a similar study conducted in Cowichan River during 2014. Between April 26 and June 7, 2018, juvenile Chinook salmon in the Nanaimo River were enumerated and sampled at approximately three week intervals by snorkel crews to investigate distribution and habitat use, and collect baseline data on size-at-age and genetic samples. Surveys

[20] British Columbia Conservation Foundation, 105 – 1885 Boxwood Road, Nanaimo, BC, V9S 5X9

occurred at six representative index sites, typically consisting of a single stream edge 30 m in length, established in the upper (n = 1), middle (n = 2), lower river (n = 2), and tidally-influenced (n = 1) locations. In addition, fish lengths and DNA samples were taken from a subsample of individuals. These preliminary results suggest that few fish rear above Second Lake. Most juveniles were detected downstream of First Lake, near known summer run spawning areas. Lower river sites exhibited variable use by juvenile Chinook salmon and we observed relatively low abundances at the sites located lowest in the watershed, especially earlier in the spring. Length data suggest Nanaimo River Chinook salmon are consistently smaller than Cowichan River for a given date. Consistent with other recent studies, Nanaimo River Chinook salmon prefer river margin habitat with intact instream/overhead vegetation, especially when newly emerged, and move into faster currents as they grow. Based on previously identified spawning locations of the ecotypes, our data also suggest that the summer run Chinook are first to emerge, perhaps due to an earlier average spawn timing or shorter incubation when compared to fall-run (lower river) Chinook. In 2018, overall peak instream juvenile abundance occurred in May, with some fish remaining in the river into June. We successfully tracked relative abundance of Chinook juveniles over time at six sites, likely observing fry from all three ecotypes found in the system. Future DNA analysis will help confirm stream use areas for different ecotypes.

Background/Introduction

In March 2018, the British Columbia Conservation Foundation and Nanaimo River Stewardship Society were retained by Fisheries and Oceans Canada, South Coast Area Salmon Stock Assessment to investigate relative abundance, habitat use preferences, and the spatial distribution of juvenile Chinook salmon in the Nanaimo River.

The Nanaimo River supports at least three Chinook salmon ecotypes; spring, summer, and fall run, that are thought to use different areas of the watershed (MOELP 1993, Carl and Healey 1984). Spring-run Chinook salmon enter the Nanaimo River from December to February, hold in canyon pools or one of the large lakes until fall and spawn upstream of Second Lake to Sadie Creek (Hardie 2002). Most spring-run fry are thought to be stream type, for an additional year before out-migrating to the ocean. Summer run Chinook salmon also enter the system as early as February, and typically hold in First Lake and South Fork junction pool prior to spawning in the river between the First Lake outlet and Wolf Creek confluence in early October (Healey and Jordan 1982). Fall-run Chinook salmon, typically the most abundant of the eco-types, enter the river in August/September and spawn in October between the Bore Hole/Lower Canyon and the Cedar Road Bridge (Hardie 2002). Spring run stocks are severely depressed (Watson 2015), perhaps to functional extinction; additional information on critical habitats and limiting factors will assist with management efforts.

While adult life histories and spawning habitat use are relatively well understood in the Nanaimo River, little is currently known about juvenile rearing requirements or factors that may be influencing their abundance and distribution in freshwater. Recent work on the Cowichan River, which drains a similar land base (939 km^2) documented habitat use and relative abundance of juvenile Chinook by snorkeling stream margins at night during the spring (Craig, 2015). Expanding this work to the neighboring Nanaimo River watershed will advance our understanding of critical habitats at a local scale and relative to the Cowichan River, one of the largest producers of Chinook salmon on the East Coast of Vancouver Island.

The Nanaimo River Hatchery (NRH) conducts a limited enhancement project on the lower river for summer run and fall run Chinook stocks. The program currently produces 450,000 fall run and 200,000 summer run fry annually[21].

Primary objectives of this study were to:

- Determine relative abundance, spatial distribution and size of Chinook fry across survey sites in the Nanaimo River;
- Collect biological data (length and DNA) from fish at all surveyed sites to confirm spatial distributions of various ecotypes; and
- Identify possible limiting factors to Chinook production by comparing these results to the neighboring Cowichan River with a similar watershed area and mean annual discharge.

Study Area

The Nanaimo River flows into its estuary on the east coast of Vancouver Island, British Columbia, just south of the city of Nanaimo and approximately 80 km north of Victoria (Figure 39). The Nanaimo River is approximately 56 km long and drains a 830 km2 watershed, which includes four small lakes, and two storage reservoirs (Hop Wo et al. 2005). Our survey sites were distributed so as to sample juveniles from each of the three Chinook salmon ecotypes previously identified in the Nanaimo River. The site aimed at enumerating spring-run Chinook salmon juveniles is located upstream of Second Lake 'Upper Nanaimo'; sites targeted for enumerating/sampling summer run juveniles are located at Wolf Creek and

Figure 39. Map of the Nanaimo River watershed (study area) with approximate sampling locations in red.

[21] B. Banks, Nanaimo River Hatchery, 2775 Rugby Road, Nanaimo, BC, V9X 1T2, pers. comm.

Borehole and targeted fall-run Chinook salmon sites are located at "Pumphouse" and "TLC" (Table 14, Figures 40 and 41). It is noted that fry from more than one ecotype may overlap at some sites, especially the Borehole site, which may contain summer and fall run progeny (fry) depending on passage conditions in a given year or mixing of juveniles from different spawning areas.

Table 14. Summary of site locations selected for juvenile Chinook use study on the Nanaimo River, spring 2018

Site Name	UTM Coordinates (Zone 10 U)		Ecotype(s) expected
Upper Nanaimo	408090.22 m E	5437924.74 m N	Spring
Wolf Creek	418717.92 m E	5438202.71 m N	Summer
Bore Hole	433804.52 m E	5435871.81 m N	Summer/Fall
Pumphouse	435889.35 m E	5435843.91 m N	Fall
TLC Park	436440.73 m E	5436969.71 m N	Fall
Raines Rock	435734.53 m E	5441177.23 m N	Unknown

Figure 40. Upper Nanaimo and Wolf Creek Survey index sites in the upper Nanaimo River watershed, locations relative (yellow) to First and Second Lakes.

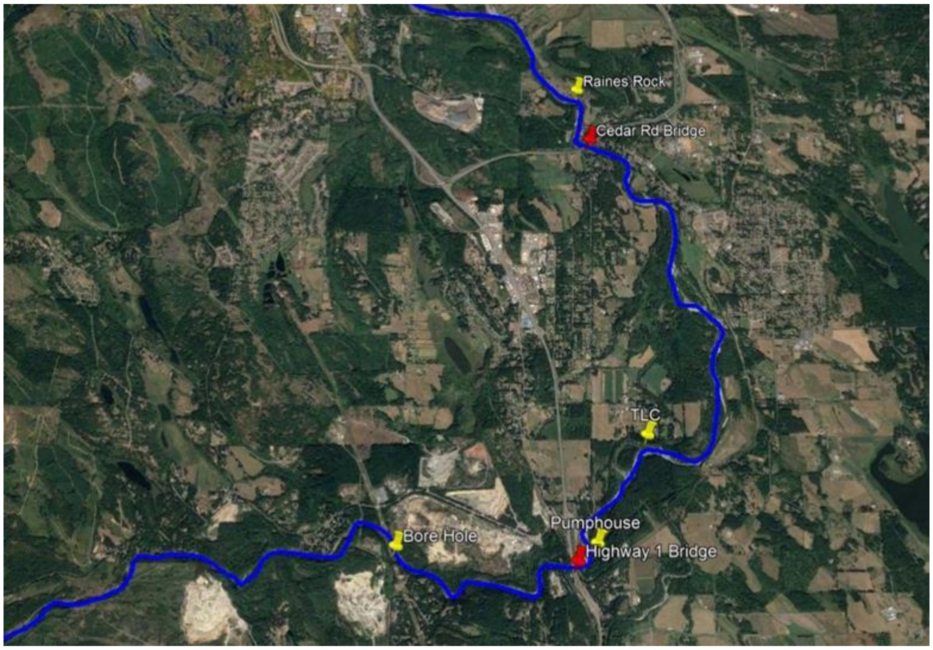


Figure 41. Survey index sites (yellow) located on the lower Nanaimo River relative to known features (bridges, red).

Methods

During initial daytime reconnaissance in March, crews (BCCF and NRH staff) identified and marked suitable index sites in each area. Index sites consisted of a 30 m length of stream edge habitat (i.e., one bank only), with upstream and downstream extents marked with flagging tape. Seasonal high flows and logistics meant that the bank on which an index site was located was dictated by road and trail access – few night time river crossings were possible.

A total of six index sites (Figures 40 and 41, Appendix H) were surveyed three times over the April 26 to June 7 study period. Sites, typically consisting of a single stream edge 30 m in length, were established in the upper river above Second Lake 'Upper Nanaimo', middle 'Wolf Creek' and ' Bore Hole, lower river 'Pumphouse' and 'TLC', and tidally influenced 'Raines Rock' locations. Efforts were made to select sites that were physically similar to those used in Craig (2015) in order to provide some comparison between the Cowichan and Nanaimo Rivers. This included sites with instream or overhanging vegetation and typically in glide/run type habitat.

The majority of observations and sampling occurred in darkness, between one and six hours after sunset. Generally, two groups of 2-3 experienced, Swiftwater-certified personnel conducted the surveys and sampling. The first crew covered upper and middle river index sites (Figure 40). A second crew completed lower mainstem index sites (Figure 41). Crews at each site were generally comprised of the same personnel to standardize observer efficiency between surveys.

Fry Abundance

Methods used for nighttime snorkeling were in line with Craig (2015), and included two snorkelers swimming into the flow if possible (often in an upstream direction), side by side using dive lights. Salmonid juveniles were enumerated by species and size class (with focus on Chinook), plus non-salmonids as encountered.

Fish beyond the limits of observation, i.e., due to transparency or obstruction (e.g., thick instream vegetation or LWD), were not enumerated. Water clarity, to the nearest half meter, was estimated and recorded for each survey. Notes were also made of habitat or water velocity preferences of Chinook fry at each site and included proximity to shore, vegetation or other instream cover.

Fry Sampling

Once snorkel counts were completed, crews used dip nets or pole seines to capture a representative sample of salmonids at the site. Depending on the site, either small hand dip nets (aquarium style), or a two-person pole seine 3.6 m wide by 1.4 m high with 5 mm knotless mesh were used for fish capture. Typically, a two person crew in dry suits used headlamps and bank-mounted flashlights to seine a manageable portion of the index site that contained concentrations of Chinook salmon juveniles. If needed, crews would capture Chinook salmon in areas adjacent to the survey site to increase catch numbers.

All species captured were counted. All Chinook salmon were briefly anaesthetized using a buffered tricaine methanesulfonate (MS-222) bath, counted, examined for condition, marks, or fin clips and measured for fork lengths using a 300 mm length board. In addition, during the first two site visits at each location, a target of 30 fish were caudal clipped with the tissue placed on Whatman sheets (provided by DFO) for future genetic analysis. Examples of the catch were occasionally photographed (Photo 13).

Results

Fry Abundance

The upper-most site, “Upper Nanaimo” exhibited the fewest fry across all sites, with a peak count of seven Chinook salmon observed. The two sites with the most fish were “Wolf Creek” and “Bore hole” with peak counts of 200 and 178 fish, respectively. We observed no Chinook salmon at “Raines Rock”, the site located lowest in the basin, and “Upper Nanaimo” the uppermost site in the basin, on the first survey, April 26, but detected a relatively small number of Chinook salmon at each of these sites during later surveys (Table 15, Figure 42). Over time, peak Chinook abundance occurred at most sites on the second survey on May 15, and decreased soon after with the exception of ‘Raines Rock’, having a maximum abundance observed on the last survey, June 7. Coho abundance increased over time at all sites where they were observed. Coho were not observed at any sites above the lower canyon (Bore Hole). Chum were more abundant in the lowest site (Raines Rock) during the first survey, decreasing over time. Similar to Coho, Chum were only observed in the locations downstream of the Lower Canyon.

Table 15. Summary of juvenile salmonid observations during night time snorkel surveys at various locations on the Nanaimo River, during April, May, and June 2018.

Site	Date	Chinook	Coho	RB (juv)	Chum
Upper Nanaimo	April 26, 2018	0	0	0	0
	May 15, 2018	7	0	9	0
	June 7, 2018	7	0	0	0
Wolf Creek	April 26, 2018	183	0		0
	May 15, 2018	200	0	2	0
	June 7, 2018	47	0	0	0
Bore Hole	April 26, 2018	97	17	0	1
	May 15, 2018	178	94	0	0
	June 7, 2018	3	130	0	
Pumphouse	April 26, 2018	8	0	6	37
	May 15, 2018	71	16	15	3
	June 7, 2018	36	390	13	0
TLC Regional Park	April 26, 2018	8	0	2	23
	May 15, 2018	30	9	12	0
	June 7, 2018	2	151	9	0
Raines Rock	April 26, 2018	0	0	0	450
	May 15, 2018	13	36	0	20
	June 7, 2018	27	48	6	0

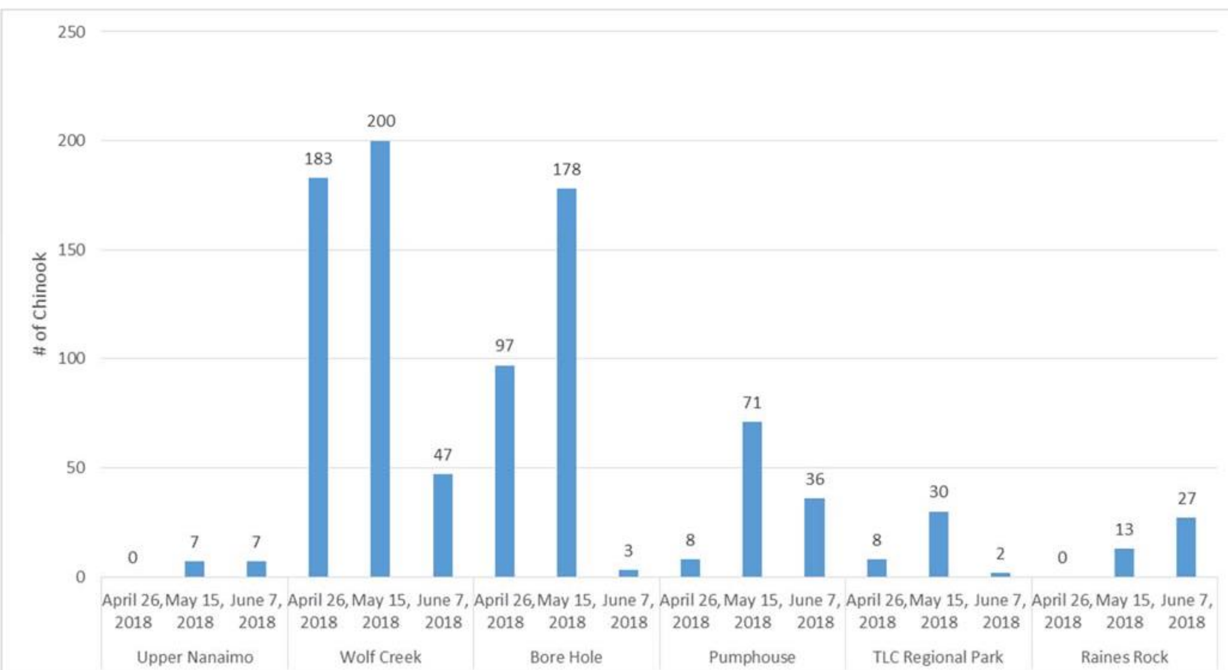


Figure 42. Juvenile Chinook salmon counts within a 30 m index site at various locations on the Nanaimo River. 2018

Fry Sampling

Tissue samples were collected from a total of 229 juvenile Chinook salmon. Only nine and 20 samples were collected from the Raines Rock and Upper Nanaimo sites, respectively, due to low fish abundances at these sites (Table 15). With exception of the upper Nanaimo site, no tissue samples were collected on the June 7 (last) survey as it was suspected that downstream fish movement may result in fish mixing from upper locations. Length data, however, were collected on all survey days (Figure 40).

Chinook salmon lengths increased over time with the exception of Wolf Creek, where the June 7 average length was lower than that observed on May 15th; however, not significant at the 95% CI. Across sites, average fork lengths during the April 26 survey ranged from 39-43 mm increasing to 47 to 62 mm on June 7 (Table 16).

Table 16. Average length and associated 95% confidence intervals (CI) of juvenile Chinook salmon sampled from multiple locations on the Nanaimo River, 2018.

Site	Date	Fork Length (mm)	95% CI
Upper Nanaimo	April 26, 2018	NA	NA
	May 15, 2018	42.6	1.0
	June 7, 2018	48.2	3.7
Wolf Creek	April 26, 2018	43.4	1.2
	May 15, 2018	53.2	6.3
	June 7, 2018	47.5	1.7
Bore Hole	April 26, 2018	41.1	1.2
	May 15, 2018	45.6	1.8
	June 7, 2018	62.0	2.6
Pumphouse	April 26, 2018	39.3	0.7
	May 15, 2018	46.8	1.4
	June 7, 2018	53.2	2.3
TLC Regional Park	April 26, 2018	40.4	0.6
	May 15, 2018	48.2	1.5
	June 7, 2018	NA	NA
Raines Rock	April 26, 2018	41.0	NA
	May 15, 2018	54.1	1.9
	June 7, 2018	58.8	2.3

Stream Discharge

Stream discharge, as reported by the Water Survey Canada (WSC) station on the lower Nanaimo River generally trended down over the study period as shown in Figure 43. Flows over the course of the study were similar on the April 26 and May 15 surveys at approximately 26 cubic meters per second (m^3/s). The June 7 survey flows were considerably lower, at around 8 m^3/s.

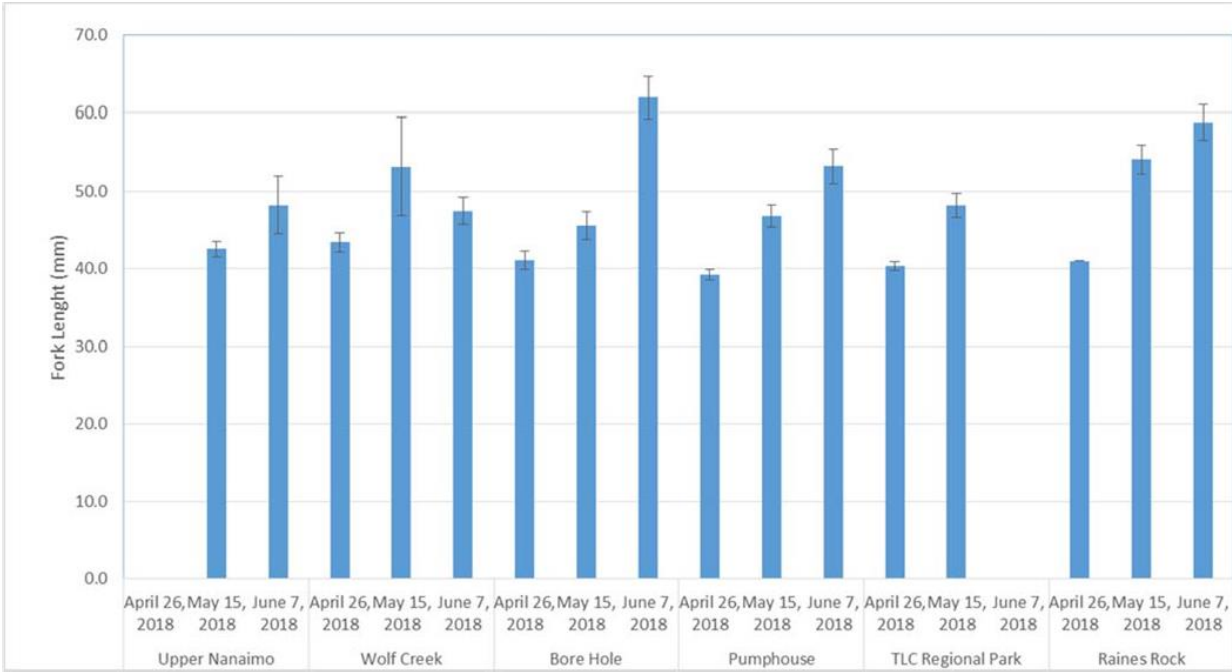


Figure 43. Average length data from sampled juvenile Chinook at various locations on the Nanaimo River, 2018. Error bars represent 95% CI.

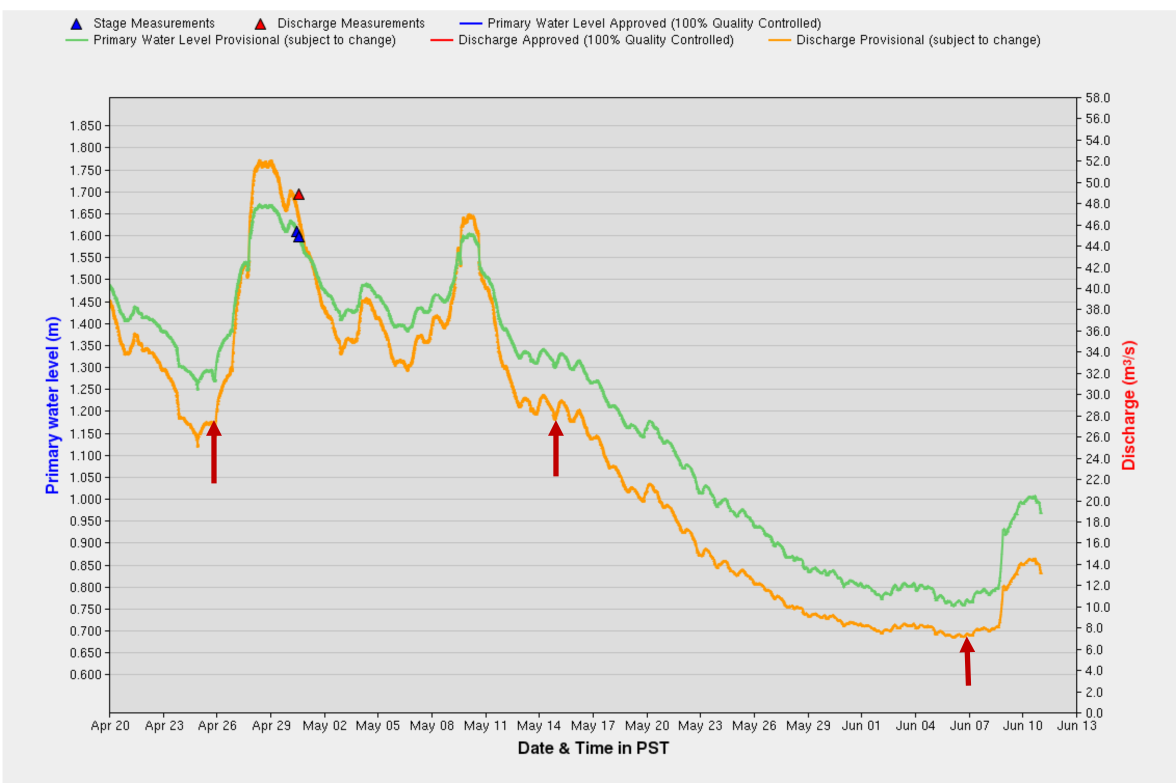


Figure 44. Stream stage and discharge for the lower Nanaimo River over the study period (WSC 2018). Red arrows depict survey dates.

Discussion/Recommendations

In this pilot study, we documented the relative abundance of Chinook salmon fry at survey sites distributed throughout the Nanaimo River. The 'Upper Nanaimo' site, anticipated as being associated with a spring-run Chinook salmon ecotype exhibited the fewest fish across sites. This finding is unsurprising given that habitat impacts in the upper Nanaimo River have depressed the spring-run ecotype's abundance in recent years. It is also possible that some summer run Chinook salmon migrated above Second Lake and that the detected upriver fry are of summer run origin. This uncertainty may be resolved through future population genetic analysis of the juveniles sampled during our surveys.

The 'Wolf Creek' site contained relatively high densities of fry, which we speculate are the progeny of summer run fish, many of which spawn in the area adjacent to and immediately upstream of the survey location. Peak residence of fry appears to be between May 15 and June 7 surveys at most sites, with the exception of the most upstream and downstream sites. A later emergence at the 'Upper Nanaimo' site can be a result of lower water temperatures in the upper watershed over the incubation period. The 'Raines Rock' site, located in the tidally influenced portion of the river may only hold fish that were displaced from spawning sites located upstream, explaining the later timing of residence there. The increase in abundance between the April 16 and May 15 survey is likely a result of fish emergence between survey dates. In contrast, the decline between the May 15 and June survey is a result of downstream out-migration (smolting). To better define peak abundance, it is recommended that weekly surveys be conducted over a similar study period.

When comparing fry densities from this study to results in the Cowichan River in 2014 (Craig 2015), it is apparent that the Nanaimo River mainstem habitat holds Chinook at only a fraction of the density. Using a direct comparison, fry per lineal meter (FPM), Cowichan River mainstem habitats peaked at between 13.6 and 60.3 FPM, compared to peak FPM of between 0.23 and 6.6 for Nanaimo River sites, an approximate 10 fold difference. This may be a result of under saturation of habitat in the Nanaimo River as a result of fry abundance being limiting, or conversely the habitat in Nanaimo is far less productive, and therefore limiting the fry production.

Fry size appears to be smaller, when compared to Cowichan River Chinook salmon, with average lengths of under 50 mm at most sites on the May 15 sampling day, compared to 65.2 +/- 1.2 mm (n=161) at the lower Cowichan River on May 17 2018[22]. This small size is consistent with previous studies completed on the Nanaimo River, wherein average lengths from rotary screw-trapped out-migrating Chinook salmon fry of approximately 42 mm on May 22, 1999 (Nagtegaal and Carter 2000). Differences in fry size between Nanaimo and Cowichan River may be a result of differences in productivity (as a result of habitat quality, prey abundance, temperature and/or water chemistry).

As seen in Cowichan, during early surveys with the smallest fry, most of the Chinook observed were close to, or directly associated with instream small woody debris or shallow margin habitat with slow to zero velocities (Photo 14). During the late survey there was a higher proportion of fish, typically in a slightly larger size class, observed more towards the thalweg in relatively fast water, consistent with findings from the Cowichan (Craig 2015).

[22] British Columbia Conservation Foundation, 105 – 1885 Boxwood Road, Nanaimo, BC, V9S 5X9, unpublished data

Three fish were recaptured in subsequent sampling events (determined by the clipped caudal fin) suggesting site residence times may exceed one month for individual fry at a given site. It is highly unlikely that, given the number of fish sampled, we would recapture a caudal clipped in a downstream site. In addition, these data are consistent with findings in Craig (2015), with tagged fish observed in the same location over a number of weeks in the upper Cowichan River. Increased survey frequency (weekly) in conjunction with a simple tagging program will assist in quantifying freshwater residence time across river sections.

If this study is repeated, it is recommended that a visual tagging portion be completed to help quantify residence time. This could include the use of visual elastomer implant (VIE) tags, which are easily detectible by night snorkeling crews. PIT tags could also be employed in conjunction with VIE tagging to achieve individual fish growth over time; however, given the average size of Nanaimo River Chinook observed during this study was below the tagging threshold for 12 mm tags (~60 mm) PIT tags may be challenging until later in the season.

Given the limited duration and scope of this project it is difficult to derive conclusions about limiting factors for Chinook salmon in the Nanaimo River; however, some insights into fry habitat saturation were gained. When comparing Nanaimo River fry densities with that of Cowichan River (Craig 2015), it appears unlikely that the limiting factor to Nanaimo River Chinook production is currently suitable fry habitat, given that maximum fry densities in physically similar sites Cowichan were nearly 10x higher. This is especially true for the 'Upper Nanaimo' site where extremely low fry densities were observed; however this may be a result of a longer incubation period due to colder waters in the upper watershed. Inspections in the upper watershed later into the season (September) may provide some insight into the presence of fry/parr that may swim-up later than anticipated.

Without a more in-depth (broad scale) habitat assessment, with focus on suitable Chinook fry habitat current limiting factors are difficult to conclude. A habitat assessment could include walking or, perhaps more conveniently, drifting sections of the river at low flows and conducting a detailed habitat assessment, to classify and eventually quantify the amount of suitable Chinook fry habitat.

Also noted is the fact that few, if any, early fry were observed in the Raines Rock pool located in the upper portion of the tidally influenced area of the river. Craig (2015) postulated that as habitat in the upper and middle portions of Cowichan River became saturated with emerging fry, they become displaced downstream, inhabiting most stream edges right into the estuary. Upriver saturation does not appear to be occurring in the Nanaimo River as few fish were observed at the lower river Raines Rock site until the last survey on June 7, presumably as they were actively out-migrating to the ocean. Otolith microchemistry may be employed to determine the importance of the estuary as a rearing area for Nanaimo River Chinook, in addition to estimating a size at ocean entry. This may also provide some insight into the proportion of yearling Chinook migrating to the ocean in fall or even the following spring as is thought to be the case for the spring run portion.

Chinook salmon production constraints within the Nanaimo River may include a lack of suitable spawning habitat, overall stream productivity (as a result of water chemistry), downstream survival of fry/overall fry abundance, poor estuary conditions, hatchery effects, poor ocean survivals, and fishery exploitation. A combination of factors appears to be resulting in relatively low adult abundance when compared to the Cowichan.

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Appendix H: Photographic record of sites surveyed for Chinook salmon juveniles during 2018 on the Nanaimo River

<table>
<tr><td></td><td></td></tr>
<tr><td>Photo 1. Upper Nanaimo survey site, looking downstream, April 2018.</td><td>Photo 2. TLC Park survey site, looking downstream, April 2018.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Photo 3. TLC Park survey site, looking upstream, April 2018.</td><td>Photo 4. Wolf Creek survey site, looking upstream, April 2018.</td></tr>
</table>

Photo 5. Wolf Creek survey site, looking downstream, April 2018.

Photo 6. Borehole survey site, looking upstream, November 2018.

Photo 7. Borehole survey site, looking downstream, November 2018.

Photo 8. Pumphouse survey site, looking upstream, November 2018.

Photo 9. Pumphouse survey site, looking downstream, November 2018.	Photo 10. Raines Rock survey site, looking upstream, November 2018.
	
Photo 11. Raines Rock survey site, looking downstream, November 2018	Photo 12. Instream woody debris within Borehole survey site, November 2018.
	
Photo 13. Typical Chinook fry observed in the Nanaimo River, May 15 2018.	Photo 14. Chinook (and Coho) using near shore habitat with instream vegetation

Estuary habitat use by juvenile Chinook Salmon

Steve Baillie[23], Karalea Filipovic, Nicolette Watson, Christina Czembor and Julian Gan[24]

Introduction

River estuaries are critical habitat in the life history of fish species that use both fresh and marine water during their life cycle, especially Pacific Salmon. Juvenile salmon use this habitat to acclimatize to marine waters, and feed until they reach an appropriate size.

When in freshwater, the fish's body absorbs and retains water, so their kidney must expel excess fluids while retaining salts. When in marine water, the reverse occurs, and the fish's body loses water and their kidney must retain fluids and expel excess salts (Bell 1996). The transition of the kidneys from one process to the other occurs within the estuary habitat (called smolting in the juvenile life stage). Similarly, when the adult salmon returns to fresh water to spawn and complete its life cycle, it must reverse this transition.

This process that takes place in estuaries underlines the importance of this area to the life history of salmon. All salmon that transit through estuaries must remain for variable lengths of time in this habitat, therefore estuaries must have appropriate conditions such as high water quality, adequate food supply, refuge areas from predators and no barriers to movement. Healey (1991) found that some Chinook fry were able to tolerate brackish and full saline environments when introduced to sea water, suggesting that they were able to transit prior to entering the estuary. Three different juvenile life history types were noted: Immediate, Delayed and Yearling migrants.

Healey also found in the Nanaimo Estuary the Immediate migrant Chinook fry would remain in the estuary until they had grown to ~70 mm in length. Yearling Chinook smolts that migrate at the same time as the Immediate migrants either remained temporarily in the outer part of the estuary, or transited through and out to open marine waters. Delayed migrant fry arrive when the Immediate migrants have left and remain in the estuary area until they have had sufficient growth.

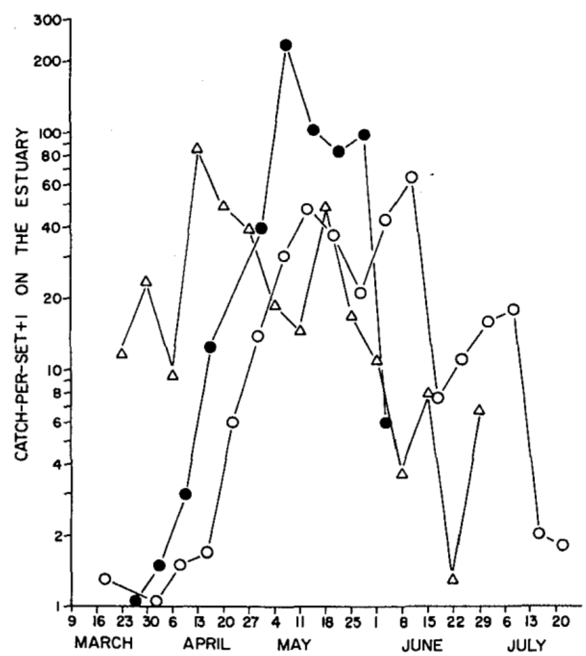

Figure 45. Catch of Chinook fry per beach seine set at Stations 28-30 on the Nanaimo River Estuary in 1975 (dots), 1976 (circles) and 1977 (triangles). Original figure from Healey (1980).

Healey conducted his research and data collection in the Nanaimo River Estuary in 1975 to 1977 (Figure 45). One aspect of his sampling program

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[24] Salmon Watersheds Lab, Earth to Ocean Research Group, Simon Fraser University, 8888 University Drive, Burnaby, BC, V5A 1S6

was to establish when and which areas of the intertidal estuary are being utilized by Chinook salmon juveniles. Healey found that the date when juvenile Chinook appeared in the estuary was variable between years, ranging from prior to mid-March (1977) to late March/early April (1975, 1976). The number of Chinook juveniles present would increase to a peak from late April to late May, then decrease until late July.

Healey divided the beach seine sites in the estuary into two areas, Area 18 (upper tidal area and upper reaches of the west channel) and Area 19 (east arm of river and the Holden Creek channel, later referred to as Stations 28-30). Descriptions are found in Schmidt et al. 1978. It is unclear whether the sample sites located on the west side near the Snuneymuxw First Nation community are included in the Area 18. Healey 1980 states that *Catches in the stream channels in the center of the mud flat averaged only two fish* [sic] */set, and on the west side of the delta only one chinook salmon was captured in eight sets*. This contrasts with the data report on this work (Schmidt et al. 1978) that reports a total of 121 sets in Area 18, averaging 10.8 Chinook fry/set. This contradiction suggests that Healey (1980) was referring to a subset of sample sites that is not defined in the document.

The purpose of this study is to examine the extent of distribution of juvenile Chinook salmon in the Nanaimo River Estuary and compare it to the results from the 1970's.

Methods

Three different assessment projects were conducted in the estuary in 2021 which contributed to this study (Table 17, Figure 43).

Table 17. Sampling dates for Chinook juveniles in the Nanaimo River Estuary, 2021.

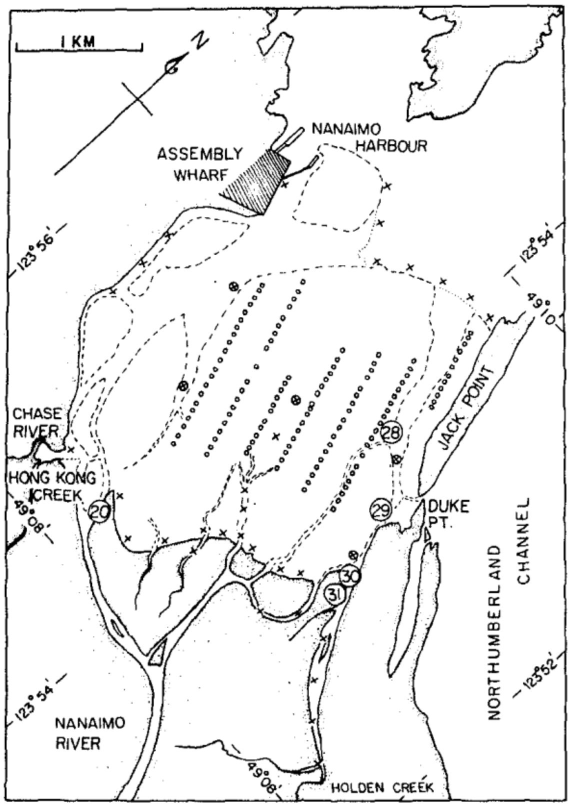
Beach Seine	Pole Seine	Fyke Trap
n/a	n/a	23-Mar-2021
n/a	n/a	6-Apr-2021
7-Apr-2021	n/a	n/a
n/a	n/a	15/16-Apr-2021
n/a	n/a	26/27-Apr-2021
6-May-2021	n/a	n/a
n/a	7-May-2021	n/a
n/a	n/a	10/11-May-2021
n/a	n/a	25/26-May-2021
7-Jun-2021	n/a	n/a
n/a	8-Jun-2021	n/a
n/a	n/a	9/10-Jun-2021

Beach Seine

Fisheries and Oceans Canada (Stock Assessment) and Snuneymuxw First Nation collaborated on an assessment of the mid to lower area of the estuary. The intention was to use methods and sample locations similar to those used by the work conducted in the mid-1970's by Healey.

The current sampling was conducted along the shoreline and tidal channels in similar locations to the earlier work. The beach seine was longer, 50 m in length with a center width of 4 m, tapering down to 2 m on the ends. Mesh size was 6mm in the center section and 12 mm along the wings, finer than Healey. Sampling was done during the flooding part of the tidal cycle, starting at the outermost sites and finishing at the highest sites at the high tide level.

We established two sites in the vicinity of the previous study (Healey 1980) and added a novel site at the tip of Jack point. Along the west side, we established four sites from the delta front upstream to the west side channel (Sandy Point, SFN #1, Haliburton and Living Forest) (Figure 46). Sets were made using



The Nanaimo River estuary. Vancouver Island, **showing the location of the fry traps (20) for juvenile chinook salmon; the stations sampled weekly on the east arm of the river and Holden Creek, (28), (29), (30), (31); the general location of seine sets made to determine the distribution of chinook salmon fry in the estuary, ×; and the location of purse seine sets made over the intertidal flats at high tide, ⊗. Small circles show the location of pilings to which log rafts are moored. Most raft storage is on the west side.**

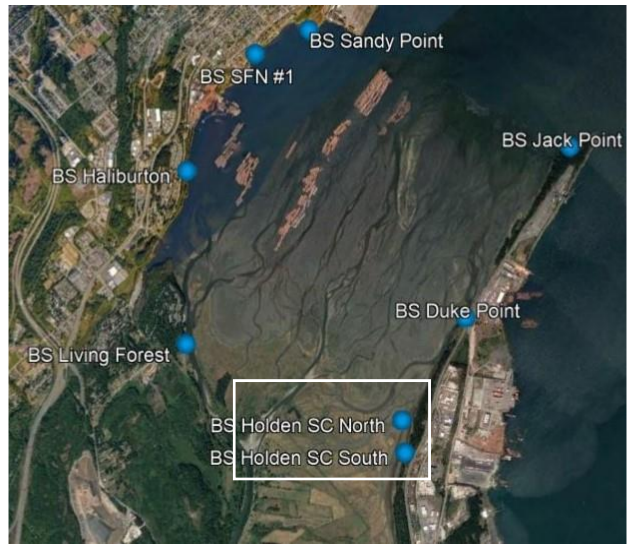


Figure 46. The map and caption on the left shows the sampling locations from the 1970's (Healey 1980). Above is a Google Earth map at approximately the same scale and orientation showing the sampling locations in 2021. The white rectangle is the area in the lower figure. Blue dots denote Beach Seine sites, Green dots are Fyke Trap locations and red dots are Pole Seine sites.

the herring skiff along an exposed shoreline and the net was hand pulled to shore. We conducted monthly surveys from April to June during 2021.

Fyke Trap

The Nature Trust, Fisheries and Oceans Canada (Resource Restoration Unit) and Snuneymuxw First Nation, as part of a berm removal project, monitored fish presence in two dendritic channels in the mid-tidal area using two-way fyke traps. Each trap has a funnel entrance on each end so that fish moving in either direction will be caught and retained in separate compartments. Each end of the trap was attached to stopnets that guided fish to the entrance of the trap. The traps were located in a pool within each channel so that the water levels were sufficient for keeping the trapped fish alive in the low water period of the tidal cycle. The traps were left to soak initially for 3 to 4 hours (23-March and 6-April), after which the trapping period was extended to 20 hours.

Pole Seine

Julian Gan, an M.Sc. student from the Simon Fraser University, was monitoring salmon populations across a number of estuaries on Vancouver Island, including the Nanaimo River Estuary mid tidal area using a pole seine. Sampling was conducted during the low tidal cycle and similar effort and number of sets were used on each sampling trip. Two sampling dates were used, 7-May and 8-June 2021. Sites were selected to cover a variety of substrate (silt, sand, gravel, cobble) and habitat (marsh, beach, meadow) types. The seine net is 33 m long by 2.4 m high, with 0.6 cm mesh and has a 2 m pole on either end.

Although the catches and Catch Per Unit Effort (CPUE) from the three methods are not directly comparable, the data does provide information on the extent of the presence of Chinook juveniles in the estuary.

Results

Beach Seining

The results from 2021 are shown in Appendix I and summarized in Figure 47 which also shows the number of Chinook fry caught per beach seine set from Healey's work in the 1970's. Peak Chinook fry catches occurred in early June which is similar to the timing of counts in the 1970's. The striking

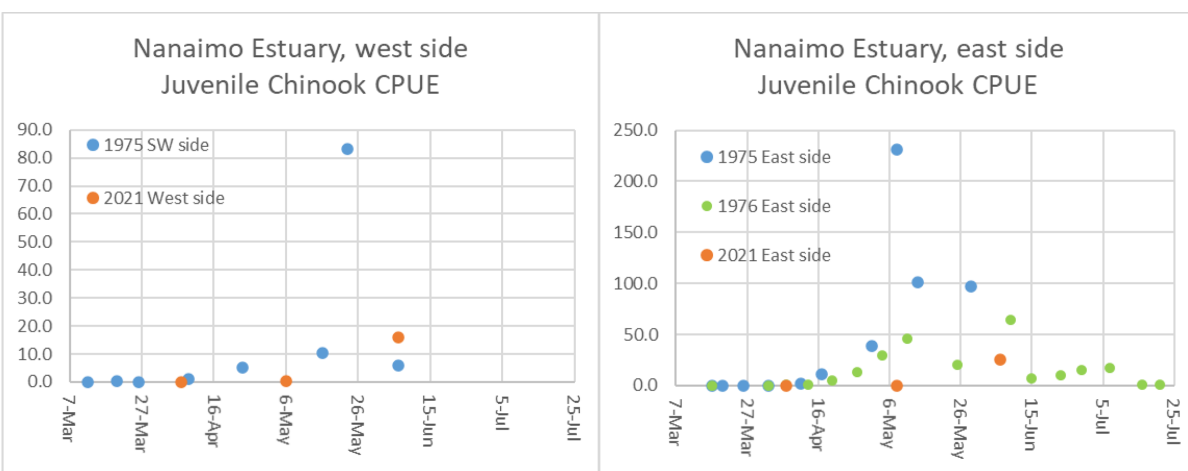


Figure 47. Catches of Chinook fry per beach seine set, Nanaimo River Estuary.

observation from the data is that catches of Chinook fry in the estuary are much lower in 2021 compared to the 1970's in the early time of the sampling period.

The number of spawners that produced the fry in both the 1974 (2400 spawners – all runs) and 1975 (525 spawners – all runs) are less than the 2020 escapement (2970 Fall run and 634 Summer run spawners) so the number of fry present should be similar or greater for both data sets under identical fishing conditions and effort.

Fyke Traps

Healey conducted several beach seine sets in tidal channels in the vegetated habitat in addition to the lower open channels in the lower tidal area. These were conducted in March and April 1975 but were not continued in May, or in subsequent years. This sampling was used to examine what habitats were used by Chinook fry and the discontinuance in these sites suggests poor or nil catches. Specific information about set catches by location is not available. We repeated this sampling effort using a stationary fyke net (Figure 48).

Figure 48. Fyke Trap deployed in dendritic channel, Nanaimo River Estuary.

The results from the fyke traps are shown in Appendix J. Catches of Chinook fry were low with the highest catch in late May and zero catch in early June. The presence of salmonid fry shows that this habitat is being used for rearing, albeit at a low level.

Comparisons of salmonid catches to the work in the 1970s is not possible due to differences in sampling methodology and lack of documentation on the earlier work.

Pole Seine

Catch results are shown in Appendix K. On the first sampling day, 7-May, 36 Chinook were captured at site NAN-08 which is the mid-tidal channel that moves water from the main channel, eastward, to the Holden Creek channel. An additional 2 Chinook were captured at site NAN-12 which is a back channel on the mainstem. On the second sampling day, 8-June, 2 Chinook were captured at NAN-08, and one at site NAN-14 which is in the main central channel. All other sampling efforts resulted in zero Chinook fry caught.

Discussion

The catches of Chinook fry by beach seine were much lower than the previous work, especially early in the season, and more evenly distributed between east and west sides of the estuary. There are several possible explanations for these observations which may include one, or a combination, of the following:

1. The Chinook fry occupy different areas in the estuary during different stages of the tidal cycle
2. Estuary habitat has changed and Chinook fry are not residing in the same locations
3. Chinook progeny are not surviving at the same rate prior to smolting

Hypothesis #1: Healey (1991) notes that during high tides, Chinook fry reside in scattered areas along the edges of marshes and when the water level drops to low tide, the fry retreat to tidal channels throughout the estuary. Since the 2021 work was conducted during high tides the Chinook fry may have been too scattered to attain high catch numbers observed in the 1970's. Seining was not conducted during the low tide period due to the difficulty in accessing the sample locations by boat. Changing the sampling to a low tide timing may provide additional information to address this hypothesis.

Hypothesis #2: Since the mid 1970's number of physical changes have occurred in the estuary. The Duke Point Industrial Park along the east side of the estuary was built in 1980-1983. Although a riparian strip was left alongside the estuary, a tidal channel (Canoe Pass) that connected the estuary with Northumberland Channel to the east was filled in and no longer exists. In addition, the Log Storage leases that spanned the outer section of the estuary (peak lease area was 638.68 hectares in 1972) have declined to 247.1 hectares by 2017, with the remaining leases located on the western side of the estuary. Additionally, the bifurcation in the river at the end of Raines Road has changed. The central channel that provides flow to the center and east side of the estuary has been subject to gravel accumulation which, at low tide, diverts more water flow to the west channel and through there to the west side of the estuary.

Hypothesis #3: can be assessed monitoring the downstream movement of Chinook fry to compare to previous data to separate the possible change in egg to fry survival and changes related to hypothesis #1 and #2.

Catch totals of Chinook fry were less in 2021 than the 1970's despite higher abundance of spawners. Uncertainties originating from sample timing during the tidal cycle, egg to fry survival and changing habitat require additional field work in order to improve the comparison to earlier results. The presence of Chinook fry on both east and west sides of the estuary suggest that both areas are used by Chinook fry in 2021.

The detection of salmonid juveniles in the fyke sampling project show that the dendritic channels were used by these species as rearing habitat in the period immediately after restoration of the intertidal marshes. This project will be repeated in future years to assess the progress of this restoration. The physical changes in this area include removal of berms and dykes that were created in the early 1900s to convert tidal marshes into agricultural fields (DFO 2020). These berms focused the movement of tidal water into small channels. By removing the berms, the whole salt marsh area is subject to overland tidal flooding so that a return to a tidal marsh habitat can be achieved.

Although very few Chinook juveniles were captured in pole seine, their presence indicated that the channels in the mid to upper estuary area are being used by these fish, similar to the results of the fyke net trap.

Healey (1980) concluded that Chinook fry distribution in the Nanaimo River Estuary varied with the tidal cycle, likely in response to changing salinities and water temperature. During low tide Chinook fry were more abundant along the channel on the east side of the estuary, less abundant in the channels along the mid levels of the estuary and the delta front, and very scarce along the channels on the west side of the estuary. At higher tidal levels Chinook fry were dispersed across the flooded estuarine area along the landward margins, but not in the open intertidal flats. Catch sizes were low in March, peaked in April to early June, depending on which year, and dropped in mid-June.

Sampling in 2021 was conducted both at high tide (beach seine), low tide (pole seine) and through a 24 hour period that encompassed a diurnal tidal cycle (fyke trap). Beach seine catches in June were relatively even between the east side and west side sites, in contrast to the earlier work. Catch sizes were low in April and May, and increased in the June samples but were generally lower in abundance than the earlier work.

Healey did not sample in the saltwater marsh channels where the fyke net and pole seine sampling occurred so no direct comparisons can be made.

Conclusions

Chinook fry were much less abundant during the early (April-May) smolt migration period, which suggests that immediate migrant Chinook fry that make up a large component of the populations at this time may be less abundant. Recent adult escapement estimates are similar to earlier periods suggesting that the spawning habitat for both Summer and Fall runs may have degraded since the 1970s. Follow up investigation would be required to assess this hypothesis.

Chinook fry were more evenly distributed between the east and west side. There have been physical changes in the estuary that may be related to this observation. As noted, the area utilized by log storage has decreased since the 1970s, and remaining leases are located on the west side, leaving the east side flats to recover although it is unknown how long that process will take. The assumption is that this will improve the rearing conditions on the east side of the estuary. Second, the majority of water discharge at mid to low tidal periods is through the channel to the west side of the estuary rather than divided between the west and central channels. Migrating Chinook smolts are likely to follow the greatest water current which would take them to the west side first. This process could explain why the Chinook fry are found in the western side of the estuary in greater abundances than previous work showed.

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Appendix I. Beach Seine catch data

Date	Side	Site	CK fry	CO fry	CO smolt	PK fry	CM fry	Others
7-Apr-21	West	Sandy Point	0	0	0	0	124	
		SFN #1	0	0	0	0	14	
		Haliburton	0	0	0	6	300	
		Living Forest	0	0	0	0	8	
	East	Jack Point	0	0	0	520	15080	
		Duke Point	0	0	0	0	0	Starry Flounder
		Holden SC (2 sets)	0	0	0	1	59	
6-May-21	West	Sandy Point	0	0	2	0	54	RBT, Pipe, juvenile flatfish, sculpin
		SFN #1	0	0	0	0	0	
		Haliburton	1	0	1	0	2	
		Living Forest	0	3	0	0	1	
	East	Jack Point	0	4	0	0	247	Shiner perch, sculpin
		Duke Point	0	0	0	0	0	Sculpin, pipefish
		Holden SC	0	0	0	0	1	Sculpin
7-Jun-21	West	Sandy Point	21	1	0	0	4	STB
		SFN #1	1	0	0	0	0	Shiner perch, flatfish, pipefish,
		Haliburton	13	0	0	0	0	Shiner perch, flatfish, pipefish, sculpin
		Living Forest	29	0	0	0	1	CTT
	East	Jack Point	76	5	0	0	44	Shiner perch, sculpin
		Duke Point	0	0	0	0	0	Pipefish
		Holden SC	0	0	0	0	0	Pipefish, sculpin

STB: Threespine Stickleback

RBT: Rainbow Trout

CTT: Cutthroat Trout

Appendix J. Fyke trap catch data

Date	Chinook	Chum	Coho
23-Mar-2021	0	0	0
6-Apr-2021	0	4	0
15/16-Apr-2021	1	11	0
26/27-Apr-2021	1	33	1
10/11-May-2021	1	0	0
25/26-May-2021	3	0	1
9/10-Jun-2021	0	0	0

Appendix K. Pole seine catch data

Date	Site ID	Chinook	Chum	Coho
7-May-2021	NAN-08	36	8	0
7-May-2021	NAN-09	0	0	0
7-May-2021	NAN-10	0	0	0
7-May-2021	NAN-10	0	0	4
7-May-2021	NAN-11	0	0	0
7-May-2021	NAN-12	2	11	9
7-May-2021	NAN-13	0	12	0
8-Jun-2021	NAN-08	2	0	0
8-Jun-2021	NAN-10	0	0	0
8-Jun-2021	NAN-11	0	0	0
8-Jun-2021	NAN-12	0	0	2
8-Jun-2021	NAN-13	0	0	0
8-Jun-2021	NAN-14	1	0	0

Water Temperatures in the Nanaimo River

Steve Baillie[25] and Nicolette Watson[25]

Introduction

Water temperature is an important component of the freshwater habitat of Pacific Salmon. As a poikilothermic species, the activity level and metabolic rate of salmon at all stages (egg, juvenile and adult) are affected by the water temperature.

From the Risk Assessment of Nanaimo Chinook meeting in January 2019, water temperature was noted as High or Very High biological risk for the following Limiting Factor:

> *LF6: high water temperatures in the lower river and estuary during the late Summer/early Fall migration period increasing mortality and causing sublethal stress on returning adult salmon*

In this document we examine the potential exposure of Summer run Chinook to high water temperatures. Other temperature related Limiting factors that were considered, but were not rated as High or Very High were:

> *LF14: Non-optimal water temperatures reducing fry survival by changing emergence time in relation to food availability (rated* Moderate*)*

> *LF22: Mortality or fitness impacts on fry as a result of poor water quality (temperature, among other conditions) (rated* Low*)*

We will examine the potential exposure of Summer run Chinook eggs and juveniles to both high and low water temperatures.

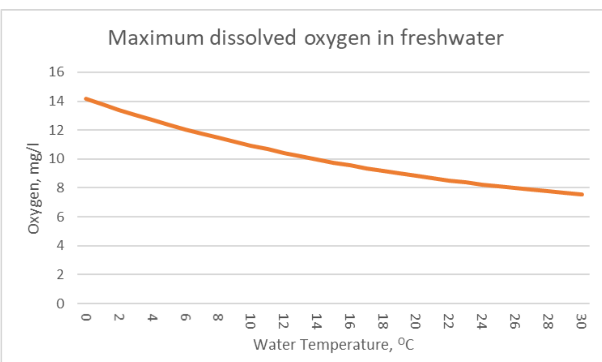

Figure 49. Relationship between water temperature and maximum oxygen level (from Wetzel 1975, Table 8-1)

As water temperature rises, the metabolic rate of the salmon increases which elevates the need for oxygen absorption (Clark et al. 1981). Warmer waters have less potential to maintain dissolved oxygen and elevated temperature can pose the risk of oxygen level falling to sub-optimal or even lethal levels for salmon (Figure 49).

Alderdice and Velsen (1978) found that Chinook eggs develop successfully within a thermal range of 2.5^{O}C and 16^{O}C, taking 159 days and 32 days to hatch, respectively at those temperatures. Healey (1991) describes a 'practical' model of 468.7/Average water temperature to estimate the number of days before hatching.

Pereira and Adelman (1985) examined the effects of temperature, size and photoperiod on the growth and smoltification of Fall Chinook juveniles and found that under various photoperiod regime (winter,

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natural and Spring/Summer) there is a greater growth rate at 15^{O}C than at 9^{O}C. They concluded that the synchronization of both size and growth rate with the photoperiod may be critical for proper smolt development. Similarly, Clark et al. (1981) found lower growth rates at lower water temperatures using Big Qualicum Fall Chinook juveniles.

Carter (2005) assembled published information on temperature effects on Steelhead Trout, Coho and Chinook Salmon. Although this report was prepared for the Klamath Basin (California) the underlying source data came from many sources in western North American. Carter also notes that despite the wide range of geographic locations, salmonid stocks do not tend to vary much in their life history thermal needs which suggests that from the southern part of the range of Chinook in California to the northern limits in Alaska, the thermal requirements do not have much variation. The following table is a summary of the thermal tolerances of early timed Chinook salmon.

Table 18. Temperature tolerances for early run Chinook Salmon. Adapted from Carter 2005.

Life Stage		Temperature range (^{O}C)
Adult migration and holding	Temperature range where adult Chinook migrate	3.3 – 13.3
	Maximum of the daily average temperature for holding	13 - 14
	Range of temperatures causing thermal blockage to migration	19 – 23.9
	Lethal range for adults	22 - 24
Incubation and emergence	Poor embryo survival	<2
	Range for normal embryo development	2 - 14
	Maximum temperature to protect embryos from acute lethal conditions	17.5 – 20
Juvenile rearing	Temperature range at which growth takes place	4.5 – 19
	Increased growth, unimpaired smoltification, lower predation	13 – 16
	Decreased growth, impaired smoltification, increased predation	17 – 20
	Lethal range for juveniles	22 - 24

Similarly, Stalberg et al. (2009) recommended the following upper optimal temperatures for Chinook, Coho and Chum:

- Spawning and incubation 10^{O}C
- Juvenile rearing 15^{O}C
- Adult migration 16^{O}C
- Smoltification 15^{O}C

We will use these results as benchmarks to compare to habitat conditions in the Nanaimo River.

Factors that affect water temperature

There are several aspects to the Nanaimo River that influence the water temperature, both natural and anthropogenic. Water temperature is primarily driven by solar radiation, that is, the absorption of thermal energy by water molecules. Most of the heat transfer occurs on the surface water of lakes and rivers. Lakes often develop a stratified temperature profile during summer, with the warmest waters on the surface and cooler waters at depth. The warm surface waters from the Nanaimo lakes drain downstream resulting in the river being warmer than the headwaters. Heat transfer also occurs from the atmosphere and could go either way, increasing or decreasing the water temperature. As described by the second law of thermodynamics, heat energy is known to move from high to low, so if the relative temperatures between the water surface and the air are different, heat will transfer from either one to the other. Transpiration of water molecules will decrease the temperature of the remaining water as the 'warmer' or higher energy molecules evaporate. Water turbidity affects the rate of thermal energy absorption, with higher turbid water absorbing greater energy. Finally, water inputs from surface tributaries and subsurface aquifers can affect the water temperature (Fondriest Environmental 2014).

Anthropogenic causes that can affect water temperature include removal of forest cover alongside the river and tributaries which increases the amount of solar energy reaching the river water, water discharge from industrial or agricultural processes that can affect water temperature, runoff from structures such as roads and parking lots that can increase the thermal properties of river water, and channelization of the watercourse increases the surface area for the same volume of water. Water impoundment facilities such as dams create artificial lakes that increase thermal energy absorption (Fondriest Environmental 2014). Specifically in the Nanaimo River, the dam on Fourth Lake has a deep water siphon for supplying water for discharge, which is cooler than the surface water, thus creating a cooling rather than a warming effect. The other two dams, on the South Nanaimo tributary, are surface draining.

The goal for this project is to record and analyze water temperatures of the Nanaimo River in different reaches that are important for early run Chinook life history stages: Adult in-migration and Holding, Egg Incubation, and Juvenile Rearing and Outmigration.

Methods

Water temperatures were obtained using HOBO Tidbit water temperature dataloggers, model MX2201, manufactured by ONSET Computer Corporation. The mean water temperature measurements were

Figure 50. Nanaimo River Watershed water temperature stations

recorded every hour by the field unit, then averaged over a 24 hour period for data analysis. Five stations were set up (See Figure 50).

The *Upstream Sadie* logger is located on the Nanaimo River mainstem above the confluence with Sadie Creek and the discharge from the Fourth Lake reservoir. The *Downstream Sadie* logger is located in the Nanaimo River mainstem downstream from the discharge of the Fourth Lake reservoir to record the effect of the water coming from this facility. The *Green Creek* logger is located in the Green Creek tributary of the Nanaimo River, away from the influence of the Fourth Lake discharge but still affected by forestry activities. The *TP Bridge* logger is located on the mainstem Nanaimo River, approximately nine kilometers downstream from the Fourth Lake/Sadie Creek confluence. The *South Fork Bridge* logger is located on the mainstem Nanaimo River, downstream from the First and Second Lakes to record the effect of the lakes on the water temperature, and upstream from the confluence with the South Nanaimo tributary and the discharges from the two Regional District of Nanaimo dams.

In addition, the water temperature data series from the Water Survey of Canada water level gauging station 08HB034 (Nanaimo River near Cassidy), located approximately 0.8 km upstream from the Trans-Canada Highway crossing, was accessed and included in the water temperature analysis. Similarly, the downloaded data was presented as mean hourly temperatures which were averaged over a 24 hour period for data analysis. Data is available from May – June 2002, March 2002 – May 2004, July 2004 – Dec 2007, Dec 2011 – July 2012, and Oct 2012 to present day. This station will be referred to as Cassidy WSC.

The water temperature data is presented as a 7 day running average of daily averages. The water temperature data is presented as a 7 day running average of daily temperatures, deemed as Weekly Average Temperature. The maximum value of this metric, called the Maximum Weekly Average Temperature (MWAT) is used to compare to benchmark data for chronic exposures (Carter 2005) at higher limits.

Because of the amount of forestry activity in the watershed there was no opportunity to provide a control water temperature station in an unlogged area to compare with water temperatures in logged areas. As an alternative, the results from the Carnation Creek Fish-Forestry Project have been summarized here. Hartman and Scrivener (1990) compared water temperatures from the same sampling stations in pre- and post-logging regimes. They found that in the period after logging activities there was an increase in stream temperatures by 0.8^{O}C during winter months and 3.2^{O}C during summer months. The temperature increase had several impacts:

- Shortening the Chum egg incubation period which resulted in decreased marine survivals
- Increasing the growth rate of Coho juveniles that resulted in fewer Age 2 smolts, instead smolting at Age 1, and higher winter freshwater survivals
- Advancing the smolting period earlier which resulted in decreased marine survivals

Although the logging activities resulted in increased water temperatures, the elevated water temperature is still less than 15^{O}C which is lower than the level which would result in lethal effects.

Results and Discussion

Water temperature regime in the Nanaimo River

Figure 51 shows the available water temperatures recorded by the DFO dataloggers and the Cassidy WSC station from the initialization of the DFO loggers on 4-Sep-2019 until 16-Dec-2021. The Heat Dome that occurred in British Columbia in early June 2021 coincides with a short term rise in water temperatures across all stations as shown by a vertical arrow.

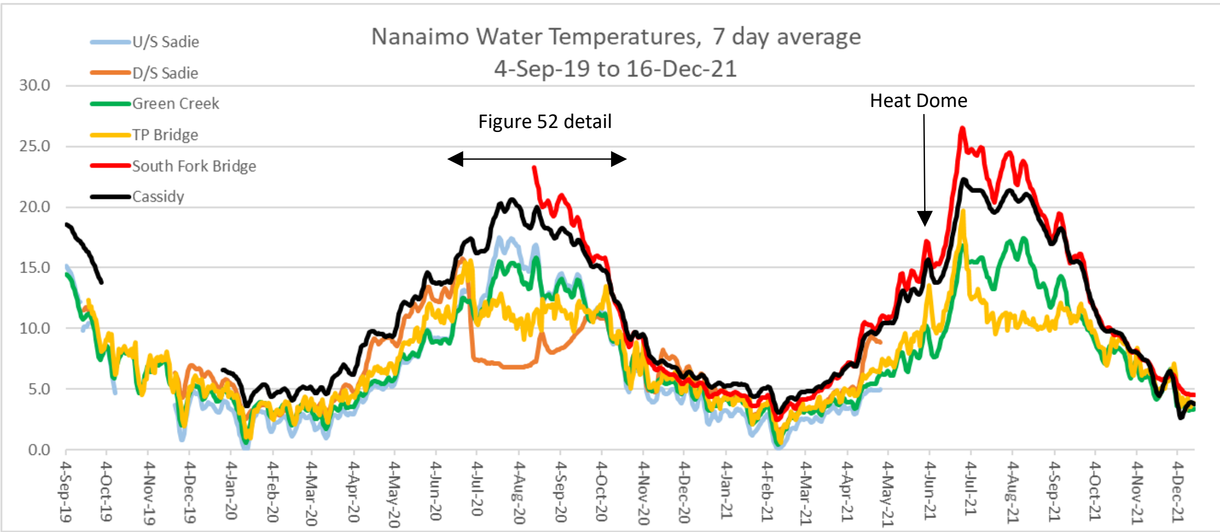

Figure 51. Nanaimo River water temperatures.

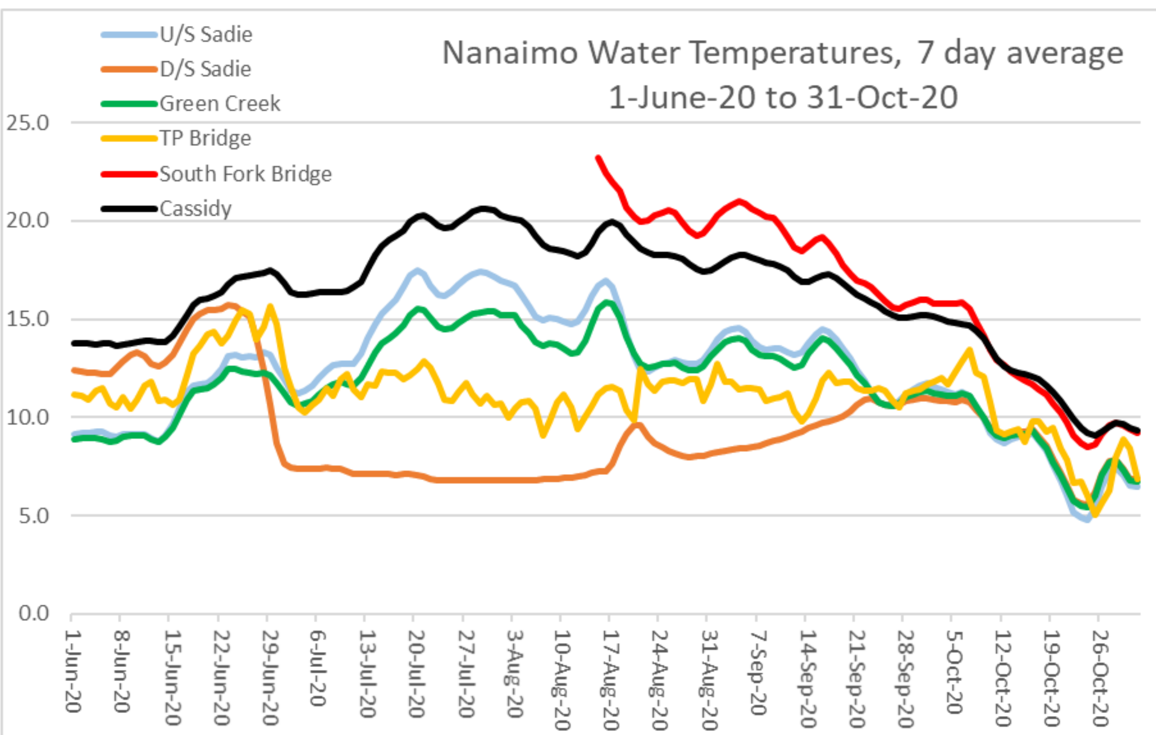

Figure 52. Nanaimo River water temperatures, detail from 1-June to 31-October, 2020

These two figures depict some interesting patterns, especially through the summer period when thermal energy absorption is greatest. The temperatures from *Upstream Sadie* and *Green Creek*, the two upper watershed stations that are not influenced by the Fourth Lake discharge, show a similar temperature profile, peaking at 15-17^{O}C through the summer. The low temperatures at the *Downstream Sadie* station, at around 7^{O}C, clearly show the influence of the deep water siphon that is used for the discharge from Fourth Lake. Similarly, further downstream at the TP Bridge station, the temperature of 10-12^{O}C shows that the water has warmed up, likely due to tributary inputs and thermal warming from solar radiation and atmospheric conditions.

Downstream from the two lakes, the river water has warmed considerably. The temperature recorded at the South Fork station (incomplete data set in 2020, but 2021 summer data can be seen in Figure 51) is well above 20^{O}C in 2020 and peaked at 26.5^{O}C on 27-Jun-21. Further downstream, at the WSC Cassidy station, the water temperature has cooled down as the water flowed downstream from the South Fork Bridge station, peaking just above 20^{O}C. This cooling may be caused by a combination of tributary inputs, aquifer inputs , transpiration and heat transfer to the atmosphere.

Adult migration and holding

Early run Chinook migrate into the Nanaimo River between February and July each year and hold until spawning activities commence in late September. Although the migration period is drawn out over five months, most activity takes place during June and July (based on only 1 year of data). The majority of Chinook hold in three locations: the confluence pool with the South Nanaimo tributary, First and Second Lakes, and the mainstem above Second Lake. Chinook are also known to temporarily hold in other areas such as the Borehole pool during migration.

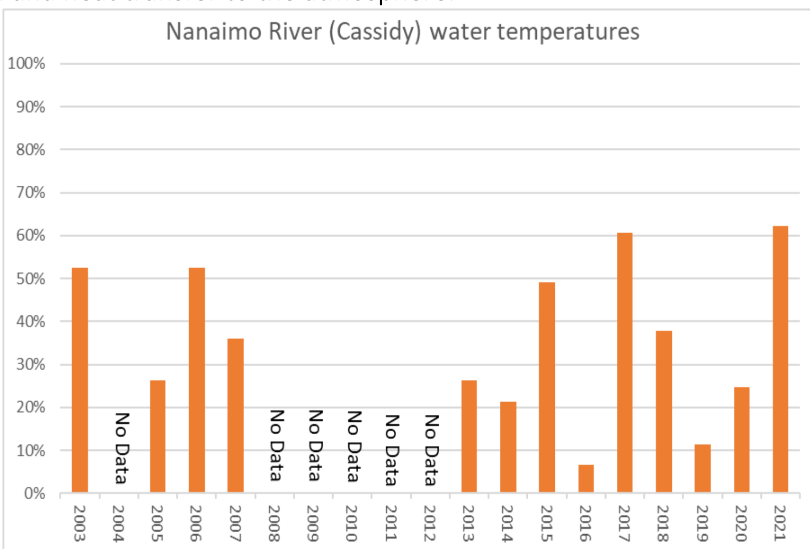

Figure 53. The proportion of the number of days in which the maximum weekly average water temperature was greater than the benchmark of 19^{O}C in June and July.

Consulting Table 18, ideal migration temperatures are between 3.3 and 13.3^{O}C, and thermal blockage to migration occurs at 19 – 23.9^{O}C. Stalberg et al. (2009) use 16^{O}C as an upper optimal temperature for migration. To examine the occurrence of higher water temperatures, we used the period of June-July, and the thermal migration barrier of 19^{O}C and the time series from the Cassidy WSC station to represent the temperature of the water which all the Chinook will have to migrate through. Figure 53

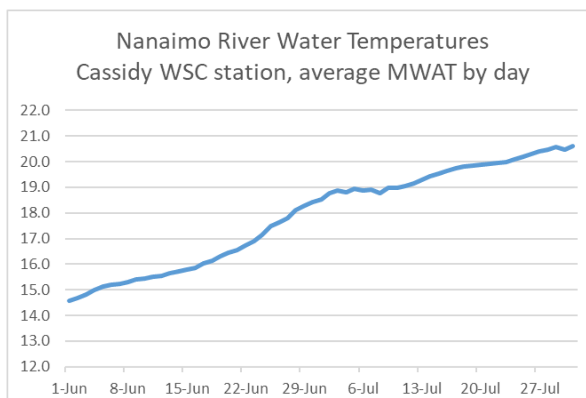

Figure 54. 7 day average, averaged over observation period (2003-2021).

shows the proportion of days during these two months for which the MWAT metric was higher than this benchmark. On average through the available data, The water temperature was above the thermal barrier to migration on 36% of the days in June and July. The majority of these days occurred in July (See Figure 54). By early September the water temperature had cooled down below the benchmark of 19^{O}C.

Egg incubation

Egg incubation is the period from spawning in late September to emergence in the following February. The majority of spawning takes place in the ~ 2 km of mainstem river below First Lake with some spawning in the river above Second Lake. The range of temperatures in which incubation typically can take place is between 2 and 14^{O}C. Temperature below 2 ^{O}C and above 17.5 ^{O}C can be lethal for embryos. .

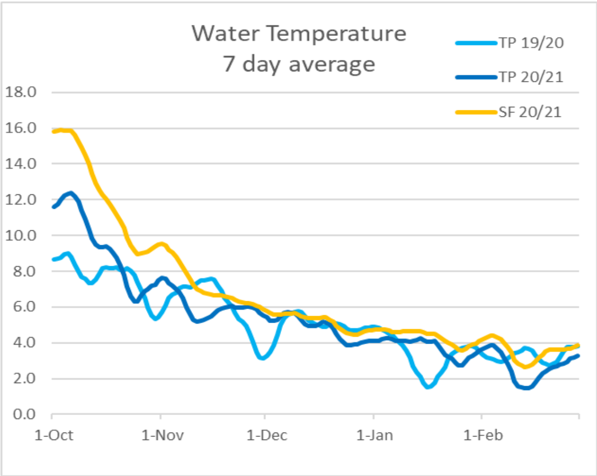

Figure 55. 7 day average, from TP Bridge and South Fork stations, 2019-20 and 2020-21.

Using the South Fork Bridge site to represent the spawning area below First Lake, and the TP Bridge site to represent the spawning area above Second Lake, Figure 55 shows the 7 day average temperature for the TP Bridge site for both 2019/2020 and 2020/2021, and the South Forks Bridge site for 2020/2021. The image shows that the South Fork temperature in October 2020 was higher than the normal incubation range but less than the lethal levels. Similarly the temperatures at the TP Bridge dropped below the ideal range during both years for short periods.

Using Healey's model of estimating the date of emergence (Healey 1991), and using 15-October as a starting point for egg incubation, we estimated the date of egg hatching based on the average temperature from that date forward. Once hatched, the alevin remains in the gravel redd for several weeks until its egg yolk is almost consumed and it must seek external food sources and it emerges from the gravel, usually in mid-February. Emergence occurs when the alevin has attained its maximum weight by metabolizing the attached yolk sac. The rate of metabolism is dependent on water temperature and oxygen level of the subsurface water.

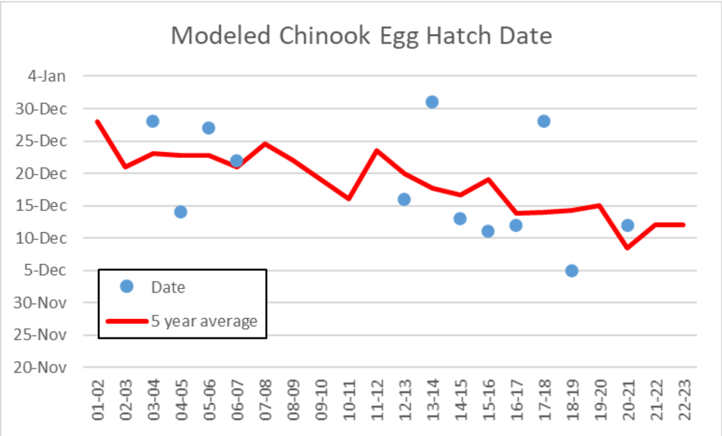

Figure 56. Modeled date of egg hatching, based on the observed water temperatures at Cassidy WSC station

We are using this process to examine the changes in the incubation period over time. The actual date of egg hatching is dependent on when the egg was deposited, the actual subsurface water temperature and oxygen level that the egg is exposed to which is slightly different that the surface temperature and oxygen level that is commonly measured (See *Spawning Gravel Quality*, this document). In addition, the water temperatures that were used (Cassidy WSC) can be different than those in the spawning areas below First Lake and above Second Lake.

Figure 56 shows the results of the modeled egg hatching date over the available time period. There is a distinct trend of earlier egg hatch dates over the short time period which is the result of increased water temperatures in the period of 16-October to December.

Juvenile rearing and migration

Juvenile Chinook emerge from the gravel redds in February and can follow one of the three life history strategy.

Immediate migrant fry will move downstream after emergence and rear in the estuary until smoltification (adapting endocrine system to a marine environment) is completed. Most Fall-timed Chinook follow this pattern. This migration takes place in February and March when water temperatures are between 4.3 and 6.7 ^{O}C (Figure 54). At the beginning of this migration period the water temperature is below the range for growth conditions (Table 18: 4.5 – 19 ^{O}C) however these fry do not remain in fresh water for long before they are in the estuary.

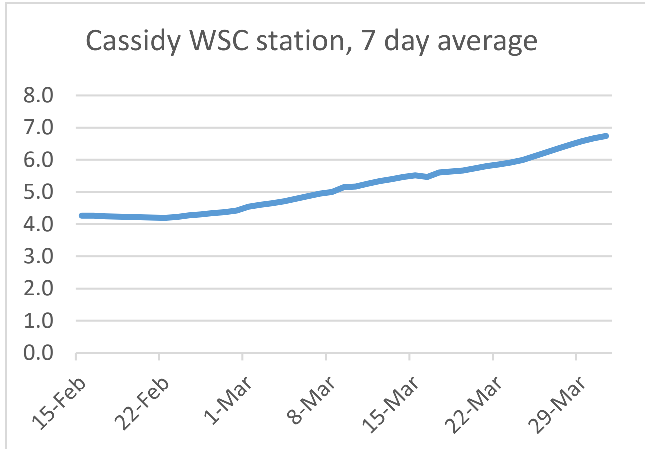

Figure 57. Water temperatures during Chinook Immediate Migrant period

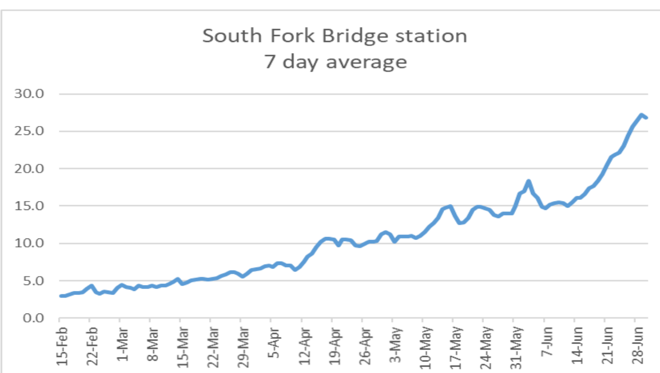

Figure 58. Water temperatures during Chinook Subyearling rearing and migration period.

Subyearling or delayed migrant fry will remain in freshwater for up to 90 days prior to moving downstream to the estuary. Most Summer run Chinook that emerge from the spawning area below First Lake follow this life history. These fry can be found from mid-February to late June and will rear in freshwater from the spawning area down to the lower reaches prior to entering the estuary. Temperatures in the river (*South Fork Bridge* site) ranged from 3.0 to 27.3^{O}C through this period (Figure 58). Immediately post-emergence the water temperature is not within the range of optimal growth, but warms up within weeks. At the end of the rearing period, water temperatures have become very warm, above the optimal growth range and within the lethal range. Ideally, the last of the Chinook fry have migrated downstream by this time and are rearing in the estuary or are in marine waters.

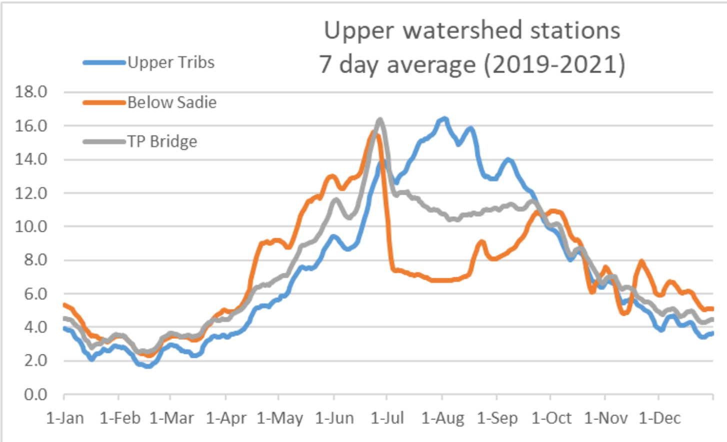

Figure 59. 7 day average water temperatures above Second Lake. Upper Tributaries consist of Green Creek *and* Upstream of Sadie *stations.*

Yearling fry remain in freshwater for one year prior to yearling fry. A small percentage (~5%) of the adults that spawn below First Lake, and about half of the adults that spawn above Second Lake (Healey and Jordan 1982) exhibit this life history. As described in the earlier, juveniles cannot survive in the river below First Lake beyond early June due to high water temperatures. It is possible that all Chinook that show a yearling life history originate from above Second Lake. We believe that these juveniles rear in either the First and Second Lakes, or in the mainstem above Second Lake.

Figure 59 shows the 7 day average from the water temperature stations above Second Lake, with the two stations that are not influenced by the cold water discharge from Fourth Lake (*Green Creek* and *Upstream Sadie*) combined, plus the station immediately downstream from the confluence with Sadie Creek (and the Fourth Lake discharge), and the *TP Bridge* station which is further downstream.

From Table 18, the ideal temperature range for growth of Summer Chinook juveniles is 4-19^{O}C. The data shows that the water temperature from January to March is below the lower benchmark which indicates that the metabolism of the yearling juveniles is low during this period. Further, the water temperatures at all stations do not surpass the 19^{O}C upper benchmark at any time during the sampling period, indicating the water temperature is within optimal growing temperatures through the remainder of the year.

Conclusions

Water temperature has a profound impact on the productivity and survival of Summer run Chinook salmon. Colder temperatures can slow down the metabolism of the fish, slowing their growth and limiting productivity while higher temperatures limit productivity due to an increase in metabolism and oxygen requirements while dissolved oxygen levels in the water are decreasing. This combination of increased demand and decreased availability can have lethal results

Adult Summer run Chinook are exposed to suitable water temperatures through most of their migration period until after the peak in early June. By July, water temperatures can rise to lethal levels and the adult Chinook must have reached cooler water by this time to hold until spawning in September and October. Areas of the river above Second Lake, within First and Second Lakes and the Confluence Pool with the South Nanaimo River are the known holding locations that provide appropriate water temperatures.

Mitigation for warmer temperatures is limited to replacing mature forests to provide shade from thermal warming in the river below the lakes however the greatest absorption of thermal energy takes place at the lakes. Regeneration and protection of mature forests on tributaries that discharge into the river through the summer period would assist with cooling the river temperatures below lethal levels.

The result from the egg incubation model suggests that the eggs are developing faster resulting in an earlier emergence of Chinook fry from the gravel. As shown by the Carnation Creek study (Hartman and Scrivener 1990), an earlier emergence is correlated with lower marine survival rates by Chum salmon fry. Chum fry migrate immediately from freshwater to the estuary, similar to Immediate migrant Chinook fry. Subyearling fry may face the same result due to a lack of food resources at an earlier date. If invertebrate productivity has not increased at the same time of emergence then the survival of the Chinook fry will be negatively affected.

Immediate Migrant Chinook fry are exposed to appropriate water temperatures while in freshwater and are not affected.

Subyearling Migrant fry are exposed to appropriate water temperatures for most of their freshwater rearing stage and are only exposed to higher water temperatures at the end of this stage in June. By this time most of the fry will have migrated downstream to the estuary and have left this habitat so avoid the adverse conditions.

Yearling fry are likely only found in the First and Second Lakes, and the river above Second Lake. The lakes likely experience thermal stratification during the warm summer months with an optimal temperature available for rearing, and the upper river remaining below lethal temperature levels throughout the summer period.

Limiting Factors

LF6 (adult migration) was rated as High biological risk to Fall-run Chinook. . Any late migrating Summer run (or early migrating Fall run) will be exposed to lethal water temperatures, supporting the Limiting Factor risk rating. Summer run Chinook that entered freshwater prior to the temperature rise will need to find temperature appropriate water in which to hold prior to spawning.

LF14 (earlier emergence of fry) was rated as Moderate biological risk. Water temperature data shows that Summer run Chinook fry are likely emerging earlier due to higher incubation temperatures and will likely have lower survival rates. Mitigation of this issue is difficult as it is probably driven by climate change. The original rating factors for the Limiting Factor 14 are: Spatial – 30-40% of critical habitat, Temporal – 3 or 4 times per decade, and Impact – 21-30% change in subsequent return. After examination of available date, we suggest the Spatial score should be 80% or more of critical habitat, the Temporal score should be 8+ times per decade and the Impact score should be 11-20% change in subsequent return. This would not change the biological risk from Moderate.

LF22 (water quality, including temperature, effects on rearing fry) was rated as Low biological risk. Immediate and Subyearling migrants are not affected by higher water temperatures as they have migrated downstream to the estuary prior to dangerous levels. Yearling fry are in low abundance and have cool habitats (upper river, lakes) to utilize for rearing. These conditions support the Limiting Risk rating.

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Water Turbidity in the Nanaimo River

Steve Baillie[26]

Introduction

Total suspended solids (TSS) has been identified as a property of water that can affect the productivity of fish stocks (Sigler et al. 1984). Suspended sediments are by-products of a natural process, resulting from the erosion of landforms and occasional entry of soil to water courses. This natural process is required for aquatic productivity as necessary nutrients are introduced into aquatic ecosystems. The rate of this process can be affected by anthropogenic activities such as dredging, road construction, mine operation and logging among other things (Sigler et al 1984; Kjelland et al. 2015).

High levels of TSS can increase the absorption of light energy resulting in the increase of water temperature (Ellis 1936, Read 1961, Ryder and Pesendorfer 1989). It also decreases the amount of light transmission resulting in lower photosynthesises by aquatic plants leading to decreased primary production and hence lower amount of dissolved oxygen produced by phytoplankton and algae (Berry et al. 2003). Other impacts include disrupting subgravel water flow in redds which lowers hatching success rate (Slaney et al. 1977), and feeding (Sigler et al. 1984).

The measurement of TSS requires laboratory analysis and time (Packman et al. 1999). As an alternative, turbidity can be measured more easily (Packman et al. 1999, Stalberg et al. 2009). Turbidity is defined as the measure of the light scattering property of water that is caused by a variety of factors such as suspended solids (inorganic and organic) and dissolved compounds (Malcolm 1985). It is easy to measure using field equipment and has been shown to correlate with suspended solids although each river system likely has different variables (Packman et al. 1999). In the Packman report they found a relationship between suspended solids and turbidity:

$$\ln(TSS) = 1.32 \ln(NTU) + 0.15$$

Where TSS is Total Suspended Solids (mg/l), and NTU is Turbidity (Nephelometric Turbidity Units)

Stalberg et al. (2009) suggested using the criteria for the protection of fisheries resources in the Canadian Council of Minsters of Environment series on environmental priorities (DFO 2000, from Caux et al. 1997). Their benchmarks for freshwater, in both TSS and Turbidity units, are:

Under clear flow conditions	Maximum increase of 25 mg/l TSS (8 NTU) over background levels for any short term exposure (i.e. 24 hours), or maximum average increase of 5 mg/l TSS (2 NTU) over background levels for longer term exposures (e.g. 24 hour to 30 days)
Under high flow conditions	Maximum increase of 25 mg/l TSS (8 NTU) over background levels at any time when background levels are between 25 and 250 mg/l TSS (8 and 80 NTU), or should not increase more than 10% of background levels when background levels are more than 250 mg/l TSS (80 NTU).

[26] South Coast Area, Fisheries and Oceans Canada, 65 Front Street, Nanaimo, BC, V9R 5H9

Table 19. Turbidity levels and associated risk to fish.

Sediment increase (mg/L)	Risk to fish and their habitat
0	No risk
< 25	Very low risk
25 - 100	Low risk
100 - 200	Moderate risk
200 - 400	High risk
> 400	Unacceptable risk

DFO (2000) also provided a table of risk levels based on increase in the TSS levels over background but doesn't provide the time frame for the measurement, whether instantaneous or averaged over a period of time (Table 19). The Daily average estimate was used for this report.

RAMS

At the Risk Assessment meeting in January 2019, Limiting Factor 13 (High suspended sediment loads and low DO that reduce egg to fry survival and emergence of alevins) was rated as High Current Biological Risk and Very High Future Biological Risk. The level of confidence was Low, suggesting more research is required. Comments about the rating include:

- more of a concern for downstream spawners
- sediment more of a concern than oxygen, unknown sedimentation levels

Sources of data

Harmac Pacific Ltd.

Harmac Pacific. Ltd. operate a pulp mill south of Nanaimo near the Duke Point Industrial Park complex. Their production process requires a significant volume of water which is supplied through a series of

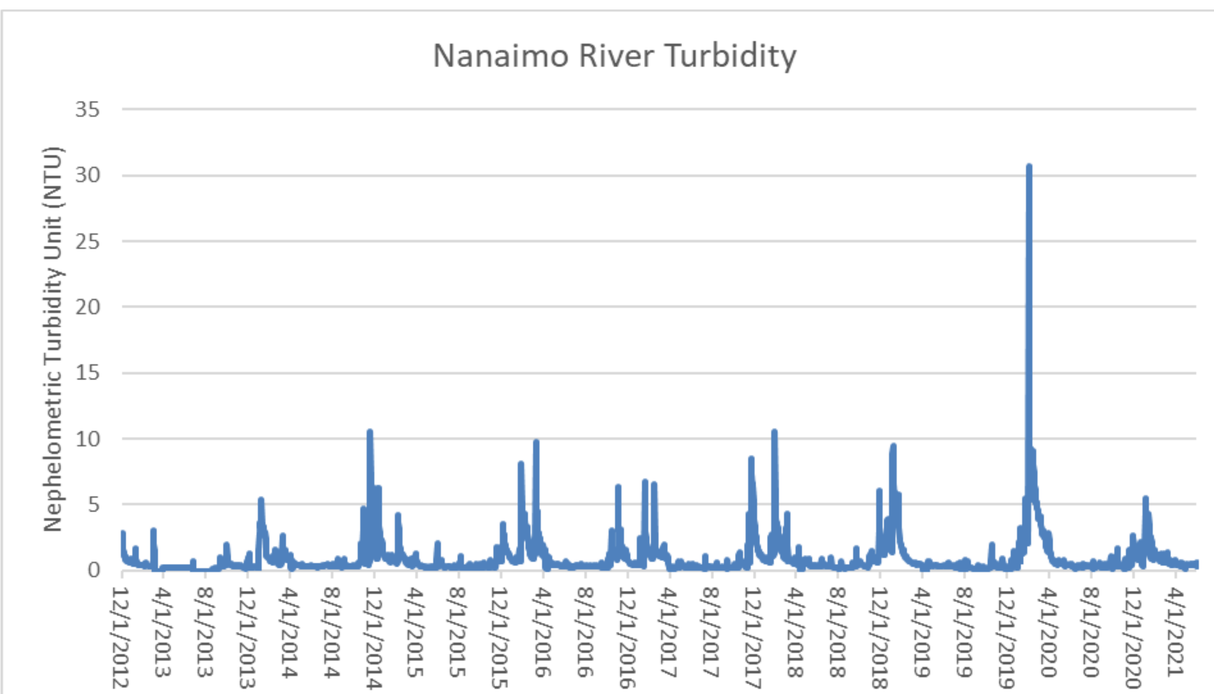

Figure 60. Turbidity measurements, from Harmac Pacific stock feed.

wells and a pipeline from a pumping facility on the Nanaimo River near the Trans-Canada Highway crossing. To supply water for this pipeline, Harmac Pacific owns and operates a dam on Fourth Lake in the upper watershed, which stores water through the fall, winter and spring period for release into the river during the summer drought period. The water supply from the river is continuously monitored for turbidity. The turbidity data from 1-Dec-2012 to 31-May 2021 (Figure 57) has been provided to DFO (3,024 daily averages). The original data was recorded in NTU units which was converted to TSS using the formula from Packman et al. 1999.

RDN

The Regional District of Nanaimo maintains a stream sampling project and provide water quality data on a scheduled basis. There are several sites within the Nanaimo River watershed including, Cedar Road Bridge crossing (site E215789). Dissolved Oxygen, conductivity, water temperature and turbidity have been recorded monthly from August to November since 2014. The Turbidity values are shown in Table 20.

Table 20. RDN turbidity data.

Nanaimo River at Cedar Road Bridge - turbidity (NTU)							
	2014	2015	2016	2017	2018	2019	2020
August	0.29	0.61	0.83	0.41	0.26	1.11	0.78
September	0.46	0.85	N/A	N/A	0.26	0.80	0.42
October	1.20	0.55	1.25	0.71	0.45	0.50	0.79
November	1.60	0.75	2.03	2.56	1.07	0.36	1.85

CABIN

Water quality samples were taken during the Canadian Aquatic Biological Information Network (CABIN) sampling that took place in early September 2020. Both Turbidity and TSS were estimated from these samples. Sampling took place over 9 sites through the watershed, both mainstem and tributary, but over a two day period at low water. Results are shown in Table 21. The TSS levels are too low to estimate a relationship between NTU and TSS.

Table 21. Turbidity data collected during CABIN sampling.

Area		Trib, Above 2nd lake		Main, Above 2nd lake		Main, below 1st Lake		Main, below Hwy 19A		Trib, below Hwy 19A
Location		Mainstem above 4th Lake	Green Creek	Main, Above 2nd Lake	~2 km d/s 4th Lake	Confluence Wolf Creek	Confluence South Forks	RDN park	Hemer Road	Haslam Creek
Site #		E320951	E320952	E320953	E320954	E320955	E320956	E320971	E320972	E299174
	Threshold									
Total Suspended Solids (mg/l)	3	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Total Dissolved Solids mg/l)	13	39	52	21	23	37	37	48	31	76
Turbidity (NTU)	0.1	0.1	0.1	0.28	0.2	0.22	0.22	0.18	0.15	0.15

The opportunistic turbidity samples are good for looking at baseline levels however to monitor turbidity events the continuous monitoring that was provided by Harmac Pacific is valuable to examine periodic events throughout the year.

Results

Habitat Status Report

Water turbidity is discussed in Section 4.2.6.2, under Water Quality (HSR 2021). The hourly readings from the Harmac database are presented however there was no comparison to Stalberg et al. 2009 benchmarks. The HSR analyzed turbidity by assessing the number of hourly instances when the turbidity exceeded 10 NTU over the time frame of the available data however the report did not include the results of this assessment nor the source of the 10 NTU benchmark. Water Quality as a State (including turbidity, water temperature, dissolved oxygen, and fecal coliform) was assigned to a risk ranking of High, based on the results of analysis of all components but without supporting comparisons to benchmarks.

Background turbidity levels during clear water periods (April-September) is 0.32 NTU (0.26 mg/l TSS) and 0.87 NTU (0.97 mg/l TSS) during high flow conditions (November – March). The background level was established by using the median level throughout the period.

For the available data from 2013 to 2021, during the clear water months (April – September) the daily average did not exceed the baseline level of 25 mg/l TSS, indicating that the turbidity levels were suitable for salmon, and was within the 'No Risk' zone for Fish and Fish Habitat scale (DFO 2000). In addition, the turbidity level did not exceed 5 mg/l TSS for periods longer than 24 hours which indicates that longer term turbidity levels were also suitable for salmon.

For the high flow period (October – March) the background turbidity level (0.97 mg/l TSS) was below the level (25 - 250 mg/l TSS) required to assess against increases in turbidity so this assessment benchmark was not used. Using the Risk to Fish and Fish Habitat scale, during the period of data collection there were four days in which the turbidity level was between 25 and 100 mg/l (18 Nov 14, 29 Jan 18, and 2-3 Feb 20) for a rating of 'Low Risk', and one day (1 Feb 20) the turbidity level was between 100 and 200 mg/l TSS, for a rating of 'Moderate Risk'.

Discussion

The HSR section on Turbidity did not provide adequate analysis or benchmark comparisons to provide a risk rating. The selected benchmark of 10 NTU was not referenced, and no quantitative analysis from available data was presented.

The analysis presented above shows that during clear water periods (April-September) there were no incidents of turbidity reaching the benchmark level of 25 mg/l above background levels in the Nanaimo River. During the highwater periods (October-March) the background turbidity level was too low to meet the criteria of the benchmark. Using the Risk to Fish and Fish Habitat table, turbidity events are rare (5 days out of 3,024 daily averages), and on one day the turbidity was rated as Moderate Risk. In addition, the assessment of subsurface sediment levels (this document) shows that there are adequate interstitial spaces in the spawning gravel to allow for adequate water flow for egg development and alevin movement out of the redds. This result suggests that turbidity is not a high risk limiting factor for the Nanaimo River.

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Riparian Disturbance Assessment in the Nanaimo River

Steve Baillie[27]

Introduction

The purpose of this report is to discuss the result of the riparian area disturbance analysis in the Nanaimo River watershed and subsequent questions that arose from the conclusions of that work. The habitat assessments that were used are reviewed, and limitations from existing benchmarks are noted. Finally, a recommendation is presented for this and future riparian area analysis.

The riparian area alongside rivers and streams is important for a productive ecosystem for salmon (Northcote and Hartman 2004):

- An intact riparian area provides shade to keep the water temperature from rising too high
- The vegetative community attracts and hosts insects for fish to feed on
- Organic inputs to the aquatic habitat for water-based arthropods to consume
- Stabilizes the substrate so that fines and sands don't enter the spawning gravel which block sub-gravel water flow and prevent eggs from surviving and stops the hatched fry from emerging
- Slows down water runoff by intercepting precipitation and transpiring subsurface water into the canopy
- The slow additions of large woody debris create complexity in the water courses, including pool/riffle complexes, back eddies, and side channels

> **Disturbance**: Riparian disturbance is limited to human causes such as rail, transmission, major rights of way, harvesting, mining, oil & gas, seismic, agriculture and urban activity, and includes logging activity prior to the last 20 years. Natural events such as fires or insect damage are no longer considered to be sources of disturbance as these processes will retain large wood and provide a measure of other riparian functions until the forest regenerates (BC 2020).
>
> This definition of disturbance does not have a recovery time component, it assumes that an area that has been disturbed in the past is still considered disturbed.

Background

Strategy 2 of the Wild Salmon Policy (WSP) (DFO 2005) addresses the habitat information requirements for sound, productive salmon habitat. To provide guidance on habitat assessment, the habitat characteristics within a Conservation Unit must be identified and indicators with benchmarks be developed to allow the assessment of the condition of those habitats. Characteristics that are found to be deficient can be addressed to restore the habitat to a more productive level.

DFO Habitat benchmarks

Stalberg et al. 2009 provides a list of proposed habitat indicators with their related metrics and benchmarks. Included in this suite was Riparian Disturbance as a Stream Habitat Indicator. This metric uses the proportion of the riparian area that is developed within 30 meters of the stream bank, with a

[27] South Coast Area, Fisheries and Oceans Canada, 65 Front Street, Nanaimo, BC, V9R 5H9

suggested benchmark of 5% based on research that notes a reduced distribution of Chinook fry in streams with areas of disturbance greater than this level. This report does not define what is considered disturbance, but cites Pacific Streamkeepers as having a detailed field protocol in place for determining the level of disturbance. The entire stream length is recommended as the level of scope for this indicator but it is unclear whether only anadromous reaches should be included. Work is underway within DFO to update the indicators in this document[28].

Pacific Streamkeepers

The Advanced Stream Habitat Survey, Module 2, Tertiary Characteristics, describes what a riparian zone is, and a series of habitat attributes to record for each habitat unit. This document does not define what is considered Disturbed or how to interpret the field data or conclude a classification of Disturbed vs. Undisturbed vs Recovered. There is no provision for accounting for the age of the trees, just the broad classification and density (Streamkeepers 2002). Although Stalberg et al. 2009 referenced the Pacific Streamkeepers modules for field data collection protocols, the connection from the data to the level of disturbance was not apparent.

Results from Habitat assessments

Two projects were initiated to describe the habitat characteristics in the Nanaimo River. M.C. Wright and Associates was contracted to provide habitat pressure and state indicator status assessments as described by Stalberg et al. 2009, using provincial and local databases and drone video data of the riparian area. D.R. Clough and Associates was contracted to build on this previous work and provide assessments of in-stream and riparian habitats and develop recovery prescriptions for potential restoration projects. Habitat descriptions and analysis methods as described by the Urban Salmon Habitat Program (USHP) were used.

Habitat Status Report

The Habitat Status Report delivered by M.C. Wright and Associates (HSR 2021) provided a comprehensive assessment of the freshwater habitat indicators that are potentially limiting salmon production in the Nanaimo River. The report concluded that, using a 100m wide riparian zone, a risk rating of High was assigned. Using a 30m riparian zone, the rating changes to Medium.

The HSR used the publicly available data from the DataBC vegetation resource inventory to classify vegetation as well as recent drone imagery provided by DFO and orthophotos from the City of Nanaimo to classify forest stand types into seven categories consistent with the *Standard for Terrestrial Ecosystem Mapping in British Columbia* (BC 1998):

- Mature conifer (>80 years old, >90% mature coniferous stand)
- Mature mixed (>80 years old, mixture of mature coniferous and deciduous vegetation)
- Young (40–80 years old)
- Early regenerating (<40 years old)
- Wetland
- Agricultural
- Anthropogenic (i.e., roads, residential and industrial buildings, gravel pits)

[28] Christine Czembor, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, BC, V9T 6N7, pers. comm.

The HSR used the mainstem from the estuary upstream to the barrier near Fourth Lake, dividing the river into 25 reaches (including the two lakes). This is the known Chinook habitat, and doesn't include tributaries. For each reach, the area values for Early regenerating Forest (<40 years old), Agricultural and Anthropogenic were summed and divided into the total riparian area of each reach to assess the level of disturbance.

Although unstated in the HSR, subsequent discussions with M.C. Wright and Associates' staff revealed that they considered a 40 year old forest would have a canopy height of 9 m.

The HSR used the 5% disturbance by area benchmark recommended by Stalberg et al. 2009 which was intended for a 30 m wide riparian zone, but not a 100 m zone. The HSR divided the anadromous reach into 25 segments and provided the disturbance data by segment rather than using the entire reach in their analysis as recommended by Stalberg et al. 2009. The HSR also incorporated a new benchmark of 10% disturbance. Below 5% was defined as Low Disturbance, between 5% and 10% was considered as Moderate disturbance and a level above 10% was considered as High disturbance. Stalberg et al. 2009 did not define a 10% benchmark but suggested that subsequent categories could be determined via distribution curve of watersheds within the Conservation Unit. The HSR did not describe the process used to define the 10% benchmark.

Using the HSR data for a 30 m riparian zone, a single 5% benchmark between Disturbed and Not Disturbed status, and the entire anadromous river in scope (not including tributaries), and defining Disturbance as a logged area with a forest that is < 40 years in age (as per the HSR procedure), plus anthropogenic uses, results in a level of disturbance of 8.2% which is above the 5% benchmark indicating that the riparian zone in the Nanaimo River mainstem is in a disturbed state (see Table 22). Table 22 shows the level of riparian disturbance within each segment (anthropogenic and < 40 years old forest), and the proportion of the total anadromous length of each reach, for weighting purposes.

Habitat Assessment Report

D.R. Clough and Associates were contracted to conduct a ground truthing review of the in-stream and riparian habitats using the Urban Salmon Habitat Program (USHP) protocols to assess the river, and to produce a suite of prescriptive restoration projects that could be undertaken (HAR 2021). Only the reaches that are important to Chinook life history were assessed, i.e. adult holding and spawning, and juvenile rearing (Reaches 2-5, 12-14, 16, 18, 22-23, 25 as defined in the HSR). The Habitat Assessment Report follows the field data collection descriptions from Johnston and Slaney 1996, and uses a spreadsheet from the USHP to interpret the data. This data entry spreadsheet incorporates the numeric

Table 22. Analysis of riparian zone disturbance using data from the Habitat Status Report, weighted by length of each reach.

Reach	Area	Anthropogenic (urban, agriculture, meadow)	< 40 year regenerated forest	Sum (% Area Disturbed)	Reach portion of anadromous length
1	Estuary to Highway	38%	4%	42%	6%
2		23%	0%	23%	11%
3		8%	2%	10%	4%
4	Highway to White Rapids Falls	4%	0%	4%	3%
5		3%	2%	5%	5%
6		0%	0%	0%	1%

7	White Rapids Falls to South Nanaimo tributary confluence	0%	1%	1%	3%
8		0%	2%	2%	3%
9		0%	0%	0%	9%
10		0%	0%	0%	3%
11		1%	1%	1%	6%
12		4%	7%	11%	3%
13	Below First Lake	2%	1%	2%	7%
14		1%	3%	5%	4%
16	Between lakes	12%	4%	16%	1%
18	Above Second Lake	1%	4%	4%	11%
19		7%	3%	10%	2%
20		0%	2%	2%	3%
21		2%	4%	6%	2%
22		4%	0%	4%	5%
23		1%	2%	4%	6%
24		5%	4%	9%	2%
25		2%	8%	10%	2%
				8.2%	

measurements from the field and produces a rating scale (See Table 23). As noted in Johnston and Slaney 1996, caution should be used when interpreting the instream data for reaches wider than 15 m for the in-stream habitat characteristics % Pool area, Pool frequency, and % wood cover in pools. In the Nanaimo River this would include the mainstem from First Lake downstream to the estuary, reaches 2 to 12. This caution was not applicable to the data associated with in-stream habitat characteristics LWD, Boulder cover, overhead cover, substrate, off-channel, holding pools, access to spawning areas, gravel quality and quantity, redd scour and inorganic nutrients, or assessing Riparian habitat.

Table 23. Reach Habitat and Riparian Score Comparison (HAR 2021: reference Table 26)

Reach	Habitat	Result	Riparian	Result
Reach 2	3.6	Fair-Poor	2.8	Fair
Reach 3	4.0	Fair-Poor	2.2	Fair-Good
Reach 4	2.7	Fair	2.0	Fair-Good
Reach 5	2.9	Fair	3.0	Fair
Reach 12	2.9	Fair	2.7	Fair-Good
Reach 13	2.9	Fair	2.3	Fair-Good
Reach 14	3.1	Fair	2.3	Fair-Good
Reach 16	3.3	Fair	2.2	Fair-Good
Reach 18	2.9	Fair	2.2	Fair-Good
Reach 22	3.6	Fair-Poor	2.0	Fair-Good
Reach 23	3.1	Fair	1.7	Fair-Good
Mean Score	3.2	Fair	2.8	Fair-Good

The field data is also incorporated into assessing several metrics associated with the riparian area such as Land Use, Riparian Slope, Bank Stability, % Crown Cover, % of Reach Accessed by Livestock and Average Vegetation Depth. The result for each metric is rated from 1 to 5, which are then averaged to get an overall score. A score of 5 is deemed as Poor and a score of 1 is deemed to be Good.

Using this process and combining across all assessed reaches, the HAR found an overall rating of 2.8, or Fair (Table 23).

Discussion

The HSR assessment concludes that the Riparian area had a High risk rating (> 5% by area was assessed as disturbed) however there is dispute whether the protocol that was used for assessing disturbance is appropriate.

The HSR supported their definition of Disturbance with various references on groundwater and transpiration changes following loss of forest vegetation, and declines in functional Large Woody Debris (LWD). The document notes that there are elevated levels of groundwater in logged areas and that summer runoff can increase for 5 to 20 years. The initial increase in flow is followed by a decline in summer flows and increased water temperature. In addition, transpiration by second growth forests are similar to old forests after 20 to 50 years. Finally, this document notes that there is a decline in functional LWD due to regenerating forests have fewer senescence than old growth forests. This supporting documentation does not specifically lead to a conclusion that a disturbed riparian area has regenerated a forest community to a level that can be considered as recovered by age 40.

The HAR concluded that the riparian area of Nanaimo River, based on the subset of reaches that are important to Chinook Salmon, had a mean score of 2.8 which can be described as Fair condition. The USHP process that was used to assess the riparian area is not designed to describe the level of disturbance but the quality of the habitat. It also does not take into account the age or seral stage of the vegetation in the riparian area although Johnston and Slaney 1996 does contain data protocols for Riparian vegetation type and Structural stage. The purpose of the HAR was to assess the quality of the in-stream and riparian habitats and provide prescriptions for habitat improvements in areas that are deficient.

Comments about the HSR conclusions

The definition of what was disturbance (< 40 years old forest) and the conclusion using that definition elicited a discussion between M.C. Wright staff and Mosaic Forest Management staff. This lead to a discussion on how to determine at what point can a disturbed forest be considered as recovered.

The HSR used the assumption that a 40 year old forest was representative of a recovered forest, and that the canopy was approximately 9 m in height. The Province of British Columbia provides information on Forest Site Indexes (a productivity metric), and expected growth curves based on the Site Index for leading tree species of the location. For the Nanaimo River, the vegetation classification is mostly Vancouver CWHxm [29], which has a Site Index of 34.1 m (BC 2013), with a standard error of 0.5. The Site Index refers to the approximate height of the canopy after 50 years. Using the Site Index growth curves (Nussbaum 1996, Figure 58), a 40 year old forest (breast height age plus 8 years) with a productivity index of 34.1 would have a canopy of approximately 25 meters in height. A further

[29] Pam Jorgenson, Mosaic Forest Management, 648 Terminal Ave. Nanaimo, BC, V9R 5E2, pers. comm.

interpolation of this growth curve suggests that this forest canopy would have exceeded 9 meters by approximately breast height age 15. This information leads to a conclusion that a 40 year old forest would be much higher than the 9 meters assumed by the HSR.

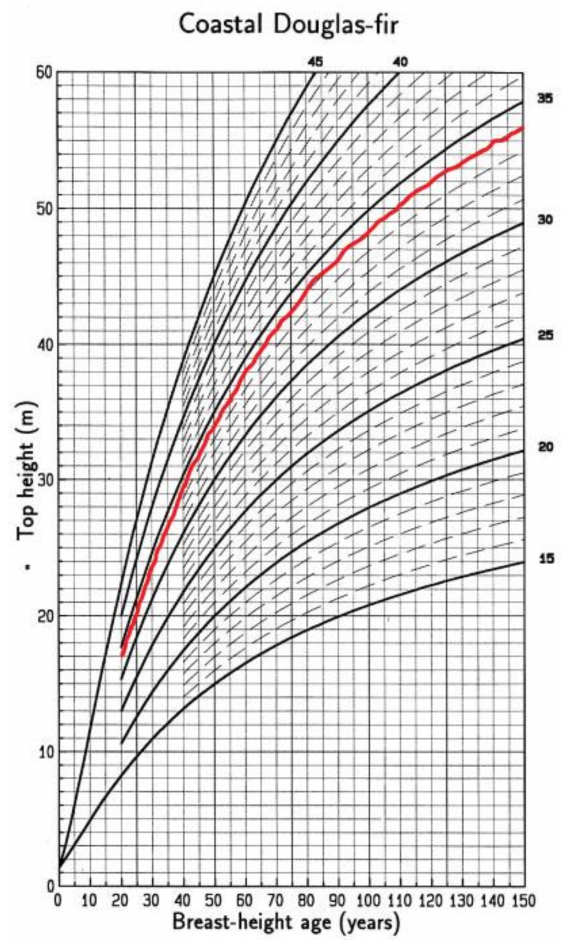

Figure 61. Growth curves for Coastal Douglas-fir, with Site Index 34.1 m highlighted in red. From Nussbaum 1996

Nussbaum 1996 provides a formula to estimate the number of years to reach breast height:

$$Number\ of\ Years\ to\ breast\ height = 13.25 - Site\ Index/6.096$$

From the discussion around the results of the HSR, the question that arose was “How do you know when a regenerated forest is no longer considered as Disturbed?”. Most references that provide protocols for assessing the status of the riparian area do not include a provision for when a growing forest can be considered as Recovered, leading to the conclusion that a disturbed area never gets to that state. This result is simply based on a lack of recovery definition.

Direction for a solution

The major attributes of salmon habitat that are affected by the removal of riparian vegetation were listed in the Introduction. Ultimately, a riparian area, once disturbed, should return to a natural state as the regenerating vegetation grows back. The time it takes for the detrimental effects to disappear could be the guideline for the definition of a Recovered Disturbed Riparian area. The different processes have different timelines to return to a natural state. Attributes such as organic inputs and insect production may recover in the early seral stages of shrub growth, other attributes such as LWD input and precipitation interception and transpiration may require a mature coniferous forest, which takes 80 to 200 years.

As an example of one attribute, the water temperature in a stream with an undisturbed riparian area is 15^{O}C during the summer period which is within the normal range for salmonid productivity. After the removal of vegetation the temperature increases to lethal levels of 22^{O}C. As riparian vegetation becomes re-established and solar thermal effects decrease, the water temperature decreases from the lethal range to a level (less than 17^{O}C) that is tolerated by salmonids (Carter 2005).

Similar benchmarks can be established for insect production (directly, or indirectly using vegetation), organic vegetation inputs (age/size of riparian vegetation), runoff of silt (turbidity measurements) precipitation interception (size/age of forest), LWD inputs (age/size of mature forest). Weighting the various attributes is subjective and will require discussion among subject experts.

Salmon productivity as a benchmark is unlikely to be sensitive enough for a single part of their habitat. Salmon require many habitat types that are used throughout their life history that affect productivity (e.g. spawning, freshwater rearing, estuarine rearing, ocean migration, fishing pressures, predator and prey levels).

The issue of riparian and stream habitat management has been under study by the BC Provincial Ministry of Forests, Range, Natural Resource Operations and Rural Development for many years. Specifically, their stated goal was to determine whether the current Forest Range Practices Act standards and practices were achieving the desired results of protecting fish values by maintaining the channel and riparian functions (Tripp et al. 2022).

This document uses the term "Properly Functioning Condition" as a concept of a recovered riparian area. It states that the Properly Functioning Condition of a habitat will be maintained if the impacts of development (disturbance) on the attributes of the riparian area are:

1) Within the range of natural variability, and
2) Beyond the range of natural variability but in a small portion of the habitat.

Properly Functioning Condition is the ability of a stream, river, wetland, or lake and its riparian area to:

1) Withstand normal peak flood events without experiencing accelerated soil loss, channel movement or bank movement;
2) Filter runoff; and
3) Store and safely release water.

Further, stream connectivity is included in the above definition.

This concept is similar to the *Direction to a Solution* suggested above in that it looks at the state of the habitat and its functioning processes as related to salmon productivity requirements, rather than the age of the regenerating forest. The protocol to assess the Properly Functioning Condition is different. Instead of using the various processes and compare to benchmarks, a series of 15 Yes/No questions have been assembled which describe the state of the physical habitat in both the stream channel and riparian area. The number of No answers provide direction on the relative health of the stream and its riparian habitat. See Appendix L for the list of questions and the interpretation of the answers.

The questions are designed to provide measurable indicators with specific thresholds that allow users to obtain results that are not dependent on a high level of expertise. This results in a more consistent assessment. Comparison field tests were conducted using different teams, level of experience and streams to ensure repeatability. The thresholds used were obtained from peer-reviewed scientific reports in most cases. For a few questions, the thresholds used were obtained from expert opinion workshops.

Each of the 15 questions has a subset of questions that provide insight on the function of the attribute in the main question. These sub-questions involve estimating, counting or measuring features in the stream and riparian area that provide direction on whether the answer is Yes or No. Tripp et al. 2022 provides illustrated guidance on how to answer the questions and interpreting the result. This method relies on the functioning of the habitat compared to a normally functioning stream, and does not use age of the regenerated forest as a guideline. Question 15 does use age of trees, but in the context of comparing the vegetation within the assessed reach to the composition of an undisturbed area (e.g.

snags, coarse woody debris, gaps, tall trees, understory, tall shrubs, low shrubs, herbaceous plants, mosses and lichens). The assessment is based on a segment that is 20x the width of the stream, with a minimum length of 100 m.

This method is the result of refining previous work by the authors in 2009 and many years of research and comparison plots. Over 1400 field sites were assessed to develop this protocol, including 51 reference streams that were undisturbed.

Conclusion

The problems identified in this document were the lack of scientific standards for defining what is riparian disturbance, assessing the status of riparian zone habitats with their role in salmonid productivity, and what protocol could be used to identify when a regenerated ecosystem returns to a recovered state after a disturbance. There are many protocols that provide instructions on describing the physical nature of the riparian area, but the interpretation of that information was difficult to follow.

Stalberg et al. 2009 provided a benchmark on what proportion of an area is disturbed to warrant concern but did not provide sufficient detail to define disturbance especially in the situation of a post-disturbance area. Simplistic approaches such as the number of years after a disturbance event or age of the regenerating forest do not take into account the severity of the different processes of the disturbance on salmonid habitat and the different time frames involved in returning to a recovered state or the productivity of the area.

The FREP paper by Tripp et al. 2022 provides a protocol to examine the habitat of both the stream and the riparian areas, using descriptions of the habitat that represent "Properly Functioning Condition". It uses a series of YES/NO questions on the nature of the habitat and grades the relative health of the habitat on the number of NO answers which does address the processes that are important to productive salmonid habitat. It does not use any time reference, either age of regenerating forest or number of years post disturbance event which was the source of much discussion on how to interpret the data. This assessment protocol should address the issues raised in this report.

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Appendix L.

Fifteen questions used to assess the relative health, or "functioning condition" of a stream and riparian habitat. From Table 2, Tripp et al. 2022

Question 1.	Is the channel bed undisturbed?
Question 2.	Are the channel banks intact?
Question 3.	Are channel LWD processes intact?
Question 4	Is the channel morphology intact?
Question 5.	Are all aspects of the aquatic habitat sufficiently connected to allow for normal, unimpeded movements of fish, organic debris, and sediments?
Question 6.	Does the stream support a good diversity of fish cover attributes?
Question 7	Does the amount of moss present on the substrates indicate a stable and productive system?
Question 8.	Has the introduction of fine sediments been minimized?
Question 9.	Does the stream support a diversity of aquatic invertebrates?
Question 10.	Has the vegetation retained in the RMA been sufficiently protected from windthrow?
Question 11	Has the amount of bare erodible ground or soil compaction in the riparian area been minimized?
Question 12.	Has sufficient vegetation been retained to maintain an adequate root network or LWD supply?
Question 13.	Has sufficient vegetation been retained to provide shade and reduce bank microclimate change?
Question 14.	Have the number of disturbance-increaser plants, noxious weeds and/or invasive plant species present been limited to a satisfactory level?
Question 15.	Is the riparian vegetation within the first 10m from the edge of the stream generally characteristic of what the healthy unmanaged riparian plant community would normally be along the reach?

The relative health or "functioning condition" of the stream and its riparian habitat is based on the total number of No answers to the 15 main indicator questions, as follows: (FREP: Forest and Range Evaluation Program)

- 0–2 No answers – Virtually all stream and riparian experts would agree the stream is healthy and in properly functioning condition. 76% of FREP reference streams had 0-2 No answers. The average for all reference streams was 1.4 No answers.

- 3–4 No answers – Functioning but at risk. Most, but not all stream and riparian experts would agree the stream is functioning properly. Some red flags are apparent. 20% of FREP reference streams had 3-4 No answers.

- 5–6 No answers – Functioning but at high risk. Most, but not all stream and riparian experts would agree the stream is not properly functioning condition. Many red flags are apparent. 4% of FREP reference streams had 5-6 No answers.

- 7 or more No answers – Virtually all stream and riparian experts would agree the stream is not functioning properly. No FREP reference streams had 7 or more No answers.