NICOLA BASIN CHINOOK RISK ASSESSMENT FINAL REPORT

A Process Developed with the Nicola Collaborative Research and Technical Committee

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Cover photo provided by Tom Willms

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ABSTRACT

DFO has developed a risk assessment methodology to aid in the identification and prioritization of factors that limit salmonid production, both now and in the future under various climate change scenarios. This methodology has been adapted from an "Ecological Risk Assessment for the Effects of Fishing" (ERAEF) framework that was initially developed to inform an ecosystem-based approach to fisheries management in Australia (Hobday et al., 2011). The modified risk assessment methodology allows us to assess the biological risk posed by man-made and natural stressors acting on Pacific salmon throughout their life cycle in freshwater, estuarine and marine environments, utilizing a life history model approach to assess consequence of these stressors on the productivity and capacity of the population and its habitat.

The Risk Assessment Method for Salmon (RAMS) approach has been applied to many ocean type Chinook populations in BC, but this process was the first application of RAMS on an Interior Fraser stream type Chinook population. The primary goal of this RAMS process was to solicit input on the limiting factors that may affect Nicola Basin Chinook freshwater survival and to determine their relative impacts on production as well as identifying where critical knowledge gaps occur. Ranking of the factors posing the highest risk to current productivity of Nicola Basin Chinook will allow for effective prioritization of management responses.

The second goal was to gather information on current and possible future recovery measures/strategies to stimulate the possible rehabilitation of Nicola Basin Chinook through remediation, restoration and/or conservation initiatives.

Here we report on the Level 1 Risk Assessment process from inception to completion through background data collection, literature review, production of informative videos, development of a cumulative effects life history model, production of GIS layers showing key habitat indicators, two key workshops and the resulting ranked limiting factors, identification of key knowledge gaps and action items, and identification of potential mitigation actions.

Photo provided by Tom Willms

EXECUTIVE SUMMARY

This summary reports on the results of a Nicola Basin Chinook Level 1 Risk Assessment (RAMS) process that was applied through two workshops with the Nicola Basin Collaborative Research and Technical Committee over 2021-2022. The goal of this process was to provide a transparent and collaborative means of assessing the risks or factors limiting the productive potential of Chinook salmon in the Nicola watershed.

The Nicola River is a tributary of the Thompson River and is a sixth order stream located in the interior of southern British Columbia (Figure ES-1). The Nicola River produces early-run Chinook (*Oncorhynchus tshawytscha*), Coho (*O. kisutch*) and Steelhead (*O. mykiss*) to the Thompson and Fraser River. Important tributaries to the Nicola for salmonids include the Coldwater River and Spius, Maka, Spahomin, Skuhun, Shackan, Quilchena, Clapperton and Guichon creeks.

Historically, the Nicola River was an important contributor to interior Fraser River salmon production. However, current salmon escapements to the Nicola system are depressed: Interior Fraser River Coho stocks were COSEWIC designated in 2002, a designation which prompted the need for immediate recovery goals to be established by the Interior Fraser Coho Recovery Team (DFO 2006)[1]; and Nicola Basin Chinook stocks (as parts of Fraser River Spring 1.2 DU) were designated by COSEWIC as endangered in November 2020.

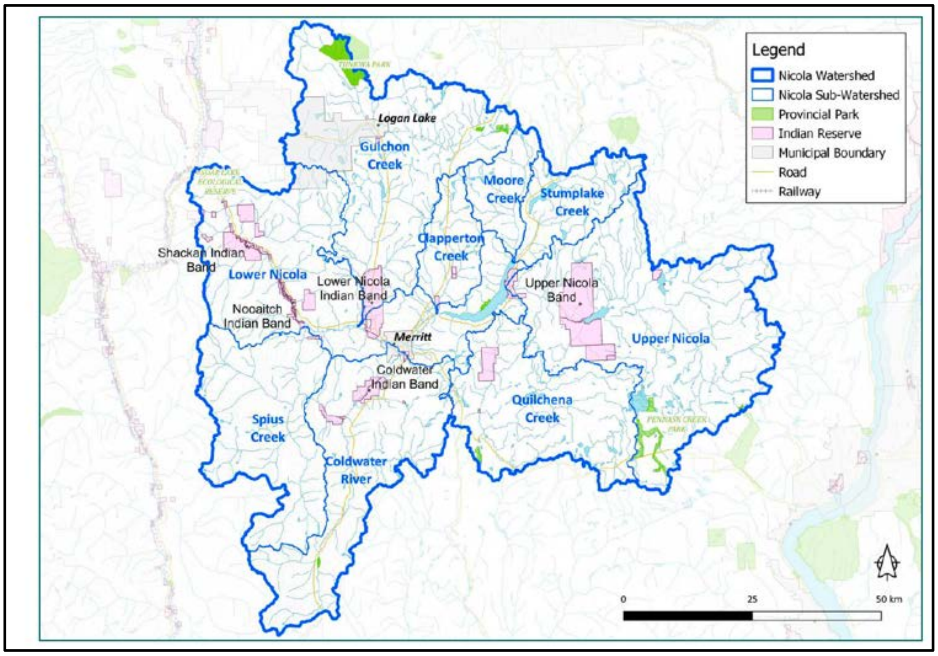

Figure ES-1. A map of the Nicola Valley showing sub-basins (blue), First Nation communities, parks and municipalities. From the Nicola Watershed Characterization report (ESSA Technologies Ltd. and Fraser Basin Council 2019)

Nicola Chinook make up part of the Fraser Spring 42 Chinook Management Unit. Coded-wire tagged (CWT) Nicola River Chinook released from the Spius Creek Hatchery is the (Pacific Salmon Treaty) PST

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[1] Interior Fraser Coho Recovery Team. 2006. Conservation Strategy for Coho salmon (*Oncorhynchus kisutch*), interior Fraser River populations. Fisheries and Oceans Canada

exploitation rate indicator stock used to assess survival and exploitation rates of Spring 4_2 Chinook in Canadian and U.S. fisheries.

DFO's outlook for Spring 4_2 Chinook states that this is a stock of concern with continued expectations for depressed abundance due to low parental escapements, ongoing unfavorable marine and freshwater survival conditions and low productivity.

All Nicola Basin Chinook exhibit a stream-type life history, with the juveniles overwintering in freshwater before entering the sea as yearlings (Healey 1991, Fraser et al. 1982). Fry emerge in the spring (Lewis and Komori 1989) and typically disperse throughout the natal streams; some remain to overwinter while a portion emigrates to the lower watersheds at this time (Scott and Olmsted 1985). There appear to be three variants within the juvenile life history (Figure ES-2).

1. Emerge, leave natal stream and rear in Lower Thompson and Fraser, mostly overwintering and smolting from Lower Fraser.
2. Emerge, remain in natal stream through first summer and migrate out into the Lower Thompson where they over-winter and smolt as 1+.
3. Third variation is to emerge and remain in natal stream and smolt from natal stream as 1+.

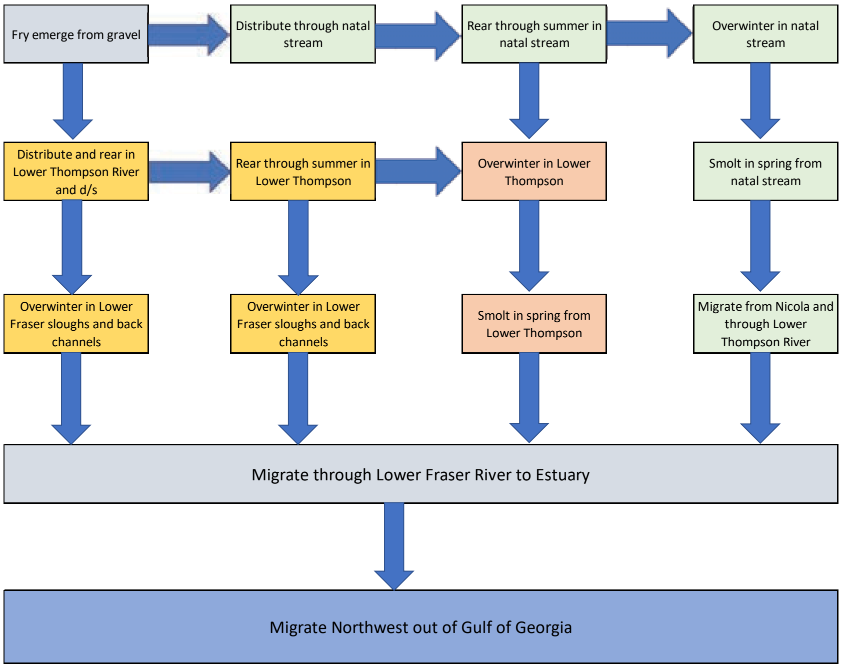

Figure ES-2. Three variants in the life history of Nicola Chinook. From RE Bailey.

It is believed that there is considerable overlap among strategies.

Spius Creek Hatchery was one of six pilot hatcheries that were built to enhance the declining interior Fraser River Chinook and Coho salmon stocks (Winton and Hilborn 1994). The hatchery was built in 1980 and enhancement of the Nicola system stocks began soon after, with broodstock initially taken from the Nicola River mainstem stock. First returns to the Nicola system occurred in 1987. The hatchery focuses on Coho and Chinook supplementation in the Nicola watershed, capturing broodstock from the Coldwater (Chinook and Coho), Spius (Chinook, Coho), and Nicola mainstem (Chinook). All current Nicola River releases are CWT'd to provide a mark group for this Chinook survival and exploitation rate indicator stock, and releases vary around 180 thousand adipose-clipped and CWT'd yearling smolts annually. There are modest releases of CWT'd fry on most years as well

(~25K): these are light BKD positives that cannot be reared to smolt (R. Bailey, pers. comm.). Hatchery contributions to the Nicola system have been estimated since 1995 using a combination of mark-recapture and deadpitch surveys. The deadpitch is an integral part of the mark-recapture. Fish are caught by angling to apply tags and the post-spawned carcasses are later examined for marks (tags, adipose clips etc.) (R. Bailey, pers. comm.).

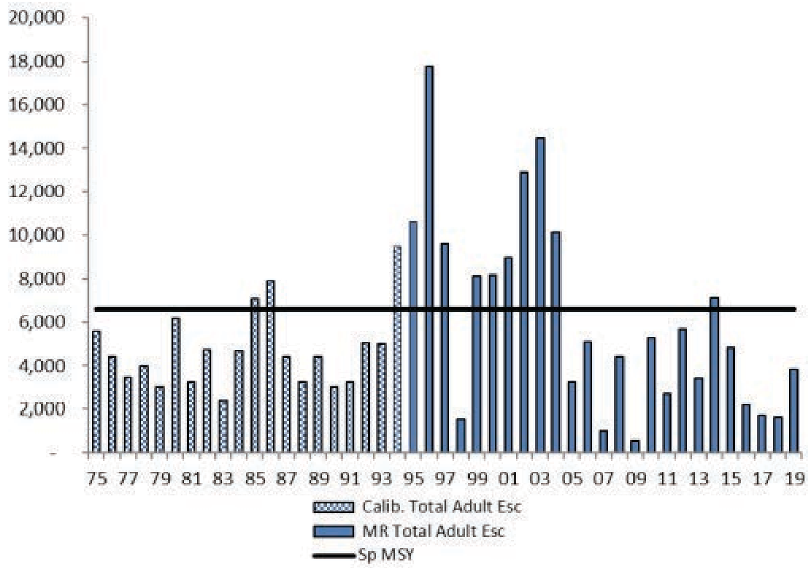

Figure ES-3. Nicola Chinook Salmon Escapements 1975-2019

Relative to historical data records, Nicola Chinook have declined appreciably over time (Figure ES-3).

Escapements have varied between 538 (2009) and 17,777 (1996), with an average of approximately 5,550. Hatchery returns started in 1987 with the largest contribution (~79%) in 1991, the smallest contribution (4%) in 1996, and an average contribution of 30% since 1987 (Figure ES-4).

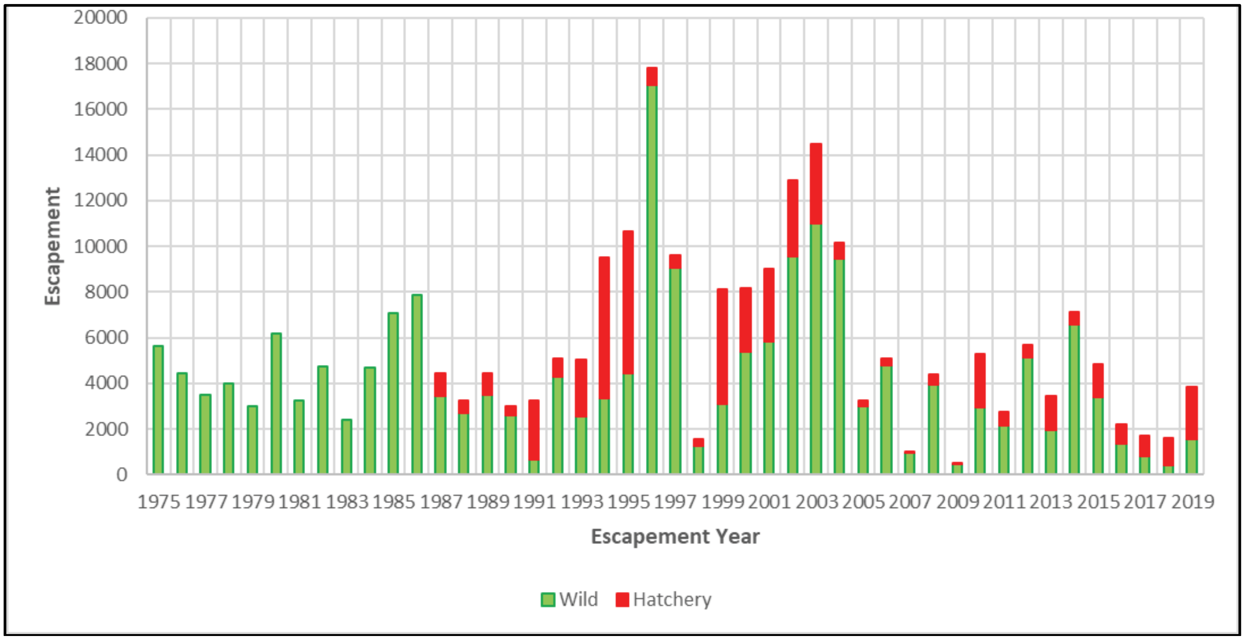

Figure ES-4. Relative Escapements of Naturally Produced and Enhanced Origin Chinook Salmon to Nicola River 1975-2019

Marine survival fluctuated considerably for Nicola Chinook before the 2000 brood year; since 2000 marine survivals have been poor although there was one moderate year (2006) (Figure ES-5).

Salmon are often considered a keystone indicator of watershed health because the various life stages are so dependent on so many components of the ecosystem. The abundance and productivity of naturally spawning Nicola Chinook is based on factors in both freshwater and the marine environments and is below target levels.

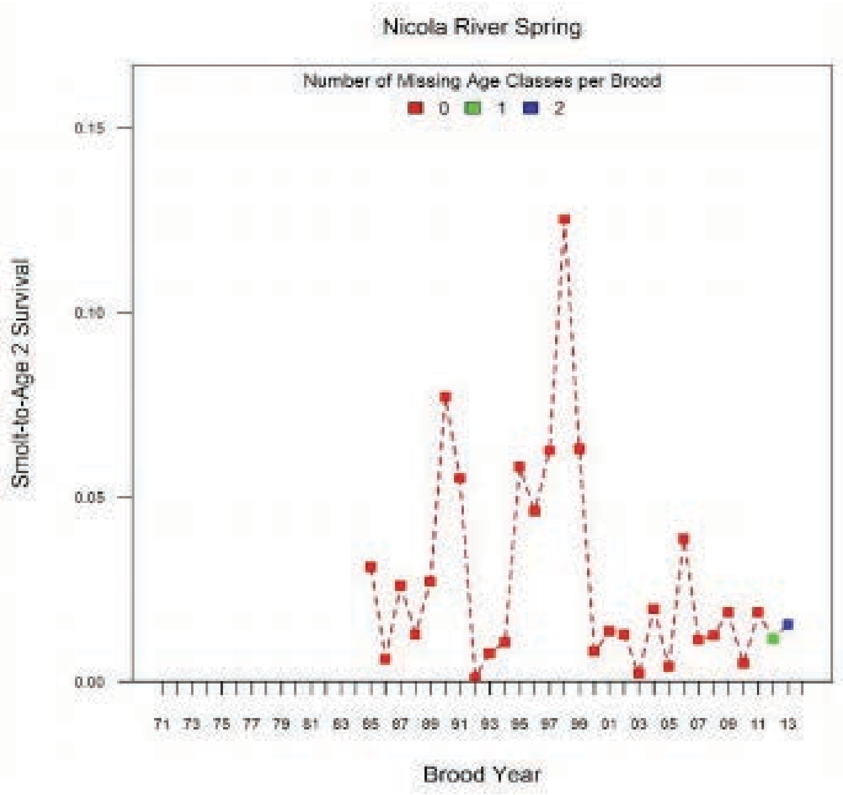

Figure ES-5.Smolt to Age-2 Survival or Nicola River Spring Chinook Salmon

On 5-6 October 2021 and 7-8 February 2022, scientific, biological, and local knowledge experts met to review current information, identify knowledge gaps, and rank the freshwater and marine risks faced by Nicola Chinook. Limiting factors ("LFs") were identified for this stock for each of three life history phases:

- terminal migration and spawning,
- freshwater incubation,
- freshwater rearing

A repeatable process using expert knowledge and opinion was used to score and quantify the biological risk posed by these LFs, which were then ranked in relation to their potential to limit the productive capacity of the stock. Both current and future (50 years hence) biological risk was assessed for each LF: this allowed evaluation of how risks may or may not increase in the future under predicted climate change scenarios.

Highest risk factors in the freshwater environments were identified in the workshops and are reported below. In total there were six limiting factors that pose a very high risk to Nicola Chinook, seven that pose a high risk and 18 that pose a moderate risk. Of the very high-risk factors, one impacts the incubation phase, and the other six impact the freshwater rearing phase. Of the high-risk factors, one impacts the terminal migration and spawning phase, four impact the freshwater incubation phase and two impact the freshwater rearing phase. The moderate risk factors primarily impact the adult migration and spawning and juvenile rearing phases.

Very High Risk factors

Terminal Migration & Spawning

None

Freshwater Incubation

LF16: High suspended sediment loads that reduce egg to fry survival and emergence of alevins

Freshwater Rearing

LF27: High water temperature combined with low DO can suffocate fry/reduce overall fitness during early summer/fall
LF32: Mortality or fitness impacts as a result of inadequate in-stream complexity and riparian complexity
LF35: Low flows reduce seasonally available off channel and tributary rearing habitat.
LF42: Lack of high-quality rearing habitat throughout the river both mainstem and side channels and tributaries
LF46: Mortality or fitness impacts as a result of hatchery introgression

High risk factors

Terminal Migration & Spawning.

LF6: Loss of good quality refuge habitat and safe migration route through the river

Freshwater Incubation

LF20: Lower low flows that dewater redds and reduce incubation survival
LF21: More frequent and higher peak flows over winter can scour/disturb redds
LF22: Egg mortality due to inadequate spawning gravel, or as a result of gravel instability
LF24: Predation of eggs, alevins and fry/smolts by fish (sculpins, brown trout) and birds (mergansers)

Freshwater Rearing

LF30: High levels of sedimentation leading to clogging of interstitial spaces and loss of rearing habitat
LF33: Increased use of low quality off channel habitats

Moderate risk factors

Terminal Migration & Spawning

LF2: Limited or delayed spawner access
LF5: Aggradation creates a migration barrier in the river during adult migration
LF7: High water temperatures in the river during the late summer/early fall migration period can increase migration mortality and sublethal stress
LF10: High suspended sediment loads can reduce spawning habitat quality by compacting gravel and reducing interstices critical for egg deposition and incubation
LF13b: Mortality due to unsanctioned fisheries during migration and at spawning grounds
LF14a: Disturbance to natural migration activity due to anthropogenic restoration impacts

Freshwater Incubation

LF17a: Increased numbers of ice days resulting in mortality of eggs and alevins

Freshwater Rearing

LF28: Low water temperature and lack of groundwater influx resulting in ice in interstitial spaces
LF29: Toxic water quality conditions can increase fry mortality or reduce fitness.
LF31: Mortality or fitness impacts as a result of lack of food

LF34: Higher and earlier flows that prematurely displace juveniles downstream and reduce overall fry survival
LF36: Mortality or fitness impacts as a result of competition or predation from Aquatic Invasive Species (AIS)
LF37: Alteration of natural riparian structure and ecological integrity as a result of colonization of invasive species
LF38: Impacts to juvenile migration as a result of invasive plant species
L**F39b**: Mortality or fitness impacts as a result of competition
LF40: Mortality as a result of high levels of predation in the river
LF43: Lack of access to historical tributary and off channel habitat.
LF45: Mortality or fitness impacts as a result of anthropogenic disturbance

Nicola Chinook are under intense threats as a result of flooding, droughts, water removals, salvage logging, fires and removal of riparian areas. The main threats come from forestry, agriculture, human development and climate change. Anthropogenic disturbance to stream banks and riparian cover is extensive throughout the Nicola Watershed (Ecoscape 2017), but riparian cover is positively correlated with lower thermal sensitivity in the Nicola Watershed (Warkentin 2020). Larger sub-catchments exhibit higher maximum stream temperatures, while smaller ones may provide important thermal refugia (Warkentin 2020). The watershed has been experiencing a higher frequency of severe flood and drought events, resulting in adverse effects to fish and fish habitat. The recent catastrophic floods of 2021 have greatly altered the river and it is as yet unknown what the prognosis is for fish and fish habitat, though loss of deep pools, refuge habitats, and river complexity are clearly apparent, as are the impacts of serious aggradation and channelization.

Primary habitat and ecosystem concerns (T. Willms, pers. comm.) in this watershed include:

- The high level of equivalent clearcut area (ECA) which has major effects on water storage and timing, duration, and intensity of freshet;
- Loss of riparian vegetation, specifically black cottonwood (*Populus trichocarpa*), and their benefits of providing shade, bank stability and instream habitat complexity;
- Effects of high summer stream temperatures on survival and growth of juvenile Chinook Salmon, Coho Salmon and Steelhead;
- Drought and suboptimal streamflow in August which has been correlated with low productivity of Chinook (Warkentin 2020);
- Issues of poor connectivity of streams and floodplains – with impacts to habitat recruitment, refugia and flood intensity;
- Major sediment avulsions and bank topping as a result of flooding- with impacts to migration, egg survival, clogging of rearing habitats, and gravel instability;
- Loss of deep pools and refuge habitats, widening of the channel and changes in lateral and longitudinal connectivity, with impacts to all life stages;
- Changes to the food web, including competitive abilities of native species such as Redside shiner (*Richardsonius balteatus*), and increases in the abundance of invasive species such as Yellow perch (*Perca flavescens*).

Possible mitigation options, research projects and next steps were discussed and are included in this report. The development of a long-term strategic plan to address key limiting factors, including plans for post-fire and post-flood recovery is highly recommended.

It should be noted that to investigate the full suite of risks threatening Nicola basin Chinook, additional workshops are required, focusing on a) risk assessments for juveniles rearing and overwintering in the Lower Thompson River and Mid-Fraser River; b) risk assessment for Nicola-origin juveniles rearing and overwintering in the Lower Fraser, and c) the early marine residence in the Salish Sea.

BACKGROUND ON THE RAMS PROCESS

The Risk Assessment Methodology for Salmon (RAMS) is a methodology designed by Fisheries and Oceans Canada to assess the degree to which Pacific salmon in freshwater, estuarine and marine environments are at risk of impacts from man-made and natural stressors and to help identify and prioritize factors that limit their production or will limit their production in the future. While the RAMS process is generally focused on identifying the limiting factors to population persistence and growth, it can also be applied to assess limiting factors to production within a single life stage, multiple populations comprising a wild salmon conservation unit (CU), or multiple CUs comprising a fisheries management unit (MU). The methodology was adapted from an Australian risk assessment approach to evaluate the effects of fishing within an ecosystem-based fisheries management framework (Hobday et al., 2011, Hyatt et al. in prep). The underlying approach has been widely used to manage fisheries in Australia, and has proven particularly useful in data-deficient systems where quantitative risk assessment is not possible. The RAMS process will not only help DFO meet its mandates under the Wild Salmon Policy but may help inform assessments of cumulative risk from impacts of multiple stressors by the *Fisheries Act*.

Pacific salmon have complex life histories, where the stability of the population size is dependent on individuals successfully transitioning through many life stages. Life stage transitions occur across different habitat types (e.g., stream, estuary, ocean) and ecosystems (e.g., freshwater, estuarine, marine), where salmon are exposed to different man-made (e.g., low flows due to water extraction, high stream temperatures due to logging of riparian forest) and natural stressors or limiting factors (e.g. predation). These limiting factors can impact survival, growth, reproduction, and, in the end, the productivity of a given population or CU. Application of RAMS operates under an assumption that we can systematically examine the biological requirements for each life stage and, on the basis of information derived from both formal assessments and expert opinion, determine how well these requirements are met in each habitat for the population or CU under consideration.

The goal of this project with the Nicola Basin Collaborative was to carry out a Level 1 RAMS process. This process was carried out to support ongoing habitat restoration initiatives as identified by the Nicola Forum.

The key objectives of the Nicola RAMS were as follows:

- Create a common understanding of the state of knowledge regarding the status of Nicola Basin Chinook and its habitat.
- Clarify the long-term outlook under climate change and effects on the population.
- Review the list of critical habitat requirements for the population.
- Identify, review, and agree on the critical habitats and sensitive areas for each stage of the salmon life history.
- Identify and rank the factors limiting the productive capacity of population, that is, the bottlenecks to production.

- Identify knowledge gaps, potential benchmarks, and research or monitoring requirements.
- Identify potential mitigation measures that could improve productivity, i.e. identify project ideas to address highest priority risks and identify linkages to planned activities which could hinder or help improve salmon productivity.
- Create a retrievable record that enables verification of origins and future replication or extension of RAMS assessment results and recommendations.

The Level 1 RAMS is typically made up of five sequential stages:

1. An initial scoping phase that consists determination of the CU/population of interest, setting objectives and collecting background information;
2. A workshop with a small group of key experts to provide an analysis of risk provided termed the Level 1 Risk Assessment;
3. Sharing of risk assessment results with the wider community;
4. A second workshop with the wider community, where the initial scores are discussed, any mitigation options are identified and evaluated, and action plans are developed to address the medium and high-risk factors and key data and research gaps identified in (2) above;
5. Implementation of action plans, mitigation options, research and studies to address high risk limiting factors.

The Nicola RAMS was carried out to complete steps 1-4 above. The first steps involved collation of information about the stock status, life history requirements of each life stage, habitat/ecosystem status and key limiting factors. This was followed by a series of two workshops to evaluate and rank the limiting factors by the level of risk they present to the population, as well as to gather additional information on knowledge gaps, habitat condition, critical habitats and action items.

Moving forward, it is recommended that step 5 is initiated with the Nicola Collaborative and Technical Committee and other important groups within the watershed including the new Restoration Table. This step should ideally involve the development of a management plan for Nicola Basin Chinook. The management plan should focus on addressing those limiting factors that pose the highest risk to the population as well as lower risk limiting factors that will likely present a high risk in the future, if unaddressed. Actions may include implementing additional management measures, habitat restoration measures, enhancement, and research to fill in high-priority data gaps. Climate change adaptation must be considered when setting both objectives and strategies to ensure that the management plan is robust to climate change.

Following a Level 1 RAMS process, there may be a follow up process which utilizes the results of step 5 above to re-assess the limiting factors at a future point. Mitigation action aimed to address high risk limiting factors following a Level 1 evaluation may result in a lowering of biological risk; while additional data gathered from research and scientific and technical studies will allow for a more focused and semi-quantitative approach termed a Level 2 Risk Assessment. Following this can be an iterative process whereby the risk assessment results are re-assessed at varying intervals as remediation, action planning, research and data collation take place between workshops, with each risk assessment increasingly quantitative in nature.

Thus, the RAMS assessment uses a hierarchical approach that also leads to a rapid identification of high-risk, cause-and-effect impacts of either natural or human-origin stressors on salmon productivity, which in turn can lead to immediate remedial action (i.e. a risk management response) (Figure 2).

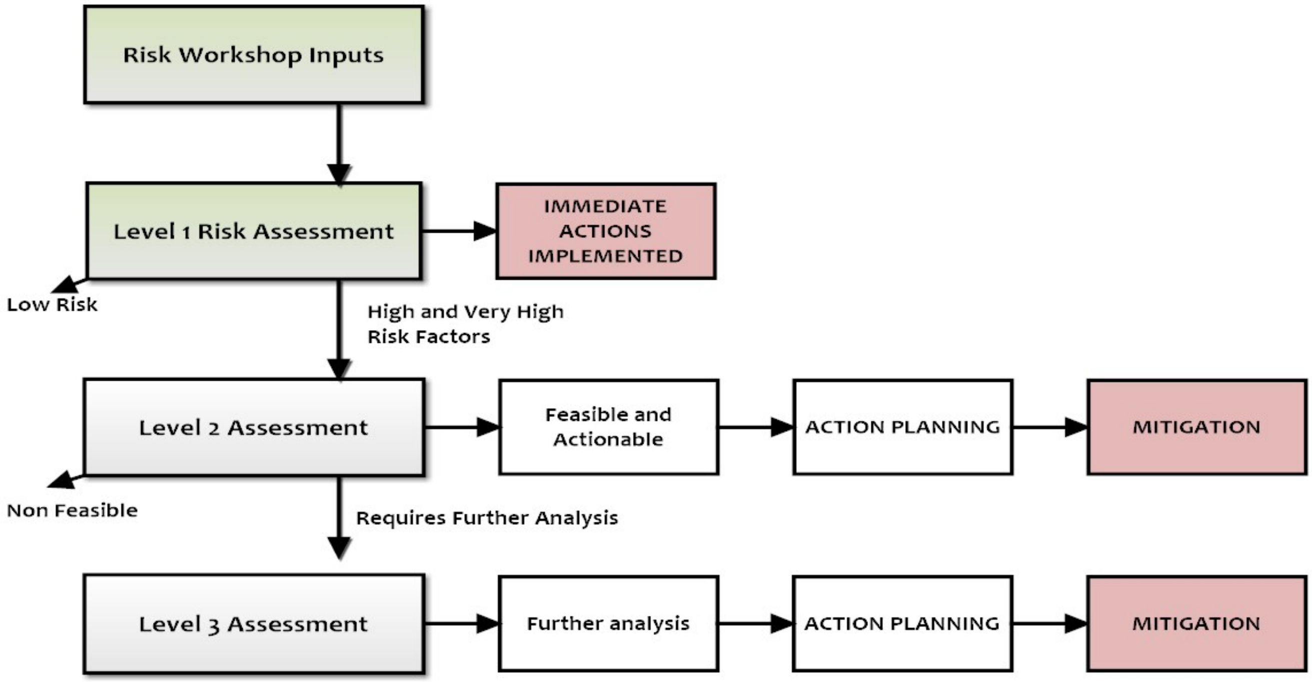

Figure 1. Flow chart depicting the hierarchical process utilized by RAMS

Here we report on the results of the RAMS Level 1 process as applied to Nicola Basin Chinook in the Nicola basin. Additional level 1 processes are still required to assess risks in the Lower Thompson and Mid Fraser, in the Lower Fraser and in the Salish Sea.

SETTING THE STAGE

The Nicola Watershed lies within the unceded traditional territories of the Nlaka’pamux and Syilx Nations. First Nations Bands in this region include:

- Upper Nicola (Syilx)
- Lower Nicola (Nlaka’pamux)
- Coldwater (Nlaka’pamux)
- Nooaitch (Nlaka’pamux)
- Shackan (Nlaka’pamux)
- Cook’s Ferry (Nlaka’pamux)

Located within the Semi-Arid Steppe Highland Ecodivision (Demarchi 2011), this area is characterized by hot summers, cold winters and low precipitation (generally between 300-500mm/yr.). Vegetation communities typically transition from semi-arid bunchgrasses e.g. bluebunch wheatgrass (*Pseudoroegneria spicata*) and needle-and-thread grass (*Stipa comata*) and ponderosa pines (*Pinus ponderosa*) at lower elevations, to montane ecosystems, including Douglas-fir (*Pseudotsuga menziesii var. glauca*), lodgepole pine (*Pinus contorta*) and Interior spruce (*Picea glauca x engelmannii*).

This ecodivision also includes a scattered component of subalpine ecosystems which are characterized by Engelmann spruce (*Picea engelemannii*) and subalpine fir (*Abies lasiocarpa*) (Demarchi 2011).

Higher precipitation areas of the watershed include those sub-catchments that drain the east slopes of the North Cascade Mountains – most notably the Coldwater River and Spius Creek. Central and eastern portions of the watershed are generally drier due to the climatic effects of lower elevations as well as being in the rain shadow of the Coast and North Cascades Mountains.

The Nicola River is a tributary of the Thompson River and is a sixth order stream located in the interior of southern British Columbia (Figure 1). The Nicola River produces early-run Chinook, Coho, and steelhead to the Thompson and Fraser River. Important tributaries to the Nicola for salmonids include the

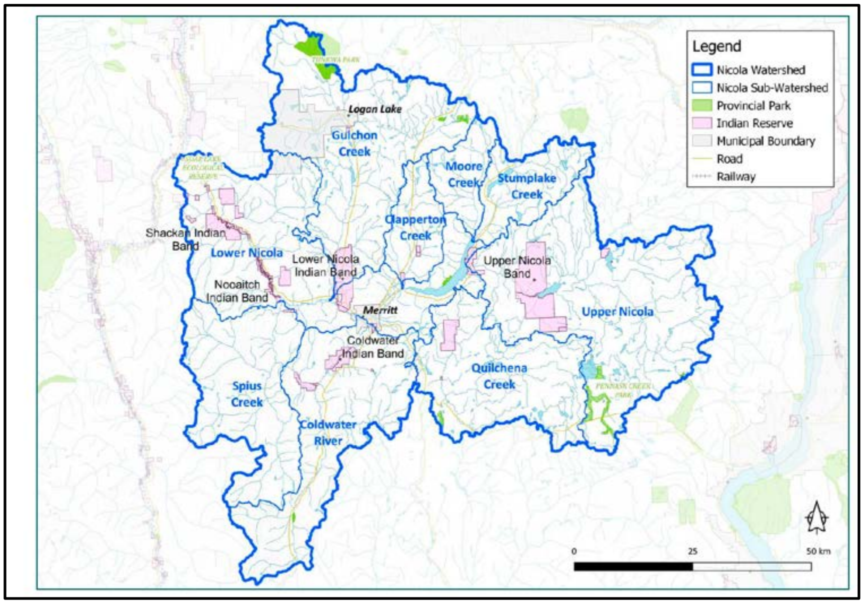

Figure 1. A map of the Nicola Valley showing sub-basins (blue), First Nation communities, parks and municipalities. From the Nicola Watershed Characterization report (ESSA Technologies Ltd. and Fraser Basin Council 2019)

Coldwater River and Spius, Maka, Spahomin, Skuhun, Shakan, Quilchena, Clapperton and Guichon creeks.

Historically, the Nicola River was an important contributor to interior Fraser River salmon production. However, current salmon escapements to the Nicola system are depressed: Interior Fraser River Coho stocks were COSEWIC designated in 2002, a designation which prompted the need for immediate recovery goals to be established by the Interior Fraser Coho Recovery Team (DFO 2006). Nicola Chinook (as parts of Fraser River Spring 1.2 DU) were designated by COSEWIC as endangered in November 2020.

Nicola Chinook make up part of the Fraser Spring 42 Chinook Management Unit. Coded-wire tagged (CWT) Nicola River Chinook released from the Spius Creek Hatchery form the Pacific Salmon Treaty (PST) exploitation rate indicator stock used to assess survival and exploitation rates of Spring 4_2 Chinook in Canadian and U.S. fisheries.

DFO's outlook for Spring 4_2 Chinook states that this is a stock of concern with continued expectations for depressed abundance due to low parental escapements, ongoing unfavorable marine and freshwater survival conditions and low productivity.

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iii. Third variation is to emerge and remain in natal stream

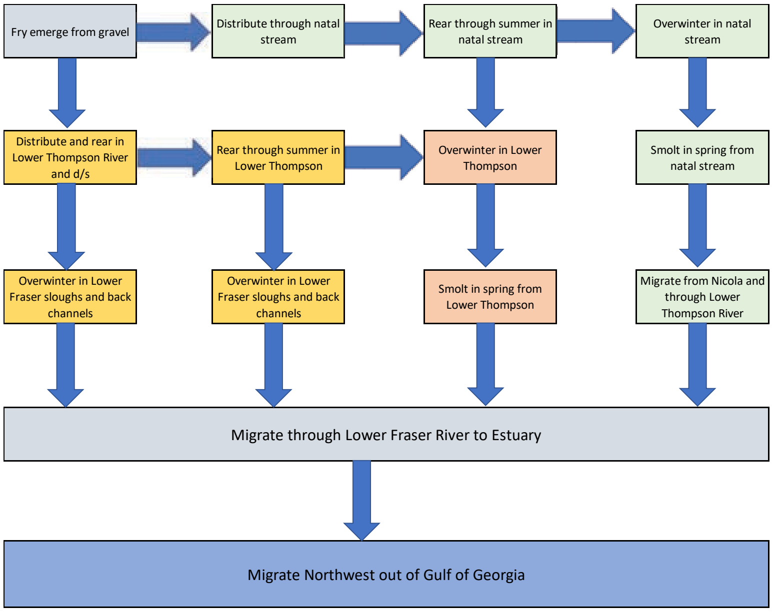

Figure 2. Three variants in the life history of Nicola Chinook. From RE Bailey.

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Relative to historical data records, Nicola Chinook escapements have declined appreciably over time (Figure 3). Escapements have varied between 538 (2009) and 17,777 (1996), with an average of approximately 5,550. Hatchery returns started in 1987 with the largest contribution (~79%) in 1991, the smallest contribution (4%) in 1996, and an average contribution of 30% since 1987 (Figure 4).

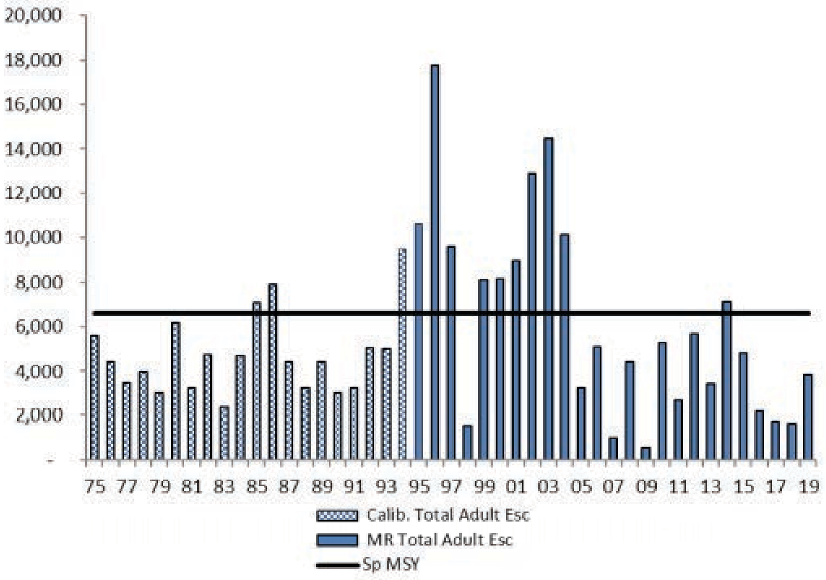


Figure 3. Nicola Chinook Salmon Escapements 1975-2019

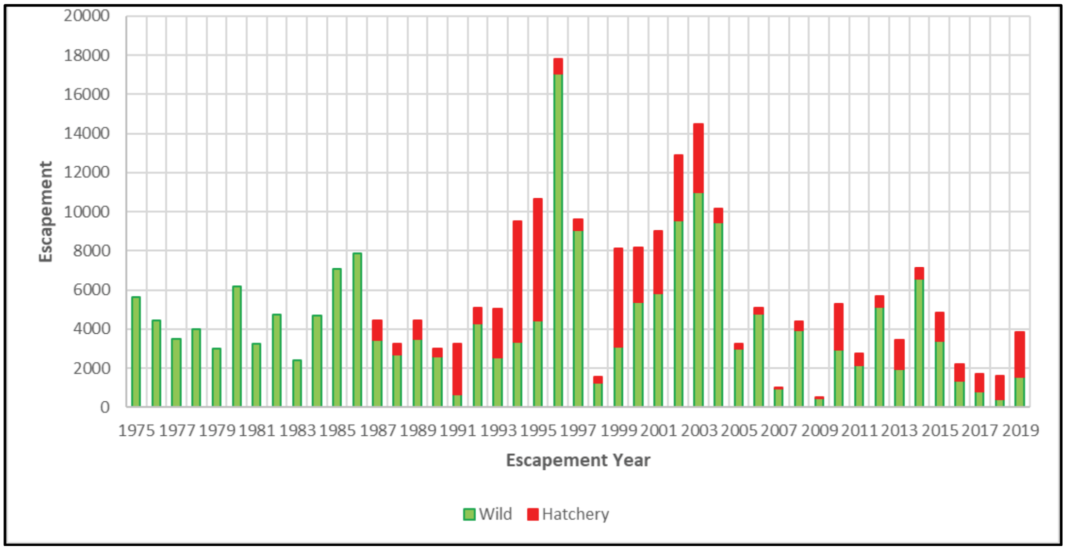


Figure 4. Relative Escapements of Naturally Produced and Enhanced Origin Chinook Salmon to Nicola River 1975-2019

Marine survival fluctuated considerably for Nicola Chinook before the 2000 brood year; since 2000 marine survivals have been poor although there was one moderate year (2006) (Figure 5).

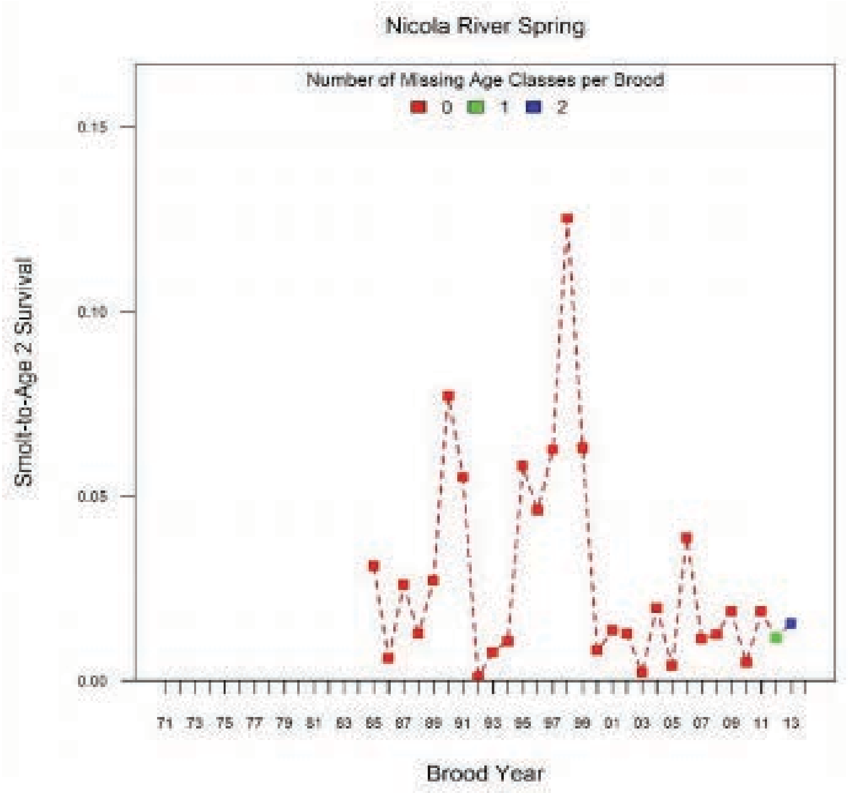


Figure 5. Smolt to Age-2 Survival or Nicola River Spring Chinook Salmon

Salmon are often considered a keystone indicator of watershed health because the various life stages are so dependent on the habitat and ecosystems in which they are found. The abundance and productivity of naturally spawning Nicola Chinook is based on factors in both freshwater and the marine environments and is below target levels. In October 2021 and February 2022, scientific, biological, and local knowledge experts met to review current information, identify knowledge gaps, and rank the freshwater and marine risks faced by Nicola Chinook. Limiting factors ("LFs") are alternative hypotheses for the causes of decline; a total of 51 LFs were identified for this stock for each of three life history phases:

- Terminal Migration and Spawning,
- Freshwater Incubation,
- Freshwater Rearing

A repeatable process using expert knowledge and opinion was used to score and quantify the biological risk posed by these LFs, which were then ranked in relation to their potential to limit the productive capacity of the stock. Both current and future (50 years hence) biological risk was assessed for each LF: this allowed evaluation of how risks may or may not increase in the future under predicted climate change scenarios. The RAMS process is described in more detail below.

NICOLA BASIN CHINOOK RAMS METHODOLOGY

The Nicola RAMS process generally followed the steps as outlined in Figure 6 below.

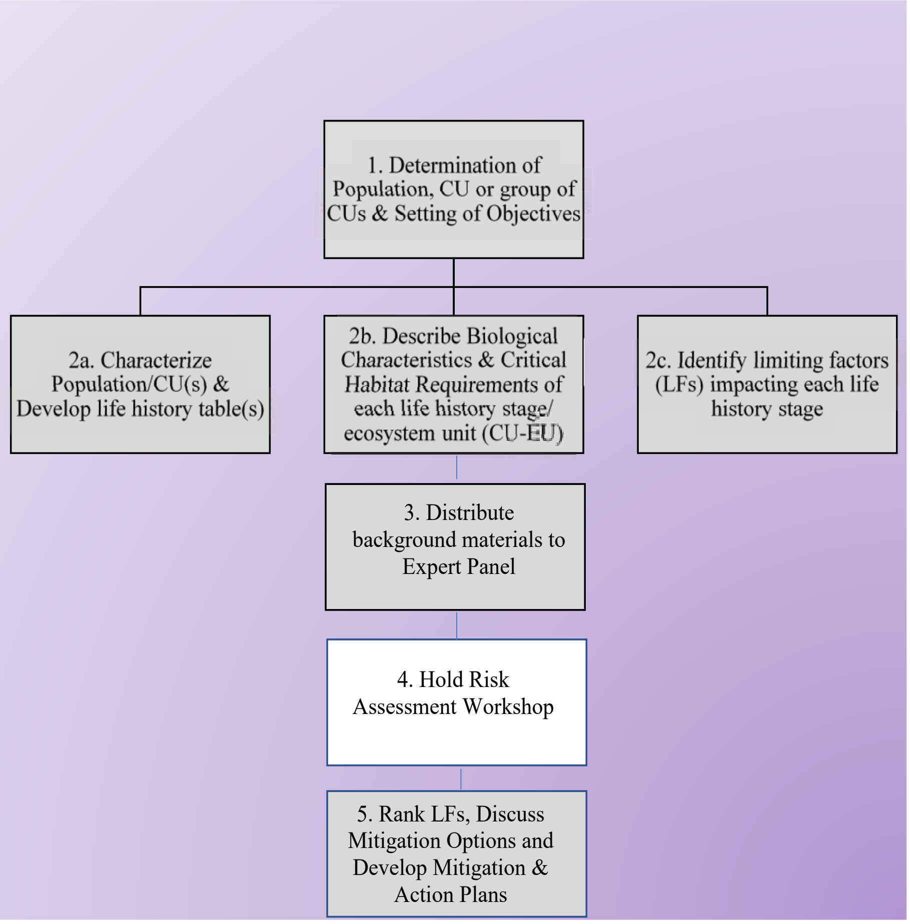


Figure 6. The steps to a Level 1 Risk Assessment Process

Scoping Phase

The first stage of the Level 1 Nicola RAMS process was the Scoping stage. This phase involved the collection of specific information for Nicola Basin Chinook and included the following steps:

1. Determine of the population of interest.

2a. Collect background data for the population of interest, its habitat and ecosystem, and develop a life history table.

2b. Describe biological characteristics and requirements of each life-history stage/ ecosystem.

2c. Gather information on the key limiting factors to production of each life history stage of the population.

1.Determination of the Population of Interest

To date, most RAMS processes have focussed on the freshwater life history stages, beginning with terminal migration and spawning (adults), incubation (eggs and alevins), early rearing (fry and smolts) and estuary rearing (smolts). For Nicola Basin Chinook, the complex life history and large number of interconnected habitats make a RAMS a particularly complex task. For this reason, the first Nicola RAMS process focussed on adult Chinook life stages during terminal migration into the Nicola River, through spawning, egg incubation, early rearing and overwintering, up to the stage that smolts leave the Nicola for the Fraser on their way to the Strait of Georgia. We did not include the Fraser River migration period, the Fraser estuary or any of the marine component in this first risk assessment process. The lower Thompson / Mid Fraser rearing and migration environments need a separate Level 1 process as does the Lower Fraser rearing and migration environment. It is expected that subsequent RAMS processes will focus on these other stages of the life history.

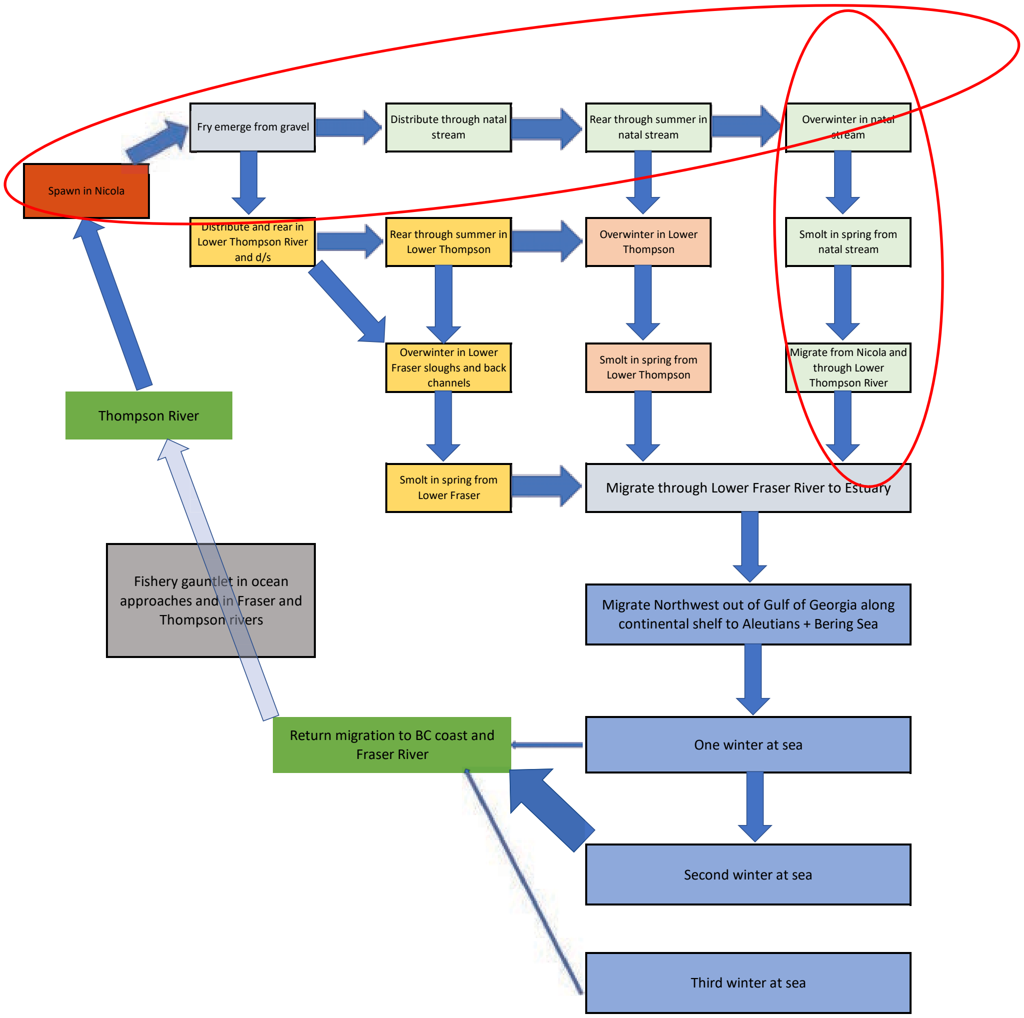


Figure 7: Nicola Watershed Chinook Life History**.** The red circles highlight the components of the life history that were addressed during this RAMS process.

2a. Background data collection for the population of interest, its habitat and ecosystem, and development of life history table

The next stage of the scoping phase was to collate the background information on Nicola Basin Chinook, as well as for the freshwater habitats and ecosystems encountered during the phases of the life history outlined in step 1 above. For Nicola Chinook, this included collation of population data such as escapements, sex ratios, spawner abundances, fecundity data, and stage-specific mortality estimates which enabled us to build a simple informative life history table for the population.

For the freshwater habitats, it included collation of information through literature review, from the PSF Pacific Salmon Explorer, geospatial analyses by MC Wright and Associates Ltd., and assessment of the many geospatial layers collated by ESSA during the Nicola Characterization Project. It also included collation of information on a number of pressure and state indicators which shed light on the state of habitat for Nicola Basin Chinook. Stalberg et al. (2009) developed a series of pressure and state indicators that could be used to monitor salmon habitat status under Strategy 2 of the Wild Salmon Policy. Pressure indicators are considered descriptors of landscape-level (and generally man-made) stressors, which can often be evaluated through the spatial analysis of remotely sensed data. State indicators are descriptors of specific habitat conditions, and are typically representative of 'on-the-ground' data collected during field operations.

During this phase, a backgrounder of Nicola Basin Chinook was created, indicators of habitat status were collated and a number of informative videos were developed that described the status of both the stock and the habitat. **Appendix 1** provides details of Nicola Chinook, stock status, life history, marine survival, hatchery production, escapements and fisheries. **Appendix 2** provides details about the habitat status and key habitat pressure indicators. Further details can be found in the videos below:

- Chinook Stock Status by Richard Bailey: https://www.youtube.com/watch?v=k3zpQoYMF8c&t=217s
- Habitat Primer by Tom Willms: https://www.youtube.com/watch?v=g2uSgr4aPy8
- Nicola Pressure Indicators by Miranda Smith (of MC Wright and Co): https://youtu.be/YCzkaLRFvMI

In addition, Kyle Wilson developed a cumulative effects life cycle model, described below.

Nicola River Chinook salmon: Cumulative effects and life cycle model by Kyle L. Wilson

The cumulative effects life cycle model for Nicola River Chinook Salmon was developed by linking aspects of the Alberta cumulative effects model (Fisheries and Oceans Canada 2019; MacPherson *et al.* 2020) with the density dependent life cycle processes from van der Lee & Koops (2020). In this model, the Nicola River Chinook life cycle was developed from conversations with Richard Bailey (personal communications) regarding the life stages and spatial structure for Chinook salmon among the watershed (Figure 8).

In the first stage, juvenile fry (stage 1) emerged from their respective egg and alevin recruitment stage. The recruitment function (top-right life stage) converts the spawning adults to the number of surviving fry such that τ represents the sex-ratio of the returning adult spawning cohort, ϕ represent the number of eggs produced per spawning female, s_ϕ egg-to-alevin survival, s_0 alevin-to-fry survival in the function f. Surviving fry then transitioned into one of three parr life stages including: (stage 2) overwintering resident parr to the Nicola River, (stage 3) fall migrants to the upper Thompson River, and (stage 4) spring migrants to the Fraser River – some parr upper Thompson River further emigrated into Fraser River. Surviving parr then transitioned into smolts (stages 5-8) from their respective overwintering habitats, which then out-migrated to the Pacific Ocean. Marine sub-adults (stage 8) then spent some time at-large in the Pacific Ocean prior to migrating back to the Nicola River for spawning (stage 9) and subsequent recruitment of eggs and alevin life stages (top-right function).

$$\begin{array}{ccccccccc}
 & & & & & & & & \text{Recruitment} \\
\text{Fry} & \text{Parr (NR)} & \text{Parr (TR)} & \text{Parr (FR)} & \text{Smolt (NR)} & \text{Smolt (TR)} & \text{Smolt (FR)} & \text{Ocean} & \text{Adult} \\
s_1(1-g_{1,2}+g_{1,3}+g_{1,4}) & 0 & 0 & 0 & 0 & 0 & 0 & 0 & f(\phi s_\phi s_0 \tau) \\
s_1 g_{1,2} & s_2(1-g_{2,5}) & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
s_1 g_{1,3} & 0 & s_3(1-g_{3,4}+g_{3,6}) & 0 & 0 & 0 & 0 & 0 & 0 \\
s_1 g_{1,4} & 0 & s_3 g_{3,4} & s_4(1-g_{4,7}) & 0 & 0 & 0 & 0 & 0 \\
0 & s_2 g_{2,5} & 0 & 0 & s_5(1-g_{5,8}) & 0 & 0 & 0 & 0 \\
0 & 0 & s_3 g_{3,6} & 0 & 0 & s_6(1-g_{6,8}) & 0 & 0 & 0 \\
0 & 0 & 0 & s_4 g_{4,7} & 0 & 0 & s_7(1-g_{7,8}) & 0 & 0 \\
0 & 0 & 0 & 0 & s_5 g_{5,8} & s_6 g_{6,8} & s_7 g_{7,8} & s_8(1-g_{8,9}) & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & s_8 g_{8,9} & s_9
\end{array}$$

Figure 8. Nicola River life cycle model.

Stage-structured life cycle model

We modelled density dependence in stage-structured survival rates as a function of baseline survival $s_{i,0}$ (survival at carrying capacity), carrying capacity of the life stage K_i, and survival compensation ratio (ω_i; the amount of improvement in survival at carrying capacity to 0 densities) using a Beverton-Holt function such that:

$$(1) \qquad s_{i,t} = \frac{s_{i,0}\omega_i}{1+\frac{(\omega_i-1)N_{i,t}}{K_i}}$$

$$(2) \qquad N_{i,t+1} = \mathrm{s}_{\mathrm{i,t}} N_{i,t}$$

where *N* is population abundance at stage *i*. This allowed for life stages to compensate to increased disturbances and lowers population densities by increasing their per-capita survival. Cumulative effects then reduce either the baseline survival or the carrying capacity of the system:

$$(3) \qquad s_{i,0} = s_{i,N} \sum_{j=1}^{J} \beta_{j,s} x_j$$

$$(4) \qquad K_i = K_{i,N} \sum_{j=1}^{J} \beta_{j,K} x_j$$

where x_j is the level of stressor *j* and $\beta_{j,s}$ or $\beta_{j,K}$ is the effect size of stressor x_j on survival or capacity, respectively. In this formulation, cumulative effects were modelled as a continuous percent loss from pristine to impacted demographic traits. We then relied upon knowledge from local watershed experts to specify and hypothesize whether, how much, and when stressors would target the different demographic rates of interest in eq. 3 and 4 and, if so, which life stages in Figure 1 were to be affected by that stressor.

The above stage-structured model is flexible and can be expanded to include any number of life stages or spatial structure. The model was based on input set of natural survival rates ($s_{i,0}$), compensation ratios (ω_i), and adult spawning female carrying capacity (K) tailored for Nicola River Chinook. Stage-specific carrying capacities were then solved for by running the model to a stable stage distribution assuming no density dependence. Without density dependence (eq. 2), this model simplifies to a stage-based matrix model and stable stage distributions can solved analytically (by finding the determinant of the dominant eigenvector) or numerically by simulating population dynamics towards equilibrium. We then modelled the effects of cumulative stressors by running the model with density dependence and finding the stable stage distribution through numerical methods by simulating population dynamics forward to equilibrium. We evaluated each stressor individually and then all stressors cumulatively using performance metrics that included: (1) adult female spawner abundances compared to baseline, (2) Nicola River parr abundances compared to baseline and (3) the Nicola River out-migrating smolt abundances compared to baseline.

2b and c. Describe Biological characteristics and Requirements of each Life-History Stage/ Ecosystem Unit. Gather information on the key limiting factors to production of each life history stage of the population

This important step of the scoping process involved the identification of critical habitat requirements and potential limiting factors/ key issues that impact the different life history stages/ecosystem for Nicola Basin Chinook. **Appendix 3** provides background information on key threats to Nicola Chinook, while **Appendix 4** provides information on the critical habitat requirements of Nicola Chinook. Within **Appendix 4** also are a series of detailed tables with information on potential limiting factors, knowledge specific to each life history stage of Nicola Chinook that is being assessed during this RAMS process (adult migration and spawning; incubation; freshwater rearing), and any information on indicators and benchmarks that may assist in understanding the conditions that are needed for Nicola Chinook to survive. Table 1 below provides a simplified list of the critical habitat requirements and potential limiting factors that were to be assessed during this Level 1 RAMS.

Table 1. Critical Habitat Requirements and Potential Limiting Factors impacting Nicola Basin Chinook

a. Terminal Migration and Spawning

Critical Habitat Requirements	Limiting Factors
1. Safe holding habitat in confluence of Thompson-Nicola prior to upriver migration into the Nicola River	**LF1:** Unsanctioned fisheries in the confluence of Thompson- Nicola
2. Adequate flows to facilitate upstream passage of spawners	**LF2:** Limited or delayed spawner access
3. Unrestricted migration and passage throughout mainstem and off-channel habitat	**LF3:** Potential delays in upstream migration due to counting fences, fishways and other manmade structures **LF4:** Reduced access through natural falls and natural barriers
4. Dynamic equilibrium in channel morphology, maintenance of channel capacity, adequate channel depths and natural level of sediment transport.	**LF5:** Aggradation creates a migration barrier in the river during adult migration
5. Clear and safe passage with adequate refuge habitat	**LF6:** Loss of good quality refuge habitat and safe migration route through the river due to channelization, loss of habitat complexity and instream cover features
6. Suitable water quality	**LF7*:** High water temperatures in the river during the late summer/early fall migration period can increase migration mortality and sublethal stress **LF8*:** Poor water quality conditions during the late summer/early fall migration period (low DO, coliform levels, deleterious substances) * Note that these LFs can be split to address migrating, holding and/or spawning salmon separately if required.
7. Availability of high quality and sufficient quantity spawning habitat	**LF9:** Lack of natural gravel recruitment to mainstem spawning sites. **LF10:** High suspended sediment loads can reduce spawning habitat quality by compacting gravel and reducing interstices critical for egg deposition and incubation **LF11**: Colonization of invasive species that reduces spawning habitat quality. **LF12.** Lack of a sufficient quantity of good quality spawning habitat
8. Low levels of predation during migration and spawning	**LF13a:** Mortality due to predation at spawning grounds **LF13b:** Mortality due to unsanctioned fisheries during migration and at spawning grounds
9. Lack of anthropogenic disturbance	**LF14a:** Disturbance to natural migration activity due to anthropogenic restoration impacts **LF14b:** Disturbance to natural spawning activity due to anthropogenic impacts **LF14c:** Disturbance to spawning or migration as a result of cattle trampling
10. Lack of disease during migration and spawning	**LF15:** Pre-spawn mortality due to disease

b. Incubation

Critical Habitat Requirements	Limiting Factors
1.Good water quality conditions	**LF16:** High suspended sediment loads that reduce egg to fry survival and emergence of alevins **LF17a:** Increased numbers of ice days resulting in mortality of eggs and alevins **LF17b:** Non-optimal water temperatures that reduce fry survival by changing emergence time in relation to food availability **LF18:** High levels of pollutants or toxins that reduce egg to fry survival **LF19:** Low DO which reduces egg to fry survival
2. Suitable flow regime	**LF20:** Lower low flows that dewater redds and reduce incubation survival
2. Suitable flow regime	**LF21:** More frequent and higher peak flows over winter can scour/disturb redds
3.Appropriate spawning gravel	**LF22:** Egg mortality due to inadequate spawning gravel, or as a result of gravel instability
4.Minimal biological disturbance to redds	**LF23:** Reduced egg to fry survival due to chum or other salmonid overspawn
5.Minimal predation of eggs, alevins and fry	**LF24:** Predation of eggs, alevins and fry/smolts by fish (sculpins, brown trout) and birds (mergansers)
6. Lack of invasive species	**LF25:** Egg /alevin mortality due to redd disturbance by invasive or expanding endemic species
7. Lack of anthropogenic disturbance	**LF26:** Egg mortality due to redd disturbance by humans

c. Early Rearing

Critical Habitat Requirements	Limiting Factors
1.Suitable water temperature, TSS, dissolved oxygen levels, pH, hardness, supersaturation	**LF27:** High water temperature combined with low DO can suffocate fry or reduce overall fitness during the early summer/fall **LF28:** Low water temperature and lack of groundwater influx resulting in ice in interstitial spaces **LF29:** Toxic water quality conditions can increase fry mortality or reduce fitness **LF30:** High levels of sedimentation leading to clogging of interstitial spaces and loss of rearing habitat
2.Adequate food supply	**LF31:** Mortality or fitness impacts as a result of lack of food
3.Adequate instream complexity and riparian complexity	**LF32:** Mortality or fitness impacts as a result of inadequate in-stream complexity and riparian complexity
4.Adequate water levels and connectivity.	**LF33:** Increased use of low quality off channel habitats
5. Natural flow regime	**LF34:** Higher and earlier flows that prematurely displace juveniles downstream and reduce overall fry survival **LF35:** Low flows reduce seasonally available off channel and tributary rearing habitat.

Critical Habitat Requirements	**Limiting Factors**
6. Absence of invasive species	**LF36:** Mortality or fitness impacts as a result of competition or predation from Aquatic Invasive Species (AIS) **LF37:** Alteration of natural riparian structure and ecological integrity as a result of colonization of invasive species LF38: Impacts to juvenile migration as a result of invasive plant species
7. Low levels of competition with other wild salmon/ hatchery fry /other species	**LF39a:** Mortality or fitness impacts as a result of competition with hatchery f **LF39b:** Mortality or fitness impacts as a result of competition with other salmon and other species ry/smolts
8.Low levels of predation to fry	**LF40:** Mortality as a result of high levels of predation in the river
9.Low levels of fish disease	**LF41:** Mortality or fitness impacts as a result of disease
10. High quality rearing habitat with good instream complexity	**LF42:** Lack of high-quality rearing habitat throughout the river both mainstem and side channels and tributaries
11. Unrestricted migration and passage: mainstem, off channel and tributary habitat	**LF43:** Lack of access to historical tributary and off channel habitat. **LF44:** Limited juvenile passage at lake fishway, tributary culverts etc.
12. Lack of anthropogenic disturbance	**LF45:** Mortality or fitness impacts as a result of anthropogenic disturbance
13. Low or no levels of artificial augmentation from hatcheries	**LF46:** Mortality or fitness impacts as a result of hatchery introgression

3 and 4. Nicola Basin Chinook Level 1 Risk Assessment Workshops

Following the scoping stage, the Nicola Basin Chinook RAMS process was carried out as a two -step process, with two workshops (both conducted by Zoom).

The objectives for each workshop were similar and were as follows:

- Create a common understanding of the state of knowledge regarding the status of Nicola Basin Chinook and its habitat.
- Clarify the long-term outlook under climate change and effects on the population.
- Review the list of critical habitat requirements for the population.
- Identify, review, and agree on the critical habitat and sensitive areas for each stage of the salmon life history.
- Identify and rank the factors limiting the productive capacity of population, that is, the bottlenecks to production.
- Identify knowledge gaps, potential benchmarks, and research or monitoring requirements.
- Identify potential mitigation measures that could improve productivity, i.e. identify project ideas to address highest priority risks and identify linkages to planned activities which could hinder or help improve salmon productivity.

- Create a retrievable record that enables verification of origins and future replication or extension of RAMS assessment results and recommendations.

Prior to each workshop, the various background materials were delivered to all attendees. These included:

- The Nicola Chinook Backgrounder document detailing key information including stock status information, life history profiles, fishery information, habitat status, possible impacts of climate change and known risks/limiting factors (This information is provided through **Appendices 1, 2 and 3**).
- The fully developed background tables organized by life history stage, with information on critical habitat and biological requirements, potential limiting factors, and information on benchmarks, causal factors and information gaps (**Appendix 4**).
- A short risk assessment guide that can be used to assist in scoring (**Appendix 5**).
- An agenda (**Appendix 6** -workshop 1 and **Appendix 7**-workshop 2).

Both workshops began with an introduction to the RAMs process, followed by a number of presentations which provided information on stock status, life history profiles, fishery management, habitat status, and the impacts of climate change. Each workshop was also provided a presentation that clearly outlined the RAMS scoring procedure.

Workshop 1: For the first workshop in October 2021, a small team of experts met to go through the RAMS scoring process. The overall aim of this meeting was to produce a "straw-dog" set of current and future biological risk scores for the liming factors collated. The expert group was made up of the following members:

Table 2. Attendees for Workshop 1- Straw Dog Risk Assessment Scoring Expert Panel

Richard Bailey, DFO emeritus
Tom Willms, UNBC
Paul Mozin, STC
Rich McCleary, DFO
Chuck Parken, DFO
Kaitlyn Dionne, DFO
Nicole Trouton, DFO
Kyle Wilson, SFU
Isobel Pearsall

The agenda for this workshop is available in **Appendix 6**. During workshop 1, the expert panel discussed each requirement/limiting factor in turn and worked through the RAMS scoring procedure to determine biological risk of each limiting factor. They also provided input on some additional limiting factors that the group suggested should be added, and which were included for workshop 2. The scoring procedure is outlined in **Appendix 5**. Briefly, each potential limiting factor was assessed over two timeframes, the first based on "current conditions", and the second based on "future conditions – those predicted for 50 years into the future". Carrying out the analysis over these two time periods allowed us to examine how the impacts of various stressors were anticipated to change due to ongoing events such as climate change or altered land use practices (e.g. forest cover removal, urbanization etc). This group met over two days, discussed each limiting factor in turn, and **Appendix 8** provides details of the final scores derived from this process.

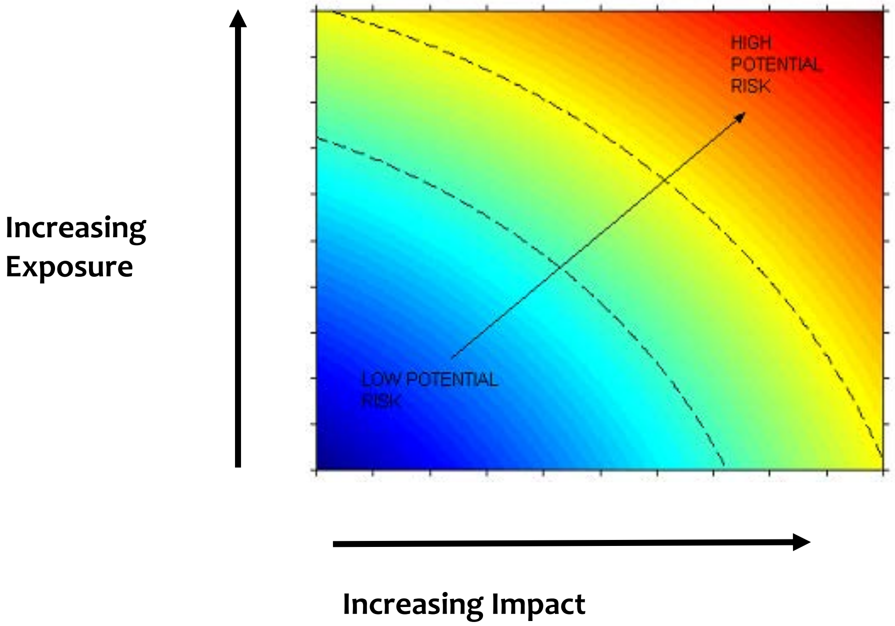
Workshop 2: In February 2022, the Nicola Research Collaborative group met over two days to assess the scores created by the "straw-dog team". This workshop was facilitated by Marcel Shepert, and the agenda is available in **Appendix 7.** The group provided input on the risk ratings from workshop 1, as well as additional information on all limiting factors, identified new sources of information, additional knowledge gaps and provided input on potential next steps and action items. Information on limiting factors, final consensus scores, identification of knowledge gaps, and potential action items from both Workshops 1 and 2 are collated in the Results section below. Attendees for the second workshop were as follows:

Table 3. Attendees for Workshop 2

Leona Antoine, NWGP
Patrick Farmer, FLNRORD
Richard Bailey, DFO Emeritus
Sarah Ostoforoff, DFO
Jon Moore, SFU
Natalie Mahara
Paul Mozin, STC
Pedro Gonzalez
Christian St-Pierre, FLNRORD
Kyle Wilson, SFU and CCIRA
Crystal McMaster, NWGP
Susan White
Chuck Parken, DFO
Jordan Rosenfeld, FLNRORD
Dale Robertson
Sarah Derosier, MoF
Tammy Brown, FLNRORD
Sara Martin, DFO
Tom Willms, UNBC
Mark Potyrala, DFO
Sean Naman, DFO
Betty Rebellato, CWF
Chelsea Enslow, MoF
Mike Simpson, FBC
Brian Holmes, Upper Nicola IB
Tracy Thomas, FLNRORD
Lauren Jarvis
David Lawrence, Nooaitch IB
Joel Harding DFO
Colin McGregor DFO
Miranda Smith, MC Wright and Associates, Ltd.
Isobel Pearsall

RAMS Scoring Process

Building on the concepts of other risk-assessment frameworks, RAMS evaluates the risk to each life history stage of a given salmon population from stressors based on two axes of information: "exposure" and "consequence". The term exposure (E) is synonymous with the term "likelihood" which is used in some risk assessment methodologies.



The first axis, exposure, is related to the exposure of a particular life history stage to a particular stressor, and the other axis is related to the outcome or consequence (C) for the salmon life history stage of the limiting factor with respect to an outcome (e.g. future abundance, size composition etc.), given exposure by that stage to the stressor.

This framework follows the same general structure and scoring dimensions of other risk assessments, subject to some modifications, and provides guidance on the scoring of the subcomponents of E and C when the RAMS is implemented.

The risk to a given life history stage from exposure to a given stressor is calculated as:

Risk = Exposure *Consequence

Details about the RAMS scoring procedure can be found in **Appendix 5.**

NICOLA BASIN CHINOOK RAMS RESULTS

Limiting Factors Posing Risk to Nicola Basin Chinook

The final consensus scores from the RAMS workshops were added to a RAMS Excel workbook which automatically shows the current and future biological risk ratings, colour coded deep red for very high risks, red for high risks, amber for moderate risks and green for low risks (Table 4 below). Key discussion points, including identification of knowledge gaps and potential actions are provided in Table 5 below.

In total there were six limiting factors that pose a very high risk to Nicola Chinook, seven that pose a high risk and 18 that pose a moderate risk (Tables 6-8).

Of the very high-risk factors, one impacts the incubation phase, and the other six impact the freshwater rearing phase. Of the high-risk factors, one impacts the terminal migration and spawning phase, four impact the freshwater incubation phase and two impact the freshwater rearing phase. The moderate risk factors primarily impact the adult migration and spawning phases and juvenile rearing.

Table 6. Very High Risk Factors

Terminal Migration & Spawning

None

Freshwater Incubation

LF16: High suspended sediment loads that reduce egg to fry survival and emergence of alevins

Freshwater Rearing

LF27: High water temperature combined with low DO can suffocate fry/reduce overall fitness during early summer/fall
LF32: Mortality or fitness impacts as a result of inadequate in-stream complexity and riparian complexity
LF35: Low flows reduce seasonally available off channel and tributary rearing habitat.
LF42: Lack of high-quality rearing habitat throughout the river both mainstem and side channels and tributaries
LF46: Mortality or fitness impacts as a result of hatchery introgression

Table 7. High Risk Factors

Terminal Migration & Spawning.

LF6: Loss of good quality refuge habitat and safe migration route through the river

Freshwater Incubation

LF20: Lower low flows that dewater redds and reduce incubation survival
LF21: More frequent and higher peak flows over winter can scour/disturb redds
LF22: Egg mortality due to inadequate spawning gravel, or as a result of gravel instability
LF24: Predation of eggs, alevins and fry/smolts by fish (sculpins, brown trout) and birds (mergansers)

Freshwater Rearing

LF30: High levels of sedimentation leading to clogging of interstitial spaces and loss of rearing habitat
LF33: Increased use of low quality off channel habitats

Table 8. Moderate Risk Factors

Terminal Migration & Spawning

LF2: Limited or delayed spawner access
LF5: Aggradation creates a migration barrier in the river during adult migration
LF7: High water temperatures in the river during the late summer/early fall migration period can increase migration mortality and sublethal stress
LF10: High suspended sediment loads can reduce spawning habitat quality by compacting gravel and reducing interstices critical for egg deposition and incubation
LF13b: Mortality due to unsanctioned fisheries during migration and at spawning grounds
LF14a: Disturbance to natural migration activity due to anthropogenic restoration impacts

Freshwater Incubation

LF17a: Increased numbers of ice days resulting in mortality of eggs and alevins

Freshwater Rearing

LF28: Low water temperature and lack of groundwater influx resulting in ice in interstitial spaces
LF29: Toxic water quality conditions can increase fry mortality or reduce fitness.
LF31: Mortality or fitness impacts as a result of lack of food
LF34: Higher and earlier flows that prematurely displace juveniles downstream and reduce overall fry survival
LF36: Mortality or fitness impacts as a result of competition or predation from Aquatic Invasive Species (AIS)
LF37: Alteration of natural riparian structure and ecological integrity as a result of colonization of invasive species
LF38: Impacts to juvenile migration as a result of invasive plant species
LF**39b**: Mortality or fitness impacts as a result of competition
LF40: Mortality as a result of high levels of predation in the river
LF43: Lack of access to historical tributary and off channel habitat.
LF45: Mortality or fitness impacts as a result of anthropogenic disturbance

The key takeaways, gaps and action items associated with each life history stage are captured below: gaps and action items are related to those relevant to Nicola Chinook, their habitat or ecosystem and/or those related to anthropogenic considerations. Most of the discussion below relates to the Very High, High and Moderate Risk factors and reflects the comments of the workshop attendees. Table 4 provides additional information on gaps and potential actions that could be applied to some of the lower risk limiting factors.

Terminal Migration and Spawning

Takeaways for Adult Migration and Spawning: *Key issues impacting adults as they return to the system include the loss of quality refuge habitat and safe migration through the river, lack of deep pools, increased aggradation, high water temperatures during the summer/early fall migration period and high suspended sediment loads. Many of these factors have been highly exacerbated since the 2021 flooding. Additional causes of these issues include fires, salvage logging and urban development, such as residential and industrial construction, forestry, road building, and agricultural activities which have negatively affected fish habitat by the removal of riparian corridors e.g., removal of cottonwoods. Degradation of riparian areas has resulted in increased erosion, loss of shade and cover as well as the loss of pool and off-channel habitat.*

Loss of cottonwoods and reduction in natural large woody debris (LWD) and bank stability, has led to increased use of rip rap to counter these issues. Meanwhile, this has resulted in additional in-river damage as result of failed anthropogenic restoration attempts. Lack of refuge habitat and deep pools also make fish more susceptible to unsanctioned fisheries which may occur along the entire river. Increases in water temperatures, exacerbated by widening and shallowing of channels, result in increased stress, possibly increased risk of disease and predation, and pre-spawn mortality.

Since the recent flooding (November 2021), the channel is wider and will now require more discharge to provide adequate depths for good fish passage. Some First Nation members of the NWGP Drought Committee are using the presence of plants that are used for indigenous harvest as indicators of drought levels. Often, community members reduce water usage based on these indicators.

One limiting factor, unsanctioned fisheries on returning adults, currently poses a low risk, but could be a more major concern in the future. This is related to the predicted increased future prevalence of fires and salvage logging which will result in earlier snowmelt and more flooding, and which could result in even fewer pools and loss of refuge habitats. Additionally, fishing gear tends to become increasingly effective over time, as do communications technologies to inform others about fish locations. Other moderate and high-risk factors that were also predicted to increase in severity in the future included those associated with aggradation, fish passage, increasing temperatures, anthropogenic impacts, predation, and lack of refuges such as deep pools. More future fires, flooding events and more rain on snow events also will exacerbate these issues, and lead to increased channelization, aggradation, and shallowing of the river.

Key knowledge gaps included a need for more understanding of groundwater refugia, and the impacts of losses of deep water pools and refuge habitats on adult migration and spawning.

Key Knowledge Gaps for the Adult Migration and Spawning Phase:

Fish

- How do fish move upriver? Is this a single migration period (one night?). How far can they travel in each migration period?
- How often are adults impeded by low flows?
- What are impacts of aggradation on fish? Does it lead to increased predation? Increased straying? There is a general lack of observational evidence.

Habitat

- What data (e.g. abundance, size, distribution) are available on woody debris?
- Are all Nicola Chinook spawning areas serviced with groundwater?
- Where are river sections losing water to or gaining water from groundwater aquifers?
- Will these systems stabilize over time or will they become chaotic post 2021 flooding?
- What is the spatial configuration of habitat- is there a broad amount of suitable habitat that is groundwater or hyporheic serviced to cool the river water adequately for pre-spawning fish?
- How many cold water serviced habitats do we need for staging adults? What constitutes abundance/scarcity of these habitats? What spatial configuration of habitat is optimal?

- Which aquifers are maintaining the groundwater refugia? This is especially important as Merritt considers using deep aquifers for domestic supply, that may contribute to cold water inputs well downstream toward Spences Bridge.
- What are the relative benefits versus risks to habitat of major flooding events such as the 2021 flood?
- How transient will the gravel be after the 2021 flooding event?
- What is the current level of armouring?

Human

- Merritt wants to draw water from a deep aquifer- would this provide refugia for migratory fish?
- Should swim surveys be re-initiated?
- Are unsanctioned fisheries occurring at the confluence of the Nicola and Thompson, and throughout the Nicola River? If so, can we estimate many fish are being removed?

Possible Actions:

Fish

- Implement local studies of fish behaviour e.g. fish migration, impacts of flows and aggradation on survival. PIT tag and telemetry methods could be utilized for these studies.
- Observe the system over the upstream migration period to determine if adults are stacking up or getting through shallow riffles successfully. A study should be designed to assess changes in sediment loads, evolving channel morphology and fish migration obstructions.

Habitat

- A map of critical habitat, location of pools, groundwater inflow, and thermal refugia is required. This exercise may need to be repeated annually for several years until the channel morphology begins to stabilize in response to upslope revegetation and riparian corridor reformation.
- More thermal mapping work should be carried out throughout the Nicola Chinook spawning areas.
    - T. Wilms (pers. comm.) suggests distributed temperature sensing using 25km sections of fibre optic lines along the thalwegs to assess groundwater influences and to assess variability i.e. lower fluctuation would be associated with higher groundwater influence.
- Surveys are required to examine important spawning areas that may have been impacted by aggradation of bed load. Surveys are needed for off channel habitats, and to determine what is functional and what is not. Water quality assessments are also needed in these spawning and rearing areas.
- Regular reassessments of riparian area condition with high resolution orthophotos or satellite imagery is required, including information on the level of hardening.
- Artificially promote thalweg development and short-term pool formation until channel morphology begins to stabilize.

- Check sediment budgets and potential channel impacts. Sediment inputs will be large for the foreseeable future due to forestry activities, wildfire impacts and loss of riparian function.
- Continue to observe the system and its possible natural recovery, particularly to see what happens after freshet.
- Restore cottonwoods along the river to create a functional riparian corridor.
- Consider adding LWD to help stabilize the river. Any LWD additions need to be planned strategically and with the guidance of an engineer to minimize risk of flooding.

Human

- Develop a strategic plan and long-term approach to rehabilitating habitats. The Nicola Collaborative should develop a Recovery Strategy where all these issues, habitat restoration plans and long-term needs could be laid out and captured in a single source.
- Longer term work needs to be done to rehabilitate the Nicola River floodplain. This needs to be repatriated, revegetated and rehabilitated.
- Implement forest harvest practices that aim to reduce rate of snow-melt, such as minimizing logging on steep and south-facing slopes can help to ensure higher base-flows of tributary streams (Goeking & Tarboton 2020).
- Use of tools such as:
    - Nicola Water Management Tool
    - Groundwater monitoring tool
- Follow up with Leona Antoine and the Indigenous communities using presence of plants that serve as drought indicators. Development of an online platform or early warning system would be of major value.
- Learn from work done on other systems, e.g. gravel removal programs on the Cowichan River.
- Make legal objectives for land use that promote watershed rehabilitation (as impacting the Nicola watershed planning area) through the land planning table.
- Look at options related to land preservation- purchase floodplain properties. Bring in economists to assess. Consult with insurance industry?
- Use cumulative effects models to encourage forward thinking land management.
- More inclusion of forestry companies in the discussions and in the Collaborative e.g. FLRORD, BC Timber Sales representation is needed.
- Options of plantings need to be prioritized over the usual engineered rock solutions. Water authorization is assessing planting programs. If a bank is armoured with rock, then planting with trees should be required to aid in rehabilitation.
- Promote this work with the Restoration Table and under PSSI. DFO Restoration cannot apply BCSRIF funds- so the Collaborative or a local group needs to propose appropriate projects and apply for funds that may be available for restoration.
- Jason Hwang and PSF will be developing a Playbook for post wildfire flood management which might be useful. The Nicola watershed could be proposed as a case study.

Warkentin (2020) noted that many of the smaller tributaries in the Nicola watershed are sources of cold water during the summer, and have less sensitivity to regional climate -representing critical thermal refugia. He suggested the following recommendations:

- Land use management such as preservation of riparian cover in small tributary streams can keep small streams cooler (Macdonald et al. 2003), while forest harvest practices that aim to reduce rate of snow-melt, such as minimizing logging on steep and south-facing slopes can help to ensure higher base-flows of tributary streams (Goeking & Tarboton, 2020).
- Beaver dam analogs have been shown to increase temperature heterogeneity and decrease temperatures downstream (Weber et al. 2017), increase downstream flows (Pollock et al. 2003), and improve habitat for rearing salmonids (Bouwes et al. 2016).
- Other suggestions include assessing historical water licenses and farm subsidy programs for water conservation retrofits.

Incubation

Key Takeaways for Freshwater Incubation: *Key concerns for Nicola Chinook eggs and alevin are predation (exacerbated due to channelization, shallower water and easier access for predators), choking of eggs from sediment (from avulsions/flooding) and changes in flow patterns (e.g. low flows resulting in redd dewatering and high winter flows and winter ice damage resulting in scour). These habitat issues are impacted by the level of forestry harvesting, wildfires and salvage logging, flooding, and groundwater availability. There are increasing number of Redside shiners (*Richardsonius balteatus*), which could pose a risk as alevin predators. These are a native species, but better adapted than Chinook to warmer waters, and therefore may have a competitive advantage in the system as it warms up.*

Avulsions in this region have added a lot of gravel to Nicola Basin systems, and the mobility and instability of this gravel can result in egg mortality. This issue is of much greater concern since the 2021 flooding event and continued avulsions and sediment inputs are also likely to worsen the situation in future. There is no shortage of good gravel but little is known about the stability of these gravels and how much fine intrusion into gravels has occurred, which could further threaten egg survival.

Flows in the Nicola watershed have been impacted by forest harvesting and mountain pine beetle (MPB) is an added concern: decreases in forest cover due to MPB results in more snow accumulation in dead forests, and in clearcut areas. Earlier snowmelt leads to increased, faster and earlier runoff, which is also less synchronized at different elevations. More frequent rain on snow events lead to scour of alevins before they emerge from the gravel (R. Bailey, pers. comm.). Deforestation due to wildfire further exacerbates these concerns.

Warkentin (2020) found that productivity appeared lower for Nicola Chinook cohorts that incubated during years with fall and winter floods greater than ~150 m^3/s. The author noted that flows over this threshold could mobilize sediments and scour incubating eggs (Warkentin 2020). Following the recent intense flooding in fall of 2021, scour and sediment concerns may increase significantly. Sufficiently high flows have occurred that could impact redds, and additionally, a significant amount of rip rap armouring was washed into the river during the floods, which could further exacerbate scour.

Ice scour is an additional issue for eggs during incubation, particularly if temperatures are cold enough to allow freezing to the depth of the eggs in the nests. Insufficient groundwater availability can increase the prevalence of anchor ice as intra-gravel temperatures are controlled by the amount of groundwater available. Cohorts that incubated in winters with more ice days tended to have lower recruitment; for every 10 additional days of river ice, recruitment was predicted to decrease by 10% (Warkentin 2020). This issue has likely been exacerbated since the flood event of 2021, with wider and shallow channels making ice scour more likely. It was suggested required flows for incubation should be reassessed due to the changes in channel morphology i.e. the river channel is wider since the flooding and more discharge will be required moving forward for incubation flows.

Key Knowledge Gaps for the Incubation Phase:

- Are City of Merritt draw down zones around wells increasing?
- Lack of information on impacts of high winter flows on egg scour.
- Lack of information on the impacts of Redside shiner on alevin.
- How will sediment and the river stabilize after the 2021 flood?

Possible Actions:

- Re-examine the guidelines for incubation flows, with new transects as the flow thresholds established pre-flood are likely not relevant moving forward.
- Establish reference wells in the Merritt area.
- Riparian Planting.
- Reforest upper slopes.
- Rehabilitate the floodplain.
- FN communities have a pilot study with the Province and should be provided with the opportunity for further feedback to the RAMS process and to provide support the confidence levels. This could be done by a presentation to the communities of the RAMS results to core council, or the discussion to set up a remediation table, including City of Merritt and other governments.

Freshwater Rearing

Key Takeaways for Freshwater Rearing: *Loss of high-quality freshwater rearing habitat is a major concern. Issues include high water temperatures impacting all juveniles at some point in their rearing life history period; increased stranding and/or lack of ability to locate refuge habitat or off channel ephemeral rearing habitats as a result of low flows/loss of refuges; sedimentation and other changes in the river (simplification, loss of riparian, high temperatures) resulting both in loss of sources of insect prey and increased risk of predation. An additional concern comes from the high likelihood of epigenetic impacts as a result of wild Chinook interbreeding with hatchery fish.*

Nicola Chinook are adapted to emerge on the ascending limb of the freshet- but with climate change the freshet is occuring earlier. Earlier snowmelt leads to increased, faster and earlier runoff, which is also less synchronized at different elevations and can impact wild fry, possibly displacing them and resulting in their moving into other habitats outside of the Nicola. If the freshet is too far advanced when fry emerge, this can lead to fish displacement and behavioural changes as a result of high flows and flooding. However, there is uncertainty about the extent of this due the high level of plasticity in Nicola Chinook, with many fish naturally moving down into the Thompson and Fraser. High flows could increase the level to which this occurs in the population, which could create impacts in these other systems (e.g. density dependence, competition etc). Warkentin (2020) noted that productivity appeared lower for cohorts that incubated during years with fall and winter floods greater than ~150 m^3/s .

There is also the potential concern that earlier freshet will create a timing mismatch for availability of ephemeral habitats. Spring- type Chinook salmon in particular use off-channel habitats such as wetlands, side-channels, sloughs and other floodplain habitat (Sommer et al. 2001). Fry move into flooded meadows at the end of April/May (R. Bailey, pers. comm.) and evidence suggests juvenile Chinook salmon rearing in these areas have much higher growth than those rearing in mainstem areas (Jeffres et al. 2008; Bellmore et al. 2013). Although these habitats are ephemeral, they are critical to recruitment (R. Bailey, pers. comm); however, irrigation activities and low water levels in off-channel areas have been identified as reducing available rearing habitat (LGL Limited, 2001) and stranding leads to inability to access thermal refugia (R. Bailey, pers. comm.).

Summer rearing habitat is considered a major limiting factor to Chinook production. The first potential contributing limiting factor as mentioned above is low stream flow during the summer rearing period when irrigation is occurring. A second potential contributing factor is high water temperature. Water temperature in the mainstem river have been recorded up to 29°C where the lethal limit is ~25°C.

Warkentin (2020) demonstrated a clear relationship between discharge and juvenile rearing survival. His analysis of over 20 years of Chinook salmon stock-recruitment data revealed that low summer flow strongly decreases productivity. August flow during spawning and fry rearing had the greatest effects – cohorts that experienced 50% below average flow in the August of spawning and rearing had 40% lower productivity. Chinook salmon cohorts are predicted to drop below replacement – and thus unable to sustain fishery mortality – in years with average August discharge less than 10.83 m^3/s (or 36% mean annual discharge) during the rearing summer. These flows only occurred for 18% of cohorts examined (Warkentin 2020).

As flow is reduced, temperatures increase, and with increased air temperatures predicted in the future, impacts to fish will likely worsen. Flooding will make it more difficult to retain water in streams over the summer. After the November 2021 flooding event, the river channel is wider and braided and so higher discharge is required to ensure adequate habitat is available.

By mid July-August, all juveniles are impacted by high temperatures, which may manifest as direct mortality (due to predation), increased disease, and smaller size when entering the ocean.

A key concern is the loss of riparian area: 25m setbacks are not found in most riparian areas and all large mature stands of mature cottonwoods have been removed. Ranchers remove cottonwoods so they can create more alfalfa fields. Clapperton and Guichon headwaters have been demolished by disease, fire and salvage logging. Much of the riverbanks bordering agricultural areas along the Nicola are actively eroding due to loss of riparian habitat and unimpeded cattle access to the river. Within the lower section of the Nicola River, only 3.5% of a total riverbank length of 234.2 km is bordered by unimpacted vegetation. The loss of riparian vegetation has resulted in increased erosion, loss of shade and instream cover, loss of pool and off channel habitat, and has increased river width and led to channel instability. Channelization has also reduced the number of back channel and wetland areas. Sediment avulsions and inputs in the Nicola have led to clogging of interstitial spaces and may prevent juveniles from rearing in these habitats (which serve as predation and thermal refuges during the summer). Increased turbidity, increasing temperatures and lower DO can all impact the food web and decrease stream productivity. All of these factors are likely worsening following the fires and floods in 2021.

Ultimately, loss of riparian cover, erosion of stream banks, low flows and warming temperatures, fire and flooding events have resulted in huge changes to this system. Most importantly, lateral connectivity, access to thermal refuges and in river complexity have been lost. There are also many additional food web changes as a result of loss of escape habitat, pools and rearing areas. These include risks of increased predation, increased competition from Redside shiners, which appear better suited to warming waters, and increases in invasive species such as Yellow perch (*Perca flavescens*), which could pose a huge risk to juvenile Chinook rearing in the Nicola.

Finally, the presence of the hatchery and increased PNI threatens the wild Nicola Chinook stocks, which are not naturally particularly productive. As ocean productivity goes down, and returns are low, a larger proportion of fish are taken for broodstock to maintain annual release groups of 180,000 CWT smolts for confidence in stock assessment data. Genetic and epigenetic impacts to wild fish, competition and loss of fitness are all very possible outcomes, only worsening the situation for Nicola Chinook.

Future issues could be even more significant, particularly in light of the recent fires, salvage logging and flooding in the region. There are concerns that there will be more armouring through Merritt, particularly post 2021-flood, which will further exacerbate these issues, leading to more heat transfer into the river, more damage to riparian areas and further loss of tree cover. Several limiting factors were predicted to worsen in the future, including those associated with aquatic invasive species, high and earlier flows, lack of access to off channel and ephemeral habitats, competition and predation.

Key knowledge gaps include lack of understanding of fish use of different habitats in the Nicola watershed, and the distribution, availability and level of lateral connection of thermally optimal habitats. Other key gaps include knowledge of the specific impacts of flow, aggradation, ice scour and flooding on fish and their food web (food resources, predators and invasive species), the level of in-river complexity and connectivity, state of tributaries and river floodplain, particularly in light of the recent major flooding event.

Key Knowledge Gaps for the Freshwater Rearing Phase:

Fish

- There is a lot of variability in thermal environments in the Nicola –do Nicola Chinook exhibit behavioural adaptations to find tolerable conditions? Preliminary results from Tom Willms' work suggests they do.
- What is prevalence of stranding? How many fish end up stranded, and is this temporary or terminal?
- How do fish use different habitats such as side-channels, tributaries and water meadows?
- How far do Chinook range when they come out of summer interstitial rearing refuge habitats to forage? Do they defend territory?
- Do clogged interstitial spaces result in changes in capacity or direct loss of survival via predation or the impacts of thermal stress?
- What will be the impact of earlier peak flows? Will fish emerge earlier (especially if groundwater temperatures are still low?)?
- What flow levels do fish need? - the currently prescribed minimum flow levels may not be adequate during droughts, and likely need to be re-evaluated.

Habitat

- How well will refuge habitats persist under ongoing climate change and the other impacts in this region?
- What is the distribution of thermally optimal habitats (i.e. cooler than average initially, warmer than average as the fish get bigger)?
- Which side channel habitats provide these optimal thermal environments and how should we protect them?
- How much disconnection to thermal refugia has occurred?
- How will flow regimes change as a result of wildfires?

Ecosystem

- Will system productivity increase to provide for the increased energetic requirements of fish rearing in higher water temperatures?
- After events such as flooding and sediment inputs, depressed productivity is likely, but there could also be increased invertebrate activity, and acceleration of gravel /fines substrate entering the river. This is currently a knowledge gap for the Nicola River. These events may not create only negative impacts.
- There are no studies on the levels of predation currently, or whether it is increasing or decreasing.

Human

- How will DFO policy impact possible mitigation solutions?

Possible Actions:

Fish

- Study to determine where fish are overwintering.

- Research is required to assess impacts of earlier and higher freshet flows on fry survival.
- A study is needed to collect smolts, check scales, diet, back calculate growth. Look at length-frequency analysis to assess level of competition. Is there any evidence of growth irregularities? Is there evidence of failure to reach critical size thresholds?

Habitat

- Surveys are needed to assess side channel TSS, DO, temperature etc.
- We need a study to assess the status and productivity of side channel habitats post flood events.
- Reassess riparian area condition with high resolution orthophotos or satellite imagery.
- Overflights are required to look at the changes in routing of Nicola River and losses in connectivity, particularly in the higher tributaries. On the ground work to assess the state of the tributaries (ie. water quality etc.).
- We need an assessment of current in-river complexity and connectivity (lateral and longitudinal).
- Assess low and high temperature tributaries.
- Restoration to restore access (some work has been ongoing to restore access to off channel habitats and tributaries) and to understand lateral connectivity.
- Assess gravel and fines input into the Nicola River.

Ecosystem

- Investigate installation of beaver dam analogues higher in the watershed (these did well on Coldwater tributaries and survived the recent 2021 flooding). Nooaitch is interested in supporting these.
- Studies are required to assess larval lamprey and impacts on Nicola Chinook.
- Look into the literature to assess the impacts of Yellow perch on salmon.
- Need to monitor areas below the dam and into town and in the various oxbows to see if perch have moved into these habitats. Carry out a marking program.
- Research structures that could reduce downstream movement of perch.
- Continue eradication methods for perch- target spawning time around Easter.

Human

- A key issue is the lack of protection of riparian areas on private land. This is a particular impediment to protection of species at risk and is a critical impediment to repatriation of the floodplain.
- Assess and manage water storage in a more precautionary approach as water seems to be leaving the watershed in a shorter period.
- Revisit conservation easements.
- Set land aside for wildlife and use for tax credits.
- Develop riparian corridors.
- Link floodplain zoning to conservation easements.
- Rezone land use in the valley bottom.
- Continue to go through RAMS processes to prioritize the key LFs and potential actions, rather than just fund “shovel ready projects” and short-term solutions like buying rip rap.

- Fund land conversion to cottonwood plantations with benefits to fish habitat as well as future harvest opportunities. Buy water licences back and change the type of agriculture in the valley ie. return to cottonwoods.
- FN in area want a comprehensive review of 2021 atmospheric flooding event and issues related to lack of storage in Nicola and Coldwater. They will not support private landowner requests for diking and hardening sites within the river.
- Education and outreach are required as many landowners are increasing use of artificial substrates and hardening the riparian areas rather than looking at plantings.
- Any major water removal from the river should be alleviated by some form of enforced mitigation.
- Broader discussions needed around use of water- homeowners should have smart meters, usage of contemporary methods of irrigation, recent technology etc.
- Broader discussions needed about minimum flows- which are often considered as targets instead of minimums.
- More enforcement procedures- may develop through the drought response committee and discussions around environmental flow needs, and water management regimes.
- Promotion of Indigenous knowledge in this regard will be highly beneficial. There is a lot of academic knowledge in the Nicola Characterization report, but local community knowledge and moving forward with the Indigenous Laws is crucial.
- The new Restoration table could explore connectivity- need to develop the Terms of Reference. This could be an important group to provide collaborative stewardship.
- Need to create more storage. Mamit Lake is getting warmer and Shackan has heat issues, so new locations are required.
- Look at studies done in the US on impacts of dam removal projects from systems with large sediment flushing.
- In Alberta, there are tax incentives for private landowners to protect riparian areas- could something like this be considered in BC? Forest practices also can remove vegetation in protected riparian areas- they just cannot place machinery within those areas.

DISCUSSION

The goal of this project with the Nicola Basin Collaborative Research and Technical Committee was to carry out a Level 1 RAMS process. This process was carried out to support ongoing habitat restoration initiatives as identified by the Nicola Forum. Background information was collated for both Nicola Basin Chinook and their habitats, and was followed by a series of two workshops. The first workshop brought together a small group of experts to create a "straw-dog" set of risk scores; and was followed four months later with the Nicola Basin Collaborative Research and Technical Committee members in a workshop to assess those scores and add additional crucial understanding.

The two workshops were separated by the November 2021 flood event, which was a one in 100 year event, and as such, not comparable with the 2017/2018 flood events. This resulted in several changes to assessments of risk posed by various limiting factors during the second workshop. These scores were ranked and the highest risk limiting factors were discussed in detail. Key knowledge gaps were identified and several potential next steps and mitigative actions were identified.

Risk was scored both for the current situation and for 50 years hence under ongoing climate change. Ability to identify current limiting factors that pose a low risk, but which might worsen significantly under ongoing climate change is an important component of a RAMS process, allowing us to potentially mitigate those future risks. Although this Level 1 RAMS focussed only on Chinook salmon, all salmon are sensitive to climate change, so it is understood that actions taken to assist Chinook will have benefits for Coho and Steelhead too.

It is apparent that Nicola Chinook are under intense threat as a result of flooding, droughts, water removals, salvage logging, fires and removal of riparian areas. The main threats come from forestry, agriculture, human development and climate change. Anthropogenic disturbance to stream banks and riparian cover is extensive throughout the Nicola Watershed (Ecoscape 2017), but riparian cover is positively correlated with lower thermal sensitivity in the Nicola Watershed (Warkentin 2020). Larger sub-catchments exhibit higher maximum stream temperatures, while smaller ones may provide important thermal refugia (Warkentin 2020). The watershed has been experiencing a higher frequency of severe flood and drought events, resulting in adverse effects to fish and fish habitat. The recent catastrophic floods of 2021 have greatly altered the river and it is as yet unknown what the prognosis is for fish and fish habitat, though loss of deep pools, refuge habitats, and river complexity are clearly apparent, as are the impacts of serious aggradation and channelization.

Primary habitat and ecosystem concerns (T. Willms, pers. comm.) in this watershed include:

- The high level of equivalent clearcut area (ECA) which has major effects on water storage and timing, duration, and intensity of freshet; storage is a concern and the watershed is less "sponge-like" requiring addition of trees and wetlands to assist with maintaining adequate baseflows and reducing flood events.
- Loss of riparian vegetation, specifically black cottonwood and their effects in providing shade, bank stability and instream habitat complexity;

- Effects of high summer stream temperatures on survival and growth of juvenile Chinook Salmon, Coho Salmon, and Steelhead;
- Drought and suboptimal streamflow in August which has been correlated with low productivity of Chinook (Warkentin 2020);
- Issues of poor connectivity of streams and floodplains – with effects to habitat recruitment, refugia and flood intensity;
- Major sediment avulsions and bank topping as a result of flooding- with impacts to migration, egg survival, clogging of rearing habitats, and gravel instability;
- Loss of deep pools and refuge habitats, widening of the channel and changes in lateral and longitudinal connectivity, with impacts to all life stages; the Nicola River and its tributaries are confined - only way the river can escape flooding is if it is allowed to move along its floodplain;
- Changes to the food web, such as the increased competitive abilities of native species such as Redside shiner and increases in invasive species such as Yellow perch.

RECOMMENDATIONS

Discussion during both workshops provided information and advice regarding key knowledge gaps, action items and potential next steps. The key priorities discussed were as follows:

- **Create a long-term strategic plan for management of Nicola Chinook.**
    a. It is suggested that the Nicola Basin Collaborative Research and Technical Committee should develop a Recovery Strategy which includes habitat restoration plans, emergency responses for fire, floods and drought, and includes long-term needs. This would allow for development of a co-ordinated and logical approach for recovery planning, as well as a well-considered rather than reactive set of emergency response guidelines. The plan needs to be developed in sync with revegetation of the watershed from upslope to valley floor.
    b. Jason Hwang at PSF will be developing a Playbook for post flood and post fire management which might be useful. The Nicola Watershed could be proposed as a case study.

- **Focus on Temperatures**
    a. Land use management such as preservation of riparian cover in small tributary streams can keep small streams cooler (Macdonald et al. 2003), while forest harvest practices that aim to reduce rate of snow-melt, such as minimizing logging on steep and south-facing slopes can help to ensure higher base-flows of tributary streams (Goeking & Tarboton 2020).
    b. Beaver dam analogs have been shown to increase temperature heterogeneity and decrease temperatures downstream (Weber et al. 2017), increase downstream flows (Pollock et al. 2003), and improve habitat for rearing salmonids (Bouwes et al. 2016).
    c. Focus on a major riparian planting program to re-establish cottonwoods as suggested by Warkentin (2020) and supported by the most recent SHIM (Ecoscape 2017).
    d. Options of plantings need to be prioritized over the usual engineered rock solutions for bank stabilization. Water authorization is assessing planting programs. If a rock wall is planted, then trees need to be added.

- **Focus on Hydrological Recovery, Water Storage and Flows**
    a. Assess and manage water storage in a more precautionary approach as water seems to be leaving the watershed faster, and wetlands and storage needs to be developed.
    b. Build out the Drought committee, water planning table and restoration table to address water quality and quantity concerns.
    c. Work with the Nicola Watershed Governance Project.
    d. Learn from work done on other systems, e.g. gravel removal programs on the Cowichan River.
    e. Re-examine the guidelines for incubation flows, with new ground transects as the flow thresholds established pre-flood are likely not relevant moving forward.

f. Establish reference wells in the Merritt area.
g. Other suggestions include assessing historical water licenses and farm subsidy programs for water conservation retrofits.

- **Focus on Sediment**
  a. Stabilization of large aggradations of sediment in the mainstem of the Nicola River is required.
  b. Learn from work done on other systems, e.g the Cowichan River.
  c. Most current amelioration work tends to focus on costly processes to mine rocks and build berms and dikes. This is expensive and not the best solution in many cases as they often fail or create acid drainage. Longer-term solution should focus on riparian planting and repatriation of the floodplain.

- **Focus on Research & Data Collation to Address Gaps**
  a. Through the Nicola Basin Collaborative Research and Technical Committee, there are strong links with academia and students, habitat practitioners, and biologists. It is recommended that work is done to address the knowledge gaps associated with highest risk limiting factors and that research/mapping/data collation programs could be developed. Funding through upcoming BCSRIF, Mitacs, CRF and PSSI initiatives as well as others.
  b. Many of the pressure indicator maps created by Miranda Smith of MC Wright and Associates Ltd. and using Pacific Salmon Explorer data could be augmented with higher resolution data, and information ground-truthed from field studies. This could include:
    i. Reassess riparian condition with high resolution orthophotographs or satellite imagery
    ii. Assess road density (paved and unpaved) pre and post the Forest Practices code, and assess level of deactivation. The road atlas layer in the PSE missed rehabilitated layers. This would need to be gathered from forest companies or from lidar/high resolution orthophotos.
    iii. Reach out to the Forest and Range Evaluation Program to ask about road crossings.
    iv. Culvert analysis is required, and a possible fish passage study would be beneficial. There is a fish passage working group in the lower Nicole which could develop models for Chinook, Coho and Steelhead accessibility constraints in this system. This is underway with the CWF.
    v. Assess the type and volume of wastewater discharge by looking into the Provincial database. The wastewater layer from PSE does not include agricultural inputs e.g. nutrients from feedlots and this would be very useful to include.
    vi. Map critical habitats for Chinook and overlay those on the habitat risk maps created for the RAMS.
    vii. Map channel instability using historical air photos.

    viii. Add a fire disturbance layer (this is currently mixed in with the forest disturbance layer in the PSF Salmon Explorer).
    ix. Generate a fish distribution/access layer, utilizing local knowledge.
    x. The Nicola is a temperature sensitive system- but the benchmark is missing. A useful addition to the maps of indicators created would be the addition of thresholds and benchmarks for where threshold temperatures for spawning/migration/rearing Chinook are not met.
c. Additional field studies and research could include:
    i. Assess the sources of sediment in the watershed- survey the erosion, incision and aggradation occurring throughout the system and in the uplands.
    ii. Implement more thermal mapping of Nicola River thermal refugia.
    iii. Implement Chinook PIT tag programs to address questions around lateral connectivity, losses to predation, survival as related to flows/water temperatures/turbidity etc.
    iv. Field studies to understand fish behaviour, stranding, use of ephemeral habitats, growth, health, plasticity, food web etc. Assess disease levels (e.g. BKD) in wild populations
    v. Research to further understand the response by Nicola Chinook to the various different stressors/limiting factors.
    vi. Survey side channels remaining post-flood, assess levels of groundwater input, food resources, temperatures and DO levels etc.
    vii. More water quality studies are required: Start surface water runoff monitoring after big rain events, particularly to assess 6PDD-Quinone, and with particular focus in rearing channels.
    viii. Routine surveys (aerial, thermal, other) of the Nicola River and tributaries should be implemented.

- **Land Planning and Preservation**
    a. Take back the Nicola River floodplain. This needs to be repatriated, revegetated and rehabilitated to return to being a functional floodplain with appropriate riparian vegetation.
    b. Make legal objectives for land use (as impacting the Nicola watershed planning area) through the land planning table.
    c. Look at options related to land preservation- purchase floodplain properties. Bring in economists to assess.
    d. More inclusion of forestry companies in the discussions and in the Collaborative e.g. FLRORD, BC Timber Sales representation.
    e. Implement forest harvest practices that aim to reduce rate of snow-melt, such as minimizing logging on steep and south-facing slopes can help to ensure higher base-flows of tributary streams (Goeking & Tarboton 2020).

- **Use New Approaches**
    a. Use cumulative effects models to encourage forward thinking land management.

b. Continue to develop the life history model built by Kyle Wilson- and add in hatchery origin fish. Add in a function to represent plasticity within the Chinook populations, possibly by adding tributaries to the model and using a different stressor-response for those to account for local adaptations. Link with research studies (5) above to better model and understand stressor responses.
c. Application of beaver dam analogues to improve storage, hyporheic exchange and available rearing habitat for juvenile salmonids.
d. Use of thermal imagery to map thermal refugia.
e. Use of tools such as:
    i. Nicola Water Management Tool
    ii. Groundwater monitoring tool

- **More Education and Outreach**
    a. There is an influx of persons into this region- into recreational properties and over the summer as tourists. Many newcomers lack place-based knowledge of ecological values specific to the Nicola (i.e. not aware of salmon and water issues). Education and outreach are required focussed on these groups to allow for greater understanding of hardening structures, the importance of fish populations in the region, impacts of water use, etc.
    b. More outreach with farmers and ranchers about impacts of unscreened water intakes/removal of cottonwoods and other riparian vegetation, issues associated with riprap.

- **More Monitoring and Enforcement**
    a. Greater understanding of prevalence of weir construction by farmers/festival attendees/others is required, as well as greater enforcement when this happens.
    b. Assess level of screening on water intakes, monitor at 10% per year.
    c. Request that organizers of local events (e.g festivals) provide funding towards restoration/clean ups.

- **Bring in Funding**
    a. Promote this work with the Restoration Table and under PSSI. DFO Restoration cannot apply for BCSRIF funds- so the Nicola Basin Collaborative Research and Technical Committee or another local group needs to put these projects together and apply for funds that are available for restoration.

- **Build Two-Eyed Seeing and Collaborative approaches using Indigenous Laws and Approaches**
    a. Hydrological recovery and future protection of the Nicola Watersheds will only happen through collaboration with First Nations, Government and Industry.
    b. FN communities have a pilot study with the Province and should be provided with the opportunity to provide further feedback to the RAMS process and to increase the confidence levels. This could be done by a presentation of the RAMS results to the

communities and to core council, and/or via the discussion to set up a remediation table, including City of Merritt and other governments.

c. Follow up with Leona Antoine and the Indigenous communities on using presence of plants that serve as drought indicators. Development of an online platform or early warning system would be of major value.
d. Work with the new Restoration Table to implement programs in the Nicola; adhere to the Indigenous Laws.

TAKEAWAYS

There is general support for the RAMS process and interest in adoption by Government, Federal, Provincial, Indigenous and local communities of this process as a standardized approach in the Nicola Watershed. It was understood that this was the "alpha test" of application of this process in the Interior Fraser region within a snow-dominated hydrograph and next steps should include discussion as to whether there are improvements/changes or simplifications that would be beneficial for adoption of RAMS in these regions.

There is interest in applying this process to the Cumulative Effects work that is ongoing in the Moore lab at SFU; the Province is partnering with the Moore lab to develop a software project to assess cumulative effects, with clear linkages to RAMS, and applicability for simulation modelling and outputs useful for interactive meetings with stakeholders. This is based on the Alberta Cumulative Effects model, and is being developed as a generic approach, applicable for different species, and will incorporate the model that Kyle Wilson presented and further the stressor-response functions. There are many potential additional tools that could also be utilized.

There is interest from the Nicola Collaborative Research and Technical Committee in reaching out to DFO to determine if there may be PSSI funds that could be applied to create an Interior or BC-wide RAMS team including an analytical scientist for that group. The RAMS process also requires local champions to move from RAMS outputs of gaps and ranked limiting factors to applying for funds, action on the ground, local mitigation and development of a management plan.

One major takeaway is the need for broader inclusion of Indigenous communities in development of a long-term plan for Nicola Basin Chinook. Leona Antoine noted that they have carried out a similar process and meet annually to discuss how thresholds and indicators have changed within the Nicola watershed. She noted that the process was more successful once the bands felt fully involved, and that this would also be true for future RAMS processes. The Fraser Collaborative Management agreement between 76 bands links the Province and Indigenous organizations in a joint technical committee and could be a potential group to encourage adoption of the RAMS process.

The next steps should be 1) the creation of a long -term strategic plan for the Nicola Watershed; 2) creation of tools and planning to assist with response to emergencies such as major floods, fire and droughts in the region; 3) further RAMS processes to gather information on Nicola Chinook rearing in the Thompson and Fraser which would allow for a more complete assessment of risks to the highly adaptable Nicola Chinook population.

Table 4. Results of Nicola Chinook Risk Assessment Scoring.

IDENTIFIED RISKS. These factors will affect the productive capacity of spring Chinook salmon in the Nicola Watershed.		CONSENSUS RISK SCORES. For each limiting factor these scores are a result of discussion between experts.						FUTURE OUTLOOK. Biological risk with climate change.	
Life History Requirement - Critical Habitat	**Issue or Limiting factor**	**SPATIAL SCALE What % of the critical habitat is affected? (1 low to 5 high)**	**TEMPORAL SCALE how often in 10years will this happen? (1 rarely to 5 frequent)**	**IMPACT What will be the change in returning adults? 1=low to 5=high impact**	**CONFIDENCE How much confidence do you have in this scoring? L=low, M=medium, H=very confident**	**Current Biological Risk category**	**Current Trend**	**Future trend**	**Future Biological Risk Category**
Adult Migration and Spawning									
Safe holding habitat confluence of Thompson-Nicola	**LF1:** Unsanctioned fisheries in the confluence of Thompson- Nicola	1	5	2	L	Low	4	5	High
Adequate flows to facilitate upstream passage of spawners	**LF2:** Limited or delayed spawner access	3	3	3	H	Moderate	4	4	High
Unrestricted access	**LF3:** Potential delays in upstream migration due to counting fences, fishways and other manmade structures	1	1	1	H	Low	3	3	Low
Unrestricted access	**LF4:** Reduced access through natural falls and natural barriers	1	2	3	H	Low	3	3	Low
Dynamic equilibrium in channel morphology, maintenance of channel capacity, adequate channel depths and natural level of sediment transport.	**LF5:** Aggradation creates a migration barrier in the river during adult migration	5	2	3	L	Moderate	4	4	High
Clear and safe passage with adequate refuge habitat	**LF6:** Loss of good quality refuge habitat and safe migration route through the river due to channelization, loss of habitat complexity, pools and instream cover features as a result of GW extraction	5	5	3	L	High	4	4	Very High
Suitable water quality	**LF7:** High water temperatures in the river during the late summer/early fall migration period can increase migration mortality and sublethal stress	5	5	2	H	Moderate	3	5	Very High

Suitable water quality	**LF8:** Poor water quality conditions during the late summer/early fall migration period (low DO, coliform levels, deleterious substances)	2	2	1	L	Low	4	4	Low
Availability of high quality and sufficient quantity spawning habitat	**LF9:** Lack of natural gravel recruitment to mainstem spawning sites.	1	1	1	H	Low	3	3	Low
Availability of high quality and sufficient quantity spawning habitat	**LF10:** High suspended sediment loads can reduce spawning habitat quality by compacting gravel and reducing interstices critical for egg deposition and incubation	4	2	3	L	Moderate	4	4	High
Availability of high quality and sufficient quantity spawning habitat	**LF11:** Colonization of invasive species (that reduces spawning habitat quality.	1	1	1	H	Low	3	3	Low
Availability of high quality and sufficient quantity spawning habitat	**LF12:** Lack of a sufficient quantity of good quality spawning habitat	1	1	1	L	Low	3	3	Low
Low levels of predation during migration and spawning	**LF13:** Mortality due to predation at spawning grounds	5	5	1	L	Low	3	4	Moderate
Low levels of predation during migration and spawning	**LF13b:** Mortality due to unsanctioned fisheries during migration and at spawning grounds	5	5	2	M	Moderate	3	4	High
Lack of anthropogenic disturbance	**LF14a:** Disturbance to natural migration activity due to anthropogenic restoration impacts	5	3	2	M	Moderate	3	3	Moderate
Lack of anthropogenic disturbance	**LF14b:** Disturbance to natural spawning activity due to anthropogenic impacts	1	3	2	M	Low	5	5	Moderate
Lack of anthropogenic disturbance	**LF14c:** Disturbance to spawning or migration as a result of cattle trampling	1	3	1	L	Low	4	4	Low
Lack of disease during migration and spawning	**LF15:** Sublethal impacts due to disease	2	5	2	L	Low	3	4	Moderate
Incubation									
Good water quality conditions	**LF16:** High suspended sediment loads that reduce egg to fry survival and emergence of alevins	4	4	5	M	Very High	4	2	Moderate

Good water quality conditions	**LF17a:** Increased numbers of ice days resulting in mortality of eggs and alevins	5	2	3	M	Moderate	3	2	Low
Good water quality conditions	**LF17b:** Non-optimal water temperatures that reduce fry survival by changing emergence time in relation to food availability	1	1	1	L	Low	3	3	Low
Good water quality conditions	**LF18:** High levels of pollutants or toxins that reduce egg to fry survival	5	1	3	M	Low	3	3	Low
Good water quality conditions	**LF19:** Low DO which reduces egg to fry survival	3	1	3	M	Low	3	3	Low
Suitable flow regime	**LF20:** Lower low flows that dewater redds and reduce incubation survival	4	3	5	M	High	3	3	High
Stable flow regime	**LF21:** More frequent and higher peak flows over winter can scour/disturb redds	4	3	5	M	High	4	3	High
Appropriate spawning gravel	**LF22:** Egg mortality due to inadequate spawning gravel, or as a result of gravel instability	4	3	5	M	High	4	3	High
Minimal disturbance to redds	**LF23:** Reduced egg to fry survival due to chum or other salmonid overspawn	1	1	3	H	Low	3	3	Low
Minimal predation of eggs and alevins	**LF24:** Predation of eggs, alevins and fry/smolts by fish (sculpins, brown trout) and birds (mergansers)	5	5	3	H	High	3	4	Very High
Lack of invasive species	**LF25:** Egg /alevin mortality due to redd disturbance by invasive or expanding endemic species	5	1	1	M	Low	3	3	Low
Lack of anthropogenic disturbance	**LF26:** Egg mortality due to redd disturbance by humans	1	1	1	H	Low	3	3	Low
Freshwater Rearing									
Good water quality conditions	**LF27:** High water temperature combined with low DO can suffocate fry or reduce overall fitness during the early summer/fall	5	5	4	L	Very High	4	4	Very High
Good water quality conditions	**LF28:** Low water temperature and lack of groundwater influx resulting in ice in interstitial spaces	2	2	5	L	Moderate	3	3	Moderate

Good water quality conditions	**LF29:** Toxic water quality conditions can increase fry mortality or reduce fitness.	3	3	3	L	Moderate	3	3	Moderate
Good water quality conditions	**LF30:** High levels of sedimentation leading to clogging of interstitial spaces and loss of rearing habitat	3	3	5	M	High	4	5	Very High
Adequate food supply	**LF31:** Mortality or fitness impacts as a result of lack of food	4	4	2	L	Moderate	4	4	High
Adequate instream complexity and riparian complexity	**LF32:** Mortality or fitness impacts as a result of inadequate in-stream complexity and riparian complexity	5	5	4	H	Very High	3	4	Very High
Adequate water levels and connectivity	**LF33:** Increased use of low quality OC habitats	4	4	4	L	High	3	3	High
Natural flow regime	**LF34:** Higher and earlier flows that prematurely displace juveniles downstream and reduce overall fry survival	5	3	2	M	Moderate	5	5	Very High
Natural flow regime	**LF35:** Low flows reduce seasonally available off channel and tributary rearing habitat.	5	5	5	H	Very High	4	5	Very High
Absence of invasive species	**LF36:** Mortality or fitness impacts as a result of competition or predation from Aquatic Invasive Species (AIS)	3	5	3	L	Moderate	4	4	High
Absence of invasive species	**LF37:** Alteration of natural riparian structure and ecological integrity as a result of colonization of invasive species	3	4	3	M	Moderate	3	3	Moderate
Absence of invasive species	**LF38:** Impacts to juvenile migration as a result of invasive plant species	3	4	3	M	Moderate	3	3	Moderate
Low levels of competition with other wild salmon/ hatchery fry /other species	**LF39a:** Mortality or fitness impacts as a result of competition with hatchery fry/smolts	1	1	1	H	Low	3	3	
Low levels of competition with other wild salmon/ hatchery fry /other species	**LF39b:** Mortality or fitness impacts as a result of competition with other salmon and other species	3	5	3	H	Moderate	3	4	High
Low levels of predation to fry	**LF40:** Mortality as a result of high levels of predation in the river	5	5	2	M	Moderate	4	4	High
Low levels of fish disease	**LF41:** Mortality or fitness impacts as a result of disease	2	2	3	L	Low	3	3	Low

High quality rearing habitat with good instream complexity	**LF42:** Lack of high-quality rearing habitat throughout the river both mainstem and side channels and tributaries	5	5	4	H	Very High	5	5	Very High
Unrestricted migration and passage: mainstem, off channel and tributary habitat	**LF43:** Lack of access to historical tributary and off channel habitat.	4	3	4	M	Moderate	3	4	High
Unrestricted migration and passage: mainstem, off channel and tributary habitat	**LF44:** Limited juvenile passage at lake fishway, tributary culverts etc	1	1	2	M	Low	3	2	Low
Lack of anthropogenic disturbance	**LF45:** Mortality or fitness impacts as a result of anthropogenic disturbance	2	5	3	M	Moderate	3	3	Moderate
Absence of negative hatchery impacts	**LF46:** Mortality or fitness impacts as a result of hatchery introgression	5	5	4	H	Very High	3	4	Very High

Table 5. Discussion, Identification of Key Gaps and Next Steps for Factors Limiting to Terminal Migration and Spawning

Limiting Factor	Discussion	Current Biological Risk category	Future Biological Risk Category	Confidence
LF1: Unsanctioned fisheries in the confluence of Thompson- Nicola	**LF1 Key Points:** ▶ Last 2 weeks of July key period for entry of adult Chinook into the Nicola River; ▶ Chinook may wait for ideal temperature or flow levels before entering into a system to start their freshwater migration- thus warming waters or low water depths may cause delays and increase ability for fishers to catch adults; ▶ Unfavorable temperatures in the Nicola system have caused thermal blockages that encourage salmon to hold in the Thompson near the mouth of the Nicola River. **Discussion:** The group noted that there is plenty of water at the Thompson-Nicola confluence, so there is no need for extended holding at that point in the adult return. 1998 was the only year when there was noticeable mortality of Chinook in the Thompson mainstem. There is a lot of uncertainty about the level of unsanctioned fishing in this area, but if it does occur, competent fishers could remove over 500 fish in just a few weekends. In 2020 there was very high water resulting in fish being held up which may have led to exhaustion by fish. It was noted that there are various other unsanctioned fisheries as the fish make their way up the Nicola, for example, at the confluence of the Coldwater and Nicola, where people may be seen fishing every morning in September. Every year nets and carcasses have been observed on this system. In the future, this risk may increase as increased prevalence of fires and salvage logging will result in earlier snowmelt and more flooding. Additionally, fishing gear tends to become increasingly effective as do communications technologies (currently there are many blind spots with no cell coverage but in the future fishers may be able to inform others about fish locations and so fishing pressure could increase).	Low	High	L

Limiting Factor	Discussion	Current Biological Risk category	Future Biological Risk Category	Confidence
	Key Gaps: ▶ Are unsanctioned fisheries occurring at the confluence of the Nicola and Thompson? ▶ If so, can we estimate many fish are being removed? ▶ Are there any other predation events occurring- for example, byotters? **Action Items:** ▶ The Cooks Ferry Band should be consulted as they are located at the confluence and will have an appraisal of this.			
LF2: Limited or delayed spawner access	**LF2 Key Points:** ▶ Drought conditions and low river water levels can result in slowed migration rates, leaving fish vulnerable to predation/poaching etc. as well as increased pre-spawn mortality; ▶ August flows when spawners are returning is important. Chinook that spawn during summers with 50% below average flow have 15% lower productivity. In combination, cohorts with 50% below average flow in the August they were spawned and the subsequent August during rearing are predicted to have 40% lower productivity (Warkentin 2020); ▶ River discharge in June-September in the last 23 years was up to 25% lower than the long-term average ; and ▶ Mean August flows in the last two decades were 26% lower than they were a century ago (Warkentin 2020). **Discussion:** In general, this limiting factor has been generally mitigated by water releases from the dam. However there still have been delays noted at the mouth of the Nicola (e.g. 1998 and 2003/4). In general flows of 7-7.5cms are achieved at Spence's Bridge, which has appeared adequate for fish passage prior to the flood. The group believes that fish likely only make it as far as 14 mile and Dot for their first night. The group suggested that	Moderate	High	H

Limiting Factor	Discussion	Current Biological Risk category	Future Biological Risk Category	Confidence
	based on Luke Warkentin’s work, that 10cms would be a more appropriate flow level requirement. Sometimes fish appear not to migrate during the day at all until August. Often there are voluntary regulations to help fish execute their terminal migration, but in 2021, there was an order on Coldwater and people shut off their water intakes. There may be barriers to entry into Coldwater and Spius, but this is generally a thermal barrier (somewhat but not necessarily totally alleviated by dam pulses). Spius has natural low flows which can exacerbate the issue. Since the recent flooding, the channel is wider and will require more discharge to provide adequate depths for good fish passage. Some First Nation members of the drought committee are using presence of plants that are used for indigenous harvest as indicators of drought levels. Often community members reduce water usage based on these indicators. In general the group felt that water storage needs to be well managed and more precautionary in approach as water seems to be leaving the watershed faster. General concern that this could get much worse over time- freshet is likely to become earlier and earlier as a result of climate change in the future. It is likely that pulses from Mamit Lake will be needed on a more frequent basis in the future. **Key Gaps:** ▶ How do fish move up river? In a single migration period (one night), and if so, how far can they travel? ▶ How often are they impeded by low flows? ▶ Where are river sections losing water or gaining water from groundwater aquifers? ▶ Water turbidity is often very high and it is hard to see the fish.	🟨	🟧	

Limiting Factor	Discussion	Current Biological Risk category	Future Biological Risk Category	Confidence

	Action items:
	▶ Implement forest harvest practices that aim to reduce rate of snow-melt, such as minimizing logging on steep and south-facing slopes can help to ensure higher base-flows of tributary streams (Goeking & Tarboton, 2020). From Warkentin 2020
	▶ Use of tools such as:
	    ▶ Nicola Water Management Tool
	    ▶ Groundwater monitoring tool
	▶ Follow up with Leona Antoine and the Indigenous communities using presence of these plants as a drought indicator. Development of an online platform or early warning system would be of major value.
		🟨	🟧	

LF3: Potential delays in upstream migration due to counting fences, fishways and other manmade structures	**LF3 Key Points:** ▶ Both artificial and natural blockages can result in delays or complete cessation of migration, leaving fish vulnerable to predation/poaching etc. as well as increased pre-spawn mortality; ▶ There are fish passage concerns at the dam in the winter (but this is only an issue if early migrants go to the lake and then drop back); ▶ Urban development, such as residential and industrial construction, and agricultural activities have negatively affected fish habitat by restricting salmonid access by inadequate culvert placements; ▶ However, this is not a large issue for Nicola Basin Chinook as there is very little use of off-channel habitat by adults. There are no counting fences, and roads are not an issue (R. Bailey pers. comm.). **Discussion:** This limiting factor was not noted as a risk as there are only barriers impacting entry into the Upper Nicola. There has been no counting fence on this system since the 1980s. There is a counting facility on the lower	Low	Low	H

Limiting Factor	Discussion	Current Biological Risk category	Future Biological Risk Category	Confidence
	Coldwater that operates to count Coho but it does not act as an impediment to Chinook migration.			
LF4: Reduced access through natural falls and natural barriers	**LF4 Key Points:** ▶ Both artificial and natural blockages can result in delays or complete cessation of migration, leaving fish vulnerable to predation/poaching etc. as well as increased pre-spawn mortality; ▶ One rock impacts Spius- rock cascade into Maka Creek (depends on flows). **Discussion:** There are few if any natural barriers of concern so this was seen as a low risk. Attendees noted that bank topping and avulsions have occurred resulting in channel spread, aggradation and shallowing of the existing channel in some places to only 1-2 inches deep, creating a potential migration barrier but this issue is covered by LF5 below.	Low	Low	H
LF5: Aggradation creates a migration barrier in the river during adult migration	**LF5 Key Points:** ▶ Major impacts from forest harvesting, agricultural and human development in the region; ▶ Anthropogenic disturbance to steam banks and riparian cover is extensive in the Nicola Watershed (Ecoscape 2017). 6-7% of streambanks along mainstem Nicola have severe erosion as a result of loss of riparian; ▶ Riparian destabilization has resulted from ranchers removing cottonwoods to increase alfalfa production (R. Bailey pers. comm.); ▶ Loss of riparian vegetation has also been shown to increase river width. Reid (2020) observed increases in average channel width on Guichon Creek from 2016 to 2018 of 10.1 m, 41.4 m and 84.6 m, respectively; ▶ Sediment movement resulted in increases in stream bed elevations in the lowest reach of Guichon (Reid 2020) as well as formation of large sediment wedges downstream of its confluence with the Nicola River;	Moderate	High	L

Limiting Factor	**Discussion**	**Current Biological Risk category**	**Future Biological Risk Category**	**Confidence**
	▶ Sediment avulsions may have braided channel sufficiently to create issues (R. Bailey pers. comm.). 2015-2017 harvesting in Clapperton and Guichon lead to avulsion events with over 500K cubic m of cobble/gravel entering the Nicola. **Discussion:** This LF is highly related to the level of forest harvesting and agriculture. Aggradation does slow the fish down and increase predation risk. Richard Bailey and Tom Willms have noted fish turned on their side and unable to continue migration upriver. However, the group noted that in 2021 there were Low flows (4-5 cms in Nicola) and yet it appeared that virtually all fish made it to the spawning grounds in relatively good condition, and no pre-spawn mortality was noted. No greater incidence of migration wounds was reported during tagging for the mark recapture studies (awaiting final marking data to confirm). However, there is very serious aggradation and channel braiding between Nooaitch and Dot. Tom Willms floated down the river in 2017; describes it as a “moonscape” with lots of sediment”. There are great concerns over the amount of material moving down from Clapperton and Guichon from salvage logging. After a few years, incision occurs, cottonwoods naturally recruit and as long as the channel is not confined by riprap and *unless* there is another flood event, the channel morphology can improve. There may even be some benefits of aggradation including recruitment of new habitats and augmentation of gravels. Overall lots of uncertainty on the risk of this LF. Fish facing issues might splash and attract predators which are likely more successful in shallower stretches (and there would be no evidence of the removal). Shifting habitat mosaics with aggrading and moving channels may also result in	🟨	🟧	

Limiting Factor	Discussion	Current Biological Risk category	Future Biological Risk Category	Confidence
	increased straying of fish. UBC (post doc working with Marwan Hassan) is developing a model relating bank strength with run off patterns. The group suggested that since the recent flooding of 2021, that delays as a result of aggradation might be more likely. There was also suggestion that sediment supply could become an issue in the future. Much uncertainty on how much the channel will continue to change, especially if flooding events continue to occur, or even afterthis year's freshet. Concerns were also expressed that gravel removal or instream work could lead to even greater channel instability. The group asked whether nature should just be left to its course, and that possibly these issues could be naturally ameliorated- or whether this should be a project for the new Restoration committee? Tracy Thomas and Brian Holmes collate the land planning table, which is building out water objectives into the strategic direction for land use. More future fires and more rain on snow events will exacerbate this issue, as well as increased channelization and shallowing. **Key Gaps:** ▶ Will these systems stabilize over time or will they become chaotic? ▶ What are the relative benefits versus risks? ▶ What are impacts of aggradation on fish? Does it lead to increased predation? Increased straying? There is a lack of observational evidence. **Action Items:** ▶ Artificially promote thalweg development and short-term pool formation? ▶ Check sediment budget and potential channel impacts.	🟨	🟧	

Limiting Factor	Discussion	Current Biological Risk category	Future Biological Risk Category	Confidence
	▶ Continue to observe the system and its possible natural recovery, particularly to see what happens after freshet. Check system in fall and assess if adults are able to move through shallow riffels. ▶ Learn from work done on other systems, e.g. gravel removal programs on the Cowichan River. ▶ Observe the system over Fall to determine if adults are stacking up or getting through- a study should be designed to assess the prevalence of barriers at low flow. ▶ Make legal objectives for land use (as impacting the Nicola watershed planning area) through the land planning table.	🟨	🟧	
LF6: Loss of good quality refuge habitat and safe migration route through the river due to channelization, loss of habitat complexity and instream cover features	**LF6 Key Points:** ▶ In the Nicola, urban development, such as residential and industrial construction, forestry, road building, and agricultural activities have negatively affected fish habitat by the removal of riparian corridors; ▶ Degradation of riparian areas has resulted in increased erosion, loss of shade and cover as well as the loss of pool and off-channel habitat; ▶ Refuge habitat needs to be deep enough with adequate surface cover to reduce predation (e.g. by otters). It also needs adequate DO; ▶ Many pools have been lost e.g. at Juliet Creek (40ft pools now 2 ft deep as result of avulsion), and there used to be lots of deep pools at Upper Coldwater which are now gone; ▶ Groundwater upwelling/discharge zones create thermally stabilized local habitats which are very important to salmon (Alexander and Poulsen 2015); ▶ McGrath and Walsh (2012) found that maximum daily temperatures were on average 11.5°C lower in groundwater upwelling areas in the Nicola River than adjacent areas. **Discussion:**	High	Very High	M

Limiting Factor	Discussion	Current Biological Risk category	Future Biological Risk Category	Confidence
	Deepwater habitats have decreased in the Nicola and Coldwater, for example at the confluence of Margaret’s and the Nicola-Spius confluence. Both depth and complexity have disappeared: 10-20 years ago there were many more pools throughout the watershed. We need the most recent SHIM report to compare to the 2017 report and quantify the loss of pool habitats and riparian areas (so far the recent report is not available, just the associated maps). Large diameter cottonwoods were knocked into the Nicola channel downstream of the dam after the 2017 flood creating slow pools- and actually improving complexity and LWD. However, this is not the case in many other areas of the Nicola River. Complexity tends to be lost in areas where the channel is confined by topography. Sunshine Valley Road is one area where sediment has filled in pools, leaving knee deep gravel flats where 1-2m pools used to exist. Around Merritt and Spius there has been long term removal of cottonwoods; and even with retention of riparian areas (and natural loss of cottonwoods into the river) there are no simple processes allowing for creation of pools unless the channel is confined around a cliff. Thus every year, more pools are lost. Farmers have spent over $0.5M to place riprap along the river, but what is really needed is retention and new planting of large cottonwoods in the riparian areas that can be recruited into the pool creation process. Richard Bailey notes that most of the spawning (75%) in the Nicola occurs between Spius and Coldwater but most pools below Nooaitch and down to Dot have been lost, and they are also all gone in the lower to mid Coldwater. Loss of pools mean more and more fish end up concentrating in the few deep pools that still exist which will lead to competition, increased stress and greater risk to local fishing, as well as disease transfer such as BKD. Deep “cauldrons” formed in the past by 2 or 3 cottonwoods have been replaced by runs that are 6” to 2 feet deep. The lack of complex terminal	🟧	🟥	

Limiting Factor	**Discussion**	**Current Biological Risk category**	**Future Biological Risk Category**	**Confidence**
	holding habitat with good thermal refugia will have detrimental impacts on fish, but more so in years when run sizes are high and competition is higher for the remaining good refuge habitats. The angling success observed in the 2021 marking program may be largely attributed to the loss of pools and the concentration of fish in the remaining pool habitats. This LF has been *greatly* exacerbated by the recent flooding events. **Key Gaps:** ▶ Need a map of critical habitat, pools, groundwater inflow, thermal refugia. ▶ Recent Nicola SHIM report to compare with 2016 data- maps available but no report? ▶ Need more data on woody debris. **Action Items:** ▶ Reassess riparian area condition with high resolution orthophotos or satellite imagery **Possible Management Lever**: ▶ For the future, groundwater extraction will be a key issue for this LF.	🟧	🟥	
LF7: High water temperatures in the river during the late summer/early fall migration period can increase migration mortality and sublethal stress	**LF7 Key Points:** ▶ Chinook spawning occurs between mid -July and mid-September, so they are extremely vulnerable to the high summer water temperatures in the Nicola System; ▶ Extensive land clearing has occurred on cattle ranches in the upper part of the watershed and has resulted in extensive losses of riparian vegetation (Walthers, and Nener, 1997); ▶ Thermal barriers exist in lower Spius, Lower Coldwater, but are not an issue in the upper Nicola, lower Coldwater and lower Spius (R. Bailey, pers. comm.);	Moderate	Very High	H

Limiting Factor	Discussion	Current Biological Risk category	Future Biological Risk Category	Confidence
	▶ Warkentin (2020) found that mean August temperatures have increased by about 2˚C in the last century in the Nicola River; ▶ Nicola runs E-W orientation so lots of shade in the afternoons as a result of topography (Bailey, pers. comm).; ▶ However, lots of boulder habitat before 9 and 14 mile canyons- lots of air-water interfaces. Despite the shade, the water is heated up as a result of high air temps (Bailey, pers. comm); ▶ Very warm air as fish reach Spence's bridge and large diurnal fluctuations in this area; ▶ Fish have been seen breaching and exposing gills to air when there are very high water temps as DO is too low (Bailey, pers. comm.); ▶ Fish will not move until temps are below 23°C; ▶ Surface water temp analysis does not clarify the refugia/OC habitat, but temp loggers show 2 thermal regimes in the valley- downstream of the Lake there is huge thermal inertia and no major fluctuations in the summer. In the Nicola/Coldwater, there are daily fluctuations and temps will dip to the low teens at night- possibly allowing adult fish to move; ▶ Impacts are more severe from intensive dairy farming and breeding which has replaced past alfalfa cattle ranching- with increased impacts on Nicola; ▶ Groundwater upwelling/discharge zones create thermally stabilized local habitats which are very important to salmon (Alexander and Poulsen 2015); ▶ McGrath and Walsh (2012) found that maximum daily temperatures were on average 11.5°C lower in groundwater upwelling areas in the Nicola River than adjacent areas. **Discussion:** In 1998 very high mortality of Chinook was noted in the Nicola, 2003 was somewhat similar. Richard Bailey has noted fish holding in riffle habitat and porpoising. Fish show these reactions when temperatures exceed	🟨	🟥	

Limiting Factor	Discussion	Current Biological Risk category	Future Biological Risk Category	Confidence
	23°C, but immediately drop back into deeper cover again when temperatures go below 22°C. This LF is very linked to the amount of flow and water levels. More water is exposed to warm air in the riffles at lower flows thus exacerbating the warming. Large boulders can also act as conduits for heat by absorbing solar radiation and passing it into the water as heat. Higher streamflows mitigate this condition by inundating/submerging the boulders. Fish entering can get through if there are suitable deep pools to hide in and groundwater fed areas, but some years temperatures are high enough to cause stress, mortality and impede migration. This LF is also linked with risk of disease e.g. BKD, which will likely worsen it the future. **Key Gaps:** ▶ What is the spatial configuration of habitat- is there a broad amount of suitable habitat that is groundwater or hyporheic serviced to cool the water adequately for prespawning fish? ▶ What spatial configuration of habitat is optimal? ▶ Are all Nicola Chinook spawning areas serviced with groundwater? ▶ How many cold water serviced habitats do we need for staging adults? ▶ What constitutes abundance/scarcity of these habitats? ▶ Merritt wants to draw water from a deep aquifer- would this provide refugia for migratory fish? ▶ T. Wilms (pers. comm.) suggests distributed temperature sensing using 25km sections of fibre optic lines along the thalwegs to assess groundwater influences and to assess variability ie lower fluctuation—higher GW influence. ▶ Should swim surveys be re-initiated? ▶ Which aquifers are maintaining the GW refugia? Warkentin (2020) provided a number of recommendations:	🟨	🟥	

Limiting Factor	Discussion	Current Biological Risk category	Future Biological Risk Category	Confidence
	▶ Many of the smaller tributaries in the Nicola watershed are sources of cold water during the summer, and have less sensitivity to regional climate -representing thermal refugia. ▶ Land use management such as preservation of riparian cover in small tributary streams can keep small streams cooler (Macdonald et al., 2003), while forest harvest practices that aim to reduce rate of snow-melt, such as minimizing logging on steep and south-facing slopes can help to ensure higher base-flows of tributary streams (Goeking & Tarboton, 2020). ▶ Beaver dam analogs have been shown to increase temperature heterogeneity and decrease temperatures downstream (Weber et al., 2017), increase downstream flows (Pollock et al., 2003), and improve habitat for rearing salmonids (Bouwes et al., 2016). ▶ Found to be useful to rearing coho salmon in the Coldwater River, a major tributary of the Nicola (Swales & Levings, 1989). ▶ Assess historical water licenses and farm subsidy programs for water conservation retrofits . **Action Items:** ▶ More thermal mapping work should be carried out throughout the Nicola Chinook spawning areas. ▶ Use cumulative effects models to encourage forward thinking land management. ▶ More inclusion of forestry companies in the discussions and in the Nicola Basin Collaborative Technical and Research Committee e.g. FLNRO, BC Timber Sales representation.	🟨	🟥	
LF8: Poor water quality conditions during the late summer/early fall migration period (low DO, coliform	**LF8 Key Points:** ▶ Agricultural development has negatively impacted fisheries values in the Nicola River & Coldwater watersheds. Cattle feeding areas and cattle access to watercourses are the primary source for loading pollutants into surface and groundwater, thereby reducing water quality;	Low	Low	L

Limiting Factor	**Discussion**	**Current Biological Risk category**	**Future Biological Risk Category**	**Confidence**
levels, deleterious substances)	▶ Other concerns to water quality result from increased population growth, e.g. large pulses of visitors in the summer results in more water demand and increased discharge of effluent; ▶ There are also leaching concerns from landfills and concerns about the Merritt sewage treatment plant; ▶ During spring runoff, phosphorus from fertilizers is washed into streams, and there are elevated coliform levels from animal wastes. Total phosphorus concentration showed a steady increase downstream until confluence with the Thompson River; ▶ Low DO is exacerbated by high nutrient levels (due to fertilizer/sewage effluent). **Discussion:** Paul Mozin noted that a small amount of water quality testing has taken place in the first or second week of September 2021, with no concerns for DO, coliforms etc. noted. But there are increasing numbers of dairy cattle and heifers on the valley floor which could lead to issues. Blue green algal blooms were noted in 2017/2018. Generally there is not a lot of information that can be used to assess the risk of this LF. Sewage is treated and discharge from Merritt. Concerns around water quality should be further assessed by the Drought Committee, the Water Planning table and the new Restoration table. The group expressed concern about how this LF might worsen in the future. **Key Gaps:** ▶ Little consistent water quality monitoring occurring, other than efforts of STC. **Actions Items:** ▶ Build out the Drought committee, water planning table and restoration table to address water quality concerns.			
LF9: Lack of natural gravel recruitment	**LF9 Key Points:** ▶ Past issues have been noted around the dam;	Low	Low	H

Limiting Factor	**Discussion**	**Current Biological Risk category**	**Future Biological Risk Category**	**Confidence**
to mainstem spawning sites.	▶ Channels move allowing for natural recruitment; ▶ But flooding will exacerbate any concerns about this LF. **Discussion:** This LF was not initially considered a major issue until after the flooding events. Questions remain now about how stable sediments will be both near and long term- and will egg survival be impacted over the winter? **Key Gaps:** ▶ How transient will the gravel be? How will eggs be impacted?			
LF10: High suspended sediment loads can reduce spawning habitat quality by compacting gravel and reducing interstices critical for egg deposition and incubation	**LF10 Key Points:** ▶ Four sub-watersheds in the Nicola watershed are evaluated as high risk for sediment (Valdal and Lewis, 2015); ▶ Much of the coarser bed material is embedded with fine gravels and sands, rendering it unsuitable for spawning. This problem has been attributed to increased soil disturbance from logging, road and pipeline construction as well as to the limited bedload transport capacity of the river (Coldwater River Study, Chapter 3); ▶ Most serious sedimentation occurs where riparian areas have been cleared and where cattle access the Nicola River mainstem or its tributaries for watering (Millar, J., Child, M., Page, N, 1997); ▶ Major avulsion events Guichon and Coldwater leading to bank topping. **Discussion:** Paul Mozin noted lots of suspended sediment in the Chutters Ranch area of the river, but suggested that this is uncommon for most of the rest of the river system outside of reach 2. There are some issues just below the dam, as sediments are mobilized from the former glacial lake bed in that area but generally the group suggested there is not much evidence of choking sediment in the Nicola. However, very fine sediments have been recently noted in Shakan Creek (post wildfire) and clay sized particles are covering the beds. Logging in Guichon in 2017 led to avulsions, and	Moderate	High	L

Limiting Factor	Discussion	Current Biological Risk category	Future Biological Risk Category	Confidence
	sediment issues as noted above. Most issues as a result of recent logging in the Coldwater are likely occurring below the area of most early timed Chinook spawning except some concerns between Kingsvale and Juliet as a result of recent fires. The risk of this LF is likely to increase with more forest fires, forest cover removal, insects and salvage logging. If sediment begins to come out of the Coldwater River into the spawning areas of the Nicola, it could have a devastating effect. This potential risk of this limiting factor has also increased greatly since the floods. Most current amelioration tends to focus on costly processes to mine rocks and build berms and dikes. This is expensive and not the best solution in many cases. Also, it is often carried out by locals who do not wish to hire biologists and may fail after a period of time. In some cases, engineer firms have been hired, and they tend to use larger rocks which have been tested for acid drainage, but the longer-term solution should focus on riparian planting. **Key Gaps:** ▶ General gap in knowledge but PM will be monitoring TSS in the future. ▶ How transient will the gravel be? How will eggs be impacted? ▶ NOTE that this LF needs to be flagged as this could be a considerable future concern, but we are simply lacking knowledge. **Action Items:** ▶ Options of plantings need to be prioritized over the usual engineered rock solutions. Water authorization is assessing planting programs. If a rock wall is planted, then trees need to be added. Consider adding LWD to help stabilize the river.	🟨	🟧	

Limiting Factor	**Discussion**	**Current Biological Risk category**	**Future Biological Risk Category**	**Confidence**
	▶ Promote this work with the Restoration Table and under PSSI. DFO Restoration cannot apply for BCSRIF funds- so the Collaborative or a local group needs to put these projects together and apply for funds which are available for restoration. ▶ Look at options related to land preservation- purchase floodplain properties. Bring in economists to assess. ▶ Develop a strategic plan and long-term approach. The Nicola Collaborative should develop a Recovery Strategy where all these issues, habitat restoration plans and long-term needs could be laid out. ▶ Jason Hwang at PSF will be developing a Playbook for post flood management which might be useful. We could propose the Nicola as a case study.	🟨	🟧	
LF11: Colonization of invasive species (that reduces spawning habitat quality.	**LF11 Key Points:** ▶ Milfoil in lake: A macrophyte inventory was commissioned in 2013 to determine the extent of the Eurasian watermilfoil (EWM) infestation and composition of macrophytes communities in Nicola Lake. The survey completed in 2013 identified that EWM appears to have established in almost all suitable habitats within the lake and that native milfoil species appear to have been displaced. (Nicola Lake Eurasian Watermilfoil Management Plan, 2015); ▶ Was not considered a high- risk issue based on information collated. **Discussion:** No invasives are known to impact spawning areas. Canary reed grass is invasive and present but not influencing spawning areas. Tom Willms did catch a common carp below the dam in 2021- not sure how many there are and their effects, suggested that they could eat eggs? There are perch in the lake but there is uncertainty if they are moving down to the Nicola and it is also unlikely that they are impacting spawning gravel.	Low	Low	H

Limiting Factor	**Discussion**	**Current Biological Risk category**	**Future Biological Risk Category**	**Confidence**
LF12. Lack of a sufficient quantity of good quality spawning habitat	**LF12 Key Points:** ▶ This LF is related to flows; ▶ Not initially considered a major risk but could be greater now post 2021 floods. **Discussion:** There is lots of good spawning habitat in the Nicola. There has been the odd incidence of spawning Chinook being pushed into lower quality spawning habitats as a result of competition, but only when returns were as high as 12-14K. Paul Mozin noted that gravel is not limiting for the current levels of returns but with the recent flooding, there are concerns about lower gravel quality. However, flood impacts were lower for the Nicola-Spius-Coldwater segment of the Nicola River. Group suggested lower confidence for this one as there are some data gaps. **Key Gaps:** ▶ Redd site selection correlates strongly with groundwater–surface water interchange zones – how available are these? ▶ Chinook do not seem to be using all the past high quality spawning grounds- why? Is this related to dewatering? ▶ How soon does fresh gravel and sediment stabilize after flooding? ▶ Some gravel is not colonized, is this a groundwater issue? ▶ What comprises high quality gravel?	Low	Low	L
LF13a: Mortality due to predation enroute and at spawning grounds	**LF13a Discussion:** Loss of pools, shallower channels, results in greater predation opportunities for bears and otters at spawning grounds. There are bald and golden eagles, but their impact is unknown. Paul Mozin has not noted many carcasses. Not much information on impact of bull trout, pike minnow etc. but these predators would likely only impact juveniles. This LF was flagged at workshop 2 because of the loss of pool habitat. **Key Gaps:**	Low	Moderate	L

Limiting Factor	**Discussion**	**Current Biological Risk category**	**Future Biological Risk Category**	**Confidence**
	▶ No studies have been done on the impact of loss of pool habitats in the Nicola on predation risk.	🟩	🟨	
LF13b (NEW LF): Mortality due to unsanctioned fisheries during migration and at spawning grounds	**LF13b Discussion:** Loss of pools and concentrations of holding fish in a few pools along the Nicola may result in greater risk of unsanctioned fisheries, which do occur every year along the entire river. Lots of uncertainty around the level of impact.	Moderate	High	M
LF14a (NEW LF): Disturbance to natural migration and spawning activity due to anthropogenic restoration impacts	**LF14a Discussion:** The most serious anthropogenic impacts are a result of adding rip rap, which subsequently is scoured during big freshet events and creates damage lower in the river. The group noted a number of relic structures that have been found in a number of places in the Nicola River. These can get broken up and damage holding areas and spawning beds. Issues include dikes (e.g. Dot trestle) and lateral shifts in the channel which changes how water moves, and results in deflection and damage of structures that were placed close to or in the river. Tom Willms noted an issue at Rotary Park where turfgrass had originally been planted right to the edge of the river, and ultimately both the turfgrass and associated rip rap ended up in the channel creating problems. Chuck Parken noted that the large amount of rip rap placed into the Nicola River also acts as a huge heat sink, exacerbating other issues. Paul Mozin divided Nicola River into confined and unconfined areas in a study in the 1990s. He looked at the level of progressive armouring of unconfined areas- in those areas a great deal of rip rap has been added. SHIM can provide the change in % of armouring along the river but it is likely above 60%. Unnatural rip rap will add heat into the river and is an additional detriment to a temperature sensitive system.	Moderate	Moderate	M

Limiting Factor	Discussion	Current Biological Risk category	Future Biological Risk Category	Confidence
	This LF has likely been exacerbated by the recent floods, but the consequences are unknown. **Key Gaps:** ▶ What is level of armouring? ▶ What is level of disturbance as a result of anthropogenic structures? **Possible Management Lever:** ▶ There is a need to restore cottonwoods along the river.			
LF14b: Disturbance to natural migration or spawning activity due to anthropogenic impacts	**LF14b Key Points:** ▶ Bass Coast Festival and Rockin' River Festival, recreation (off road vehicles) in headwaters, recreational properties may result in impacts to spawning activity; ▶ Many recreational properties in this region and movement of lower mainlanders to rural acreages along the river. Many newcomers lack place-based knowledge of ecological values specific to the Nicola (i.e. not aware of salmon and water issues). **Discussion:** Lots of ATV traffic at the time that the early Chinook population moves into the Coldwater River. Lots of tire tracks, lawn chairs and people noted in August. Some years RVs park nearby. Chuck Parken flew upper Coldwater and noted that Highways had constructed 3 foot high rock weirs across the river – this was so that water trucks could drive to the manmade pool to pump water into trucks used for wetting down dust in construction areas– this was reported and is believed to occur about 3 times every 5 years- how prevalent are issues like this in the Nicola? Richard Bailey noted the music festival occurs every year, during which attendees commonly re-engineer pools with rocks to make for deeper waters to bathe in. Farmers also often create weirs so that they can direct water to their irrigation intakes. He noted that fish are mostly	Low	Moderate	M

Limiting Factor	Discussion	Current Biological Risk category	Future Biological Risk Category	Confidence
	harassed in their holding habitats rather than their spawning areas, often as a result of swimming activity. This harassment can result in fish having difficulty accessing and reaching their spawning habitats. Future risk may increase as more people move or visit this area. Backcountry area use increased between 5 and 10 times over the past year or two as a result of COVID. **Key Gaps:** ▶ Are any routine aerial surveys of the Nicola River carried out? ▶ How often do farmers/Highways/festival attendees construct weirs? ▶ No program to look at pumps (and level of screening), little local monitoring or enforcement **Action Items:** ▶ Request that organizers of local events (e.g festivals) provide funds towards restoration/clean ups. ▶ More outreach, education. ▶ More monitoring and enforcement. ▶ Focus on screening irrigation intakes- (monitoring 10% per year) would be a great program, and speaking with more ranchers/farmers.	🟩	🟧	
LF14c (NEW LF): Disturbance to spawning or migration as a result of cattle trampling	**LF14c Discussion:** Quite a rare event but Chuck Parken noted cattle within the lower Coldwater. Trampling of redds and disturbance of spawning is possible, but most cows are on higher elevation ranges and are not located lower in the river valley floors at spawning time. This may change with influx of dairy operations. Uncertainty about the temporal and spatial exposure as well as the impacts of this factor. **Key Gaps:** ▶ How often does cattle trampling in river occur?	Low	Low	L

Limiting Factor	**Discussion**	**Current Biological Risk category**	**Future Biological Risk Category**	**Confidence**
	- What are the impacts on adults? Spawning habitats? Holding pools? Redds?			
LF15: Pre-spawn mortality due to disease	**LF15 Discussion:** Key concerns are myxobacteria which has been found in hatchery smolts, possibly Cryptobia (leeches on gills transmit this but they have not been observed yet in the Nicola), BKD and Ich. Richard Bailey noted large concerns with Ich around other Thompson basin spawning grounds- and levels of disease can explode when fish are confined to pools and temperatures are above 20°C. Ich has not yet been noted in the Nicola, but could be an issue. However, the Nicola is known as a "hot" system for BKD and has some of the highest levels of BKD in the hatchery in the Province- rates are so high in eggs and juveniles in the hatchery that they often result in culling. However, unfed fry are sometimes released when they carry BKD which may pose a risk to the wild population in this system. Broodstock collected from the Nicola are mostly natural origin (when possible), but there are no recent data available on level of BKD in the wild population. Presence of BKD tends to reflect the stress level of the fish, and results in impacts on fitness, (but unless the level of disease is extreme, mortality of adults is unlikely). Sublethal impacts are the most likely outcome, and possible gamete impacts. In 1998 low water and high temperatures were associated with a large pre spawn mortality event, which may have been related to disease impacts. Overall this LF was scored low confidence due to a lack of information. Impacts of disease are likely to worsen with increasing water temperatures in the future under ongoing climate change. **Key Gaps:** - BKD data may be obtainable from DFO; Laura Brown did MSc and PhD work to look at impacts of BKD as a result of the proportion of enhanced fish in the system.	Low	Moderate	L

Limiting Factor	Discussion	Current Biological Risk category	Future Biological Risk Category	Confidence
	▶ Uncertainty of impacts of BKD on fitness in the wild. ▶ Not much information on this on the Nicola- some indications from angling crews only. **Action Items:** ▶ Flag as a possible research project through the Nicola Basin Collaborative Research and Technical Committee.	🟩	🟧	

Table 6. Discussion, Identification of Key Gaps and Next Steps for Factors Limiting to Incubation

Limiting Factor	Discussion	Current Biological Risk category	Future Biological Risk Category	
LF16: High suspended sediment loads that reduce egg to fry survival and emergence of alevins	**LF16 Key Points:** ▶ Spius Creek has shown elevated concentrations of suspended solids during peak discharge in May (Scott & Olmsted, 1985); ▶ Suspended solids in Coldwater and Nicola Rivers also have exceeded recommended limits during May and June during increasing discharge (Scott & Olmsted, 1985). **Discussion:** Issues are confined mostly to the area between the dam to town and Coldwater and Nicola below the areas of recent wildfires. The level of impact is difficult to rate, but will depend on how much sediment is mobilized and how long it takes to stabilize. This LF was flagged as a result of the 2021 flooding. The hope is that the LF will be a moderate risk in the future if the system settles down, gravel bars stabilize and vegetation grows back, but the group scored the current risk as high given recent flooding, fires and salvage logging.	Very High	Moderate	M
LF17a: Ice days resulting in	**LF17a Key Points:**	Moderate	Low	M

mortality of eggs and alevins	▶ Cohorts that incubated in winters with more ice days tended to have lower recruitment; for every 10 additional days of river ice, recruitment was predicted to decrease by 10% (Warkentin 2020); ▶ Anchor ice and ice scour can kill incubating eggs and alevins (Warkentin 2020). **Discussion:** Ice scour can be very detrimental to eggs in redds, particularly if the freeze is deep enough. A lack of groundwater can lead to freezing of eggs if the weather gets very cold for a long period. The groundwater also helps prevent the gravels becoming frozen and then being scoured/moved as a slab by rain on snow events. This is likely more of a problem since the flood events, with wider and shallow channels making ice scour more likely. In the future with continued climate change, there may be fewer ice days which would result in a lower future biological risk for this limiting factor. Medium confidence in scoring of impact as it will be very dependent on the extent and severity of the ice.			
LF 17b: Non-optimal water temperatures that reduce fry survival by changing emergence time in relation to food availability	**LF17b Discussion:** The group stated that this is very unlikely to be an issue.	Low	Low	L
LF18: High levels of pollutants or toxins that reduce egg to fry survival	**LF18 Discussion:** Paul Mozin has done some sampling for salt and road chemicals, and Highland Valley has an agreement with the 8 bands and regularly samples water after significant rain events, snow run off or freshet. The transportation corridor runs along Coldwater River which could result in discharge of pollutants into the river. Off channel complexes host most of the Coho and Chinook that are rearing, and could be at particular risk. The City of Merritt is allowing dumping of effluent into the river. However, they had a site for monitoring in 2021 and did not find any significant pollutant	Low	Low	L

	levels downstream of the treatment plants. The Coldwater Band had a study done on the reserve, testing above and below the highway, and found a significant rise in salt. Leona Antoine has the City of Merritt weekly testing data which is distributed to all bands. There is not much information on 6PPD-Quinone which could be a concern here. This LF is flagged as a potential issue due to the lack of information. **Key Gaps:** ▶ Lack of surface water runoff monitoring, conflicting information, lack of a structured sampling program. **Action Items:** ▶ Request the Highland Valley data. ▶ Start surface water runoff monitoring after big rain events, particularly to assess 6PDD-Quinone, and with particular focus in rearing channels.			
LF19: Low DO which reduces egg to fry survival	**LF19 Discussion:** Unlikely to be an issue as hyporheic mix is critical to redd site selection. Highly connected to LF17b. The groundwater and hyporrheic mix ensures appropriate redd temperatures and DO levels.	Low	Low	M
LF20: Lower low flows that dewater redds and reduce incubation survival	**LF20 Key Points:** ▶ This indicator was identified during a 2-hour flow threshold refinement workshop with local experts (Richard Bailey, DFO and Richard McCleary, MFLNRO) on February 19, 2016; ▶ The critical flow threshold was identified at the same workshop based on expert opinion. No optimal threshold has been identified to date; ▶ Dewatering of redds may be accentuated as a result of low groundwater influx leading to freezing of redds. **Discussion:** Water management is carried out through the dam to control incubation flows. However this is beyond our control in drought years. The shallow channel from the main lake to dam means that lake levels exist below which water cannot be released.	High	High	M

	At times there have been critically low flows between the dam and town portion of the Nicola River. Although these flows are regulated, there are concerns now after floods, these regulated flows may not be adequate. Guidelines developed in the 1980s, and conservative at the time, were reassessed in the early 2000s and appeared adequate, but some of the panel suggested that this needs to be further assessed now. The Nicola River Water Governance has looked at cultural flows but work has been delayed as a result of COVID. It was suggested that groundwater transects should be reassessed based on new numbers for depth and velocity ie the river channel is wider since the flooding and more discharge will be required moving forward for incubation flows. Richard Bailey also noted that the understanding of the hyporheic web does need updating and empirical work is required. There is a lack of knowledge about water removals from dugouts, and water removed through deeper wells may have a delayed response in-river. This issue is flagged, but is unlikely to be an issue downstream of the Coldwater confluence. **Key Gaps:** ▶ Are City of Merritt draw down zones around wells increasing? **Action Items:** ▶ Re-examine the guidelines for incubation flows, on ground transects as thresholds established pre-flood are likely not relevant moving forward. ▶ Establish reference wells in the Merritt area.			
LF21: More frequent and higher peak flows over winter can scour/disturb redds	**LF21 Key Points:** ▶ Winter flow issues are due to rain on snow events leading to possible ice scour. Ice jams can result in fisheries losses due to scouring of gravels and a loss of eggs as well as forcing fish out of overwintering areas (DFO, 1998); ▶ Flows have been impacted by forest harvesting and mountain pine beetle (MPB) is an added concern: decreases in forest cover due to MPB results in more snow accumulation in dead forests, and in clearcut areas. Earlier snowmelt leads to increased, faster and	High	High	M

	earlier runoff, which is also less synchronized at different elevations; ▶ Productivity appeared lower for cohorts that incubated during years with fall and winter floods greater than ~150m3/s. Flows over this threshold could mobilize sediments and scour incubating eggs (Warkentin 2020); ▶ Observations of gravel movement at high flows in the Nicola; ▶ More frequent rain on snow events lead to scour of alevins before they emerge from the gravel (R. Bailey, pers. comm.). Alevins emerging later than early April are less impacted. **Discussion:** Following the recent intense flooding in fall of 2021, this LF is flagged for further consideration. High flows have occurred that could impact redds, and lots of rip rap entered the river during the floods, which could also exacerbate the risks of scouring. **Key Gaps:** ▶ Information on impacts of high winter flows on egg scour. **Action Items:** ▶ FN communities have a pilot study with the Province and should be provided with the opportunity for further feedback and to provide support the confidence levels. This could be done by a presentation to the communities of the RAMS results to core council, or the discussion to set up a remediation table, including City of Merritt and other governments.			
LF22: Egg mortality due to inadequate spawning gravel, or as a result of gravel instability	**LF22 Key Points:** ▶ Avulsions have added a lot of gravel to the Nicola Basin systems, which is mobile and can result in mortality of eggs as a result of gravel instability. **Discussion:** The risk of this LF may be much greater post the 2021 flooding event. Avulsions and sediment inputs are likely to worsen in future. No shortage	High	High	M

	of good gravel but not much information on how stable the gravels currently are. **Action Items:** ▶ Reforest upper slopes. ▶ Riparian planting. ▶ Give the floodplain back to the river.			
LF23: Reduced egg to fry survival due to Chum & other salmonid overspawn	**LF23 Key Points:** ▶ This LF is not an issue in any of these systems as Chum are not spawning in the systems. **Discussion:** There are no salmon or other species in large enough abundance or size to disturb chinook redds in system.	Low	Low	H
LF24: Predation of eggs, alevins and fry/smolts by fish (sculpins, brown trout) and birds (mergansers)	**LF24 Key Points:** ▶ There is not likely to be very much egg predation as eggs are well buried; ▶ No brown trout but there are rainbows and charr, sculpins, pike-minnow plus many mergansers and mink. Mergansers are the dominant avian predators; ▶ As fry grow, they may become nocturnal to avoid predation (R. Bailey, pers. comm.). Mergansers may be the key reason. **Discussion:** No brown trout, but lots of pike minnow and perch which may spread downstream. Pike minnow are very abundant in the Nicola system and could have very detrimental impacts on alevin. There are also very high concentrations of birds along this system. Eggs are fairly deep so may be quite protected from predation, but impacts to free swimming stages could be quite high. Egg predation rates are unknown. Actions associated with this LF are further considered in the Freshwater Rearing section, as risk is to alevin and fry. **Key Gaps:** ▶ What are the impacts of redside shiner?	High	Very High	H

LF25: Egg mortality due to redd disturbance by invasive species	**LF25 Key Points:** ▶ Invasive species are a concern in the Nicola watershed but none are known to be impacting eggs. **Discussion:** Not considered a major issue.	Low	Low	M
LF26: Egg mortality due to redd disturbance by humans	**LF26 Key Points:** ▶ Not thought to be significant except in Upper Coldwater due to quads. **Discussion:** Some instream walking is carried out by stock assessment dead pitch staff. There are concerns of recreational use in the upper Nicola, quad riding in rivers, but it was agreed that this likely poses a minor risk to redds in the Nicola (though possibly a greater risk in the Coldwater).	Low	Low	H

Table 7. Discussion, Identification of Key Gaps and Next Steps for Factors Limiting to Freshwater Rearing

General notes:

Fish emerge April-May and are marginal in the river. As waters come up the juveniles can access grasses and other habitats. Bill Rublee's studies showed that fish do best when the water pushes them out into the fields and other ephemeral channels. Over the next month, flows increase from 2cms to 200cms and then drop down to very low levels in August. As waters begin to retreat, fish move back from ephemeral habitats and have grown to a level that they can maintain their station within the channel (Richard Bailey, pers. comm.). This period is critical.

Limiting Factor	Discussion	Current Risk	Future Risk	
LF27: High water temperature combined with low DO in the lower mainstem river and off channel areas can suffocate fry or reduce overall fitness during the early summer/fall	**LF27 Key points:** ▶ Salmonid production in Nicola & Coldwater rivers are constrained by relatively high water temps, & distribution of fish is influenced by local variations in water temps as fish seek cooler areas with groundwater inflows, shade etc (Walthers and Nener, 1997); ▶ Stream locations with larger upstream catchment areas have higher maximum temperatures as well as greater climate sensitivity to air temperatures Warkentin (2020); ▶ Sites with more riparian vegetation cover had lower climate sensitivity. Streams with 100% riparian forest cover had maximum	Very High	Very High	M

	temps ~1.2°C lower than streams without riparian cover. Many smaller tributaries contribute cool water to the mainstem in the warmest days of summer and are less sensitive to warm regional air temperatures; ▶ Mortality, reduced feeding and elevated stress hormones have all been associated with stream heating (Peatt and Peatt, 2013); ▶ Juveniles burrow into gravels to find cooler groundwater and survive summer temperatures of 23-25 C. (Peatt and Peatt, 2013); ▶ Providing more outflow from Nicola Lake during summer and fall often improves conditions for salmon, however, this can back-fire when the water released from Nicola Lake is too warm; ▶ Coldwater River is generally cooler than Guichon Creek or Nicola River. **Discussion:** Growth is good when temps are above 10°C but not when they get extremely high over the summer. Tom Willms has been PIT tagging Coho and noted diel movement into and out of thermal refugia. He noted that Chinook also behave like Coho, and use off channel habitats every day. Juveniles are better able than adults to exploit thermal discrete hyporheic upwellings and can nose into these and cool off their entire body. There is a great deal of benefit to cool alcoves and channels and beaver dam analogues. Fish migrate daily into and out of different habitats, staying protected during the day when predation risk is highest. There is huge spatial heterogeneity in the thermal environment of the Nicola which helps fish meet their requirements. Concern around impacts of LF27 will depend on behavioural regulation ie the ability of the fish to move and exploit these different thermal environments. Paul Mozin noted dying fish during the 2021 heat dome. Possibly larger fish are unable to get into the cooler interstices of rocks. 7-11mg/L DO is still believed adequate for fish in these systems. Tom Willms spot checked DO in deep upwelling areas and found ~3mg/L which is quite low but fish were still using these areas. Fish may be able to use these low DO regions as long as temperatures are low enough. However, at higher	🟥	🟥	

	temperatures e.g. 25°C it is hard for them to adequately to transport oxygen across the gills. The group agreed that there is a great deal of variability in thermal environments and fish may be able to use behavioural adaptations to find tolerable conditions. The extraordinary plasticity of the Nicola populations may allow them to exploit environments that are more difficult. It is possible that they could get stranded and unable to find refugia when needed, however, especially when conditions are poor, and fine sediments have either blocked access to off channel refugia or infilled interstices in the cobble. Mark Shrimpton's work noted that fish in Coldwater showed lots of downstream movements not associated particularly with smolting. It appears likely that fish scatter everywhere. High water temperatures may cause them to move down early, but this could result in a cost. Al Caverly, Provincial biologist has photographs of dead Chinook, likely associated with warm conditions in the Coldwater. In mid July-August, all juveniles are impacted by high temperatures. Risks may be direct mortality (due to predation), increased disease, and smaller size when entering the ocean. This LF is believed to be of even greater risk post-flood due to the loss of riparian cover which will further exacerbate water temperatures, lack of functional riparian, channel braiding, and loss of connectivity. **Key Gaps:** ▶ Lots of variability in thermal environments –do Nicola Chinook exhibit behavioural adaptations to find tolerable conditions? ▶ What is the prevalence of stranding- if fish are unable to find refugia when needed? ▶ Key knowledge gaps are how the fish respond ie what will the behavioural alterations, will system productivity increase to provide for the increased requirements of fish rearing in higher temperatures, how well will refuge habitats persist?	🟥	🟥	

	▶ What is the distribution and accessibility of thermally optimal habitats (ie cooler than average initially, warmer than average as the fish get bigger)? ▶ Which side channel habitats provide these optimal thermal environments and how should be protect them? ▶ There are few data on fish condition and changes to condition in drought versus non drought years. **Action Items:** ▶ Study to assess the status and productivity of side channel habitats post flood events. ▶ Paul Mozin has RST data for 5-10 years for 2 stations in Coldwater and one in the Nicola including fish condition information which would be very useful to look at.	🟥	🟥	
LF28: Low water temperature and lack of groundwater influx resulting in ice scour over winter	**LF28 Key Points:** ▶ In addition to thermal benefits, groundwater flow can also stop the formation of anchor ice during winter months; ▶ In the fall, some Chinook move into the lower Thompson- those remaining in the Nicola are particularly dependent on groundwater thermal refugia, particularly when rearing in interstitial spaces amongst boulders. **Discussion:** If it is very cold over the first winter that juveniles are rearing, anchor ice can form, and if there are large rain on snow occurs, the ice can start to move and create scour. There have been very cold snaps e.g. 2019, 2021, when anchor ice could have resulted in mortality. The entire channel by Nicola Lake can freeze up and could reduce rearing in the section between the dam and the Coldwater River (although we have a knowledge gap related to what proportion of Nicola fish are overwintering there). However, many juveniles hide in big boulders and groundwater serviced areas and may be at less risk of these events (which would likely impact the incubation stage more). Availability of groundwater is critical to the amount of anchor ice formation. In Merritt, wells result in removal of	Moderate	Moderate	L

	groundwater which creates issues, though the City did build dikes to assist with the ice jam issues. Regardless, ice jams do avalanche down the river. In 1995/6 there was an event in the Nicola basin, particularly in the Coldwater, when ice backed up the river water and the town was flooded. **Key Gaps**: ▶ Where exactly are the juveniles rearing? ▶ How far does ice scour extend? (Bark peeling off trees can be a clue to ice scour events). **Action Items:** ▶ Survey side channels remaining post-flood, assess levels of groundwater input, food resources, temperatures and DO levels etc.			
LF29: Toxic water quality conditions can increase fry mortality or reduce fitness.	**LF29 Key Points:** ▶ With the exception of Pb, Nicola Lake sediments show little evidence of metal contamination. The minor Pb contamination may have been by local traffic which used leaded gasoline until the late 1970s. Nicola Lake sediments exhibit gross contamination by DDT and minor contamination by chlordane and HCH. (Macdonald, R.W., Shaw, P. and Gray, C., 1999); ▶ Existing impacts from Highland Valley Copper Mine include increased copper molybdenum levels in downstream waters and in fish. Additional impacts include bioaccumulation of molybdenum in alfalfa crops utilizing water from Guichon Creek (DFO, 1998). **Discussion:** There have been spikes in salinity in the Coldwater at times, associated with the application of chemicals to the Coquihalla Highway. No toxicology work has been done in this area, so there is no current information on extent of 6PPD-Quinone. There is some information about fire retardants, which have accidentally been applied in the river. Paul Mozin has tested for water quality and so far there is no direct evidence that this has been impacted- however sample effort has been	Moderate	Moderate	L

	low. Coldwater bands are concerned about highway spills, while pesticides from agriculture and pharmaceuticals in Merritt sewage are other potential issues. During the atmospheric river event, the solid waste facilities at Merritt failed. The City of Merritt will continue to dump partially treated waste into the Nicola River. A water quality table is being established with the Province. **Action Items:** ▶ Development of a Recovery Plan requires moving the treatment plant so that it is adjacent to the Nicola River. ▶ Request the Highland Copper data (noted in LF18 above) to increase confidence on the scoring of this LF.			
LF30: High levels of sedimentation leading to clogging of interstitial spaces	**LF30 Key Points:** ▶ Sediment avulsion e.g. Guichon creek leads to clogging of interstitial spaces and preventing parr from rearing in these habitats (which serve as predation and thermal refuges during the summer). **Discussion:** This issue could be major, particularly in light of the recent fires, disease, salvage logging and flooding in the region. Sedimentation and clogging can also impact insect populations, a major food source. Chuck Parken notes a dearth of insect populations in the region. Lots of sediments noted in the Nicola (Skahun cloudy, lots of silt piles seen in Shackin and Skahun, and also in smaller creeks). Richard Bailey noted that if sediments made their way downstream of Shackin, the area is very steep and there could be severe consequences to rearing and migration habitats. Post flooding this LF could be far more of a risk so is flagged. Sediment transport clogging interstitial spaces that fish overwinter in would pose a large issue. **Key Gaps:**	High	Very High	M

	▶ This LF is flagged as it could be a major risk but lack of knowledge is hindering the scoring. **Action Items:** ▶ As for LF18 studies are required to determine where fish are overwintering. ▶ Surveys are needed to assess side channel TSS, DO, temperature etc.	🟧	🟥	
LF31: Mortality or fitness impacts as a result of lack of food	**LF31 Key Points:** ▶ Nicola Dam has attenuated high peak flows over a longer time-so high flows during freshet have increased. This has led to increased erosion and turbidity that may decrease aquatic productivity downstream; ▶ In general, however, these systems are productive, not like coastal rivers. The Nicola is also eutrophied by treated sewage and agricultural runoff (R. Bailey, pers. comm.); ▶ Rearing Chinook show little evidence of territoriality (R. Bailey, pers. comm.). **Discussion:** The Nicola River appears to be changing, and as noted above, there are fewer insects, including the large stoneflies that used to be very obvious on this system. Caddisfly are also much less abundant. Paul Mozin noted a CABIN MoE site on the Coldwater River, and data collected there have not indicated any major change in these populations over the last 10-15 years -however the site is also much higher up in the watershed. Insects in the river are likely negatively impacted by bank topping events. The most dense activity is from mayflies, (some of which are known to be silt dwellers). Fish may have to travel further to find aggregations of food, putting them at more predation risk. Tom Willm's tagging work shows that Chinook enter refugia as early as 9am in the morning, which ties in with observations that there is no insect activity after 9am in this region. Increased turbidity, increasing temperatures and lower DO can all impact the food web and decrease stream productivity. All of these factors are likely worsening.	Moderate	High	L

	Key Gaps: ▶ Are there other data from additional CABIN sites? ▶ After events such as flooding and sediment inputs, depressed productivity is likely, but there could also be increased invertebrate activity, and acceleration of gravel /fines substrate entering the river. This is currently a knowledge gap for the Nicola River. It may not be a consistently negative impact. **Action Items:** ▶ A study is needed to collect smolts, check scales, diet, back calculate growth. Look at length-frequency analysis (similar to Blair Holtby's work on length-frequency as a proxy for density of juveniles) to assess level of competition. Is there any evidence of growth irregularities? Is there failure to reach critical sizes? ▶ Assess low and high temperature tributaries. ▶ Look at studies done in the US on impacts of dam removal projects from systems with large sediment flushing. ▶ Assess gravel and fines input into the Nicola River.			
LF32: Mortality or fitness impacts as a result of inadequate in-stream complexity and riparian complexity	**LF32 Key Points:** ▶ Most prevalent hazard is riparian loss; ▶ Vast majority of riparian disturbances are on S6 streams, although there is extensive private land and ranching based riparian disturbance in the lower ends of watersheds. 46% of all S6 monitoring sites had almost no buffer (<1m); 28% of samples had at least a 10 m buffer. Rex and Maloney (2010) found that in stream conditions were affected by upstream riparian harvesting 20-30 years after activity; ▶ The number of catchments with a high and very high riparian hazard (stream bank stability, shading,) increased from 2003-2013 (riparian being the greatest hazard, followed by streamflow hazard (ie. floods, bank erosion, channel instability); ▶ Primary factor contributing to elevated riparian and streamflow hazard is salvage logging by forests affected by pine beetle (Valdal and Lewis, 2015); ▶ Newly emerged fry found associated with riparian vegetation and brush piles. Later, as they grow >40mm in spring and early	Very High	Very High	H

	summer, high densities of juveniles found associated with bushes and willow sapling areas with lots of woody debris (Levings and Lauzier, 1987). By late summer/early fall they are found in habitats with cobble and boulder substrates in faster stream flows **Discussion:** There are pike minnow throughout this area and redside shiners in side channels. Complexity in the system has been reduced over time, and there are fewer refuges for juvenile Chinook to hide in. 2.5m setbacks are not found in most riparian areas and there are no large mature stands of mature cottonwoods still in existence. Clapperton and Guichon headwaters have been demolished by disease, fire and salvage logging. More armouring is proposed through Merritt, further exacerbating the issue. Ranchers remove cottonwoods so they can create more alfalfa fields (but are then concerned when these areas flood). Paul Mozin noted that in the Sunshine Area, an attempt is being made to add plantings in order to increase the ecological function of areas of rip rap. One major issue is the lack of protection of riparian areas on private land. This is a particular impediment to protection of species at risk. In Alberta, there are tax incentives for private landowners to protect riparian areas- could something like this be considered in BC? Forest practices also can remove vegetation in protected riparian areas- they just cannot place machinery within those areas. This removal does lead to increased erosion. **Action Items**: ▶ Revisit conservation easements. ▶ Set land aside for wildlife and use for tax credits. ▶ Develop corridors. ▶ Link floodplain zoning to conservation easements. ▶ Rezone land use in the valley bottom. ▶ Go through a process like this to prioritize the key LFs and potential actions, rather than just fund “shovel ready projects” and short-term solutions like buying rip rap.	🟥	🟥	

	▶ Fund land conversion to cottonwood plantations with benefits to fish habitat as well as harvest opportunities. Buy water licences back and change the type of agriculture in the valley ie. return to cottonwoods. ▶ FN in area want a comprehensive review of 2021 atmospheric flooding event and issues related to lack of storage in Nicola and Coldwater. They will not support private landowners for request for diking and hardening sites within the river. ▶ Reassess riparian area condition with high resolution orthophotos or satellite imagery. ▶ Education and outreach is required as many landowners are increasing use of artificial substrates and hardening the riparian areas rather than looking at plantings.	🟥	🟥	
LF33: Increased stranding in isolated off channel habitat and tributaries	**LF33 Key Points:** ▶ Spring- type Chinook salmon in particular use off-channel habitats such as wetlands, side-channels, sloughs and other floodplain habitat (Sommer et al., 2001); ▶ Fry move into flooded meadows at the end of April/May (R. Bailey, pers. comm.); ▶ Recent evidence suggests juvenile Chinook salmon rearing in these areas have much higher growth than those rearing in mainstem areas (Jeffres et al., 2008; Bellmore et al., 2013). These habitats are ephemeral but critical to recruitment (R. Bailey, pers. comm.); ▶ Irrigation activities and low water levels in off-channel areas identified as reducing available rearing habitat (LGL Limited, 2001); ▶ Stranding leads to inability to access thermal refugia (R. Bailey, pers. comm.); ▶ Winter flow issues result from rain on snow events. There is also the potential concern about earlier freshet creating a timing mismatch for availability of ephemeral habitats . **Discussion:** Lateral connectivity to thermal refugia is a major topic. Paul Mozin has observed fry in off channel habitat, and varying levels of connectivity.	High	High	L

	How much stranding occurs? Some stranding has been observed by Richard Bailey in the Coldwater in the past. The level of risk depends on the habitat the fish find themselves in e.g. off channel habitat with healthy riparian as compared to braided shallow sections with no riparian vegetation. Farmer fields are another issue- and here the level of stranding may be directly related to water use by the farmers. Increasing prevalence of avulsions can result in lack of access to critical rearing areas. Ramping rates may impact stranding too as fish can detect and possibly respond to the decreases in flow. This LF links with reservoir operations. **Key Gaps**: ▶ How much disconnection to thermal refugia has occurred? Connectivity is critical. How many fish end up stranded? Are they just stranded short term until the fall rains start? ▶ How do fish use different habitats such as channels, tributaries and meadows? ▶ How will DFO policy impact possible mitigation solutions? ▶ What flow levels do fish need- minimum flow levels may not be adequate during droughts, and should not be used as targets. **Action Items**: ▶ If removing water from the stream, mitigation is enforced (like carbon offsetting). ▶ Broader discussions are needed around use of water- homeowners should have smart meters, usage of contemporary methods of irrigation, recent technology etc. ▶ Broader discussions needed about minimum flows- which are often considered as targets. ▶ More enforcement procedures- may develop through the drought response committee and discussions around environmental flow needs, and water management regimes. ▶ Bringing forward of Indigenous knowledge in this regard will be highly beneficial. There is a lot of academic knowledge in the Nicola Characterization report, but local community knowledge and moving forward with the Indigenous Laws is crucial.	🟧	🟧	

	▶ Overflights are required to look at the changes in routing of Nicola River and losses in connectivity, particularly in the higher tributaries. On the ground work to assess the state of the tributaries (ie water quality etc) is required. ▶ The new Restoration table could explore connectivity issues and needs to develop the Terms of Reference. This could be an important group to provide collaborative stewardship.			
LF34: Higher high flows that prematurely displace juveniles downstream and reduce overall fry survival	**LF34 Key Points:** ▶ Flows in this region have been impacted by forest harvesting and mountain pine beetle (MPB); ▶ Earlier snowmelt leads to increased, faster and earlier runoff, which is also less synchronized at different elevations and can impact wild fry, and result in movement out of the Nicola; ▶ Early migration before freshet may result from ice break up and changes in stream flow due to early snowmelt; ▶ LF34 will be exacerbated with climate change which will likely lead to earlier peak flows as well as increased flooding; ▶ Chinook smolts over 90mm are less impacted by flooding; ▶ Warkentin (2020) noted that productivity appeared lower for cohorts that incubated during years with fall and winter floods greater than ~150 m3s-1 . **Discussion:** Nicola Chinook are adapted to emerge on the ascending limb of the freshet, but with climate change the freshet is getting earlier. If the freshet is too far advanced when fry emerge, there could be issues. However, there is uncertainty about the level of possible fish displacement and behavioural changes as a result of high flows and flooding. There is a high level of plasticity in Nicola Chinook and many fish naturally move down into the Thompson and Fraser. High flows could increase the level to which this occurs in the populations, and could also have impacts in these other systems (e.g. density dependence, competition etc). As reservoirs warm up, this can also result in higher temperatures. **Key Gaps:**	Moderate	Very High	M

	▶ What will be the impact of earlier flows? Will fish emerge earlier (especially if groundwater temperatures are still low)? **Action Items:** ▶ Research is required to assess impacts of earlier and higher flows on fry survival.	🟧	🟥	
LF35: Low flows reduce seasonally available off channel and tributary rearing habitat.	**LF35 Key Points:** ▶ Warkentin's (2020) analysis of over 20 yrs of Chinook salmon life-cycle data revealed that low summer flow strongly decreases productivity. August flow during spawning and fry rearing had the strongest effects – cohorts that experienced 50% below average flow in the August of spawning and rearing had 40% lower productivity.; ▶ Chinook salmon cohorts are predicted to drop below replacement – and thus unable to sustain fishery mortality – in years with average August discharge less than 10.83 m^3s-1 (or 36% mean annual discharge) during the rearing summer. He noted that these flows only occurred for 18% of cohorts examined; ▶ Chinook salmon cohorts are predicted to drop below replacement – and thus unable to sustain fishery mortality – in years with average August discharge less than 10.83 m^3s-1 (or 36% mean annual discharge) during the rearing summer(Warkentin 2020). **Discussion:** Luke Warkentin's work showed a clear relationship between discharge and juvenile rearing survival. This LF is tied to other LFs associated with water quality, particularly increased temperatures. As flow is reduced, temperatures increase, and with increased air temperatures in the future, this could worsen. Flooding will make it more difficult too to retain water in streams over the summer. After the November 2021 flooding event, the channel is wider and so higher discharge is requited to supply adequate habitat. Summer baseflow has been extended by 1 month and for a longer period to ameliorate low flow conditions. There is a lot of natural storage in	Very High	Very High	H

	Guichon, though most is dammed, but not Coldwater. For the latter, once storage is lost, it is completely gone. Also, groundwater is lost as a result of fires as trees are no longer present and able to take up and store water. Instead aquifers end up discharging the water that would otherwise have been transpired. RB noted that the Douglas Lake Ranch manager, Stu, could not walk across the river years ago, but now the water is often only ankle deep. **Key Gaps**: ▶ Question about whether there will be increased flows as a result of wildfires? **Action Items:** ▶ Need to create more storage. Mamit Lake is getting warmer and Shackin has heat issues, so new locations are required. ▶ Look at beaver dam analogues higher in the watershed (these did well on Coldwater tributaries and survived the recent 2021 flooding). Nooaitch is interested in supporting these.			
LF36: Mortality or fitness impacts as a result of competition with Aquatic Invasive Species (AIS)	**LF36 Discussion:** Crayfish are present in the Nicola, as well as larval lamprey, the latter requiring fine sediment, and can provide a good food source for juvenile salmon and may increase in abundance in the future if suspended sediment continues to increase. Other AIS may include Smallmouth bass and Northern pike which could move into the river (CP). The key concern is Yellow perch which are present in the lake. The confidence associated with the risk scores for this LF is low as studies (e.g. mark-recapture studies) have not been done to assess the extent of invasive species spread in the Nicola. However, there are 90,000 Perch in Douglas Lake currently and they are known to be moving downstream into the Nicola, and there are no structures to prevent their outmigration. Climate change is likely to lead to a worsening situation, as many invasive species may be able to outcompete native species. Additionally, the situation may be worse post-flooding, as many of the suitable habitats left for Chinook overlap perch habitat. **Action Items:**	Moderate	High	L

	▶ Studies are required to assess larval lamprey and impact on Nicola Chinook;. ▶ Need to monitor below the dam and into town and in the various oxbows to see if perch has moved into these habitats. Carry out a mark-recapture program. ▶ Research structures that could reduce downstream movement of perch. ▶ Continue eradication methods for perch- target spawning time around Easter. ▶ Look into the literature to assess the impacts of Yellow perch on salmon (ask Brian Holmes).	🟨	🟧	
LF37: Alteration of natural riparian structure and ecological integrity as a result of colonization of invasive species	**LF37 Discussion:** The two main species of concern are Canary reed grass and knapweed. Canary reed grass has been found along Guichon Creek, where it outcompeted cottonwood stakes and is also known to outcompete willow. It is unknown if this is found adjacent to the Nicola River, but if so, it could pose a risk. It has a thick root matrix, and will grow along the banks of small streams and cover gravel bars, removing the pool riffle channel structure. This is less of a concern on larger systems, but it can smother smaller systems, reduce their complexity and decrease the resilience of stream ecosystems. Knapweed is an additional concern as it is poisonous and can impact regeneration of natural species. Some past rehabilitation work done in Guichon Creek resulted in introduction of many invasive plants, which were also moved around by machinery. Forestry in the region are careful about maching washing, but issues can occur when emergency service vehicles come in as they move in quickly and spread of invasives could result. Action Items: ▶ When disturbance occurs, standard operating procedures are to plant grass to stabilize sediment. Perhaps Forest Practices should re-evaluate which species are planted? ▶ There are techniques to remove the reed grass and these have been successful. This has occurred in the Hope area, so study of these techniques could be beneficial.	Moderate	Moderate	M

LF38: Impacts to juvenile migration as a result of invasive plant species	**LF38 Discussion:** The team agreed to pool LF 37 and 38.	Moderate	Moderate	M
LF39: Mortality or fitness impacts as a result of competition with a) hatchery fry/smolts and b) other species	This LF was split. **Key Points:** ▶ There are virtually no fry releases into the Nicola Basin; ▶ Coho and steelhead fry numbers also depressed (R. Bailey, pers. comm.); ▶ Lauzier and Levings (1991) found that Chinook and rainbow trout showed temporal and spatial separation, minimizing competition in the Nicola River; ▶ Wild fry tend to use river margins while larger hatchery (and wild) fish use areas of deeper faster water for rearing. **Discussion:** LF39a: Hatchery fish are released as yearling smolts (85% of production) so there is very little competition. LF39b: However, Redside shiners (native fauna to BC) have colonized many of the side channels, and are about 8-12cm in size, making them a size that would create competition rather than serve as prey to the Chinook. They also tend to prefer warm waters so may have higher ability to withstand increasing water temperatures and subsequently, have higher competitive ability with young Chinook. The participants noted that these are a native species and the key concern here is their increase as a result of warmer temperatures- the goal should be to reduce temperatures, not to start removal of this native species.	Low Moderate	Low High	H
LF40: Mortality as a result of high levels of predation in the river	**LF40 Key Points:** ▶ Fry predation from birds, mink, sculpins and pike minnows (R. Bailey, pers. comm.); ▶ Avian predation on smolts can be an issue when flows are low 9R. Bailey, pers. comm.); ▶ Hatchery fish can predate wild fish (Levings and Lauzier, unpub data).	Moderate	High	M

	Discussion: Aggregation of juveniles into thermal refuges may increase predation rates by mergansers, pike minnows, herons, kingfishers and possibly even seagulls. Because many juveniles hide in interstitial spaces, they may however be less at risk to avian predators- but mink may be another issue. Tom Willms noted that many PIT tagged fish in his studies did not return and could have been taken by predators like mink (several went missing in off channel habitat). Otters are an additional issue. There are low numbers of bull trout, and these are mainly found in upper cooler waters. Chinook may need to be more active during the day to get food (especially as temperatures are increasing and metabolic demands increase) and may therefore be more exposed to predation. This LF may be a concern as a result of the lack of complexity in river, reducing escape habitat for smolts, and if any action is taken, it should be to increase complexity, not remove predators. **Key Gaps:** ▶ No studies of predation currently, or whether it is increasing.	🟨	🟧	
LF41: Mortality or fitness impacts as a result of disease	**LF41 Key Points:** ▶ Two issues apparent in hatchery fish: BKD and Myxobacterial issues that resulted in depressed survivals in 1992 brood and some other years (R. Bailey, pers. comm). **Discussion:** Hard to quantify the impact of this LF and there was low confidence in this rating as little information is available. However, BKD is an issue in the hatchery stocks based on testing done in the past in Nicola, Spius and Coldwater. This might increase as a risk in the future as thermal concerns exacerbate this issue. **Key Gaps:** ▶ No knowledge of disease levels in wild fish.	Low	Low	L

LF42: Lack of high-quality rearing habitat throughout the river both mainstem and side channels and tributaries	**LF42 Key Points:** ▶ Summer rearing habitat is considered a major limiting factor to Chinook production; ▶ One of the potential contributing limiting factors is low stream flow during the summer rearing period when irrigation is occurring; ▶ A second potential contributing factor is high water temperature. Water temperature in the mainstem river have been recorded up to 29C where the lethal limit is ~24C; ▶ Juvenile Nicola Chinook burrow into the streambed gravel in groundwater upwelling areas during the hottest part of the day, where temperatures are 16°–17°c compared to ambient river temperatures of 23°—25°c; ▶ Sebastian (1982) reported that within the Nicola River, glide and pool habitats near Merritt are the most productive areas for rearing juvenile Chinook salmon; ▶ Note that periodic access to groundwater-moderated thermal refugia can be critical (R. Bailey, pers. comm.); ▶ Chinook fry prefer low velocity areas (0.15m/s) and are thus usually found along the stream margins and within backwater areas (silt sized bed material). As the fry grow, they utilize deeper and faster areas in the main river. Juveniles have been recorded to overwinter amongst boulders on the stream bottom; ▶ Much of the riverbanks bordering agricultural areas are actively eroding due to loss of riparian habitat and unimpeded cattle access to the river. Within the lower section of the Nicola River, only 3.5% of a total riverbank length of 234.2 km is bordered by unimpacted vegetation; ▶ The loss of riparian vegetation has resulted in increased erosion, loss of shade and instream cover, and loss of pool and off channel habitat ; ▶ Loss of riparian vegetation has also been shown to increase river width and channel instability ;	Very High	Very High	H

	- Channelization has also reduced the number of back channel and wetland areas. Chinook that rear for one year in freshwater are particularly vulnerable to these impacts (DFO, 1998) . **Discussion:** This LF is considered a major issue particularly as a result of recent avulsions, sediment inputs, groundwater extraction and flooding. River complexity has been lost, including the pool-riffle-run structure, instream habitat complexity, and connectivity. Sediment can obstruct access to off channel and side channels, and bank topping events lead to channel braiding and loss of riparian. Sediment can also impact interstitial spaces through infilling. **Data Gaps:** - How far do Chinook move when they come out of summer interstitial rearing refuge habitats to forage? - Do clogged interstitial spaces result in changes in capacity or direct loss of survival via predation? **Action Items:** - We need an assessment of current in-river complexity and connectivity (lateral and longitudinal).	🟥	🟥	
LF43: Lack of access to historical tributary and off channel habitat.	**LF43 Key Points:** - Irrigation ditches can obstruct normal river flows, juvenile salmon rearing in the river are swept with the unscreened diverted water into farmers fields/ are attracted to ditches for quieter habitat to rear ; - Fish can become trapped/killed during periodic dewatering over summer; - High velocities in entrance channels are likely to prevent smaller fish from swimming upstream and back to the river. **Discussion:** - Noted as a key issue as related to summer drought periods and the 2021 flooding impacts.	Moderate	High	M

	Action Items: ▶ Restoration to restore access (some work has been ongoing to restore access to off channel habitats and tributaries), screening of water intakes, and to understand lateral connectivity.			
LF44: Limited juvenile passage at lake fishway, tributary culverts etc	**LF44 Discussion:** This was not thought to be a major risk. Most impacts are related to lateral passage.	Very Low	Very Low	M
LF45: Mortality or fitness impacts as a result of anthropogenic disturbance	**LF45 Discussion:** Disturbance to rearing habitats has occurred as a result of modifications and recreational activity, as noted above. Water intake diversions have trapped juveniles in Guichon, Chutters Ranch area and Coldwater and may also be impacting fry and smolts in the Nicola. **Key Gaps:** ▶ No information on potential losses associated with water intakes and screening. **Action Items:** ▶ Education and signage to inform the public.	Moderate	Moderate	L
LF46: Hatchery introgression	**LF46 Key Points:** ▶ Degree of interaction between hatchery and wild fish is largely dependent on timing of migration. In 1985, after a colder than average winter, fry emergence and migration were later, and thus many hatchery fish were using the river at the same time as wild fry. **Discussion:** Spring Chinook are not particularly productive. As ocean productivity goes down, and returns are low, a larger proportion of fish are taken for broodstock to allow for confidence in stock assessment using CWTs. However this is resulting in low PNI is this system and this is not likely to improve. There is a need for information for fish management- but also the conflicting need to maintain a wild population. Consideration as to	Very High	Very High	H

	whether the hatchery production targets could be reduced from 200K hatchery smolts is required and conversations are needed with the Upper Fraser groups about this issue. DFO can mitigate by reducing the number of hatchery fish spawning in some systems, but this may be difficult to do in the Nicola. It is possible to angle hatchery fish only, but this requires handling a lot of fish with possible catch and release impacts to wild fish.	🟥	🟥	

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APPENDIX 1- CHARACTERIZING NICOLA BASIN CHINOOK

The Nicola River is a tributary of the Thompson River and is a sixth order stream located in the interior of southern British Columbia (Figure A1-1). The entire Nicola watershed covers an area of 7211 km^2, with the mainstem approximately 188.5 km in length (MOE 2021). The Nicola River produces early-run Chinook, Coho, and steelhead to the Thompson and Fraser River. Important tributaries to the Nicola for salmonids include the Coldwater River and Spius, Maka, Spahomin, Quilchena, Clapperton and Guichon creeks. The Coldwater River is the second largest tributary, draining an area of 914 km^2 and is the most important stream for Coho and early-run Chinook, as well as steelhead in the Nicola watershed. Guichon Creek is the largest tributary to the Nicola (1,230 km^2) and supports all three of the aforementioned species as well.

Historically, the Nicola River was an important contributor to interior Fraser River salmon production. However, current salmon escapements to the Nicola system are depressed: Interior Fraser River Coho stocks were COSEWIC designated in 2002, a designation which prompted the need for immediate recovery goals to be established by the Interior Fraser Coho Recovery Team (DFO 2006)[2]. Nicola Chinook were designated by COSEWIC as endangered in November 2020. In addition, Bull Trout are listed as a Species of Concern by British Columbia Conservation Data Centre; and Nicola River steelhead, which are an important component of the Thompson River stocks, are regarded as an extreme conservation concern by the Ministry of Environment (MOE), and have been designated as endangered by COSEWIC in 2020.

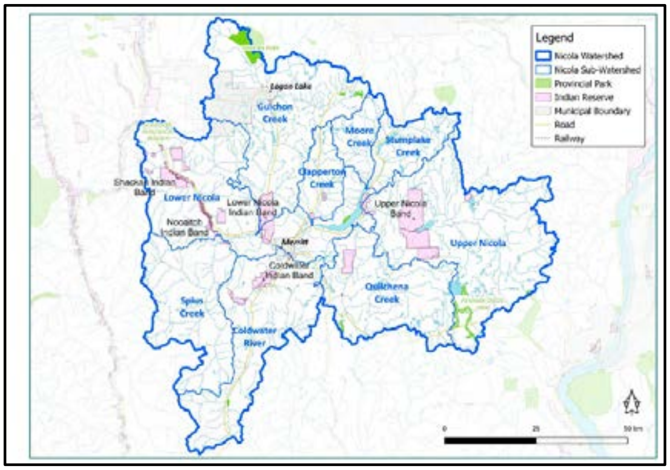

Figure A1-1. A map of the Nicola Valley showing sub-basins (blue), First Nation communities, parks and municipalities. From the Nicola Watershed Characterization report (ESSA Technologies Ltd. and Fraser Basin Council 2019)

Status of Nicola Chinook:

Nicola Chinook make up part of the Fraser Spring 42 Chinook Management Unit. There are two designatable units (DUs) within this management unit:

1) DU14 BC South Thompson Stream Summers. CK-16. South Bessette Creek. Spawning locations include: Bessette Creek, Creighton Creek; Duteau Creek; Harris Creek. Assessed as Endangered and in Red Zone
2) DU15 BC Lower Thompson Stream. CK-17 Lower Thompson Springs. Spawning locations include: Bonaparte River; Coldwater River; Deadman River; Louis Creek; Nicola River; Spius Creek. COSEWIC Endangered (Nov 2020), and WSP Red.

Specific fishery management actions are implemented annually to protect the Spring 4$_2$ Chinook management unit. The evaluation of these actions is based, in part, on the exploitation rate analysis provided by Chinook Technical Committee (CTC) indicator stocks. This annual analysis uses coded-wire tag (CWT) recoveries from fisheries and escapements to represent the impacts on all stocks within the management unit. The CWT indicator stock for the Spring 42 management unit is Nicola River.

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[2] Interior Fraser Coho Recovery Team. 2006. Conservation Strategy for Coho salmon (*Oncorhynchus kisutch*), interior Fraser River populations. Fisheries and Oceans Canada

Spring 4_2 Chinook return to spawn from early March through late July and migration peaks in June in the lower Fraser River. These populations primarily mature as adults at age 4 (90%) with lower numbers maturing at age 5 (7%) and occasionally at age 3 (3%).

Coded-wire tagged (CWT) Nicola River Chinook released from the Spius Creek Hatchery is the (Pacific Salmon Treaty) PST exploitation rate indicator stock used to assess survival and exploitation rates of Spring 4_2 Chinook in Canadian and U.S. fisheries. Based on CWT recoveries from fisheries, Fraser Spring 4_2 Chinook have historically been encountered in Fraser River First Nations gill net fisheries, Fraser River and tributary recreational fisheries, marine troll fisheries (e.g. West Coast Vancouver Island (WCVI) and North Coast), and recreational fisheries in the Strait of Juan de Fuca and Strait of Georgia, with lower rates in other marine recreational fisheries.

There are no pre-season or in-season abundance forecasts developed for this aggregate. DFO's outlook for Spring 4_2 Chinook states that this is a stock of concern with continued expectations for depressed abundance due to low parental escapements, ongoing unfavorable marine and freshwater survival conditions and low productivity.

Escapements in 2018 declined compared to the parental escapements in 2014. For those systems where escapement estimates are available, escapements were ~12% of the parental escapement and were far below estimated Sgen values for Spius, Coldwater and Nicola, despite hatchery supplementation. In 2019, escapements to Nicola and Spius both declined below parental brood escapements (2015), however estimated escapements to the Coldwater improved over parental brood, however, escapements to all systems remained considerably below estimated Smsy values. Escapement to the Nicola River in 2020 exceeded parent brood levels, although the estimated spawning escapement did not exceed 4,000.

Nicola Chinook Populations:

Nicola Chinook populations are made up of 3 (or maybe 4) closely related stocks of spring-run Chinook, all belonging to lower Thompson 1.2 Spring CU (WSP) and DU (COSEWIC).

- Nicola River
- Spius Creek
- Coldwater River

There may be an additional 4th remnant in the Upper Nicola River and Spahomin Creek, above Nicola Lake. There appears to be some spatial overlap in the spawning distributions, but modest (though incomplete) temporal separation. The areas of spatial overlap include:

- Lower Coldwater River below Kingsvale, down to IR 1 Bridge
- Spius Creek below Big Box Canyon downstream to the hatchery

The timing of arrival in terminal area and onset of spawning regulated by 1) access to spawning grounds and extreme terminal areas and 2) temperatures in-river and in intra-gravel environments. The timing for the different stocks are shown below:

Stock	Arrival	Spawning
Spius Creek	April to August	Mid August to Early September
Coldwater River	April to August	Mid August to Early September
Nicola River	June to September	September

Life History:

Nicola Basin Chinook return to spawn mostly at age 4 after 2 years of ocean rearing, with some returning at age 3. Precocious male yearlings (“Jimmies”) that have residualized have been observed on occasion, and it is believed that precocious parr may exist but these have not yet been identified. The adults enter the lower Fraser from March to July (based on Albion test recoveries of CWT fish and spawner presence in streams). They are managed as part of the spring (early run) stock group as a result of this early migration through the lower Fraser (spring runs peak on or before July 15- though Nicola Basin Chinook are occasionally recovered at Albion or in the lower Fraser as late as August).

Nicola Basin Chinook show two distinctly different patterns:

1) Spius and Coldwater are pre-freshet migrants which arrive in the Nicola system in April through June mostly:
2) Nicola mainstem fish arrive in the Thompson in late June and July mostly, with peak of entry near the end of July.

All Nicola Basin Chinook exhibit a stream-type life history, with the juveniles overwintering in freshwater before entering the sea as yearlings (Healey 1991, Fraser et al. 1982). Fry emerge in the spring (Lewis and Komori, 1989) and typically disperse throughout the natal streams; some remain to overwinter while a portion emigrates to the lower watersheds at this time (Scott and Olmsted 1985). Bradford and Taylor (1997) found that larger fish were more likely to move downstream than smaller ones in upper Fraser populations, noting that such variability in early life history could make identification of limiting factors/habitats quite difficult.

Juveniles emerge in April and May and newly emerged fry rear in marginal and newly flooded (ephemeral) habitats until they are able to maintain station and territory on channel. There appear to be three variants within the juvenile life history (Figure A1-2).

iv. Emerge, leave natal stream and rear in Lower Thompson and Fraser, mostly overwintering and smolting from Lower Fraser.

v. Emerge, remain in natal stream through first summer and migrate out into the Lower Thompson where they over-winter and smolt as 1+ .

vi. Third variation is to emerge and remain in natal stream and smolt from natal stream as 1+.

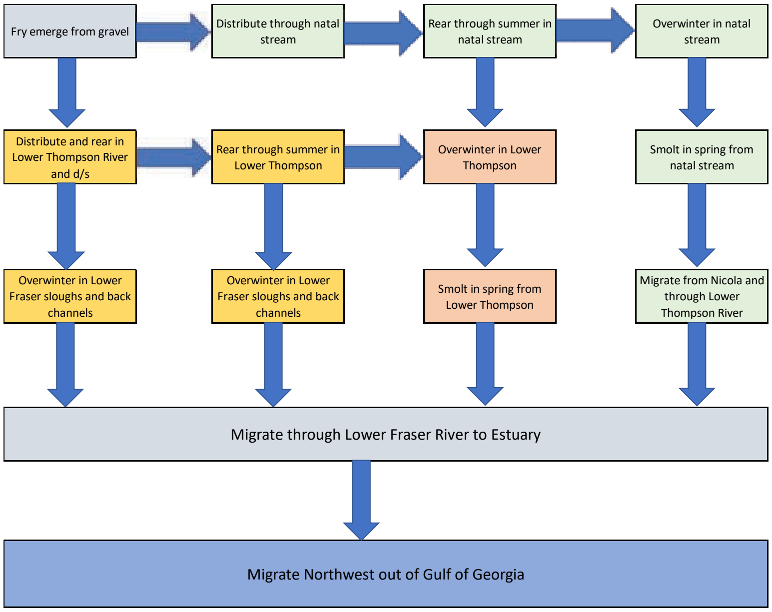


Figure A1-2. Three variants in the life history of Nicola Chinook. From RE Bailey.

It is believed that there is considerable overlap among strategies. Some move passively and others actively downstream into the Thompson and Fraser, while others remain in the natal stream, feeding on drifting and emerging insects throughout the summer. Later in the fall, some of these rearing juveniles leave Nicola system and also move downstream into the Thompson to overwinter. The remaining fish overwinter in interstices of larger rock in areas serviced by ground water to avoid freezing in anchor ice.

Lauzier and Levings (1991) found that newly emerged Chinook fry were found in riparian vegetation and brush piles during freshet. In the Nicola River, as young of the year juveniles grow (>40mm) in late spring/early summer, they were found associated with the margins, cutbanks, log debris and available cover (Lauzier and Levings, 1991). In late summer and early fall, juveniles were found in habitats that have cobble and boulder substrates and faster streamflows. They noted that emigration occurred from the Nicola throughout the year. In Guichon River they were mostly found in pool habitats.

Chinook salmon are thought to use predominantly cobble substrate and other cover as overwintering habitat (e.g. Hillman et al. 1987), and use such habitat in the lower Nicola River (Levings and Lauzier, unpub data). Swales et al. (1986) found that juveniles exhibit a shift in preference for microhabitats during the winter, moving into areas with pool debris, bank cover or stream bank shelter areas. They noted that although some juveniles appear to overwinter in main-channel areas, others appear to emigrate from tributary streams into deeper, warmer habitats found further downstream. Additionally, they found that the habitats for Coho, steelhead and Chinook were quite different in these interior streams, with Coho predominantly found in ponds and pools with organic cover, Chinook found in deep pools with large debris cover, while steelhead were found in rock crevices or beneath large substrates. Swales and Levings (1989) noted that warm water areas such as groundwater-fed ponds in the Nicola may be particularly important areas for food production in winter. They also found some juvenile Chinook utilization of off-channel ponds on the floodplain of the Coldwater River, though to a much lower level than juvenile Coho.

Ocean Distribution:

Juvenile Nicola Chinook enter Straits of Georgia in April and May. They migrate north along the continental shelf, continuing around Gulf of Alaska to the vicinity of Kodiak Island. Nicola-origin adults have been identified in troll fishery catches off Kodiak and in Bering Sea Pollock fishery bycatch. On their return migration, it is believed that they swim directly from the Aleutians to Juan de Fuca Entrance (with some a few hundred kms to the north and south). CWT recoveries have occurred off the West Coast of Canada, in entrance fisheries and within the Gulf of Georgia as they move through towards the Fraser River.

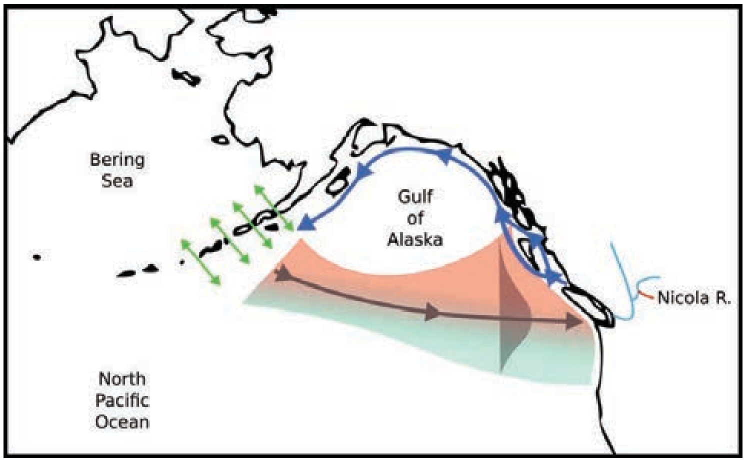


Figure A1-3. Oceanic Distribution of Nicola Chinook. From RE Bailey.

The adult Chinook enter the Fraser in spring and early summer. Spius and Coldwater spawners are the first entrants into the Fraser in March, peaking around the end of April. The first Nicola fish enter in May, and Nicola migrants have been recorded as peaking past Albion in late June.

Spius and Coldwater adults enter the Nicola system in May and early June and migrate into middle and upper areas of systems on the freshet, spawning in mid-late August and early September. Nicola adults enter Nicola system starting in June and entry peaks in late July. These Chinook stage in deeper pools throughout the Nicola until spawning in September.

Spawning:

Up to 75% of Chinook spawning in the Nicola mainstem (Nicola population) occurs between the confluences of Spius Creek and the Coldwater River, with the remainder generally distributed in the reach downstream of the Spius confluence and in the reach upstream of the Coldwater confluence to Nicola Lake. A modest number may spawn in the lower reaches of Spius Creek and the Coldwater River. Spawning above Nicola Lake, based on fence counts (although we now know that these Chinook avoid fences), is usually minimal (<25 spawners between 1995 and 1998), but from an aerial survey in 1999, 199 spawners were recorded in the mainstem and Spahomin Creek (Bailey et al. 2000).

Spawners select groundwater-influenced sites with modest flow for redd construction. Pool tailouts and runs of appropriate gravel-size and depth are preferred. The onset of spawning typically occurs with 12°C water. If access is possible, Spius Creek fish will enter Maka Creek. Flows decrease through summer and pools may become isolated by the time spawning occurs. Spawning may occur for several kms above uppermost Coquihalla Hwy crossing in Coldwater River, although most spawning is observed upstream of Juliet Creek to the last highway crossing.

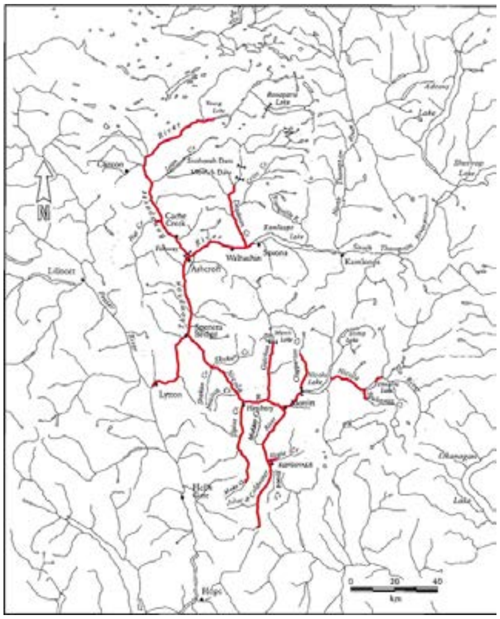


Figure A1-4. Streams with records of spawning Chinook in the Nicola Watershed (DFO 1998).

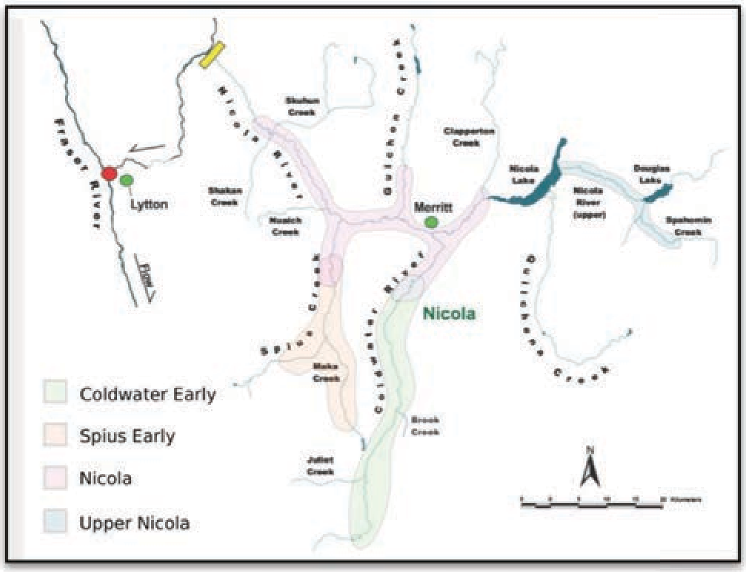


Figure A1-5. Spawning locations of Nicola Chinook. From RE Bailey.

Stock Enhancement:

Spius Creek Hatchery was one of six pilot hatcheries that were built to enhance the declining interior Fraser River Chinook and Coho salmon stocks (Winton and Hilborn 1994). The hatchery was built in 1980 and enhancement of the Nicola system stocks began soon after, with broodstock initially taken from the Nicola River mainstem stock. First returns to the Nicola system occurred in 1987. The hatchery focuses on Coho and Chinook supplementation in the Nicola watershed, capturing broodstock from the Coldwater (Chinook and Coho), Spius (Chinook, Coho), and Nicola mainstem (Chinook).

Since initiation of the Nicola enhancement program, releases have been made in the Nicola River, Spahomin, Spius and Maka creeks and the Coldwater River. Early enhancement in Coldwater and Spius featured yearling smolts but a lack of water and containers to support Nicola indicator led to use of fed fry strategies. Fed fry are released into into Maka, Spius and, Spahomin creeks and the Coldwater River and are typically not CWT'd but are otolith marked for assessment of enhanced contribution.

Past releases into the Nicola River have consisted of marked and unmarked fish. Releases in the Nicola mainstem above Nicola Lake have been minimal, compared with the much greater releases of fry below the lake. All current Nicola releases are CWT'd to provide a mark group for this Chinook survival and exploitation rate indicator stock, and vary around 180 thousand adipose-clipped and CWT'd yearling smolts. There are modest releases of CWT's fry on most years as well (~25K)

Hatchery contributions to the Nicola system have been estimated since 1995 using a combination of mark-recapture and deadpitch surveys. This has been carried out only rarely for Spius and Coldwater.

Stock Assessment:

Prior to 1995, most escapement assessments to the Nicola River were determined using aerial overflights, typically 2 flights per year. Stratified mark-recapture studies also were initiated in 1995 as a partnership between NTA (now STC) and DFO. Stock assessment for the Coldwater River and Spius Creek also consists of aerial overflight surveys, while the Upper Nicola River and Spahomin Creek have not been regularly surveyed, rather they depend on opportunistic aerial overflights or foot surveys.

Escapements:

Relative to historical data records, Nicola Chinook have declined appreciably over time. The Coldwater River is the most significant contributor of Chinook to the Nicola watershed. Additionally, within the last 30 years, hatchery releases have contributed significantly to smolt production in the Nicola watershed.

Escapement estimates of Chinook salmon in the Fraser River watershed are from a combination of aerial and ground surveys and subsequent expansion of the counts (English et al. 2007). Since 1995, estimates are available for the Nicola mainstem from the intensive mark/ recapture program (Bailey et al. 2000, R. Bailey pers. comm.). Comparison of data from the two methods indicates that visual counts were 5-40% lower than mark/recapture estimates (Bailey et al. 2000), and these comparisons were used to calibrate estimates for 1975-1994. Escapements have varied between 538 (2009) and 17,777 (1996), with an average of approximately 5,550. Hatchery returns started in 1987 with the largest contribution (~79%) in 1991, the smallest contribution (4%) in 1996, and an average contribution of 30% since 1987.

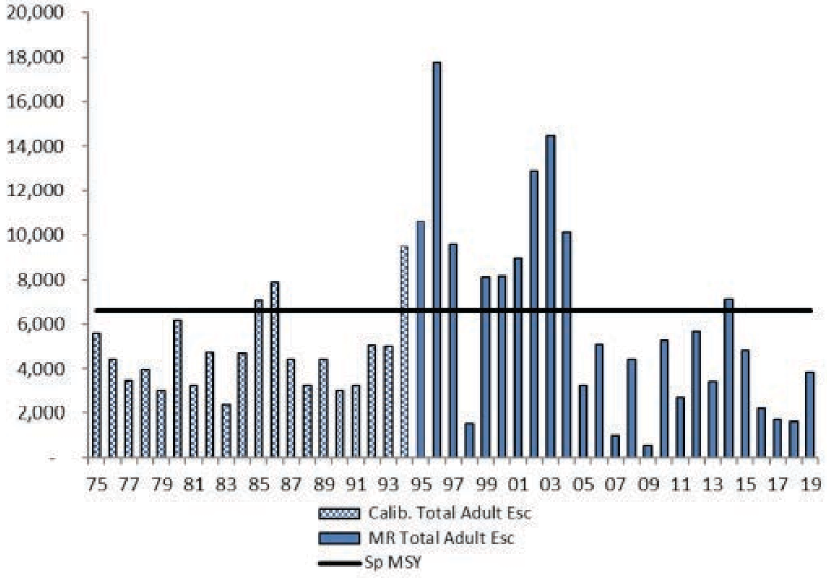


Figure A1-6. Nicola Chinook Salmon Escapements 1975-2019

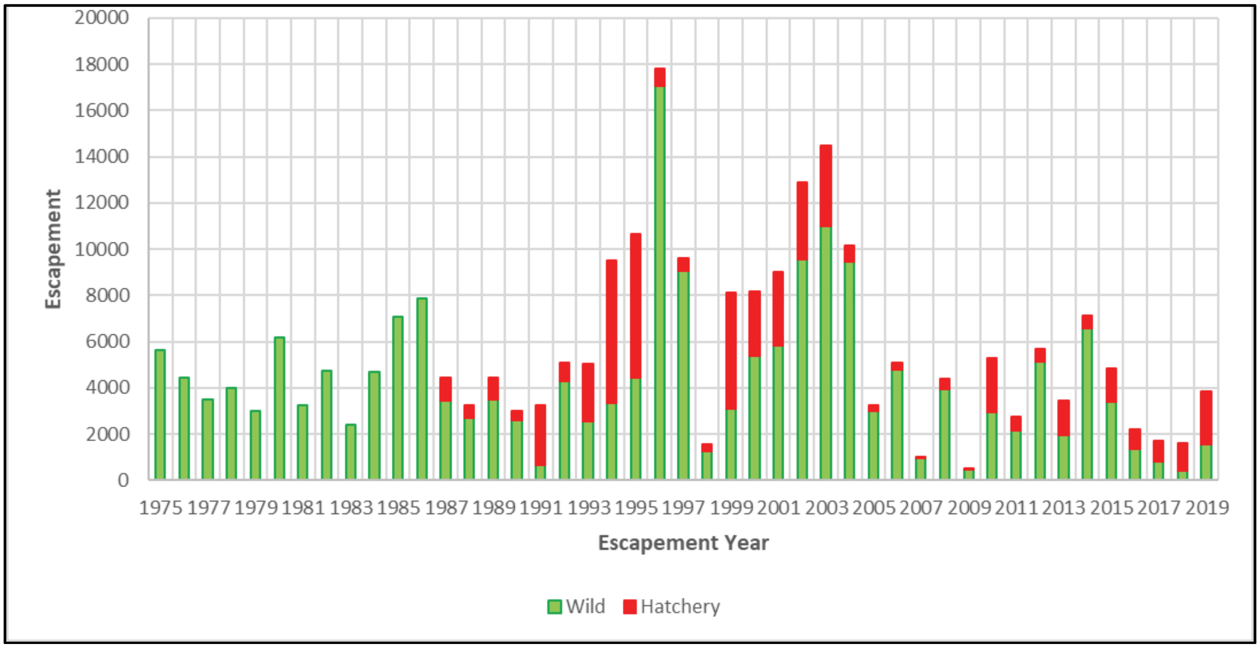


Figure A1-7. Relative Escapements of Naturally Produced and Enhanced Origin Chinook Salmon to Nicola River 1975-2019

In the Coldwater River and Spius Creek, escapement estimates from aerial overflights have shown returns to the Coldwater varying between 15 (in 2009) and almost 2,100 (in 1985), with an average of approximately 650 Chinook returning; for Spius Creek, escapements ranged between 15 (in 2007) and just over 1,850 (in 2004), with an average of approximately 380. Because the enhancement to these systems, starting in 1987, was comprised of unmarked fish, there is no easy way to discern the proportion of hatchery fish in the escapements; however, it is believed unlikely that this would exceed 20% in most years. Otolith marks are also currently used, and SEP has a guestimate of hatchery contributions. More recently, parental based tagging is being explored as a genetic means to determine hatchery contributions.

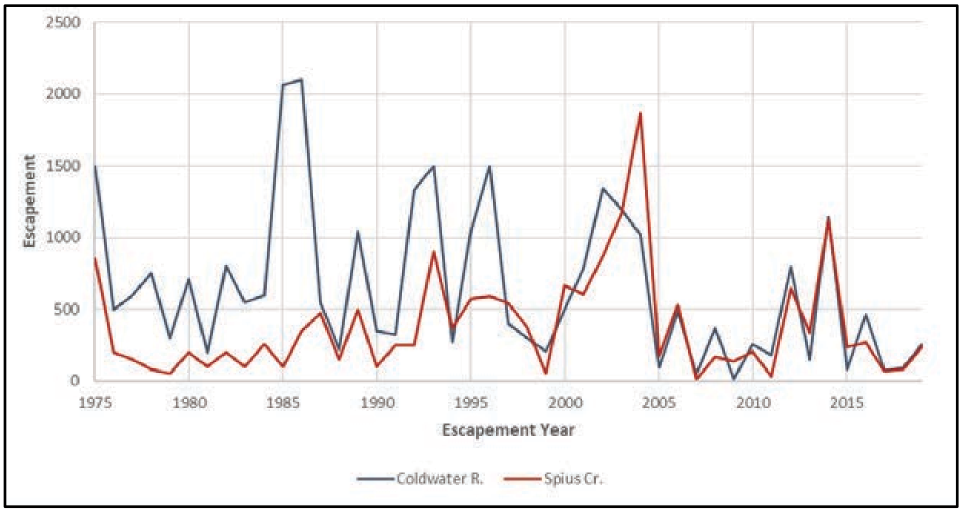


Figure A1-8. Relative Escapements of Chinook Salmon to the Coldwater River and Spius Creek 1975-

Marine Survival:

Marine survival fluctuated considerably for Nicola Chinook before the 2000 brood year; since 2000 marine survivals have been poor although there was one moderate year (2006).

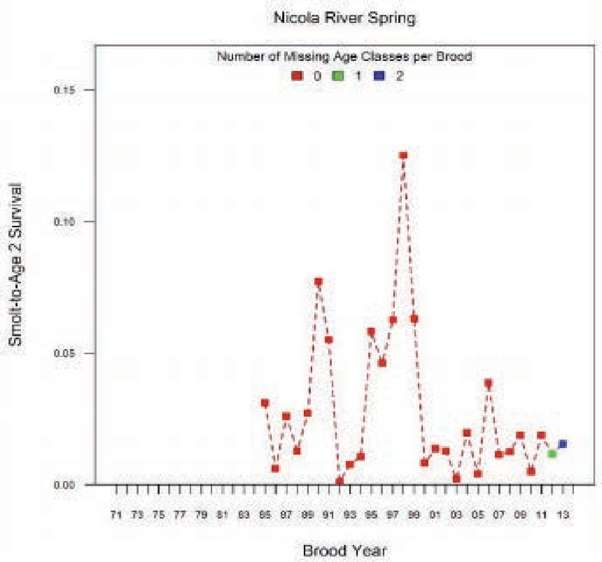


Figure A1-9. Smolt to Age-2 Survival for Nicola River Spring Chinook Salmon

Fisheries:

Coded-wire tagged (CWT) Nicola River Chinook released from the Spius Creek Hatchery is the PST exploitation rate indicator stock used to assess survival and exploitation rates of Spring 42 Chinook in Canadian and U.S. fisheries. Based on CWT recoveries from fisheries, Fraser Spring 42 Chinook have historically been encountered in Fraser River First Nations gill net fisheries, Fraser River recreational fisheries, marine troll fisheries (e.g. WCVI and North Coast), and recreational fisheries in the Strait of Juan de Fuca and Strait of Georgia, with lower rates in other marine recreational fisheries.

Exploitation data for Nicola Chinook are available from 1985 to the present and range from 10 to 60%, with greatest impacts in freshwater and approach fisheries. Recent exploitation rates have been below 30%.

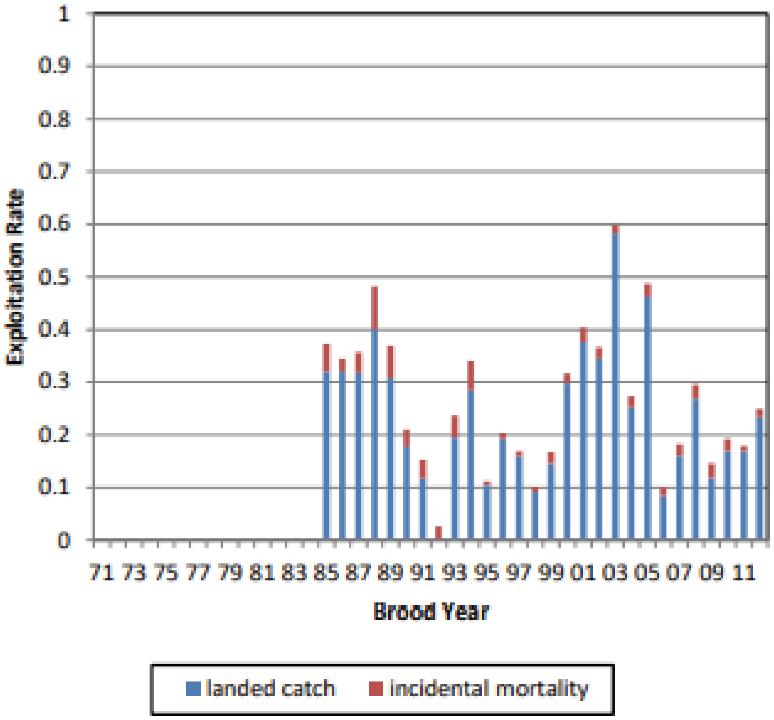


Figure A1-10. Exploitation Rates for Nicola River Spring Chinook Salmon

APPENDIX 2: CHARACTERIZING THE NICOLA BASIN HABITAT & ECOSYSTEMS

Information on the Nicola Basin was gathered from a number of sources, with a large component of the information below compiled by Tom Willms and Miranda Smith.

The Nicola River is a tributary of the Thompson River and is a sixth order stream located in the interior of southern British Columbia (Figure A2-1). The entire Nicola watershed covers an area of 7211 km^2, with the mainstem approximately 188.5 km in length (MOE 2021). The Nicola River produces early-run Chinook, Coho, and steelhead to the Thompson and Fraser River. Important tributaries to the Nicola for salmonids include the Coldwater River and Spius, Maka, Spahomin, Quilchena, Clapperton and Guichon creeks. The Coldwater River is the second largest tributary, draining an area of 914 km^2 and is the most important stream for Coho and early-run Chinook, as well as steelhead in the Nicola watershed. Guichon Creek is the largest tributary to the Nicola (1,230 km^2) and supports all three of the aforementioned species as well.

Nicola Lake is the largest lake in the watershed (area 2,500 hectares), with its outlet controlled by a dam, operated primarily for irrigation purposes. The majority of salmonid production occurs downstream of Nicola Lake; although there is potential for production upstream, it is seasonally sporadic due to insufficient water during summer.

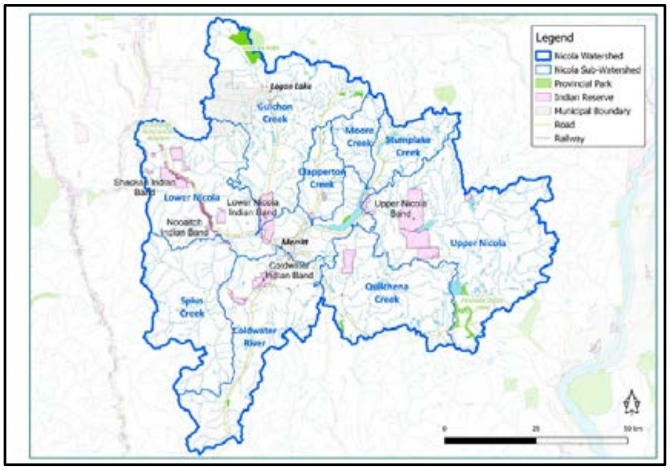


Figure A2-1. A map of the Nicola Valley showing sub-basins (blue), First Nation communities, parks and municipalities. From the Nicola Watershed Characterization report (ESSA Technologies Ltd. and Fraser Basin Council 2019)

Nicola Basin Climate & Vegetation:

Elevations in the Nicola Basin vary from approx 230 m at the Thompson confluence to 2000 m near the Pennask Lake summit, resulting in a broad range of microclimates within the watershed. Most of the region is semi-arid, with very hot summers though the high altitude in this area results in cooler winters than in the surrounding basins. The entire basin also receives less rainfall than nearby areas, as it is in a rain shadow. The basin is also associated with three major valley surficial aquifers (Guichon, Coldwater and Nicola Valley) which provide base flows for the rivers.

Low elevation areas on the lee side of the Cascade Mountains are dry (precipitation between 200 to 300 mm per annum) with hot summers and cool winters, whereas higher elevations are relatively wet (upwards of 400 mm per annum) and cool in all seasons. Plateau areas have hot summers and cool winters, while valleys have daytime temperatures in excess of 16°C for five months of the year and periods of hot weather with temperatures in excess of 32°C are frequent during July and August. This usually corresponds with low rainfall, high evaporation rates, and depressed river flows that place stress on the natural riverine ecology and on agricultural crops due to large moisture deficits. Occasionally in winter, Arctic air enters the area bringing clear skies and cold temperatures, sometimes as low as -35°C. Frost free periods range between 110-120 days in the Nicola Valley while growing degree days vary between 1500 and 1700. In the higher lying areas and in the Coldwater River Valley these values are about 10 to 20 percent lower.

Snow depths increase with elevation and have a significant influence on the potential supply of water in the Nicola River watershed. The hydrograph for the Nicola, Coldwater, and Spius Creek are all driven by snowmelt. Generally, the largest snowpacks and therefore water yields occur in the Spius Creek and Coldwater River sub-basins, draining the east slopes of the Cascade Mountains. Lesser snowpacks occur in the Guichon , Clapperton and Upper Nicola sub-basins. Snow accumulations of more than 40 cm (16 inches) per annum are rare at lower elevations. Peak flows in these systems occur in late April through early June followed by a rapid decrease to base summer flows in July. Flows continue to decrease through the summer until fall storms, most notably in the Spius and Coldwater watersheds, provide surplus precipitation and an increase in flow conditions. This spike in stream flow continues until precipitation begins to accumulate as snow. Stream temperature conditions across the watershed start to cool by mid-September coincident with decreasing air temperatures. Winter flows are characteristically low but are occasionally punctuated by short duration high flow events as the consequence of rain on snow events and have been associated with stream ice breakup, ice scour and ice jams. Flows in the Nicola mainstem during summer and fall are moderated by Nicola Lake and regulated to some degree by the Nicola Lake Dam. Water released from the dam during July and August, however, frequently exceeds lethal temperature thresholds for salmonids. During 2000-2015, the Nicola, Coldwater and Spius had approximately twice as many years with below average minimum summer discharge (8-10 years when Doyle Index <4.5) compared with the Deadman and Bonaparte (4-5 years).

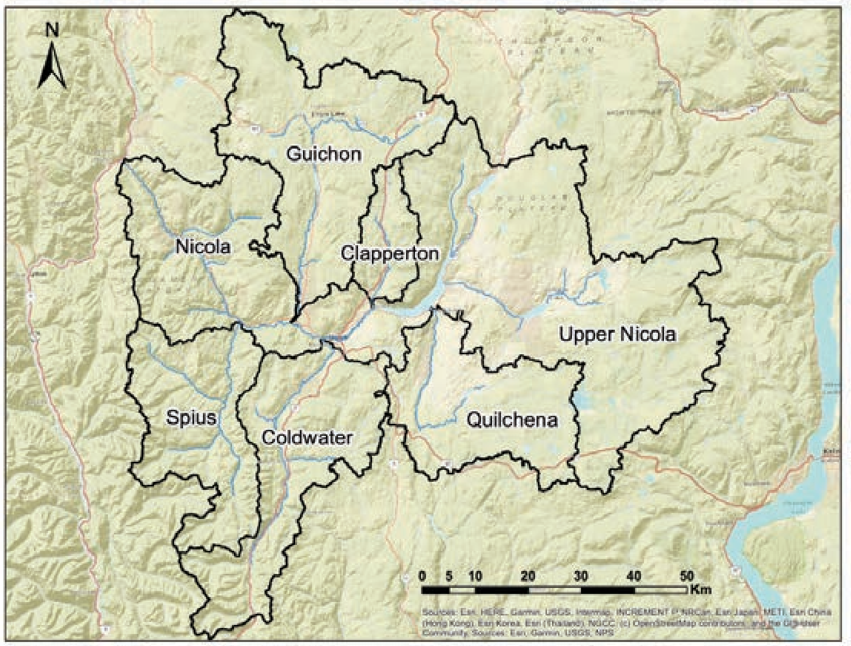
As a result of the climate in this area, much of the landscape is covered by grasslands and open forest parklands. Bunchgrass and sagebrush species dominate the lower elevations (250-1000 masl) of this area as they have adapted to survive in hot, dry climates with low precipitation. Cottonwood forests exist along the river courses (where they have not been impacted by urban and agricultural development) and the open park-like forests have few widely spaced trees of species such as ponderosa pine (*Pinus ponderosa*) and Interior Douglas-fir (*Pseudotsuga menziesii var. glauca*). The Ponderosa Pine (PP) biogeoclimatic zone (19% of basin) occupies the valleys between 335-900 m in elevation. The Interior Douglas-fir (IDF) zone lies between 360 m and 1450 m and constitutes about 33% of the land area. Above the IDF the Montane Spruce (MS) zone (45% of river basin) occurs between elevations of 1100-1600 masl. The highest elevation forested zone in the region is the Engelmann Spruce – Subalpine Fir zone (ESSF) which occurs at elevations of 1275-2050 masl. At elevations above the ESSF, forests give way to non-forested ecosystems of what was formerly the Alpine Tundra (AT) zone (3%). This zone is now subdivided into three separate zones, two of which occur in the Nicola Watershed: the Coast Mountain-heather and Interior Mountain-heather ecosystems.

The Nicola Watershed has widespread industrial uses. Agriculture is the primary land use within the valley bottom of the Nicola River from its confluence with the Thompson River upstream to Nicola Lake and is common along the lower half of the Coldwater River and lowest 10km of Spius Creek. Agriculture operations typically draw surface water for irrigation during the dry summer months, however, irrigation from groundwater wells in shallow, unconfined aquifers has become more prevalent in recent years. Upland areas of the watershed are commonly used for forestry and cattle grazing.

Excessive exploitation rates, habitat alteration, disruption and destruction from various human activities in the watershed, as well as effects of climate change appear to be contributing to the decline of fish stocks in the Nicola River.

Nicola Basin Watersheds:

Table 1 provides details on the various watersheds of the Nicola Basin which are shown in Figure A2-2.



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community; Sources: Esri, Garmin, USGS, NPS

Figure A2-1. Key Watersheds of the Nicola Basin

Table 1. Watershed Characterization in the Nicola Basin (from Tom Willms)

	Watershed measurements	Stream Habitat & Forestry Impacts

Nicola River	- Watershed area – 7,211 km^2
	- 6th order stream
	- 188.5 in length (MOE, 2021)
		- Two distinct geomorphic zones:
		  - **Low gradient**, **tortuous meandering** segment between Nicola Lake and Merritt. Stream flows through naturally erodible glaciolacustrine silts (Figure A2-3).
		  - **Steeper, riffle-pool morphology** segment between Merritt and confluence with Thompson River at Spences Bridge.
		- Stream is generally unconfined upstream of Nooaitch but **becomes more confined downstream**.
		- Segment between **Coldwater and Spius confluence** has **extensive groundwater input** and a high degree of channel complexity - important for rearing.
		  - Also includes much of the spawning habitat for late-run Chinook.
		  - Extensive groundwater influence (Willms and Whitworth 2017).
		- Segment **downstream of Spius Creek** is generally **more confined** by topography and exhibits more abundant **deep pool habitat.**
		  - In the absence of cottonwood forests, shade is provided by steep topography in this reach.
		- **Flows** in the Nicola are **partly regulated** by the **Nicola Lake dam.**
		- Important work has been done in recent years, through development of the **Nicola Water Management Tool** (Alexander et al. 2019), to improve decision-making processes and information for dam releases.

Upper Nicola Watershed	- Watershed area – 2,300 km^2 - Elevations range from 600-1600 masl. (Warkentin 2020)	- Streams are generally low gradient and less confined by topography than western sub-basins - Storage is abundant (lakes & wetlands) - Percent clear cutting since 2000: Spahomin Creek = 13%, Quilchena Creek =19%, Clapperton Creek = 23% (Warkentin, 2020). - Conservation concerns in this watershed relate more to **non-anadromous fish species** than the sub-catchments downstream of Nicola Lake. - Introduction of **Yellow perch** (*Perca flavescens*) is of **extreme conservation concern** with respect to native species
Clapperton Creek Watershed	- Watershed area – 232 km^2, 29.5 km long (MOE, 2021) - 4th order stream - Elevations range from 600-1700 masl. (Warkentin 2020)	- Headwaters (Guichon/Nicola Plateau) have been extensively salvage logged. **ECA** in this watershed **tripled** between 2003-2013 to **44%** (Valdal and Lewis 2015). Warkentin (2020) report similar area estimates of **logging** at **36% over the last 20 years.** - Stream is steep and confined in bedrock in lower reaches, upstream of alluvial fan. - **Storage is limited** to some **small reservoirs**. - Stream is **strongly groundwater influenced** and maintains relatively strong baseflow of **suitable temperatures for salmonids**. - Important **thermal refuge habitat** for juvenile Chinook, Coho and Steelhead.
Guichon Creek watershed	- Watershed area – 1230km^2, 80.6 km long (MOE, 2021) - 5th order stream - Elevations range from 575-1700 masl (Warkentin 2020)	- **Headwaters** (Guichon Plateau) have been **extensively salvage logged**. ECA in this watershed tripled between 2003-2013 to 32% (Valdal and Lewis 2015) **(Figure A2-4)**. - Mamit Lake and the **extensive wetlands** of the Plateau provide **important storage capacity** for the watershed. - Guichon Creek flows generally unconfined through glaciofluvial deposits as exhibited by extensive eskers between Mamit Lake and its confluence with the Nicola River. - Important spawning and rearing habitat for Chinook, Coho and Steelhead.
Coldwater River watershed	- Watershed area = 961 km^2, 91.7 km long (MOE, 2021) - 5th order stream - Elevations range from 594 – 2000 masl. (Warkentin 2020)	- **13% percent of the watershed has been clear** cut since 2000 (Warkentin 2020). - The Coldwater Watershed **lacks the types of storage seen in other parts of the Nicola Watershed** (e.g. large lakes and extensive wetlands). Oral accounts of the upper watershed tell of more extensive wetlands prior to construction of Coquihalla highway. - Low summer base flows (e.g. 2015) have led to **water use restrictions** to protect critical flows for aquatic life. - The upper reaches of the Coldwater River provide **critically important spawning habitat** for **Interior Fraser Coho**, but also for **early run Chinook** and **Steelhead**. - **Mainstem and off-channel habitats** downstream of spawning sites are used for **rearing** during periods freshwater **residency as juveniles** (Shrimpton et al. 2014).

		- Turcotte and Shrimpton (2021) found that **fine-scale site fidelity existed in over half of Coho spawners** in the system and that the **remainder strayed to new spawning sites**. o This **plasticity in homing behaviour may play a critical role in population resilience**, in light of the major disturbance events observed in recent years. - Golder (2020) completed Part One of a two part study investigating **groundwater/surface water interactions** on the Coldwater. o Identified both gaining and losing reaches. o Reported on proportions of water withdraws with respect to user groups and sources of water (i.e. surface water or groundwater, and shallow or deep aquifers). o **70% of groundwater withdrawn is from shallow unconfined aquifers.** o Report may be **key in prioritizing suitable reaches for restoration works** (e.g. gaining reaches) and may also highlight the need for **improved water conservation** efforts in losing reaches.
Spius Creek watershed	- Watershed area - 799 km^2, 48.5 km long (MOE, 2021) - 5th order stream - Elevations range from 524-2200 msal. (Warkentin 2020)	- % of the watershed has been **clear cut** since 2000 (Warkentin 2020). - Spius Creek and its tributaries tend to be **steep** and generally **confined by topography**. - Instream **flow** becomes a **concern** during years of early **snowpack depletion.** - Spius Creek provides critical habitat for some unique early run Chinook, as well as for Steelhead and Interior Fraser Coho Salmon.

Figure A2-3. The meandering nature of the Nicola River between Nicola Lake and Merritt

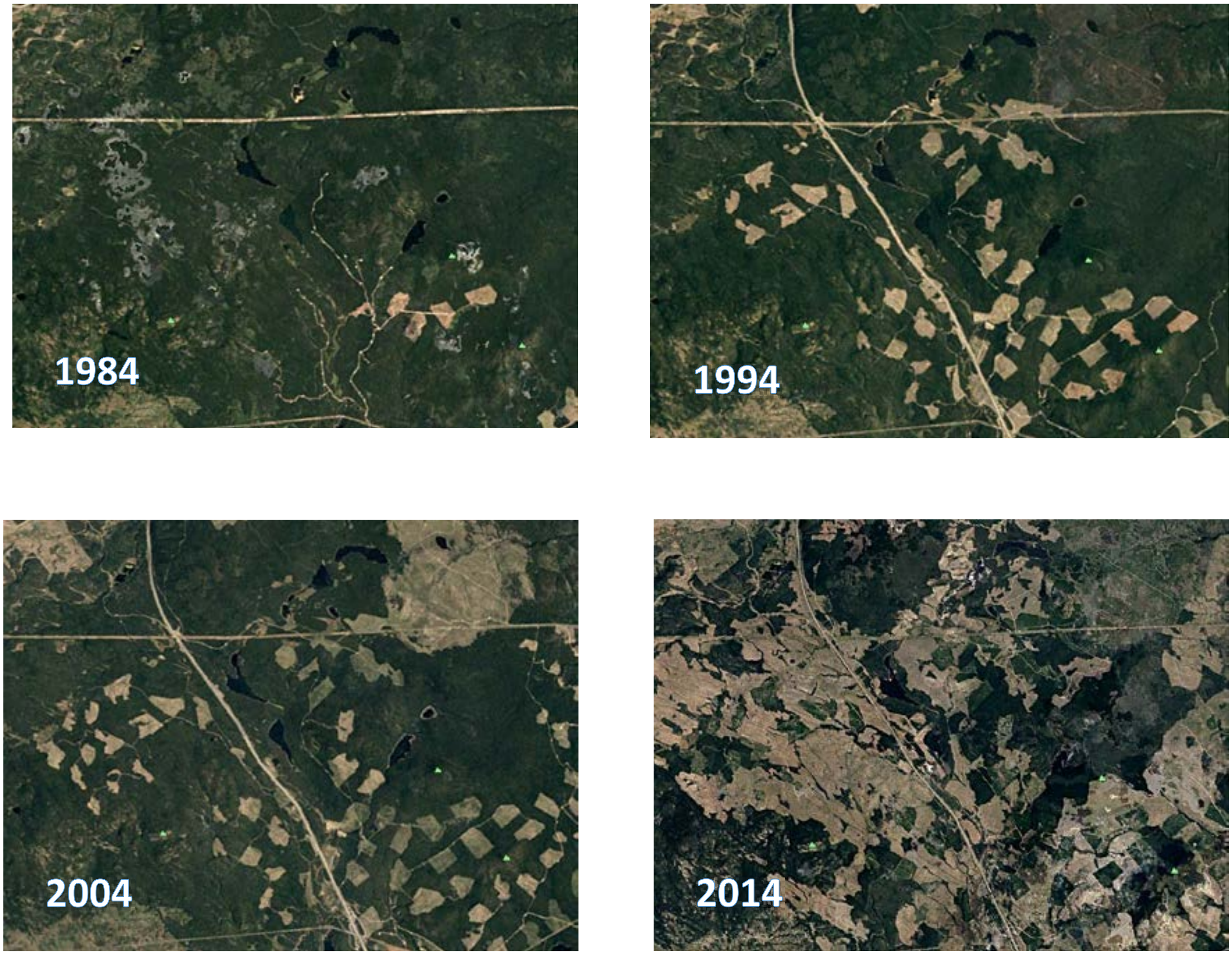


Figure A2-4. Images showing the extensive logging in Guichon Creek 1994-2014 (provided by Tom Willms).

Nicola River Hydrology:

- The Nicola River hydrograph exhibits a pattern typical of snow-dominated regimes (Figure A2-5).
- **Peak flows** are experienced in **late April – early May**.
- Fall flooding, characteristic of rain-dominated hydrographs of coastal BC, have historically been minimal.
- Rainfall during the summer is infrequent, so **conservation of groundwater is critical** in maintaining cool and sufficient stream flows for fish and other aquatic organisms.
- Key flow information from Warkentin (2020) for the Nicola Watershed (as related to habitat):
    - **Mean August flows** in the last two decades were **26% lower** than they were a century ago;
    - More precipitation in the form of rain vs. snow; and
    - More conspicuous peaks in average daily flow in November in recent decades.

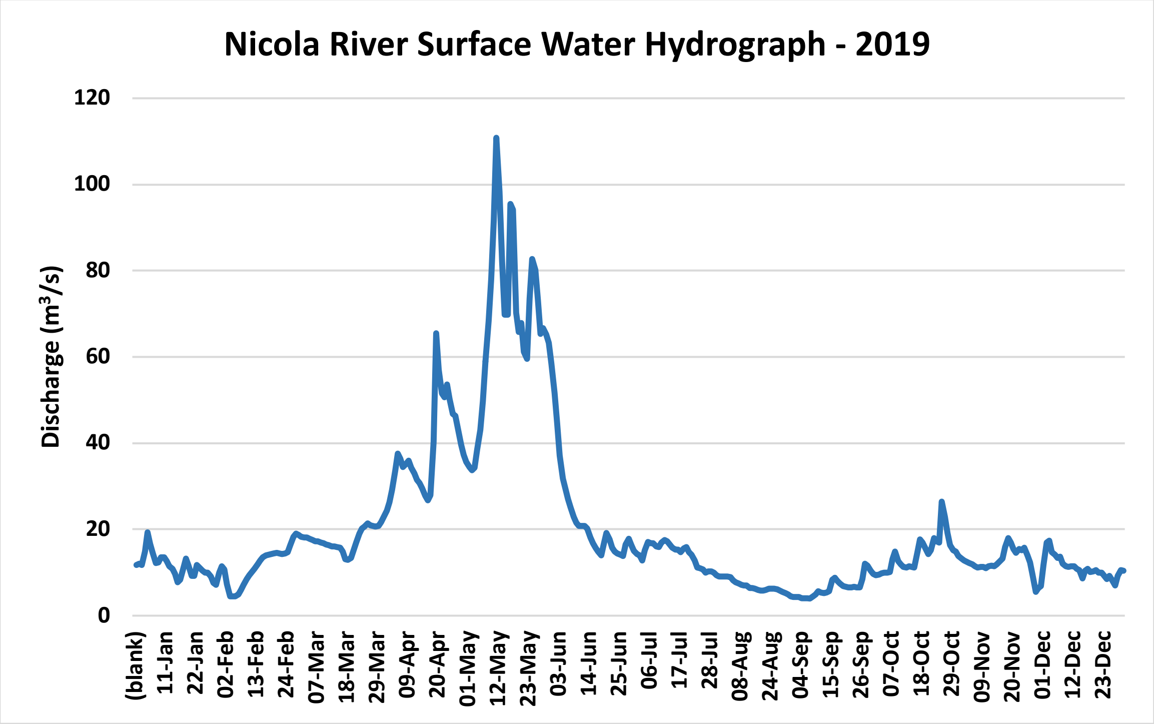


Figure A2-5. Typical surface water hydrograph for the Nicola River. Data from the Water Survey of Canada 2020 (Tom Willms)

Flooding

Lewis (2016) conducted a Hydrologic Hazard Assessment for the Merritt TSA and noted the following:
"The primary factor contributing to elevated riparian and streamflow hazard is extensive salvage of MPB-affected forests over the past decade resulting in elevated Equivalent Clearcut Area (ECA) and harvesting adjacent to streams in higher elevation Sub-basins, Basins and Watersheds."

- Flooding in 2017 and 2018 and 2021 resulted in **major channel shifts** throughout the watershed
- Flood effects resulted in **emergency situations** for many residents living in this area and was the focus of major instream works
- Reid (2020) observed **increases in average channel width** on Guichon Creek from 2016 to 2018 of **10.1 m**, **41.4 m** and **84.6 m**, respectively. Data are not yet available for the impacts of the catastrophic flooding of 2021, but similar increases in Nicola River channel width are clear.
- Sediment movement resulted in **increases in stream bed elevations** in the lowest reach of Guichon (Reid 2020) as well as **formation of large sediment wedges** downstream of its confluence with the Nicola River. Similar sediment movement occurred during the 2021 flooding event.
- 2017/2018 and 2021 flood effects provide **opportunities for habitat restoration**
- Important to note that Reid (2020) identifies **risk** that **near-term flooding** may result in **further** lateral **channel instability**

Stream Temperatures

Warkentin (2020) found that mean August temperatures have increased by about 2˚C in the last century.

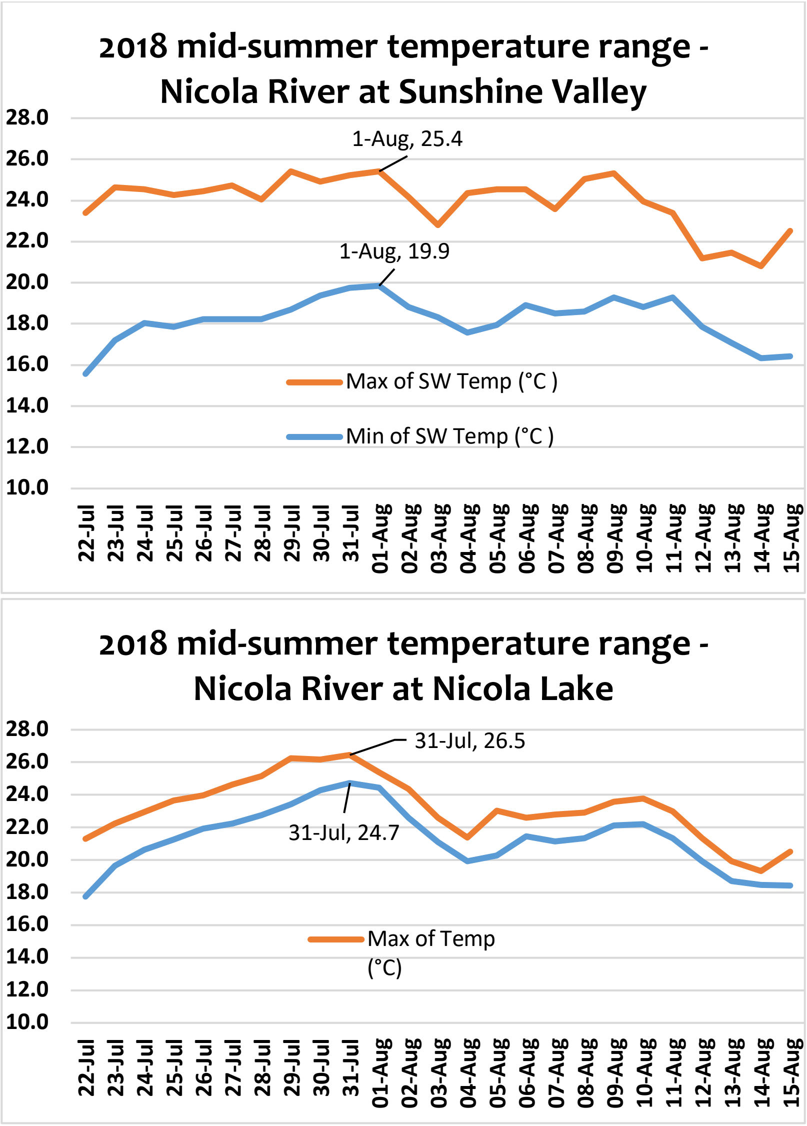


Figure A2-6. Mid-summer temperature ranges from two sites along the Nicola River mainstem in 2018 (Tom Willm's original data).

Key Habitat Themes

- **Riparian cover** is positively correlated with **lower thermal sensitivity** in the Nicola Watershed (Warkentin 2020).

- **Anthropogenic disturbance** to steam banks and riparian cover is **extensive** in the Nicola Watershed (Ecoscape 2017).
- Larger sub-catchments exhibit higher maximum stream temperatures. Conversely, smaller ones may provide important **thermal refugia** (Warkentin 2020).
- The watershed has been experiencing a higher frequency of **severe flood** and **drought** events, resulting in adverse effects to fish and fish habitat.

Key Habitat Issues include the following:

- Level of **equivalent clearcut area** (ECA) in the watershed: effects in water storage and timing, duration, and intensity of freshet.
- **Loss of riparian vegetation**, specifically black cottonwood (*Populus trichocarpa*), and their effects in providing shade, bank stability and instream habitat complexity.
- Effects of **high summer stream temperatures** on survival and growth of juvenile Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon (*O. kisutch*) and Steelhead (*O. mykiss*).
- Drought and **suboptimal streamflow** in August. Correlated with low productivity of Chinook (Warkentin 2020).
- **Connectivity of streams and floodplains** – effects to habitat recruitment, refugia and flood intensity.

Many of these habitat issues are further discussed in the following section.

An Overview and Ranking of Select Habitat Pressures to Chinook Salmon:

Prepared by Miranda Smith, MC Wright and Associates Ltd.

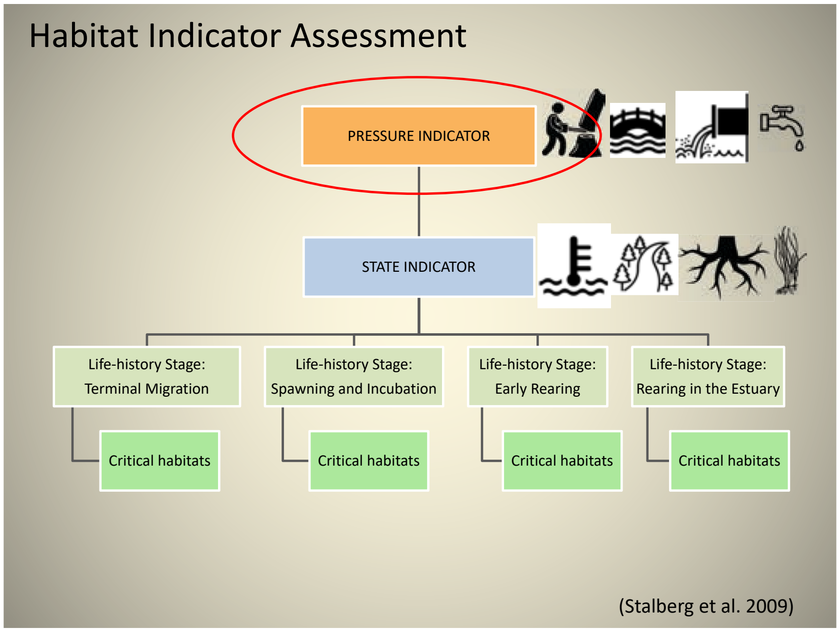
Indicators are used to measure current status while benchmarks allow us to determine the level of progress and/or success in achieving established objectives and/or targets. Indicators measure characteristics of the environment such as habitat/ecosystem conditions and are intended to provide quantifiable information on the current and potential state of the given habitat/ecosystem. A benchmark is a standard metric against which current habitat condition can be measured or compared both spatially and temporally to determine progress or risk.

Stalberg et al. (2009) developed a series of pressure and state indicators that could be used to monitor salmon habitat status under Strategy 2 of the Wild Salmon Policy. Pressure indicators are considered descriptors of landscape-level (and generally man-made) stressors, which can often be evaluated through the spatial analysis of remotely sensed data. State indicators are descriptors of specific habitat conditions, and are typically representative of 'on-the-ground' data collected during field operations.

The status of each indicator may be identified as red (high risk), amber (moderate risk) or green (low risk) by comparing benchmarks with existing metrics, based on available data. Where a lack of data is apparent, the indicator may be listed as data limited and recommendations can be provided to describe which type of data/monitoring might allow the indicator status to be better addressed.

.

During the scoping phase of the Nicola RAMS we collected information on a number of habitat based and ecosystem based indicators with benchmarks to track health within the Nicola Basin. We focussed on collating habitat pressure indicators. Examples include Forestry activities, mining, industrial development, road networks, recreational activity. These pressures impact Nicola Chinook life stages directly, or impact the habitat in which the fish are living (as depicted in the figure).



Habitat Indicator Assessment

PRESSURE INDICATOR

STATE INDICATOR

Life-history Stage: Terminal Migration

Critical habitats

Life-history Stage: Spawning and Incubation

Critical habitats

Life-history Stage: Early Rearing

Critical habitats

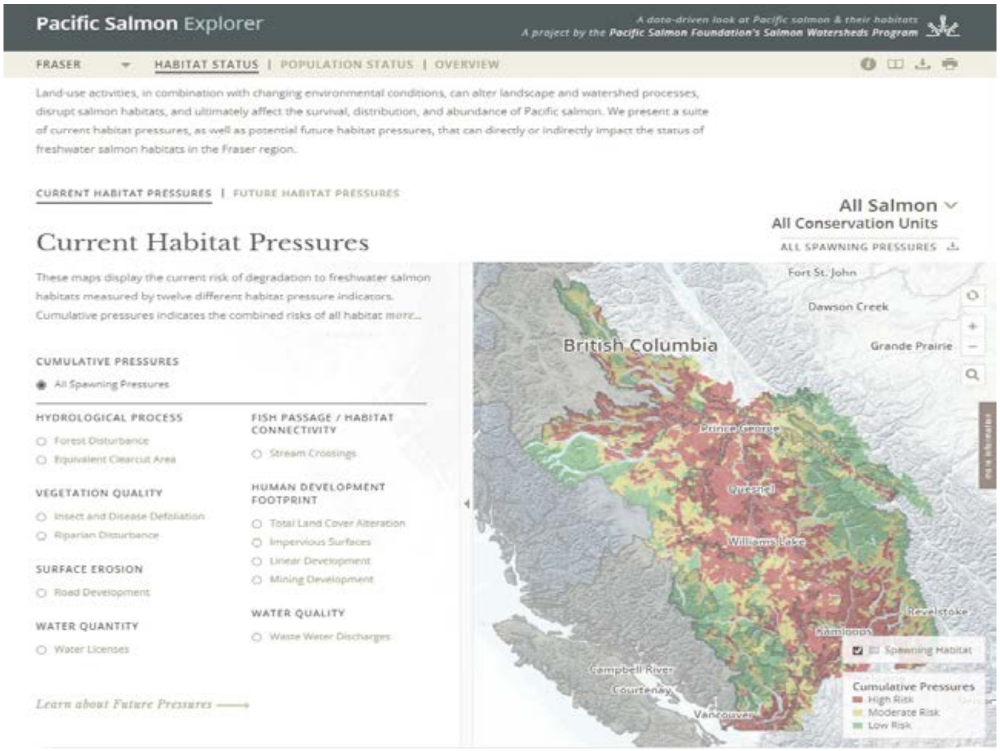
Life-history Stage: Rearing in the Estuary

Critical habitats

(Stalberg et al. 2009)

Figure A2-7. The relationship between habitat pressure and state indicators and the different salmon life biustory stages and their critical habitats.

Miranda Smith obtained information on various indicators from the Pacific Salmon Explorer (PSE).



Land-use activities, in combination with changing environmental conditions, can alter landscape and watershed processes, disrupt salmon habitats, and ultimately affect the survival, distribution, and abundance of Pacific salmon. We present a suite of current habitat pressures, as well as potential future habitat pressures, that can directly or indirectly impact the status of freshwater salmon habitats in the Fraser region.

Current Habitat Pressures

These maps display the current risk of degradation to freshwater salmon habitats measured by twelve different habitat pressure indicators. Cumulative pressures indicates the combined risks of all habitat more...

Figure A2-8. Splash pages of the Pacific Salmon Explorer- bottom image shows example habitat pressures which are evaluated by the Pacific Salmon Explorer.

The PSE has collated a number of datasets that cover the entire geographic area of interest and which are typically publicly available. The data are open access and fully available on the PSF. These pressures are measured against benchmarks based on best available science; but where no benchmarks available, relative comparison across watersheds is carried out.

However, at times the data may be lower resolution given the large area that is covered by the PSE. In these cases, Miranda performed additional analyses. Miranda presented the results of the PSE for pressure indicators for the Nicola Watershed, and where possible, showed the raw data contributing to the risk rankings to provide a better understanding of the spatial distribution of pressure in the watershed

Total Land Cover Alterations

Defined as the percentage of the total watershed area that has been altered by human activity.

This indicator aims to capture changes in cumulative watershed processes such as hydrology and geomorphology that can affect downstream spawning and rearing habitats:

- Agriculture
- Urbanization
- Forestry
- Fire disturbance
- Mining activity
- Road development

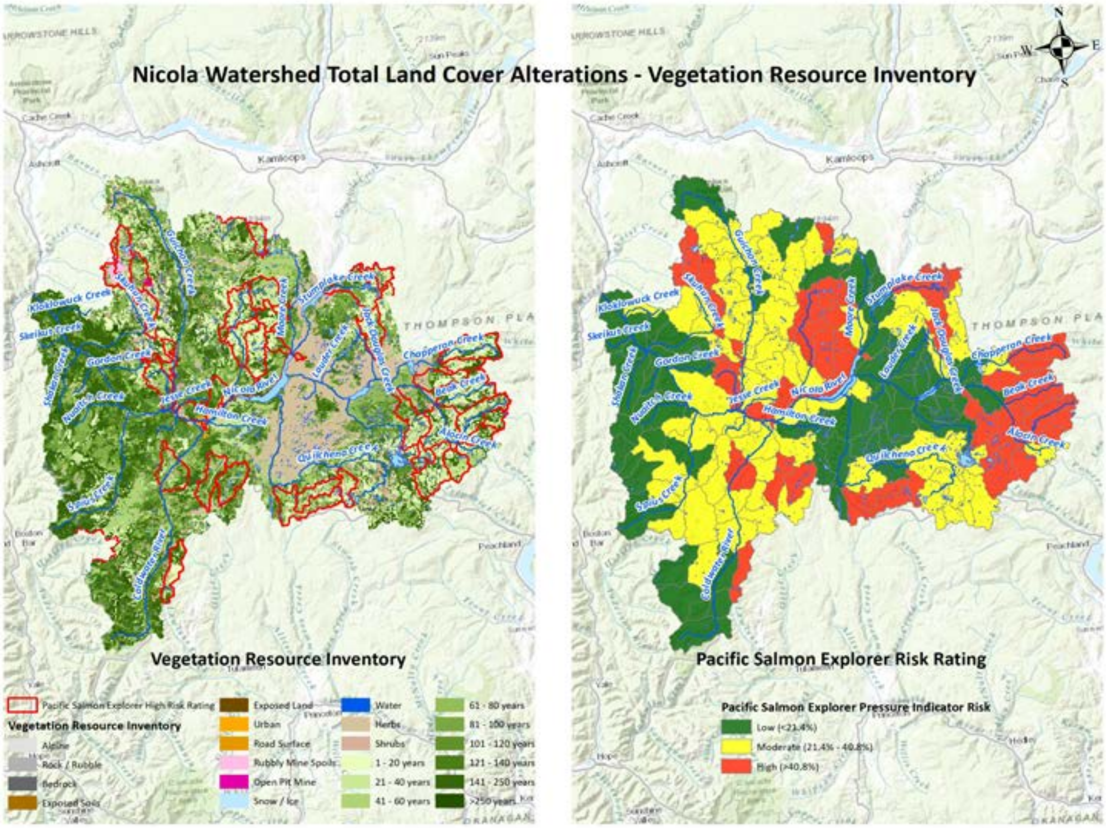


Figure A2-9. Nicola Watershed Total Land Cover Alterations- Vegetation Resource Inventory

These maps showed that this pressure poses a high risk in the Upper Nicola, Clapperton Creek, Skuhun Creek (mining), Hamilton Creek / Nicola River confluence (city of Merritt), select sub-basins of the Coldwater River, and upper tributaries to Quilchena Creek.

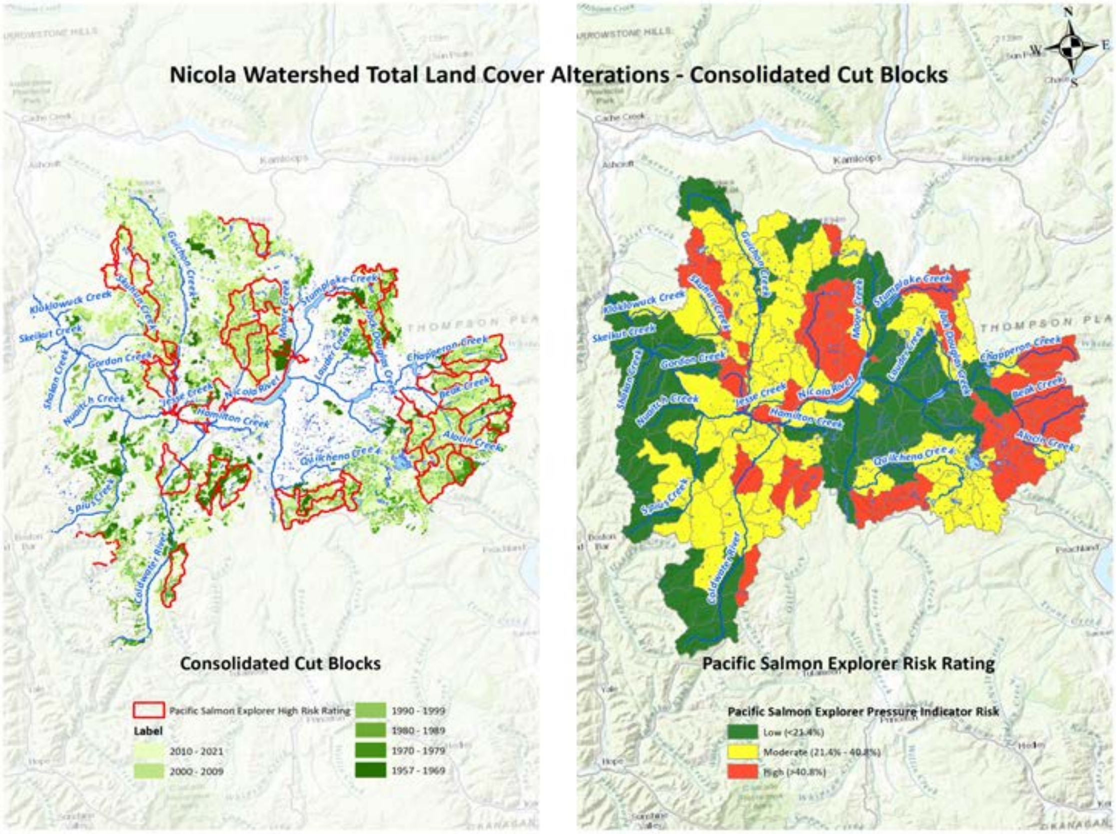


Figure A2-10. Nicola Watershed Total Land Cover Alterations- Consolidated Cut Blocks

Key Points for Land Cover Alterations:

- *The primary form of land cover alterations is forest harvesting*
- *Sub-basins of the Upper Nicola show high harvest levels in the past 20 years*
- *Clapperton and Guichon creeks headwater show extensive salvage logging with significant increase in ECA over past 20 years, but this risk was underrepresented in the Pacific Salmon Explorer (PSE) ranking*

Riparian Disturbance

Defined as the percentage of the riparian zone, defined as a 30m buffer around all streams, lakes, and wetlands, that have been altered by human activity in the watershed.

Disturbance to the riparian zone can affect salmon habitat by:

- Destabilizing stream banks
- Increasing surface erosion and sedimentation
- Reducing nutrient and woody debris inputs
- Increasing stream temperatures

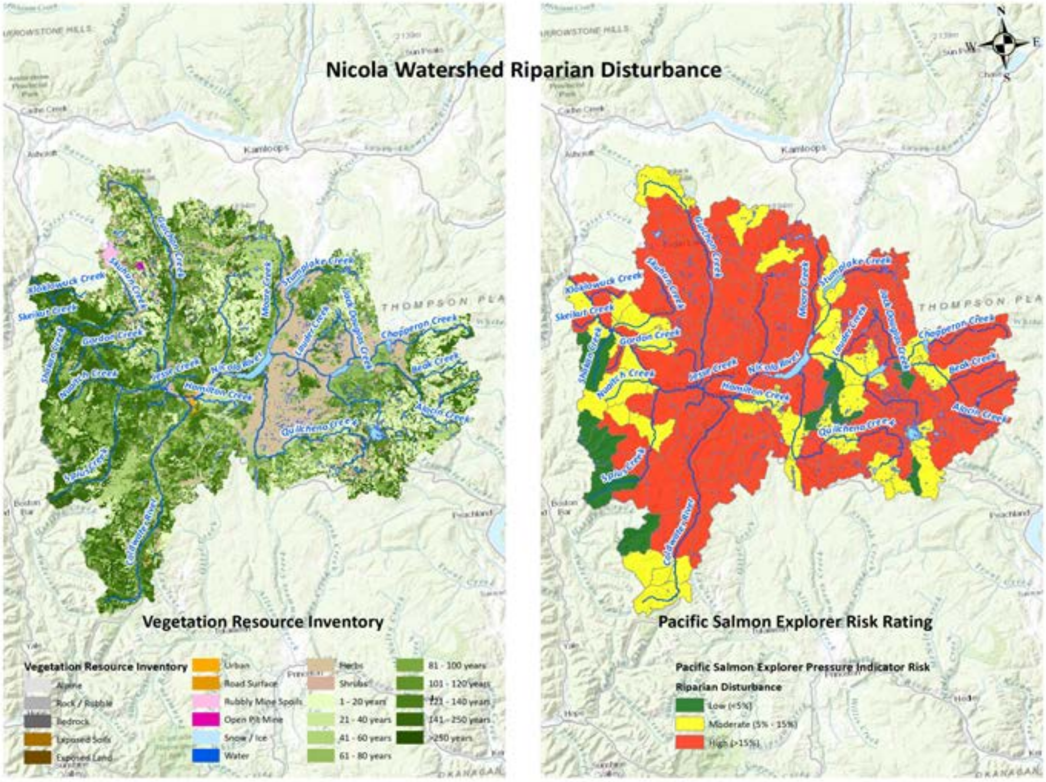


Figure A2-11. Nicola Watershed Riparian Disturbance

Majority of the watershed was defined as high risk for this pressure indicator, but there are general data limitations of PSE data given the resolution of input data (from the Freshwater Atlas). Typically it is best to evaluate riparian condition via high recent resolution orthophotographs. Some concerns about accuracy of this layer are the result of the risk of missing the narrow 30m buffer and that the location of streams on the ground may be quite different than those mapped in the Freshwater Atlas.

Key Points:

- *Majority of riparian in the Nicola watershed considered significantly impacted (i.e. high risk) based on PSE analysis*
- *Data limitations may affect accuracy of this analysis*
- *Recommend re-assessing riparian condition in priority watersheds using high resolution orthophotograph and / or satellite imagery*

Road Density

Defined as the percentage of the average density of all roads within a watershed

Road development can result in the following:

- Interruption of subsurface flow
- Increased peak flows
- Interference with natural patterns of overland water flow
- Generation of fine sediment via erosion, which can impact downstream spawning and rearing habitats

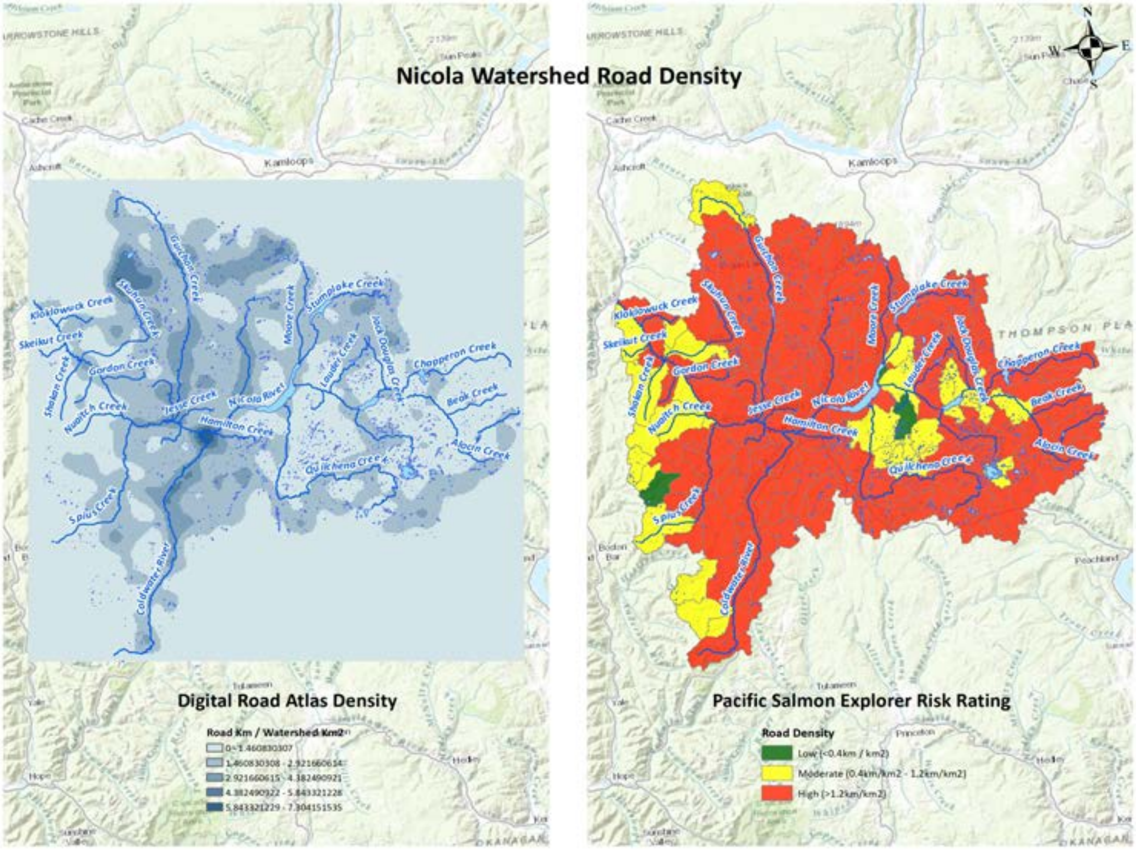


Figure A2-12. Nicola Watershed Road Density

Again, the PSE rankings show the majority of the watershed as high risk to this pressure indicator. An additional density analysis of raw data identified the highest densities around the City of Merritt, headwaters of Skuhun Creek, Clapperton / Guichon watersheds, along Coldwater River

Key Points

- *According to PSE risk rankings, majority of watershed considered high risk*
- *Closer look at the data and a relative comparison across sub-basins identifies key areas where road densities are higher, provides a more focused look at this indicator*

Stream Crossings

Defined as the percentage of the total number of stream crossings per km of the total length of modeled salmon habitat in the watershed

Stream crossings can create problems by:

- Interfering or blocking access to upstream spawning or rearing habitats
- Affect water delivery to streams, causing increased peak flows, and become a source of fine sediment

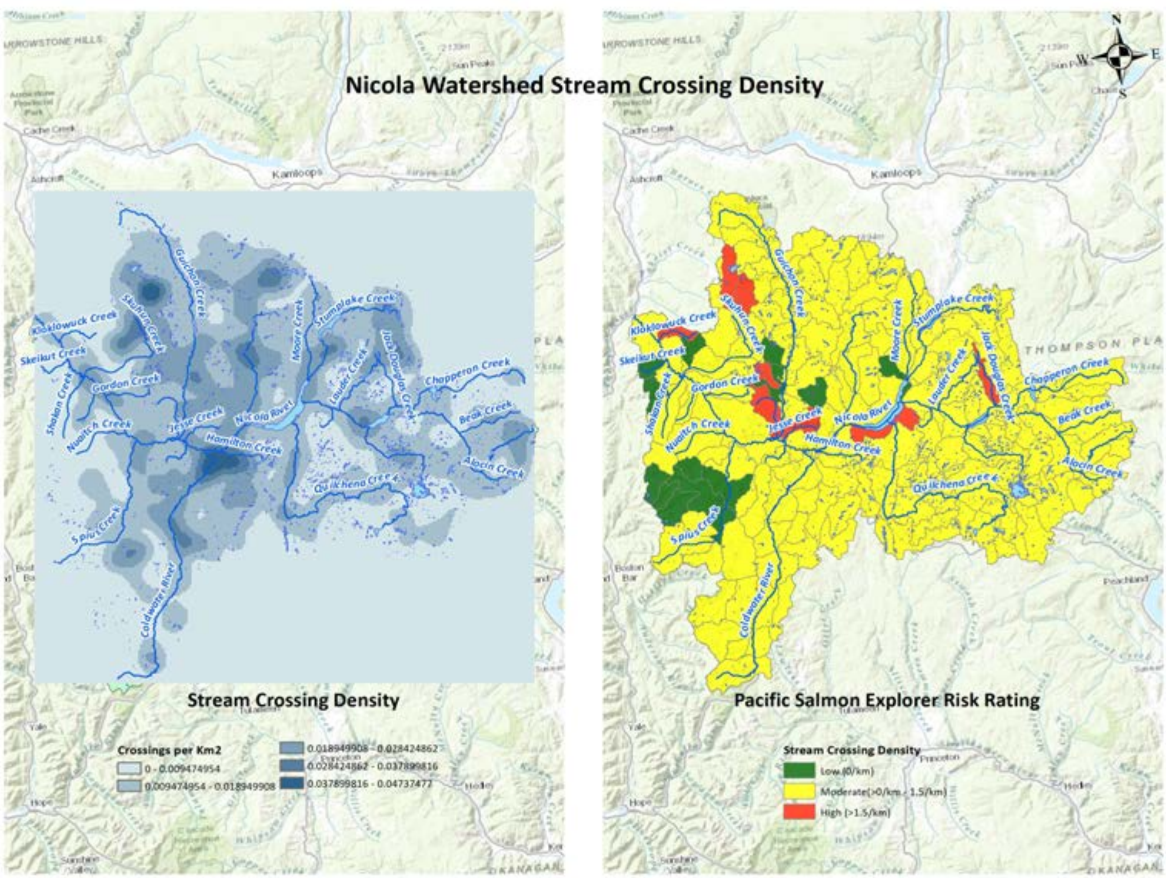


Figure A2-13. Nicola Watershed Stream Crossing Density

Generally, stream crossings appear to pose a moderate risk to the habitat in the Nicola watershed based on the PSE data. However additional density analysis shows clusters of high density crossings in upper reaches of some watersheds, these likely not weighted as heavily in PSE ranking due to limited fish distribution up here. But they still remain potential sediment sources and are important.

Key points:

- *According to PSE risk rankings, majority of watershed considered moderate risk*
- *Closer look at the data and a relative comparison across sub-basins identifies key areas where stream crossing densities are higher, provides a more focused look at this indicator, and demonstrates high concentrations of crossings in upper reaches*

Water Licences

Defined as the total number of water licences permitted for water withdrawal for domestic, industrial, agricultural, power, and storage uses from points of diversion within a watershed

Heavy allocation and surface and subsurface water use can result in:

- Reduction of instream flows that could limit access to spawning and rearing habitats, and / or expose redds
- Increase water temperatures

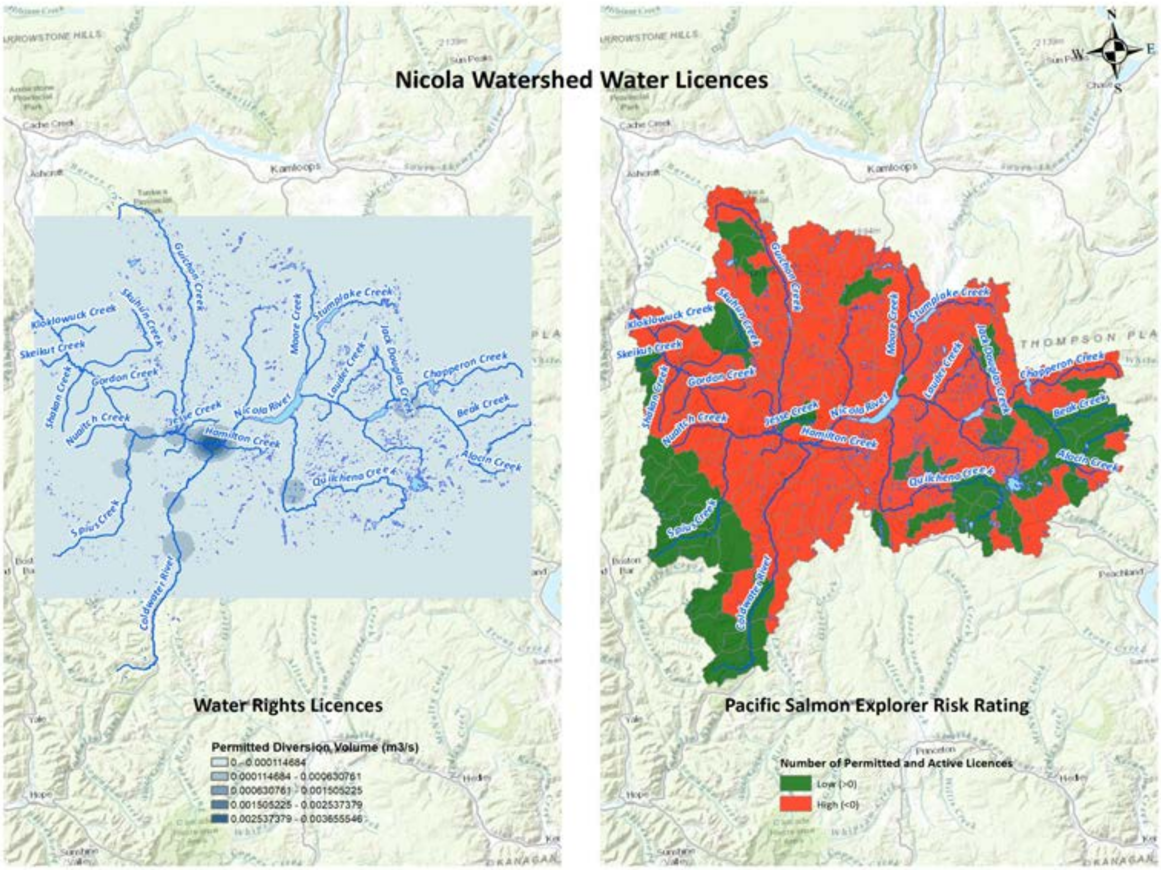


Figure A2-14. Nicola Watershed Water Licenses

These figures show that there are active permitted water licence(s) in the majority of Nicola watershed. Further analysis of permitted diversion volume shows that majority of volume is allocated near the City of Merritt, and select locations in Quilchena Ceek, Coldwater River, and Spius Creek watersheds.

Key Points

- *According to PSE risk rankings, majority of watershed considered high risk due to presence of at least one active permitted water licence*
- *Limitation to this approach: not considering volume of extraction, simply presence / absence*
- *Closer look at the data and a relative comparison across sub-basins identifies key areas where extraction volumes are highest, which are focused around the City of Merritt, and select locations in the Quilchena Creek, Coldwater River, and Spius Creek watersheds*

Forest Disturbance and Equivalent Clearcut Area (ECA)
Both of these are hydrological processes that can change watershed hydrology by affecting rainfall interception, transpiration, and snowmelt processes. Changes over time can affect salmon habitats through altered peak flows, low flows, and annual water yields.

Forest Disturbance is defined as:

% of total watershed that has been disturbed by logging and burning in the last 60 years.

ECA is defined as:

% of total watershed considered functionally and hydrologically comparable to a clearcut forest.

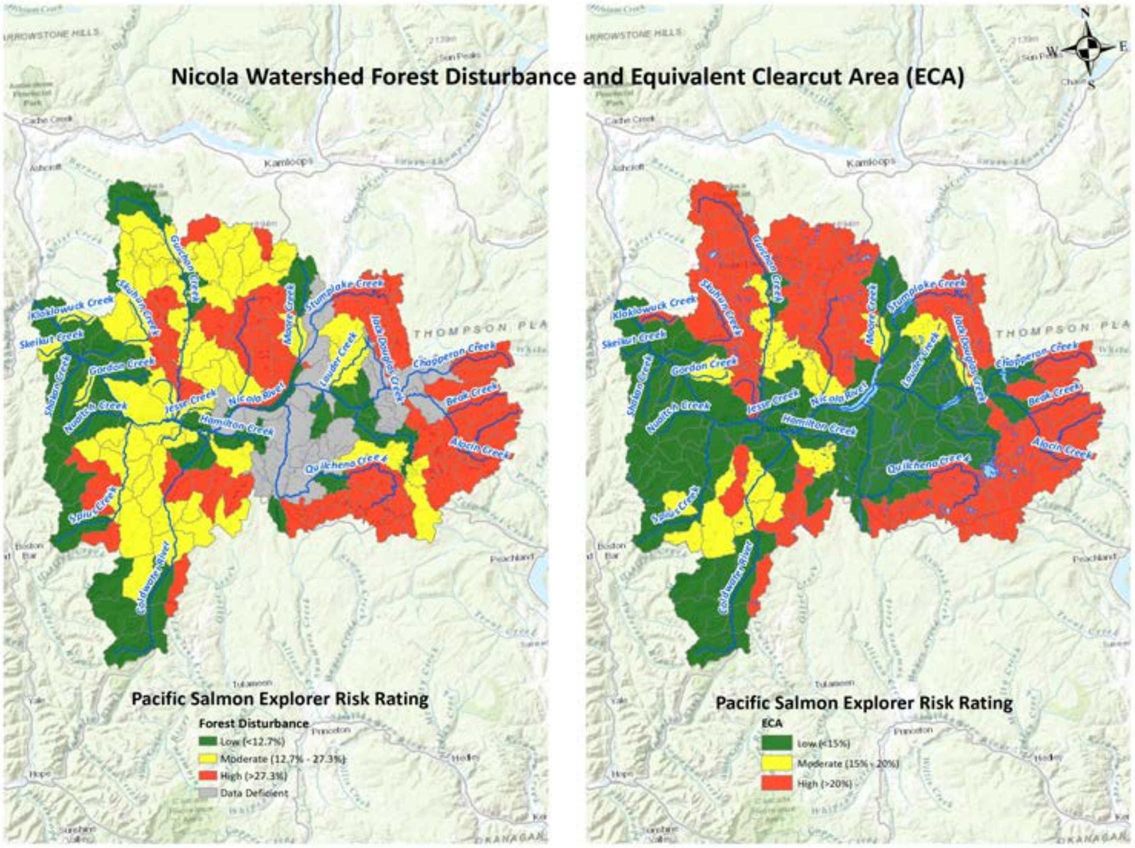


Figure A2-15. Nicola Watershed Forest Disturbance and Equivalent Clearcut Area (ECA)

The PSF forest disturbance layer upper Guichon and Clapperton appear under-represented based on what VRI data showed.

Impervious Surfaces and Mine Development

Factors that can lead to changes in geomorphology and hydrology. Mining can contribute to deposition of fine sediments and water quality issues, and impervious surfaces can lead to increased nutrient and contaminant loads downstream.

Impervious Surfaces are defined as:

% of total watershed that is represented by hard, impervious surfaces (i.e. pavement).

Mine Development is defined as:

The number of active and past producing coal, mineral, or aggregate (gravel) mine sites within a watershed.

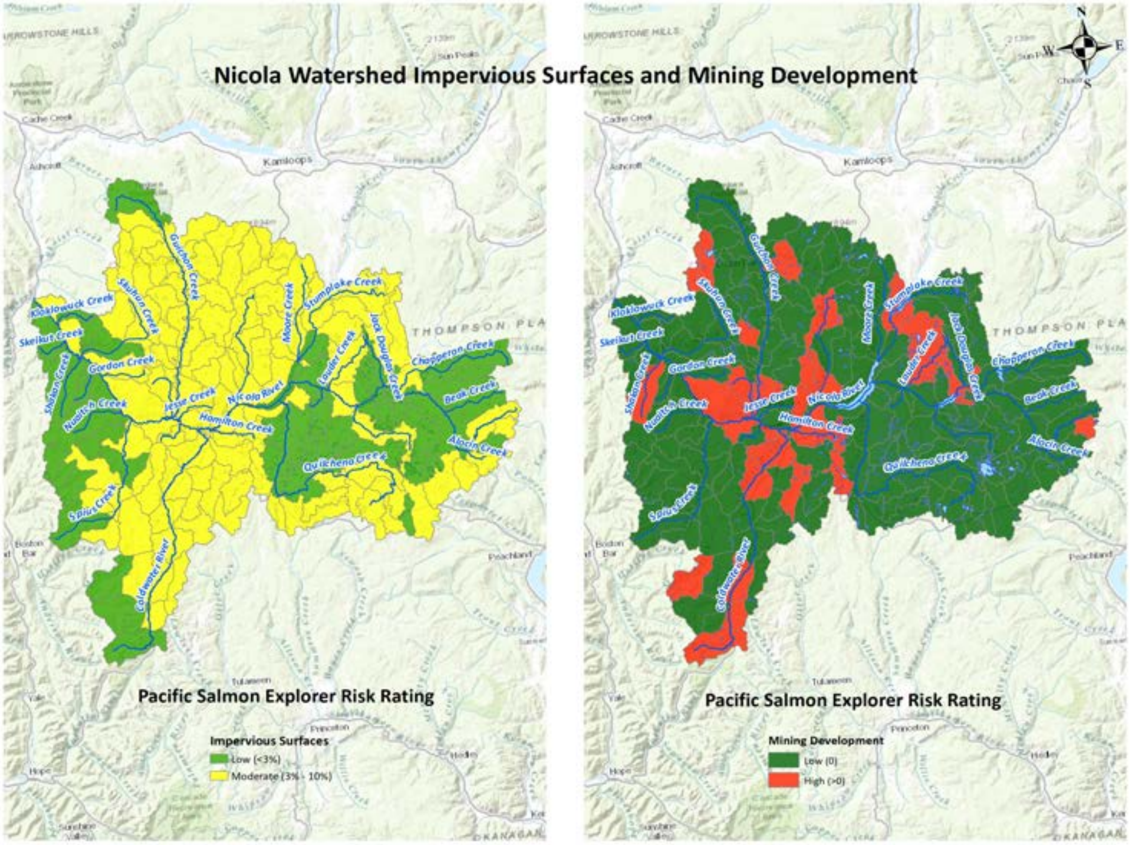


Figure A2-16. Nicola Watershed Impervious Surfaces and Mining Development

Impervious surfaces do not appear to be a high risk pressure indicator on the Nicola watershed. Meanwhile, both past and present mining activity are noted throughout the watershed, notably in the Nicola River, Coldwater River, Skahan Creek, Skuhun Creek, Guichon Creek, Clapperton Creek, and Lauder Creek sub-basins.

Insect and Disease Defoliation and Wastewater Discharges

Insect and Disease Defoliation: Can reduce precipitation interception, reduce transpiration, and increase soil moisture, which affects peak flows and groundwater supplies.

Wastewater Discharges: Can impact water quality through chemical contamination or excessive nutrient enrichment

Insect and Disease Defoliation is defined as:

% of pine forests that have been killed by insects or disease in each watershed.

Wastewater Discharges are defined as:

# of permitted wastewater management discharge sites within a watershed.

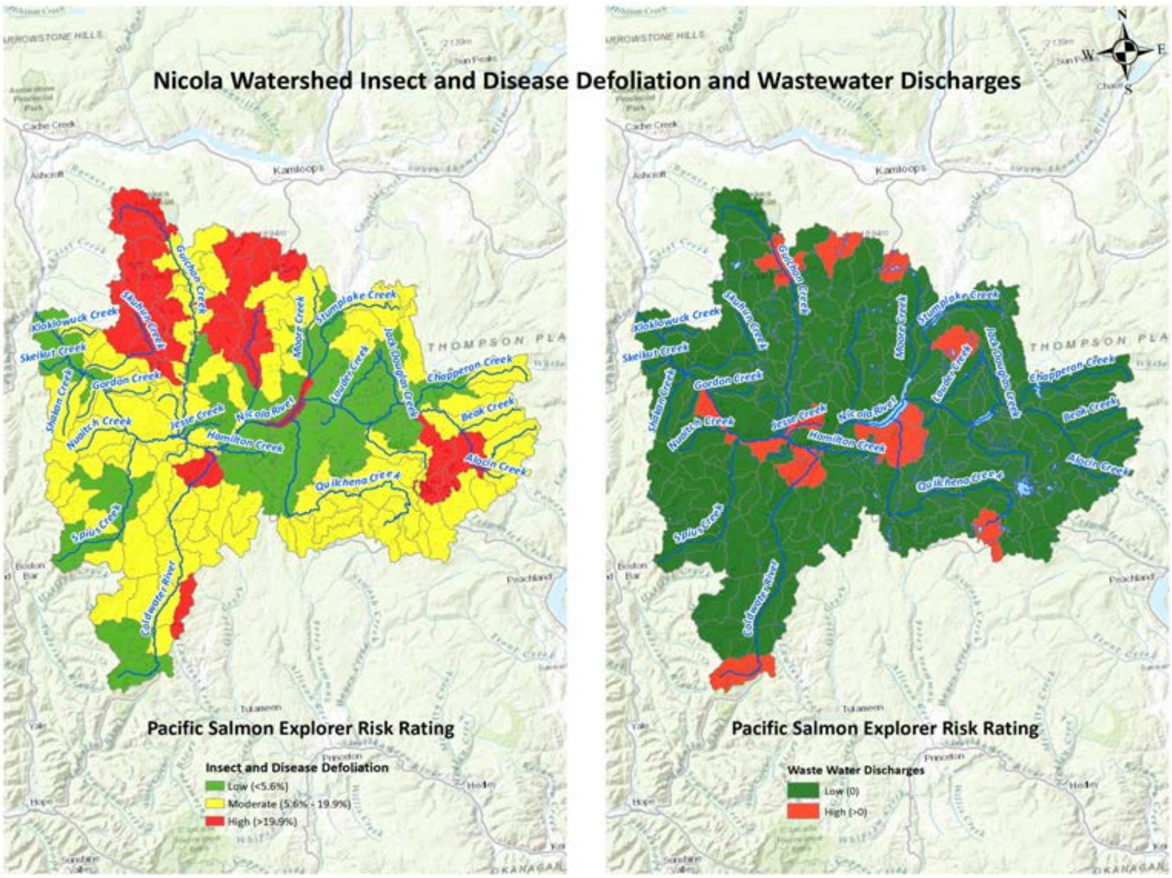


Figure A2-17. Nicola Watershed Insect and Disease Defoliation and Wastewater Discharges

The risk maps show high levels of defoliation in the Skuhuh, upper Guichon, Clapperton, upper Nicola, and portions of the Coldwater River watershed. Wastewater discharges are permitted throughout select sub-basins in the Nicola watershed. However, no metrics were readily available at the time of writing for type of discharge and contamination potential.

Summary of Pressure Indicators

The map below shows all the pressures collated for the Nicola watershed. The following are the overarching findings:

- *According to the PSE, majority of the Nicola Watershed is considered high risk for cumulative spawning pressures.*
- *Analyses of individual pressures indicated riparian disturbance, road density, and water licences to be of highest risk*
- *Note that select sub-basins are at high risk of land cover alterations and forest disturbance, which has significant consequences on hydrology and geomorphology (i.e. upper Guichon and Clapperton Creek watersheds)*

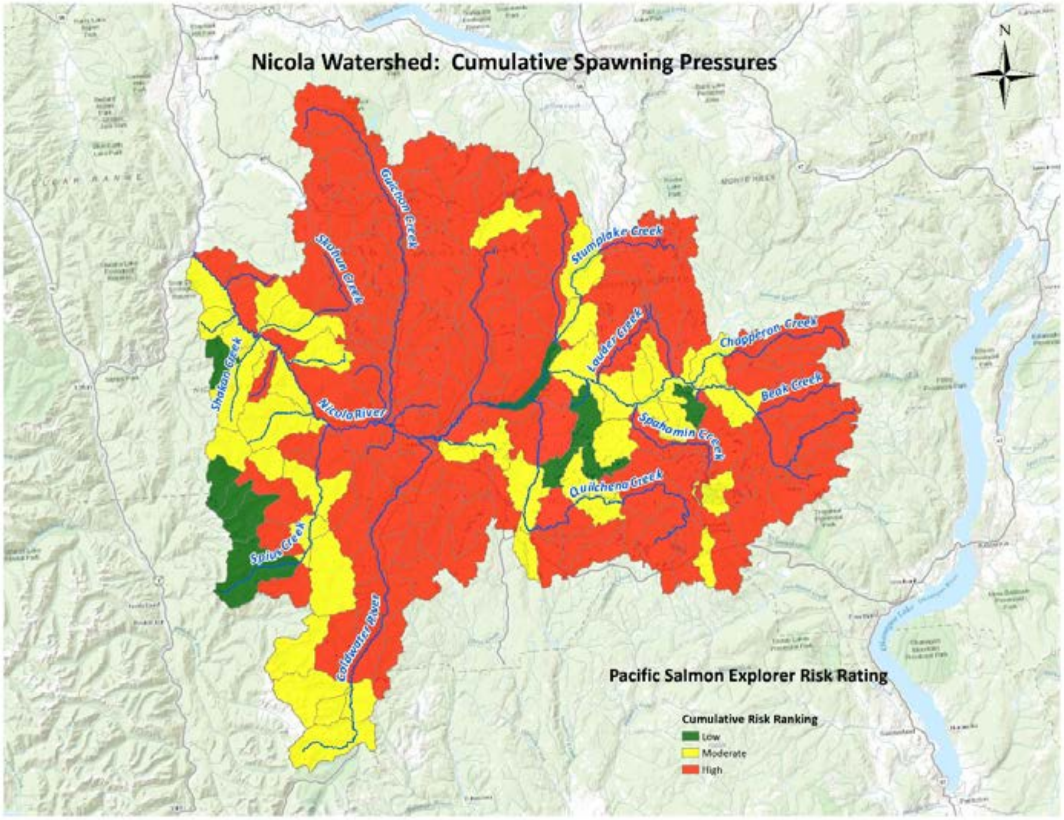


Figure A2-18. Nicola Watershed Cumulative Spawning Pressures

Data Gaps and Recommendations

- Riparian Disturbance
  Conduct a more detailed analyses of riparian condition in key areas of interest. This can be accomplished by acquiring and reviewing high resolution orthophotograph and / or satellite imagery. Use these results to refine the riparian risk ranking to better speak to the spatial trends occurring in the watershed.

- Flow and Temperature
  Map the flow and temperature data in relation to known benchmarks and / or best available science to show relative risks in the watershed

- Critical Habitats
  Acquire and map critical chinook habitat location data (i.e. spawning grounds, rearing habitats, etc.) and overlay on risk maps to better understand how risks affect chinook salmon on a more local level

- Channel Stability
  Map areas of channel instabilities to better understand current and potential future impacts to chinook habitat. This could accomplished via historical air photo analyses of key habitats

- Terrain Assessment

Geotechnical assessment of key watersheds to understand root causes of watershed instability and areas suitable for instream remediation works

- It would be useful to also create overlays of all of these pressure indicators and add layers of chinook distribution and key habitats in relation to these pressure indicators. For example, some sub-basins with data in the maps above may be high risk, but may also be well outside the limits of Chinook distribution.

Indicators from the Fish-Water Management Tool:

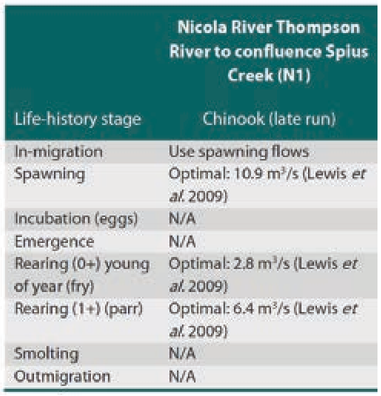
We also collated information on indicators and benchmarks appropriate for Nicola Basin Chinook from Alexander et al. (2019), interviews with Mike Bradford, information provided by Tom Willms, Doyle (2004), Pehl (2004), and Walthers and Nener (1997). Alexander et al. (2019) provided flow and temperature benchmarks for all life stages of Nicola Chinook.

Flows (Information from Alexander et al. 2019).

Flow benchmarks were derived from work done by Lewis *et al.* (2009), who used contemporary methods to generate weighted usable width versus flow, constructed using the most recent habitat suitability curves and combined transect data from Kosakoski and Hamilton (1982), Ptolemy (1984), and all suitable recent data from MOE (2004-2007). The Lewis *et al.* (2009) flow recommendations built on approaches identified in Lewis *et al.* (2004) and Bruce and Hatfield (2003) and generated minimum risk / optimal flows for fish. The authors noted that this provides a higher standard of protection for fish survival and production than those provided by minimum instream flows (i.e., gives a presumptive flow standard that is more about "thriving" than "persisting"). The authors noted however, that the habitat suitability profile for Chinook is based on larger bodied Chinook of coastal British Columbia and Vancouver Island instead of the smaller-bodied Chinook in the Nicola Watershed.

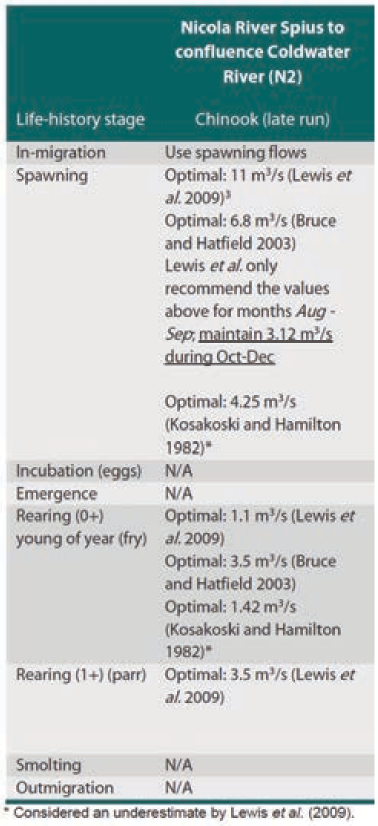
Alexander et al. (2019) noted that work done by Lewis *et al.* (2009) supports the recommendation of Kosakoski and Hamilton (1982) "to ensure that the salmonid production potential of the Nicola River system is maintained, it is recommended that there be no increase in water diversion...during low flow periods, and no new water diversion licences unless they are supported by storage."

Table A2-1. Optimal instream flows for Chinook (late run) from Nicola River -Thompson River to the confluence with Spius Creek (N1). *Source*: Lewis *et al.* (2009) and references therein. From Alexander at al. (2019)



	Nicola River Thompson River to confluence Spius Creek (N1)
Life-history stage	Chinook (late run)
In-migration	Use spawning flows
Spawning	Optimal: 10.9 m^3/s (Lewis *et al.* 2009)
Incubation (eggs)	N/A
Emergence	N/A
Rearing (0+) young of year (fry)	Optimal: 2.8 m^3/s (Lewis *et al.* 2009)
Rearing (1+) (parr)	Optimal: 6.4 m^3/s (Lewis *et al.* 2009)
Smolting	N/A
Outmigration	N/A

Table A2-22. Optimal instream flows for Chinook (late run), Nicola River Spius to the confluence with Coldwater River (N2). *Source*: Lewis *et al.* (2009) and references therein. From Alexander at al. (2019)



	Nicola River Spius to confluence Coldwater River (N2)
Life-history stage	Chinook (late run)
In-migration	Use spawning flows
Spawning	Optimal: 11 m^3/s (Lewis *et al.* 2009)[3] Optimal: 6.8 m^3/s (Bruce and Hatfield 2003) Lewis *et al.* only recommend the values above for months *Aug - Sep*; maintain 3.12 m^3/s during Oct-Dec Optimal: 4.25 m^3/s (Kosakoski and Hamilton 1982)*
Incubation (eggs)	N/A
Emergence	N/A
Rearing (0+) young of year (fry)	Optimal: 1.1 m^3/s (Lewis *et al.* 2009) Optimal: 3.5 m^3/s (Bruce and Hatfield 2003) Optimal: 1.42 m^3/s (Kosakoski and Hamilton 1982)*
Rearing (1+) (parr)	Optimal: 3.5 m^3/s (Lewis *et al.* 2009)
Smolting	N/A
Outmigration	N/A

* Considered an underestimate by Lewis *et al.* (2009).

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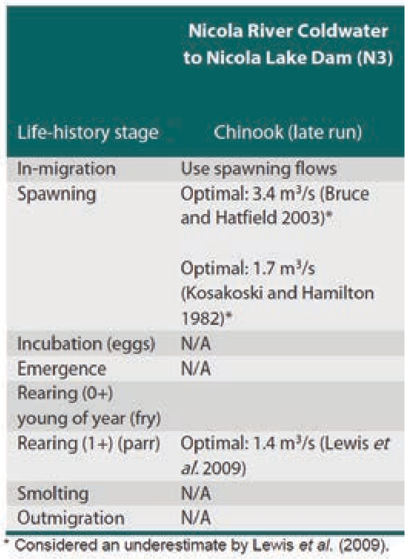
[3] Note: for Chinook adults, habitat suitability does not decline with flows greater than 11 m^3/s

Table A2-3. Optimal instream flows for Chinook (late run), from Nicola River Coldwater to Nicola Lake Dam (N3). *Source*: Lewis *et al.* (2009) and references therein. From Alexander at al. (2019)

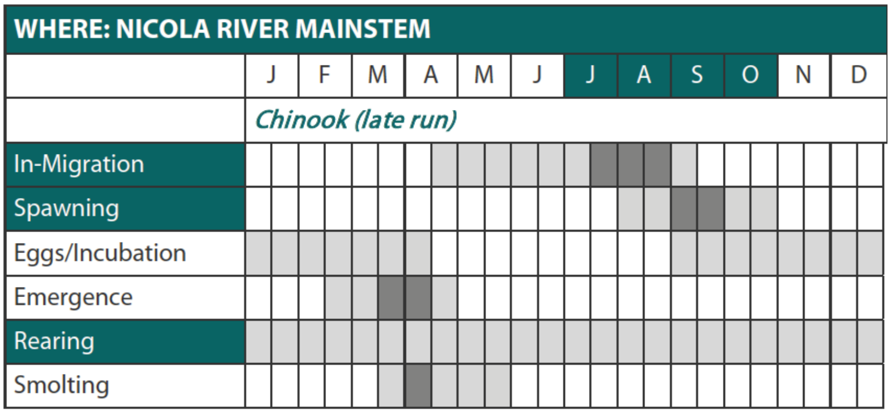


	Nicola River Coldwater to Nicola Lake Dam (N3)
Life-history stage	Chinook (late run)
In-migration	Use spawning flows
Spawning	Optimal: 3.4 m^3/s (Bruce and Hatfield 2003)* Optimal: 1.7 m^3/s (Kosakoski and Hamilton 1982)*
Incubation (eggs)	N/A
Emergence	N/A
Rearing (0+) young of year (fry)	
Rearing (1+) (parr)	Optimal: 1.4 m^3/s (Lewis *et al.* 2009)
Smolting	N/A
Outmigration	N/A

* Considered an underestimate by Lewis *et al.* (2009).

From the first week of July to the last week of October, the Nicola Lake dam has the largest influence on downstream flows. Key life-history events for Nicola Chinook that overlap with the July to October period are provided in the table below.

Table A2-4. Chinook (late run) salmon life-history events that overlap July-October period when Nicola Lake Dam releases have influence on downstream flows. Dark gray shading indicates peak period. Light gray shading indicates active period. (From Alexander et al. 2019).



WHERE: NICOLA RIVER MAINSTEM

	J		F		M		A		M		J		J		A		S		O		N		D	
	Chinook (late run)																							
In-Migration								░	░	░	░	░	░	▓	▓	▓	░							
Spawning															░	░	▓	▓	░	░				
Eggs/Incubation	░	░	░	░	░	░	░										░	░	░	░	░	░	░	░
Emergence				░	░	▓	▓	░																
Rearing	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░
Smolting						░	▓	░	░	░														

Benchmarks for each period of the life history are provided below:

In-migration flows

Draft presumptive standards for Chinook salmon (late run) in-migration attraction flows. The optimal draft presumptive standards are the same as optimal spawning flows. The critical flow threshold was originally 5.66 m3/s based on Kosakoski and Hamilton (1982) and was reduced to 4 m3/s, the value used in 2015 and 2016, at a workshop on August 25 and 26, 2016. Based on professional experience, the time period relevant in critically dry years was determined as August 15 to September 5.

Table A2-5. Definition for chinook (late run) in-migration flows reach N1.

CH3-RQ	**Optimal**	**Fair**	**Critical**
Values:	**≥5.5m^3/s**	**between**	**≤3 m^3/s**
Location:	Nicola River Thompson River to confluence Spius Creek (N1)		

Table A2-6. Definition for chinook (late run) in-migration flows reach N1. **Critically dry years** only.

CH1-MQ	Optimal	Fair	Critical
Values:	≥8.9m^3/s	between	≤4 m^3/s
Location:	Nicola River Thompson River to confluence Spius Creek (N1)		

Chinook (late run) - Spawning flows

Kosakoski and Hamilton (1982) identified N2 as the critical reach in the Nicola River, and spawning chinook as the critical life-history stage (Lewis *et al.* 2009). The 2004-2007 MOE data support the conclusion that chinook adults have the highest flow requirements at a critical low flow spawning period in September. Kosakoski and Hamilton list the optimum flow for spawning chinook in the N2 reach (WSC gauge 08LG007) as 4.25 m3/s (31% Mean Annual Discharge (MAD), whereas the the relationships in Bruce and Hatfield (2003) suggest an optimal flow of 6.8 m3/s (49% MAD); both of these values contrast with optimum flows from more recent empirical data of 11 m3/s (80% MAD) (Lewis *et al.* 2009). Kosakoski and Hamilton (1982) recommended a minimum instream flow of 3.12 m3/s (23% MAD) for spawning chinook in the N2 reach. Lewis *et al.* (2009) recommended higher spawning flows (closer to optimum) for spawning chinook salmon in the months of August and September, while maintaining the Kosakoski and Hamilton minimum flow of 3.12 m3/s for the months of October through December, which are suitable for the rearing life-history stages of chinook, steelhead and coho. Optimal threshold defined as average of optimal flows reported by Lewis *et al.* (2009) and Bruce and Hatfield (2003). Critical threshold defined Kosakoski and Hamilton (1982) minimum spawning flow.

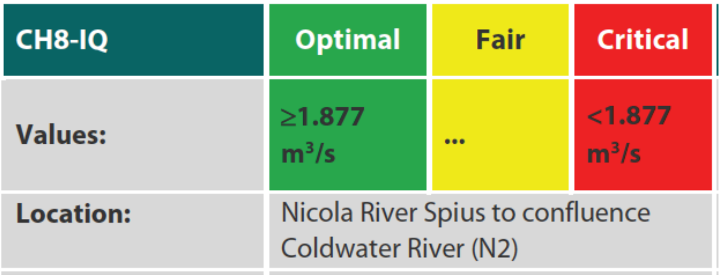
Table A2-7. Definition for chinook (late run) spawning flows, reach N2.

CH2-SQ	Optimal	Fair	Critical
Values:	≥8.9m^3/s	between	≤3.12 m^3/s
Location:	Nicola River Spius to confluence Coldwater River (N2)		
Time period relevant:	September 1st to 30th		

Chinook (late run)- incubation flows.

The purpose of this indicator is to prevent the dewatering of eggs that occurs when water levels are below the initial level at the time of spawning. The management strategy is to reduce flows to a level that can be sustained throughout the incubation period as soon as spawning is complete. The indicator was identified during a 2-hour flow threshold refinement workshop with local experts (Richard Bailey, DFO and Richard McCleary, MFLNRO) on February 19, 2016. The critical flow threshold was identified at the same workshop based on expert opinion. No optimal threshold has been identified to date.

Table A2-8. Definition for chinook (late run) incubation flows, reach N2 October-March

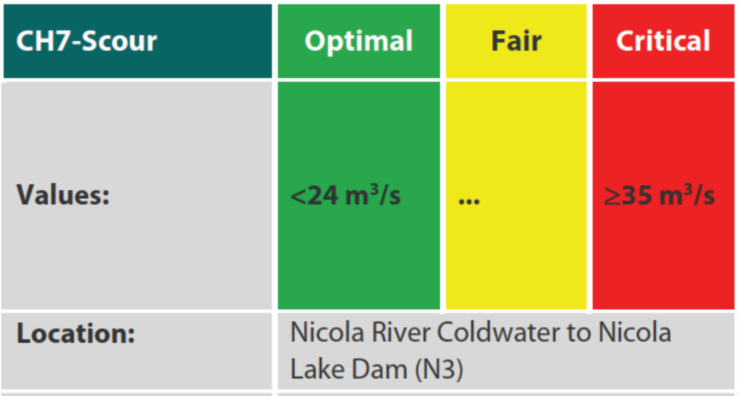


CH8-IQ	Optimal	Fair	Critical
Values:	≥1.877 m^3/s	…	<1.877 m^3/s
Location:	Nicola River Spius to confluence Coldwater River (N2)		

Chinook (late run) - Egg scour flows

High flows may scour eggs during incubation below the dam (citing observations of gravel movement at high flows).

Table A2-9. Definition for chinook (late run) incubating egg scouring flows, reach N3

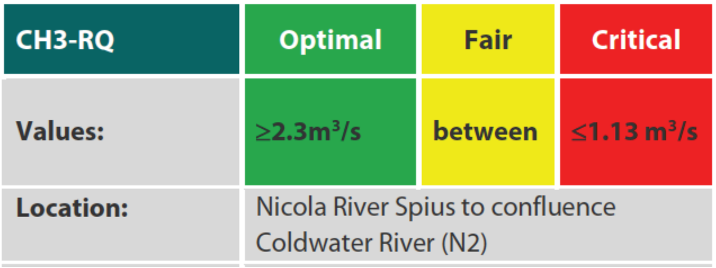


CH7-Scour	Optimal	Fair	Critical
Values:	<24 m^3/s	…	≥35 m^3/s
Location:	Nicola River Coldwater to Nicola Lake Dam (N3)		

Chinook (late run) - Rearing flows

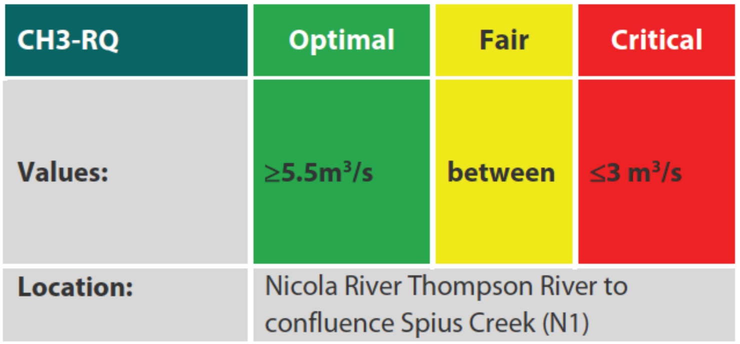
Lewis *et al.* (2009) and Bruce and Hatfield (2003) reported optimal rearing flows for reach N2 of 1.1 m3/s and 3.5 m3/s respectively. Optimal flows are defined as an average of the two reported values (2.3 m3/s).

Table A2-10. Definition for chinook (late run) rearing flows, reach N2.



CH3-RQ	Optimal	Fair	Critical
Values:	≥2.3m³/s	between	≤1.13 m³/s
Location:	Nicola River Spius to confluence Coldwater River (N2)		

Table A2-11. Definition for chinook (late run) rearing flows, reach N1.

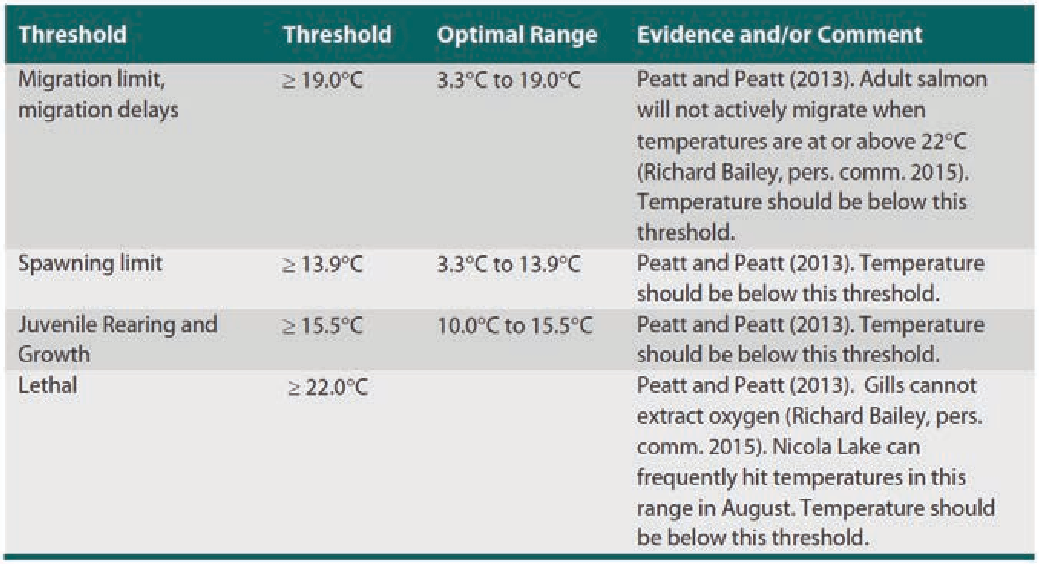


CH3-RQ	Optimal	Fair	Critical
Values:	≥5.5m³/s	between	≤3 m³/s
Location:	Nicola River Thompson River to confluence Spius Creek (N1)		

Water temperatures (from Alexander et al. 2019)

Alexander et al. (2019) recommend the maximum temperature limits for salmon using the mainstem Nicola River.

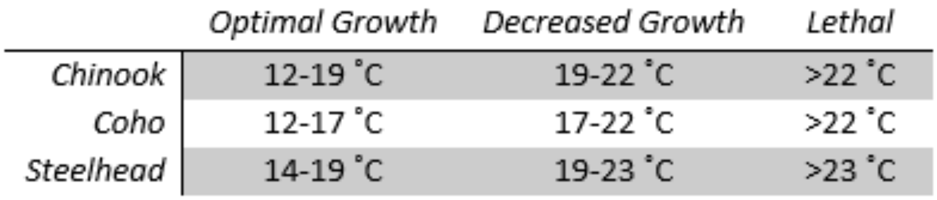
Table A2-12. Maximum Temperature limits for Chinook salmon in the mainstem Nicola River (for the Nicola Fish/Water management tool). From Alexander et al. 2019.



Threshold	Threshold	Optimal Range	Evidence and/or Comment
Migration limit, migration delays	≥ 19.0°C	3.3°C to 19.0°C	Peatt and Peatt (2013). Adult salmon will not actively migrate when temperatures are at or above 22°C (Richard Bailey, pers. comm. 2015). Temperature should be below this threshold.
Spawning limit	≥ 13.9°C	3.3°C to 13.9°C	Peatt and Peatt (2013). Temperature should be below this threshold.
Juvenile Rearing and Growth	≥ 15.5°C	10.0°C to 15.5°C	Peatt and Peatt (2013). Temperature should be below this threshold.
Lethal	≥ 22.0°C		Peatt and Peatt (2013). Gills cannot extract oxygen (Richard Bailey, pers. comm. 2015). Nicola Lake can frequently hit temperatures in this range in August. Temperature should be below this threshold.

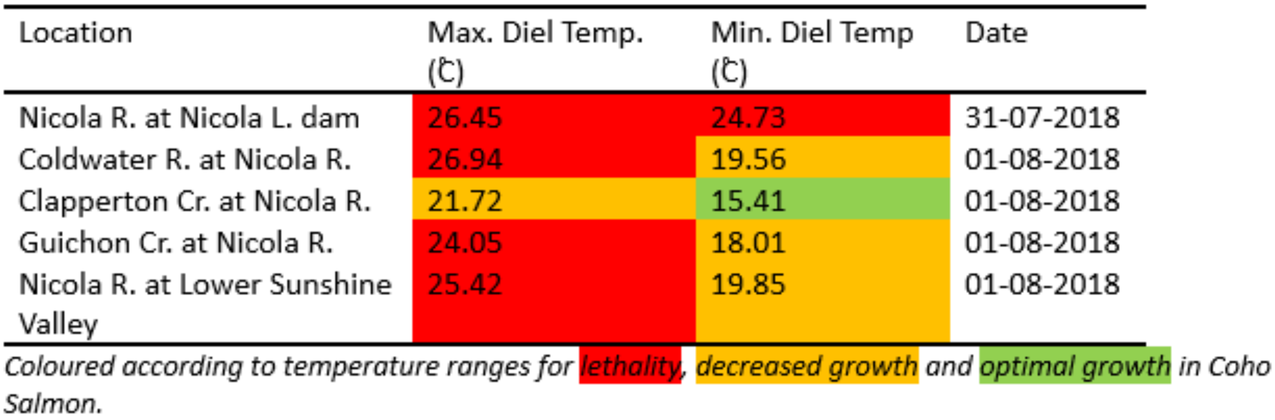
Tom Willms provided the following information:

Table A2-13. Temperature ranges for growth and lethality according to target fish species (Richtern and Kolmes 2005; McCulloch et al. 2001)



	Optimal Growth	*Decreased Growth*	*Lethal*
Chinook	12-19 ˚C	19-22 ˚C	>22 ˚C
Coho	12-17 ˚C	17-22 ˚C	>22 ˚C
Steelhead	14-19 ˚C	19-23 ˚C	>23 ˚C

Table A2-14. Application of generalized temperature thresholds to hottest stream day of 2018.



Location	Max. Diel Temp. (˚C)	Min. Diel Temp (˚C)	Date
Nicola R. at Nicola L. dam	26.45	24.73	31-07-2018
Coldwater R. at Nicola R.	26.94	19.56	01-08-2018
Clapperton Cr. at Nicola R.	21.72	15.41	01-08-2018
Guichon Cr. at Nicola R.	24.05	18.01	01-08-2018
Nicola R. at Lower Sunshine Valley	25.42	19.85	01-08-2018

Coloured according to temperature ranges for lethality, decreased growth and optimal growth in Coho Salmon.

APPENDIX 3: THREATS TO NICOLA BASIN CHINOOK

Excessive exploitation rates, habitat alteration, disruption and destruction from various human activities in the watershed, as well as effects of climate change appear to be contributing to the decline of fish stocks in the Nicola River.

Key Watershed Issues:

The Nicola River watershed is an important contributor to populations of interior Fraser early-run Chinook and Coho salmon and Thompson steelhead. In spite of its importance, the river is one of the most threatened rivers in the province, mainly due to impacts from forestry, agriculture, irrigation and urban developments. Forestry is the major land use in the area, with harvesting operations and associated road building often causing increased levels of suspended sediments in streams from erosion of roads and cutbanks, landslides and soil disturbances in general (Rood and Hamilton 1995, DFO 1998). Other sources of impacts to flow and water quality in streams include agricultural developments, water diversion, alteration/loss of riparian habitat, linear and urban influences, pipeline construction, and mining activities (Rood and Hamilton 1995, Kosakoski and Hamilton 1982, DFO 1998).

There has been considerable loss of riparian vegetation along the Nicola River, which has reduced stream shading and resulted in warmer stream temperatures during summer. Additional thermal stresses are imposed due to flows being reduced by water withdrawals for irrigation and other land use practices, resulting in greater daily temperature variations (Walthers and Nener 1997). Also, frequent destabilization of stream banks has resulted in wider channels and shallower waters being more susceptible to warming during summer. This has occurred in the Nicola Basin as a result of cottonwood removal by ranchers to increase hay production. Increases in water temperature, if too great, can adversely affect growth, distribution, behaviour, disease resistance and ultimately survival and production of salmonids. Studies by Walthers and Nener (1997) suggest that salmonid production in both the Nicola and Coldwater rivers are constrained by relatively high water temperatures, with the distribution of fish influenced by local variations in water temperatures as fish tend to seek cooler areas with groundwater inflows, shade, and other features.

Within the Nicola system, Rood and Hamilton (1995) regarded the Nicola River, Spahomin Creek and Coldwater River as sensitive streams due to high water demands, whereas Spius and Maka creeks and the Coldwater River were regarded as sensitive due to their low flows. The same authors regarded the Coldwater River as sensitive due to high peak flows, whereas Maka Creek was regarded as sensitive due to recent logging activity covering more than 20% of the watershed.

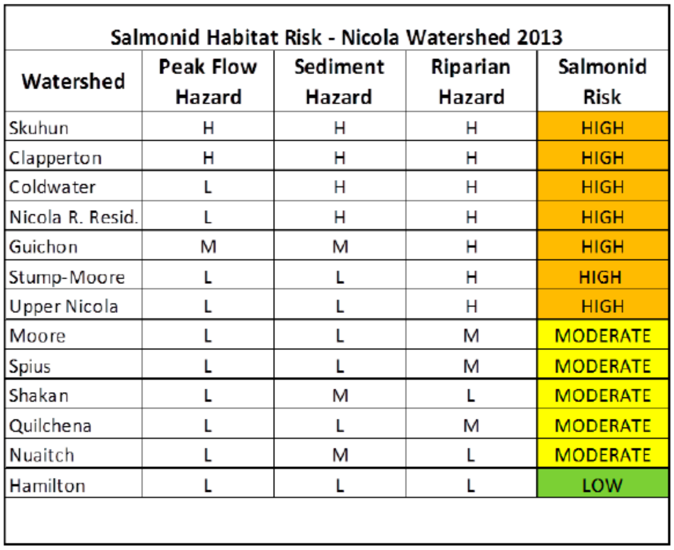
In general, this watershed has undergone a significant loss of stability including loss of riparian cover, bank instability, low flows during summer, high siltation and increased water temperatures. All of these factors have major impacts on Nicola Chinook stocks with their year-long dependency on freshwater habitat, as well as their food resources such as insect populations (Miles 1995, Millar et al. 1994). Beniston et al. (1988) noted that low flows during late summer and winter in the Coldwater river may be the primary factor limiting juvenile Chinook production.

Valdal and Lewis (2015) used a GIS-based watershed assessment procedure (WAP) to assess the potential hazards for habitat condition for fish. They assessed three key hazard categories:

- water quality (for potential sediment input);
- water quantity – peak flow (hydrologic impacts); and riparian hazard (clearing of near-stream areas).

Using this information, they determined the risk to salmonid production throughout the Nicola watershed, and found that twelve of 13 watersheds assessed (Table A3-1) were at moderate risk or higher (in 2013). High risk habitat conditions in 7 of the watersheds were determined not likely to sustain salmonid populations. Most of the risk was due to impacts to riparian clear cutting although the sediment hazard was also widespread. They also noted that risk significantly increased between 2003 and 2013, as a result of elevated riparian loss and increases in peak flows (Figure A3-1 and A3-2).

Table A3-1: Hazard levels and Salmonid risk for Nicola Watersheds.



Salmonid Habitat Risk - Nicola Watershed 2013

Watershed	Peak Flow Hazard	Sediment Hazard	Riparian Hazard	Salmonid Risk
Skuhun	H	H	H	HIGH
Clapperton	H	H	H	HIGH
Coldwater	L	H	H	HIGH
Nicola R. Resid.	L	H	H	HIGH
Guichon	M	M	H	HIGH
Stump-Moore	L	L	H	HIGH
Upper Nicola	L	L	H	HIGH
Moore	L	L	M	MODERATE
Spius	L	L	M	MODERATE
Shakan	L	M	L	MODERATE
Quilchena	L	L	M	MODERATE
Nuaitch	L	M	L	MODERATE
Hamilton	L	L	L	LOW

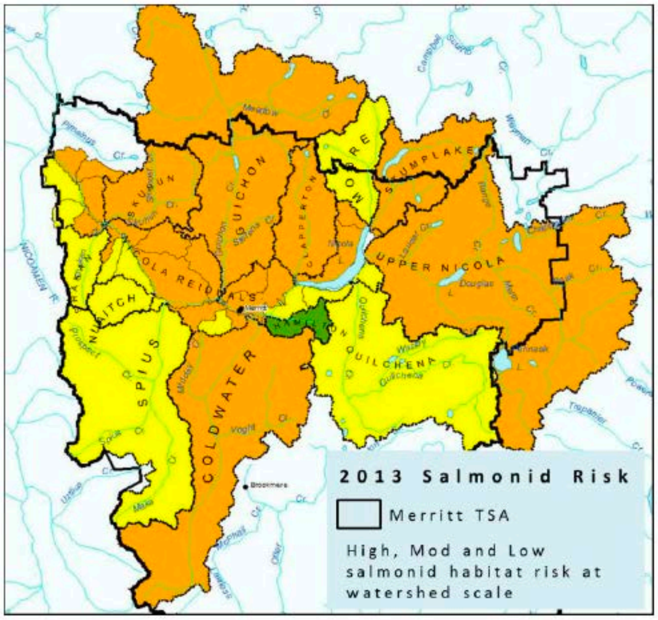
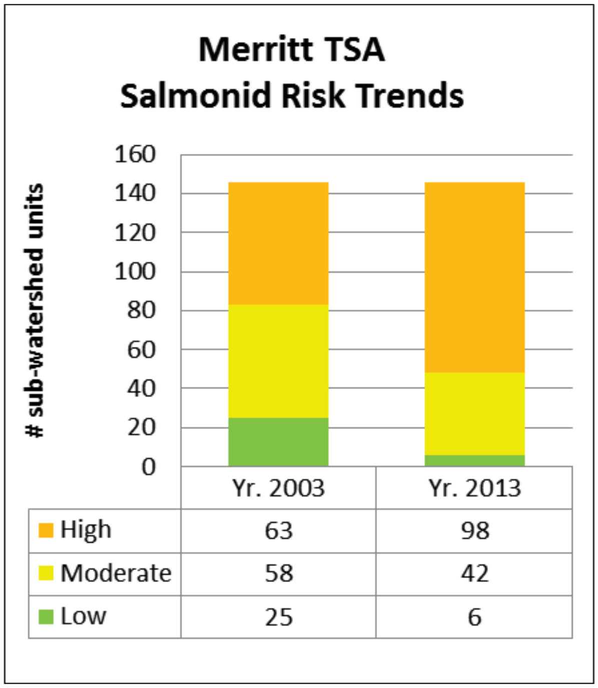


Figure A3-1: Salmonid habitat risk levels by watershed.



	Yr. 2003	Yr. 2013
High	63	98
Moderate	58	42
Low	25	6

Figure A3-2: Salmonid habitat risk trends at the watershed unit scale.

The Nicola River Sensitive Habitat Inventory Mapping and Aquatic Habitat Index (Ecoscape 2017) noted the following:

- **6-7%** of streambanks along the Nicola Mainstem had **severe bank erosion** – largely attributed to **removal of riparian vegetation**
- 32% of LDB and 55% of RDB exhibited anthropogenic alteration
- **Primary impacts** attributed to **agricultural**, **urban** and **highway infrastructure**/activities
- 12 high-priority restoration-potential sites identified based on differential between existing AHI and potential AHI

Major Threats and Limiting Factors:

We can look at Nicola watershed as "a canary in the coal mine" (Richard Bailey, pers. comm.). This watershed is flow- and temperature-sensitive, and is being increasingly pressured by development and climate change.

Seasonal variations in water conditions pose a variety of challenges during the period of freshwater residence (Alexander and Poulsen 2015).

Alexander et al. (2019) noted that by season, these are:

- **Winter**: Threat of freezing both for eggs in gravel and for off-channel rearing juveniles. Anchor ice formation and "rain-on-snow" events often have a profound negative influence, as well as ice jam breakups and resulting scour.
- **Spring**: Freshet activity can lead to scour of incubating eggs, displacement of rearing fish, and stranding if freshets recede rapidly. Rapidly receding flows can also be an artifact of large dam adjustments ("Ramping").
- **Summer**: Low flows and high stream temperatures exacerbated by solar radiation, and "heat sinks" (Nicola Lake). 26°C is lethal to salmonids (high temperatures reduce their ability to extract oxygen from the water). At temperature above 22°C adult salmon will not actively migrate. Late summer diurnal fluctuations in stream temperature can result in localized daytime stream temperatures exceeding 25°C and overnight temperatures sometimes remaining as warm as 20°C. Low flows exacerbate this situation. Groundwater-based thermal refugia are critical to salmon survival in these conditions and returning adult fish can only survive hot dry summers because of local, cooling groundwater inflows (WWSS 2009).
- **Fall**: Extended periods of low water result in disconnection of habitats which disrupts adult salmon spawning migration and obstructs the ability of rearing juveniles to re-distribute to over-winter habitats. It is important to maintain enough water in the river to support salmon migration and provide off-channel connectivity for juveniles where needed.

The key threats to Chinook include the following:

1. Water quantity.

Total annual water use in the watershed was estimated at 74 million cubic metres (in 2006). The agricultural sector accounts for approximately 80% of this water use. Groundwater discharge to surface water is the primary source of stream base flow. Any groundwater extractions and off-stream use in the Nicola Watershed will reduce downstream flows. Approximately 30% of all water use was estimated to come from groundwater in 2006. Groundwater extraction from surficial aquifers will have a local effect on stream flows. Groundwater extraction from confined aquifers will have a more widespread effect on stream flows. There is a timing and distribution challenge between when water is needed and when it is available. During typical drought periods (1 in 10 year event) every sub-basin in the Nicola Watershed has a water deficit through the summer and fall (July to Oct) and therefore there is insufficient water to meet irrigation and instream flow requirements even when dam storage is factored in. In the summer of 2015 there were severe drought conditions in this region following a winter with record low snowpack and low precipitation and high temperatures in the spring and summer. Discharge in Coldwater River fell below the Theoretical Critical Level for juvenile salmonids triggering a Fish Protection Order which limited water or banned withdrawals for irrigation (Schick, 2015). Extensive salvage logging in plateau regions of the watershed may result in increased water yield in the near term, however, the more important effects have been the changes seen in timing and intensity of freshet flows and summer droughts. The consistent and general trend will be an increasing water deficit (in drought years) over the next 40 years as there will be less water supply and greater water use unless action is taken.

Groundwater is critical in maintaining productive stream habitats for stream resident salmonids. In dry years, the amount of water extracted from the rivers and streams for irrigation, together with low seasonal flows, leaves insufficient quantities for fish spawning and rearing. Pressures on groundwater resources include semi-desert weather patterns, high levels of agricultural irrigation usage, and extensive groundwater usage by urban and rural development, mining etc. Current water licenses are fully to over-allocated, and removals are lacking in co-ordination. There are concerns that unregulated new wells will have an even greater impact on groundwater supply. New zoning and land development pressures are increasing demand. Other concerns include inadequate groundwater controls or regulations which further threaten base flows in streams. The resulting low stream flows have impacted fish populations by reducing critical spawning, incubation and rearing habitat; impeded upstream fish access and increased summer water temperatures. Elevated water temperatures place salmonids at risk to physiological stress and diseases. These concerns are likely to worsen in the future, as there is further population influx from the lower mainland, as well as climate change concerns. Key knowledge gaps include an understanding of surface and groundwater interactions.

2. Water quality.

Poor water quality from land use practices such as agriculture and mining is another major concern. Active metal mines within the region include the Highland Valley Copper mine in the upper Guichon and Pukaist drainages: this mine is the 5th largest open pit copper mine in the world, and poses a significant risk to salmonids. Molybdenum is oxidizing and dissolving into process water at Highland Valley Copper which creates a potentially critical water quality issues in the Guichon Creek river system once the mine is decommissioned. There is also intensive agricultural activity in this region, concentrated along the lower and more productive reaches of most streams. Valley bottoms are used for crop production and winter feeding, and upland areas are used for summer range activities. Agricultural development has negatively impacted fisheries values in the Nicola and Coldwater watersheds. Cattle feeding areas and cattle access to watercourses are the primary source for loading pollutants into surface and groundwater, thereby reducing water quality. Other concerns to water quality in the watershed result from increased population growth in this region, including large pulses of visitors in the region during the summer. Increasing numbers of people create more water demand, and increased discharge of effluent, as well as leaching concerns from landfills. The region is traversed by a network of transportation and utility systems. Transportation corridors are concentrated in valley bottoms, adjacent to waterways and floodplain habitat. Major transportation routes include the Coquihalla Highway, Telus fibre optic line, B.C. Hydro major transmission lines as well as oil and gas pipelines owned by Westcoast energy, Trans Mountain Pipeline and Fortis BC. The close proximity of highways and railways to major waterways creates a risk for chemical spills to enter the river and impact fisheries resources. Rock stabilization procedures and sidecast/ballasting materials generated during routine maintenance of roads and railways can impact riparian areas and instream habitat. Of increasing concern is the application of biosolids in the watershed. In 2015, local First Nations set up blockades to stop the transport and subsequent application of biosolids within their unceded traditional territory.

3. Changes to Hydrology.

There are low flows in April, and low summertime and fall flows that affect Chinook. Flows can be substandard for egg incubation, early rearing, and can lead to dewatering in fall and winter. Migration barriers can occur on both the mainstem and tributaries because of low flows through fall- pulses of water are required to mitigate this issue. Attraction flows for Chinook migration in August to early September in the mainstem require adequate cold water to be effective. Flows in this region have been impacted by forest harvesting and mountain pine beetle (MPB) is an added concern: decreases in forest cover due to MPB results in reduced interception and increased snow accumulation in affected forests, and in clearcut areas. Earlier snowmelt leads to increased, faster and earlier runoff, as a result of increased synchronization of flows to mainstems from different elevations. Forest disturbance can result in reduced evapotranspiration thus groundwater aquifers are unable to absorb snow melt, exacerbating surface run off and associated erosion. Downstream effects in the watershed have included changes to channel morphology and damage to infrastructure.

4. Habitat Degradation.

Urban development, such as residential and industrial construction, and agricultural activities have negatively affected fish habitat by the removal of riparian corridors, destruction and/or alteration of stream channels and confinement of floodplains from construction of dikes and berms. Historical and/or recent logging has occurred in most drainages of the Nicola watershed. Most recently, the watersheds of the upper Nicola River, Clapperton Creek and Guichon Creek have seen equivalent clearcut areas in excess of 30% (Valdal and Lewis 2015). Road building and logging activities have degraded riparian habitats, leading to increased sediment delivery, reduced channel instability, and reductions in the quality of spawning and rearing habitats. Other concerns include extensive bank armoring with rip rap, a reduction in channel complexity, channelization, encroachment, bank erosion and bank degradation. Loss of living forest results in reduced evapotranspiration thus groundwater aquifers are unable to absorb snow melt, exacerbating surface run off and associated erosion. Degradation of riparian areas has resulted in increased erosion, loss of shade and cover as well as the loss of pool and off-channel habitat. Loss of riparian vegetation has also been shown to increase river width and channel instability. In the Nicola River, high water temperatures from July to mid-September can be lethal to fish and are a result of low flows and lack of riparian shade.

5. Other.

There are many additional impacts as a result of anthropogenic activities such as music festivals, recreation (off-road vehicles and ATVs), and recreational properties. For example, concerns exist around impacts to riparian vegetation from erosion caused by waves from wakeboard boats.

There are a number of concerns around the Nicola Dam and other dams in the watershed, including the following:

- Fish passage concerns during winter;
- The length of time that high flows occur during freshet have increased over time as dams have attenuated peak flows over a longer period;
- Erosion and turbidity issues during high flows which may impact aquatic productivity downstream;
- Impoundment of large volumes of water and release of epilimnetic flow throughout the summer results in lethal downstream temperatures that exhibit low diel variability;
- Manipulation and simplification of flow regimes may have unintended and unrecognized consequences to the aquatic ecology of the system;
- Over-reliance on dams in mitigating downstream flood-effects has resulted in a false sense of security among residence and development impacts to floodplain ecosystems; and
- Human errors in operating dams have resulted in de-watering events that may have long-term consequences to fish populations.

Other concerns exist as a result of invasive plants and animals in lakes in this region, especially Yellow perch in Nicola Lake.

6. Climate Change.

The Nicola Basin is an arid region with hot summers and low rainfall. The impacts of climate change are already apparent with more frequent and intense droughts, rising water temperatures and increased flooding events (ESSA Technologies Ltd. and Fraser Basin Council, 2019). Warming summers and increasing human demand for water resources is putting significant stress on water resources in the basin (ESSA Technologies Ltd. and Fraser Basin Council, 2019). While the impacts of climate change are being observed, the hydrological consequences are not as well understood. In the Nicola Watershed Characterization report, both a literature review and interviewees expressed a need to conduct research and monitoring at a sub-watershed scale to understand how hydrology is changing and how to manage for shifting drought and flood conditions (ESSA Technologies Ltd. and Fraser Basin Council, 2019).

Based on climate model projections, temperatures in Merritt are predicted to rise and precipitation is predicted to increase (Figure A3-3 & A3-4). For the 1951-1980 period, the annual average temperature in Merritt was 5.5°C; for 1981-2010 it was 6.3°C. Under high emissions scenario, the annual average temperatures are projected to be 7.8°C for the 2021-2050 period, 9.7°C for the 2051-2080 period and 11.2°C for the last 30 years of this century (Figure A3-5) (ClimateData.ca, 2021). Between 1951-1980 annual precipitation in Merritt was 376 mm. Under high emissions scenario, this is projected to be 2% higher for the 2021-2050 period, 8% higher for the 2051-2080 period and 11% higher for the last 30 years of this century (Figure A3-6) (ClimateData.ca, 2021).

However, one additional significant change is that less of this precipitation will fall as snow- with significant impacts to snowpack and hydrology in summer and fall.

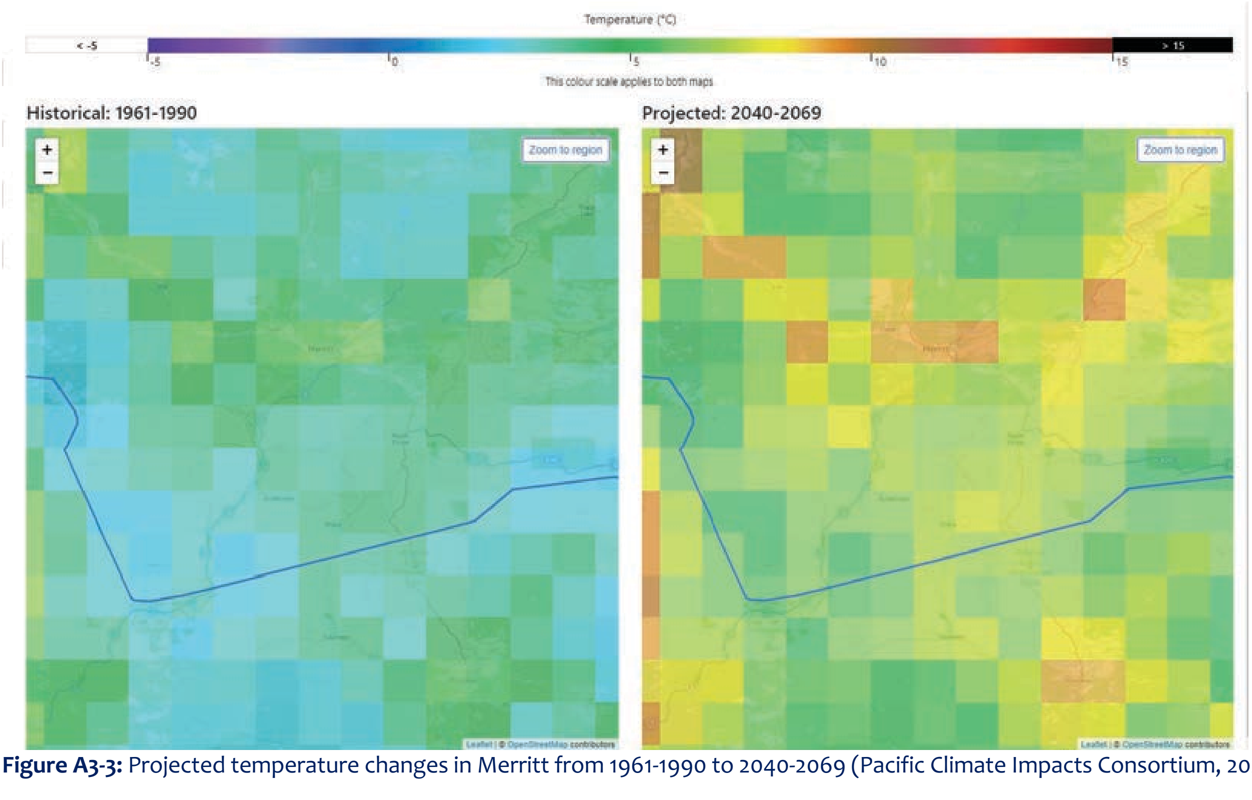


Figure A3-3: Projected temperature changes in Merritt from 1961-1990 to 2040-2069 (Pacific Climate Impacts Consortium, 2021)

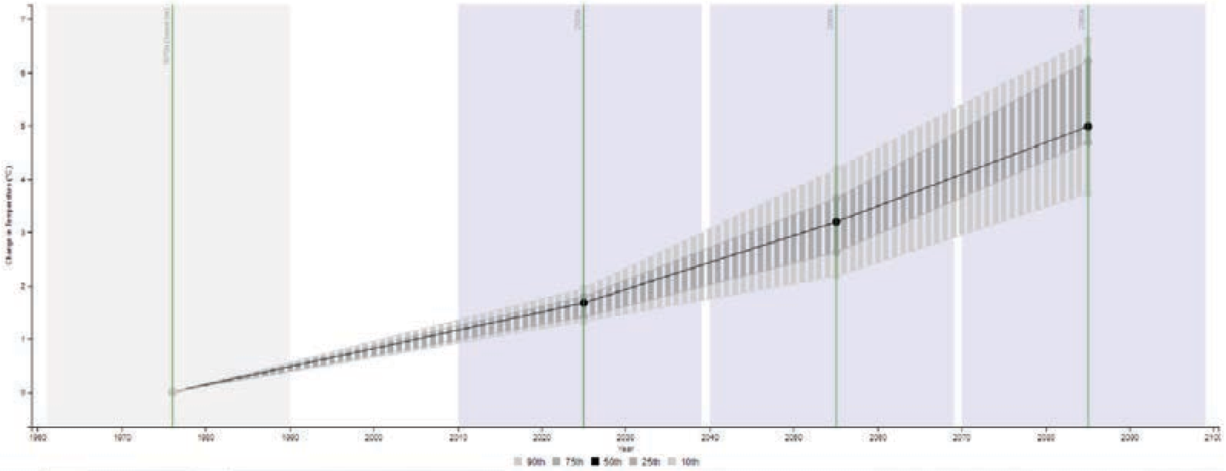


Figure A3-4: The range of projected change in Annual-Temperature for Thompson Nicola over three time periods according to PCIC-standard set of GCM projections (Pacific Climate Impacts Consortium, 2021). This figure shows the range of projected change in annual temperature for the Thompson-Nicola over three time periods (2020s, 2050s and 2080s). Black line indicates the mid point (median), dark grey shading is middle 50% of projections, and light grey shading is the range of the central 80% of the projections.

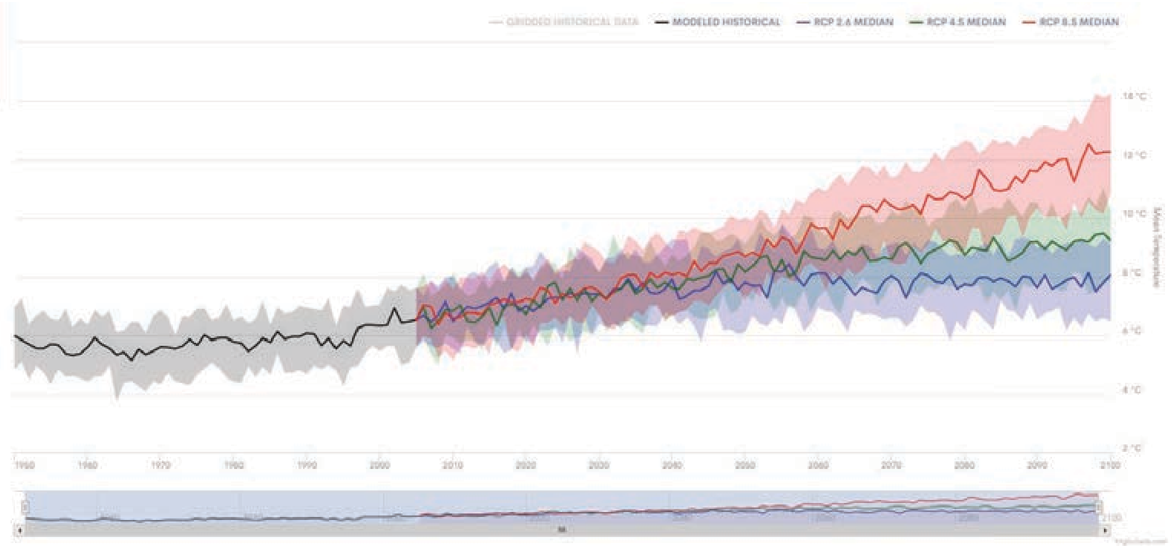


Figure A3-5: Annual mean air temperature in Merritt, B.C. from 1950-2005 and three model projection scenarios from 2005-2100 (ClimateData.ca, 2021).

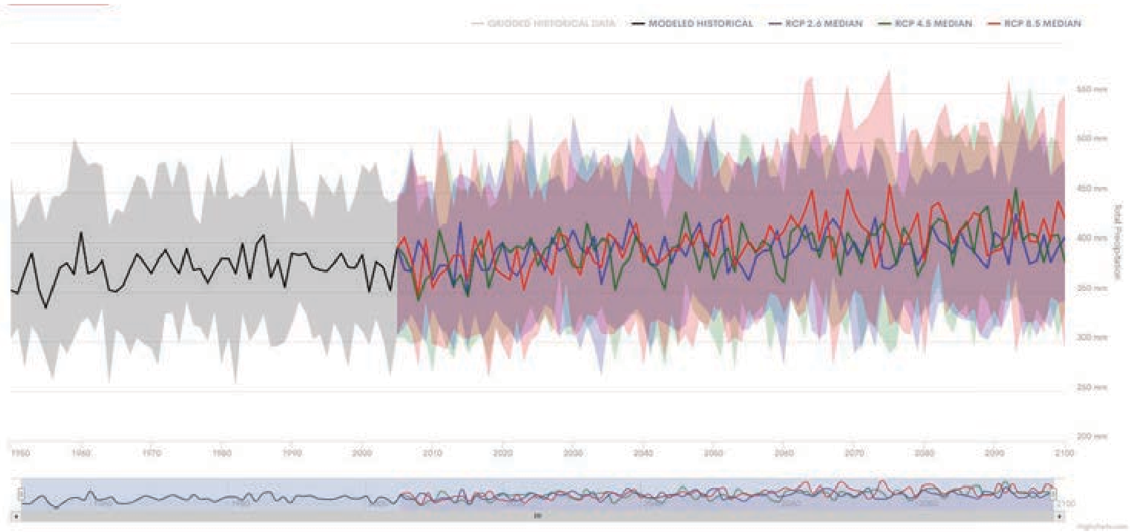


Figure A3-6: Total annual precipitation (mm) in Merritt, B.C. from 1950-2005 and three model projection scenarios from 2005-2100 (ClimateData.ca, 2021)

When comparing historic conditions with current conditions, it becomes clear that the climate in the Nicola Basin has changed substantially over the past century (Warkentin 2020). Daily average air temperatures in January between 1920-1980 never exceeded 0°C. Since 1980 daily average air temperature in January has rose above freezing five times. Daily average temperatures in August have increased by about 2°C (Warkentin 2020). Precipitation patterns in the basin have also shifted compared to historic values. Rainfall has nearly doubled in some recent years compared with historic values (Figure A3-7) (Warkentin 2020).

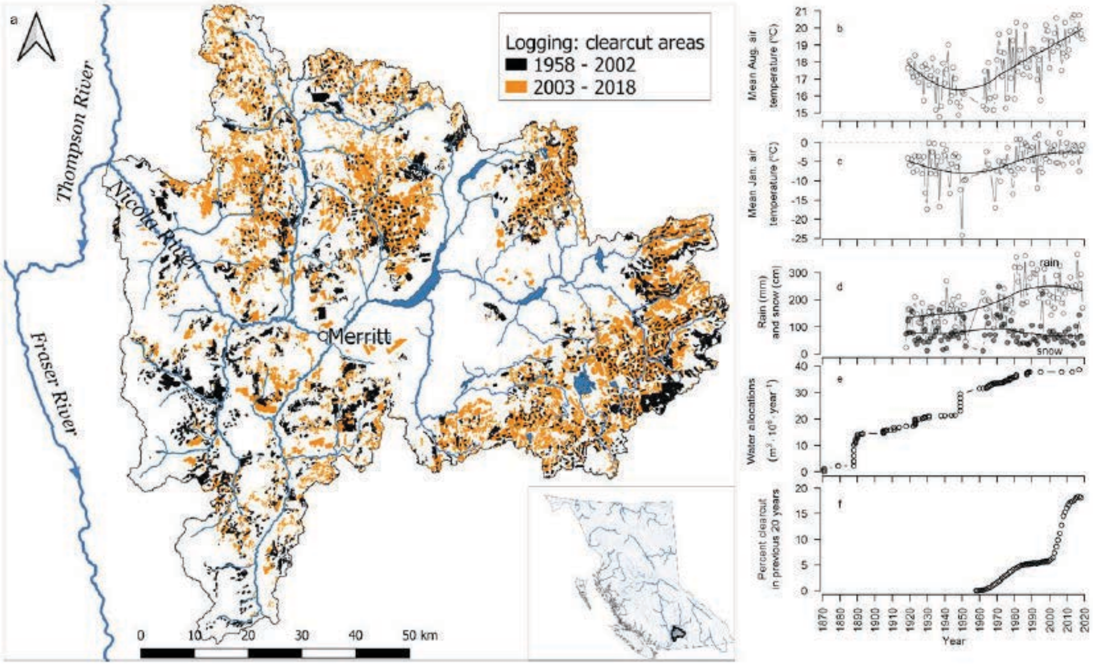


Figure A3-7: Warkentin 2020. a) The Nicola River watershed with clearcut areas. b and c) Historical changes in annual mean August and January air temperatures, d) rain and snow, e) water allocations for the mainstem Nicola River (not including conservation and dam storage licenses), and f) percent of Nicola watershed clearcut in previous 20 years (rolling sum).

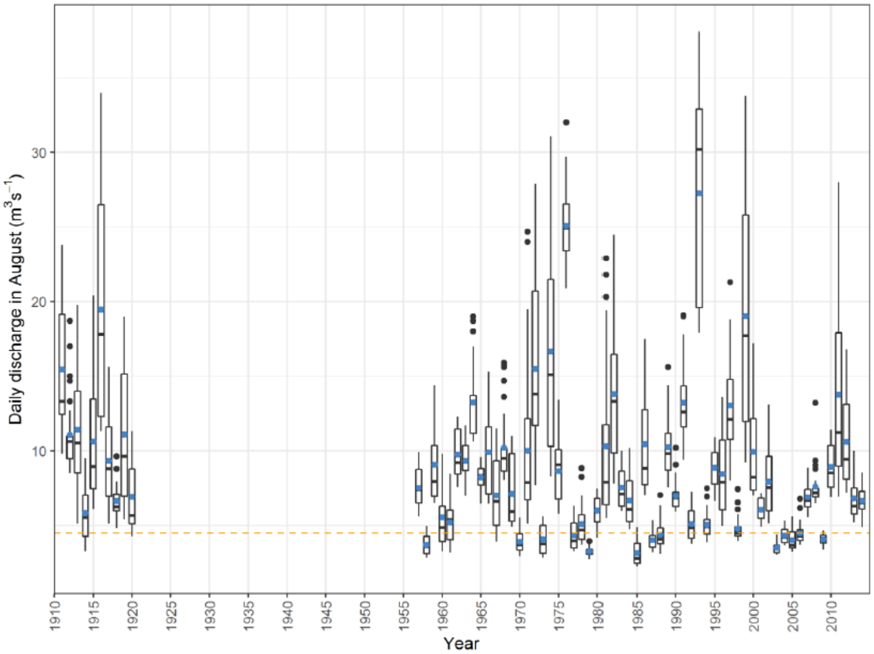


Figure A3-8: Warkentin 2020. Boxplots (black) and mean values (blue) of August daily discharge in the Nicola River, 1911-2014. The orange dashed line indicates 15% mean annual discharge (4.47m^3/sec)

The hydrology of the Nicola River is changing in response to changing temperature and precipitation patterns. Between 1911-1920 average August discharge never fell below 15% mean annual discharge (MAD), compared to 1992-2014 where MAD fell below this value five times (Figure A3-8) (Warkentin 2020). When comparing flows from the last twenty years to flows from 100 years ago, average August flows have decreased 26%. River discharge in June-September in the last 23 years has been up to 25% lower than the long term average, whereas the average from 1910-1921 was up to 50% greater than the long-term average (Figure A3-9) (Warkentin 2020). A model developed by Warkentin (2020) predicts that Chinook cohorts with juveniles that rear in summers with 50% below average flow will have 30% lower productivity. Chinook that spawn in summers with 50% below average flow will have 15% lower productivity.

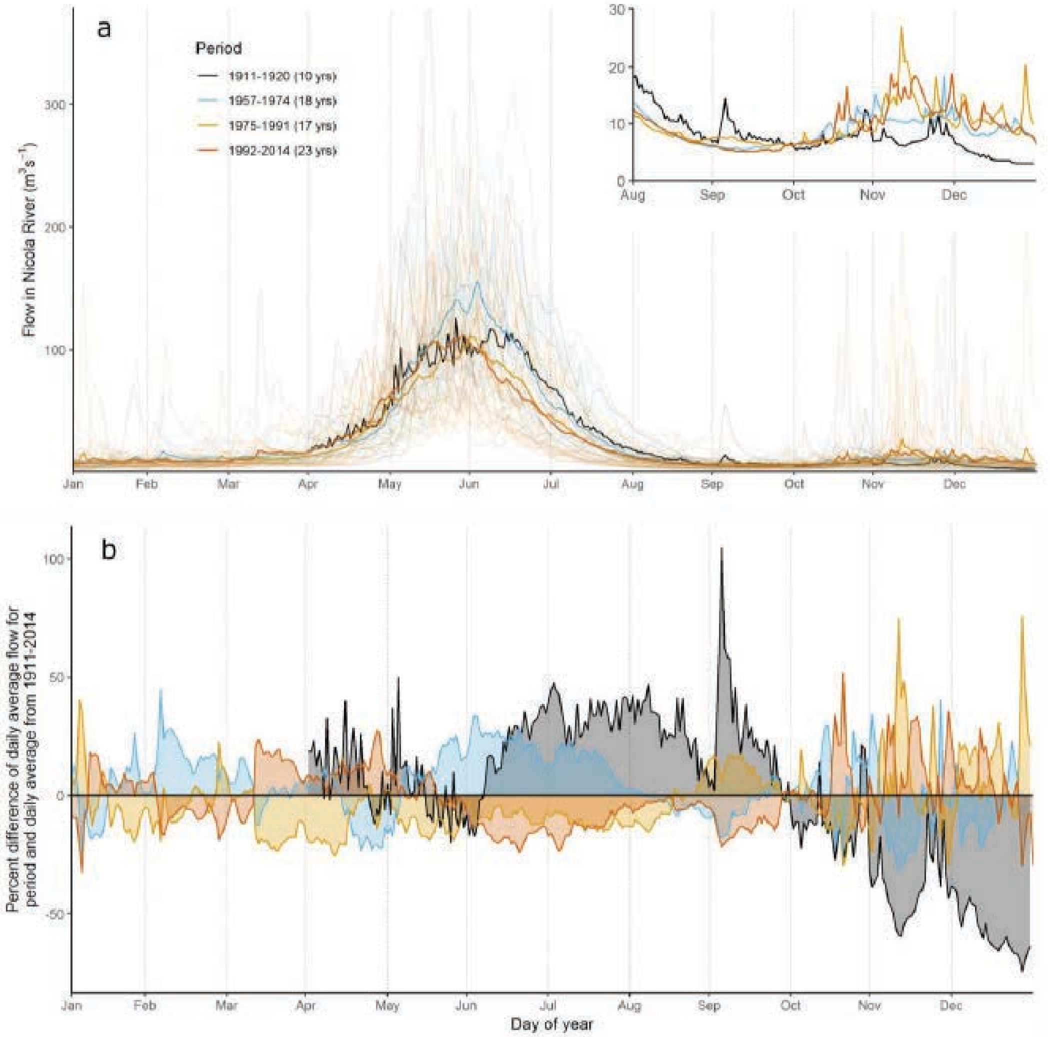


Figure A3-9: Warkentin 2020. a) Hydrographs for the Nicola River, 1911-2014, divided into four period. Bold lines are average daily flows for each day of the year within each period, and faint lines are actual daily flows for each year. b) Percent difference between average daily flow in the four periods and the long-term historical average for each day of the year.

Expected Future Changes (from the Nicola Characterization Report) include the following:

a. Increasing water demand from irrigation sector and municipal water use;
b. Increasing population in the Nicola Valley;
c. More recreation in the form or camping and off-road vehicle use;
d. Continued shift in forest harvesting from lodgepole pine in the MS to other species in different ecosystems (e.g. Douglas-fir in the IDF zone);
e. Gradual transition towards hydrologic recovery of MPB salvage-logged forests in middle-elevations. Effects to streamflow are difficult to predict; and
f. Potential for lower summer base-flows, earlier peak flows and more pronounced high flow events in the fall due to climate change and cumulative impacts from activities within the watershed.

APPENDIX 4: CRITICAL HABITAT REQUIREMENTS & LIMITING FACTORS

Habitat Requirements:

Nicola Chinook have the same general habitat requirements as spring-run Chinook Salmon in other populations. They require suitable spawning and juvenile rearing habitat within the Nicola watershed, and foraging habitat for smolt and immature adults in the Strait of Georgia and eventually the North Pacific Ocean where they need to attain adult size before return. We have developed a list of critical habitat requirements for Nicola Chinook, and have collated a number of benchmarks around temperature and flow requirements from a number of sources (**Appendix 3** above)

Adult Nicola Chinook need to navigate back to the Fraser estuary, and swim through the Fraser River until they reach the Thompson River, and finally, their key spawning grounds in Nicola River, Spius Creek, Coldwater River and above Nicola Lake. Throughout the terminal migration, beginning in the Fraser estuary, they require adequate water quality and flows, clear access, and low levels of predation throughout their migration corridor to their home spawning grounds. Access can be limited through a combination of obstacles such as dams, debris jams, waterfalls, river aggradation, high flows presenting velocity barriers, and low flows restricting connectivity to upstream habitats. Delays in migration due to these factors are known to reduce survival through increased exposure to predation and a loss of vital energy reserves (Diewert, 2007). Successful terminal migrations of adult chinook can be attributed to a lack of barriers to fish passage, appropriate flows and temperatures to facilitate migration, and critical holding habitats such as deep pools, cut banks, and LWD.

Nicola Basin Chinook (late run) salmon are very vulnerable to summer flow and temperature stress issues. Nicola Basin Chinook bound for Spius and Coldwater enter the Nicola River from the 2nd or 3rd week of April, Nicola River fish begin entry in mid-late June, with arrival peaking in the 3rd week of July, and complete by the 3rd week of August; the locations that these adults are found are predictable based on depth and temperature. It is understood that thermal refugia created by influent groundwater are very important at this time and influence the redd site selection. When water temperature exceeds 24°C adult Chinook have been observed to move from pools into better-oxygenated riffle habitats, where they stay until the temperature drops to 23°C, at which point they move back into pools (possibly because of associated lower rates of predation) (Richard Bailey, pers. comm.).

The spawning beds chosen by Chinook vary considerably in physical characteristics, and can range from water depths from a few centimetres to several metres (Groot and Margolis, 1991). However, Chinook typically spawn in deeper, higher velocity zones than other species. As Chinook salmon eggs have the smallest surface area to volume ratio when compared with other Pacific salmon species, their eggs are most sensitive to reduced oxygen levels. As such spawning grounds with adequate subgravel flows (and typically coarse gravels) are targeted during redd selection, and successful spawning is dependent on the availability and quantity of these grounds. Provided the conditions of good subgravel flow are met, Chinook Salmon will spawn in a broad range of water depths, water velocities, and substrates (Scott and Crossman 1973; Healey 1991; Diewert 2007). However, the requirement for sufficient subgravel flow may mean that suitable Chinook Salmon spawning habitat is more limited in most rivers than superficial observation might suggest (Healey 1991).

Stream-type chinook require about 16 m^2 of gravel per spawning pair (Burner 1951), though this value may be too large for the small-bodied Nicola Chinook. The substrate must be small enough to be moved by the fish and large enough to allow good intragravel water flow to the incubating eggs and developing alevins. Redds of stream-type Chinook tend to be in a coarser gravel with a few large cobbles in the bottom of the nest (Diewert, 2007). In terms of thermal conditions, spawning Chinook Salmon require cooler water temperatures than those that can be tolerated during the adult migration. The onset of spawning is coincident with first detection of 12°C water.

Interestingly, it appears that the fish spawning in the Nicola River and its tributaries tend to be small bodied and appear to have adapted to the typical late summer conditions found in these streams (Triton, 2009). This is particularly true for Maka Creek fish. Additionally, when compared with generic spawner preference data, it appears that these smaller fish displayed spawner preferences that departed from the generic BC curves in a 2009 study. It appeared that the Nicola fish use lower energy hydraulic habitats, which also have smaller substrates. In general fish appeared to select sites at the tail-out of riffles.

Egg to fry survival during the incubation phase varies widely and is influenced by stream flow, dissolved oxygen, gravel composition, water temperature, spawn timing, and spawner density. Studies have shown that spawning grounds with a slightly larger gravel size (and therefore higher permeability for oxygen delivery and waste removal) consistently generate higher egg to fry survival rates (Diewert, 2007). Successful incubation requires stable flows that are adequate to supply enough oxygen, but not so high as to cause gravel movement or streambed scour. Floods, which scour the bottom or result in heavy siltation, are generally associated with high egg mortality, as is dewatering of redds (Groot and Margolis, 1991). The upper lethal temperature for Chinook Salmon fry is 25.1°C (Scott and Crossman 1973). Stock-specific differences in thermal tolerance may also occur (Perry et al. 2013; Plumb and Moffitt 2015). Successful incubation also requires good water quality (i.e. absence of waste water, pesticides, toxic chemicals, petroleum products, and organic compounds). Note that healthy riparian vegetation is critical to incubation as it helps to moderate extreme high and low temperatures (Diewert, 2007).

The health of freshwater environments is crucial given the more extended freshwater rearing period for stream-type Chinook. Juvenile abundance tends to be highest in shallow waters with low velocity and small substrate particle size, although individuals occur over a wide range of substrate types, water depths, and velocities (Chapman and Bjornn 1969; Everest and Chapman 1972). During their freshwater residence, stream-type fry tend to reside in tributaries and along river margins, and ephemeral habitats created by the freshet can be critical for short periods. As they grow they move to habitats with increasing velocity and depth, likely increased food abundance and also allows for segregation of Chinook juveniles from potential competitors such as Coho and steelhead. During the winter, they typically move out of tributaries into the river mainstem, where they seek refuge in deep pools or spaces between boulders and rubble. Optimal substrate size for escape from predators and for winter cover is from 10 to 40 cm. Interior stocks may overwinter in the interstices of large rocks in groundwater serviced mainstem habitats.

During the summer, juvenile Chinook burrow into the streambed gravel in groundwater upwelling areas during the hottest part of the day, where temperatures are 16°–17°c compared to ambient river temperatures of 23°—25°c. This behaviour is likely rooted in a combination of avoidance of thermal stress and avoidance of visual predators. Juveniles exit these habitats at night to feed, and typically return shortly after dawn.

Juvenile chinook mainly feed on a variety of invertebrate species as well as on adult and larval insects, particularly those entrained in surface film. Optimal substrate for the maintenance of a diverse and healthy invertebrate population includes a combination of mud, gravel and rubble with rubble dominant. A pool to riffle ratio of about 1:1 appears to provide an optimal mix of food-producing and rearing areas for Chinook in streams. Healthy, natural streamside vegetation is important in maintaining temperatures, controlling erosion and sedimentation and supplying food items that are an important component of stream-type Chinook diets. Additionally, freshwater rearing habitat must have water of sufficient quality and quantity (Diewart 2007). Increasing evidence suggests that, in both winter and summer, groundwater and hyporheic water are important moderators of stream temperature and can create thermal refugia for stream-type Chinook Salmon (for example, protection from anchor ice formation) (R. Bailey pers. comm. 2018).

Stream-type Chinook spend a relatively short time in the estuary as compared with ocean-type Chinook. However, coastal estuaries are still important to stream-type Chinook as they provide an environmental transition zone, extensive opportunities for feeding and growth, and refuge from predators.

Chinook Salmon are believed to require productive nearshore marine habitats, and survival during the period of early ocean residence may influence total production (Brown et al. 2013a). Chinook Salmon generally remain in sheltered, nearshore environments for varying periods depending on factors such as food availability, competition, predation, and environmental conditions. Coastal areas provide a rich habitat with opportunities for feeding and growth. Throughout this period, kelp and other shoreline vegetation provide an important refuge from predators as well as a productive environment for plankton, a major dietary component for juvenile Chinook Salmon (Williams 1989; Healey 1991; Diewart 2007). Therefore, the health of coastal ocean ecosystems plays a key role in the production of Chinook Salmon stocks.

As they grow and mature, Chinook Salmon disperse widely throughout the North Pacific where they eat mainly small fish (primarily Herring and sandlance), with crab larvae, squid and large zooplankton also contributing to their diet. While migration patterns and other aspects of their marine ecology remain poorly understood, ocean residence is recognized as a very important component of the life cycle of all Pacific salmon. During their time at sea, Chinook Salmon migrate varying distances while increasing in size and acquiring the energy reserves required for reproduction. While distribution patterns vary among years and stocks, all stream-type Chinook Salmon utilize coastal and offshore habitats during a period of rapid growth that is critical to reproductive success (Diewart 2007).

Adult Chinook Salmon generally require access to their home spawning grounds to successfully reproduce at a sufficient level of fitness. Strays can reproduce successfully outside their natal streams, but may have lower fitness. Features such as human-made dams, beaver dams, waterfalls, or rock/mud slides that block upstream migration can limit access to spawning areas and impact production (Diewart 2007; R. Bailey pers. comm. 2018). Suitable adult homeward/upstream migration conditions are limited to areas and seasons where water temperatures are generally lower than 19°C (Yates et al. 2008). Adult Chinook Salmon stop migration and seek temperature refuges when water temperatures exceed 22°C (Alexander et al. 1998). However Nicola fish rarely encounter summer temperatures during holding and migration that are much less than 16°C. If conditions such as high water temperature or extreme flows (high or low) are encountered when spawners arrive at their river of origin, fish will hold in the vicinity of the river mouth waiting for conditions to improve. This delay in river entry can adversely affect survival and spawning success as fish may be exposed to unsanctioned fishing.

The overall productive capacity of the Nicola watershed is dependent on maintaining high quality spawning and rearing habitat. For stream type Chinook in particular, a high-quality rearing habitat is required throughout the year, and given the harsh winter conditions in this region, the quality of overwintering habitat may be critical to total smolt output in streams. Groundwater is also a critical ingredient for producing stream-resident fish in BC, required for at least 9 months of the year, critical for successful terminal migration, incubation, and stream rearing.

Information Tables for Critical Habitat Requirements, Generic Limiting Factors, Benchmarks and Indicators for Nicola Stream Type Chinook Salmon:

ADULT TERMINAL MIGRATION & SPAWNING

* Note, for each life history component, firstly a generic information table is provided with general limiting factors and indicators/benchmarks for Stream-type Chinook in BC (note that not all of these are necessarily applicable to Nicola Basin Chinook). This table is followed by a similar information table that provides information specific for the systems important to Chinook within the Nicola Watershed. Some Limiting factors will be deemed non-relevant if they are not applicable for Nicola Chinook.(Note all the citations are available in Pearsall et al. 2022 RAMS Methodology Guidance Report).

Critical Habitat Requirements	Limiting Factors	Factors Affecting Habitat Features	Benchmarks	Potential Indicators	Details
1. Safe holding habitat in confluence of Thompson-Nicola prior to upriver migration into the Nicola River	**LF1**: Unsanctioned fisheries in the confluence of Thompson- Nicola	-Lack of suitable holding habitat -Lack of riparian cover -Low water levels allowing easy access to migrating fish -High water temperatures delaying migration -Lack of escape habitat -Lighting -Poaching, lack of monitoring and enforcement	-Hicks (2002) suggested that barriers to migration exist for Chinook salmon when maximum daily water temperatures are greater than 21-22°C	-Area of habitat -Riparian cover -Water temperatures & flows -Presence of poachers	-Chinook may wait for ideal temperature or flow levels before entering into a system to start their freshwater migration- thus warming waters or low water depths may cause delays and increase ability for fishers to catch adults. Therefore, this factor is linked to LF2 and 3.
2. Adequate flows to facilitate	**LF2:** Limited or delayed spawner access	-Lack of storage	-Maximum sustained current velocity for adult upstream migration is 240	-Discharge (cms) -Water withdrawals	-Drought conditions and low river water levels can result in slowed migration rates, leaving fish vulnerable

Critical Habitat Requirements	Limiting Factors	Factors Affecting Habitat Features	Benchmarks	Potential Indicators	Details
upstream passage of spawners		-Drought conditions -Water diversion for industrial, domestic, resource development e.g. logging -Reservoir operation -Sediment aggradation reduces resilience of adult fish -Debris management -Hydroelectric power operation	cm/s. (Thompson 1972 in Allen and Hassler 1986). -Obstacle current maximum during adult upstream migration is 610 cm/s (Weave 1963 in Allen and Hassler 1986). -Observed spawning at velocities ranging from 30 -76 cm/s (Briggs 1953 in Healey 1991). Observed Chinook spawning at velocities ranging from 37 to 189 cm/s and averaging over 100 cm/s (Chapman et al.1986). The useable spawning and embryo incubation velocity range is about 20 to 115 cm/s with an optimal range of about 30 to 90 cm/s (Raleigh et al.1986). -Compare watershed ratios for extraction and rank based on proportion (low, med, high) (Stalberg et al. 2009). -Road density (km road/km^2 of sub-basin) Higher risk: >0.4 km/km^2 Lower risk < 0.4 km/km^2 (Stalberg et al. 2009). -Water depths required > 0.2m -Road density (km road/km^2 of sub-basin): Higher risk: >0.4 km/km^2 Lower risk < 0.4 km/km^2 (Stalberg et al. 2009) - Stalberg et al. (2009) 1 in 2 year 30-day duration summer minimum flow is less than 20% of the mean annual discharge= poor. Flows ≥20% of the mean annual discharge are considered sufficient.	-Road density -Level of discharge in cms -Density of road crossings -Volume of water extraction -Land alteration	to predation/poaching etc. as well as increased pre-spawn mortality.

Critical Habitat Requirements	**Limiting Factors**	**Factors Affecting Habitat Features**	**Benchmarks**	**Potential Indicators**	**Details**
3. Unrestricted migration and passage throughout mainstem and off-channel habitat	**LF3:** Potential delays in upstream migration due to counting fences, fishways and other manmade structures **LF4:** Reduced access through natural falls and natural barriers	-Woody debris accumulations at fishways or other areas, enumeration fences and falls -Sedimentation -Natural barriers	-Rated opportunity of upstream fish passage (good, fair or poor with parameters) -Road density (km road/km^2 of sub-basin): Higher risk: >0.4 km/km^2 Lower risk < 0.4 km/km^2 (Stalberg et al. 2009)	-Available Fish access -Migration time through fences/falls etc. -Density of road crossings	-Both artificial and natural blockages can result in delays or complete cessation of migration, leaving fish vulnerable to predation/poaching etc. as well as increased pre-spawn mortality
4. Dynamic equilibrium in channel morphology, maintenance of channel capacity, adequate channel depths and natural level of sediment transport.	**LF5:** Aggradation creates a migration barrier in the river during adult migration	-Bank erosion -Channel shifting -Habitat degradation -Riparian disturbance -Bedload aggradation -Logging -Landslides -Extreme rain on snow events	-Natural rates of sediment transport-silt loads exceeding 4,000 mg/l may stop the upstream migration of adult salmon (Bell 1973). -Location and duration of passage issues due to deposition of coarse sediments coupled with low flows -Rated opportunity of upstream fish passage (good, fair or poor with parameters) -Those river sections exceeding a benchmark level of riparian disturbance of 5% of the riparian area are of a moderate concern, and those that exceeding a benchmark level of riparian disturbance of 10% of the riparian area are a high concern (Stalberg et al. 2009). -Road density (km road/km^2 of sub-basin): Higher risk: >0.4 km/km^2 Lower risk < 0.4 km/km^2 (Stalberg et al., 2009)	-Sediment transport rates -Number of natural/manmade slides in the watershed -Percentage of intact riparian along channel lengths -Depth of channel -Road density -Turbidity, TSS -Land alteration	-Loss of functional riparian cover can result in changes to erosion and deposition patterns and magnitude across stream reaches. -Instream works have the potential to de-stabilize upstream sites and mobilize upstream channel and floodplain sediment.
5. Clear and safe passage with adequate refuge habitat	**LF6:** Loss of good quality refuge habitat and safe migration route	-Lack of riparian cover and LWD in streams leading to high levels of	-Welsch (1991) suggested a buffer strip about 30m wide on each side of the stream provides adequate erosion	-Percentage and stage of intact riparian cover (though larger	-Loss of functional riparian cover and loss of LWD results in lack of refuge habitat resulting in increased risk of predation and poaching.

Critical Habitat Requirements	Limiting Factors	Factors Affecting Habitat Features	Benchmarks	Potential Indicators	Details
	through the river due to channelization, loss of habitat complexity, pools, and instream cover features	predation on spawners due to visibility - Diking in rivers can lead to channelized rivers and reduced natural complexity - LWD jams and migration of channel to valley wall create scenarios with sufficient scour forces to create deep pools.	control and maintains undercut stream banks characteristic of good habitat. -Rated opportunity of upstream fish passage (good, fair or poor with parameters) - LWD habitat condition may be determined, at the reach level, using the following diagnostics described in Johnston and Slaney (1996): Good = >2 pieces of functional LWD per bankful width; Fair = 1 – 2 pieces of functional LWD per bankful width; and Poor = <1 piece of functional LWD per bankful width. -An acceptable minimum depth for Chinook salmon spawning and migration is 20 cm. -Deep pools are very important for adult holding during migration, spawning and rearing, particularly those with riparian cover that provide cool water refugia (Torgersen et al. 1999). 40-60% pools optimal for spawning and rearing. - Those river sections exceeding a benchmark level of riparian disturbance of 5% of the riparian area are of a moderate concern, and those that exceeding a benchmark level of riparian disturbance of 10% of the riparian area are a high concern (Stalberg et al. 2009). -Road density (km road/km^2 of sub-basin): Higher risk: >0.4 km/km^2 Lower risk < 0.4 km/km^2 (Stalberg et al. 2009)	Chinook usually hide down in deeper pools) -Frequency & quality of deep (>1m) holding pools -Amount of LWD -Density of road crossings	-Healthy, natural streamside vegetation is important in maintaining temperatures, controlling erosion and sedimentation and supplying food item that are important to juvenile Chinook (Allen and Hassler 1986; Healey 1991). -Aggradation can reduce channel capacity and exacerbate any flooding issues, as well as reduce the depth of holding pools. -Extensive shallow glides with a lack of suitable holding pools leaves Chinook vulnerable to predation.

Critical Habitat Requirements	Limiting Factors	Factors Affecting Habitat Features	Benchmarks	Potential Indicators	Details
6. Suitable water quality	**LF7*:** High water temperatures in the river during the late summer/early fall migration period can increase migration mortality and sublethal stress **LF8*:** Poor water quality conditions during the late summer/early fall migration period (low DO, coliform levels, deleterious substances) * Note that these LFs can be split to address migrating, holding and/or spawning salmon separately if required.	-High temperature water (climate change, low flows) -Water extraction -Warm surface runoff -Climate change -Input from sewage and septic systems, industrial run off etc. -Loss of riparian vegetation due to logging/ diking -Natural bank erosion/ slides	- Hicks (2002) suggested that barriers to migration exist for Chinook salmon when maximum daily water temperatures are greater than 21-22°C. -Chinook salmon tolerate water temperatures ranging from 5.6-10.6°C during spawning (Bell1986). More recently, a temperature range of 5.6-12.8°C was proposed as a reasonable recommendation for spawning Pacific salmon (Hicks 2002; Richter and Kolmes 2005). Hicks (2002) reported that average temperature exposures of 15.6-17°C can lead to a reduction in reproductive success. -DO levels greater than 6.3 mg/l are recommended for successful upstream migration of anadromous salmonids (Davis 1975). Reiser and Bjornn (1979) recommended dissolved oxygen levels of at least 80% saturation, with temporary levels no lower than 5.0 mg/L, to satisfy the needs of migrating fish. - Those river sections exceeding a benchmark level of riparian disturbance of 5% of the riparian area are of a moderate concern, and those that exceeding a benchmark level of riparian disturbance of 10% of the riparian area are a high concern (Stalberg et al. 2009). -Stalberg et al. (2009) defines the maximum daily Upper Optimum Temperature and Impairment Temperatures for in-migrating and	-Stream water temperature, DO levels, TSS, coliform counts etc. -Acid runoff historically and currently -Permitted waste management discharges -Amount of riparian disturbance -Licensed water extraction	-These LFs consider the impact of non-optimal water quality directly impacting returning adults. LF 7 is related to LF1 and LF2.

Critical Habitat Requirements	**Limiting Factors**	**Factors Affecting Habitat Features**	**Benchmarks**	**Potential Indicators**	**Details**
			spawning Chinook as 14°C and 20°C, respectively. -Stalberg et al. (2009) provided benchmarks for Total Suspended Sediments (mg/l, ppm) as: 25 mg/L in 24 hours when background is less than or equal to 25; a mean of 5 mg/l in 30 days when background is less than or equal to 25; 25 mg/ when background is between 25 and 250; 10% when background is greater than 250		
7. Availability of high quality and sufficient quantity spawning habitat	**LF9:** Lack of natural gravel recruitment to mainstem spawning sites. **LF10:** High suspended sediment loads can reduce spawning habitat quality by compacting gravel and reducing interstices critical for egg deposition and incubation **LF11**: Colonization of invasive species (e.g. *Didymo* sp) that reduces spawning habitat quality. **LF12.** Lack of a sufficient quantity of good quality spawning habitat	-Absence of major tributaries to deliver bedload to mainstem -Development -Landslides -Flooding -Logging impacts	-Chinook spawn in deeper high velocity zones than other salmonids. Optimum habitats would have depths ≥70 cm and velocities 40-150cm/ (Burt 2006). -Redds range in size from 2 to 40 m^2, occur at depths of 10-700 cm and at water velocities of 10-150 cm/s (Healey 1991). Typically, the redds are 5-15 m^2 and located in areas with water velocities of 40-60 cm/s. The depth of the redd is inversely related to water velocity, and the female buries her eggs in clean gravel or cobble 10-80 cm in depth (Healey 1991). - Stream-type chinook require about 16 m^2 of gravel per spawning pair. The substrate must be small enough to be moved by the fish and large enough to allow good intragravel water flow to the incubating eggs and developing alevins. Redds of stream-type Chinook tend to be in a coarser gravel with a few large cobbles in the bottom of the nest.	-Rate of bedload delivery at prime spawning sites -Area/lineal length of spawning grounds -Quality of spawning grounds -Presence/absence of invasive species reducing spawning habitat quality -Level of suspended sediment -Composition of spawning gravel -Density of road crossings	-Since Chinook have the largest eggs of all Pacific salmon and therefore, the smallest surface-to-volume ratio, their eggs are more sensitive to reduced oxygen levels. As a result, adequate subgravel flow is the most important factor in the choice of redd sites by all Chinook. -A lack of prime spawning habitat can limit Chinook salmon production as later spawners may be forced to build redds in secondary locations or on top of previously constructed redds resulting in reduced overall production. -Because of their large size, Chinook salmon are able to spawn in higher water velocities and utilize coarser substrates than other salmon species. -Female Chinook salmon select areas of the spawning stream with high subgravel flow such as pool tailouts, runs, and riffles (Vronskiy 1972; Burger et al. 1985; Healey 1991).

Critical Habitat Requirements	Limiting Factors	Factors Affecting Habitat Features	Benchmarks	Potential Indicators	Details
			-Particles of less than 6.4 mm have the potential to infiltrate redds and prevent the emergence of fry (Lisle 1989). When fines (particles less than 6.4 mm) exceeded 30% of the substrate, survival to emergence was reduced by 50% (Kondolf 2000). When concentrations of fine sediments < 0.84 mm in diameter exceed about 10 % of the gravel matrix, hatching survival is dramatically reduced (Reiser and White 1988). Suitable spawning gravel for Chinook salmon ranges in size from about 0.3 to 15 cm. The upper size being dependent upon size of spawner. The optimal size range is estimated to be about 2 to 10.6 cm (Raleigh *et al.* 1986). -Boulders need to be between 1-10% with little use of the habitat if boulders make up more than 20% of the substrate. Little utilization of habitat if there is >20% sand (BCCF 2015). -Road density (km road/km^2 of sub-basin): Higher risk: >0.4 km/km^2 Lower risk < 0.4 km/km^2 (Stalberg et al. 2009)		
8. Low levels of predation during migration and spawning	**LF13:** Mortality due to predation at spawning grounds	-Natural predatory behavior by bears, seals and birds -Low levels of LWD and riparian cover -High numbers of predators -Low turbidity	-Abundance of bears, seals and birds along migration routes, within holding pools and at spawning grounds. - Those river sections exceeding a benchmark level of riparian disturbance of 5% of the riparian area are of a moderate concern, and those that exceeding a benchmark level of riparian disturbance of 10% of the	-Presence and abundance of predators -Riparian disturbance -Amount of LWD -Turbidity -Discharge and flows	-Lack of riparian cover, reduced access and higher levels of stress as a result of high water temperatures and low flows will exacerbate predation: thus, this LF is linked to LFs 2-7

Critical Habitat Requirements	**Limiting Factors**	**Factors Affecting Habitat Features**	**Benchmarks**	**Potential Indicators**	**Details**
		-Low flows -High temperatures -High levels of fish stress	riparian area are a high concern (Stalberg et al. 2009). - LWD habitat condition may be determined, at the reach level, using the following diagnostics described in Johnston and Slaney (1996): Good = >2 pieces of functional LWD per bankful width; Fair = 1 – 2 pieces of functional LWD per bankful width; and Poor = <1 piece of functional LWD per bankful width.	-Water temperatures	
9. Lack of anthropogenic disturbance	**LF14:** Disturbance to natural spawning activity due to anthropogenic impacts	--Livestock, urban development, ATVs and off-road vehicles. -Urban development has a much more long-term threat if physical and cultural planning is absent. - Instream works during flood emergencies results in lasting effects to spawning habitat, - Rip rap reduces sources of gravel recruitment outside of major flood events.	-> 10% prespawn mortality	-Presence of activities such as off-roading, quadding, watersports and other human activities close at spawning grounds. - Presence of livestock in streams at or near spawning grounds.	

Critical Habitat Requirements	Limiting Factors	Factors Affecting Habitat Features	Benchmarks	Potential Indicators	Details
10. Lack of disease during migration and spawning	**LF15:** Pre-spawn mortality due to disease	-Fungal, bacterial or viral organisms -Temperatures and flows -Abundance of spawners	-> 10% prespawn mortality	-Presence of disease in population e.g. Vibrio.	-Disease spread is exacerbated by higher temperatures so this LF is linked to LFs2 -7

ADULT TERMINAL MIGRATION & SPAWNING

NOTES SPECIFIC FOR THE NICOLA

Critical Habitat Requirements	Limiting Factors	Potential Indicators	Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin
1. Safe holding habitat in confluence of Thompson-Nicola prior to upriver migration into the Nicola River	**LF1**: Predation (by humans) in the confluence of Thompson-Nicola	-Area of estuarine habitat -Riparian cover -Water temperatures & flows -Presence of poachers	-For Nicola- the “estuary” is the confluence of the Thompson and Nicola Rivers. -Unfavorable temperatures in the Nicola system have caused thermal blockages that encourage salmon to hold in the Thompson near the mouth of the Nicola River -Cowen et al. (2007)- a mark–recovery study was used to investigate the effect of angling on immediate hooking mortality & subsequent spawning success of Chinook salmon in the Nicola River 1996 to 2002. The immediate hooking mortality rate was lower than mortality rates reported for marine and other freshwater fisheries. Higher hooking mortality rates were found for fish hooked in critical locations, which were associated with heavy bleeding. However, increased bleeding did not translate into reduced spawning success for those fish that survived.
2. Adequate flows to facilitate upstream passage of spawners	**LF2:** Limited or delayed spawner access	-Discharge (cms) -Water withdrawals -Road density -Year and level of discharge -Density of road crossings -Volume of water extraction -Land alteration	-The Nicola River hydrograph exhibits a pattern typical of snow-dominated regimes. Peak flows are experienced in late April – early May. -There are low flows in April, and low summertime and fall flows that affect Chinook. Migration barriers can occur on both the mainstem and tributaries because of low flows through fall- pulses of water are required to mitigate this issue. - During typical drought periods (1 in 10-year event), every sub-basin in the Nicola Watershed has a water deficit through the summer and fall (July to October) and therefore there is insufficient water to meet irrigation and instream flow requirements even when dam storage is factored in. - Existing minimum fish flow requirements for the Upper Nicola River are set at approx. 20%. Data summarized by Doyle (2004) suggests that in 2003 7-day average low flow equated to only approx. 0.053 cms, less than 10% of existing minimum fish flow. (Pehl 2004). - Upper Nicola, Guichon: in-stream flows for fisheries not met except in wet years, Middle and Lower Nicola, Coldwater, Spius: in-stream fishery flows met in average runoff conditions with current levels of storage on

Critical Habitat Requirements	Limiting Factors	Potential Indicators	Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin
			Nicola River, under drought significant shortfalls occur, Clapperton: in-stream flows for fisheries not met except in wet years (Ministry of Environment 1983). - Low summer base flows (e.g. 2015) in the Coldwater River have led to water use restrictions to protect critical flows for aquatic life. - August flows when spawners are returning is important. Chinook that spawn during summers with 50% below average flow have 15% lower productivity. In combination, cohorts with 50% below average flow in the August they were spawned and the subsequent August during rearing are predicted to have 40% lower productivity (Warkentin 2020) -Attraction flows for Chinook migration in Aug to early Sept in the mainstem require adequate cold water to be effective. -R. Bailey (pers. comm.) notes that upstream migration is likely fine as long as flows >4cms but there are times when mainstem passage can be compromised by low flows. However, temperature is the key concern, except in upper Nicola, lower Coldwater and lower Spius. -Flows in this region have been impacted by forest harvesting and mountain pine beetle (MPB) is an added concern: decreases in forest cover due to MPB results in more snow accumulation in dead forests, and in clearcut areas. -Earlier snowmelt leads to increased, faster and earlier runoff, which is also less synchronized at different elevations -Fall flooding, characteristic of rain-dominated hydrographs of coastal BC, have historically been minimal but risk of flooding is much higher now as a result of MPB salvage harvesting which has resulted in elevated Equivalent Clearcut Area (ECA) and harvesting adjacent to streams in higher elevation Sub-basins, Basins and Watersheds (Lewis 2016) -Flooding in 2017 and 2018 resulted in major channel shifts throughout the watershed. -Flood effect of Guichon Creek resulted in an emergency situation for many residents living in this area and was the focus of major instream works. - Estimated that up to 75% of chinook spawning in the Nicola River occurs in the 21 km section between Coldwater and Spius Creek junctions, the remaining 25% is generally distributed equally between the section downstream of Spius Creek, and the section between the Coldwater confluence and Nicola Lake (Kosakoski and Hamilton, 1982). - Ranching and agriculture irrigation withdrawals were high, and Nicola River flows were below fisheries maintenance levels several times during the early 1980s. This led to fish mortality and decreased production through entrapment, reductions in available spawning habitat and increased water temperatures. (Millaret al.1997) - Agriculture demands greatest volume of water (76%) annually, industrial sector demands 11%, domestic sector demands 8%, business/commercial/institutional/recreation resort demands remaining 5% (Summit 2007).

Critical Habitat Requirements	**Limiting Factors**	**Potential Indicators**	**Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin**
			- From 1911-1920 average August discharge never fell below 15% MAD of 4.47m3/s, whereas from 1992-2014, it fell below this value five times. Average August flow decreased by 26% comparing flows from 100 years ago with the past two decades. River discharge in June-September in the last 23 years was up to 25% lower than the long-term average, compared to 1910-1921, when flows were up to 50% greater than the long-term average (Warkentin 2020). -Freshwater flow regimes and density dependence were the main drivers of population dynamics for Chinook salmon. Mean flow in August during spawning and rearing and ice days were the most important variables (Warkentin 2020) - The median of yearly average August flows has decreased by 37% over the last century, despite a considerable development of storage reservoirs to offset withdrawals during the same period. This corresponds to a 27% decrease in productivity of Chinook salmon based on the effect on rearing juveniles and a 37% decrease in recruitment based on the combined effect on rearing and spawning, to a level where every 100 spawners produce 73 recruits. (Warkentin 2020) - Sites with higher catchment areas had higher maximum temperatures as well as greater thermal sensitivity. In addition, sites with greater riparian vegetation cover had lower thermal sensitivity. Other geographic features, namely lakes, also influenced thermal regimes. Collectively, these results identify factors that, even after accounting for spatial autocorrelation, are associated with warmer temperatures and greater climate sensitivity that pose risks to cold-water fishes such as chinook (Warkentin 2020.) - The Coldwater River and Spius Creek watersheds lack the types of storage seen in other parts of the Nicola Watershed (e.g. large lakes and extensive wetlands). Oral accounts of the upper Coldwater watershed tell of more extensive wetlands prior to construction of Coquihalla highway. - In the Nicola Watershed, climate change is having a very significant effect on the precipitation patterns and hydrology in leading to drier and more prolonged periods of low flows through the summer and winter in some years. In general, the watershed has been experiencing a higher frequency of severe flood and drought events, resulting in adverse effects to fish and fish habitat. - Mean August flows in the last two decades were 26% lower than they were a century ago (Warkentin 2020). -Key flow information from Warkentin (2020) for the Nicola Watershed (as related to habitat): • Mean August flows in the last two decades were 26% lower than they were a century ago; • More precipitation in the form of rain vs. snow; and • More conspicuous peaks in average daily flow in November in recent decades.
3. Unrestricted migration and passage throughout mainstem and off-channel habitat	**LF3:** Potential delays in upstream migration due to counting fences, fishways and	-Available Fish access -Migration time through fences/falls etc. -Density of road crossings	-Attraction flows from the dam gate in August make it difficult for Chinook to use the fishway -There are fish passage concerns at the dam in the winter - Urban development, such as residential and industrial construction, and agricultural activities have negatively affected fish habitat by restricting salmonid access by inadequate culvert placements. - However, this is not a large issue for Nicola Basin Chinook as there is very little use of off-channel habitat by adults. There are no counting fences, and roads are not an issue (R. Bailey pers. comm.)

Critical Habitat Requirements	Limiting Factors	Potential Indicators	Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin
	other manmade structures **LF4:** Reduced access through natural falls and natural barriers		- One barrier of note is Maka Creek access.
4. Stable channel morphology, maintenance of channel capacity, adequate channel depths and natural level of sediment transport	**LF5:** Aggradation creates a migration barrier in the river during adult migration	-Sediment transport rates -Number of natural/manmade slides in the watershed -Percentage of intact riparian along channel lengths -Depth of channel -Road density -Turbidity, TSS -Land alteration	-In Nicola Lake concerns exist around impacts to riparian vegetation from erosion caused by waves from wakeboard boats. -Other major impacts are from forest harvesting, agricultural and human development in the region. -Anthropogenic disturbance to steam banks and riparian cover is extensive in the Nicola Watershed (Ecoscape 2017). 6-7% of streambanks along mainstem Nicola have severe erosion as a result of loss of riparian. -Riparian destabilization has resulted from ranchers removing cottonwoods to increase alfalfa production (R. Bailey pers. comm.) -Urban development, such as residential and industrial construction, and agricultural activities have negatively affected fish habitat by the removal of riparian corridors, destruction and/or alteration of stream channels. -Historical and/or recent logging has occurred in most drainages of the Nicola watershed, and upper watershed areas of the upper Nicola River, Guichon Creek and Clapperton Creek have been extensively logged. Clearcutting in the Spius and Coldwater watersheds are much less but have been recently concentrated at higher elevation forests. -Percent clear cutting since 2000 within important sub-catchments of the upper Nicola are as follows (Warkentin 2020): • Spahomin Creek = 13% • Quilchena Creek = 19% • Chapperon Creek = 23% -Headwaters (Guichon/Nicola Plateau) have been extensively salvage logged. ECA in this watershed tripled between 2003-2013 to 44% (Valdal and Lewis 2015). Warkentin (2020) report similar area estimates of logging at 36% over the last 20 years. - 6% percent of the Spius Creek watershed has been clear cut since 2000 (Warkentin 2020). - 13% percent of the Coldwater River watershed has been clear cut since 2000 (Warkentin 2020) -Road building and logging activities have degraded riparian habitats, leading to bank erosion and degradation, increased sediment delivery, reduced channel instability, and reductions in the quality of spawning and rearing habitats. -Loss of riparian vegetation has also been shown to increase river width. -Reid (2020) identified a risk that near-term flooding may result in further lateral channel instability.

Critical Habitat Requirements	Limiting Factors	Potential Indicators	Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin
			-Upland forestry operations change the timing of snow melt and alter sediment loads, contributing to a more intense freshet, channel movement and bank erosion. -Sediment avulsions may have braided channel sufficiently to create issues (R. Bailey pers. comm.) -Reid (2020) observed increases in average channel width on Guichon Creek from 2016 to 2018 of 10.1 m, 41.4 m and 84.6 m, respectively. -Sediment movement resulted in increases in stream bed elevations in the lowest reach of Guichon (Reid 2020) as well as formation of large sediment wedges downstream of its confluence with the Nicola River. -General trend towards channel widening and increased storage of coarse sediment (growth of bars) downstream of Juliet Creek (based on historic air pictures). Rip rap is the most common form of bank protection observed along the Coldwater River. Damage and failure, followed by repair, have been common. (Northwest Hydraulic Consultants 2002). - Measurements from the 1953 air photo indicate an average width of 26 m and a sinuosity of 1.7. By 2003, extensive clearing for agriculture had been completed with significant loss of the riparian vegetation. The channel widened by some 150% to 62 m and straightened, with a reduction of sinuosity to about 1.1, largely a consequence of meander cut-offs. Reduced sinuosity of the Coldwater River is most likely due to destruction and removal of the riparian vegetation and consequent reduction in the bank strength (Millar and Eaton 2011). -Excessive irrigation (from ranching and agriculture) in some areas may have increased sedimentation by increasing surface runoff and groundwater (Millar et al. 1997) - Within the Thompson-Nicola HMA agricultural activity is intensive and concentrated along the lower, more productive reaches of most stream systems. Valley bottom areas are used for crop production and winter feeding, while upland areas are utilized for summer range activities. (DFO, 1998). Agriculture has impacted fisheries value in the Nicola, Coldwater, Bonaparte, Deadman River watersheds. Impacts within these systems include sedimentation, channelization, degradation of riparian habitat, degraded water quality, increased water temperatures, low instream flows and channel degradation which has resulted in the reduction of fisheries values (DFO 1998). - Much of the riverbanks bordering agricultural areas are actively eroding due to loss of riparian habitat and unimpeded cattle access to the river. Within the lower section of the Nicola River, only 3.5% of a total riverbank length of 234.2 km is bordered by unimpacted vegetation. The upper Nicola River above Nicola Lake has suffered extensive losses of riparian vegetation due to ranching activities. The loss of riparian vegetation has resulted in increased erosion, loss of shade and instream cover, and loss of pool and off channel habitat. Loss of riparian vegetation has also been shown to increase river width and channel instability in those areas where riparian vegetation was removed. Channelization has also reduced the number of back channel and wetland areas. Chinook that rear for one year in freshwater are particularly vulnerable to these impacts. (DFO 1998) - Shifts in land-use from beef production to locally intensive feed lots used by dairy industry. Many dairy farms using existing infrastructure from formerly depressed beef industry. - Instream works during flood emergencies have the potential to exacerbate channel instability issues upstream and to mobilize large quantities of sediment due to introduction of head-cuts in channel.

Critical Habitat Requirements	**Limiting Factors**	**Potential Indicators**	**Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin**
			-Over 35% of the Coldwater watershed has been logged (estimated from 1990 Landsat imagery) and harvesting has been concentrated in upper headwater areas and tributary watersheds. Forestry development in combination with fire history has resulted in local encroachments, slope instability problems and accelerated sediment production. (DFO 1998) - The Coquihalla Highway was completed in 1986 and closely parallels the upper Coldwater river. The construction of the Coquihalla Highway involved placement of riprap bank protection and/or alteration of the stream channel by diversion at 15 sites along the river mainstem. River diversions required extensive armoring of the channel banks at each bridge crossing and channelization of the river upstream and downstream of the bridge sites. (DFO 1998) - It is likely that habitat problems related to water diversions for irrigation, channelization, municipal waste discharges, logging, and pipeline construction have contributed to reduction in system productivity (Kosakoski and Hamilton 1982) -During and after the spread of the Mountain Pine Beetle throughout the region, logging increased substantially: 17% of the entire watershed was logged in the last 20 years. Six major tributaries had over 20% of their area logged in the last 20 years, up to 36% in Clapperton Creek (Warkentin 2020) - Clear cut logging can cause a lagged, long term reduction in base flows starting approximately 15 years after harvest. Watersheds with large increases in logging in the last 10-20 years, such as the Nicola, may be at risk of further decreases in summer discharge from a legacy of forestry. (Warkentin 2020) - 2016 SHIM and AHI notes 1.9 km of livestock access to the Nicola mainstem, - Rip rap covers between 3-4% of stream banks. - Extreme bank erosion due to urban and agricultural development was between 6-7% in 2016 (prior to major flood events of 2017/18). - Key points from 2016 SHIM and AHI (Ecoscape 2017): • 6-7% of streambanks along the Nicola Mainstem had severe bank erosion – largely attributed to removal of riparian vegetation. • 32% of LDB and 55% of RDB exhibited anthropogenic alteration. • Primary impacts attributed to agricultural, urban and highway infrastructure/activities.
5. Clear and safe passage with adequate refuge habitat	**LF6:** Loss of good quality refuge habitat and safe migration route through the river due to channelization, loss of habitat complexity, pools, and	-Percentage and stage of intact riparian cover (though larger Chinook usually hide down in deeper pools) -Frequency & quality of deep (>1m) holding pools	-In the Nicola, urban development, such as residential and industrial construction, forestry, road building, and agricultural activities have negatively affected fish habitat by the removal of riparian corridors. -Degradation of riparian areas has resulted in increased erosion, loss of shade and cover as well as the loss of pool and off-channel habitat. -Rock stabilization procedures and sidecast/ballasting materials generated during routine maintenance of roads and railways can impact riparian areas and instream habitat. -Adults enter the river in the 2nd or 3rd week of April, their arrival peaks in the 3rd week of July, and is complete by the 4th week of August. Locations of these adults are predictable based on depth and temperature

Critical Habitat Requirements	Limiting Factors	Potential Indicators	Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin
	instream cover features	-Amount of LWD -Density of road crossings	-When water temperature exceeds 24°c adult Chinook move from pools into better-oxygenated riffle habitats, where they stay until the temperature drops to 23°c, at which point they move back into pools because of associated lower rates of predation -Mass wasting is a high concern in the Clapperton Creek Residual area. Nine large stream bank failures were noted during the field survey. Mass wasting sites were all located in the private land sector. Not clear whether they were natural or due to private land development. Mass wasting events have a large impact to the sediment budget of Clapperton Creek. (Henderson Environmental Consulting Ltd 1999). -SHIM Mapping found 32% of right downstream bank and 55% of left downstream bank had been altered in the Nicola.
6. Suitable water quality	**LF7*:** High water temperatures in the lower river and estuary during the late summer/early fall migration period can increase migration mortality and sublethal stress **LF8*:** Poor water quality conditions during the late summer/early fall migration period (low DO, coliform levels, deleterious substances)	-Stream water temperature, DO levels, TSS, coliform counts etc -Acid runoff historically and currently -Permitted waste management discharges -Amount of riparian disturbance -Licensed water extraction	- Chinook spawning occurs between mid -July and mid-September, making this species extremely vulnerable to the high summer water temperatures in the Nicola System. Chinook attempting to spawn upstream of Nicola Lake are likely strongly impacted by high water temperatures. Extensive land clearing has occurred on cattle ranches in the upper part of the watershed and has resulted in extensive losses of riparian vegetation. (Walthers and Nener 1997). - The assessment of the Nicola River by Millar et al. (1997) identified 3 primary biophysical factors in the watershed that limit fish production including high water temperatures due to riparian clearing, the loss of cold-water inflows and the increase in warm water sources - Land uses have likely significantly altered and aggravated a naturally elevated thermal regime. Numerous studies have demonstrated relationships between loss of riparian vegetation due to ranching activities, which likely contributes to the higher water temperatures measured. (Walthers, and Nener 1997). -Warkentin (2020) found that mean August temperatures have increased by about 2˚C in the last century in the Nicola River -Rainfall during the summer is infrequent, so conservation of groundwater is critical in maintaining cool and sufficient stream flows for fish and other aquatic organisms -Larger sub-catchments exhibit higher maximum stream temperatures. Conversely, smaller ones may provide important thermal refugia (Warkentin 2020). -Riparian cover is positively correlated with lower thermal sensitivity in the Nicola Watershed (Warkentin 2020). - Nicola River- high water temperatures July to mid-September can be lethal to fish and are a result of lack of riparian shade and low flows. -Thermal barriers exist in lower Spius, Lower Coldwater and Upper Nicola, but are not an issue in the upper Nicola, lower Coldwater and lower Spius (R. Bailey pers. comm.). -Agricultural development has negatively impacted fisheries values in the Nicola River, Coldwater watersheds. Cattle feeding areas and cattle access to watercourses are the primary source for loading pollutants into surface and groundwater, thereby reducing water quality. -Runoff from cattle feedlots and fertilizer applications, and sewage effluent discharge from the communities of Merritt and Lower Nicola have affected water quality (Langer and Nassichuk 1976).

Critical Habitat Requirements	Limiting Factors	Potential Indicators	Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin
	* Note that these LFs can be split to address migrating, holding and/or spawning salmon separately if required.		-Other concerns to water quality in the watershed result from increased population growth in this region, including large pulses of visitors in the region during the summer. Increasing numbers of people create more water demand, and increased discharge of effluent, as well as leaching concerns from landfills. Concerns exist about risk from the Merritt sewage treatment plant. -The region is traversed by a network of transportation and utility systems. Transportation corridors are concentrated in valley bottoms, adjacent to waterways and floodplain habitat. -Major transportation routes include the Canadian Pacific Railway, the Canadian National Railway, B.C. Railway, the Trans Canada Highway, the Coquihalla Highway, B.C. Tel fibre optic line, B.C. Hydro major transmission lines as well as oil and gas pipelines owned by Westcoast energy, Trans Mountain Pipeline and B.C. Gas. -Construction of the Coquihalla Highwater through the Coldwater subbasin caused changes in rearing and spawning habitats and compensation measures were implemented (Rosenau and Andrew 1985, Beniston et al 1987, 1988). - Sewage plant in Merritt discharges excessive amounts of suspended solids, nutrients and coliforms. Cattle operations also affect water quality through nutrient and coliform runoff (over winter feeding areas situated beside surface water/irrigation ditches) Nicola Lake is classified as eutrophic as a result of inputs, and has a large scale algal bloom each summer. Algal growth also develops in the streams entering Nicola Lake and could potentially reduce fish production through the smothering of spawning beds and reducing food stores. (Ministry of Environment 1983). - Copper and Molybdenum was mined near Logan lake in the 1980s. Their activities coincided with increased copper and molybdenum levels in the headwaters of Guichon Creek. (Millar, et al. 1997) - Total phosphorus concentration showed a steady increase downstream until confluence with the Thompson River. The large backload of phosphorus is probably the result of agricultural activities in the river headwaters. A considerable amount of phosphorus probably results from cattle activities. (Holmes 1979). - Temperatures at all sites in the Nicola River study are during the summer of 1995 reached levels known to cause mortality in anadromous salmon (21-25C). The highest reported temperatures occurred in the Coldwater (26.12C). Chinook salmon spawn between mid-July to mid-September making them vulnerable to high summer water temperatures. The sites below Nicola Lake and in the lower Nicola clearly experience unfavorable conditions, with temperatures sustained above 21C for days. These conditions impose significant environmental barriers to summer spawning migrations. In comparison to all other sites, Nicola/Spius experienced the most favourable water temperature conditions with no high temperature spikes and limited periods of temperature above 21C. (Walthers and Nener 1998) - High water temperature due to riparian clearing, the loss of Coldwater inflows or the increase in water sources: riparian clearing for development/cattle access/crop production/forestry has exposed large areas of shallow water to direct sunlight causing water temperatures to increase (sometimes 25C (lethal) or higher) in the summer months. Low DO is also a result. Low DO is exacerbated by high nutrient levels (due to fertilizer/sewage effluent). (Millar, J., Child, M., Page, N, 1997)

Critical Habitat Requirements	**Limiting Factors**	**Potential Indicators**	**Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin**
			- in 2003, daily maximum temperatures above 28C were recorded in some areas that could result directly in fish mortalities, while temperatures of 23C were common from late July – August, limiting fish production (Pehl 2004). - Temperatures recorded in 2003 suggest that water temperatures in the Upper Nicola River system exceeded critical levels. These temperatures suggest that during peak migration and spawning critical temperatures were exceeded and in late July and early August temperatures were at the upper end of the lethal threshold for salmonids. (Pehl 2004). - During early Chinook migration the average temperature exceeded preferred migration temperatures and could potentially have resulted in loss to egg viability. Temperatures during spawning are important for managing limited energy reserves. (Pehl 2004). - During the first week of July through mid-September, recorded maximum water temperature at all sites exceeded the threshold of temperatures preferred by adult salmon during spawning migration (16C) and reached lethal thresholds. (Walthers and Nener 1997). - Agricultural development has also degraded water quality within the Thompson Nicola HMA. Surface runoff and contaminated groundwater seepage from feedlots, winter feeding ground contribute to high nutrient loads. During spring runoff, phosphorus from fertilizers is also washed into streams, along with elevated coliform levels from animal wastes. Water quality is also impaired by increased bank erosion resulting from cattle access to streams. (DFO 1998).
7. Availability of high quality and sufficient quantity spawning habitat	**LF9:** Lack of natural gravel recruitment to mainstem spawning sites. **LF10:** High suspended sediment loads can reduce spawning habitat quality by compacting gravel and reducing interstices critical for egg	-Rate of bedload delivery at prime spawning sites -Area/lineal length of spawning grounds -Quality of spawning grounds -Presence/ absence of invasive species reducing spawning habitat quality -Level of suspended sediment	-See above for details of forestry harvesting, development and agriculture resulting in increased aggradation and high suspended sediment loads - Important spawning areas have been noted in reaches just below Nicola Lake, in floodplain gravel fans between the Coldwater River and Spius Creek, and in the lower reaches adjacent to the Thompson River confluence. -Nicola: It has been estimated that up to 75% of chinook spawning in the Nicola River occurs in the 21 Km section between the Coldwater River and Spius Creek junctions (Reach N2). The remaining 25% is generally distributed equally between the section downstream of Spius Creek (Reach N1), and the section between the Coldwater confluence and Nicola Lake (Reach N3) (Kosakoski & Hamilton 1982) -Spius: Spawning is sparsely distributed throughout, with the vicinity of the bedrock canyon located approximately 10 Km from the mouth being the most heavily utilized area. Suitable spawning habitat appears to be limited, with substrates consisting primarily of large cobble and boulders. (Kosakoski & Hamilton 1982) Coldwater: Spawning is scattered, largely between Brodie and Merritt, although a significant number of chinook spawn upstream of this section. (Kosakoski & Hamilton 1982) -Groundwater significantly influences redd site selection -Louis Creek: majority of spawning activity was associated with water velocities between 0.3 and 0.5m/sec and stream depth of 10-30cm, spawning substrates were dominated by a mix of small (2-16 mm) and large (16-64mm) gravels 46 and 35% respectively. (Triton 2009, HIS Report)

Critical Habitat Requirements	Limiting Factors	Potential Indicators	Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin
	deposition and incubation **LF11**: Colonization of invasive species that reduces spawning habitat quality. **LF12.** Lack of a sufficient quantity of good quality spawning habitat	-Composition of spawning gravel -Density of road crossings	-Data from 4 streams sampled (Louis, Nicola, Coldwater, Spius) were pooled; substrate compositions, water depths and water velocity were similar among streams. Stream gradients associated with spawning were approx. 1% and channel morphology was generally riffle/pool (Triton 2009) - Four sub-watersheds in the Nicola watershed are evaluated as high risk for sediment (Valdal and Lewis 2015). - Much of the coarser bed material is embedded with fine gravels and sands, rendering it not suitable for spawning. This problem has been attributed to increased soil disturbance from logging, road and pipeline construction as well as to the limited bedload transport capacity of the river (Coldwater River Study, Chapter 3) - Clapperton Creek Subbasin #28 – cattle damage including eroding stream banks and sediment trails to creeks were observed dispersed through throughout the sub-basin (Henderson Environmental Consulting Ltd, 1999). - Loss of riparian vegetation as a result of land clearing or animal grazing led to bank erosion and siltation, increased nutrient levels, increased temperatures, and reduced food sources and rearing habitat (Millar, J., Child, M., Page, N, 1997) - Bank instability and siltation due to forestry and agricultural activity: In general the Nicola has been entrained and confines throughout its valley in an effort to maximise usable land. Through field observations, most serious sedimentation occurs where riparian areas have been cleared and where cattle access the Nicola River mainstem or its tributaries for watering (Millar, J., Child, M., Page, N, 1997) - Forestry activities within the Thompson-Nicola HMA have degraded riparian habitat along streambanks which has increased sediment delivery and impacted instream habitat by reducing channel stability and the quality of spawning and rearing habitats. (DFO 1998)
8. Low levels of predation during migration and spawning	**LF13:** Mortality due to predation at spawning grounds	-Presence and abundance of predators -Riparian disturbance -Amount of LWD -Turbidity -Discharge and flows -Water temperatures	

Critical Habitat Requirements	**Limiting Factors**	**Potential Indicators**	**Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin**
9. Lack of anthropogenic disturbance	**LF14:** Disturbance to natural spawning activity due to anthropogenic impacts	-Presence of activities such as boating, kayaking, quadding, watersports and other human activities close at spawning grounds	- Bass Coast Festival and Rockin' River Festival, recreation (off road vehicles) in headwaters, recreational properties may result in impacts to spawning activity. -Many recreational properties in this region and movement of lower mainlanders to rural acreages along the river. Many newcomers lack place-based knowledge of ecological values specific to the Nicola (i.e. not aware of salmon and water issues).
10. Lack of disease during migration and spawning	**LF15:** Pre-spawn mortality due to disease	-Presence of disease in population e.g. Vibrio.	BKD is the key concern

INCUBATION

Critical Habitat Requirements	**Limiting Factors**	**Factors Affecting Habitat Features**	**Benchmarks**	**Potential Indicators**	**Details**
1.Good water quality conditions	**LF16:** High suspended sediment loads that reduce egg to fry survival and emergence of alevins **LF17a:**	-Riverside development and natural erosion -Unstable and eroding channel banks that release fine sediments -Logging, landslides -Lack of riparian cover -Climate change	-TSS < 25_mg/L in 24 hrs when background is ≤ 25 mg/L (Stalberg et al. 2009) at established sampling sites in the middle and lower reaches of the mainstem -Target WQ parameters: DO: 5-S mg/L. Egg mortality increases rapidly at DO concentrations below 13 ppm averaging 3.9% at 13 ppm and 37.9% at less than 5 ppm (Gangmark and Bakkala 1960 in Healey 1991). As	-Total suspended solids during high flows -Depth of fine substrates over redds -Linear measure of eroding silt banks -% Egg to emergent fry	-Pacific salmon eggs have a high surface area to volume ratio so are sensitive to reduced oxygen levels -Incubation temperatures outside the ideal range can cause hatching and emergent times that reduce survival. -In extreme cases, freezing of redds can result in the loss of all eggs in the affected areas. Although Chinook eggs

Critical Habitat Requirements	**Limiting Factors**	**Factors Affecting Habitat Features**	**Benchmarks**	**Potential Indicators**	**Details**
	Ice days resulting in mortality of eggs and alevins **LF 17b:** Non-optimal water temperatures that reduce fry survival by changing emergence time in relation to food availability **LF18:** High levels of pollutants or toxins that reduce egg to fry survival **LF19:** Low DO which reduces egg to fry survival	-Industrial and human development	percent saturation decreases during incubation, growth decreases and abnormalities and mortality increase. Lower lethal limit = 1.6 mg/l (Silver *et al.* 1963 in Allen and Hassler 1986). The lower limit of DO concentration for developing embryos is 2.5 mg/l at temperatures less than 7 ^{0}C; optimal levels are greater than 8 mg/l at temperatures between 7 and 10 ^{0}C and greater than 12 mg/l at temperatures over 10 ^{0}C (Raleigh *et al.* 1986). -Minimum requirements of dissolved oxygen for eyed or hatched fish eggs from October to May (minimum of 11.2 mg/L), and alevins or juvenile fish from June to September (minimum of 8.0mg/L) (Obee 2011). As percent saturation decreases during incubation, growth decreases and abnormalities and mortality increase. Lower lethal limit = 1.6 mg/l. -Temperature range for the incubation of Chinook eggs is from 4.5 to 12.8 ^{0}C. -Geist et al. (2006) suggest an upper limit of 16.5 but others show mortality above 12 (McCullough et al. (2001)). Trade-offs between early emergence and survival. Warm water and low DO = low survival but early emergence. Cold temps and high DO = high survival but late emergence (Turcotte 2020). - Those river sections exceeding a benchmark level of riparian disturbance of 5% of the riparian area are of a moderate concern, and those	survival -mg/L of DO -Water temperatures at emergence - Permitted waste management discharges -Level of intact riparian area -Road density -Water chemistry	and alevins can withstand a wide fluctuation in temperature, decreased survival and impaired development occurs at incubation temperatures below 5.0 ^{0}C and above 15 ^{0}C. -Lower incubation temperatures (i.e. < 5) will equate to higher DO, higher survival but later emergence (Turcotte 2020). This is due to more surface water influence and less GW. -Healthy riparian vegetation helps moderate extreme high and low temperatures.

Critical Habitat Requirements	**Limiting Factors**	**Factors Affecting Habitat Features**	**Benchmarks**	**Potential Indicators**	**Details**
			that exceeding a benchmark level of riparian disturbance of 10% of the riparian area are a high concern (Stalberg et al., 2009). -Road density (km road/km^2 of sub-basin): Higher risk: >0.4 km/km^2 Lower risk < 0.4 km/km^2 (Stalberg et al. 2009)		
2. Suitable flow regime	**LF20:** Lower low flows that dewater redds and reduce incubation survival	-Lack of storage -Drought conditions during fall/winter -Water diversion for industrial, domestic, resource development e.g. logging -Reservoir operation -Debris management -Hydroelectric power operation -Natural mid-winter high pressure events can cause winter droughts and low flows which may cause redd desiccation if spawning flows were high.	-Road density (km road/km2 of sub-basin): Higher risk: >0.4 km/km^2 Lower risk < 0.4 km/km^2 (Stalberg et al., 2009) -Stalberg et al. (2009) 1 in 2 year 30-day duration summer minimum flow is less than 20% of the mean annual discharge= poor. Flows ≥20% of the mean annual discharge are considered sufficient. - Instream flow needs of 3.12 m3/s (22.3% of MAD) for Nicola between Coldwater and Spius (ESSA 2019; Kosakoski and Hamilton 1982) - Equivalent Clearcut Area <25% for fisheries sensitive watersheds (B.C. Ministry of Forests 1999).	-Frequency, timing, magnitude & duration of discharge -% watershed altered by development type, road density -<x% change in elevation of the redds	- Improper operation of dams can cause dewatering or scour events downstream.

Critical Habitat Requirements	**Limiting Factors**	**Factors Affecting Habitat Features**	**Benchmarks**	**Potential Indicators**	**Details**
2. Suitable flow regime	**LF21:** More frequent and higher peak flows over winter can scour/disturb redds	-Greater flow variation due to resource development, primarily forestry, land development, land clearing activities -Climate Change			
3.Appropriate spawning gravel	**LF22:** Egg mortality due to inadequate spawning gravel	-Inadequate numbers of fish for spawning gravel maintenance -Sediment derived from resource development, primarily forestry, land development, land clearing activities	-Gravel – 15cm is upper usable limit, 2-10cm preferred, ≤5% silt (≤0.8mm) is optimal -Particles of less than 6.4 mm have the potential to infiltrate redds and prevent the emergence of fry (Lisle 1989). When fines (particles less than 6.4 mm) exceeded 30% of the substrate, survival to emergence was reduced by 50% (Kondolf 2000). -When concentrations of fine sediments < 0.84 mm in diameter exceed about 10 % of the gravel matrix, hatching survival is dramatically reduced (Reiser and White 1988). Suitable spawning gravel for Chinook salmon ranges in size from about 0.3 to 15 cm. The upper size being dependent upon size of spawner. The optimal size range is estimated to be about 2 to 10.6 cm (Raleigh *et al.* 1986). -Egg survival is negatively related fine sediment (<0.85 mm) levels in spawning gravels, with models based on empirical data suggesting that every 1 percent increase in fine sediment in spawning gravels leads to a 10 to 15	-Sediment size of spawning gravel -Spawner abundance -Areas of high development, sources of erosion or sedimentation -Density of road crossings -% watershed altered by development type, road density	-A slightly larger gravel size (higher permeability for oxygen delivery and waste removal) generates higher egg to fry survival rates. -Since Chinook have the largest eggs of all Pacific salmon and therefore, the smallest surface-to-volume ratio, their eggs are more sensitive to reduced oxygen levels. As a result, adequate subgravel flow is the most important factor. - Spawning areas with slightly larger gravel size and low rates of sedimentation consistently generate higher survival rates. -In cases where large amounts of silt build up in spawning beds survival rates are greatly reduced. This situation can occur in areas where streamside activities such as logging, road building, or agricultural practices result in high sediment runoff into the river or where high flows move sediments from upstream areas into spawning beds.

Critical Habitat Requirements	**Limiting Factors**	**Factors Affecting Habitat Features**	**Benchmarks**	**Potential Indicators**	**Details**
			percent reduction in egg to fry survival (Jensen et al., 2009). -Because their eggs are the largest of the Pacific salmon, ranging from 6 to 9 mm in diameter (Rounsefell 1957; Nicholas and Hankin 1988), with a correspondingly small surface-to-volume ratio, they may be more sensitive to reduced oxygen levels and require a higher rate of irrigation than other salmonids -Redd depth generally 60-700cm. -Road density (km road/km^2 of sub-basin): Higher risk: >0.4 km/km^2 Lower risk < 0.4 km/km^2 (Stalberg et al. 2009)		
4.Minimal disturbance to redds	**LF23:** Reduced egg to fry survival due to chum or other salmonid overspawn	-Overspawn -Scour -Flow levels -Distribution of chum spawners -Lack of prime spawning habitat	-Frequency of overspawn -Abundance of chum -Relative timing and locations of chum and Chinook spawning -Quality of spawning habitat	-Year and location of chum overspawn on Chinook redds. -Egg to fry survival at these sites relative to undisturbed sites. -Discharge in cms	-Smaller size Chinook spawn in similar habitat to chum and therefore overspawn is more likely. -A lack of prime spawning habitat can limit Chinook salmon production as later spawners may be forced to build redds in secondary locations or on top of previously constructed redds resulting in reduced overall production.
5.Minimal predation of eggs, alevins and fry	**LF24:** Predation of eggs, alevins and fry/smolts by fish (sculpins, brown trout) and birds (mergansers)	-Natural predatory behaviour -Low levels of LWD -High numbers of predators -Low turbidity -Low flows	- LWD habitat condition may be determined, at the reach level, using the following diagnostics described in Johnston and Slaney (1996): Good = >2 pieces of functional LWD per bankful width; Fair = 1 – 2 pieces of functional LWD per bankful width; and Poor = <1 piece of functional LWD per bankful width.	-Degree of predation on eggs and alevins -% Egg to emergent fry survival -Crayfish, sculpin, brown trout, merganser etc abundance -Amount of LWD -Discharge	-Low levels of LWD may impact predation due to high visibility. -Low turbidity would also lead to high visibility. -Lack of escape habitat exacerbates predation levels.

Critical Habitat Requirements	Limiting Factors	Factors Affecting Habitat Features	Benchmarks	Potential Indicators	Details
6. Lack of invasive species	**LF25:** Egg mortality due to redd disturbance by invasive species	-Loss and disturbance to spawning habitat - Japanese knotweed, crayfish, koi etc		- Degree of red disturbance	
7. Lack of anthropogenic disturbance	**LF26:** Egg mortality due to redd disturbance by humans	-Speedboats, urban development, docks - Instream works outside of reduced risk timing windows.		-Numbers of floathomes -Numbers of docks -Number of wakeboards - Machines working within wetted portions of stream channels	Regulations, compliance and enforcement more effective during non-emergency scenarios.

INCUBATION

Critical Habitat Requirements	**Limiting Factors**	**Potential Indicators**	**Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin**
1.Good water quality conditions	**LF16:** High suspended sediment loads that reduce egg to fry survival and emergence of alevins **LF17a:** Ice days resulting in mortality of eggs and alevins **LF 17b:** Non-optimal water temperatures that reduce fry survival by changing emergence time in relation to food availability **LF18:** High levels of pollutants or toxins that reduce egg to fry survival	-Total suspended solids during high flows -Depth of fine substrates over redds -Linear measure of eroding silt banks -% Egg to emergent fry survival -mg/L of DO -Water temperatures at emergence - Permitted waste management discharges -Level of intact riparian area -Road density -Water chemistry	- Cohorts that incubated in winters with more ice days tended to have lower recruitment; for every 10 additional days of river ice, recruitment was predicted to decrease by 10% (Warkentin 2020). Anchor ice and ice scour can kill incubating eggs and alevins (Cunjak et al. 1998; Huusko et al. 2007 cited in Warkentin 2020). - Spius Creek water temperatures averaged 3-5 degrees C less than at the lower site, but both followed a similar pattern, generally responding to air temperature and precipitation. At upper and lower sites, maximum water temperature coincided with the first major freshet. Water was neutral, soft and clear and the dominant ions were calcium, magnesium, silica and sodium. Levels of hardness and total alkalinity were marginally lower than recommended values for salmonid incubation in June water samples. Conductivity values were lower than recommended levels in all samples. Nutrient levels were generally low; a slight increase in concentration of total phosphate was noted in the May sample. Elevated concentration of suspended solids during peak discharge in May exceeded recommended limits but declined to an acceptable level in June. All other chemical parameters were within recommended limits for intensive culture of salmonids (Scott & Olmsted 1985). - Coldwater river: Water temperatures at the upper site averaged 0.5-2.0C less than at the lower site, both followed similar pattern, responding to air temperature and precipitation. At both sites, maximum water temperatures were correlated with high maximum air temperatures but not with discharge. Coldwater river was slightly alkaline and turbid. Dominant ions were calcium, magnesium, silica and sodium. Conductivity values were lower than recommended levels in all samples. Nutrient levels were low with the exception of total phosphate in May and June samples (possibly because of agriculture runoff). Suspended solids and aluminum exceeded recommended limits during May and June during increasing discharge. All other chemicals parameters were within recommended limits. (Scott & Olmsted 1985). -The Nicola River site water was slightly alkaline, well buffered and turbid. Dominant ions were calcium, magnesium, sodium and silica. Nutrient levels were low with the exception of total phosphate which exceeded recommended levels for salmonid culture in May and June (likely due to agriculture). Suspended solids and aluminum levels exceeded recommended limits during peak discharge in May and June. All other chemical parameters were within recommended limits (Scott & Olmsted 1985). -Highest densities of juvenile chinook are found in Reach 2 (Spius Creek to Coldwater River) contributing ~40% of total Nicola River smolt carrying capacity. Reach N1 (Thompson River to Spius Creek) contributes another 40%. Other reaches may be limited by high summer water temperatures, particularly in August (Kosakoski and Hamilton1982).

Critical Habitat Requirements	**Limiting Factors**	**Potential Indicators**	**Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin**
	LF19: Low DO which reduces egg to fry survival		
2. Suitable flow regime	**LF20:** Lower low flows that dewater redds and reduce incubation survival	-Frequency, timing, magnitude & duration of discharge -% watershed altered by development type, road density -<x% change in elevation of the redds	-Flows can be substandard for egg incubation and early rearing, and can lead to dewatering in fall and winter. -Groundwater is critical in maintaining productive stream habitats for stream resident salmonids. In dry years, the amount of water extracted from the rivers and streams for irrigation, together with low seasonal flows, leaves insufficient quantities for fish spawning. Pressures on groundwater resources include semi-desert weather patterns, high levels of agricultural irrigation usage, and extensive groundwater usage by urban and rural development, mining etc. - In Lower Spius Creek peak Chinook catches (of emergence and emigration) occurred in May 18-19 during an increase in discharge and water temperature. A secondary peak of nearly equal magnitude occurred June 7 (Scott & Olmsted 1985). - In Coldwater Creek peak catch at the upper trap occurred April 20, several days after the first increase in discharge, in the lower trap, peak catch occurred May 5, during relatively constant discharge and water temperatures. (Scott & Olmsted 1985). - In the Nicola River stream, discharge and water temperatures were stable when emergence and emigration began in early April. Peak captures of chinook fry were during stable flows. (Scott & Olmsted, 1985). - The minimum flow requirement for the incubation of salmon eggs in the reach between the Nicola Dam and Coldwater confluence has been estimated to be 1.1m3/s. The lowest discharge (0.04m3/s) recorded in mid-January 1988 represents less than 3 % of the minimum incubation flow. It is very likely that salmon redds downstream of the channel blockage were dewatered and thus exposed to sub-freezing air temperatures for several weeks. (Doyle et al. 1993). - Ice jams can result in fisheries losses due to scouring of gravels and a loss of eggs as well as forcing fish out of overwintering areas. (DFO 1998) - Like many salmonids, evidence of density dependence was strong. In addition, cohorts that experienced more ice cover appeared to have lower productivity, anchor ice and ice scour can kill incubating eggs and alevins (Warkentin 2020) - Productivity appeared lower for cohorts that incubated during years with fall and winter floods greater than ~150m3/s. Flows over this threshold could mobilize sediments and scour incubating eggs, but this is speculative given the sample size and lack of statistical support (Warkentin 2020). -Chinook are generally spawning during lowest flows (T. Willms pers. comm.). Flows below this that would result in de-watering of redds would likely be attributed to improper dam operation. Low flows affect productivity of chinook due to habitat availability for spawning and rearing and also the effects to temperature. -ECA: <10% for Coldwater and Spius Creek due to lack of storage and <15 for all other subcatchments. (T. T. Willms pers. comm.). -Richard Bailey (pers. comm.) suggests that dewatering of redds and loss of moderating groundwater flows in redds is resulting in increased freezing and ice scour, and can result in significant loss of eggs.

Critical Habitat Requirements	**Limiting Factors**	**Potential Indicators**	**Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin**
2. Suitable flow regime	**LF21:** More frequent and higher peak flows over winter can scour/disturb redds		-Flows in this region have been impacted by forest harvesting and mountain pine beetle (MPB) is an added concern: decreases in forest cover due to MPB results in more snow accumulation in dead forests, and in clearcut areas. Earlier snowmelt leads to increased, faster and earlier runoff, which is also less synchronized at different elevations. However, peak flows in this region happen after emergence. Winter flow issues are due to rain on snow events leading to possible ice scour. There is a potential issue with earlier freshet creating a timing mismatch for availability of ephemeral habitats though - Severe January 1984 ice breakup in the Nicola River caused numerous jams, high velocity surges, overbank flooding. Considerable bank erosion, bed scour and deposition took place over many kilometres of spawning reaches. As ice jams release, water levels drop rapidly, the potential for stranding fish is evident. The chaos of the ice drive is believed to have caused significant mortality to salmon eggs and overwintering juveniles throughout the system (Doyle et al. 1993). - Warkentin (2020) noted that productivity appeared lower for cohorts that incubated during years with fall and winter floods greater than ~150 m3s-1
3.Appropriate spawning gravel	**LF22:** Egg mortality due to inadequate spawning gravel, or as a result of gravel instability	-Sediment size of spawning gravel -Spawner abundance -Areas of high development, sources of erosion or sedimentation -Density of road crossings -% watershed altered by development type, road density	Avulsions have added a lot of gravel to the Nicola Basin systems, which is mobile and can result in mortality of eggs as a result of gravel instability Sediment avulsion in Guichon Creek is resulting in clogging of interstitial spaces (Richard Bailey pers.comm.).
4.Minimal disturbance to redds	**LF23:** Reduced egg to fry survival due to Chum or other	-Year and location of chum overspawn on Chinook redds.	This LF is not an issue in any of these systems as Chum are not spawning in the systems

Critical Habitat Requirements	**Limiting Factors**	**Potential Indicators**	**Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin**
	salmonid overspawn	-Egg to fry survival at these sites relative to undisturbed sites. -Discharge in cms	
5. Minimal predation of eggs, alevins and fry	**LF24:** Predation of eggs, alevins and fry/smolts by fish (sculpins, brown trout) and birds (mergansers)	-Degree of predation on eggs and alevins -% Egg to emergent fry survival -Crayfish, sculpin, brown trout, merganser etc abundance -Amount of LWD -Discharge	There is not likely to be very much egg predation as eggs are well buried but there are many sculpins and pike-minnow in these systems. No brown trout but there are rainbows and charr, plus many mergansers and mink. As fry grow, they may become nocturnal to avoid predation (R. Bailey pers. comm.)
6. Lack of invasive species	**LF25:** Egg mortality due to redd disturbance by invasive species	- Degree of redd disturbance	-Invasive species are a concern in the Nicola watershed but none are known to be impacting eggs
7. Lack of anthropogenic disturbance	**LF26:** Egg mortality due to redd disturbance by humans	-Numbers of floathomes -Numbers of docks -wakeboards	-Not significant except in Upper Coldwater due to quads. - Generally not an issue but can become a major issues during flood emergencies. - Regulations, compliance and enforcement more effective during non-emergency scenarios.

EARLY REARING

Critical Habitat Requirements	Limiting Factors	Factors Affecting Habitat Features	Benchmarks	Possible Indicators	Details
1.Suitable water temperature, TSS, dissolved oxygen levels, pH, hardness, supersaturation	**LF27:** High water temperature combined with low DO can suffocate fry or reduce overall fitness during the early summer/fall **LF28:** Low water temperature and lack of groundwater influx resulting in ice scour over winter **LF29:** Toxic water quality conditions can increase fry mortality or reduce fitness. **LF30:** High levels of sedimentation leading to clogging of interstitial spaces	-Industrial development, waste discharge, spills, input from sewage, septic systems and agriculture -Bank erosion and suspended sediment loads can be exacerbated by forestry, rural land clearing and urban development -Air temperature, nitrogen and pH levels, municipal/ domestic sewage discharge, agricultural activities, urban development, effluent from fish hatchery operations throughout the watershed -Climate change -Acid Rain	-Target WQ parameters: DO: 5-S mg/L, water Temp: Rearing: 15C (Richter and Kolmes, 2005). Chinook upper optimum temp (UOTR) is 14C, Impairment Temp (IT) is 20 C. -Positive growth of juveniles occurs between 4.5 and 19.1^{0}C, maximum growth occurs at 14.8^{0}C, distribution is limited >22C and upper lethal limit occurs when temperatures >25.1^{0}C (McCullough 1999). -Observed temperature range for juvenile Chinook is from 0 to 24 ^{0}C with an optimal range of from 12 to 18 ^{0}C (Raleigh *et al.* 1986). -Sedimentation: Levels of 509 to 1217 ppm are fatal to juveniles. Levels of 500 ppm result in stress responses. Levels of 100 to 300 ppm result in reduced feeding. -Suspended sediment levels of 100-300 ppm result in reduced feeding of juveniles, level of 500 ppm result in stress response in juveniles and levels >500 ppm are fatal to juveniles (Lloyd 1987). -The BC generalized depth and velocity habitat suitability index curves for Chinook suggest optimum Chinook stream rearing habitats would have depths ≥ 18 cm and velocities ranging from 15–50 cm/s (Burt, 2006). -Davis (1975) noted that fry/juveniles function without impairment at DO levels of 7.75 mg/l, show initial oxygen distress at 6.00 mg/l, and widespread	-Water quality monitoring that includes water temperature, pH, conductivity, DO, total phosphate, TKN, BOD, TOC, TDS and TSS. - Permitted waste management discharges -% watershed altered by development type, road density - P and N concentrations. - Algae blooms. - CCME benchmarks for aquatic life.	-Once hatched, alevins are sensitive to dissolved oxygen and carbon dioxide concentrations. They will migrate towards adequate DO levels if necessary (>6 mg/L). As well, a buildup of CO_2 around an alevin induced "ventilation" swimming to circulate more water and dissipate the CO_2 (Barnes, 1969 in Quinn, 2005). -Conversely, some water turbidity as a result of sediment may be beneficial due to reduced visibility of the juveniles to predators -Road density results in greater sedimentation - Rearing chinook will optimize metabolize or escape high temperatures by using thermal refugia – trade-offs exist w.r.t. DO concentrations in groundwater serviced habitats.

Critical Habitat Requirements	Limiting Factors	Factors Affecting Habitat Features	Benchmarks	Possible Indicators	Details
			impairment at 4.25 mg/l. Juvenile Chinook can survive short term exposures to 3 mg/l at temperatures less than 5 ^{0}C; optimal levels are greater than 9 mg/l at temperatures less than 10 ^{0}C and 13 mg/l at temperatures over 10 ^{0}C (Raleigh *et al.* 1986). Lower tolerance limit for DO is 3 mg/l at 8-18^{0}C and 4.5 mg/l at 16-25^{0}C (Whitemore et al. 1960 in Allen and Hassler1986). -Road density (km road/km^2 of sub-basin): Higher risk: >0.4 km/km^2 Lower risk < 0.4 km/km^2 (Stalberg et al., 2009) - The Upper Optimum Temperature and Impairment Temperatures for the juvenile life stage of salmonids were defined in Stalberg et al. (2009) as a maximum weekly average water temperature of 15°C and 20°C, respectively. -Benchmarks defined by Stalberg et al. (2009) for Total Suspended Sediments (mg/l, ppm): 25 mg/L in 24 hours when background is less than or equal to 25; mean of 5 mg/l in 30 days when background is less than or equal to 25; 25 mg/ when background is between 25 and 250;10% when background is greater than 250		
2.Adequate food supply	**LF31:** Mortality or fitness impacts as a result of lack of food	-Urban and resource development can reduce productivity by reducing the food availability as well	Juvenile chinook mainly feed on a variety of invertebrate species as well as on adult and larval insects, particularly those floating on the surface of the stream. A pool to riffle ratio of about 1:1 appears to provide an optimal mix of food-producing and	-Abundance and composition of drifting and benthic invertebrates -Level of riparian integrity	-Primary food organisms for Chinook fry include drifting aquatic insects and larval stages of terrestrial insects (Quinn 2005). -Juvenile Chinook salmon are generally opportunistic predators that consume prey based on availability though they

Critical Habitat Requirements	**Limiting Factors**	**Factors Affecting Habitat Features**	**Benchmarks**	**Possible Indicators**	**Details**
		as the quantity and quality of natural rearing habitat. -Type and quality of substrate can impact type of invertebrate populations available. -Riparian condition, presence of overhead vegetation impact food availability -Food supply may be related to low nutrient levels -Lack of returning spawner carcasses	rearing areas for chinook in streams. -Optimal substrate for the maintenance of a diverse and healthy invertebrate population includes a combination of mud, gravel and rubble with rubble dominant (Raleigh *et al.* 1986). -Riparian: Good status: 90% intact, high ecological complexity. Moderate status: 5-25% fragmented, moderate level of ecological complexity. Lower status: >25% fragmentation, partially functioning (nhc, 2009) -Those river sections exceeding a benchmark level of riparian disturbance of 5% of the riparian area are of a moderate concern, and those that exceeding a benchmark level of riparian disturbance of 10% of the riparian area are a high concern (Stalberg et al., 2009). -Road density (km road/km^2 of sub-basin): Higher risk: >0.4 km/km^2 Lower risk < 0.4 km/km^2 (Stalberg et al., 2009)	-Road density	can exhibit selectivity as well (Macneale et al. 2009). In freshwater systems, they consume aquatic and terrestrial insects (larvae/nymphs and adult life stages) with major prey items - including Chironomidae and Ephemeroptera (Merz 2001; Macneale et al. 2009).
3.Adequate instream complexity and riparian complexity	**LF32:** Mortality or fitness impacts as a result of inadequate in-stream complexity and riparian complexity	-Inadequate instream & riparian complexity can result in reduced productivity and food availability, increased predation, reduced fry survival. -Primarily due to urban and resource development	-Healthy, natural streamside vegetation is important in maintaining temperatures, controlling erosion and sedimentation and supplying food items that are an important component of stream-type chinook diets. -Welsch (1991) suggested a buffer strip about 30m wide on each side of the stream provides adequate erosion control and maintains undercut stream banks characteristic of good habitat. -Riparian: Good status: 90% intact, high ecological complexity. Moderate status: 5-25% fragmented, moderate	-Frequency of stream complexity -Amount of LWD -% or Linear measure of riparian status or condition (Good, Fair or Poor)	Healthy, natural streamside vegetation is important in maintaining temperatures, controlling erosion and sedimentation and supplying food item that are important to juvenile Chinook (Allen and Hassler 1986; Healey 1991).

Critical Habitat Requirements	Limiting Factors	Factors Affecting Habitat Features	Benchmarks	Possible Indicators	Details
			level of ecological complexity. Lower status: >25% fragmentation, partially functioning (nhc, 2009) -% pool habitat: Good: >55%, Fair 40-55% and Poor: <40%. Pool frequency: G < 2 channel width per pool, Fair: 2-4 CWPP, Poor: > 4 CWPP. - LWD habitat condition may be determined, at the reach level, using the following diagnostics described in Johnston and Slaney (1996): Good = >2 pieces of functional LWD per bankful width; Fair = 1 – 2 pieces of functional LWD per bankful width; and Poor = <1 piece of functional LWD per bankful width. -Those river sections exceeding a benchmark level of riparian disturbance of 5% of the riparian area are of a moderate concern, and those that exceeding a benchmark level of riparian disturbance of 10% of the riparian area are a high concern (Stalberg et al. 2009).		
4.Adequate water levels and connectivity.	**LF33:** Increased stranding in isolated off channel habitat and tributaries	- Riverside and floodplain development, urban development -Industrial and domestic water use/extraction -Low flows -Low water levels due to extraction of water -Operation of weirs	-Optimal depth for juvenile rearing is from 30 to 122 cm. -Number of fish stranded in tributaries -Juvenile Chinook in streams use waters that range in depth from 15 to 122 cm (Reiser and Bjornn 1979). Optimal depth for juvenile rearing is from 30 to 122 cm (Thompson 1972 in Allen and Hassler 1986). -Chinook salmon prefer slightly deeper and higher velocity (0-38 cm/s) areas than coho salmon (Bjornn and Reiser 1991; Healey 1991).	-% watershed altered by development type -Channel stability -Discharge -Sedimentation	-Increased mortality results from predation or lack of food/drying up of habitat. -Spring- type Chinook salmon in particular use off-channel habitats such as wetlands, side-channels, sloughs and other floodplain habitat (Sommer et al., 2001). Recent evidence suggests juvenile Chinook salmon rearing in these areas have much higher growth than those rearing in mainstem areas (Jeffres et al. 2008; Bellmore et al. 2013). These habitats are ephemeral

Critical Habitat Requirements	**Limiting Factors**	**Factors Affecting Habitat Features**	**Benchmarks**	**Possible Indicators**	**Details**
		-Amount of total water storage available -Low rainfall during spring-fall -Low snow pack -Climate change			but critical to recruitment (R. Bailey pers. comm.)
5. Natural flow regime	**LF34:** Higher high flows that prematurely displace juveniles downstream and reduce overall fry survival **LF35:** Low flows reduce seasonally available off channel and tributary rearing habitat.	-Increased mortality results from predation or lack of food/drying up of habitat -Low water levels due to extraction of water for industrial and domestic water use. -Riverside and floodplain development, urban development, forestry -Operation of weirs, hydroelectric power -Low rainfall -Drought, lack of water storage	-Chinook fry select water velocities ranging from 0 to 60 cm/s with an optimal range of 0 to 40 cm/s at depths of greater than 15 cm. -FLNRO -biological requirement for juvenile summer-fall rearing is 20% MAD (Province of BC 2010) -Juvenile Chinook were found in flows ranging from 0 to 38 cm/s (Reiser and Bjornn, 1979) and up to 60 cm/s but optimal range is less than 40 cm/s (Raleigh et al. 1986). -Chinook fry rarely found in still water or where velocity was greater than 30 cm/s (Murphy *et al.* 1989 in Healey 1991). - Stalberg et al. (2009) 1 in 2 year 30-day duration summer minimum flow is less than 20% of the mean annual discharge= poor. Flows ≥20% of the mean annual discharge are considered sufficient.	-Stream flows -Licensed water extraction -% watershed altered by development type, road density	
6. Absence of invasive species	**LF36:** Mortality or fitness impacts as a result of competition or predation by Aquatic Invasive Species (AIS)	-Presence of aquatic invasive species -Presence of riparian invasive plant species		-Presence of invasive species	

Critical Habitat Requirements	**Limiting Factors**	**Factors Affecting Habitat Features**	**Benchmarks**	**Possible Indicators**	**Details**
	LF37: Alteration of natural riparian structure and ecological integrity as a result of colonization of invasive species **LF38**: Impacts to juvenile migration as a result of invasive plant species				
7. Low levels of competition with other wild salmon/ hatchery fry /other species	**LF39:** Mortality or fitness impacts as a result of competition with other salmon, hatchery fry/smolts and/or other species	-Presence of hatchery fry or other competitive species -Relative timing of release of hatchery fish and wild fish outmigration -Low food availability - Interspecific competition between salmonids and minnow species (e.g. redside shiner) in off-channel habitats during periods of high stream temperatures (Reeves et al. 1987)		-Abundance of competitors/other salmonids/other competitive species -Relative timing of release	

Critical Habitat Requirements	Limiting Factors	Factors Affecting Habitat Features	Benchmarks	Possible Indicators	Details
8.Low levels of predation to fry	**LF40:** Mortality as a result of high levels of predation in the river	-Density of predators (e.g. mergansers and otter) -Availability of alternate food sources (invertebrates) -Amount of refuge habitat for fry -Low levels of LWD -Lack of riparian cover - Stress, aerobic scope and reduced ability of individuals to avoid predation at high stream temperatures.	-Those river sections exceeding a benchmark level of riparian disturbance of 5% of the riparian area are of a moderate concern, and those that exceeding a benchmark level of riparian disturbance of 10% of the riparian area are a high concern (Stalberg et al. 2009). - LWD habitat condition may be determined, at the reach level, using the following diagnostics described in Johnston and Slaney (1996): Good = >2 pieces of functional LWD per bankful width; Fair = 1 – 2 pieces of functional LWD per bankful width; and Poor = <1 piece of functional LWD per bankful width.	-Abundance of predators -Amount of LWD -Riparian quality	-Good vegetative cover, habitat complexity and high levels of LWD may reduce predation due to provision of refuge and reducing visibility -The timing of hatchery released fry can offset competition with wild fry and potentially reduce early marine mortality.
9.Low levels of fish disease	**LF41:** Mortality or fitness impacts as a result of disease	-Crowding/lack of appropriate habitat -High water temperatures	-Many fish diseases become more virulent at temperatures over 15.6 ^{0}C (McCullough 1999).		
10. High quality rearing habitat with good instream complexity	**LF42:** Lack of high-quality rearing habitat throughout the river both mainstem and side channels and tributaries	-Urban development -Lack of LWD -Loss of riparian cover	-During their freshwater residence, stream-type fry tend to reside in tributaries and along river margins. As they grow they move to habitats with increasing velocity and depth, likely increased food abundance and also allows for segregation of chinook juveniles from potential competitors such as coho and steelhead. -During the winter, they typically move out of tributary into the river mainstem, where they seek refuge in deep pools or spaces between	-% watershed altered by development type, road density -Amount of LWD -Level of riparian disturbance	-Mainstem and large side channel edge habitats with suitable velocities and intact overstream and/or instream riparian vegetation cover are critically important for Chinook fry rearing, particularly early in the season (BCCF 2015) -Healthy natural streamside vegetation is important for maintaining temperatures, controlling erosion and sedimentation and supplying food items important to juvenile Chinook (Healey 1991).

Critical Habitat Requirements	Limiting Factors	Factors Affecting Habitat Features	Benchmarks	Possible Indicators	Details
			boulders and rubble. Optimal substrate size for escape from predators and for winter cover is from 10 to 40 cm. Interior stocks may overwinter in off-channel habitats. -Deep >1m holding pools, functional LWD, boulder cover are requirements -% pool habitat: Good: >55%, Fair 40-55% and Poor: <40%. -Pool frequency: G < 2 channel width per pool, Fair: 2-4 CWPP, Poor: > 4 CWPP. -LWD pieces per channel width: G > 2, F: 1-2 and P: < 1. -Boulder cover in riffles: G: >20% F: 10-30% and P: <10%. (Johnstone and Slaney 1996). -Juvenile Chinook utilize water depths that range from 15 to 122 cm (Reiser and Bjornn 1979) - Those river sections exceeding a benchmark level of riparian disturbance of 5% of the riparian area are of a moderate concern, and those that exceeding a benchmark level of riparian disturbance of 10% of the riparian area are a high concern (Stalberg et al. 2009). - Nicola Chinook utilize off-channel habitats similar to Coho Salmon.		-Note that periodic access to groundwater-moderated thermal refugia can be critical - Important to maintain habitat forming processes like natural levels of bank erosion and channel migration. Lateral channel movements and avulsion create groundwater fed relic-channels that are connected to the mainstem throughout the summer. These habitats allow diel migration for optimizing feeding and metabolism, and avoiding lethal temperatures in the mainstem.
11. Unrestricted migration and passage: mainstem, off channel and tributary habitat	**LF43:** Lack of access to historical tributary and off channel habitat **LF44:** Limited juvenile passage at lake fishway,	-Changes in flow rates -Development -Diking in lower river -Presence of artificial structures	- Those river sections exceeding a benchmark level of riparian disturbance of 5% of the riparian area are of a moderate concern, and those that exceeding a benchmark level of riparian disturbance of 10% of the riparian area are a high concern (Stalberg et al. 2009).	-% watershed altered by development type, road density -Riparian disturbance -Discharge	Side channels need to have sufficient discharge before Chinook are consistently present (BCCF 2015)

Critical Habitat Requirements	**Limiting Factors**	**Factors Affecting Habitat Features**	**Benchmarks**	**Possible Indicators**	**Details**
	tributary culverts etc	impeding movement		- Bank alterations, berms and dikes.	
12. Lack of anthropogenic disturbance	**LF45:** Mortality or fitness impacts as a result of anthropogenic disturbance	- Noise/ light/ Pollution -Boats/ marinas/ floathomes / buildings etc			
13. Low or no levels of artificial augmentation from hatcheries	**LF46:** Hatchery introgression	-Low population numbers results in decision to increase augmentation to increase abundance -Poor fitness of wild fish resulting in lower levels of productivity	-Proportion of population from natural spawning activity.	- Proportion of F1 generation in spawning population < 25%	This LF can be included for populations that may be impacted by local hatchery production

EARLY REARING

Critical Habitat Requirements	**Limiting Factors**	**Possible Indicators**	**Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin**
1.Suitable water temperature, TSS, dissolved oxygen levels,	**LF27:** High water temperature combined with low DO	-Water quality monitoring that includes water temperature, DO levels and	-There has been considerable loss of riparian vegetation along the Nicola River, which has reduced stream shading and resulted in warmer stream temperatures during summer. Additional thermal stresses are imposed due to flows being reduced by water withdrawals for irrigation and other land use practices, resulting in greater daily temperature variations (Walthers and Nener 1997). Also, frequent destabilization of stream banks has resulted in wider channels and shallower waters being more susceptible to warming

Critical Habitat Requirements	**Limiting Factors**	**Possible Indicators**	**Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin**
pH, hardness, supersaturation	can suffocate fry or reduce overall fitness during the early summer/fall **LF28:** Low water temperature and lack of groundwater influx resulting in ice scour over winter **LF29:** Toxic water quality conditions can increase fry mortality or reduce fitness. **LF30:** High levels of sedimentation leading to clogging of interstitial spaces	suspended sediment levels. - Permitted waste management discharges -% watershed altered by development type, road density	during summer. Studies by Walthers and Nener (1997) suggest that salmonid production in both the Nicola and Coldwater rivers are constrained by relatively high water temperatures, with the distribution of fish influenced by local variations in water temperatures as fish tend to seek cooler areas with groundwater inflows, shade, and other features. -Warkentin (2020) found that stream locations with larger upstream catchment areas had higher maximum temperatures as well as greater climate sensitivity to air temperatures. Sites with more riparian vegetation cover had lower climate sensitivity. Streams with 100% riparian forest cover had maximum temps ~1.2°C lower than streams without riparian cover. Many smaller tributaries contribute cool water to the mainstem in the warmest days of summer and are less sensitive to warm regional air temperatures. -- During summer 2015, the Nicola Basin experienced severe drought conditions following a winter with low record snowpack and low precipitation and high temperatures in spring and summer. Discharge in Coldwater River fell below the Theoretical Critical Level (TCL) for juvenile salmon triggering a fish protection order (limited/banned surface withdrawals), (Schick et al. 2016) - Study looked at long term juvenile abundance data and examined to what extent in annual summer drought intensity (measured by discharge/temperature) explains juvenile chinook abundance given the influence of stock size (brood spawners). No one index of summer drought or winter flow explained any more of the variation in juvenile abundance than any other. Data had limited number years in the stock-recruitment time series, making it difficult to draw statistical conclusion. (Schick et al. 2016) - Low discharge and lack of riparian vegetation have aggravated a naturally elevated thermal regime in the mainstem (LDL Limited 2001). - Mortality, reduced feeding and elevated stress hormones have all been associated with stream heating of 1-4C. Tributary streams are important habitats for juveniles but the loss of stream shade can affect their energy reserves (Peatt and Peatt 2013). - Chinook salmon behavior monitoring shows juvenile burrowing into gravels to find cooler groundwater and survive summer temperatures of 23-25 C. (Peatt and Peatt 2013). - The lower end of the thermal tolerance range for the juvenile stages of anadromous salmonids was taken to be 21C and the upper end of the ranges was 25C. Preferred temperatures are also much lower than tolerance limits and the levels of both preferred and tolerable temperature for adults are usually lower than juveniles. Water temperatures at all sites reached the upper end of the thermal tolerance range for pacific salmonids. Mid July- early August were the hottest, and average water temperatures exceeded 21C at all sites for each of these weeks. Average temperatures for July and August always exceeded the preferred temperature ranges for both rearing and migrating fish (>11.5-15C, >16C, respectively). Preferred temperatures have been shown to correspond with physiological optimum temperatures at which metabolic rate, metabolic scope, sustained swimming speed and growth rate are optimized. (Walthers and Nener 1997) - Juvenile chinook are vulnerable to high water rearing temperatures during summer months. Moyle (1993) suggests that the water temperature for growth is between 5-17.5 C for juvenile salmon. While higher temperatures may not be directly lethal, they do cause metabolic rates to increase (growth then decreases as most/all food is used for maintenance). Juveniles use cool water seepage sites, off-channel

Critical Habitat Requirements	**Limiting Factors**	**Possible Indicators**	**Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin**
			ponds and cool creeks as refugia. During sampling of the mid-Nicola reaches in 1985 salmonids were only found within a 10-foot radius of the Clapperton Creek outflow into the Nicola River. During the warm summer months appropriate habitat with a favourable thermal regime is clearly restricted to areas with cool inputs of surface or ground water. Chinook runs rear primarily in small tributaries which are highly susceptible to the thermal and hydrological impacts associated with global warming. (Walthers & Nener 2000) - Juvenile chinook burrow into the streambed during the hottest portion of the day, in areas where incoming groundwater temperatures are 16-17C. (compared to river temperature of 23-25C). Continued development-related groundwater extraction puts this stock at risk (Douglas 2007). - With the exception of Pb, Nicola Lake sediments show little evidence of metal contamination. The minor Pb contamination could be supplied by local traffic which used leaded gasoline until the late 1970s. Nicola Lake sediments exhibit gross contamination by DDT and minor contamination by chlordane and HCH. (Macdonald et al.1999) - Existing impacts from Highland Valley Copper Mine include increased copper molybdenum levels in downstream waters and in fish. Additional impacts include bioaccumulation of molybdenum in alfalfa crops utilizing water from Guichon Creek (DFO 1998) - Highest densities of juvenile Chinook are found in Reach 2 (Spius Creek to Coldwater River) contributing ~40% of total Nicola River smolt carrying capacity. Reach N1 (Thompson River to Spius Creek) contributes another 40%. Other reaches may be limited by high summer water temperatures, particularly in August (Kosakoski and Hamilton 1982).
2.Adequate food supply	**LF31:** Mortality or fitness impacts as a result of lack of food	-Abundance and composition of drifting and benthic invertebrates -Level of riparian integrity -Road density	- Nicola Dam has attenuated high peak flows over a longer time- so high flows during freshet have increased. This has led to increased erosion and turbidity that may decrease aquatic productivity downstream. -In general, however, these systems are productive, not like coastal rivers. The Nicola is also eutrophied by treated sewge and agricultural runoff (R. Bailey, pers. comm.) - Levings et al. (1984) present stomach content data from 1984 for Chinook from Coldwater and Nicola Rivers. Chironomid larvae were found in almost half the Chinook stomachs. The next most frequently occurring items were hymenoptera larvae and nematodes. Chironomid larvae were found in chinook salmon ranging from 37 to 83 mm length. Hymenoptera larvae were found in individuals ranging from 60 to 74 mm, and Hymenoptera adults in individuals from 64 to 90 mm. They also found evidence of feeding on beetles and bees, as well as gammaridean amphipods.
3.Adequate instream complexity and riparian complexity	**LF32:** Mortality or fitness impacts as a result of inadequate in-stream	-Frequency of stream complexity -Amount of LWD -% or Linear measure of riparian status or	-See above for notes on loss of riparian forest and decreases in stream complexity - Most prevalent hazard is riparian (10/13 sub- watersheds in Nicola watershed) At the sub-unit scale, risk over the last 10 years (2003-2013) is largely due to elevated riparian hazard followed by increases in peak flow hazard (Valdal & Lewis 2015). - Vast majority of riparian disturbances are on S6 streams, although there is extensive private land and ranching based riparian disturbance in the lower ends of watersheds. 46% of all S6 monitoring sites had

Critical Habitat Requirements	Limiting Factors	Possible Indicators	Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin
	complexity and riparian complexity	condition (Good, Fair or Poor)	almost no buffer (<1m); 28% of samples had at least a 10 m buffer. Rex and Maloney (2010) found that in stream conditions were affected by upstream riparian harvesting 20-30 years after activity. - The number of catchments with a high and very high riparian hazard (stream bank stability, shading,) increased from 2003-2013 (riparian being the greatest hazard, followed by streamflow hazard (ie floods, bank erosion, channel instability). Primary factor contributing to elevated riparian and streamflow hazard is salvage logging by forests affected by pine beetle (Valdal and Lewis 2015) - Fish population monitoring in the 3 years following the Coquihalla Highway construction (1986-1988) indicated that habitat capability for juvenile salmonids was enhanced by (1) use of large rip rap for bank protection and (2) installed instream mitigation structures. Annual estimates of the percentage of increase that mitigation structures contributed to rearing habitat capability were in the range of 13-19% for chinook. Rock spurs and boulder groups attracted the greatest fish utilization. (Northwest Hydraulic Consultants 2002) - In terms of absolute smolt yield, the Brodie-Kingsvale section of the Coldwater River likely produces nearly 35% of the total yield for chinook. In 1978, this reach was extremely complex in terms of rearing habitat diversity as well as having some of the best spawning habitat. (LDL Limited 2001). - Coldwater River is confined by 58 km of highway, 46 km of railway and 88 km of pipelines. These encroachments have resulted in shortening of the mainstem length, a reduction in the number of side-channels or off-channel wetlands and extensive damage or elimination of riparian vegetation. 13% of the lower Coldwater mainstem length has been rip rapped to protect infrastructure (LDL Limited 2001). - The upper Coldwater channel upstream of Kingsvale has been confined by linear developments while the lower Coldwater channel has been impacted primarily by the loss of riparian vegetation that has precipitated lateral instability, over-widening and extensive gravel bars. (LDL Limited 2001). - An extensive fire that occurred about 1938 consumed the riparian vegetation on the east side of the upper Coldwater River, upstream of the Brook Creek headwaters. In 1960, a fire also burned much of the southwest side of Midday Creek. (LDL Limited 2001). - In 1985/86/87 highest juvenile chinook population densities were found in Guichon Creek and in the Nicola River at the mouth of Guichon. Chinook were closely associated with log debris and cut bank cover. (Lauzier and Levings 1991) - Six principal causes of the impacts to channel and habitat condition within the Coldwater River watershed summarized: channel is confined by linear developments in the upper Coldwater mainstem, riparian and floodplain areas degraded by agriculture development and livestock grazing in lower Coldwater, streamflow and water temperatures are affected by water withdrawal and loss of riparian vegetation, sediment is being generated from slope instability and bank erosion, hydrology of basin as changes as a result of forest clearing associated with logging, agriculture, urban/linear development. Habitat concerns included: lack of rearing habitat complexity and lack of cover in the mainstem, seasonal low flows in the lower Coldwater, loss of side and back channel rearing and overwintering areas, substrate sedimentation and consolidation limiting rearing and spawning, sub-optimal to lethal water temperatures for salmonids of 21-29C

Critical Habitat Requirements	Limiting Factors	Possible Indicators	Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin
			- In the Coldwater River, catches were highest in natural main-channel pools containing large log debris and were very low in riprap areas and in side channels. Only small numbers of chinook were caught in the two off channel ponds in the Coldwater River and were absent from the Nicola River pond. Highest catches were recorded in the two Nicola side channels, although catches were 5 times lower than for Coho salmon. Although some Chinook salmon overwinter in main channel areas it seems likely that before the onset of winter conditions, many fish emigrate from tributary streams into deeper, warmer, downstream habitats (Swales et al. 1986) - For a 50% increase in riparian tree cover, maximum temperature was on average 0.6 C lower. Streams with larger catchments had higher climate sensitivity, while those with more riparian cover and higher lake influence were less climate sensitive. (Warkentin 2020)
4.Adequate water levels and connectivity.	**LF33:** Increased stranding in isolated off channel habitat and tributaries	-% watershed altered by development type -Channel stability -Discharge -Sedimentation	-Spring- type Chinook salmon in particular use off-channel habitats such as wetlands, side-channels, sloughs and other floodplain habitat (Sommer et al. 2001). Recent evidence suggests juvenile Chinook salmon rearing in these areas have much higher growth than those rearing in mainstem areas (Jeffres et al., 2008; Bellmore et al. 2013). These habitats are ephemeral but critical to recruitment and it is suggested that inability to access thermal refugia and stranding may be critical concerns (R. Bailey pers. comm.) -Groundwater is critical in maintaining productive stream habitats for stream resident salmonids. In dry years, the amount of water extracted from the rivers and streams for irrigation, together with low seasonal flows, leaves insufficient quantities for fish rearing. Pressures on groundwater resources include semi-desert weather patterns, high levels of agricultural irrigation usage, and extensive groundwater usage by urban and rural development, mining etc. -Density of Chinook fry generally decreased with stream order and distance from confluence (Schnick 2016, v2). -Irrigation activities and low water levels in off-channel areas identified as reducing available rearing habitat (LDL Limited 2001). -Guichon Creek has experienced widespread flooding and channel instability during the spring of 2017 and 2018. The flooding resulted in damage to infrastructure and restriction of access to communities, and subsequent concerns for salmonids. Sediment supplied to the channel from lateral erosion contains a large proportion of sand and silt. The presence of high silt load in the system, particularly if silt is depositing during low velocity flows, could reduce water and therefore oxygen flow within channel bed substrate (Reid 2020)
5. Natural flow regime	**LF34:** Higher high flows that prematurely displace juveniles downstream and reduce	-Stream flows -Licensed water extraction -% watershed altered by development type, road density	-Flows in this region have been impacted by forest harvesting and mountain pine beetle (MPB) is an added concern: decreases in forest cover due to MPB results in more snow accumulation in dead forests, and in clearcut areas. Earlier snowmelt leads to increased, faster and earlier runoff, which is also less synchronized at different elevations. - LF30 will be exacerbated with climate change which will likely lead to earlier peak flows as well as increased flooding - Flows can be substandard for early rearing, and can lead to dewatering in fall and winter - Within the Nicola system, Rood and Hamilton (1995) regarded the Nicola River, Spahomin Creek and Coldwater River as sensitive streams due to high water demands, whereas Spius and Maka creeks and the

Critical Habitat Requirements	Limiting Factors	Possible Indicators	Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin
	overall fry survival **LF35:** Low flows reduce seasonally available off channel and tributary rearing habitat.		Coldwater River were regarded as sensitive due to their low flows. The same authors regarded the Coldwater River as sensitive due to high peak flows, whereas Maka Creek was regarded as sensitive due to recent logging activity covering more than 20% of the watershed -Warkentin (2020) noted that productivity appeared lower for cohorts that incubated during years with fall and winter floods greater than ~150 m3s-1 -Beniston et al. (1988) noted that low flows during late summer and winter in the Coldwater river may be the primary factor limiting juvenile Chinook production -LF31 also will be exacerbated with climate change which will likely increase incidence of summer low flows -Warkentin's (2020) analysis of over 20 yrs of Chinook salmon life-cycle data revealed that low summer flow strongly decreases productivity. August flow during spawning and fry rearing had the strongest effects – cohorts that experienced 50% below average flow in the August of spawning and rearing had 40% lower productivity. Chinook salmon cohorts are predicted to drop below replacement – and thus unable to sustain fishery mortality – in years with average August discharge less than 10.83 m^3s-1 (or 36% mean annual discharge) during the rearing summer. He noted that these flows only occurred for 18% of cohorts examined. -Based on a stock recruit model for the Nicola, Spius, Coldwater regions (2001-2006, 2008, 2010-2012), there were more fry then expected in lower flow years with less fry than expected in higher flow years (Schick et al. 2016) -For the Nicola, minimum summer flows typically occur in August to September whereas during 2015, near minimum flows were reached in early July coinciding with longer day length and higher air temperatures (resulted in water temps that exceeded BC guidelines). (Schick et al. 2016) -Study results provide partial support for the hypothesis that fish abundance was affected by drought conditions in that abundance reductions were greatest in tributaries versus the Nicola Mainstem and also that reductions were greatest in the lower Coldwater where water withdrawals were most acute. (Schick 2016 v2). -Migration of wild fry seemed to be related to discharge patterns in the Nicola River. Fry emigration began usually between mid-April and mid-May as the freshet generated by snowmelt began (Levings & Lauzier 1987). -The naturalized (no withdrawals) mean annual flow for Coldwater River at Merritt is approx. 8.5m3/sec. Juvenile salmon require 1.2m3/sec to maintain abundant rearing habitat. Historic data shows that Coldwater River in stream flow of 1.3m3/sec is frequently occurring in summer at Coldwater Brookmere station. Flows recorded in the lower Coldwater River at Merritt are now frequently less than 0.43m3/sec for extended periods of the summer (well under the 10% survival flow). Measurements by the Ministry of Environment in 2004 and 2005 confirm that habitat diminishes rapidly at less than 10% mean annual flow. (Bennett & Caverly 2009) -There is no firm evidence in the historic flow record to suggest that these low flow periods in Coldwater River are the result of climate change. There is evidence that climate changes have caused low flow conditions to begin earlier in the summer. Low flows are lower than in the past, but no clear climate

Critical Habitat Requirements	**Limiting Factors**	**Possible Indicators**	**Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin**
			change signal. Cool ground water inputs may be essential to protect salmon from impacts of climate change. (Bennett & Caverly 2009). -In-stream flow measurements form August – September 2005 at 2 Coldwater River sites show that all flow levels were less than the guidelines. Surface water losses up to 0.147 m3/sec or 40% were occurring in the Coldwater River between the Mountain festival site and Claybanks Park (Bennett & Caverly, 2009) -Mean monthly discharge of the Coldwater River ranges from 1.3m3/s (September) to 30m3/s (May). Lowest flow of the year occurs in August/September. (Summit 2002) -65% of total licenced quantity for Coldwater River is used in support of irrigation (Summit, 2002) -The Coquihalla Highway crosses the Coldwater River 5 times. Rip rap extends a considerable distance upstream and downstream of the bridge at some crossings, laterally constraining the channel and preventing flow across the floodplain. Transmountain pipeline and West Coast Energy pipeline cross the Coldwater River six times. (Northwest Hydraulic Consultants 2002) -Mean August flows during Chinook rearing had the strongest effect on productivity. Cohorts with greater flows in their rearing summers had higher productivity. The model predicts chinook cohorts whose juveniles rear during summers with 50% below average flow have 30% lower productivity. (Warkentin 2020). -In Coldwater River the channel widened by approximately 25% between he 2013 and 2018 image sets. Two major flood years occurred in the Nicola Watershed over this period; 2017 and 2018. Some signs of lateral channel migration were apparent, with vegetation bands and zones of lateral erosion apparent from the satellite imagery. A comparison of active channel areas between imagery dates revealed several locations of lateral migration, in some places approaching 10m. However, most of the channel was stable between 2013-2018. On average, the Nicola River (one reach of interest) widened by nearly 50% in the gravel section of the reach, though much less widening occurred in the lower gradient section of channel downstream. Lateral instability was apparent with the channel displacing by up to 40m in some locations. The channel stability may have been a result of major flooding in 2017 and 2018 (Reid 2020a). -Summer low flows reduce the available rearing habitat in the middle and upper Coldwater River (DFO1998). - Water withdrawal by agricultural activities for irrigation amplifies low flow problems by further reducing the available rearing habitat, increasing water temperatures and the incidence of fry stranding in off channel habitats Average water temperatures during 1994 exceeded 21C in July and August and reached 29C during the last week of July, well above the lethal tolerance range for Pacific salmonids (DFO 1998).
6. Absence of invasive species	**LF36:** Mortality or fitness impacts as a result of competition with Aquatic	-Presence of invasive species	-Yellow perch are in Nicola Lake and are a big concern for predation on juveniles - A macrophyte inventory was commissioned in 2013 to determine the extent of the Eurasian watermilfoil (EWM) infestation and composition of macrophytes communities in Nicola Lake. The survey completed in 2013 identified that EWM appears to have established in almost all suitable habitats within the lake and that native milfoil species appear to have been displaced. (Nicola Lake Eurasian Watermilfoil Management Plan 2015) - Of 70 sampled locations within 38 mapped macrophyte beds, 30 were categorized as having EWM as a dominant species and 24 as subdominant in Nicola Lake. Migratory chinook and EWM occupy distinctly

Critical Habitat Requirements	**Limiting Factors**	**Possible Indicators**	**Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin**
	Invasive Species (AIS) **LF37:** Alteration of natural riparian structure and ecological integrity as a result of colonization of invasive species **LF38**: Impacts to juvenile migration as a result of invasive plant species		separate habitats. Some research suggests there is little evidence to support the idea that EWM will lead to dramatic declines in fisheries. Other research has observed some fish species avoid EWM beds due to reduced prey availability (invertebrates). Juvenile chinook may overwinter offshore but adjacent to "productive littoral areas" to benefit from both pelagic and littoral food sources (Triton Environmental Consultants 2014) - EWM appears to have established within almost all areas suitable for macrophyte establishment within Nicola Lake; it was a common constituent of almost all macrophyte communities encountered with the exception of a few areas. Of the 70 sampled locations within 38 mapped macrophyte beds, 30 were categorized as having EWM as a dominant component, 24 as a subdominant component and 4 as present but slight, 7 as trace component, and 5 non detectable. (Golder Associates 2013)
7. Low levels of competition with other wild salmon/ hatchery fry /other species	**LF39:** Mortality or fitness impacts as a result of competition with other salmon, hatchery fry/smolts and/or other species	-Abundance of competitors/other salmonids/other competitive species -Relative timing of release	-There are virtually no fry releases into the Nicola Basin. -Coho and steelhead fry numbers also depressed (R. Bailey pers. comm.) -Lauzier and Levings (1991) found that Chinook and rainbow trout showed temporal and spatial separation, minimizing competition in the Nicola River.
8.Low levels of predation to fry	**LF40:** Mortality as a result of high levels of	-Abundance of predators -Amount of LWD -Riparian quality	-Fry predation from birds, mink, sculpins and pike minnows (R. Bailey pers. comm.)

Critical Habitat Requirements	**Limiting Factors**	**Possible Indicators**	**Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin**
	predation in the river		
9.Low levels of fish disease	**LF41:** Mortality or fitness impacts as a result of disease		-Two issues apparent in hatchery fish: BKD and Myxobacterial issues that resulted in depressed survivals in 1992 brood and some other years (R. Bailey pers. comm.)
10. High quality rearing habitat with good instream complexity	**LF42:** Lack of high-quality rearing habitat throughout the river both mainstem and side channels and tributaries	-% watershed altered by development type, road density -Amount of LWD -Level of riparian disturbance	-Juvenile Nicola Chinook burrow into the streambed gravel in groundwater upwelling areas during the hottest part of the day, where temperatures are 16°–17°c compared to ambient river temperatures of 23°—25°c -Sebastian (1982; cited in Millar et al. 1997) reported that within the Nicola River, glide and pool habitats near Merritt are the most productive areas for rearing juvenile chinook salmon Note that periodic access to groundwater-moderated thermal refugia can be critical (R. Bailey, pers. comm.) -Chinook fry prefer low velocity areas (0.15m/s) and are thus usually found along the stream margins and within backwater areas (silt sized bed material). As the fry grow, they utilize deeper and faster areas in the main river. Juveniles have been recorded to overwinter amongst boulders on the stream bottom - Chinook production was thought to be limited more by rearing area than spawning area; rearing area for juvenile chinook may have decreased in the Nicola River during the late 1970s and early 1980s as channelization activities reduced the areas available for refuge habitat (Millar, J., Child, M., Page, N, 1997) - Juvenile chinook overwintering in the Nicola and Coldwater rivers were generally most abundant in deep pools containing log debris (DFO 1998) -Summer rearing habitat is considered a major limit factor to chinook production. One of the potential contributing limiting factors is low stream flow during the summer rearing period when irrigation is occurring. A second potential contributing factor during summer is high water temperature. Water temperature in the mainstem river have been recorded up to 29C where the lethal limit for Coldwater salmonids is ~24C. Additionally, during abnormally high or low flow winters, winter rearing habitat may become limiting (through either flushing or dewatering). (Summit 2002)
11. Unrestricted migration and passage: mainstem, off channel and tributary habitat	**LF43:** Lack of access to historical tributary and off channel habitat. **LF44:** Limited	-% watershed altered by development type, road density -Riparian disturbance -Discharge	-Irrigation ditches can obstruct normal river flows, juvenile salmon rearing in the river are swept with the unscreened diverted water into farmers fields/ are attracted to ditches for quieter habitat to rear. Fish can become trapped/killed during periodic dewatering over summer. High velocities in entrance channels are likely to prevent smaller fish from swimming upstream and back to the river. During 1985, several ditches were identified as areas of high density of salmonid rearing and eventual fish – loss due to dewatering. The Neale ditch was estimated to contain he greatest number of salmonids with a total of 4,100 +/- 400 chinook estimated to have been loss in early October when flows were cut off (Fleming 1987).

Critical Habitat Requirements	Limiting Factors	Possible Indicators	Nicola, Spius, Guichon, Clapperton, Coldwater, Spahomin
	juvenile passage at lake fishway, tributary culverts etc		-Small juveniles being diverted out of the streams and into the hayfields due to lack of screening at the irrigation intakes. This situation appeared to result in high losses and significant mortality for the young salmon and steelhead that were being captured. (Pacific Fisheries Resource Conservation Council, 2003). -Instream diversion dams routing water from the stream into the irrigation ditches also blocked access to spawning and rearing grounds. As flows became lower and lower the rancher would continue to make the dams larger in order to diver more water making this obstruction even more difficult for fish to traverse. (Fisheries and Oceans Canada now indicated that this situation has now mostly been resolved). (Pacific Fisheries Resource Conservation Council 2003).
12. Lack of anthropogenic disturbance	**LF45:** Mortality or fitness impacts as a result of anthropogenic disturbance		-Forestry activities are primarily concentrated in the tributaries of the Coldwater River, with approx. 20% of the total Coldwater drainage area being recently logged (as of mid 90s). (LDL limited, 2001). -44.5% of Nicola Lake shoreline is considered disturbed, 55.5% is considered natural. Agriculture land use accounts for 33.7% of the shoreline, transportation accounts for 25.8% Rural and Single family residential represent the other major land uses around the lake. (Ecoscapes Environmental Consultants Ltd. 2012)
13. Low or no levels of artificial augmentation from hatcheries	**LF46:** Mortality or fitness impacts as a result of hatchery introgression	- Proportion of F1 generation in spawning population < 25%	-Degree of interaction between hatchery and wild fish is largely dependent on timing of migration. In 1985, after a colder than average winter, fry emergence and migration were later, many hatchery fish were using the river at the same time as wild fry. As hatchery fry are larger than wild chinook fry there was a possibly for predation (not determined). (Levings & Lauzier 1987).

This is as far as the Nicola RAMS will go. Subsequent processes will examine rearing and migration of smolts in the Fraser River and estuary, and marine RAMS will examine risks in the marine waters of the Strait and open Pacific west coast waters.

REARING IN THE ESTUARY- Will not be assessed for the Nicola RAMS

Critical Habitat Requirements	Limiting Factors	Factors Affecting Habitat Features	Benchmarks	Potential Indicators	Details
1.Adequate food supply to minimize competition with hatchery smolts	**LF47:** Low early marine survival of Chinook fry and smolts in the estuary due to the	-Reduced food availability -Competition with hatchery smolts		-% marine survival in estuary -Estimates of aquatic	-In general, Chinook salmon are opportunistic feeders, consuming larval and adult insects, polychaetes, copepods, mysid shrimp, and amphipods when they first enter estuaries, with increasing

Critical Habitat Requirements	Limiting Factors	Factors Affecting Habitat Features	Benchmarks	Potential Indicators	Details
and other stocks for food and habitat	lack of adequate food supply (particularly in first 4 months of marine life)	-Competition with other salmonids		invertebrates during March to June, including harpacticoids, decapods, amphipods, mysids and insects (fry) -Estimates of juvenile herring in nearshore areas in March and April	dependence on larval and juvenile fish (including other salmonids) as they grow larger (Brennan et al., 2004; Duffy, 2010).
2.Adequate water temperatures for smoltification and outmigration	**LF48:** Mortality or reduced fitness as a result of failure to develop to smolt	-High water temperatures e.g. climate change, warm water outflows	-Temperature range for smoltification and outmigration is from 3.3 to 12.2 ^{0}C. Smolt lethal and loading stress occurs at temperatures over 18.3 ^{0}C.		
3.High quality rearing habitat characteristics (adequate vegetation for cover/to ameliorate water temps), high habitat complexity	**LF49:** Lack of good quality estuarine and nearshore habitat	-Historical log booming, log dumps, channelization and diking, infilling for industrial developments, -Amount of development and/or disturbance to natural riparian, foreshore, intertidal and nearshore habitat -Diking, riparian disturbance -Log handling issues	-Stream-type Chinook spend a relatively short time in the estuary as compared with ocean-type Chinook. However, coastal estuaries are still important to stream-type Chinook as they provide an environmental transition zone, extensive opportunities for feeding and growth, and refuge from predators.	-% or area of altered subtidal, intertidal and foreshore habitat -Area of existing log boom area -Area of eelgrass beds -Area of sedge -Area of anoxic sediments -Percent undeveloped estuary -Percent of disturbed and undisturbed habitat -Capacity of the estuary habitat to accommodate the salmon	-Chinook smolts require intertidal and subtidal vegetation for foraging & rearing, and intertidal pools and channels for refuge -Healthy natural streamside vegetation is important for maintaining temperatures, controlling erosion and sedimentation and supplying food items important to juvenile Chinook (Healey 1991). -Smolts require adequate migration corridors between rearing areas and the ocean; these areas must have appropriate cover and food for migrating smolts (Raleigh *et al.* 1986). - Ocean-type Chinook salmon typically reside in estuaries for several months before entering coastal waters of higher salinity (Healey 1980; 1982; Congleton et al. 1981; Levy and Northcote 1981; Kjelson et al. 1982; Beamer et al. 2005; Bottom et al. 2005).

Critical Habitat Requirements	Limiting Factors	Factors Affecting Habitat Features	Benchmarks	Potential Indicators	Details
					-They require food, cover and conditions that are intermediate between fresh and saltwater to complete smoltification (Healey, 1991; Allen and Hassler, 1986). -Throughout this period, kelp and other shoreline vegetation provide an important refuge from predators as well as a productive environment for insects and plankton. -Chinook salmon fry prefer protected estuarine habitats with lower salinity, moving from the edges of marshes during high tide to protected tidal channels and creeks during low tide, although they venture into less-protected areas at night (Healey 1980; 1982; Levy and Northcote 1981; 1982; Kjelson et al. 1982; Levings 1982). -As the fish grow larger, they are increasingly found in higher-salinity waters and increasingly utilize less-protected habitats, including delta fronts or the edges of the estuary before finally dispersing into marine habitats (Beamer et al. 2005). In contrast to fry, Chinook salmon fingerling, with their larger size, immediately take up residence in deeper-water estuarine habitats (Everest and Chapman 1972; Healey 1991).
4. Low levels of predation and competition e.g with hatchery fry, other species	**LF50:** Predation of fry in the lower river and estuary	-Predation is affected by the abundance & type of predators. -Competition for food and habitat may vary with relative size and timing of hatchery releases.	-Goal to maintain the seal population to ____ resident adults in the estuary/lower river	-____% or __ ha of eelgrass and other vegetative cover in the estuary -Area of vegetative cover, eelgrass cover, sedge beds, kelp	-Presence of habituated Harbor Seals noted in many areas, not only in estuaries but also moving into river systems. -Chinook are preferred source of food by resident *Orcinus orca* -Predation on Chinook fry is affected by the abundance of predators. Competition for food and habitat can be challenging for smaller wild fry if larger

Critical Habitat Requirements	**Limiting Factors**	**Factors Affecting Habitat Features**	**Benchmarks**	**Potential Indicators**	**Details**
				-Timing and abundance of hatchery fry release -# of adults or % mortality due to predation	hatchery fry are released between mid-April to June. Good vegetative cover and habitat complexity in the estuary can provide refuge areas for fry from predators. -The timing of hatchery released fry can offset competition with wild fry and potentially reduce early marine mortality.
5.Good water quality	**LF51:** Reduced fry survival due to decreased water quality	-Effluent from pulp mills, industrial, urban and agricultural development -Sewage treatment facilities, septic fields -Industrial use -Pleasure boats, marinas Climate change. Effluent from pulp mills, industrial and urban development	-DO levels between 5-9 mg/L -Temperature range for smoltification and outmigration is from 3.3 to 12.2 ^{0}C (McCullough, 1999). He also found that smolt lethal and loading stress occurs at temperatures over 18.3 ^{0}C. Wedemeyer *et al.* (1980) in McMahon (1983) noted the following: elevated water temperatures can accelerate smoltification and shorten the smolting period which may result in seaward migration of smolts at a time when the conditions are unfavourable. Temperature should not exceed 10 ^{0}C in late winter to prevent accelerated smoltification; temperatures should not exceed 12 ^{0}C during smolting and seaward migration in the spring to prevent shortened duration of smolting and onset of desmoltification as well as to reduce the risk of pathogens	- Stratification, DO levels, TSS - Number and type of industrial developments -Type and amount of effluent discharged. -Permitted waste management discharges	
6. Low levels of competition or predation from aquatic invasive species	**LF52:** Mortality of fry and smolts due to predation and competition from AIS	-Presence of aquatic invasive species			
7. Low levels of anthropogenic interference e.g. light/sound pollution	**LF53:** Mortality or reduced fitness as a result of anthropogenic disturbance	- Lights in the estuary, noise pollution - Boat traffic and anthropogenic activity			Highly lit estuaries can result in increased levels of predation by seals and other predators

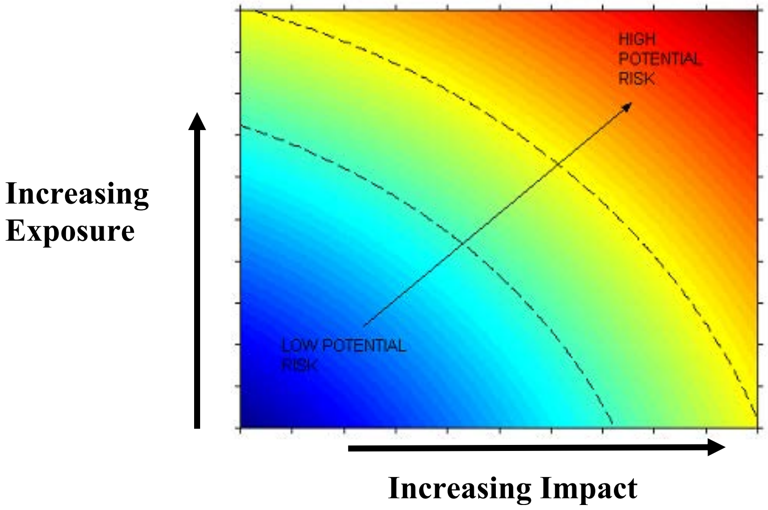
Critical Habitat Requirements	**Limiting Factors**	**Factors Affecting Habitat Features**	**Benchmarks**	**Potential Indicators**	**Details**
8.Adequate Salinity Regime	**LF54:** Inadequate Freshwater in Estuary	-Climate change			
9. Adequate amounts of escape habitat	**LF55:** Lack of adequate escape habitat- areas of eelgrass, kelp, LWD, boulders etc where fish can hide	-Development			

APPENDIX 5: RISK ASSESSMENT PROCESS

At the Straw Dog Scoring workshop we conducted a first pass (Level 1) risk assessment using expert opinion to determine the risk posed by human and natural factors limiting the productive capacity of the Nicola watershed to produce Chinook salmon. These 'limiting factors' were assessed for two time frames, first based on "current conditions", and second based on "future conditions - 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. At some future date, the highest ranked risks may be re-assessed based on more quantitative methods and relationships (Level 2).

The framework for this risk-assessment is based on accepted methods from the Government of Canada Treasury Board 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".

Thus, the biological risk of a limiting factor is related to the amount of exposure that the population has to this factor (in both time and space) and the impact it has on the population. The impact is related to the percent change in the return of Chinook to the river, but changes in key biological characteristics such as age at maturity, sex composition, fecundity, and run timing of the Chinook populations are also considered. The following graph shows how biological risk increases as both impact and exposure increase.



Stages of Risk Assessment:

The first phase of the risk assessment was to decide on the populations and species that will be considered for the Risk Assessment, as well as to determine objectives. Following this phase, we had a second phase called Scoping. The Scoping phase involves the collection of specific information for the population under consideration. Following the Scoping phase is the Risk Assessment scoring phase.

Setting of Objectives:

Nicola Chinook have a very plastic and complex life history, depicted in Figure A5-1 below.

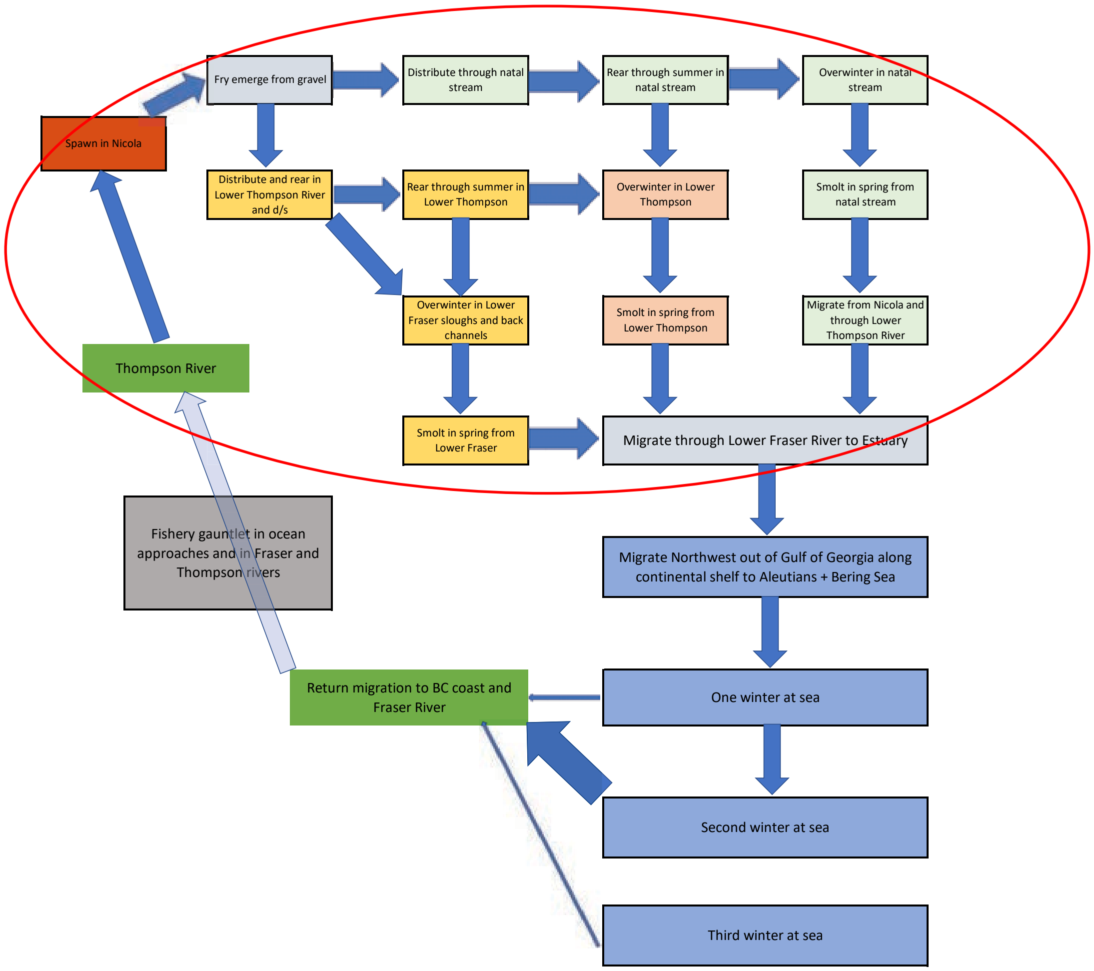


Figure A5-1: Nicola Watershed Chinook Life History

The red circle highlights the component of the life history that will be addressed during this RAMS process

To date, most RAMS processes have focussed on the freshwater life history stages, beginning with terminal migration and spawning (adults), incubation (eggs and alevins), early rearing (fry and smolts) and estuary rearing (smolts). For Nicola Chinook, the complex life history and large number of interconnected habitats make a RAMS a particularly complex task. For this reason, the first Nicola RAMS process was focussed on adult life stages during terminal migration into the Nicola River, through spawning, egg incubation, early rearing and overwintering, up to the stage that smolts leave the Nicola and Thompson Rivers for the Fraser on their way to the Strait of Georgia. We did not include the Fraser River migration period, the Fraser estuary or any of the marine component in this first risk assessment process. It is expected that subsequent RAMS processes will focus on those other stages of the life history.

Scoping Phase:

Scoping involves three steps:
1. Characterizing the population of interest & developing a life history table
2. Describing the biological characteristics & requirements of each life history stage in its habitat
3. Identification of limiting factors and key issues impacting each life history stage

Characterization:

The first step is to gather relevant population data for the population under consideration. We examined the data that are available for each life history stage for the species such as fecundity data, relative abundances, percentage mortality data etc. This enables us to build a simple life history table such as depicted in Table A5-1.

We are particularly interested in the values of recruits per spawner (R/S) and the numbers of spawners. These values provide information on the productivity parameter (α) and the capacity parameter (β) of the Ricker curve- and are two important statistics that describe the relationship of the salmon with the habitat and ecosystem. Given that the risk assessment process should enable us to prioritise key limiting factors, knowledge of these statistics will enable us to examine the possible benefits of various mitigative strategies that are designed to improve either the productivity or the habitat capacity for the population under consideration.

Table A5-1. Generic Life History Table.

Habitat	Life History Phase	Estimated mortality rate	Estimated relative abundance
1. River	Spawner		
	Eggs		
2. River	Fry		
3. River/estuary	Smolt		
4. Ocean	Ocean year 1		
	Ocean year 2 + (recruits)		Recruit abundance is tightly defined by the cohort analysis
5. Terminal area	Terminal migrant		
6. River	Holding adult		
7. River	Spawner		

Number of Spawners = S
This estimates the β statistic (capacity parameter of Ricker curve)

Number of Recruits = R

R/S is estimate of α, a measure of the productivity of the population.

Critical Habitat Requirements:

Different life history stages of salmon occur in interconnected habitats and have various requirements during their life history (Figure A5-2). As part of the risk assessment process, we need to examine the biological requirements for each life history stage, and determine how well these requirements are met in the available habitats available for the population under consideration. This step involved identification of the critical habitat requirements for each life history stage of Nicola Chinook.

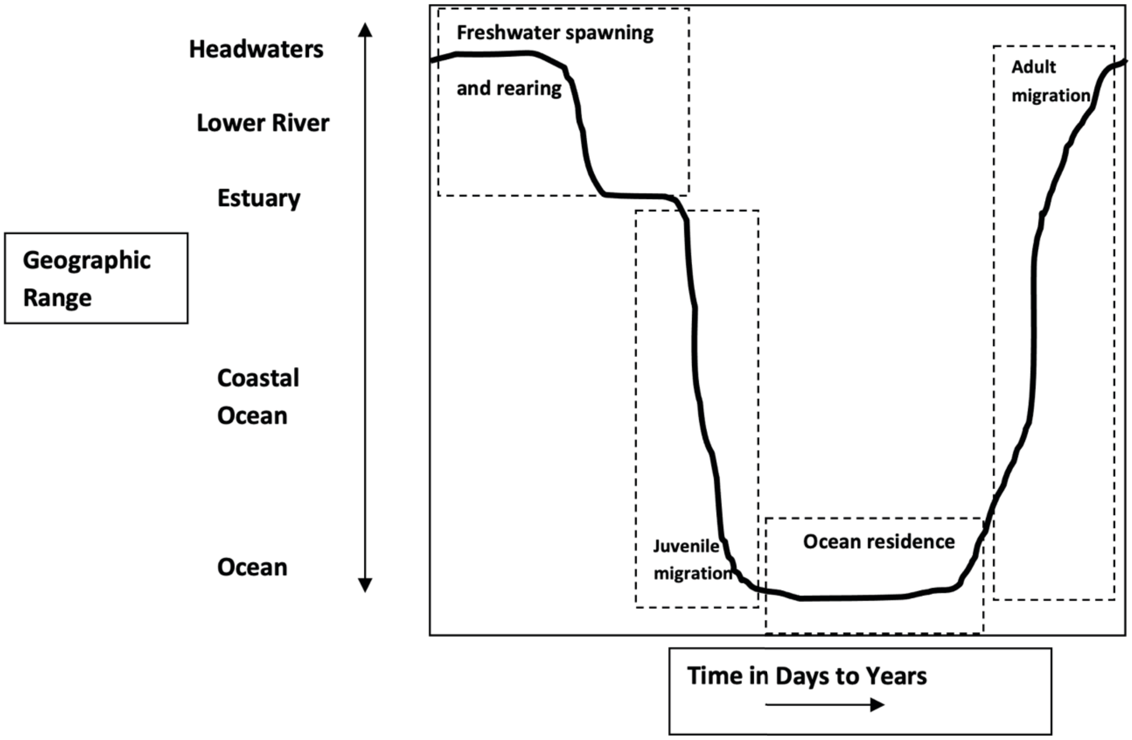


Figure A5-2. The concept of salmon life history trajectory across ecosystem units (the space-time landscape). Nicola Chinook will have various critical habitat requirements at each life history stage.

Gather limiting factors and assess their risk to the Nicola Chinook population:

The next step involved the identification of limiting factors and key issues that impact the different life history stages of Nicola Chinook. These lists of limiting factors, organized by life history stage and habitat encountered, are basically a number of alternative hypotheses for declines in salmonids. In many cases, there may be knowledge gaps, incomplete time series and other data gaps, which are identified.

The list of critical habitat requirements, possible limiting factors and their possible impacts on Nicola Chinook are provided in **Appendix 4** above. This information was further developed and provided as a handout at the straw dog workshop. At the workshop, the expert panel was asked to look over these suggested limiting factors and to provide feedback. Often at this stage, additional limiting factors may be added.

Risk Assessment Scoring Phase:

The key steps for the scoring process are:
1. Risk assessment scoring of biological risk by each workshop participant
2. Consensus is reached amongst the group
3. Scoring the level of uncertainty; data and knowledge gaps are identified
4. Limiting factors are ranked in order of those posing a Very High, High, Moderate
5. Development of action items to address high risk factors and knowledge gaps

During the workshop, the Panel examined the key limiting factors that are affecting Nicola Chinook, and worked as a team to provide an initial scoring of the "exposure" and "impact" for each limiting factor.

In each case, the final consensus score was reached by the group after discussion and were recorded into an Excel spreadsheet, where automatic calculations resulted in a final "Biological Risk Score".

Colour-coding of these scores enables easy visual interpretation of the level of risk for each limiting factor, with dark red denoting "Very High Risk", pale red "High Risk", orange "Medium Risk" and pale green "Low Risk" or "Very Low Risk".

Scoring the "Exposure" Term

Exposure is based on combining 1) the spatial scale of the limiting factor, and 2) the temporal scale of the limiting factor. The methodology required the Panel to use ***their expert opinion and/or knowledge of data or reports*** as they scored each of these terms, and then discussed with others in the group to develop a consensus value. Rationale and citation of existing data/reports is documented at this step. Once these two scores are entered into the Excel Spreadsheet, the final value for the "Exposure" term is automatically calculated.

a. The Spatial Scale Score

Limiting factors are rated in terms of the spatial scale based on the percentage of the critical habitat of a particular life history stage which is affected, or on the percentage of the population itself that is affected (Table A5-2).

A full rationale should be provided for this score.

By critical habitat, we mean any area of habitat that is necessary for the survival or recovery of Nicola Chinook.

Table A5-2. Spatial Impact Score Guide

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

b. The Temporal Scale Score

The frequency at which an identified factor limits production of the species is called the "temporal score". The 5 categories of temporal frequency are described in Table A5-3 below. The group's opinion on the temporal score should be supported by a short rationale and/or citation of documented knowledge such as data or reports.

Table A5-3. Temporal Impact Score Guide

Score	Frequency of the limiting factor occurring
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" Term

The "impact" score is based on the expected magnitude of impact of the factor 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. The possible impact scores related to change in subsequent return to river are shown in Table A5-4. Longer term change resulting from impacts on sex ratio, fecundity, age of maturity, size, etc. also could be significant.

The expert team worked to agree on a score which was entered into the Excel spreadsheet for each limiting factor. Again, the full rationale for how a particular impact score was derived must be provided. If there is disagreement amongst the experts, or if key information is lacking, the Hobday method suggests the highest impact score be assigned to that particular factor.

Table A5-4. Impact criteria to score potential risk.

Level	Score	Description
Minor	1	Less than 10% change in subsequent return to river.
Moderate	2	11-20% change in subsequent return to river.
Major	3	21-30% change in subsequent return to river.
Severe	4	31-50% change in subsequent return to river.
Critical	5	50% + change in subsequent return to river.

Recording the uncertainty/confidence levels in scores

There is always some level of uncertainty associated with predicting impacts of any limiting factor on fish or fish habitat. Uncertainty can arise due to 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 uncertainly does need to be described and taken into account at this risk assessment stage.

Thus, this risk assessment methodology requires that straw dog team provided confidence ratings for the risk scores that were produced from the Level 1 risk assessment. These ratings may be 1 (low confidence) or 2 (medium confidence) or 3 (high confidence) (Table A5-5).

Table A5-5. Confidence Scores

Confidence	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:

Finally, workshop participants were also be asked to provide scores for the following:

Current Trend –In the context of the last 10 years is this limiting factor increasing, decreasing or showing no trend? Score this between (1) strongly decreasing, (2) somewhat decreasing, (3) stable, (4) somewhat increasing, and strongly increasing (5).

Future Trend – What will be the trend 50 years from today? This will require workshop participants to discuss the predicted impacts of climate change. Score this between (1) strongly decreasing, (2) somewhat decreasing, (3) stable, (4) somewhat increasing, and strongly increasing (5).

APPENDIX 6: AGENDA FOR WORKSHOP 1 (STRAW DOG SCORING TEAM)

Nicola RAMS Agenda- Straw Dog Scoring

When: Weds October 6 and Thursday October 7 1-4.30pm

Where: ZOOM

October 6:
- 1pm: Welcome & Goals (IP)
- 1.20pm: Stock Assessment Summary (RB)
- 1.40pm: Habitat Overview (TW)
- 2pm: Climate Change Predictions (IP)
- 2.05pm: Habitat Status Maps (MS/IP)
- 2.20pm: Scoring Methodology (IP)
- 2.15pm: Nicola Model (KW)
- 2.30pm: Work through limiting factors for Adult Migration and Spawning
- 3pm: Break
- 3.15pm: Continue discussion of limiting factors for Adult Migration and Spawning and begin Incubation Phase
- 4.30pm: Adjourn

October 7:
- 1pm: Recap of Day 1
- 1.20pm: Complete Incubation and work through limiting factors for Juvenile Rearing
- 3pm: Break
- 3.15pm: Ranking of scores, afternoon discussion to collate data gaps, potential action items, next steps.
- 4.30pm: Adjourn

APPENDIX 7: AGENDA FOR WORKSHOP 2 (NICOLA COLLABORATIVE TECHNICAL AND RESEARCH COMMITTEE) RAMS WORKSHOP.

When: Monday February 7 and Tuesday February 8 9-4.30pm

Where: ZOOM

February 7:

- 9am: Welcome & Goals (Isobel Pearsall)
- 9.20am: Stock Assessment Summary (Richard Bailey)
- 9.40am: Habitat Overview (Tom Willms)
- 10am: Climate Change Predictions (Isobel Pearsall)
- 10.05am: Habitat Status Maps (Miranda Smith)
- 10.30am: Break
- 10.45am Scoring Methodology (Isobel Pearsall)
- 11am: Nicola Model (Kyle Wilson)
- 11.30am: Examine high and very high risk limiting factors for Adult Migration and Spawning
- 12.30pm: Break
- 1.30pm: Continue discussion of limiting factors for Adult Migration and Spawning and begin assessment of high and very risks for the Incubation Phase
- 4.30pm: Adjourn

February 8:

- 9am: Recap of Day 1
- 9.20am: Complete Incubation Phase and work through high and very high risk limiting factors for Juvenile Rearing
- 10.30am: Break
- 10.45am: Continue discussion of limiting factors for Juvenile Rearing
- Noon: Break
- 1pm: Ranking of scores, afternoon discussion to collate data gaps, potential action items, next steps.
- 4.30pm: Adjourn

APPENDIX 8: STRAW DOG RAMS SCORING RESULTS

Note that * denotes that these LFs were flagged after 2021 flooding for further discussion at the Nicola Collaborative Research and Technical Committee 2nd RAMS workshop.

NICOLA BASIN CHINOOK

Life History Phase:	Life History Requirement - Critical Habitat	Sort order by LF & CONFIDENCE	Issue or Limiting factor	**Current Biological Risk category**	**Future Biological Risk Category**
Terminal Migration and Spawning					
adult	**Safe holding habitat confluence of Thompson-Nicola**	**1**	LF1: Unsanctioned fisheries in the confluence of Thompson-Nicola	Low	High
adult	**Adequate flows to facilitate upstream passage of spawners**	**2**	LF2: Limited or delayed spawner access	Low	Moderate
adult	**Unrestricted access**	**3**	LF3: Potential delays in upstream migration due to counting fences, fishways and other manmade structures	Low	Low
adult	**Unrestricted access**	**4**	LF4: Reduced access through natural falls and natural barriers	Low	Low
Adult *	**Dynamic equilibrium in channel morphology, capacity, and depths and natural level of sediment transport**	**5**	LF5: Aggradation creates a migration barrier in the river during adult migration	Low	Low
adult	**Clear and safe passage with adequate refuge habitat**	**6**	LF6: Loss of good quality refuge habitat and safe migration route through the river due to channelization, loss of habitat complexity, pools and instream cover features as a result of GW extraction	High	Very High
adult	**Suitable water quality**	**7**	LF7: High water temperatures in the river during the late summer/early fall migration period can increase migration mortality and sublethal stress	Moderate	Very High

NICOLA BASIN CHINOOK

Life History Phase:	Life History Requirement - Critical Habitat	Sort order by LF & CONFIDENCE	Issue or Limiting factor	**Current Biological Risk category**	**Future Biological Risk Category**
adult	**Suitable water quality**	**8**	LF8: Poor water quality conditions during the late summer/early fall migration period (low DO, coliform levels, deleterious substances)	Low	Low
adult	**Availability of high quality and sufficient quantity spawning habitat**	**9**	LF9: Lack of natural gravel recruitment to mainstem spawning sites.	Low	Low
adult	**Availability of high quality and sufficient quantity spawning habitat**	**10**	LF10: High suspended sediment loads can reduce spawning habitat quality by compacting gravel and reducing interstices critical for egg deposition and incubation	Low	Moderate
adult	**Availability of high quality and sufficient quantity spawning habitat**	**11**	LF11: Colonization of invasive species (e.g. Didymo sp) that reduces spawning habitat quality.	Low	Low
Adult *	**Availability of high quality and sufficient quantity spawning habitat**	**12**	LF12. Lack of a sufficient quantity of good quality spawning habitat	Low	Low
Adult *	**Low levels of predation during migration and spawning**	**13a**	LF13: Mortality due to predation at spawning grounds	Low	Moderate
adult	**Low levels of predation during migration and spawning**	**13b**	LF13b:Mortality due to unsanctioned fisheries during migration and at spawning grounds	Moderate	High
adult	**Lack of anthropogenic disturbance**	**14a**	LF14a: Disturbance to natural migration activity due to anthropogenic restoration impacts	Moderate	Moderate
adult	**Lack of anthropogenic disturbance**	**14b**	LF14b: Disturbance to natural spawning activity due to anthropogenic impacts	Low	Moderate
adult	**Lack of anthropogenic disturbance**	**14c**	LF14c: Disturbance to spawning or migration as a result of cattle trampling	Low	Low

NICOLA BASIN CHINOOK

Life History Phase:	Life History Requirement - Critical Habitat	Sort order by LF & CONFIDENCE	Issue or Limiting factor	**Current Biological Risk category**	**Future Biological Risk Category**
adult	**Lack of disease during migration and spawning**	**15**	LF15: Sublethal impacts due to disease	Low	Moderate
Freshwater Incubation					
egg – alevin *	**Good water quality conditions**	**16**	**LF16:** High suspended sediment loads that reduce egg to fry survival and emergence of alevins	Moderate	Moderate
egg - alevin	**Good water quality conditions**	**17a**	**LF17a:** Increased numbers of ice days resulting in mortality of eggs and alevins	Moderate	Low
egg - alevin	**Good water quality conditions**	**17b**	**LF17b:** Non-optimal water temperatures that reduce fry survival by changing emergence time in relation to food availability	Low	Low
egg - alevin	**Good water quality conditions**	**18**	**LF18:** High levels of pollutants or toxins that reduce egg to fry survival	Low	Low
egg - alevin	**Good water quality conditions**	**19**	**LF19:** Low DO which reduces egg to fry survival	Low	Low
egg – alevin *	**Suitable flow regime**	**20**	LF20: Lower low flows that dewater redds and reduce incubation survival	High	High
egg – alevin *	**Stable flow regime**	**21**	LF21: More frequent and higher peak flows over winter can scour/disturb redds	Moderate	Moderate
egg – alevin *	**Appropriate spawning gravel**	**22**	LF22: Egg mortality due to inadequate spawning gravel, or as a result of gravel instability	Moderate	High
egg - alevin	**Minimal disturbance to redds**	**23**	LF23: Reduced egg to fry survival due to chum or other salmonid overspawn	Low	Low
egg - alevin	**Minimal predation of eggs and alevins**	**24**	LF24: Predation of eggs, alevins and fry/smolts by fish (sculpins, brown trout) and birds (mergansers)	High	Very High
egg - alevin	**Lack of invasive species**	**25**	LF25: Egg /alevin mortality due to redd disturbance by invasive or expanding endemic species	Low	Low

NICOLA BASIN CHINOOK

Life History Phase:	Life History Requirement - Critical Habitat	Sort order by LF & CONFIDENCE	Issue or Limiting factor	**Current Biological Risk category**	**Future Biological Risk Category**
egg - alevin	**Lack of anthropogenic disturbance**	**26**	LF26: Egg mortality due to redd disturbance by humans	Low	Low
Freshwater Rearing					
Fry *	**Good water quality conditions**	**27**	**LF27:** High water temperature combined with low DO can suffocate fry or reduce overall fitness during the early summer/fall	High	Very High
Smolts *	**Good water quality conditions**	**28**	**LF28:** Low water temperature and lack of groundwater influx resulting in ice in interstitial spaces	Low	Low
fry/smolts	**Good water quality conditions**	**29**	LF29: Toxic water quality conditions can increase fry mortality or reduce fitness.	Moderate	Moderate
fry/smolts	**Good water quality conditions**	**30**	**LF30:** High levels of sedimentation leading to clogging of interstitial spaces and loss of rearing habitat	Moderate	Very High
fry/smolts	**Adequate food supply**	**31**	LF31: Mortality or fitness impacts as a result of lack of food	Moderate	High
fry/smolts	**Adequate instream complexity and riparian complexity**	**32**	LF32: Mortality or fitness impacts as a result of inadequate in-stream complexity and riparian complexity	Very High	Very High
fry/smolts	**Adequate water levels and connectivity**	**33**	LF33: Increased use of low quality OC habitats	Moderate	High
fry/smolts	**Natural flow regime**	**34**	LF34: Higher and earlier flows that prematurely displace juveniles downstream and reduce overall fry survival	Moderate	Very High
fry/smolts	**Natural flow regime**	**35**	LF35: Low flows reduce seasonally available off channel and tributary rearing habitat.	Very High	Very High
fry/smolts	**Absence of invasive species**	**36**	LF36: Mortality or fitness impacts as a result of competition or predation from Aquatic Invasive Species (AIS)	Low	Moderate

NICOLA BASIN CHINOOK

Life History Phase:	Life History Requirement - Critical Habitat	Sort order by LF & CONFIDENCE	Issue or Limiting factor	**Current Biological Risk category**	**Future Biological Risk Category**
fry/smolts	**Absence of invasive species**	**37**	LF37: Alteration of natural riparian structure and ecological integrity as a result of colonization of invasive species	Low	Low
fry/smolts	**Absence of invasive species**	**38**	LF38: Impacts to juvenile migration as a result of invasive plant species	Low	Low
fry/smolts	**Low levels of competition with other wild salmon/ hatchery fry /other species**	**39**	LF39:Mortality or fitness impacts as a result of competition with other salmon, hatchery fry/smolts and/or other species	Low	Low
fry/smolts	**Low levels of predation to fry**	**40**	LF40: Mortality as a result of high levels of predation in the river	Moderate	High
fry/smolts	**Low levels of fish disease**	**41**	LF41: Mortality or fitness impacts as a result of disease	Low	Low
fry/smolts	**High quality rearing habitat with good instream complexity**	**42**	LF42: Lack of high-quality rearing habitat throughout the river both mainstem and side channels and tributaries	Very High	Very High
fry/smolts	**Unrestricted migration and passage: mainstem, off channel and tributary habitat**	**43**	LF43: Lack of access to historical tributary and off channel habitat.	Moderate	High
fry/smolts	**Unrestricted migration and passage: mainstem, off channel and tributary habitat**	**44**	LF44: Limited juvenile passage at lake fishway, tributary culverts etc	Low	Low
fry/smolts	**Lack of anthropogenic disturbance**	**45**	LF45: Mortality or fitness impacts as a result of anthropogenic disturbance	Low	Low
fry/smolts	**Absence of negative hatchery impacts**	**46**	LF46: Mortality or fitness impacts as a result of hatchery introgression	Very High	Very High