



# West Shore Arctic Grayling Abundance and Critical Habitats

**Mesilinka River Snorkel Surveys 2024**

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# West Shore Arctic Grayling Abundance and Critical Habitats: Mesilinka River Snorkel Surveys 2024

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## Prepared For

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# Executive Summary

Following construction of the W.A.C. Bennett dam in 1967 and the formation of Williston Reservoir, well over 200 km of critical Arctic Grayling habitats were flooded in the Parsnip River, Finlay River, and the lower reaches of tributaries to these systems. Flooding of these critical habitats resulted in the extirpation of many local populations and restriction of surviving Arctic Grayling to larger stream networks above the flood zone including the Nation River, Omineca River, Osilinka River, and Mesilinka River, which are tributaries to Williston Reservoir's west shore.

In 2024, the Fish and Wildlife Compensation Program – Peace Region (FWCP) and study partners initiated a multi-year snorkeling study of Arctic Grayling abundance and critical habitats in west shore streams, beginning with the Mesilinka River which has had prior snorkeling surveys in long-term index sites over the 1992-1999 period. The study addresses key information gaps about conservation status, locations of critical habitats, and limiting factors which limit FWCP's ability to proceed with effective conservation, restoration, and enhancement actions for Arctic Grayling, thereby addressing Action #9 of the FWCP's *Rivers, Lakes, and Reservoirs Action Plan*: "Conduct research and monitoring of Arctic Grayling to obtain data related to conservation status, critical habitats, and key limiting factors."

To balance needs for accuracy and precision in index sites versus good spatial coverage to understand Arctic Grayling distribution and critical habitats, the snorkeling study design includes two elements: 1) replicated surveys in long-term index sections and 2) single-pass reconnaissance surveys. In long-term index sections, to improve accuracy and estimate precision for estimates of abundance ( $N$ ), detection probability ( $p$ ) < 1 was accounted for both with a mark-resight study and also by applying a no-mark modeling approach that analyzes variability of the replicate counts relative to expectations for binomially-distributed count data given the parameters  $N$  and  $p$ .

In August 2024, replicated snorkeling surveys were conducted under ideal viewing conditions of low, clear flows (6.3-8.4 m underwater visibility in long-term index sections). Arctic Grayling >20 cm were observed at very low abundance. Raw counts, mark-resight estimates for  $N$ , and no-mark estimates for  $N$  were significantly and substantially lower in 2024 versus the 1992-1999 period. The comparison suggested that 2024 system capacity may be as little as 20% of that observed during the 1992-1999 period. Single-pass, reconnaissance surveys in the upper Mesilinka River, Lay Creek, and Tutizika River suggested extreme low abundance of Arctic Grayling never exceeding one per reconnaissance reach, indicating a potential range contraction over the course of the past 3 decades.

Field observations and environmental data from 2024 potentially link the population decline to the operation of known limiting factors for Arctic Grayling. Observed water temperatures approached but did not exceed 16.7°C limit for adult Arctic Grayling occupancy estimated previously in the Parsnip River watershed. However, they exceeded the preferred thermal range for the species of 10.1-13.0 °C above which Arctic Grayling expend a significant amount of energy to thermoregulate, potentially identifying warm August water temperature in the Mesilinka River as a factor reducing system capacity.

Hydrological changes leading to increased peak flows, increased fine sediment, and loss of pool habitat also affect Arctic Grayling system capacity and are linked to watershed disturbance. Cumulative watershed disturbance within the Mesilinka River watershed, as estimated by the GIS indicator Equivalent Clearcut Area, has undergone a five-fold increase from <10% during the 1992-1999 period to approximately 40% in 2024. Observations of the field crew indicated loss of pool habitat, which may be related to loss of riparian forest, bank erosion, and mass wasting, as a potential factor limiting capacity for the core of the Arctic Grayling distribution in the Mesilinka River.

The implications of declines in the Mesilinka River Arctic Grayling population for viability of Arctic Grayling within the Omineca core area (metapopulation) as a whole are currently unknown and depend on demographic connections (for adult and juvenile life stages) among adjacent populations in the Mesilinka, Osilinka, and Omineca watersheds. To gain the necessary clarity about critical habitats, their relative importance, and priorities for conservation and enhancement, we have several recommendations focused on upcoming Arctic Grayling surveys in the Omineca core area:

1. During mark-resight studies to estimate detection probability and abundance (recommended and conditionally approved for 2025), limit marking to a concise period immediately prior to snorkeling to minimize violations of the assumption of site closure.
2. Account for the effects of variable visibility on snorkeling detection probability for Arctic Grayling, by i) incorporating mark-resight studies into the surveys where feasible, ii) conducting repeat surveys of long-term index sections during comparable visibility conditions (not applicable in 2025), or iii) by incorporating visibility as a covariate of detection probability during statistical analysis.
3. Continue development of no-mark modeling methods to analyze replicated count data in collaboration with UNBC's Freshwater Fish Ecology Laboratory.
4. Conduct adult Arctic Grayling abundance monitoring in adjacent streams of the Omineca core area (Osilinka River, Omineca River) to contextualize the decline in Arctic Grayling abundance in the Mesilinka River and to update the conservation status assessment for the core area as a putative metapopulation (conditionally approved for 2025).
5. Conduct a retrospective study of demographic interconnectedness and key natal watersheds among streams of the Omineca core area using the non-lethal technique of fin ray microchemistry.

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# 1 Introduction

Following construction of the W.A.C. Bennett dam in 1967 and the formation of Williston Reservoir, over 200 km of critical Arctic Grayling (*Thymallus arcticus*) habitats were flooded in the Parsnip River, Finlay River, and the lower reaches of tributaries to these systems. Flooding of these critical habitats resulted in major impacts to Arctic Grayling of the upper Peace Basin, including the extirpation of many local populations and restriction of surviving Arctic Grayling to larger stream networks above the flood zone (Stamford et al. 2017).

Arctic Grayling populations survive in unflooded portions of the Parsnip, Nation, Omineca, Osilinka, Mesilinka, Ingenika, and Finlay watersheds. However, remnant populations face current threats both from Williston Reservoir's footprint impacts and other human-caused ecological and physical habitat changes. Remnant populations appear to be demographically and genetically isolated from each other and the reservoir appears to restrict their migrations between streams (Clarke et al. 2005). The Arctic Grayling is also a species for which land use-related habitat degradation has been linked to population declines (Armstrong 1986; USFWS 2010; Cahill 2015; Stamford et al. 2017). Forestry and other land use activities, which have been facilitated by reservoir creation, threaten remnant populations in the Williston Reservoir watershed and provide increased access for anglers to remote areas where protective regulations are difficult to enforce.

A key aim of the Fish and Wildlife Compensation Program – Peace Region (FWCP) is to conserve and enhance fish and their habitat, which supports and maintains thriving fish populations in watersheds that are functioning and sustainable (FWCP 2020: *Peace Region Rivers, Lakes, & Reservoirs Action Plan*). To facilitate this aim for Arctic Grayling populations, FWCP conducted a major study to evaluate the existing knowledge base relative to key strategic objectives for species and habitat conservation and enhancement. The resulting *Arctic Grayling Synthesis Report* (Stamford et al. 2017) identified key knowledge gaps limiting FWCP's ability to initiate conservation and enhancement actions, and described conservation units termed 'core areas.' Core areas are defined in Stamford et al. (2017) as groups of populations within which the potential for genetic and demographic connections exist, like the metapopulation concept of Levins (1969). Highest priority knowledge gaps and monitoring needs were summarized in the companion document *Arctic Grayling Monitoring Framework* (Hagen and Stamford 2017).

Within core areas on the western shore of Williston Reservoir (Nation, Omineca, Ingenika), highest-priority information gaps identified in the guidance documents include: 1) the lack of abundance and trend data for assessing the status of populations (ID #2, Table 1; Hagen and Stamford 2017), and 2) the lack of critical habitat information for key life stages (ID #2, #4, #5, Table 1; Hagen and Stamford 2017). The rationale for prioritizing these information gaps is presented in FWCP's recommended sequence of monitoring actions and exemplifies that knowledge of status and critical habitat locations is key to enable further assessments of limiting factors within these locations. Understanding these factors (e.g., resources, environmental conditions, competition) that restrict the growth of populations (i.e., limiting factors) is fundamental for directing successful enhancement actions (Hagen and Stamford 2017).

To address the lack of quantitative population data (since the 1990s; Wilson et al. 2008) and detailed critical habitat information for Arctic Grayling on Williston's west shore (outside of the Ingenika River), in 2024

FWCP-Peace Region initiated a 5-year monitoring study beginning with the Omineca core area. The study is led by Chu Cho Environmental in collaboration with University of Northern BC's Freshwater Fish Ecology Laboratory (FFEL), BC Ministry of Water, Land, and Resource Stewardship (WLRS), Tsay Keh Dene Nation, Kwadacha Nation, and senior consultants John Hagen and Mike Stamford. The study is modeled on a successful, 5-year snorkeling study in the Parsnip River watershed (Parship core area) that included replicated snorkeling surveys in long-term index sections to assess trend, as well as reconnaissance snorkeling and environmental DNA (eDNA) surveys to estimate total abundance and the distribution of critical habitats (Hagen and Stamford 2023).

Downstream snorkeling surveys are an attractive population monitoring methodology for stream-dwelling, subadult and adult salmonids including Arctic Grayling. Relative to other methodologies such as electrofishing or seine netting, snorkeling surveys are non-invasive, relatively rapid, and can be utilized within a variety of habitats. Up to 10 km of stream habitat can be surveyed in a day (Hagen and Baxter 2005), meaning that the sampling fraction within stream reaches can be high and extrapolation errors reduced relative to other methods. Although these attributes are attractive, the accuracy of snorkeling counts may vary widely among systems, with species differences, underwater visibility, instream cover, and observer experience all being potential variables affecting snorkeling detection probability (Northcote and Wilkie 1963; Schill and Griffith 1984; Slaney and Martin 1987; Zubik and Fraley 1988; Young and Hayes 2001; Hagen and Baxter 2005).

Because snorkelers do not normally observe all the fish present in a survey reach, the accuracy of snorkeling surveys (detection probability) is measured using methods such as mark-resight trials, which improve estimates of population growth rate (trend) and abundance (Slaney and Martin 1987; Zubik and Fraley 1988; Young and Hayes 2001; Hagen and Baxter 2005; Korman et al. 2010). In the Parsnip River watershed, a no-mark method for analyzing detection probability and abundance was also developed in collaboration with UNBC's FFEL, using replicated snorkeling count data between 1995-2022 (Hagen and Stamford 2023). Briefly, the method analyzes variability of the replicate counts relative to expectations for binomially-distributed count data given parameters  $N$  (abundance) and  $p$  (detection probability), which are fit to available replicate data (Olkin et al. 1981; Royle 2004).

Already-existing time series of calibrated snorkeling counts provide extremely valuable baseline abundance data and enable evaluations of change (trends) in Arctic Grayling populations and exist for only two streams (Ingenika and Mesilinka rivers) entering the west shore of Williston Reservoir. Prior surveys in the mainstem Mesilinka River were completed over seven years in three index sections between 1992 through 1999 to evaluate responses in fish abundance during a slow-release fertilization experiment (Wilson et al. 2008). These data, therefore, provided a rare opportunity to evaluate changes in the state of the population and their potential relation to watershed conditions, so these same Mesilinka surveys were prioritized for the first year of the project. In this report, we detail results from snorkeling surveys in these same index sections, which were analyzed using both replication and mark-resight methods to estimate their accuracy. Results also include single-pass reconnaissance snorkeling surveys in previously unsurveyed sections of the Mesilinka watershed to evaluate the distribution of Arctic Grayling upstream of index sections.

## 2 Goals and Objectives

The FWCP is partnership between BC Hydro, the Province of BC, Fisheries and Oceans Canada, First Nations and public stakeholders. In the Peace Region, FWCP's aim is to conserve and enhance fish and wildlife impacted by the construction of the W.A.C. Bennett and Peace Canyon dams on the Peace River, and the subsequent creation of the Williston and Dinosaur Reservoirs (FWCP 2020).

The first goal of the West Shore Arctic Grayling snorkeling study is to enable conservation and enhancement actions that maintain or improve the status of populations on the west shore and the productivity of their critical habitats. The second goal is to work with study collaborators and supporters to achieve effective fish and fish habitat stewardship and enhancement actions in west shore watersheds. These goals are well aligned with the overarching strategic objectives of FWCP's *Rivers, Lakes, and Reservoirs Action Plan* (FWCP 2020).

The study had the following specific objectives in 2024 (Year 1):

1. Conduct replicated snorkeling counts of Arctic Grayling and other species in three long-term index sites of the Mesilinka River.
2. Conduct a concurrent mark-resight study in long-term index sites to facilitate estimation of snorkeling detection probability and abundance of Arctic Grayling, then utilize the estimates to evaluate changes in Arctic Grayling populations and system capacity relative to the 1992-1999 period.
3. Acquire counts of Arctic Grayling and other species in reconnaissance sites of the Mesilinka River using a single-pass snorkeling survey method, to refine estimates of the distribution of critical summer rearing habitat.
4. Identify key information needs addressed by the 2024 study results, additional information needs which remain, and conservation actions which are justified based on integrated results of this study and prior FWCP Arctic Grayling studies in the Omineca core area.

These study objectives address Action #9 of the Rivers, Lakes, and Reservoirs Action Plan (FWCP 2020):

“Conduct research and monitoring of Arctic Grayling to obtain data related to conservation status, critical habitats, and key limiting factors” (p. 12).

### 3 Study Area

The Omineca Core Area, situated approximately 280 kilometers north of Prince George, is the largest among eight core areas described for the upper Peace Basin (Figure 1). Arctic Grayling critical habitats are distributed among three main drainages, including Omineca River, Mesilinka River, and Osilinka River watersheds on the eastern slopes of the Omineca Mountains (Stamford et al. 2017). Flooding of Williston Reservoir inundated approximately 34 km of fluvial habitat in the lower Omineca River, and about four kilometers of lower Mesilinka River as well as Black Canyon about 20 kilometers downstream from Mesilinka confluence. Black Canyon was a box canyon with a set of bedrock constrained rapids and, prior to flooding, may have restricted upstream movements by fish and demographic connections between large river habitats in the lower Omineca and Finlay rivers. Other anthropogenic disturbances from, for instance, linear developments, forest extraction, and angling exploitation, have been most extensive in the downstream reaches including lower Omineca River, Osilinka River, and Mesilinka River while the Omineca watershed remains relatively undisturbed upstream of the Osilinka River (Stamford et al. 2017).

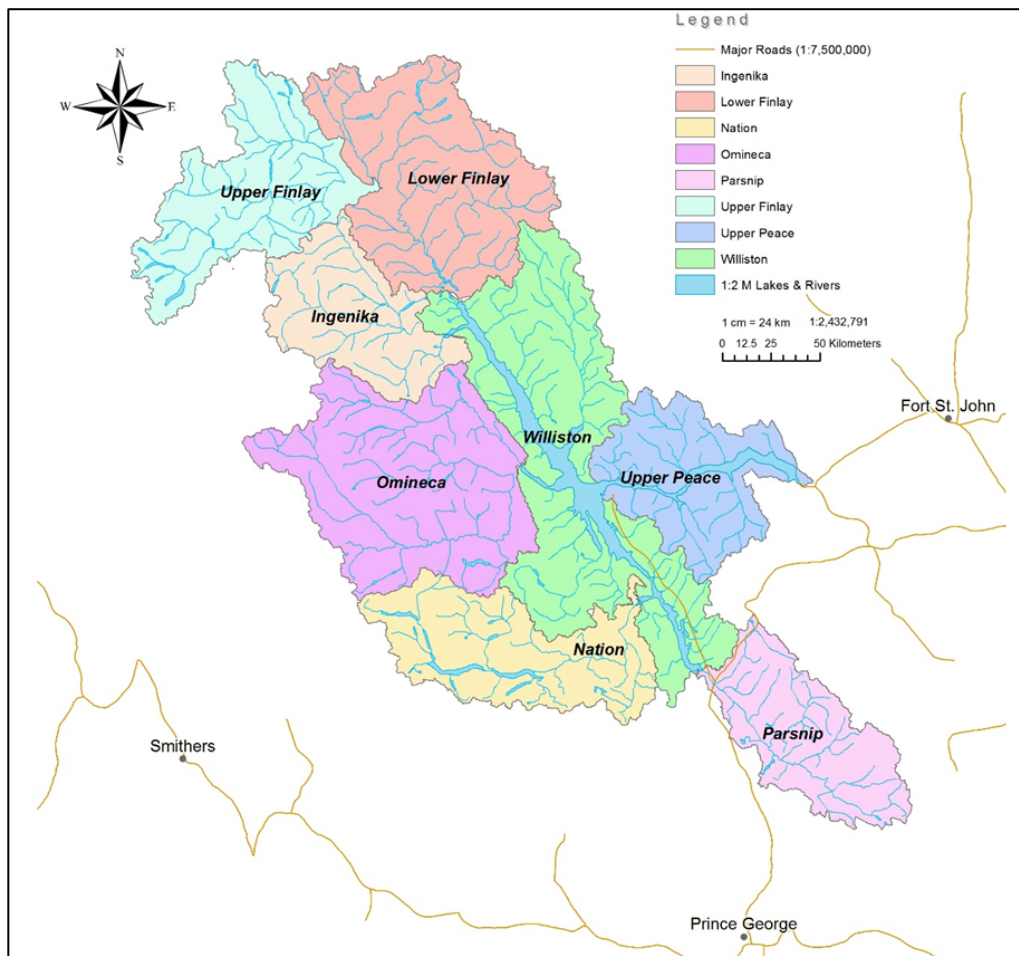


Figure 1. Arctic Grayling ‘core areas’ (putative metapopulations) comprising the range of Arctic Grayling in the Williston Reservoir watershed (reprinted from Stamford et al. 2017).

The Mesilinka River is a sixth order lake-headed stream and drains an area of 3,298 km<sup>2</sup>, which comprises about 25% of the Omineca core area. The river flows for about 120 kilometers before draining into Williston Reservoir at the furthest downstream end of Omineca core area. Streamflow is snowmelt driven, with peak discharge occurring, on average, from late-May through June with summer baseflows being attained by mid-August (Water Survey of Canada Station 07EC003 *Mesilinka River above Gopherhole Creek*). A substantial portion of the watershed drains higher elevation, mountainous areas. Sediment loads are moderated during spring runoff by the presence of Aiken and Tutizzi Lakes, however, and water clarity is relatively high in the Mesilinka River mainstem for much of the year.

The Mesilinka River is exceptionally low in nutrients (Nitrogen and Phosphorus) and the salmonid fish populations (growth, abundance, and trophic structure) were studied intensively between 1992 and 1999 during a slow-release fertilizer experiment (Wilson et al. 2008).<sup>1</sup> Forestry and fisheries reconnaissance inventories (Beak International 1998; ECL Envirowest 1998; Environmental Dynamics 2000, 2001) have also provided past records of Arctic Grayling distribution in the Mesilinka River watershed (Figure 2). These records have indicated Arctic Grayling use the mainstem Mesilinka River between the mouth and Aiken Lake, and potentially also the lower reaches of larger tributaries (Lay, Kliyul creeks) (Stamford et al. 2017).

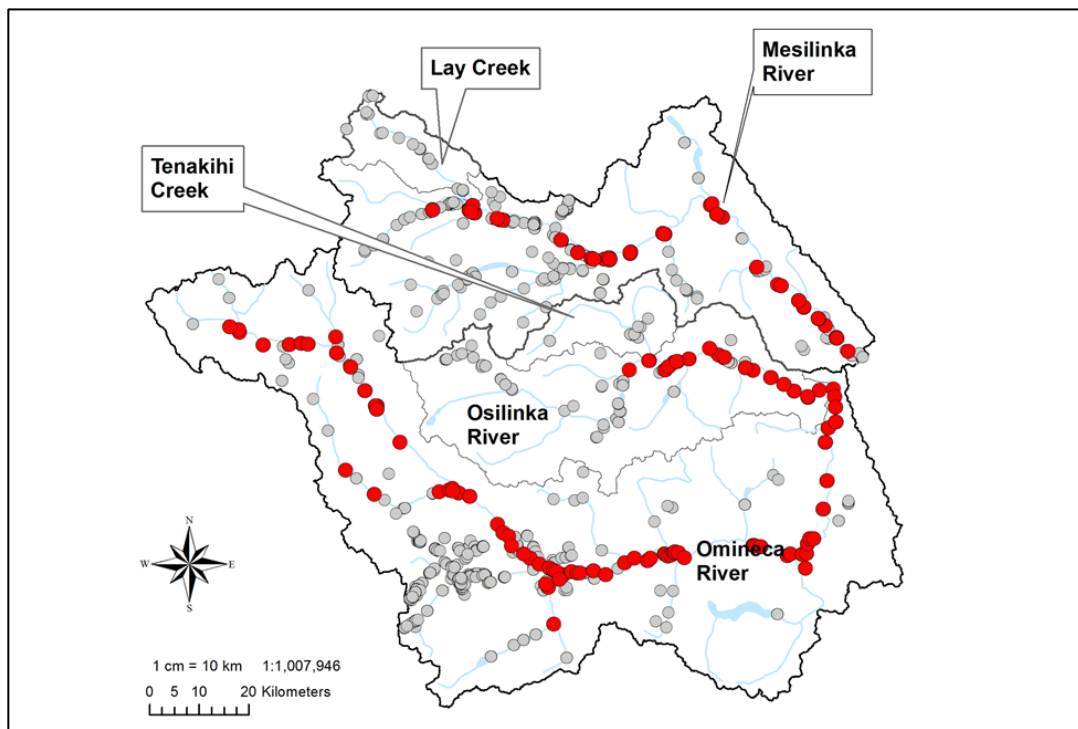


Figure 2. Distribution of records for past sampling of Arctic Grayling (red circles) and all other species (light grey circles) within sub-basins of the Omineca core area (reprinted from Stamford et al. 2017).

<sup>1</sup> After six years of fertilizer additions a significant response in the benthic invertebrate community was observed, mostly an increase in Chironomids (midges), but only a weak and insignificant response in the growth and abundance of Arctic Grayling (Wilson et al. 2008).

Prior observations, as well as tagging and genetic studies of Mesilinka River Arctic Grayling, suggest population connections with other watersheds although the extent of these are unknown (Clarke et al. 2005; Stamford and Taylor 2005; Wilson et al. 2008; Shrimpton and Clarke 2012; Shrimpton et al. 2012). During the 1992-1999 fertilization experiment, many tagged Arctic Grayling were recovered in the Mesilinka River and often within the same reach where they were captured in previous years, but other adults were recaptured in the Osilinka River (Wilson et al. 2008). Early spring recaptures of three tagged adults entering the lower Mesilinka River suggest they may have been migrating upstream to spawn after overwintering somewhere in the lower Omineca River or Williston Reservoir (Wilson et al. 2008). There are also reports from locals observing large groups of adult Arctic Grayling migrating upstream during early spring under the lower bridge crossing of the Mesilinka River about five kilometers upstream from the mouth (Stamford et al. 2017).

In addition to Arctic Grayling, other species present in the Mesilinka River watershed include Bull Trout (*Salvelinus confluentus*), Rainbow Trout (*Oncorhynchus mykiss*), Mountain Whitefish (*Prosopium williamsoni*), Lake Trout (*Salvelinus namaycush*), Pygmy Whitefish (*Prosopium coulterii*), Lake Whitefish (*Coregonus clupeaformis*), Slimy Sculpin (*Cottus cognatus*), Longnose Sucker (*Catostomus catostomus*), Largescale Sucker (*Catostomus macrocheilus*), Burbot (*Lota lota*), Peamouth Chub (*Mylocheilus caurinus*), and Lake Chub (*Couesius plumbeus*) (BC Geographic Warehouse, accessed March 2025).

## 4 Methods

### 4.1 Study Design

Fausch et al. (2002) pointed out that a focus on a limited number of index sites within a stream network, which is typical, may leave many key features affecting abundance and the distribution of critical habitats out of view. Examples of potential features affecting Arctic Grayling distribution and abundance are waterfalls or high gradient sections limiting access, unsuitable thermal regimes, key geomorphology attributes affecting habitat suitability, and distributions of competitor species. They argue that a more continuous view of the entire, spatially heterogeneous river environment, which they term the 'riverscape,' is essential for effective research and conservation of fishes and other aquatic biota (Fausch et al. 2002) which is a study goal.

Achieving the study goals requires not only that the abundance of Arctic Grayling in west shore tributaries be understood with reasonable accuracy and precision, but also that spatial coverage is adequate to enable estimates of distribution and total abundance. To balance these needs, we have designed a multi-year study with two core study components. The first of these is the use of replicated snorkeling counts in index sections to provide a quantitative baseline for comparisons over time. To optimize the data for no-mark methods of analyzing the replicated count data, while remaining cost-effective, ideally 4-6 sites in a river would be replicated a minimum of 2 times (Dowd 2020; Hagen and Stamford 2023). This was not possible in the Mesilinka River watershed, where we wished to re-survey the 3 long-term index sections that had been previously established. Because of the length of these sections, these surveys utilized the entire budget allocated for the replicated surveys in 2024.

The second core component of the study design is comprised of single-pass snorkeling surveys paired with environmental DNA (eDNA) sampling to delineate critical adult/subadult rearing habitat and estimate abundance in reconnaissance sections. Application of these methods in the Parsnip River watershed 2018-2022 enabled estimates of total Arctic Grayling abundance among Parsnip River tributaries and refined estimates of the distribution of critical habitats (Hagen and Stamford 2023). Single-pass reconnaissance surveys, which were included in the 2024 study in the Mesilinka River watershed, enable greater spatial coverage by foregoing replication by additional crews. Environmental DNA analysis, which was not conducted in 2024 because of budget limitations but is proposed for subsequent study years, is also a cost-effective and accurate means for refining estimates of the distribution of Arctic Grayling when fish are present within 1.5 km of the sampling location (Hagen and Stamford 2023).

The use of replicated count data for estimating detection probability and abundance requires an abundance of data and/or the use of untested assumptions about the statistical distribution of Arctic Grayling counts (Olkin et al. 1981; Royle 2004; Joseph et al. 2009). In the Parsnip River watershed, where this method has been used successfully, this abundance of data exists because virtually all snorkeling surveys in long-term index sections since 1995 have been replicated (Hagen and Stamford 2023). Replicated count data from west shore tributaries however, is sparse. They have long-term potential but require augmentation in the short term. We have augmented the west shore replicated count data in two ways. First, we have included

a mark-resight calibration component in our study design to increase the site-specific accuracy and precision of abundance estimates, as well as providing validation for the development of hierarchical models. This was especially important in 2024 because of a change in the snorkeling crew size relative to prior surveys in the Mesilinka River from the 1992-1999 period, and the existence of mark-resight estimates from 1992-1999 enabling a quantitative comparison between the two periods.

The second way our study design augments replication data from the west shore tributaries is through the incorporation of replicated count data from both the west shore and Parsnip River tributaries<sup>2</sup> into a single, generalized modeling approach for Williston Arctic Grayling. In this generalized approach, variation in detection probability among sites and years is modeled through the incorporation of environmental covariates stream width and underwater visibility.

## 4.2 Survey Conditions

The feasibility and safety of snorkeling surveys in mountain streams depends on good water clarity and low-to-moderate stream flows. Advance knowledge of stream flows and precipitation at the field site can help minimize unanticipated costs from aborted field days due to high, dirty water and safety concerns. The Water Survey of Canada (WSC) Station *Mesilinka River above Gopherhole Creek (07EC003)* is located on the Mesilinka River near its mouth. In August 2024, this WSC station provided real-time stream discharge data that was utilized to assess the conditions during snorkeling surveys.

Two physical habitat attributes potentially affecting snorkeling detection probability were collected in the field. These include: 1) underwater visibility and 2) wetted stream width. We measured underwater visibility in snorkeling survey sections in two ways: 1) horizontal underwater Secchi disk visibility (Figure 3), and 2) horizontal underwater distance at which the species identity of a 375 mm Arctic Grayling model could no longer be discerned. Since 2022, we have approximated visibility to a black-and-white Secchi disk using a white waterproof notebook, which has approximately the same area of white as a Secchi disk, held against a black dry suit leg. We measured wetted stream width using a laser range finder. Visibility was measured three times per reach, at the beginning, middle and at the end of the index, while wetted stream width was measured at up to 10 locations within each reach.

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<sup>2</sup> from the 2020-2022 period when field methods in the Parsnip were identical to this study (Hagen and Stamford 2023).



**Figure 3. Black-and-white Secchi disk used to estimate horizontal underwater visibility, August 2021.**

An initial comparison of the thermal regime in the Mesilinka River during the 1992-1997 and 2024 surveys was completed from a database created through a concurrently funded FWCP project (O'Connor et al. 2025). Two monitored sites were compared, BELT2 (Zemlak and Langston, 1997) and the Water Survey of Canada Station 07EC003, which were both located at the terminus of Treatment Reach 2 (Figure 4). Mean daily average temperature in August was summarized for comparison at these sites in each survey period. Daily averages for 1992-1997 and 2024 at BELT2 and 07EC003 were presented, alongside daily average for each individual year in 1992-1997 where data was available.

### 4.3 Snorkel Counts

Over the August 12-17 period, 2024, we conducted replicated snorkeling surveys in the three long-term index sections of the Mesilinka River watershed that were previously surveyed during the 1992-1999 fertilization experiment (Figure 4; Wilson et al. 2008). Since that time, these sites have been referred to as Control Reach (Figure A-1; 89.6-99.2 stream km from the mouth), Treatment Reach 1 (Figure A-2; 52.9-61.2 km), and Treatment Reach 2 (Figure A-3; 22.1-30.3 km).

Single-pass snorkeling surveys of 5 reconnaissance sections of the Mesilinka River watershed were conducted over the August 13-15 period. These included a 5.4 km section within the Lay Creek canyon (Figure A-4), a 1.3 km section of lower Lay Creek (Figure A-4), a 2.2 km section of the Mesilinka River immediately below Lay Creek (Figure A-4), a 4.9 km section of the upper Mesilinka River (Figure A-5; 120 to

126 km upstream of the mouth), and a 1.2 km section of the Tutizika River located below Tutizzi Lake (Figure A-6).

Snorkeling surveys were conducted by a crew of 4 observers in dry suits. Two observers were deployed to each side of the stream, with at least one crew member on each side being highly experienced with snorkeling surveys for Arctic Grayling (5 years or more). A fifth crew member was a trained Swiftwater Rescue Technician in charge of safety, who followed the line of snorkelers in an inflatable kayak. Survey lane locations and lane widths were based on underwater visibility conditions and visually estimated habitat suitability (usable wetted width for subadult and adult Arctic Grayling). Where possible observers counted fish in a lane extending in front and to one side only. When the usable wetted width exceeded the width of 4 lanes surveyed in this manner, one or more observers would extend their lane widths and look both ways. In areas where the usable width was less than the sum of the lane widths, one snorkeler would drift through behind the others and temporarily stop counting. If fish moved in reaction to observers, frequent communication ensured that double counting did not occur. In August 2024, in most locations it appeared that the entire suitable width of the Mesilinka River could be covered using these methods.

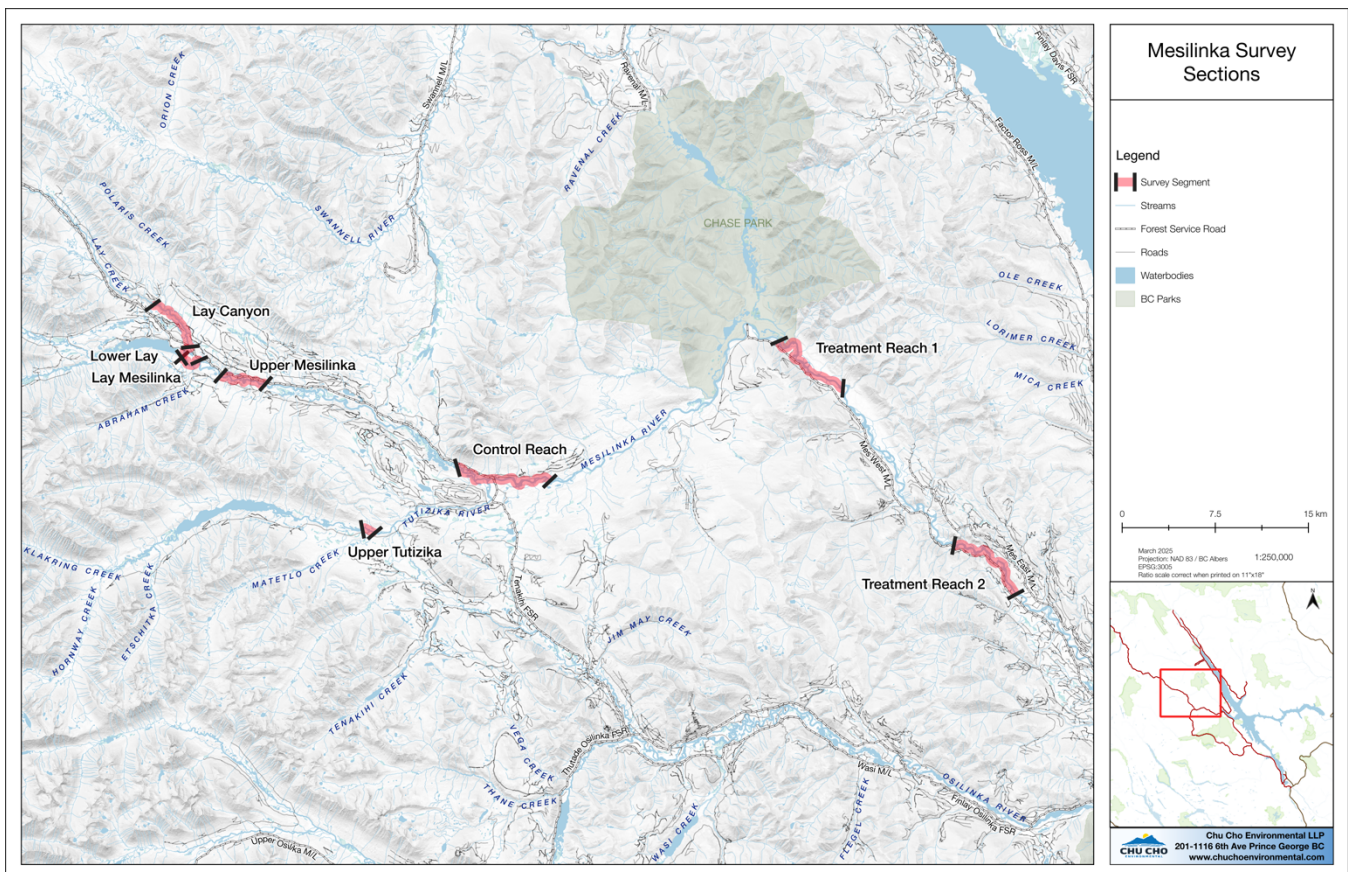


Figure 4. Stream sections utilized to monitor Arctic Grayling abundance in the Mesilinka River in 2024 and during the 1992-1999 fertilization experiment (red sections), as well as sections utilized for single-pass reconnaissance surveys in 2024 (5 sections).

Replicate snorkeling surveys in the long-term index sections of the Mesilinka River occurred on two subsequent days except for Control Reach, where a gap of two days occurred between replicates. To avoid counting bias related to prior knowledge, crew members rotated to the opposite side of the river during the second replicate. Single-pass reconnaissance sections were surveyed by just one crew but were otherwise surveyed using the same method.

Snorkelers recorded observations on wrist-mounted dive slates, with data grouped into 1-km subsections of each long-term index reach. Observed fish were tallied in one of five size categories: 0-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, and 50+ cm. All Arctic Grayling were also inspected for the presence of marks, and marked fish were tallied separately (Section 4.3.1). Snorkeling data were offloaded to the safety boater approximately every 3 km. In addition to their role as the swiftwater rescue technician, the kayaker had the additional duties of announcing the 1-km section boundaries and recording up to 10 wetted stream widths per reach (at each 1-km waypoint marker) with the aid of a laser rangefinder.

Reliable counts require a disciplined effort to organize divers in lanes across the stream, and regular communication among divers to avoid overcounting or missed areas of suitable habitat (Northcote and Wilkie 1963; Schill and Griffith 1984; Slaney and Martin 1987; Hagen and Baxter 2005). In our study, this was facilitated using crews led by biologists with >20 years of snorkeling survey experience.

### 4.3.1 Fish Capture and Marking

Snorkeling-based abundance estimates from long-term index sections should be of comparable accuracy and precision across a time series, to enable reliable estimates of trend. One means of increasing the comparability of surveys is to use identical methods across the time series. In 2024, our snorkeling study design incorporates four observers instead of the six utilized during the 1992-1999 fertilization experiment. During the 1992-1999 period, the population estimation method involved the expansion of counts made by the four mid-channel lanes (to account for the portion of the total wetted width which was not covered), to which the counts made by the two shore lanes were added without expansion (Wilson et al. 2008). This approach was originally designed and evaluated for Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*; Slaney and Martin 1987). In contrast, our study design recognizes that Arctic Grayling prefer areas adjacent to the thalweg of > 1 m depth and are less oriented to riparian cover than other Williston species (Blackman 2004). By defining the survey lane locations and lane widths based on underwater visibility conditions and habitat suitability, our snorkeling surveys in the Mesilinka River could be conducted by a relatively efficient crew size of four swimmers (plus an attending rescue technician in an inflatable kayak).

An alternative to employing the identical methods across a time series is to account for changes in accuracy and precision using quantitative tools for estimating detection probability and abundance in different periods. In 2024, we utilized established mark-resight methods to estimate detection probability and abundance in the Mesilinka River and enable comparisons of these estimates to the 1992-1999 survey period (see Section 4.3.2).

Arctic Grayling capture and tagging occurred between August 8-10, 2024. Fish were captured by angling with artificial flies and small lures in the three long-term index sections of the Mesilinka River. Very low Arctic Grayling capture rates in Control Reach and no captures in Treatment Reach 2 meant the mark-resight study component could only be completed in Treatment Reach 1.

The length of the long-term index sections, which range from 8.3 km to 9.6 km, suggests the assumption of a closed population is reasonable for the mark-resight study. To increase the validity of our assumption, fish capture and marking was not conducted in the top and bottom kilometer of the index sections and replicate swims were completed on consecutive days within four days of the release of marked fish.

Captured fish were not anaesthetized to minimize potential effects of capture and handling on their post-release behaviour. All captured fish were netted in order to facilitate handling then tagged with two, T-anchor tags (Floy Tag & Manufacturing, Inc., Seattle, WA), which were inserted into opposite sides of the fish's back near the posterior insertion of the dorsal fin (Figure 5; Figure 6). Biological sampling included measurements of fork length (mm) and weight (g), a visual assessment of sex, and a sample of a single pelvic fin ray for future genetic and ageing analysis.



Figure 5. Female Arctic Grayling captured and tagged in the Mesilinka River, August 2024. The orange tag signifies the fish was 370 mm or less.



Figure 6. Tagged, male Arctic Grayling illustrating the need for tagging on both sides of the dorsal fin. The white tag signifies the fish was 375 mm or larger. The two colours of tags were utilized to validate subjective underwater size estimation.

### 4.3.2 Analysis of Count Data

Water clarity, stream size, and other factors affect count accuracy such that observed counts are only a portion of the actual number of fish present (see Section 1). Since 1992, snorkel counts have been adjusted for detection probability  $p < 1$  because estimates of actual abundance are necessary to evaluate the effects of the fertilization enhancement (Wilson et al. 2008) and assess conservation status (Stamford et al. 2017). Detection probability and abundance in the Mesilinka River have been estimated through mark-resight studies and also by models incorporating factors affecting detection probability.

To facilitate inference into Arctic Grayling abundance in the Mesilinka River, we present mark-resight results from all years where available, expanded counts from Wilson et al. 2008 and binomial-likelihood model results from 2024.

The primary analysis method utilized by Wilson et al. (2008) to estimate abundance of Arctic Grayling and other species was not mark-resight. Instead, the primary analysis method involved expanding counts based on stream width and visibility, and on assumptions about how these variables affected detection probability (adapted from Slaney and Martin 1987). Counts from four mid-channel lanes were expanded, while unadjusted counts from two shore lanes were added to the total without expansion. This method is incomparable with the estimates provided by our field methods standardized in the Williston watershed as described above. The Mean of the expanded counts in each index section from 1992-1997 was calculated and used to calculate 95% confidence intervals based on data from Wilson et al. (2008).

In order to ensure comparison of snorkel counts adjusted for detection probability we estimated  $p$  and  $N$  using a binomial likelihood model using replicated count data based on the methods of Hagen and Stamford (2023). A long-term objective of this study is to improve on methods for analyzing replicated count data, which is being conducted in collaboration with the Freshwater Fish Ecology Laboratory (FFEL) at UNBC. Model outputs from a hierarchical model in development were unavailable for this version of the draft report.

#### 4.3.2.1 Mark-Resight Analysis

We followed the mark-resight methods implemented by Wilson et al. (2008). Capture and marking methods are outlined in Section 4.3.1. Estimated abundance was calculated for each replicated swim count. This method also allows for an empirical estimation of detection probability ( $p$ ) based on the difference between observed and estimated abundance.

Mark-resight estimates were completed following Chapman's modification of the Lincoln-Peterson mark-recapture method:

$$\hat{N} = \frac{(M + 1)(C + 1)}{(R + 1)} - 1$$

Where:

$\hat{N}$  = Estimated abundance

$M$  = Number of fish marked in each index section

## West Shore Arctic Grayling Abundance and Critical Habitats

$C$  = Number of fish observed during the swim

$R$  = Number of marked fish observed during the swim

This method relies on several key assumptions:

1. Closed population during the survey period – no immigration or emigration between sampling events;
2. Equal capture probability – every individual in the population has an equal chance of being captured in both sampling events;
3. No tag loss or misidentification – marks are not lost, overlooked, or mistaken for unmarked individuals;
4. Random mixing – marked individuals mix randomly with the unmarked population before the second sampling event; and
5. Instantaneous sampling – the time between the first and second capture events is short enough to prevent significant changes in population size.

To provide unbiased estimates this method also requires:

1. The product of the marked and observed fish ( $M * C$ ) must be more than four times the total estimated population ( $MC > 4 * \hat{N}$ ; Robson and Reiger 1964); and
2. The number of marks ( $M$ ) should be  $\geq 20\%$  of the total estimated population ( $M/\hat{N} \geq 20\%$ ; Vincent 1971)

Detection probability from mark-resight data was calculated as follows:

$$\bar{p} = \frac{\bar{C}}{\hat{N}}$$

Where:

$\bar{p}$  = Mean detection probability across replicates

$\bar{C}$  = Mean number of fish observed during replicates

$\hat{N}$  = Estimated abundance from the mark-resight for replicates

We estimated confidence intervals for mean  $\hat{N}$  by estimating confidence intervals for mean  $p$  within a maximum likelihood framework utilizing the binomial probability density function. The deterministic approximation to the method of likelihood profile (Haddon 2001) is as follows:

$$LL(p) = LL(p)_{max} - \frac{\chi^2_{1,1-\alpha}}{2}$$

Where:

$\chi^2_{1,1-\alpha}$  = the  $(1 - \alpha)^{\text{th}}$  quantile of the  $\chi^2$  distribution with 1 degree of freedom

We then divided average  $\bar{C}$  across both replicates by the upper and lower confidence limits of  $\bar{p}$  to estimate the upper and lower confidence limits of  $\hat{N}$ .

#### 4.3.2.2 Binomial Likelihood Model

We used a binomial-likelihood model to estimate detection probability and abundance (Olkin et al. 1981; Royle 2004) within replicated index count data. The method assumes a closed population between replicates, and that Arctic Grayling counts were binomially-distributed random variables

$$n_{ir} \sim \text{Binomial}(N_i, p)$$

Where  $i$  is the site,  $r$  is the replicate among  $R$  replicated surveys,  $N_i$  is the population size at site  $i$  and  $p$  is detection probability. The likelihood statement for data from a site is detailed in Royle (2004) and represented here as:

$$L(N_i, p | \{n_{i1}, \dots, n_{iR}\}) = \prod_{r=1}^R \text{Binomial}(n_{ir}; N_i, p)$$

We estimated  $p$  and  $N_i$  by maximizing the joint likelihood across replicated data from sites in the Ingenika River, Parsnip River watershed, and Mesilinka River since 2020. By only including data from 2020 onwards we felt most confident in the standard collection of covariates wetted width (m) and underwater visibility (m), which were included as covariates of  $p$ . These covariates were previously selected as the most important predictors of  $p$  in a model selection exercise using Akaike information criterion corrected for small sample sizes. The model was fit in Microsoft Excel using the Solver add-in.

## 5 Results

### 5.1 Survey Conditions

#### 5.1.1 Stream Discharge and Water Clarity

Snorkeling surveys in the Mesilinka River watershed occur during mid-August each year, which follows the completion of spring migrations from spawning and overwintering areas to preferred summer rearing areas, and which is also well before dropping water temperatures in the fall trigger emigration to overwintering areas (Northcote 1993; Blackman 2002; Martins et al. 2022).

Snorkeling surveys conducted during the August 8<sup>th</sup> – 17<sup>th</sup>, 2024 period were conducted under conditions of dry weather. Discharge in the Mesilinka River ranged from 27.7 to 33.4 m<sup>3</sup>/s and was below the long-term average level (Figure 7). Observed underwater visibility levels were excellent during the August, 2024 snorkeling surveys. Mean Secchi visibility ranged from 8.3 m to 12.3 m, while the distance at which the species identity of an Arctic Grayling model could be identified ranged from 6.3 m to 8.4 m (Table 1). Furthermore, it appears that the 2024 surveys were conducted under conditions of lower flow and higher underwater visibility than August surveys conducted during the 1992-1999 period (Table 1). Unfortunately, a direct comparison of underwater visibility between 2024 and the 1992-1999 period is not possible because visibility levels were estimated in different ways. Calibration of visibility levels to enable better comparisons will be conducted when we are in the field in 2025.

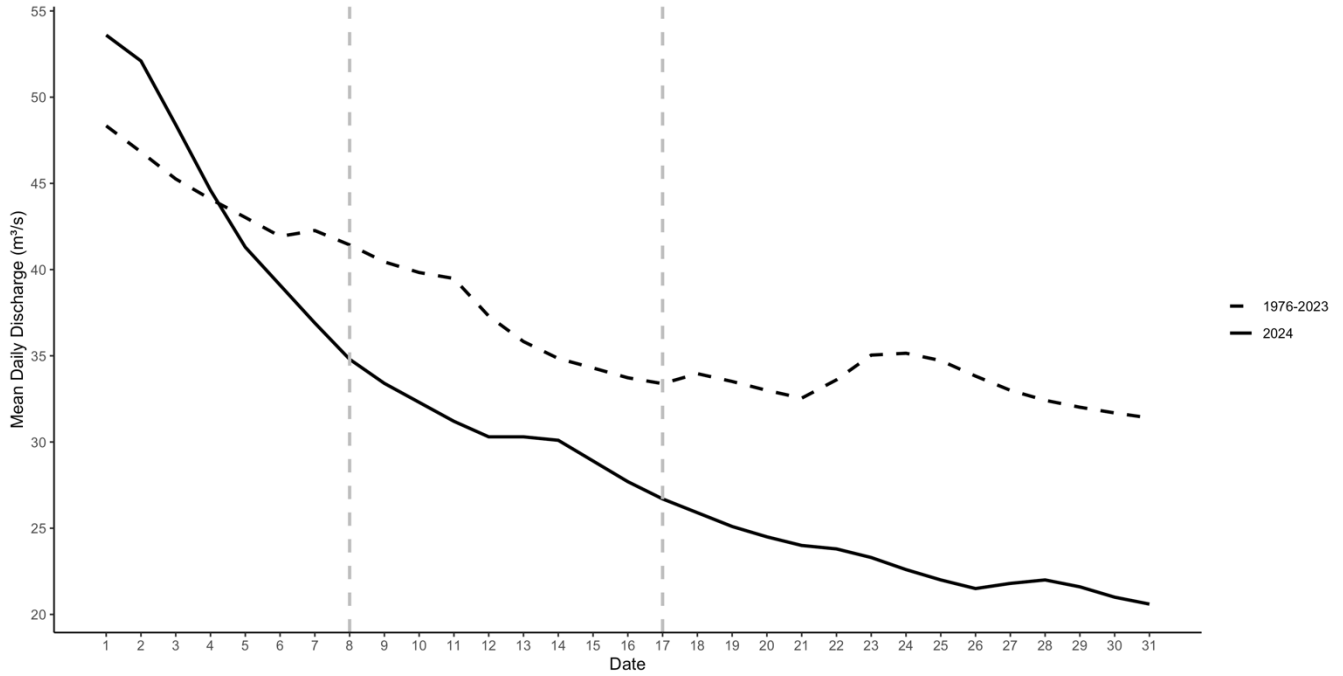


Figure 7. Mean daily discharge (m<sup>3</sup>/s) for Mesilinka River (WSC station 07EC003) during the month of August. The black dashed line shows the historical mean daily discharge from 1976 to 2023 and the solid black line shows the mean daily discharge for 2024. The survey period is indicated with vertical gray bars.

**Table 1. Summary of survey conditions in long-term index sections of the Mesilinka River. Values for the 1992-1999 surveys are reprinted from Wilson et al. 2008.**

Reach	Distance Swam (km)	Swim Dates	Year	Underwater Visibility* (m)	Mean Secchi disk visibility (m)	Mean Wetted Width (m)	Discharge (m <sup>3</sup> /s)
Control	7.5	Aug 22, 23	1992	4.2		37.6	23
	7.5	Aug 16,17	1993	4.8		37.6	46
	6.5	Aug 17,19	1994	2.3		45.7	43
	7.5	Aug 16	1995	2.5		38.5	50
	7.5	Aug 20	1997	2.8		37.8	43
	6.7	Aug 18	1999	3.8		41.1	40
	9.6	Aug 12, 15	2024	6.3 <sup>†</sup>	8.3 <sup>†</sup>	34.1 <sup>‡</sup>	29.6
T1	7.2	Aug 20, 21	1992	4		40.8	26
	7.2	Aug 18, 20	1993	4		40.8	43
	6.5	Aug 15,16	1994	2.5		52	47
	7.2	Aug 14,15	1995	3.2		43	37
	7.2	Aug 18,19	1997	3.1		43.5	47
	7.2	Aug 16,17	1999	3.0, 4.0		46.2	43
	8.5	Aug 13, 14	2024	8.4 <sup>†</sup>	10.9 <sup>†</sup>	38.4 <sup>‡</sup>	30.2
T2	8.1	Aug 18,19	1992	4		38.7	27
	8.1	Aug 19	1993	4		38.7	43
	8.0	Aug 18	1994	2		37.2	42
	8.1	Aug 21, 22	1997	2.7, 4.0		40.1	40
	8.1	Aug 19, 20	1999	3.3		41.4	39
	8.3	Aug 16, 17	2024	8.1 <sup>†</sup>	12.3 <sup>†</sup>	41.8 <sup>‡</sup>	27.2

\*1992-1999 horizontal underwater visibility measured using a gloved hand; 2024 used a 375 mm grayling fish model.

<sup>†</sup>Mean measurement based on three observations.

<sup>‡</sup>Mean measurement based on ten observations.

### 5.1.2 Water Temperature

The observed daily mean in August 2024 at 07EC003 exceeded the average observed daily mean and standard deviation from August 1992-1997 at BELT2 (Figure 8). The maximum observed daily mean temperature in 2024 was 16.1°C, and the maximum observed daily mean temperature from 1992-1997 was 15.1°C. This initial comparison of thermal regimes at the bottom of the long-term index reach Treatment 2 reveals an observable warm shift between the 1992-1997 data and 2024. This observation should be interpreted with caution given it is taken from one site, comparing one year to an average across multiple. The 2024 result is warmer than the previous study period, but did not breach 16.7°C which has been defined as a warm-edge limit for Arctic Grayling occupancy based on past FWCP-funded projects in the Parsnip River (O'Connor 2023). The difference in discharge observed between study period (Table 1) reveals a starker contrast, and the results for observed temperature should be taken in conjunction with that observation.

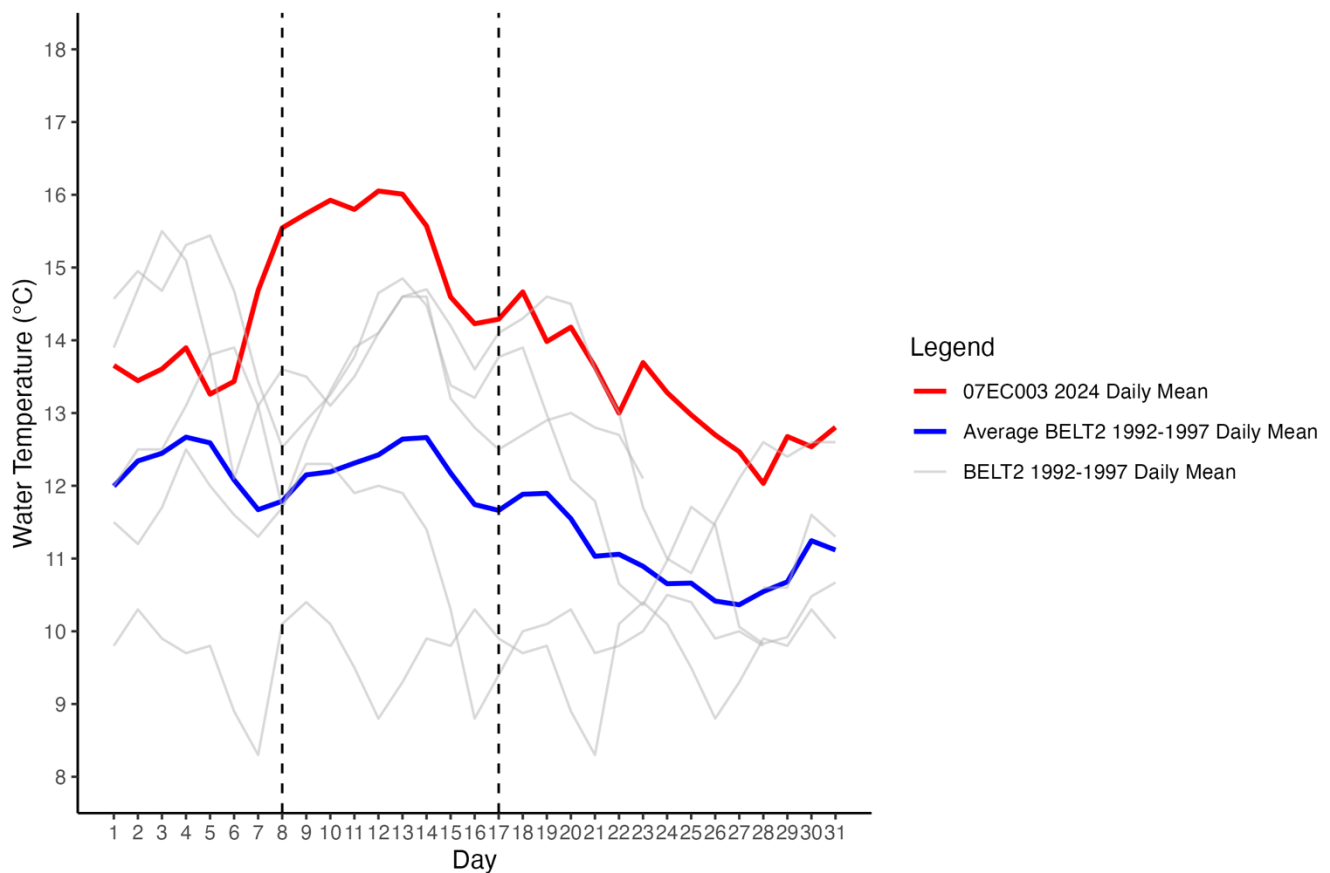


Figure 8. August daily average temperatures observed at a site at the downstream terminus of Treatment Reach 2 in the Mesilinka River. The red line shows the 2024 daily mean for Water Survey of Canada gauge 07EC003, which is located in the Mesilinka River above Gopherhole Creek (within Treatment Reach 2). The blue line shows the average of the daily means recorded at a site below Treatment Reach 2 (BELT2) from 1992-1997 and the grey lines show the daily means at BELT2 for each year in 1992-1997, excluding 1996. The 2024 survey period is indicated by the vertical dashed bars.

## 5.2 Unadjusted Snorkel Counts in Long-Term Index Sections

In long-term index sections of the Mesilinka River, snorkel counts of Arctic Grayling > 20 cm in 2024 ranged from 4 to 28. Raw count data for all target species across the 1992-1999 and 2024 study periods is presented in Table 2.

For all three long-term index sections, counts of Arctic Grayling in 2024 (averaged across the two surveys) are the lowest recorded despite exceptionally good survey conditions (Section 5.1). Averages of mean Arctic Grayling counts across the 1992-1999 period were approximately 4-fold, 2-fold, and 4-fold higher than the 2024 mean counts in the Control, Treatment 1, and Treatment 2 reaches, respectively (Table 2).

In our study, Arctic Grayling were the highest priority for snorkeling observations and our focus for analyses of abundance and trend. However, Bull Trout, Rainbow Trout, and Mountain Whitefish were also counted simultaneously during snorkeling surveys. Long-term trends in raw counts of these other species are not strongly evident, although shifts in the relative importance among reaches is indicated for Bull Trout and Mountain Whitefish potentially related to effects of the stream fertilization experiment (Wilson et al. 2008).

Bull Trout snorkel counts have been consistently low among years and index sections (Table 2). A more reliable method for monitoring Bull Trout abundance in the Mesilinka River watershed is through counts of gravel nests, or 'redds,' following the completion of spawning. Recently, FWCP has approved the addition of Mesilinka River tributary Lay Creek as one of eight long-term index sections in the Williston Reservoir watershed for monitoring Bull Trout abundance and trend using redd counts (O'Connor et al. 2024).

The time series of snorkeling count data indicates that Rainbow Trout are relatively abundant in Treatment Reach 1 and Treatment Reach 2 (Table 2). Unlike the long-term index sections of the Parsnip River watershed (Hagen and Stamford 2023), Rainbow Trout are numerically dominant over Arctic Grayling in some years in index sections of the Mesilinka River. Rainbow Trout counts are of interest because of potential interspecific competition with Arctic Grayling and Bull Trout, with Rainbow Trout expected to become increasingly more prevalent as systems warm (Parkinson and Haas 1996; Parkinson et al. 2012; Hawkshaw and Shrimpton 2014).

Counts of Mountain Whitefish (Table 2) are especially high and variable. Mountain Whitefish are too numerous to count reliably and for this reason were assigned the lowest priority during our snorkeling surveys. Therefore, Mountain Whitefish counts should be considered of low precision and accuracy relative to the other three species.

**Table 2. Observed counts for target species > 20 cm fork length in three long-term index section of the Mesilinka River. Values for the 1992-1999 surveys are reprinted from Wilson et al. 2008. Complete raw count data is found in Appendix B, Table B-1.**

Reach	Year	Arctic Grayling			Rainbow Trout			Bull Trout			Mountain Whitefish		
		Swim 1 count	Swim 2 count	Mean count	Swim 1 count	Swim 2 count	Mean count	Swim 1 count	Swim 2 count	Mean count	Swim 1 count	Swim 2 count	Mean count
Control	1992	54	34	44	4	11	7.5	4	4	4	493	861	677
	1993	24	24	24	6	12	9	3	5	4	306	369	337.5
	1994	10	12	11	19	9	14	4	3	3.5	80	90	85
	1995	30	-	30	6	-	6	5	-	5	326	-	326
	1997	33	23	28	7	11	9	3	2	2.5	334	258	296
	1999	16	16	16	20	9	14.5	2	0	1	185	269	227
	2024	9	4	6.5	15	9	12	9	5	7	519	414	466.5
T1	1992	69	38	53.5	29	34	31.5	16	13	14.5	648	677	662.5
	1993	35	36	35.5	29	34	31.5	8	9	8.5	225	297	261
	1994	32	18	25	49	36	42.5	11	5	8	317	274	295.5
	1995	71	54	62.5	92	56	74	14	18	16	1370	1099	1234.5
	1997	71	68	69.5	43	87	65	13	21	17	766	1062	914
	1999	35	85	35	53	99	76	28	50	39	879	2282	1580.5
	2024	28	22	25	20	20	20	8	6	7	436	329	382.5
T2	1992	26	29	27.5	34	64	49	16	22	19	136	222	179
	1993	20	28	24	50	74	62	19	26	22.5	202	269	235.5
	1994	17	19	18	34	38	36	10	5	7.5	130	165	147.5
	1997	29	26	27.5	114	114	114	15	16	15.5	517	1020	768.5
	1999	26	26	26	152	133	142.5	33	46	39.5	806	782	794
	2024	7	5	6	77	57	67	14	19	16.5	1159	753	956

- No survey conducted due to poor conditions.

## 5.3 Detection Probability and Abundance

Water clarity, stream size, and other factors affect snorkeling count accuracy such that raw counts are only a portion of the actual number of fish present (Section 1). Since 1992, snorkel counts have been adjusted for detection probability ( $p$ ) < 1 because estimates of actual abundance are necessary to evaluate the effects of the fertilization enhancement (Wilson et al. 2008) and assess conservation status (Stamford et al. 2017). Detection probability and abundance in the Mesilinka River have been estimated through mark-resight studies and also by models incorporating factors affecting detection probability.

### 5.3.1 Mark-Resight Studies 1992-2024

Over the August 8-10<sup>th</sup> period in 2024, eighteen marks were deployed in Arctic Grayling >20 cm in the Mesilinka River, 3 within the Control Reach, and 15 within Treatment Reach 1. Fork lengths ranged from 220 to 402 mm with a mean of  $323 \pm 50.3$  mm. The relatively low rate of capture, which included several recaptures of already-marked fish, provided preliminary evidence of low grayling densities in 2024.

In 2024, Lincoln-Peterson mark-resight analysis of snorkel count data was only conducted for Treatment Reach 1, given the very low number of marks deployed elsewhere and our adherence to recommendations by Robson and Regier (1964) as to the number of marks necessary for reasonably accurate and precise population estimates.

Within Treatment Reach 1, 2024 Lincoln-Peterson estimates of abundance  $N$  were 41 and 36 for replicates 1 and 2, respectively (Table 3). This corresponded to a mean of  $N = 39$  with 95% confidence intervals of 32-55 (estimated using the method of likelihood profile). Corresponding estimates of  $p$  were 0.67 and 0.61 for replicates 1 and 2, respectively (mean = 0.64; 95% CI = 0.46-0.79), indicating good conditions for the survey and good performance of the snorkeling method. Guidelines recommended by Robson and Regier (1964) for the number of marks relative to the count and resulting population estimate ( $M \cdot C > 4N$ ) were met for these estimates, as was the guideline suggested by Vincent (1972) that the initial marking of fish ( $M$ ) be  $\geq 20\%$  of the total estimated population ( $N$ ).

To ensure reliable comparisons between mark-resight results from the 1992-1999 and 2024 periods, we only compared mark-resight estimates where the requirement for  $M \cdot C > 4N$  was met, which resulted in a total of 12 estimates of mean  $N$  (including Treatment Reach 1 in 2024) suitable for a comparison across time. The first obvious result of the comparison is that the resighting of marked fish occurred at a much higher  $p$  (roughly two-fold higher) in Treatment Reach 1 in 2024 relative to the 1992-1999 period.

As a consequence of low detection probability of marked fish among replicates during the 1992-1999 period, along with higher raw counts during the surveys, mean mark-resight population estimates are much higher and confidence limits broader relative to 2024. In Treatment Reach 1, the next lowest mean estimate of  $N$  (1993) is more than 4-fold higher than the 2024 estimate and confidence intervals do not overlap, suggesting a substantial population decline.

**Table 3. Summary of mark-resight population estimates for Arctic Grayling >20 cm completed in the Mesilinka River. Values for the 1992-1999 surveys are reprinted from Wilson et al. (2008). Means and confidence limits for mark-resight population estimates are based only on replicates meeting the requirement for  $MC>4N$ .**

			Swim 1			Swim 2			Mark Resight Population Estimate*					Model Estimates of $N$	
Reach	Year	M	$C_1$	$R_1$	$MC>4N$	$C_2$	$R_2$	$MC>4N$	$N_1$	$N_2$	Mean	LCL	UCL	Expanded Counts 1992-1999**	Binomial-likelihood***
Control	1992	28	54	13	yes	34	5	yes	114	169	142	98	210	71	
	1993	25	24	7	yes	24	6	yes	81	93	87	61	157	40	
	1994	12	10	0	-	12	0	no	-	-	-	-	-	64	
	1995	29	30	5	yes	-	-	-	155	-	155	97	496	84	
	1997	17	33	1	no	23	4	yes	-	86	86	49	288	75	
	1999	9	16	4	yes	16	3	no	34	-	34	21	97	31	
	2024	3	9	1	no	4	1	no	-	-	-	-	-		13
T1	1992	21	69	3	no	38	2	no	-	-	-	-	-	100	
	1993	19	35	5	yes	36	5	yes	120	123	122	85	251	59	
	1994	3	32	1	no	18	0	no	-	-	-	-	-	81	
	1995	33	71	13	yes	54	13	yes	175	134	154	138	252	155	
	1997	45	71	9	yes	68	8	yes	331	353	342	250	592	164	
	1999	44	35	10	yes	85	13	yes	147	276	212	167	338	119	
	2024	15	28	10	yes	22	9	yes	41	36	39	32	55		51
T2	1992	13	26	0	-	29	1	no	-	-	-	-	-	42	
	1993	5	20	1	no	28	0	-	-	-	-	-	-	34	
	1994	3	17	0	-	19	1	no	-	-	-	-	-	70	
	1997	21	29	7	yes	26	3	no	83	-	83	53	182	61	
	1999	17	26	6	yes	26	5	yes	69	81	75	53	142	61	
	2024	0	7	0	-	5	0	-	-	-	-	-	-		13

\* Mark-resight population estimates were not utilized in the analysis of abundance if they did not meet guidelines of  $MC>4N$  (Robson and Regier 1964)

\*\* Counts expanded using the method of Wilson et al. (2008) - see text

\*\*\* Point estimates of  $N_{it}$  from Binomial-likelihood model for  $p$  and  $N$  based on replicated count data - see text

# Point estimates of  $N_{it}$  from Poisson-mixture model for  $p$  and  $N$  based on replicated count data - see text

Good performance of the 2024 snorkeling method is not the most likely explanation of the discrepancy between mark-resight estimates of detection probability and abundance for the two time periods. Reduced underwater visibility and increased stream size (Table 1) during 1992-1999 certainly affected count accuracy and precision (Hagen and Stamford 2023). A second factor is the much longer period preceding snorkeling surveys over which tagging occurred (two weeks vs 4 days), which may have violated the assumption of site closure. Therefore, mark-resight data alone are likely inadequate for an accurate comparison of abundance between the 1992-1999 and 2024 time periods.

### 5.3.2 Binomial-Likelihood Model

Estimates of  $N$  from the Wilson et al. (2008) expanded count method are lower than mean mark-resight estimates from the same surveys in almost all cases (Table 3). To enable comparison of 2024 results from the Control and Treatment 2 reaches, where reliable mark-resight estimates were not available, to the 1992-1999 period, we utilized a binomial likelihood model. All the expanded 1992-1999 counts for Treatment Reach 1 are nonetheless significantly higher than the mean 2024 mark-resight  $\hat{N}$  (approximately 1.5-fold to 4-fold higher) and do not fall within the 2024 estimate's confidence interval, thereby corroborating the mark-resight results suggesting a significant population decline in this reach.

Fit to replicated counts, underwater visibility ( $FISH\_VIS$ ), and stream width ( $WIDTH$ ) data from the Ingenika River, Parsnip River watershed, and Mesilinka River since 2020, the resulting logistic model for  $p$  was:

$$p = \frac{1}{1 + \exp \{-(1.502 - 0.0549 * WIDTH + 0.0546 * FISH\_VIS)\}}$$

Resulting estimates of  $\hat{N}$  in 2024 were 13, 51, and 13 for the Control, Treatment 1, and Treatment 2 reaches, respectively. Similar to the mean mark-resight estimate for Treatment 1, these estimates are all lower than estimates from 1992-1999, whether they be computed using the Wilson et al. (2008) expansion method or from mark-resight data (Table 3). The differences are most substantial for the Control and Treatment 2 reaches, where the 1992-1999 estimates are higher by at least 3-fold relative to the 2024 binomial-likelihood model outputs.

By way of validation, the binomial-likelihood model estimate of 51 for Treatment 1 is 30% higher than the mean mark-resight estimate of 39 but falls within its confidence limits. This lack of accuracy, although not grievous, may be due to the underrepresentation in the model of replicated count data from Williston Reservoir's west shore, where index sections have greater widths and higher underwater visibility. This underrepresentation should be rectified within the next few years according to the study design.

## 5.4 Changes in System Capacity

Accurate estimates for abundance in long-term index reaches may not be feasible for the 1992-1999 period, given the concerns about the accuracy of mean mark-resight estimates of  $N$  and the lack of validation for the Wilson et al. (2008) expansion method, as described above. Mean mark-resight estimates and expanded counts can, however, be seen as ‘high’ and ‘low’ estimates for the 1992-1999 period for comparing to the most accurate estimates available for 2024, which are the mean mark-resight estimate for Treatment 1 and the binomial likelihood  $N$  estimates for Control and Treatment 2 (Figure 9). This comparison suggests that 2024 system capacity may be as little as 20% of that observed during the 1992-1999 period. Two facts are caveats on this inference: 1) results from 2024 are a snapshot from a single year, and 2) results from 1992-1999 were collected during an enhancement experiment.

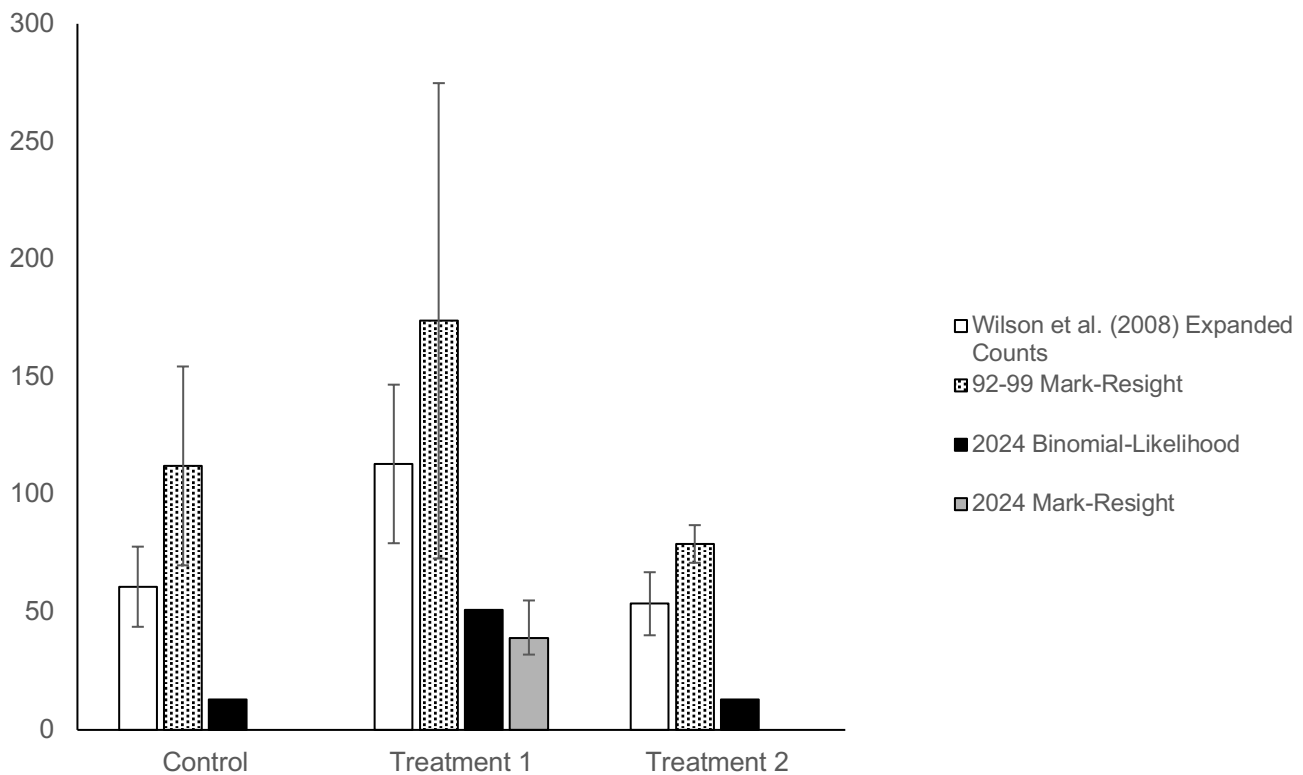


Figure 9. Mean estimated abundance of Arctic Grayling > 20 cm fork length in three long-term index sections of the Mesilinka River, for two time periods 1992-1999 and 2024. Error bars for 92-99 expanded counts and mark-resight represent 95% confidence intervals of the means. Error bars for the 2024 mark-resight were estimated using the likelihood profile method.

## 5.5 Single-Pass Reconnaissance Swims

Single-pass reconnaissance swims in lower Lay Creek, the Mesilinka River below Aiken Lake and upper Tutizika River revealed extreme low densities of Arctic Grayling never exceeding one grayling per reconnaissance reach (Table 4; Appendix A). The lowest 1.5 km of Lay Creek was extensively braided, cutting new channels through the forest and creating numerous debris jams that might hinder movements upstream. Nonetheless, no obvious impasses for fish were observed during the reconnaissance snorkel survey. In 2024, the Lay Creek confluence with Mesilinka River was downstream of Aiken Lake, while in 1996 Lay Creek entered Aiken Lake some distance upstream from the outlet (ECL 1997). Reduced visibility in reconnaissance sections of the upper Mesilinka River (visibility 5.5 and 5.0 meters) likely affected our ability to observe Arctic Grayling given the broad stream width to be surveyed. Nonetheless, given the stream distances surveyed (6.7 km in Lay Creek, 7.1 km in upper Mesilinka; Table 4, Figure 4), it appeared that Arctic Grayling were largely absent from prime-looking rearing habitats, the same areas where adults and yearling juveniles were observed in snorkel surveys and captured by angling both in 1996 (ECL 1997) and 2003 (Clarke et al. 2005). Assessing the potential importance of these streams and reaches for other life stages (e.g., fry and yearlings) will require other sampling methods.

With respect to other species, it is noteworthy that Rainbow Trout are abundant as they were in 1996 (ECL 1997) in the vicinity of Aiken Lake (Lay C Lower, Lay C Confluence, Mesilinka Upper) and in the Tutizika system, potentially indicating a role for interspecific competition in limiting the distribution of Arctic Grayling in the Mesilinka watershed.

**Table 4. Results of reconnaissance surveys completed in the Mesilinka River and upper river tributaries. Complete raw count data is available in Appendix B, Table B-2.**

Stream	Reach**	Length (km)	Wetted Width (m)	Visibility (m)	Date	Arctic Grayling	Bull Trout	Rainbow Trout	Mountain Whitefish
Lay C.	Lower Lay	1.3	14.3*	14 <sup>†</sup>	Aug. 13	1	0	42	85
Lay C.	Lay Canyon	5.4	16.5 <sup>‡</sup>	17 <sup>†</sup>	Aug. 14	1	0	4	27
Mesilinka R.	Lay Mesilinka	2.3	31.5 <sup>‡</sup>	5.5 <sup>‡</sup>	Aug. 13	1	3	33	493
Mesilinka R.	Upper Mesilinka	4.8	32 <sup>‡</sup>	5 <sup>‡</sup>	Aug. 15	1	4	39	351
Tutizika R.	Upper Tutizika	1.2	17 <sup>†</sup>	7.3 <sup>‡</sup>	Aug. 15	0	1	55	208

<sup>†</sup> single measurement

<sup>‡</sup> mean of two measurements

\* mean of three measurements

\*\* reach names are consistent with Figure 4.

## 6 Discussion

### 6.1 Performance of Snorkeling Methods

In British Columbia and in the Williston Reservoir watershed, the health (conservation status) of Arctic Grayling populations in conservation units (core areas) has been assessed using an indicator-based approach (Stamford et al. 2015, 2017). Adult abundance and trend are two key indicators of conservation status (McElhany et al. 2000; O’Grady et al. 2004; USFWS 2010) and are integrated into this approach. Extirpation risks posed by demographic stochasticity, inbreeding depression, long-term genetic losses and genetic drift are magnified greatly at very low levels of adult abundance (Franklin 1980; Nunney and Campbell 1993). Trend is an obvious indicator of population viability - unless the external factors driving negative population growth in the first place (often overharvest and habitat destruction in salmonid populations) can be identified and corrected, extirpation may be a likely outcome (Caughley 1994). FWCP’s current monitoring framework for Arctic Grayling (Hagen and Stamford 2017) identifies a role for abundance monitoring data not only in indicating conservation status, but also in indicating locations of critical habitats, the effects of limiting factors and threats, and the effectiveness of conservation and enhancement actions. A key question therefore is whether our study methods are adequate for these tasks.

As introduced in Section 1, snorkeling surveys are an efficient, non-invasive method for evaluating stream-dwelling trout populations when conditions are suitable, but their accuracy may vary significantly among stream locations and target species (Northcote and Wilkie 1963; Schill and Griffith 1984; Slaney and Martin 1987; Zubik and Fraley 1988; Young and Hayes 2001; Hagen and Baxter 2005). Mark-resight results for Mesilinka River Arctic Grayling in 2024 indicate a situation of high detection probability resulting in relatively precise estimates of abundance (see section 5.3.1). This is a particularly important result in 2024 because snorkeling field methods were changed somewhat relative to the 1992-1999 period. As described in Section 4.3, the snorkeling crew of four observers (instead of six) prioritized snorkeling lanes most suitable for Arctic Grayling, at preferred depths and reduced velocity adjacent to the thalweg as characterized by Blackman (2004). In contrast during 1992-1999, the snorkelling crew consisted of six observers and surveys of shoreline areas were assigned to two of the six (Wilson et al. 2008).

Snorkeling detection probability (equivalent to  $C$  divided by Lincoln-Peterson  $N$ ) in Treatment 1 in 2024 (mean = 0.64; Section 5.3) was roughly double that observed across sites during 1992-1999, a contrast that points to the potential importance of two factors affecting the estimates of  $p$ . First, the assumption of site closure may have been less valid during 1992-1999, when the marking period occurred over approximately 2 weeks prior to snorkeling surveys (Wilson et al. 2008), versus the four-day period immediately preceding swims in 2024. This was the result of marking for multiple species during 1992-1999 while also attending to other fertilization study objectives in the field. Second, underwater visibility during 1992-1999 snorkeling counts appears to have been substantially lower (Table 1). While quantifying the relative effects of these alternatives is not possible, they can be accounted for in the future by incorporating two recommendations of this study (see section 7): 1) limiting marking to a concise period immediately prior to snorkeling during mark-resight studies, and 2) accounting for the effects of variable visibility on detection

probability, either by incorporating a mark-resight element, by conducting repeat surveys in long-term index sections during comparable visibility conditions, or by incorporating visibility as a covariate of  $p$  during analysis.

Mark-resight estimates of  $N$  in 2024 and during the 1992-1999 period were invaluable for assessing the accuracy and reliability of the snorkeling count data and enabling a more accurate comparison of abundance across time. A mark-resight study has been proposed as a component of the 2025 snorkeling study of the Osilinka River watershed, which we strongly recommend (see section 7). However, the requirement for capturing and handling fish is both invasive and time-consuming. This latter factor significantly increases study costs, particularly in situations of low abundance (e.g., 2024) where capture rates may be low. No-mark,  $N$  estimators for the binomial-likelihood model or similar methods (Olkin et al. 1981; Royle 2004) are therefore attractive alternatives for analyzing replicated count data. Our computation of  $N$  in Treatment 1, using both the Lincoln-Peterson mark-resight estimator and the binomial-likelihood model with stream width and visibility as covariates of  $p$ , enabled us to further evaluate the potential of the modeled approach for estimating abundance of Williston Arctic Grayling. As described in Section 5.3.2, the binomial-likelihood model estimate for  $N$  in Treatment 1 was 30% higher than the Lincoln-Peterson estimate but fell within its 95% confidence limits.

Two prior mark-resight estimates provide additional validation for the method improving confidence in its use. In the first case, the binomial-likelihood model estimate for  $N$  in a small reach of the upper Table River surveyed in 2019 (35-31 km; Hagen and Gantner 2020) was 14% higher than the Lincoln-Peterson estimate but well within its 95% confidence interval. In the second, Lincoln-Peterson and binomial-likelihood estimators produced identical estimates for  $N$  for a 4-km reach of the Ingenika River surveyed in 2020 (Hagen and Stamford 2021). With just 3 sites currently available for evaluating model performance against empirical data, additional mark-resight validation is desirable. Nonetheless, so far it appears that models analyzing replicated snorkel count data can produce reasonably accurate estimates of  $p$  and  $N$ , and continued model development is warranted. Importantly, the use of the binomial-likelihood model enabled us to generate population estimates for Control and Treatment 2 reaches, where fish abundance in 2024 was too low to enable efficient marking, for comparison with all years in the 1992-1999 period.

The binomial-likelihood model has several weaknesses. Importantly, the approach does not perform well and may not produce stable results in the circumstance of very low abundance and zero counts (Olkin et al. 1981; Royle 2004), which will likely occur during future snorkeling surveys in Williston Reservoir's west shore tributaries. Joint likelihood models are computationally demanding and may create difficulties attaining model convergence. This second weakness has so far also limited our ability to produce a valid method for estimating confidence intervals for the model outputs. To address these weaknesses, models have been developed which combine the logistic model for  $p$  with a prior distribution for  $N$  (e.g.,  $N$ -mixture models; Royle 2004) to improve stability and performance particularly for the situations where the binomial-likelihood model performs poorly (low abundance and zero counts). A future objective of this study is to utilize the  $N$ -mixture approach to develop improved methods for analyzing replicated Arctic Grayling count data. This development is underway and is being conducted in collaboration with the Freshwater Fish Ecology Laboratory (FFEL) at UNBC. Previous evaluation of the  $N$ -mixture modeling approach has identified that outputs are particularly sensitive to the prior distribution for  $N$  (Joseph et al. 2009). Good model performance

using this approach may therefore require exploration of alternative statistical distributions with a large sample size of snorkeling sites to enable good model fit. The study design for the 2025 snorkeling study incorporates these recommendations (see section 7).

## 6.2 Population Changes and Potential Limiting Factors

The 25-year gap in abundance monitoring for adult Arctic Grayling in the Mesilinka River watershed lends urgency to this snorkeling study and to the interpretation of the results (Stamford et al. 2017). Comparisons of estimates of abundance  $N$  from the 1992-1999 period versus 2024 suffers from changes in 1) snorkeling crew size, 2) underwater visibility, and 3) changes in the no-mark estimators for  $N$ . Despite these challenges, all comparisons between the two time periods where detection probability was taken into account suggest a significant, substantial decline in August abundance of Arctic Grayling >20 cm (Sections 5.2, 5.3.1, 5.3.2). In Section 5.4, we suggest that the 2024 system capacity for adult Arctic Grayling summer rearing may be as little as 20% of that observed during the 1992-1999 period. Wilson et al. (2008) did not observe significant changes in adult Arctic Grayling abundance resulting from fertilization, so the 2024 decline cannot reasonably be attributed to the enhancements. A further fact to consider is that results from 2024 are a snapshot from a single year and may not be representative of average current conditions. Continued abundance monitoring in the Mesilinka River watershed to corroborate this estimated decline is therefore warranted but not planned for this multi-year project given the need to establish index sections and baseline abundance estimates for other tributaries to Williston Reservoir's west shore.

It is important to note that the apparent decline of adult Arctic Grayling in the Mesilinka River system in the past 25 years contrasts with the population trend in index reaches of the Parsnip core area, which has been prioritized for long-term monitoring since 1995. In the Parsnip River watershed, replicated snorkel count data from long-term index sites indicates a significant increase in abundance since 1995 (Hagen and Stamford 2023). Factors driving increases in the Parsnip core area are unknown but suggested possibilities have included: 1) the pristine state (until recent linear developments and forest disturbance) of much of the Anzac River sub-basin which is the hub of Parsnip River Arctic Grayling abundance, 2) potential adaptation of Arctic Grayling to the post-flooding environment of the Parsnip River watershed and resultant increases in population productivity, and 3) the elimination of recreational angling harvest of Arctic Grayling beginning in the late 1990s (Hagen and Stamford 2023). The opposite trends for the Parsnip and Mesilinka populations must be interpreted with caution at this time due to potential risks of extrapolating inferences about conservation status and limiting factors based on only a small number of index locations that may not be representative of the whole geographic area of interest (Fausch et al. 2002). A more spatially complete picture of patterns of Arctic Grayling abundance throughout the Williston Reservoir watershed is an anticipated outcome of this multi-year study.

Nonetheless, a significant change in Arctic Grayling abundance in the Mesilinka River watershed signals the operation of one or more important limiting factors, which we refer to here as 'stressors' for compatibility with recent developments in cumulative effects assessment procedures in western Canada. Core components of Alberta's Fisheries Sustainability Assessment (FSA; MacPherson et al. 2020) and British Columbia's Cumulative Effects Modeling to Prioritize Recovery Actions (CEMPRA; Bayly et al. 2023) are 1)

stressor-response curves that hypothesize how changes in putative limiting factors (biotic and abiotic) affect the ecosystem's productive capacity for that species ('system capacity'), 2) corresponding metrics indicating the magnitude of stressors within target watersheds (current conditions), and 3) a mathematical mechanism for combining the independent effects of individual stressors into an overall assessment of the cumulative effects of all stressors on system capacity. An improved understanding of how natural and anthropogenic stressors are limiting Arctic Grayling populations in the Williston Reservoir watershed is essential for effective planning of conservation and enhancement actions. FWCP's Arctic Grayling Synthesis Document (Stamford et al. 2017) suggests that scientific evidence exists for several stressors on Arctic Grayling system capacity. Field observations in 2024 potentially link the population decline to the operation of known stressors.

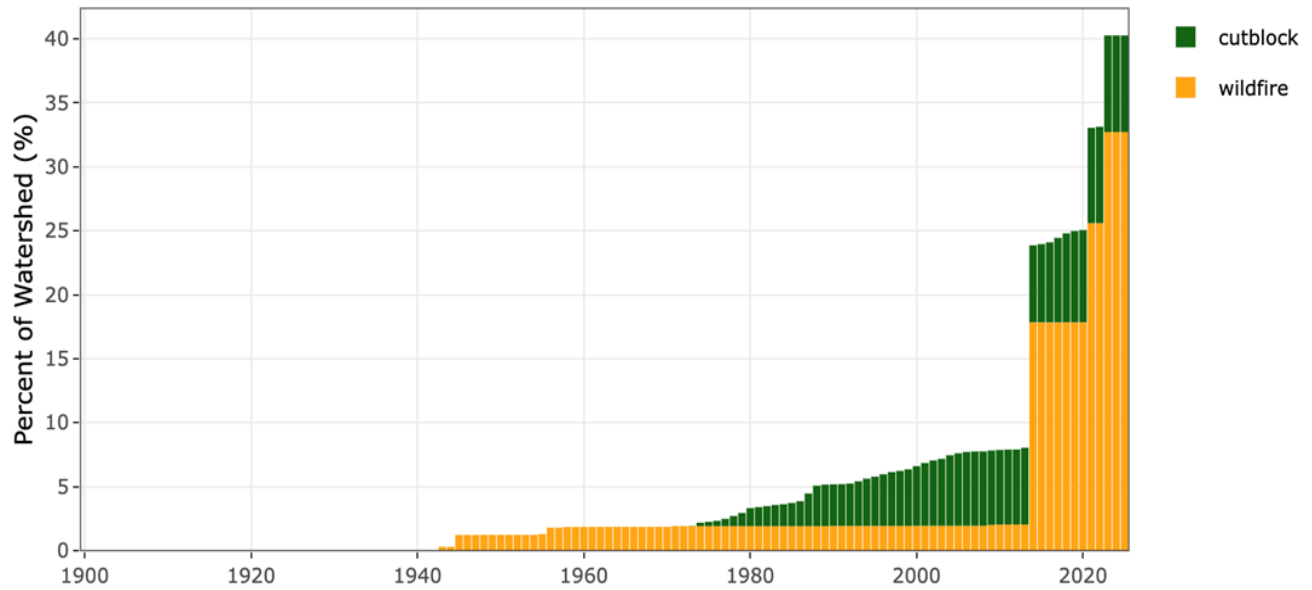
Temperature is a key factor regulating developmental processes and is an important selective factor maintaining variability among salmonid populations (Taylor 1991). Young-of-year Arctic Grayling fry and yearlings prefer warm (~16°C) summer rearing areas and survival is probably linked to rapid growth rate during the first year (Deegan et al. 1999; Stewart et al. 2007; Hawkshaw et al. 2013). In contrast, subadults (age-2 and older) and adults can show higher growth rates during years when stream discharge is higher and summer water temperatures are lower (e.g., approaching 10°C; Lohr et al. 1996; Deegan et al. 1999). Recent research in the Parsnip River watershed by FWCP in collaboration with UNBC's FFEL identified water temperature of 16.7°C as the warm edge limit in describing the distribution and abundance of adult Arctic Grayling in the upper Peace Basin (Martins et al. 2022; Bottoms et al. 2023; O'Connor 2023). In August 2024, maximum weekly average temperatures in Treatment 2 were higher than observed at the same location over the 1992-1999 period (Section 5.1.2) but did not breach the 16.7°C limit for adult Arctic Grayling occupancy (O'Connor 2023). However, the preferred thermal range observed for Parsnip adult Arctic Grayling was much lower at 10.1-13.0 °C. Above this range, Parsnip Arctic Grayling expended a significant amount of energy to thermoregulate (Bottoms et al. 2023). Therefore, warm August temperatures approaching the limit of Arctic Grayling realized thermal niche in 2024 could act as a potential factor reducing system capacity for adult Arctic Grayling summer rearing in the Mesilinka River. It's also possible that some adults in the Mesilinka population migrated elsewhere to rear in 2024 as a consequence of these thermal conditions.

Hydrological changes leading to increased peak flows, increased fine sediment, and loss of pool habitat also affect Arctic Grayling system capacity. Elevated fine sediment affects growth and survival of alevins and fry (Birtwell et al. 1984; McLeay et al. 1987). Elevated peak flows may be another stressor of particular importance to Arctic Grayling populations, particularly during the critical period immediately following emergence. Tack (1974) noted absence of a whole year class in Chena River following a flood event and Clark (1992) found a significant correlation between recruitment levels and stream flows over a 14-year period. Large numbers of grayling fry have also been observed stranded in pools isolated from the mainstream after water levels dropped (de Bruyn and McCart 1974; Cowie and Blackman 2003). Availability of pools and deeper glides of reduced velocity appear to be a key habitat requirement for adult Arctic Grayling in the Parsnip River watershed (Blackman 2004; Bottoms et al. 2023). Changes in stream depth, magnitude of peak flows and sediment inputs are all linked to watershed disturbance (Schumm 1969; Guthrie 2002; Tschaplinski and Pike 2017; Winkler et al. 2010, 2015).

A key field observation during 2024 was extremely high disturbances to the natural forest cover adjacent to and upslope of the long-term index sites from both fire and forest extraction (Figure 10), and associated signs of habitat degradation such as loss of riparian forests, extensive bank erosion, mass wasting, and fine sediment flows. Furthermore, both during the angling (marking) and snorkeling, the availability of Arctic Grayling holding waters was very limited and Arctic Grayling were always present in the few deeper, low velocity runs and pools. At the watershed scale, the cumulative forest disturbance history, as indicated by the GIS indicator equivalent clearcut area, has seen a five-fold increase from <10% during the 1992-1999 period to approximately 40% in 2024 (Figure 11).



Figure 10. Fire-related disturbance In the Mesilinka River watershed, August 2024.



**Figure 11. Cumulative forest disturbance history in the Mesilinka River watershed, as indicated by Equivalent Clearcut Area. Data is sourced from the Consolidated Cutblocks and Wildfire Perimeter dataset available on the British Columbia Data Catalogue, and was visualized using the watershedBC tool (v0.1) (Bevington 2025).**

A comprehensive cumulative effects analysis is beyond the scope of this report. Nonetheless, the association of a compelling population decline with watershed disturbance, which is invariably also linked to water temperature increases (Beschta and Taylor 1988; Hartman et al. 1996; Johnson and Jones 2000; Johnson 2004; Moore et al. 2005), should be evidence enough to rationalize conservation, restoration, and enhancement actions. The key pathway for habitat conservation and mitigating further increases in hydrological stressors is through watershed-scale land use objectives (e.g., Government Actions Regulations or First Nations led stewardship initiatives). Given the stark decrease in population size, and watershed condition over the past 30 years, the urgency should be elevated for the Mesilinka River watershed.

Mitigating inputs of fine and coarse sediments into Mesilinka River watershed stream courses is the most obvious target for restoration actions. Observations of the field crew suggest increased pool habitat could enhance system capacity, but the technical feasibility, risks, and benefits of this action would need to be considered carefully given the size and dynamic nature of the Mesilinka River. Large wood applications in river restoration have been shown to increase channel depth and roughness but are just one method to be used in conjunction with other efforts to restore watershed resilience and floodplain heterogeneity (e.g., wetland, riparian and lateral floodplain connectivity restoration; Mason et al. 2025). We suggest strategic planning for restoration actions to increase watershed resilience be rooted in case studies from interior fire-affected landscapes in North America similar to the relatively dry northern Rocky Mountain setting in the Mesilinka River (e.g., Wohl et al. 2024).

Arctic Grayling have a complex migratory life history with distinct habitat areas used for overwintering, spawning, juvenile rearing, and adult rearing, which may not be located in the same stream (Stamford et al. 2017). Therefore, it is important to consider the context for the changes in adult abundance in summer

habitats of the Mesilinka River relative to the larger Arctic Grayling population of the Omineca core area, and whether other information needs remain that limit FWCP's ability to identify and prioritize conservation, restoration, and enhancement actions (Section 6.3).

### 6.3 Context within the Omineca Core Area

Low abundance in 2024 of adult/subadult Arctic Grayling in the Mesilinka River in both downstream index sections and upstream reconnaissance surveys relative to prior years (Wilson et al. 2008; ECL 1997; Clarke et al. 2005) is alarming considering that historically the majority of the population has been comprised of resident individuals (Stamford et al. 2017). Retrospective movements from otolith microchemistry, for instance, found 100% of adults ( $n=10$ ) captured upstream of Tutizika River originated from natal areas in Mesilinka River and 70% of them remained their whole lives within the system (Clarke et al. 2005). The remaining 30% migrated to Omineca River as subadults, then once mature at around age five, they returned to upper Mesilinka River and Lay Creek where they remained until they were captured between ages 8 and 10 years old (Clarke et al. 2005). Migratory behaviour between the Mesilinka and Omineca watersheds was also described by Wilson et al. (2008) where several adults tagged in the index sections were recaptured in Mesilinka River during subsequent years while other tags were recovered in the adjacent Osilinka River.

The snapshot in time provided by the 2024 snorkel survey results suggest that Mesilinka River Arctic Grayling are in serious decline, which appears to include a range contraction from upstream habitats in reconnaissance survey sites. Possibly, low abundance of adults during 2024 is a result of adults migrating to alternative summer rearing areas elsewhere in the Omineca core area (i.e., Osilinka and Omineca rivers) due to reduced available habitat and possibly to avoid stress from warm temperatures in the Mesilinka River. Water temperature of 16.2°C out of Aiken Lake might explain their absence in upper Mesilinka River, compared with the 1990's when Arctic Grayling were more abundant, and water temperatures were cooler (maximum 15.4°C, Koning et al. 1995). Alternatively, ecological conditions have changed since the 1992-1999 period due to habitat erosion, loss of riparian forest, and climate change induced warming, reducing the productivity of the Mesilinka River.

Past evidence that a significant portion of adults captured in the Mesilinka River had migrated among summer rearing areas in Omineca River, Mesilinka River, and Osilinka River is unequivocal (Clarke et al. 2005; Wilson et al. 2008). All three of these streams also provide critical natal habitats where fry rearing areas are often associated with tributary confluences (Stamford et al. 2017). Past otolith microchemistry results suggest that, in contrast to Mesilinka River Arctic Grayling, both Osilinka and Omineca are resident populations: all adults sampled ( $n=20$ ) remained within their respective streams for their whole lives (Clarke et al. 2005). This suggests that at that time both the Omineca and Osilinka rivers provided reliable adult rearing habitats that promoted locally moving populations, while Mesilinka adults may have depended on other streams to improve their growth and survival.

Alternatively, the more vagrant migratory behaviour observed among Mesilinka adults, together with the prior high adult abundance estimated in the 1990s, are a consequence of habitat loss due to flooding of Williston Reservoir. Inundation of Black Canyon probably facilitated immigration by individuals displaced by flooding

and consequently may have boosted adult abundance in Mesilinka during the 1990's. Such a scenario is supported by genetic assignment tests among the same adults that were counted in the 1990's, which found only 11% of adults captured in Mesilinka were correctly assigned to a unique Mesilinka genotype (Stamford and Taylor 2005). For context, correct assignments among nine other Peace basin populations (unique genotypes) ranged between 32-100% of individuals captured from their respective streams (Stamford and Taylor 2005). In other words, in the 1990's, 89% of adults captured and snorkel counted in Mesilinka River were genetically more like those in Table, Anzac, Nation, or Ingenika, which suggests that those adults being counted in the 1990's were mostly fish that originated from natal areas elsewhere. Possibly, the intrusion from surrounding populations has diminished and the Arctic Grayling that survive in Mesilinka River are better adapted to the flooded conditions and low adult abundance estimates in 2024 might more accurately reflect the current adult rearing capacity for Mesilinka River.

Adult abundance monitoring in adjacent streams (Osilinka River, Omineca River) together with evaluations of adult movements (e.g., microchemistry, mark-resight/mark-recapture), which have been conditionally approved for summer 2025 and are recommended (Section 7), will help distinguish between these alternatives and address key data gaps limiting FWCP's ability to identify and prioritize conservation and enhancement actions, such as the relative importance and current condition of critical habitats in sub-basins of the Omineca core area (Stamford et al. 2017).

An important result from the 2024 snorkel survey is the common presence of numerous yearling-sized Arctic Grayling downstream in reach T2 (Appendix B). The yearling (100-180mm) life history stage is rarely encountered in adult snorkel surveys and generally rare in sampling records in the upper Peace River basin (Stamford et al. 2017). The yearlings were observed swimming in quiet waters alone, and in schools of around ten in the relatively complex T2 reach of the Mesilinka River, which has been previously described as potentially optimal but difficult to sample for this poorly understood life history stage (EDI 2001; ECL 1997). Possibly, the warm temperatures and low flow conditions in Mesilinka River during 2024 was especially optimal for yearling-sized grayling and good survival might help recovery of the adult population. Alternatively, the lower Mesilinka River, together with lower Omineca River (ECL 1997) provide rearing habitat for yearlings arriving from other spawning streams (e.g., Osilinka River) and once mature they will home to their natal stream of origin. Further evaluations of movements among streams (e.g., using microchemistry) and continued adult abundance monitoring will help distinguish between these hypotheses about survival and habitat use by yearling Arctic Grayling and address the lack of understanding of juvenile grayling habitat use in the Omineca, Osilinka, Mesilinka mainstems, another key data gap identified by Stamford et al. (2017) which limits FWCPs ability to prioritize conservation, restoration, and enhancement actions.

## 7 Recommendations

With the caveat that 2024 snorkeling results in the Mesilinka River are a snapshot from just one year, our conclusion has been that the adult Arctic Grayling population of this system has likely experienced a significant, substantial loss of system capacity since the 1990's. The implications of this conclusion for viability of Arctic Grayling within the Omineca core area (metapopulation) as a whole are currently unknown, depending as they do on interconnectivity among adjacent populations in the Mesilinka, Osilinka, and Omineca watersheds and the relative importance of the Mesilinka River for other life stages. To gain the necessary clarity about critical habitats, their relative importance, and priorities for conservation and enhancement, we have several recommendations focused on upcoming Arctic Grayling surveys in the Omineca core area:

1. During mark-resight studies to estimate detection probability and abundance (recommended and conditionally approved for 2025), limit marking to a concise period immediately prior to snorkeling to minimize violations of the assumption of site closure.
2. Account for the effects of variable visibility on snorkeling detection probability for Arctic Grayling, by i) incorporating mark-resight studies into the surveys where feasible (conditionally approved for 2025), ii) conducting repeat surveys of long-term index sections during comparable visibility conditions (not applicable in 2025), or iii) by incorporating visibility as a covariate of detection probability during statistical analysis.
3. Continue development of modeling methods to analyze replicated count data in collaboration with UNBC's Freshwater Fish Ecology Laboratory, by i) exploring alternative statistical distributions in N-mixture models and by ii) optimizing the number of snorkeling sites to enable good fit of the distribution model to empirical mark-resight estimates without violating assumptions about site closure between replicate surveys.
4. Conduct adult Arctic Grayling abundance monitoring in adjacent streams of the Omineca core area (Osilinka River, Omineca River) to contextualize the decline in Arctic Grayling abundance in the Mesilinka River and to update the conservation status assessment for the core area as a putative metapopulation.
5. Conduct a retrospective study of demographic interconnectedness and key natal watersheds among streams of the Omineca core area using the non-lethal technique of fin ray microchemistry, to identify the importance of the Mesilinka River (and other streams) across the Arctic Grayling life history and enable prioritization of conservation, restoration and enhancement actions within the core area.

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## Appendix A – Snorkel Survey Reaches

This appendix contains detailed maps of all stream sections swam during the 2024 snorkel swims in Mesilinka River. The first three maps (Figure A-1, A-2, A-3) show the 2024 effort within the historical survey sections swam by Wilson et al. 2008 during the 1992-1999 Mesilinka Fertilizer Experiment (PFWFPC Report No. 319). The latter three maps (Figure A-3, A-4, A-5) show the 2024 reconnaissance sections, which were explored to identify Arctic Grayling distribution in habitats outside of the 2024 index sections including upper Mesilinka River, Lay Creek, and Tutizika Creek. These maps provide higher resolution detail of the surveyed reaches providing a visual interpretation of snorkelling effort and spatial coverage.

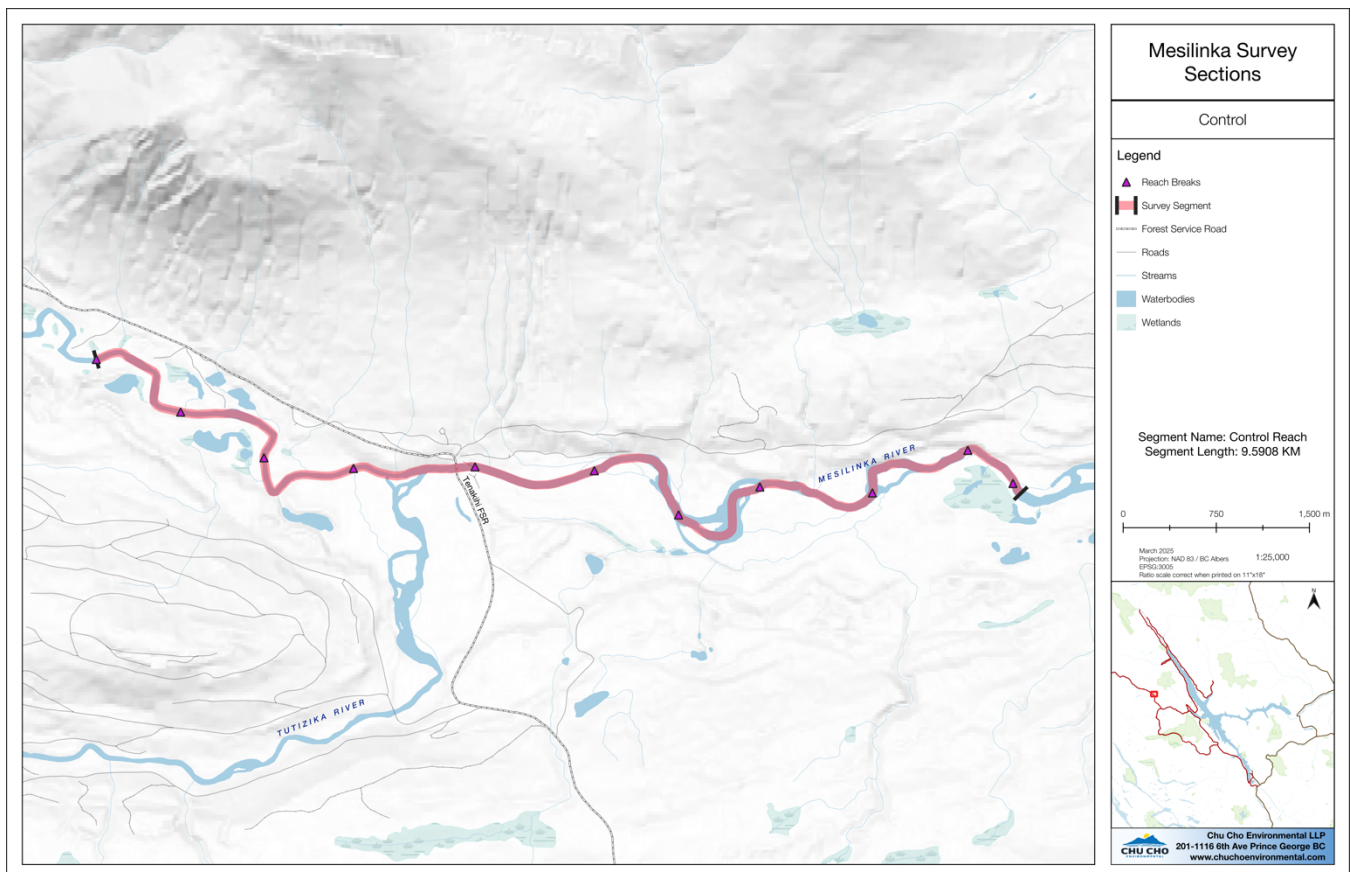


Figure A-1. Control reach index section divided into 1 km reach breaks utilized for snorkel surveys to monitor Arctic Grayling abundance, 1992-1999 and 2024.

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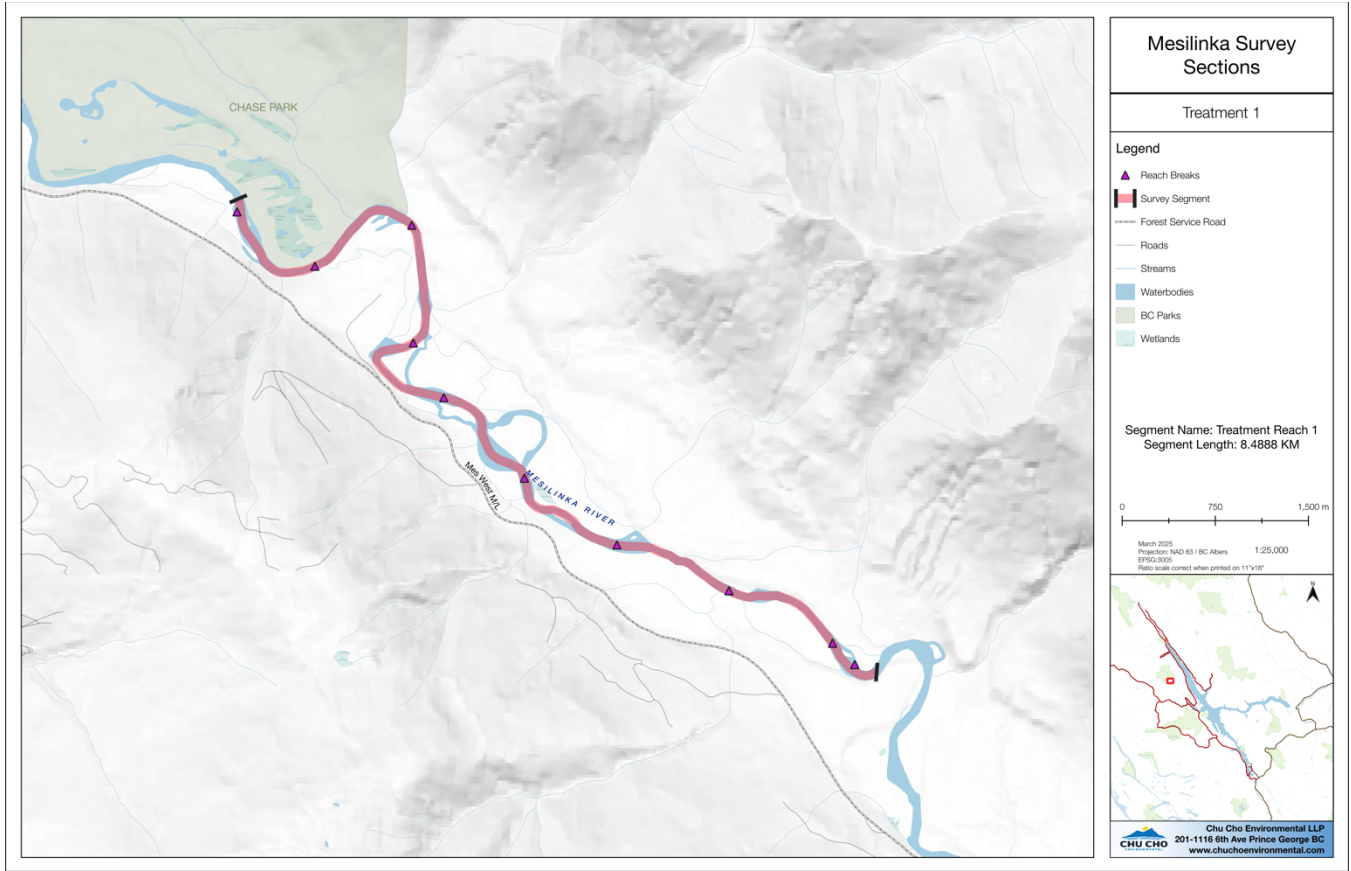


Figure A-2. Treatment 1 (T1) reach index section divided into 1 km reach breaks utilized for snorkel surveys to monitor Arctic Grayling abundance, 1992-1999 and 2024.

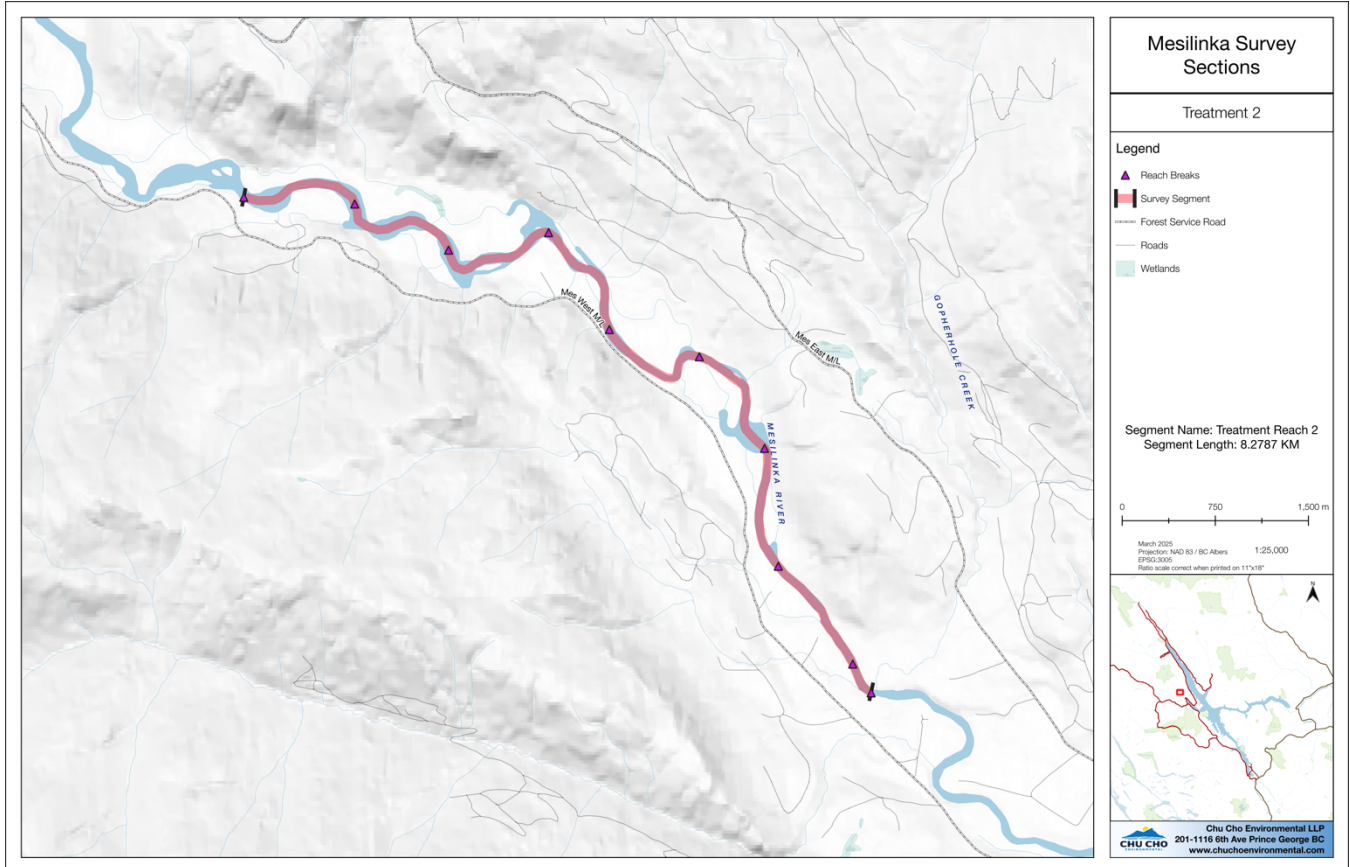


Figure A-3. Treatment reach 2 (T2) index section divided into 1 km reach breaks utilized for snorkel surveys to monitor Arctic Grayling abundance, 1992-1999 and 2024.

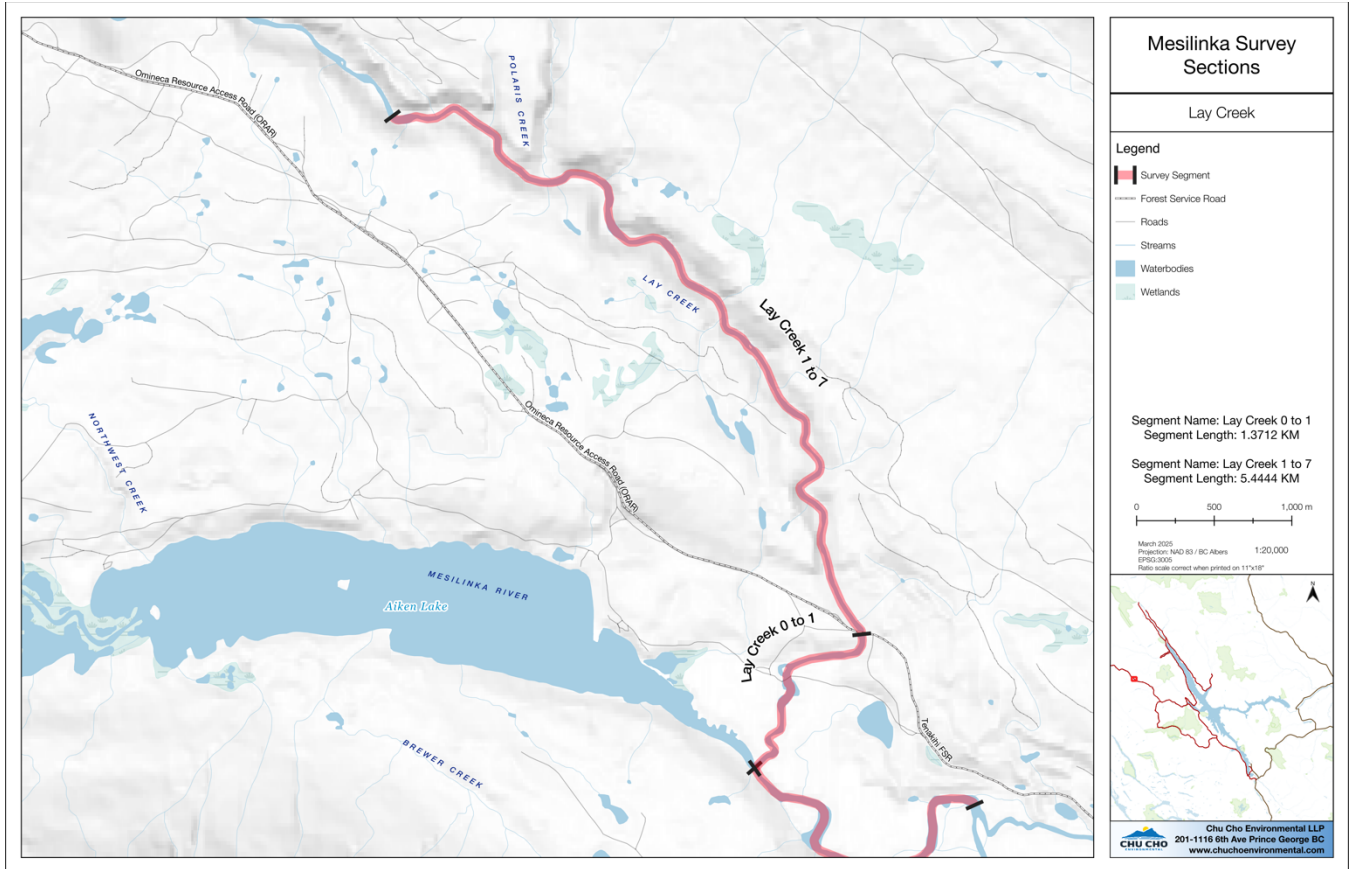


Figure A-4. Stream sections of Lay Creek and upper Mesilinka River swam for reconnaissance purposes to identify adult Arctic Grayling distribution in Upper Mesilinka watershed.

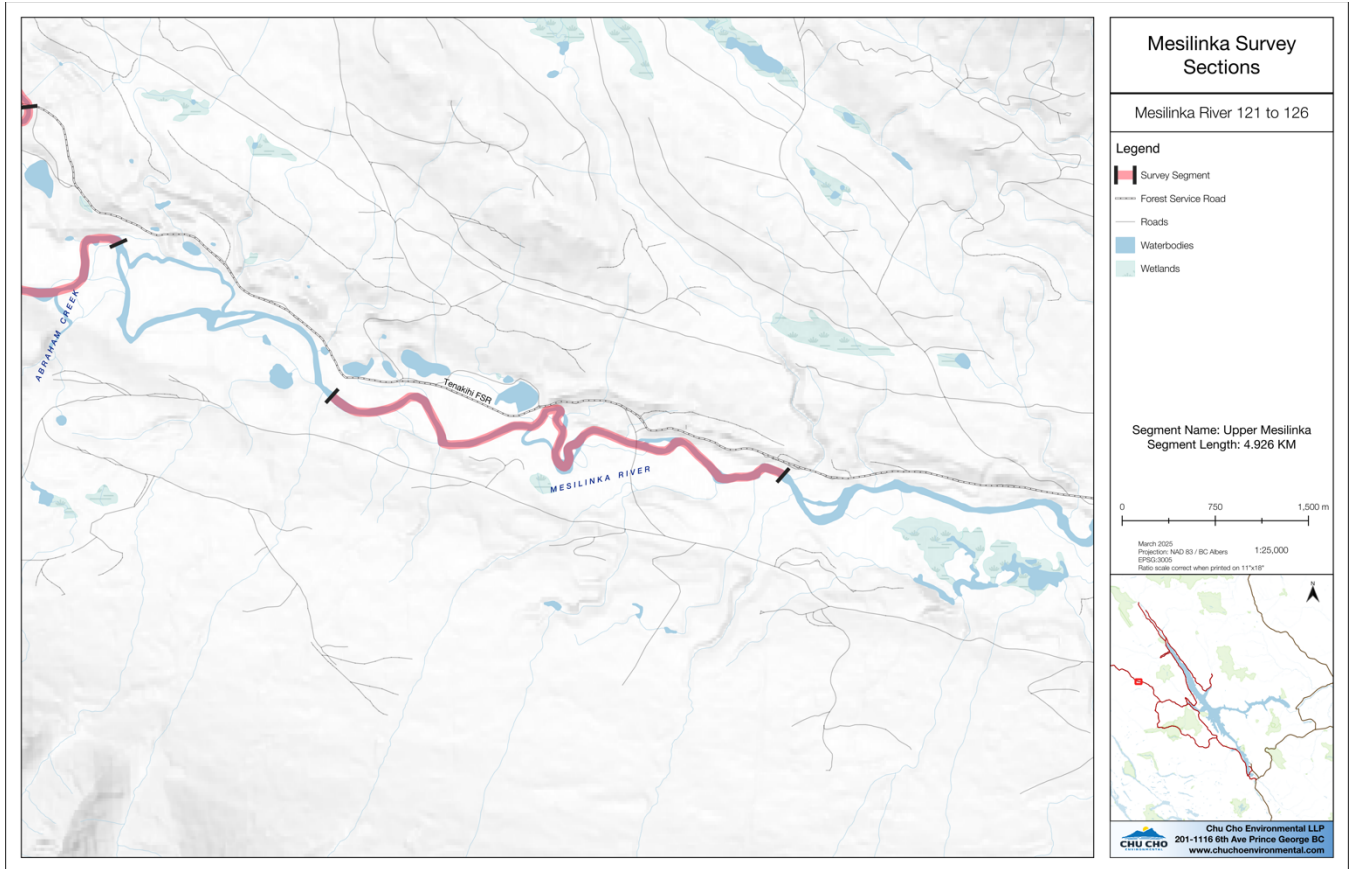


Figure A-5. Stream section of Mesilinka River swam for reconnaissance purposes to identify adult Arctic Grayling distribution in Upper Mesilinka Watershed.

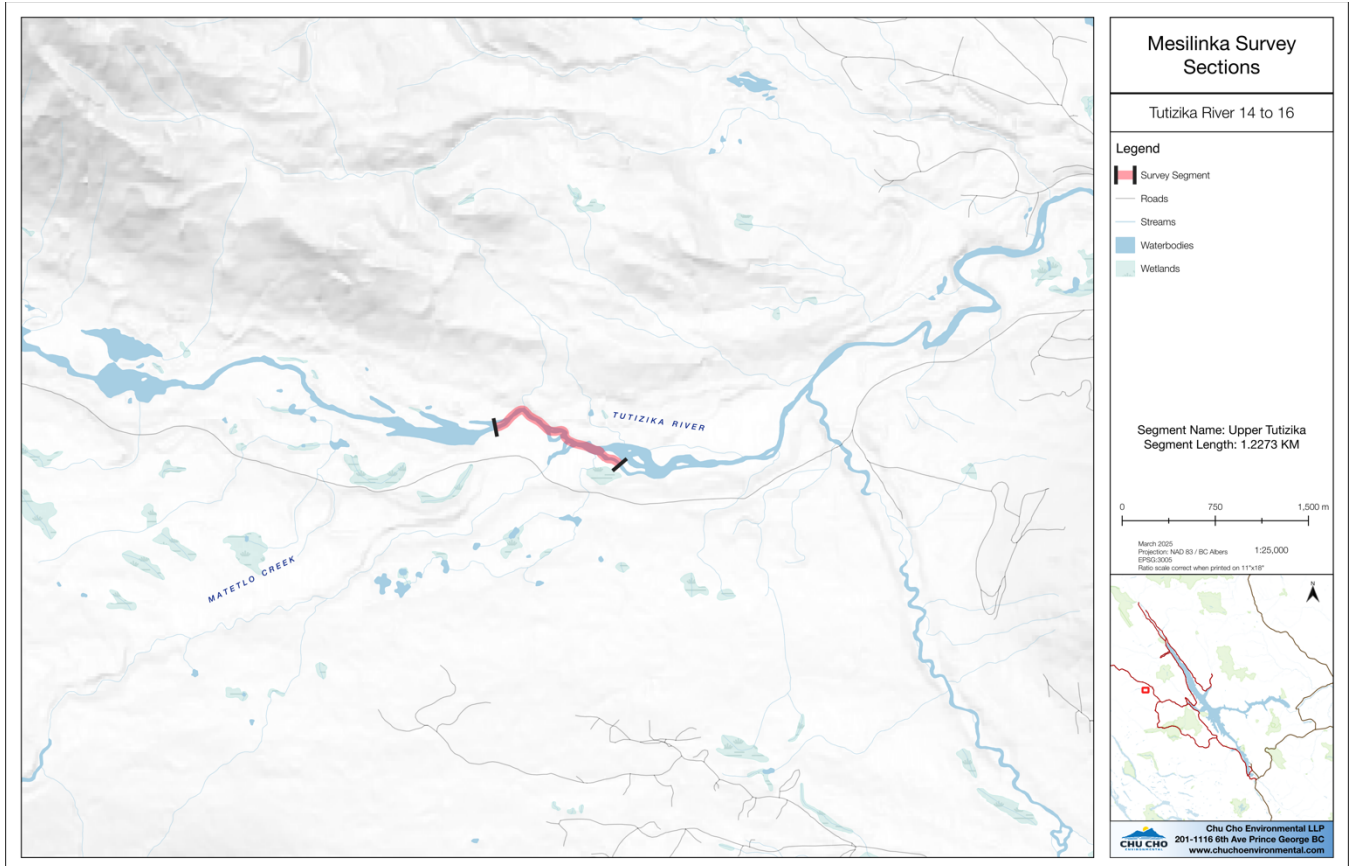


Figure A-6. Stream section of upper Tutizika River swam for reconnaissance purposes to identify adult Arctic Grayling distribution in Upper Mesilinka Watershed.

## Appendix B – Observed Snorkel Data

Table B-1. Raw counts of fish species observed during snorkel counts in three index reaches of Mesilinka River

Date	River	Reach	Sub	Rep.	Spp.	<20 cm	20- 30 cm	30- 40 cm	40- 50 cm	50+ cm	Total	Wt. Tags Obs.*	Or. Tags Obs.*	Other Spp.
2024-08-12	Mesilinka	Control	C0	1	BT	0	0	0	0	0	0			
2024-08-12	Mesilinka	Control	C1	1	BT	0	0	0	0	0	0			
2024-08-12	Mesilinka	Control	C2	1	BT	0	0	0	0	0	0			
2024-08-12	Mesilinka	Control	C3	1	BT	0	0	1	0	1	2			
2024-08-12	Mesilinka	Control	C4	1	BT	0	0	0	0	0	0			
2024-08-12	Mesilinka	Control	C5	1	BT	0	0	0	0	0	0			
2024-08-12	Mesilinka	Control	C6	1	BT	0	1	2	0	0	3			
2024-08-12	Mesilinka	Control	C7	1	BT	0	0	1	0	0	1			
2024-08-12	Mesilinka	Control	C8	1	BT	0	1	1	1	0	3			
2024-08-12	Mesilinka	Control	C0	1	GR	0	0	0	0	0	0			
2024-08-12	Mesilinka	Control	C1	1	GR	0	0	0	0	0	0			
2024-08-12	Mesilinka	Control	C2	1	GR	0	0	0	0	0	0			
2024-08-12	Mesilinka	Control	C3	1	GR	1	0	3	0	0	4			
2024-08-12	Mesilinka	Control	C4	1	GR	0	0	0	0	0	0			
2024-08-12	Mesilinka	Control	C5	1	GR	0	0	0	0	0	0			
2024-08-12	Mesilinka	Control	C6	1	GR	0	0	3	1	0	4	1		
2024-08-12	Mesilinka	Control	C7	1	GR	2	0	2	0	0	4			
2024-08-12	Mesilinka	Control	C8	1	GR	3	0	0	0	0	3			
2024-08-12	Mesilinka	Control	C0	1	MW	0	10	4	0	0	14			
2024-08-12	Mesilinka	Control	C1	1	MW	0	41	3	0	0	44			
2024-08-12	Mesilinka	Control	C2	1	MW	0	0	0	0	0	0			
2024-08-12	Mesilinka	Control	C3	1	MW	31	126	26	0	0	183			
2024-08-12	Mesilinka	Control	C4	1	MW	32	55	2	0	0	89			
2024-08-12	Mesilinka	Control	C5	1	MW	23	39	7	0	0	69			
2024-08-12	Mesilinka	Control	C6	1	MW	55	59	15	0	0	129			
2024-08-12	Mesilinka	Control	C7	1	MW	109	71	17	0	0	197			
2024-08-12	Mesilinka	Control	C8	1	MW	58	32	12	0	0	102			
2024-08-12	Mesilinka	Control	C0	1	RB	0	0	1	0	0	1			
2024-08-12	Mesilinka	Control	C1	1	RB	0	1	1	0	0	2			
2024-08-12	Mesilinka	Control	C2	1	RB	0	0	0	0	0	0			
2024-08-12	Mesilinka	Control	C3	1	RB	0	2	0	0	0	2			
2024-08-12	Mesilinka	Control	C4	1	RB	3	1	0	0	0	4			
2024-08-12	Mesilinka	Control	C5	1	RB	0	0	0	0	0	0			
2024-08-12	Mesilinka	Control	C6	1	RB	3	4	1	0	0	8			
2024-08-12	Mesilinka	Control	C7	1	RB	0	2	0	0	0	2			
2024-08-12	Mesilinka	Control	C8	1	RB	0	2	0	0	0	2			
2024-08-15	Mesilinka	Control	C0	2	BT	0	0	0	0	0	0			
2024-08-15	Mesilinka	Control	C1	2	BT	0	0	0	0	0	0			
2024-08-15	Mesilinka	Control	C2	2	BT	0	0	0	0	0	0			
2024-08-15	Mesilinka	Control	C3	2	BT	0	0	1	0	1	2			
2024-08-15	Mesilinka	Control	C4	2	BT	0	0	0	0	0	0			
2024-08-15	Mesilinka	Control	C5	2	BT	0	0	0	0	1	1			
2024-08-15	Mesilinka	Control	C6	2	BT	1	1	0	0	0	2			
2024-08-15	Mesilinka	Control	C7	2	BT	0	0	1	0	0	1			
2024-08-15	Mesilinka	Control	C8	2	BT	1	0	0	0	0	1			

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2024-08-15	Mesilinka	Control	C0	2	GR	0	0	0	0	0	0		
2024-08-15	Mesilinka	Control	C1	2	GR	0	0	0	0	0	0		
2024-08-15	Mesilinka	Control	C2	2	GR	0	0	0	0	0	0		
2024-08-15	Mesilinka	Control	C3	2	GR	4	0	0	0	0	4		
2024-08-15	Mesilinka	Control	C4	2	GR	0	0	0	0	0	0		
2024-08-15	Mesilinka	Control	C5	2	GR	0	0	1	0	0	1		
2024-08-15	Mesilinka	Control	C6	2	GR	0	1	0	0	0	1		
2024-08-15	Mesilinka	Control	C7	2	GR	0	0	2	0	0	2		
2024-08-15	Mesilinka	Control	C8	2	GR	0	0	0	0	0	0		
2024-08-15	Mesilinka	Control	C0	2	MW	2	10	9	0	0	21		
2024-08-15	Mesilinka	Control	C1	2	MW	23	16	11	0	0	50		
2024-08-15	Mesilinka	Control	C2	2	MW	42	40	5	0	0	87		
2024-08-15	Mesilinka	Control	C3	2	MW	42	86	46	1	0	175		
2024-08-15	Mesilinka	Control	C4	2	MW	27	15	4	0	0	46		
2024-08-15	Mesilinka	Control	C5	2	MW	20	38	9	0	0	67		
2024-08-15	Mesilinka	Control	C6	2	MW	21	25	0	0	0	46		
2024-08-15	Mesilinka	Control	C7	2	MW	72	62	15	0	0	149		
2024-08-15	Mesilinka	Control	C8	2	MW	36	19	3	0	0	58		
2024-08-15	Mesilinka	Control	C0	2	RB	0	1	0	0	0	1		
2024-08-15	Mesilinka	Control	C1	2	RB	0	0	0	0	0	0		
2024-08-15	Mesilinka	Control	C2	2	RB	0	0	1	0	0	1		
2024-08-15	Mesilinka	Control	C3	2	RB	0	1	0	0	0	1		
2024-08-15	Mesilinka	Control	C4	2	RB	0	0	0	0	0	0		
2024-08-15	Mesilinka	Control	C5	2	RB	0	2	0	0	0	2		
2024-08-15	Mesilinka	Control	C6	2	RB	0	1	0	0	0	1		
2024-08-15	Mesilinka	Control	C7	2	RB	1	2	1	0	0	4		
2024-08-15	Mesilinka	Control	C8	2	RB	0	0	0	0	0	0		
2024-08-13	Mesilinka	Treatment 1	T1	1	BT	0	0	1	0	1	2		
2024-08-13	Mesilinka	Treatment 1	T2	1	BT	0	0	2	0	0	2		
2024-08-13	Mesilinka	Treatment 1	T3	1	BT	0	0	0	1	1	2		
2024-08-13	Mesilinka	Treatment 1	T4	1	BT	0	0	0	0	0	0		
2024-08-13	Mesilinka	Treatment 1	T5	1	BT	0	0	1	0	0	1		
2024-08-13	Mesilinka	Treatment 1	T6	1	BT	0	0	0	0	0	0		
2024-08-13	Mesilinka	Treatment 1	T7	1	BT	0	0	0	0	0	0		
2024-08-13	Mesilinka	Treatment 1	T8	1	BT	0	0	1	0	0	1		
2024-08-13	Mesilinka	Treatment 1	T9	1	BT	0	0	0	0	0	0		
2024-08-13	Mesilinka	Treatment 1	T1	1	GR	0	1	0	0	0	1		
2024-08-13	Mesilinka	Treatment 1	T2	1	GR	2	1	6	0	0	9		
2024-08-13	Mesilinka	Treatment 1	T3	1	GR	2	2	4	0	0	8		4
2024-08-13	Mesilinka	Treatment 1	T4	1	GR	0	1	0	0	0	1		
2024-08-13	Mesilinka	Treatment 1	T5	1	GR	0	3	0	0	0	3		1
2024-08-13	Mesilinka	Treatment 1	T6	1	GR	0	1	5	1	0	7	2	2
2024-08-13	Mesilinka	Treatment 1	T7	1	GR	1	0	2	0	0	3		
2024-08-13	Mesilinka	Treatment 1	T8	1	GR	0	0	1	0	0	1		1
2024-08-13	Mesilinka	Treatment 1	T9	1	GR	0	0	0	0	0	0		
2024-08-13	Mesilinka	Treatment 1	T1	1	MW	54	30	8	0	0	92		
2024-08-13	Mesilinka	Treatment 1	T2	1	MW	61	55	4	0	0	120		
2024-08-13	Mesilinka	Treatment 1	T3	1	MW	103	150	19	0	0	272		LSU
2024-08-13	Mesilinka	Treatment 1	T4	1	MW	6	6	0	0	0	12		
2024-08-13	Mesilinka	Treatment 1	T5	1	MW	80	57	25	4	0	166		LSU
2024-08-13	Mesilinka	Treatment 1	T6	1	MW	31	21	7	0	0	59		LSU
2024-08-13	Mesilinka	Treatment 1	T7	1	MW	31	12	2	0	0	45		
2024-08-13	Mesilinka	Treatment 1	T8	1	MW	50	27	7	0	0	84		
2024-08-13	Mesilinka	Treatment 1	T9	1	MW	16	2	0	0	0	18		CCG

2024-08-13	Mesilinka	Treatment 1	T1	1	RB	0	9	2	0	0	11		
2024-08-13	Mesilinka	Treatment 1	T2	1	RB	0	2	1	0	0	3		
2024-08-13	Mesilinka	Treatment 1	T3	1	RB	1	2	1	0	0	4		
2024-08-13	Mesilinka	Treatment 1	T4	1	RB	0	0	0	0	0	0		
2024-08-13	Mesilinka	Treatment 1	T5	1	RB	0	1	0	0	0	1		
2024-08-13	Mesilinka	Treatment 1	T6	1	RB	0	0	0	0	0	0		
2024-08-13	Mesilinka	Treatment 1	T7	1	RB	0	0	0	0	0	0		
2024-08-13	Mesilinka	Treatment 1	T8	1	RB	0	2	0	0	0	2		
2024-08-13	Mesilinka	Treatment 1	T9	1	RB	0	0	0	0	0	0		
2024-08-14	Mesilinka	Treatment 1	T1	2	BT	0	0	0	0	1	1		
2024-08-14	Mesilinka	Treatment 1	T2	2	BT	0	0	0	0	0	0		
2024-08-14	Mesilinka	Treatment 1	T3	2	BT	0	0	1	0	1	2		
2024-08-14	Mesilinka	Treatment 1	T4	2	BT	0	0	0	0	0	0		
2024-08-14	Mesilinka	Treatment 1	T5	2	BT	0	0	1	0	0	1		
2024-08-14	Mesilinka	Treatment 1	T6	2	BT	0	0	0	0	0	0		
2024-08-14	Mesilinka	Treatment 1	T7	2	BT	0	1	0	0	0	1		
2024-08-14	Mesilinka	Treatment 1	T8	2	BT	0	0	1	0	0	1		
2024-08-14	Mesilinka	Treatment 1	T9	2	BT	0	0	0	0	0	0		
2024-08-14	Mesilinka	Treatment 1	T1	2	GR	0	0	0	1	0	1		
2024-08-14	Mesilinka	Treatment 1	T2	2	GR	3	0	0	1	0	4		
2024-08-14	Mesilinka	Treatment 1	T3	2	GR	0	1	4	0	0	5		3
2024-08-14	Mesilinka	Treatment 1	T4	2	GR	0	1	0	0	0	1		1
2024-08-14	Mesilinka	Treatment 1	T5	2	GR	3	1	0	0	0	4		
2024-08-14	Mesilinka	Treatment 1	T6	2	GR	4	4	3	2	0	13	1	3
2024-08-14	Mesilinka	Treatment 1	T7	2	GR	1	0	1	0	0	2		
2024-08-14	Mesilinka	Treatment 1	T8	2	GR	0	0	3	0	0	3		1
2024-08-14	Mesilinka	Treatment 1	T9	2	GR	0	0	0	0	0	0		
2024-08-14	Mesilinka	Treatment 1	T1	2	MW	5	27	4	0	0	36		
2024-08-14	Mesilinka	Treatment 1	T2	2	MW	41	13	7	1	0	62		
2024-08-14	Mesilinka	Treatment 1	T3	2	MW	56	61	18	26	0	161		
2024-08-14	Mesilinka	Treatment 1	T4	2	MW	24	27	10	0	0	61		
2024-08-14	Mesilinka	Treatment 1	T5	2	MW	37	29	10	2	0	78		
2024-08-14	Mesilinka	Treatment 1	T6	2	MW	31	27	12	0	0	70		LSU
2024-08-14	Mesilinka	Treatment 1	T7	2	MW	20	7	3	0	0	30		
2024-08-14	Mesilinka	Treatment 1	T8	2	MW	23	19	8	0	0	50		LSU
2024-08-14	Mesilinka	Treatment 1	T9	2	MW	9	10	7	1	0	27		
2024-08-14	Mesilinka	Treatment 1	T1	2	RB	5	6	6	0	0	17		
2024-08-14	Mesilinka	Treatment 1	T2	2	RB	6	2	0	0	0	8		
2024-08-14	Mesilinka	Treatment 1	T3	2	RB	2	0	1	0	0	3		
2024-08-14	Mesilinka	Treatment 1	T4	2	RB	0	0	0	0	0	0		
2024-08-14	Mesilinka	Treatment 1	T5	2	RB	0	0	0	0	0	0		
2024-08-14	Mesilinka	Treatment 1	T6	2	RB	0	1	0	0	0	1		
2024-08-14	Mesilinka	Treatment 1	T7	2	RB	0	2	1	0	0	3		
2024-08-14	Mesilinka	Treatment 1	T8	2	RB	1	0	0	0	0	1		
2024-08-14	Mesilinka	Treatment 1	T9	2	RB	0	0	1	0	0	1		
2024-08-16	Mesilinka	Treatment 2	T1	1	BT	0	0	3	1	0	4		
2024-08-16	Mesilinka	Treatment 2	T2	1	BT	0	0	1	0	0	1		
2024-08-16	Mesilinka	Treatment 2	T3	1	BT	0	4	2	0	0	6		
2024-08-16	Mesilinka	Treatment 2	T4	1	BT	0	0	0	0	0	0		
2024-08-16	Mesilinka	Treatment 2	T5	1	BT	0	0	1	0	0	1		
2024-08-16	Mesilinka	Treatment 2	T6	1	BT	0	0	1	0	0	1		
2024-08-16	Mesilinka	Treatment 2	T7	1	BT	1	0	0	0	0	1		
2024-08-16	Mesilinka	Treatment 2	T8	1	BT	0	0	0	0	1	1		
2024-08-16	Mesilinka	Treatment 2	T9	1	BT	0	0	0	0	0	0		

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2024-08-16	Mesilinka	Treatment 2	T1	1	GR	0	1	0	0	0	1	
2024-08-16	Mesilinka	Treatment 2	T2	1	GR	0	0	0	0	0	0	
2024-08-16	Mesilinka	Treatment 2	T3	1	GR	0	0	0	0	0	0	
2024-08-16	Mesilinka	Treatment 2	T4	1	GR	0	0	0	0	0	0	
2024-08-16	Mesilinka	Treatment 2	T5	1	GR	0	0	1	0	0	1	
2024-08-16	Mesilinka	Treatment 2	T6	1	GR	0	0	0	0	0	0	
2024-08-16	Mesilinka	Treatment 2	T7	1	GR	6	1	1	0	0	8	
2024-08-16	Mesilinka	Treatment 2	T8	1	GR	0	1	0	0	0	1	
2024-08-16	Mesilinka	Treatment 2	T9	1	GR	10	2	0	0	0	12	
2024-08-16	Mesilinka	Treatment 2	T1	1	MW	171	128	34	1	0	334	
2024-08-16	Mesilinka	Treatment 2	T2	1	MW	188	151	47	0	1	387	LSU
2024-08-16	Mesilinka	Treatment 2	T3	1	MW	91	103	41	4	0	239	
2024-08-16	Mesilinka	Treatment 2	T4	1	MW	72	113	20	0	0	205	
2024-08-16	Mesilinka	Treatment 2	T5	1	MW	70	80	27	4	0	181	
2024-08-16	Mesilinka	Treatment 2	T6	1	MW	83	86	7	0	0	176	LSU
2024-08-16	Mesilinka	Treatment 2	T7	1	MW	192	153	26	0	0	371	
2024-08-16	Mesilinka	Treatment 2	T8	1	MW	109	50	6	0	0	165	
2024-08-16	Mesilinka	Treatment 2	T9	1	MW	57	57	20	0	0	134	
2024-08-16	Mesilinka	Treatment 2	T1	1	RB	4	19	12	0	0	35	
2024-08-16	Mesilinka	Treatment 2	T2	1	RB	4	7	3	0	0	14	
2024-08-16	Mesilinka	Treatment 2	T3	1	RB	4	12	4	0	0	20	
2024-08-16	Mesilinka	Treatment 2	T4	1	RB	0	2	2	0	0	4	
2024-08-16	Mesilinka	Treatment 2	T5	1	RB	2	1	1	0	0	4	
2024-08-16	Mesilinka	Treatment 2	T6	1	RB	0	5	5	0	0	10	
2024-08-16	Mesilinka	Treatment 2	T7	1	RB	0	0	0	0	0	0	
2024-08-16	Mesilinka	Treatment 2	T8	1	RB	0	3	1	0	0	4	
2024-08-16	Mesilinka	Treatment 2	T9	1	RB	0	0	0	0	0	0	
2024-08-17	Mesilinka	Treatment 2	T1	2	BT	0	1	3	0	0	4	
2024-08-17	Mesilinka	Treatment 2	T2	2	BT	0	2	3	0	0	5	
2024-08-17	Mesilinka	Treatment 2	T3	2	BT	0	1	1	0	1	3	
2024-08-17	Mesilinka	Treatment 2	T4	2	BT	0	2	2	0	0	4	
2024-08-17	Mesilinka	Treatment 2	T5	2	BT	0	1	0	0	0	1	
2024-08-17	Mesilinka	Treatment 2	T6	2	BT	0	0	0	0	0	0	
2024-08-17	Mesilinka	Treatment 2	T7	2	BT	0	0	1	0	1	2	
2024-08-17	Mesilinka	Treatment 2	T8	2	BT	0	0	0	0	0	0	
2024-08-17	Mesilinka	Treatment 2	T9	2	BT	0	0	0	0	0	0	
2024-08-17	Mesilinka	Treatment 2	T1	2	GR	0	1	0	0	0	1	
2024-08-17	Mesilinka	Treatment 2	T2	2	GR	0	1	0	0	0	1	
2024-08-17	Mesilinka	Treatment 2	T3	2	GR	0	0	0	0	0	0	
2024-08-17	Mesilinka	Treatment 2	T4	2	GR	1	0	0	1	0	2	
2024-08-17	Mesilinka	Treatment 2	T5	2	GR	0	0	0	0	0	0	
2024-08-17	Mesilinka	Treatment 2	T6	2	GR	0	0	0	0	0	0	
2024-08-17	Mesilinka	Treatment 2	T7	2	GR	1	0	2	0	0	3	
2024-08-17	Mesilinka	Treatment 2	T8	2	GR	0	0	0	0	0	0	
2024-08-17	Mesilinka	Treatment 2	T9	2	GR	0	0	0	0	0	0	
2024-08-17	Mesilinka	Treatment 2	T1	2	MW	79	68	45	0	0	192	
2024-08-17	Mesilinka	Treatment 2	T2	2	MW	56	65	28	0	0	149	
2024-08-17	Mesilinka	Treatment 2	T3	2	MW	58	88	28	1	0	175	
2024-08-17	Mesilinka	Treatment 2	T4	2	MW	53	37	18	2	0	110	
2024-08-17	Mesilinka	Treatment 2	T5	2	MW	55	80	20	2	0	157	
2024-08-17	Mesilinka	Treatment 2	T6	2	MW	71	42	15	0	0	128	
2024-08-17	Mesilinka	Treatment 2	T7	2	MW	131	107	22	1	0	261	
2024-08-17	Mesilinka	Treatment 2	T8	2	MW	48	21	11	0	0	80	
2024-08-17	Mesilinka	Treatment 2	T9	2	MW	17	40	11	1	0	69	

2024-08-17	Mesilinka	Treatment 2	T1	2	RB	0	2	4	0	0	6
2024-08-17	Mesilinka	Treatment 2	T2	2	RB	7	13	2	0	0	22
2024-08-17	Mesilinka	Treatment 2	T3	2	RB	1	4	3	0	0	8
2024-08-17	Mesilinka	Treatment 2	T4	2	RB	2	10	2	0	0	14
2024-08-17	Mesilinka	Treatment 2	T5	2	RB	1	2	1	0	0	4
2024-08-17	Mesilinka	Treatment 2	T6	2	RB	0	4	0	0	0	4
2024-08-17	Mesilinka	Treatment 2	T7	2	RB	1	6	3	0	0	10
2024-08-17	Mesilinka	Treatment 2	T8	2	RB	0	0	1	0	0	1
2024-08-17	Mesilinka	Treatment 2	T9	2	RB	0	0	0	0	0	0

\* White (Wt) or orange (Or.) tags observed by swimmers

**Table B-2. Raw counts of fish species observed during snorkel counts in five reconnaissance reaches of Mesilinka River, Lay Creek and Tutizika River.**

Date	Stream	Reach	Sub	Rep.	Spp.	<20 cm	20-30 cm	30-40 cm	40-50 cm	50+ cm	Total
2024-08-14	Lay Cr.	Canyon		1	BT	0	0	0	0	0	0
2024-08-14	Lay Cr.	Canyon		1	GR	0	0	1	0	0	1
2024-08-14	Lay Cr.	Canyon		1	MW	22	49	14	0	0	85
2024-08-14	Lay Cr.	Canyon		1	RB	9	25	8	0	0	42
2024-08-13	Lay Cr.	Lower		1	BT	0	0	0	0	0	0
2024-08-13	Lay Cr.	Lower		1	GR	0	0	1	0	0	1
2024-08-13	Lay Cr.	Lower		1	MW	0	19	8	0	0	27
2024-08-13	Lay Cr.	Lower		1	RB	0	2	2	0	0	4
2024-08-13	Mesilinka	Lay Con.		1	BT	0	0	0	0	3	3
2024-08-13	Mesilinka	Lay Con.		1	GR	0	0	1	0	0	1
2024-08-13	Mesilinka	Lay Con.		1	MW	248	150	94	1	0	493
2024-08-13	Mesilinka	Lay Con.		1	RB	10	17	6	0	0	33
2024-08-12	Mesilinka	Control	C0	Tr.	BT	0	0	0	0	0	0
2024-08-12	Mesilinka	Control	C1	Tr.	BT	0	0	0	0	0	0
2024-08-12	Mesilinka	Control	C2	Tr.	BT	0	0	0	0	0	0
2024-08-12	Mesilinka	Control	C3	Tr.	BT	1	0	0	0	0	1
2024-08-12	Mesilinka	Control	C4	Tr.	BT	0	0	0	0	0	0
2024-08-12	Mesilinka	Control	C5	Tr.	BT	0	0	0	0	0	0
2024-08-12	Mesilinka	Control	C6	Tr.	BT	0	0	1	1	0	2
2024-08-12	Mesilinka	Control	C7	Tr.	BT	2	0	0	0	0	2
2024-08-12	Mesilinka	Control	C8	Tr.	BT	0	0	0	0	0	0
2024-08-12	Mesilinka	Control	C0	Tr.	GR	0	0	0	0	0	0
2024-08-12	Mesilinka	Control	C1	Tr.	GR	0	0	0	0	0	0
2024-08-12	Mesilinka	Control	C2	Tr.	GR	0	0	1	0	0	1
2024-08-12	Mesilinka	Control	C3	Tr.	GR	0	1	0	0	0	1
2024-08-12	Mesilinka	Control	C4	Tr.	GR	0	0	0	0	0	0
2024-08-12	Mesilinka	Control	C5	Tr.	GR	0	0	0	0	0	0
2024-08-12	Mesilinka	Control	C6	Tr.	GR	1	0	0	0	0	1
2024-08-12	Mesilinka	Control	C7	Tr.	GR	0	0	1	0	0	1
2024-08-12	Mesilinka	Control	C8	Tr.	GR	0	0	0	0	0	0
2024-08-12	Mesilinka	Control	C0	Tr.	MW	2	0	1	0	0	3
2024-08-12	Mesilinka	Control	C1	Tr.	MW	35	13	0	0	0	48
2024-08-12	Mesilinka	Control	C2	Tr.	MW	0	0	0	0	0	0
2024-08-12	Mesilinka	Control	C3	Tr.	MW	25	18	11	0	0	54
2024-08-12	Mesilinka	Control	C4	Tr.	MW	19	7	0	0	0	26
2024-08-12	Mesilinka	Control	C5	Tr.	MW	23	11	6	0	0	40
2024-08-12	Mesilinka	Control	C6	Tr.	MW	22	12	5	0	0	39

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2024-08-12	Mesilinka	Control	C7	Tr.	MW	42	33	11	0	0	86
2024-08-12	Mesilinka	Control	C8	Tr.	MW	16	7	2	0	0	25
2024-08-12	Mesilinka	Control	C0	Tr.	RB	0	0	1	0	0	1
2024-08-12	Mesilinka	Control	C1	Tr.	RB	0	0	0	0	0	0
2024-08-12	Mesilinka	Control	C2	Tr.	RB	0	0	0	0	0	0
2024-08-12	Mesilinka	Control	C3	Tr.	RB	1	2	0	0	0	3
2024-08-12	Mesilinka	Control	C4	Tr.	RB	0	0	0	0	0	0
2024-08-12	Mesilinka	Control	C5	Tr.	RB	0	1	1	0	0	2
2024-08-12	Mesilinka	Control	C6	Tr.	RB	3	3	0	0	0	6
2024-08-12	Mesilinka	Control	C7	Tr.	RB	1	1	0	0	0	2
2024-08-12	Mesilinka	Control	C8	Tr.	RB	0	0	0	0	0	0
2024-08-15	Mesilinka	Upper		1	BT	0	1	1	1	1	4
2024-08-15	Mesilinka	Upper		1	GR	1	0	0	0	0	1
2024-08-15	Mesilinka	Upper		1	MW	183	114	54	0	0	351
2024-08-15	Mesilinka	Upper		1	RB	16	17	5	1	0	39
2024-08-15	Tutizika	Upper		1	BT	0	1	0	0	0	1
2024-08-15	Tutizika	Upper		1	MW	109	71	28	0	0	208
2024-08-15	Tutizika	Upper		1	RB	35	19	1	0	0	55