Ingenika River Arctic Grayling 46 Years Post-Flooding

2019 Snorkeling Counts in Index sites

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Ingenika River Arctic Grayling 46 Years Post-Flooding: 2019 Snorkeling Counts in Index sites.

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Signature Page

Chu Cho Environmental has prepared this report using sound technical and professional judgment based on our extensive expertise and experience in developing and conducting works of this nature. We have identified and developed this report in order to provide clear and concise information regarding the outcomes form the 2019 Ingenika River Arctic Grayling snorkel surveys.

Jeff Strohm – Fisheries Biologist, Chu Cho Environmental

Executive Summary

Previous analysis by the Fish and Wildlife Compensation Program – Peace Region (FWCP) has identified two high priority knowledge gaps limiting the program's ability to initiate conservation and enhancement actions for Ingenika River Arctic Grayling:

- 1. A lack of population monitoring data required to estimate conservation status (i.e. likelihood of persisting into the future), and
- 2. Insufficient data indicating critical habitats for key life history stages.

These two information gaps also address FWCP's *Streams Action Plan* priority action *1b-3*:

> Undertake Arctic Grayling monitoring as per recommendations of the monitoring program and develop specific, prioritized recommendations for habitat-based actions which correspond to the monitoring results (FWCP 2014a).

This study is monitoring Arctic Grayling adult abundance using snorkel survey methods applied in long-term index sites delineated along the Ingenika River, a watershed of critical interest to the Tsay Keh Dene Nation. The method was originally conceived of and implemented in 2004 by FWCP, where index sites were selected, and the snorkel survey method was implemented to estimate adult and subadult abundance in critical summer rearing habitats (Cowie and Blackman 2012). Low fish densities were observed in 2004, which raised concern for the population's status (Stamford et al. 2017), but because the surveys were not repeated, the population trend was unknown. Consequently, in August 2018, we investigated Arctic Grayling abundance in the Ingenika core area using these same methods to evaluate the same index sites as in 2004 and provided a first look at trends in abundance between two time points. These counts indicated stable Arctic Grayling abundance in the Ingenika core area, with the 2018 estimate being within 13% of the 2004 estimate of 282 adult Arctic Grayling. The results supported the original conservation assessment *at-high-risk* of extirpation due to a consistently small population size and assumed lack of connectivity with surrounding populations (e.g. Lower Finlay core area; Stamford et al. 2017).

Due to exceptionally poor visibility associated with intense rainfall during summer 2019, only 7 of 17 index sites were surveyed. All seven were located in the upper and middle index sections where previous surveys (i.e. 2004 and 2018) determined these to contain the highest densities and abundance of Arctic Grayling. Therefore, only a simple analysis of density and abundance was permissible this year and results suggest that the Ingenika continues to exhibit distinct zones of habitat use in the upper and middle reaches. The chute at river Km 95 continued to function as a migration barrier, even at high flows with sparse Grayling densities upstream, and no large Grayling >40cm were observed. The available habitat immediately below the chute (index 4) seems to have changed with high flows. In 2004, and 2018 this site contained the highest density of Grayling, but in 2019 densities dropped by nearly 60%. Underwater visibility was lower this year in the upper index sites, but still well within the range of acceptability, making it difficult to contribute lower counts exclusively to reduced visibility. This highlights the need for a more detailed investigation of detection probability (accuracy of snorkeling surveys) and factors affecting this key parameter for estimating abundance and trend. In our 2020 study, which has been conditionally funded, we

will estimate detection probability in two ways: 1) through a mark-resight study, which is a common method for assessing the accuracy of snorkeling surveys but which is relatively costly making it difficult to acquire the necessary replication of detection probability estimates; and 2) through a relatively novel no-mark approach in which replicated count data (3 replicates at each of 4 sites) are analyzed to estimate detection probability and population size based on the variability among replicates. These data will be utilized within a quantitative analysis framework in 2020 to estimate population size and its limits of confidence.

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The primary threat facing this population continues to be the expansion of forestry and other land use activities into the relatively pristine middle and upper portions of the Ingenika River watershed, which contain critical summer rearing habitats for adult and subadult life stages.

Using some of the time that would have otherwise been allocated to full data analyses, we instead conducted some advance planning for snorkeling surveys in the Mesilinka River watershed. The long-term vision for this study is to rotate among sites in the Mesilinka River and Finlay River watersheds, in addition to the Ingenika River, to improve estimates of Arctic Grayling conservation status and limiting factors for the Williston Reservoir watershed as a whole. The data synthesis and a more recent eDNA study identified possible demographic connections might occur between these core areas (Lower Finlay, Ingenika) that might have significant effects on abundance estimates.

1 Introduction

In their lifetimes, members of the Tsay Keh Dene Nation born before the completion of the W.A.C. Bennett Dam in 1967 have seen incredible physical and ecological changes in their traditional territory. Williston Reservoir, which reached full pool in 1972 (Hirst 1991), flooded approximately 110 km of the lower Finlay River valley, with profound effects on fish and wildlife communities. The Arctic Grayling (*Thymallus arcticus*) is an especially coveted and sought-after sustenance species for the Nation. Since flooding, Arctic Grayling have disappeared from most of the direct tributaries to Williston Reservoir. Only six larger watersheds are known to contain sufficient habitat complexity to sustain populations including: Parsnip, Nation, Omineca, Mesilinka, Finlay, and Ingenika (Stamford et al. 2017). The Ingenika River watershed is of critical interest to the nearby community of Tsay Keh Dene. Utilizing a snorkeling survey methodology applied in long-term index sites along the Ingenika River, this study is designed to monitor Arctic Grayling population status and the distribution of critical habitats in this watershed.

In 2016, a major study was conducted by the Fish and Wildlife Compensation Program – Peace Region (FWCP) to evaluate the existing knowledge base relative to conservation objectives for Arctic Grayling.[1] The resulting Arctic Grayling Synthesis Report (Stamford et al. 2017), along with the companion summary document Arctic Grayling Monitoring Framework (Hagen and Stamford 2017), identify key knowledge gaps limiting FWCP's ability to initiate conservation and enhancement actions for Arctic Grayling.

The most important information gap identified for the Ingenika River Arctic Grayling population was the lack of monitoring data for assessing the population's 'conservation status' (Stamford et al. 2017). Conservation status can be defined as an assessment of the overall population viability, or health. The two most important indicators of conservation status are the total abundance of adult individuals, and the population trend (McElhany et al. 2000; O'Grady et al. 2004). The reason that total abundance is so important is that at very small population sizes, the extirpation risks posed by environmental and demographic stochasticity, and genetic processes (inbreeding depression and long-term genetic losses and genetic drift) are greatly magnified (Simberloff 1988; Nunney and Campbell 1993). Guidelines for minimum viable population sizes for sensitive fish species may be based on quantitative models, or on the commonly cited "50/500" rule in conservation biology (Franklin 1980, Nunney and Campbell 1993), where 50 is the minimum effective population size required to avoid immediate risk of extirpation through inbreeding and 500 is the minimum variance effective size needed to avoid extirpation over the long term. Empirical studies of extinction in mammals and birds have generally suggested that an adult census population size of $N < 50$ is clearly insufficient for a population's long-term persistence, populations of $50 < N < 200$ are marginally secure, and those of $N > 200$ are secure at least over time frames as limited as those used in the studies (reviewed in Boyce 1992). With respect to population trend, a sustained population decline obviously threatens a

[1] *Streams Action Plan* Action 1b-1: Review existing information (including provincial management plan), summarize status and trends of Arctic Graying and its habitats, undertake actions that are within the FWCP scope and lead directly to the development of conservation and enhancement actions, and develop a cost-effective monitoring program to assess status and trends (FWCP 2014a).

population's viability, if threats cannot be identified and mitigated (Caughley 1994). Trend needs to be evaluated at appropriate time scales, often decadal. Minimum guidelines for evaluating trend can be 2-3 generations, for example (USFWS 2002, COSEWIC 2010), or 5 or more population estimates over a minimum ten-year period (Humbert et al. 2009; Kovach et al. 2016).

A second, key information gap limiting the ability to initiate conservation actions for Ingenika River Arctic Grayling was the lack of information indicating critical habitats for key life stages (Stamford et al. 2017). Critical habitats limit or have the potential to limit the number of Arctic Grayling surviving to adulthood in the population. For conservation actions to be effective in maintaining an Arctic Grayling population, they must target limiting factors operating within critical habitats for that population.

For subadult and adult Arctic Grayling of the Ingenika River watershed, FWCP-led monitoring of abundance and critical summer rearing habitats was conceived and implemented for the first time in 2004 (Cowie and Blackman 2012). The study methodology, which utilized snorkeling surveys in index sites laid out along the accessible length of the Ingenika River, was utilized for the second time in August 2018. Study results from 2004 and 2018 enabled an initial investigation of Arctic Grayling trend between these two time points. Low fish densities observed in 2004 had previously raised concern for the population's status (Stamford et al. 2017), but because the surveys were not repeated the population trend was unknown. The results from 2018 indicated the population was stable, but potentially at high risk due to its small size and assumed lack of connectivity with surrounding populations.

In 2019, we were only able to complete snorkeling surveys in a portion of the long-term index sites, due to exceptionally high water and turbidity throughout the month of August. Consequently, this report does not contain all the analyses that were planned for the snorkeling survey data. With some of the time that would have otherwise been allocated to these analyses, we have instead conducted some advance planning for snorkeling surveys in the Mesilinka River watershed. The long-term vision for this study is to rotate among sites in the Mesilinka River and Finlay River watersheds, in addition to the Ingenika River, to improve estimates of Arctic Grayling conservation status and limiting factors for the Williston Reservoir watershed as a whole. Although these adult rearing areas have been grouped into three separate core areas (Omineca, Ingenika, Lower Finlay, respectively), some uncertainty remains about their demographic independence that can be addressed by concordantly monitoring adult abundance (Stamford et al. 2017).

Key questions for FWCP and the Tsay Keh Dene Nation continue to be: What is the status of the Ingenika River Arctic Grayling population now, more than 45 years after such extensive habitat loss, and apparent isolation from other grayling populations by flooding? Where are the critical habitats for Arctic Grayling in the watershed located, and are they threatened? Although our study was abbreviated in 2019, it contributes to the longer-term effort to address these questions.

2 GOALS AND OBJECTIVES

Within the Peace Region, FWCP's goal is to conserve and enhance fish and their habitat in order to support the maintenance of thriving fish populations in watersheds that are functioning and sustainable (FWCP 2014b: *Peace Basin Plan*).

By addressing high-priority knowledge gaps of the Arctic Grayling monitoring program (Stamford et al. 2017; Hagen and Stamford 2017), our study is aligned with FWCP's *Streams Action Plan* priority action *1b-3*:

> *Action 1b-3*: Undertake Arctic Grayling monitoring as per recommendations of the monitoring program and develop specific, prioritized recommendations for habitat-based actions which correspond to the monitoring results (FWCP 2014a).

Provisional fish conservation goals for the Tsay Keh Dene Nation (Hagen et al. 2018) include:

1. Conserve wild fish and their habitats.
2. Optimize fishery benefits for the Tsay Keh Dene and all residents of British Columbia.
3. Provide opportunities for employment, training, and information exchange for the Tsay Keh Dene Nation and its members, within a partnership with FWCP that is strategic, effective, and efficient.
4. Utilize both scientific and traditional community knowledge when prioritizing fish populations and habitats for conservation actions.

In support of FWCP and Tsay Keh Dene goals, the 2019 study had the following specific objectives:

1. To acquire counts of Arctic Grayling and other species in established index reaches of the Ingenika River watersheds, using a snorkeling survey methodology consistent with surveys in 2004 and 2018.
2. To evaluate changes in Arctic Grayling abundance since 2004 by comparing counts in index sections.
3. To monitor the distribution of summer critical rearing habitats for subadult and adult Arctic Grayling along the Ingenika River mainstem and compare this distribution with that observed during the 2004 and 2018 surveys.
4. To communicate the study results directly to members of the Tsay Keh Dene Nation in the fall and winter of 2019/2020.

3 STUDY AREA

The Ingenika River watershed lies within the traditional territory of the Tsay Keh Dene Nation and is of critical interest to the community of Tsay Keh Dene, which is located approximately 20 km from the lower Ingenika River at the head of Williston Reservoir's Finlay Reach. The Ingenika River watershed has played a central role in Tsay Keh Dene culture and heritage and is still used today for traditional hunting, gathering, fishing and other cultural activities. Many Tsay Keh Dene citizens grew up in the community of Grassy Bluff that is located adjacent to the Ingenika River, and consequently the river and its resources hold special significance to them.

The post-impoundment Ingenika River is a 7^{th} order stream with a watershed area of 5,491 km^2 (Cowie and Blackman 2012). The Ingenika originates in the McConnell Range of the Omineca Mountains and flows east for approximately 140 km to the Rocky Mountain Trench and Williston Reservoir. Major, accessible tributaries of the Ingenika River include Swannell River, Pelly Creek, Wrede Creek, and Frederikson Creek. The mainstem Ingenika has been divided into 4 basic reaches based on habitat similarities (Table 1). It should be noted, however, that the 'Headwater' reach above Km 109 is further divided into sections that are i) accessible to fish migrating from the lower River or Williston Reservoir, and ii) isolated above an impassable waterfall at 9 V 661477 6302342, located at approximately Km 117.

Table 1: Reach descriptions for the mainstem Ingenika River (adapted from Cowie and Blackman 2012).

Reach ID	Length (km)	River km	Snorkeling sites	Sampling fraction*	Habitat description	Substrate** (dominant/ subdominant	Gradient %
Lower	40.6	0 to 40.6	13-17	28%	Mean wetted width: 49m; slow velocity; single channel	Fines**	0.2%
Mid	48.9	40.6 to 89.5	6-12	42%	Mean wetted width: 40m; braided multi-channel; frequent log jams	Gravel Fines/cobble	0.3%
Upper	19.5	89.5 to 109	4-5 (d/s chute) 1-3 (u/s chute)	100% 54%	Mean wetted width: 41m; boulder/riffle; single channel	Boulder Cobble	1.0%
Headwater	36	109 to 143.4	None	0%	Mean wetted width: <25m; bedrock step-pool; entrenched	Bedrock Boulder/cobble	1.5%

*Stream channel length snorkeled as a proportion of the total channel length in the reach
**Fines <2mm, gravel 2-64 mm, cobble 64-256 mm, boulder >256mm.

Streamflow in the Ingenika River watershed is snowmelt driven, with peak discharge occurring, on average, in early-June.[2] Much of the watershed drains higher elevation, mountainous areas, but glaciers are not

[2] Water Survey of Canada, data on file: https://wateroffice.ec.gc.ca/report/real_time_e.html?stn=07EA004

present in tributary watersheds. Consequently, in most years water clarity is excellent throughout watershed sub-basins throughout most of the year, and by August the mainstem Ingenika River is clear (Cowie and Blackman 2012).

The most significant factor affecting fish populations in the Ingenika River watershed has been the flooding of the river's lower 12 km caused by the construction of W.A.C. Bennett Dam, which resulted in loss of habitat and population decline after demographic and genetic connections with the lower Finlay River were removed (Stamford et al. 2017 and references therein). Land use and related habitat degradation in the unflooded portion of the Ingenika River watershed is restricted to the Swannell River watershed, and the lower 40 km of the Ingenika River watershed downstream of Pelly Creek. The Ingenika's headwaters and major tributaries Pelly Creek, Wrede Creek, and Frederickson Creek remain largely pristine.

Arctic Grayling of the Ingenika River watershed appear to be isolated from other populations (Stamford et al. 2017 and references therein) and are therefore classified as a separate conservation unit or 'core area.' [3] Core areas are defined as groups of populations that are demographically linked and genetically similar (Stamford et al. 2015), although a core area may also comprise a single population. As such, the system of core areas is meant to be a proxy for the potential metapopulation structure. In the Williston Reservoir watershed, the distribution of Arctic Grayling is comprised of the Ingenika core area as well as the Parsnip, Nation, Omineca, Lower Finlay, Upper Finlay, Williston, and Upper Peace core areas (Stamford et al. 2017).

Within the Ingenika core area, Arctic Grayling are thought to primarily be a mainstem population. Periodic use of tributaries occurs by rearing adults, and possibly during spawning, but the importance of tributary reaches for the population is incompletely resolved (Stamford et al. 2017).

In addition to Arctic Grayling (*Thymallus arcticus*), native salmonids inhabiting the Ingenika River watershed include Bull Trout (*Salvelinus confluentus*), Dolly Varden (*Salvelinus malma*: verified) Rainbow Trout (*Oncorhynchus mykiss*), Mountain Whitefish (*Prosopium williamsoni*), Lake Whitefish (*Coregonus clupeaformis*), Kokanee (*Oncorhynchus nerka*), and possibly Pygmy Whitefish (*Prospium coulteri*). Burbot (*Lota lota*), Peamouth (*Mylocheilus caurinus*), Lake Chub (*Couesius plumbeus*), Largescale Sucker (*Catostomus macrocheilus*), Longnose Sucker (*Catostomus catastomus*), White Sucker (*Catostomus commersoni*), Slimy Sculpin (*Cottus cognatus*), Prickly Sculpin (*Cottus asper*), and Longnose Dace (*Rhinichthys cataractae*) are also present (Bruce and Starr 1985; Cowie and Blackman 2004; BCGW 2019).

[3] Close genetic connections between Ingenika and Finlay River Grayling were assumed to have been severed by flooding of Williston Reservoir (Stamford et al. 2017).

4 METHODS

4.1 Study Design

Cowie and Blackman (2012) stratified the Ingenika River into 4 reaches, three of which were sub-sampled (Lower = 5 sites, Mid = 7 sites, Upper = 5 sites, Headwaters = 0 sites; Table 1) using single pass snorkeling surveys in 2004. The sampling fraction for each of these reaches was approximately related (positively) to the expected densities of Arctic Grayling (Table 1). In our study, we retained the same site locations and stratification scheme. A new distribution of sampling sites would potentially introduce a large degree of uncertainty into the comparison between years, related to spatial variation in fish density. We introduced one minor modification of the study design beginning in 2018 to improve analysis of the snorkeling count data. This included dividing the Upper reach into two sections, one upstream and one downstream of a chute obstruction (u/s chute, d/s chute; Table 1). We observed a strong effect from this chute on Arctic Grayling distribution in the field.

A plan to replicate snorkeling swims three times in 3-4 sites was included for the design of the 2019 study, which would enable an evaluation of the accuracy and precision of snorkeling counts. These can vary substantially from system to system. Drawing from past studies and experience, factors affecting the accuracy of snorkeling counts have included species differences, underwater visibility, instream cover, stream size, and observer experience (Northcote and Wilkie 1963; Schill and Griffith 1984; Slaney and Martin 1987; Zubik and Fraley 1988; Young and Hayes 2001; Korman et al. 2002; Hagen and Baxter 2005). An assessment of snorkel count accuracy using mark-resight methods (Ibid.) was proposed as an additional study component for 2019 but was unfortunately not approved for funding.

4.2 Survey Conditions

The Water Survey of Canada (WSC) Station 07EA004 is located on the lower Ingenika River upstream of the Swannell River confluence: the only WSC flow monitoring station for the Ingenika River watershed. This WSC station provided real time stream discharge data which was utilized to assess the potential safety and feasibility for snorkeling surveys in August 2019. These data were also utilized to compare flow conditions in the Ingenika River watershed in August 2019 with historical conditions.

A primary factor affecting detection probability in streams is underwater visibility (Hagen and Baxter 2005). In our study, we measured underwater visibility at index sites in two ways: 1) horizontal underwater secchi disk visibility, and 2) horizontal underwater distance at which identifying features for a 30 cm Arctic Grayling model became undiscernible.

4.3 Snorkeling Methods

In 2019 we attempted to conduct snorkeling surveys in 17 index sites along the Ingenika River (Figure 4.1: upper Ingenika River; Figure 4.2: lower Ingenika River) over the five-day period between August 5-9th, similar to the original August 10-13 period surveyed in 2004.

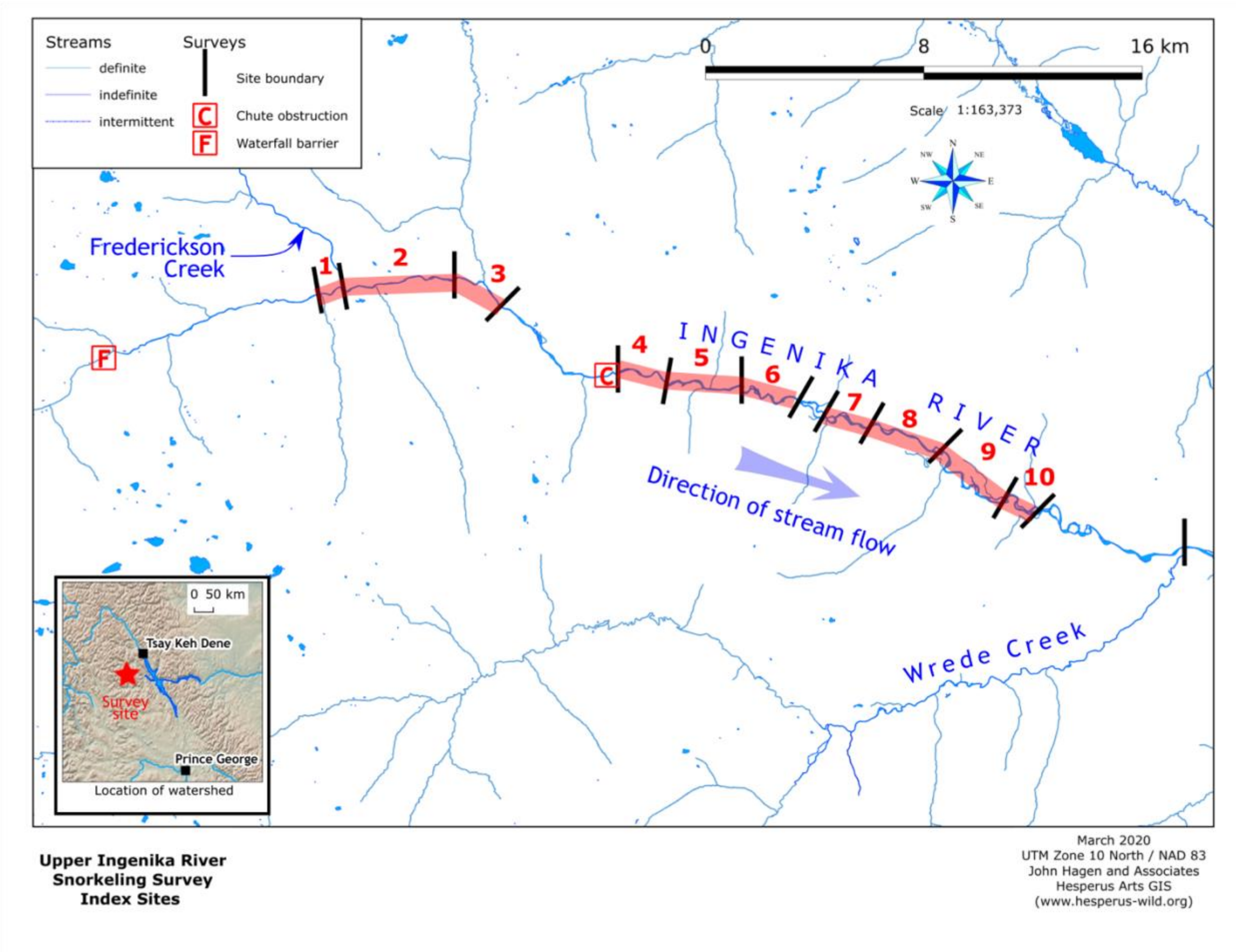

Figure 4.1 Stream sections (sites) of the upper Ingenika River utilized for snorkeling surveys to monitor Arctic Grayling abundance, 2004, 2018 and 2019.

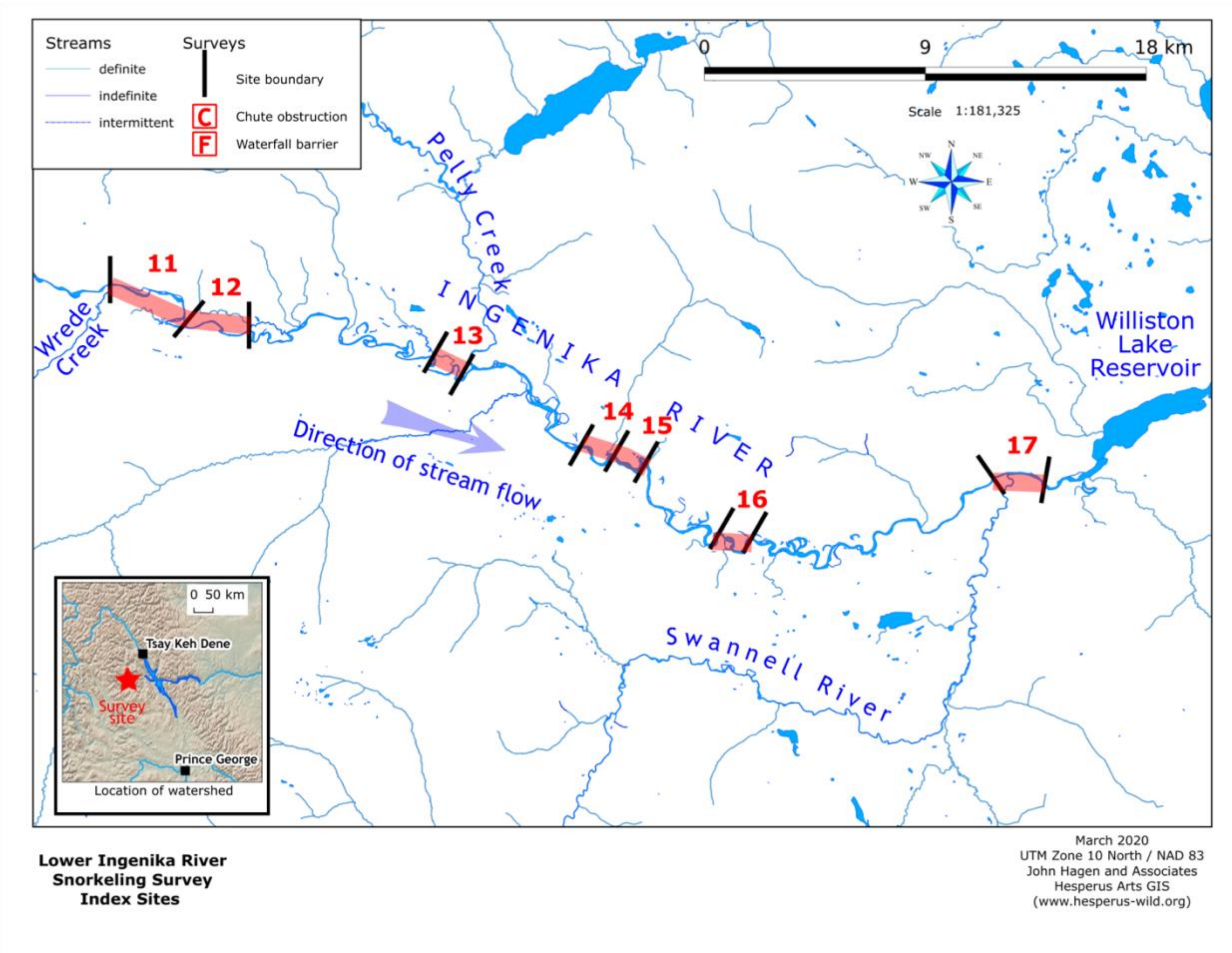

Figure 4.2 Stream sections (sites) of the lower Ingenika River utilized for snorkeling surveys to monitor Arctic Grayling abundance, 2004, 2018, and 2019.

Consistent with methods in 2004 (Cowie and Blackman 2012), snorkeling surveys were conducted by a crew of 3 observers (Figure 4.4), organized in lanes of width determined by horizontal underwater visibility and estimated habitat suitability (usable wetted width for subadult and adult Arctic Grayling[4]). All observers were experienced in conducting snorkeling surveys and consistently received in-the-water training (refreshers) with the study protocol prior to the survey period. A fourth crew member trained in swiftwater rescue was in charge of safety, and drifted through behind the line of snorkelers in an inflatable kayak that was capable of navigating the range of stream features encountered, but which could also be easily stowed in the basket of the helicopter for efficient transport (Figure 4.5, Figure 4.6). Where possible observers counted fish in a lane extending in front and to one side only. When the usable wetted width exceeded the

[4]In the Williston Reservoir watershed, adult and subadult Arctic Grayling >20 cm utilize pool and glide habitats of >80 cm depth generally, with preferred locations being deeper water adjacent to the thalweg and relatively limited use of wood debris cover (Blackman and Hunter 2001).

width of 3 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. Observed fish were classified to species, and tallied in one of five size categories: 0-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, and 50+ cm.

At the start of each survey, estimates of underwater visibility, and fish sizes were practiced on 20 cm, 30 cm, and 40 cm models held suspended in the water column (Figure 4.3). Particular attention was paid to the magnification effect of water, and all models were viewed repeatedly above, and below the surface to hone perspective of the underwater magnification effect.

Figure 4.3 Size estimation practice using Arctic Grayling models representing the three size classes used in this study (20, 30, and 40cm)

Reliable counts require a disciplined effort to organize divers in lanes across the stream, and regular communication among divers to avoid overcounting or missing areas of suitable habitat (Northcote and Wilkie 1963; Schill and Griffith 1984; Slaney and Martin 1987; Hagen and Baxter 2005). To avoid double counting fish, observers attempted to count only fish that were in their lane as they passed by. However, because fish moved in reaction to the survey team, frequent communication was necessary to ensure that double counting did not occur.

Figure 4.4 Snorkeling survey in the lower Ingenika River, August 2019.

Figure 4.5 Helicopter basket used to transport the deflated rescue kayak and snorkeling gear.

Figure 4.6 Inflated kayak containing swiftwater rescue and survey equipment.

4.4 Analysis

The change in Arctic Grayling abundance in the Ingenika River between 2004 and 2019 was only assessed in a descriptive manner, given the limited amount of survey data collected due to unseasonably high flows and turbidity. The resulting reduced number of index sites swum in 2019 compromised our ability to estimate population size and compare with previous years (e.g. 2018; Hagen et al. 2019). An analysis of basic trends in density and abundance compared to previous years was all that was appropriate for this reduced dataset.

Methods to estimate detection probability p (the proportion of the population present actually seen by divers) and population size N based on replicated count data (e.g. Olkin et al. 1981; Royle 2004; Joseph et al. 2009) are currently being developed. This effort is being led by the Eduardo Martins lab of the University of Northern British Columbia. Models of p and N could not be applied to our data in 2019 because our study was canceled before replicated count data were collected at a minimum of 3 sites as planned.

5 RESULTS AND DISCUSSION

5.1 Survey Conditions

The month of August 2019 was unseasonably rainy, and even when surveys began flows were significantly higher than those seen during previous years, including 2018 (Figure 5.1). The declining hydrograph in the first week of August suggested we could proceed with planned surveys, and underwater visibility levels were sufficient for two days of surveys on August 5 and August 6. Heavy rainfall on the evening of August 6 and onwards, however, led to spring freshet-like conditions for the rest of the month.

Secchi disk visibility was initially comparable to 2018 in the uppermost index site (Figure 5.2), but it had decreased by nearly 40% by the time index section 4 was surveyed. In 2019, secchi disk visibility was 89% of what was observed in 2018 for the three middle index sections that were completed (Figure 5.2).

Visibility necessary for identification of Arctic Grayling models was identical for 2018 and 2019 in the middle index sections (Figure 5.3). Unfortunately, these data were not recorded for the uppermost 4 index sites in 2018. For the one site where there is overlapping data, fish model visibility in 2019 was 76% of what was observed in 2018. However, by the morning of August 7th, fish model visibility had declined below 3 m at index site 10 which was deemed inadequate for snorkeling surveys. Increasing discharge thereafter led to the cancelation of the 2019 snorkeling count program for the Ingenika River watershed. In both 2018, and 2019 index sites were surveyed once.

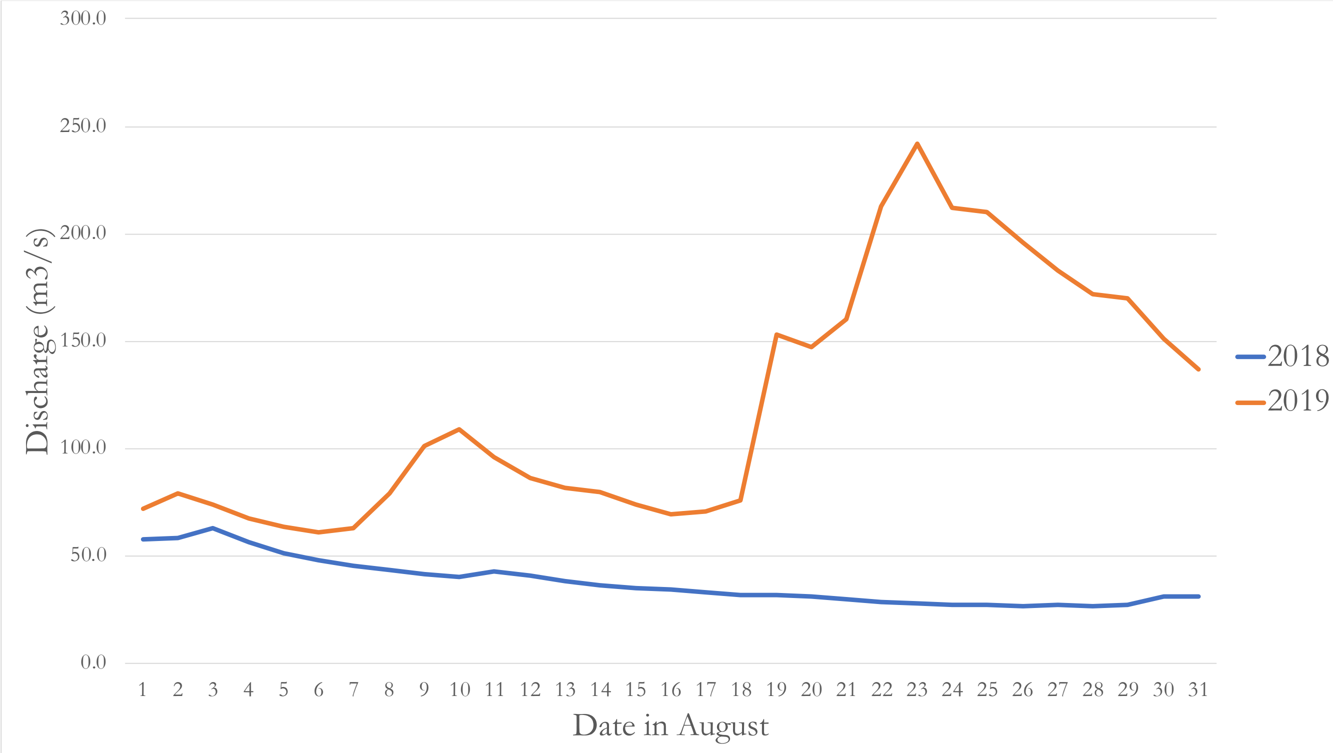

Figure 5.1 Daily discharge measurements from Water Survey of Canada Hydrometric Station 07EA004 (Ingenika above Swannell River), in August 2018 (blue), and 2019 (orange).

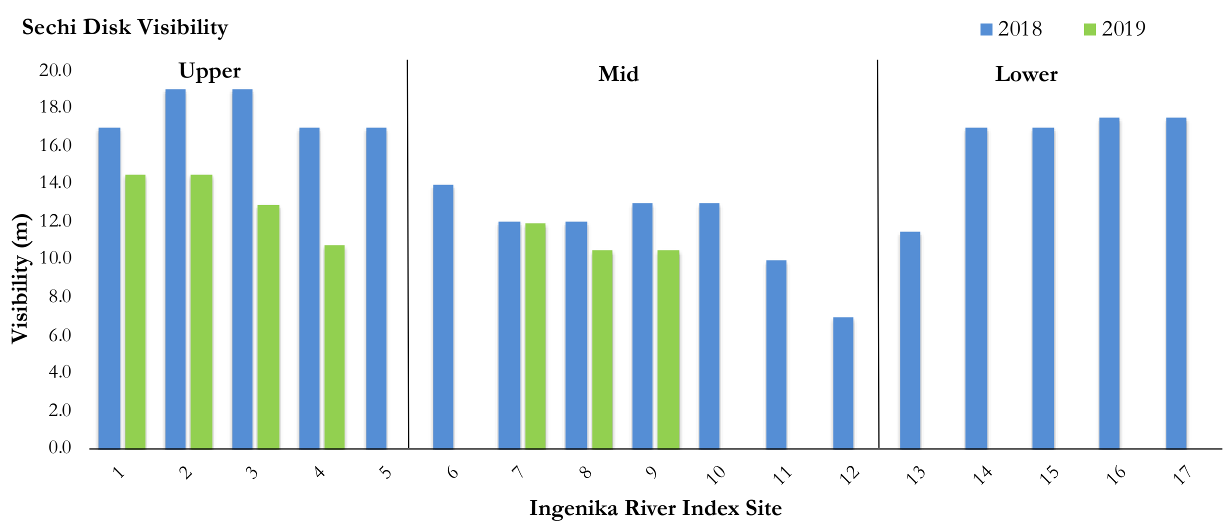

Figure 5.2 Horizontal underwater distances at which a secchi disk was no longer visible.

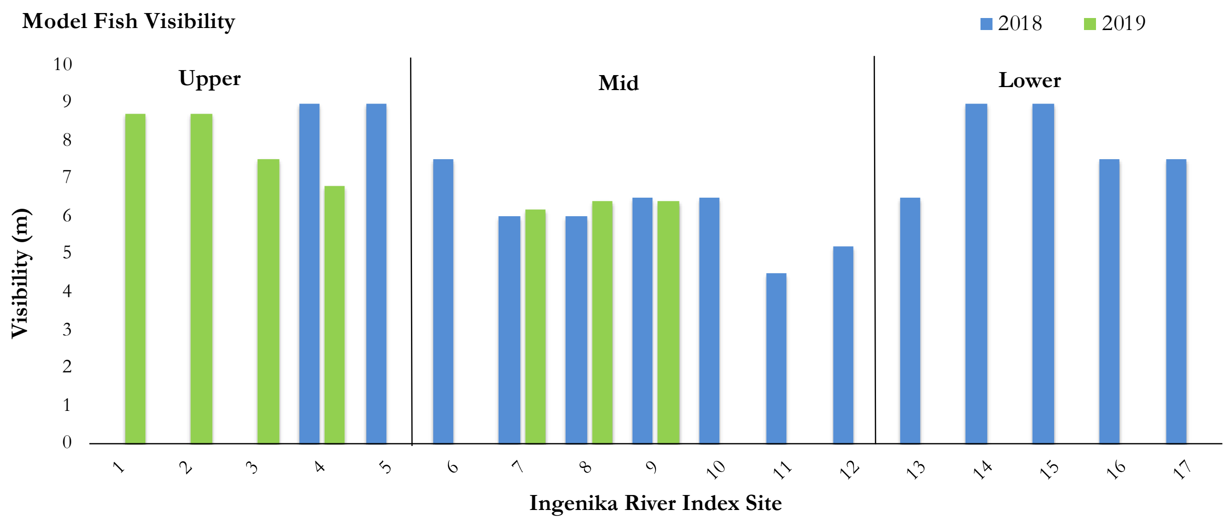

Figure 5.3 Horizontal underwater distances at which the 30 cm Arctic Grayling model fish could no longer be identified to species.

5.2 Critical Adult Summer Rearing Habitat and Arctic Grayling Abundance

Within the 7 index sites that were surveyed in 2019, patterns of density and abundance mirror those of 2004 and 2018 with distinct zones evident in the upper and middle index sections (Figure 5.4, Table 2). The most important feature along the Ingenika River affecting the distribution of Arctic Grayling continues to be the chute located approximately 95 km from the mouth, which divides the Upper reach into 'd/s chute' and 'u/s chute' sections (Figure 5.4, Figure 5.5, Table 2).

In 2019, Grayling were present upstream of the chute (Sites 2-3) and continued to exhibit extremely low densities, while the density of fish in the site immediately downstream of the chute (Site 4) was still the highest recorded (Figure 5.4). This abrupt change in abundance suggests that this chute is a migration obstruction for most Arctic Grayling even during high flow events. However, the density of Grayling within index site 4 was half of what has been observed in 2004, and 2018. This pattern of lower densities also continued into the three middle index sections that were surveyed, although the disparity was not as substantial (Figure 5.4).

This observed change in density and abundance highlights the need for a better understanding of local factors which influence detection probability and abundance. Within index site 4, which saw the largest decrease in observed Grayling, both the secchi disk, and model fish visibilities were substantially lower in 2019 (Figure 5.2, Figure 5.3). It is tempting to dismiss these results as an artifact of reduced visibility exclusively. However, the fact that visibility within the middle index sections was comparable between years, and yet 2019 abundances were still low suggests that this view may be too simplistic. Without the results of a mark-resight study (which has been conditionally approved for 2020) it is difficult to ascertain whether the patterns observed in 2019 are artifacts of difficult survey conditions (lower visibility, higher velocity), or suggest a shift in fish habitat use in an attempt to balance energy expenditures and foraging success. Specifically, as water velocities increase, the percentage of detected prey that Arctic Grayling can capture decreases (Hughes and Dill 1990), which suggests the fish might have moved to more lucrative habitats to improve their foraging success and overwintering survival.

Table 2 August snorkeling counts of Arctic Grayling, Bull Trout, Rainbow Trout, and Mountain Whitefish (GR, BT, RB, MW, respectively) >20 cm in index sites along the Ingenika River, 2004, 2018, and 2019. Empty cells in 2019 represent index sections that were not surveyed due to poor visibility.

			2019 Counts >20 cm				2018 Counts >20 cm				2014 Counts >20 cm			
Site	Reach	Site Length	GR	BT	RB	MW	GR	BT	RB	MW	GR	BT	RB	MW
1	Upper u/s chute	1.1	0	14	0	32	0	11	5	46	0	0	3	28
2	Upper u/s chute	4.4	3	14	6	109	3	42	23	266	8	1	2	60
3	Upper u/s chute	2.2	1	1	4	46	2	8	17	115	1	3	1	26
4	Upper d/s chute	2.2	18	8	9	72	39	41	3	121	40	0	1	46
5	Upper d/s chute	3.1					12	4	1	102	23	3	0	58
6	Mid	2.6					4	0	2	98	6	0	0	84
7	Mid	1.9	1	7	5	63	8	8	2	175	10	1	1	56
8	Mid	3.2	11	4	7	84	15	6	0	34	11	1	0	90
9	Mid	3.8	15	7	7	132	23	15	1	108	17	1	1	81
10	Mid	1.5					8	8	1	17	6	0	0	33
11	Mid	4.1					34	70	23	216	14	4	2	55
12	Mid	3.2					9	18	2	173	11	1	0	47
13	Lower	2.9					1	20	1	407	6	1	1	157
14	Lower	2.1					3	15	1	34	0	2	0	79
15	Lower	1.8					0	9	0	79	0	3	0	0
16	Lower	2.3					0	7	0	54	0	1	0	0
17	Lower	2.3					0	10	0	153	0	1	0	76
	2019 Survey sites only		49	55	38	538	90	131	51	865	87	7	9	387
Total	***All***	44.7	49	55	38	538	161	292	82	2198	153	23	12	976

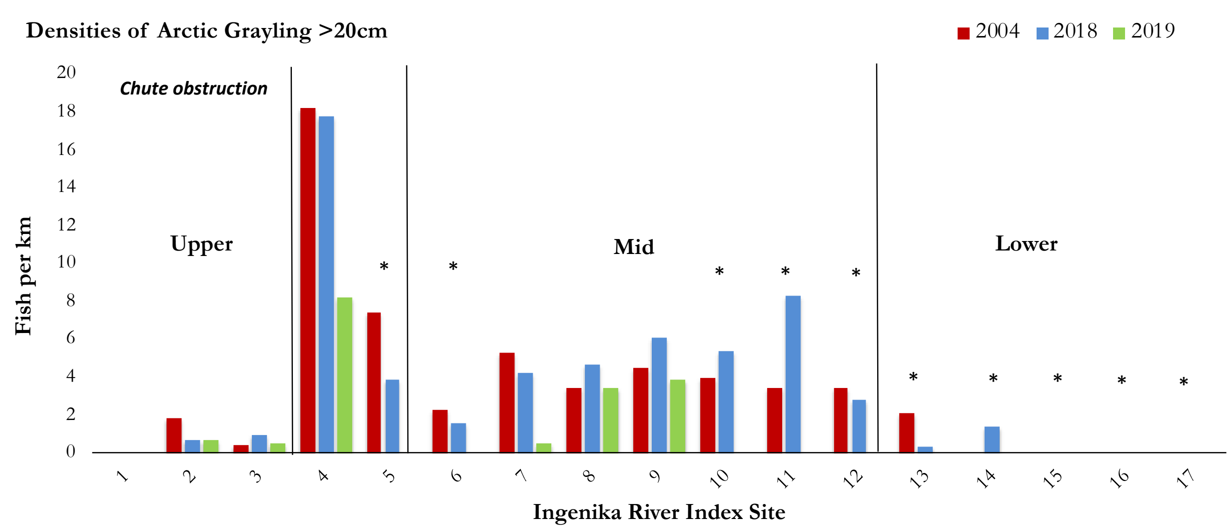

Figure 5.4 Densities (fish/km) of Arctic Grayling >20 cm in index sites along the Ingenika River, 2019 (green), 2018 (blue) and 2004 (red bars). Asterisks represent index sections that were not surveyed in 2019 due to poor visibility.

Arctic Grayling in Ingenika River display a classic size distribution with larger individuals (30 cm and larger) finding habitats furthest upstream while smaller individuals (<30 cm) rear in the larger downstream habitats, closer to probable spawning areas (Figure 5.6; Hughes and Reynolds 1994; Baccante 2010). The process appears to be growth dependent, possibly linked to the lower energetic cost required by larger fish to migrate further upstream after spawning (Hughes 1999). Interestingly, the age structure in Alaskan populations indicate the smaller fish (<25 cm) include slow growing individuals as old as nine or 10 years, which might also be sexually mature and suggests partial migration exists in Arctic Grayling (Jonsson and Jonsson 1993; Hughes 1999). Possibly, both resident and migratory individuals also exist in Ingenika River, which stresses the importance of including smaller individuals (<30 cm) in the adult counts and the need to evaluate the age structure to accompany abundance estimates. Presence of both resident and migratory individuals in Arctic Grayling populations carry strong implications for interpreting adult abundance estimates and identifying critical habitats within core areas.[5]

Remarkably, the largest and presumably oldest and most experienced individuals (i.e. >40 cm are probably older than 10 years; Decicco and Brown 2006) were not observed upstream of the chute obstruction, but were consistently (both in 2018 and 2019) distributed in the 'Mid' and 'Upper d/s chute' reaches (Figure 5.6, 5.7). This strongly suggests that optimal, perhaps *most* critical adult rearing habitat in Ingenika River exists downstream of the chute. In contrast, the relatively wide distribution of the more common size class (i.e. 30-40 cm) probably includes a wider range of ages. Possibly, some of the smaller individuals in this size class (i.e. <35 cm) are younger and exhibit more exploratory behaviour in finding rearing habitats including those marginal areas where survival might be less certain (e.g. 'Upper u/s chute'), which has been observed in other populations (e.g. Tack 1980).

In 2019, there was a clear absence of the smaller Arctic Grayling observed, with only one seen in the 20-30cm size class, and none <20cm (Figure 5.7). Smaller Arctic Grayling were more distributed in the lower river sites in 2018 (Figure 5.6), which suggests they were also rearing downstream during 2019. Absence of the smallest size class (i.e. <20cm) in 2018 and 2019 are in strong contrast to results from the 2004 survey, in which a total of 27 Arctic Grayling <20cm were observed (Cowie and Blackman 2012). This may indicate that downstream snorkeling surveys are a poor method for assessing these juveniles (probably age one or two), which find distinct habitat types relative to the larger size classes (Blackman and Hunter 2001; Blackman 2002). Although the reason for the discrepancy between years is not clear, juvenile salmonids <20cm are highly susceptible to predation and known to exhibit daytime concealment (Cunjak et al. 1988; Hillman et al. 1992; Thurow and Schill 1996), and a 10-fold increase in the presence of Bull Trout predators in 2018 and 2019 relative to 2004 (Figure 5.8, Section *5.4*) is a plausible factor potentially triggering a shift in the type of habitat they use. Alternatively, the rarity of juvenile Arctic Grayling in 2018 may have indicated a year-class failure resulting from environmental stochasticity, which has been observed elsewhere following a severe flood event (Tack 1974).

[5] Adult Arctic grayling show strong site fidelity to rearing areas, but also gather with individuals that originate from different natal areas (Buzby and Deegan 2000; Stamford et al. 2019). Possible adult migrations between adjacent core areas (e.g. between Ingenika and Finlay rivers) is a serious data gap requiring rigorous investigations (Stamford et al. 2017).

Figure 5.5 Upstream photograph of the chute obstruction (at river Km 95) which appears to be a factor affecting the distribution of fish in the Ingenika River. Note the two swimmers for scale.

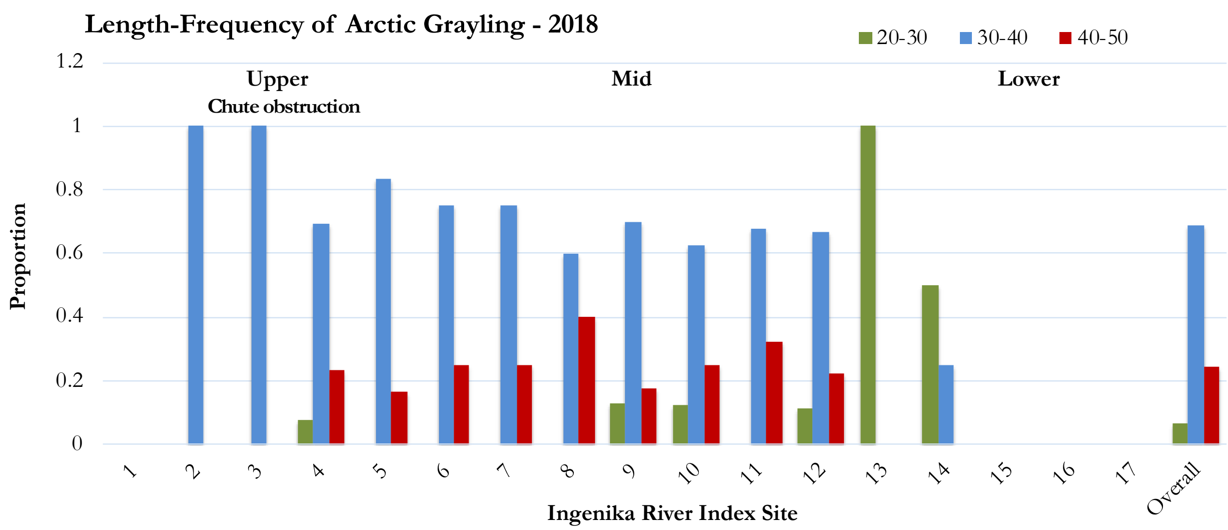

Figure 5.6 Proportion of observed Arctic Grayling in size classes 20-30 cm (green bars), 30-40 cm (blue bars), and >40 cm (red bars) among sites and overall, Ingenika River snorkeling surveys 2018. Size estimates are based on visual estimates by snorkelers.

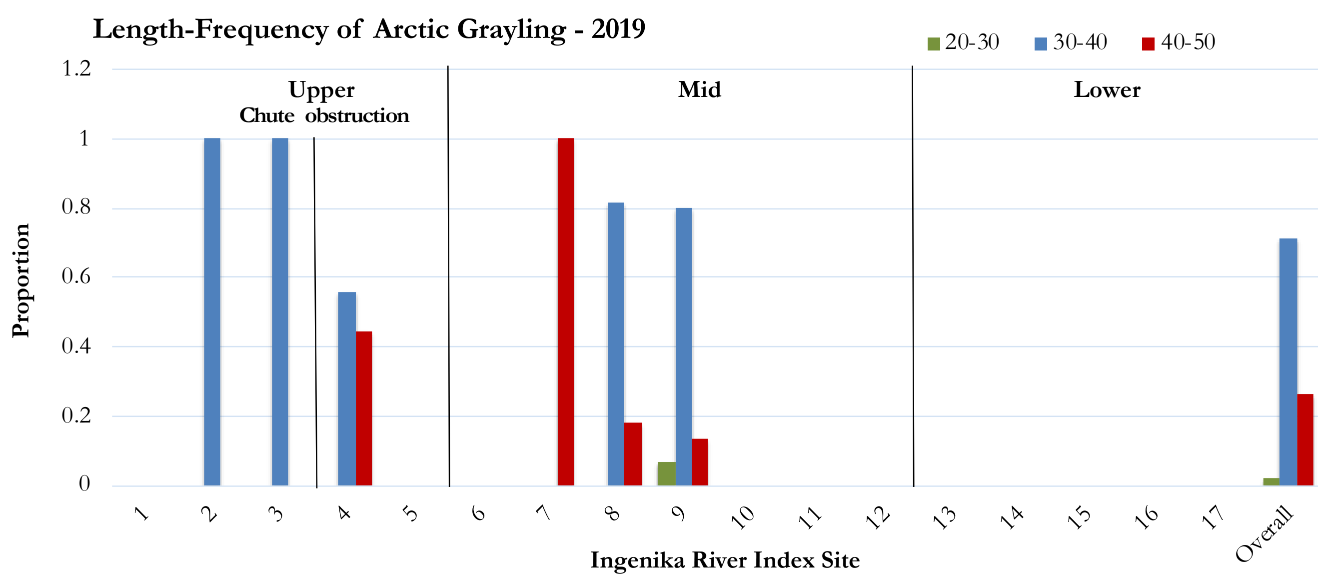

Figure 5.7. Proportion of observed Arctic Grayling in size classes 20-30 cm (green bars), 30-40 cm (blue bars), and >40 cm (red bars) among sites and overall, Ingenika River snorkeling surveys 2019. Size estimates are based on visual estimates by snorkelers.

5.3 Other Species

Although Arctic Grayling were the first priority for snorkeling observations, Bull Trout (Figure 5.9, Table 2), Rainbow Trout (Figure 5.9, Table 2), and Mountain Whitefish (Table 2) were also counted during continuous surveys along the length of the Ingenika River.[6] Because Mountain Whitefish were too numerous in many locations to count reliably, counts (Table 2) and estimated densities should be considered of low precision and accuracy relative to the other 3 species, and the comparison between years may not be reliable.

In 2019, densities of Bull Trout were lower than 2018 in every index section that was surveyed, aside from index section 1 (Figure 5.8). This section is above the confluence with Frederickson Creek, which is an important spawning tributary (Hagen and Spendlow 2017). While this shift in the distribution of large-bodied, migratory Bull Trout is interesting, the counting of gravel nests, or 'redds,' following the completion of spawning[7] is a preferred method for assessing changes in abundance among years. The high-water events of 2019 were associated with reduced Bull Trout redd counts in index sections of both the Attichika Creek watershed (near the Kemess Mine; Strohm et al. 2020) and also elsewhere in the Williston Reservoir watershed (Hagen et al. 2020).

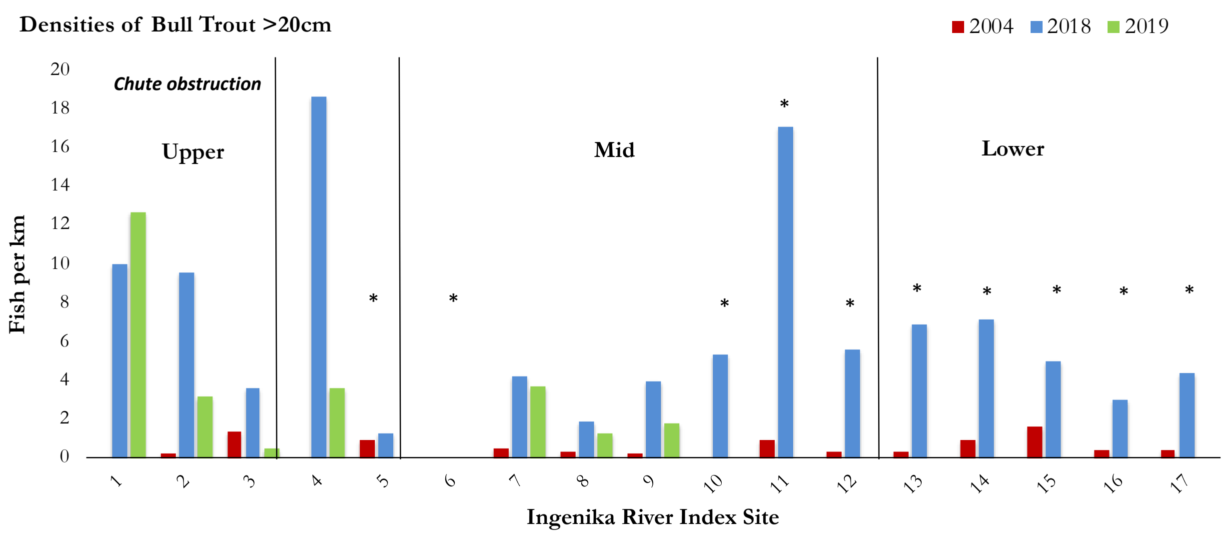

Figure 5.8 Densities (fish/km) of Bull Trout >20 cm in index sites along the Ingenika River, 2019 (green) 2018 (blue) and 2004 (red bars). Asterisks represent index sections that were not surveyed in 2019 due to high flows.

In 2018, Rainbow Trout >20 cm were at their highest abundance in sites upstream of the 95 km chute in the vicinity of Frederickson Creek (Sites 1-3), and in Site 11 downstream of Wrede Creek (Table 2, Figure

[6] More detailed information is contained within the Ingenika snorkeling database, available from FWCP and Chu Cho Environmental.

[7] A program of redd counts has already been initiated within the Ingenika River watershed to monitor changes in Bull Trout abundance over time (Hagen and Spendlow 2017).

5.9). In 2019, Rainbow Trout were observed at much lower densities above the chute barrier, and at higher densities in the middle index sections where they were almost absent in 2018. Counts still remain higher than those observed in 2004 (Table 2). Over the longer term, Rainbow Trout abundance will continue to be of interest because of potential competitive interactions among Rainbow Trout, 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 et al. 2013; Hawkshaw and Shrimpton 2014). Potential explanations for the change in distribution observed between 2018 and 2019 include increased river velocity affecting migration, and reduced detection probability (Pert et al. 1994).

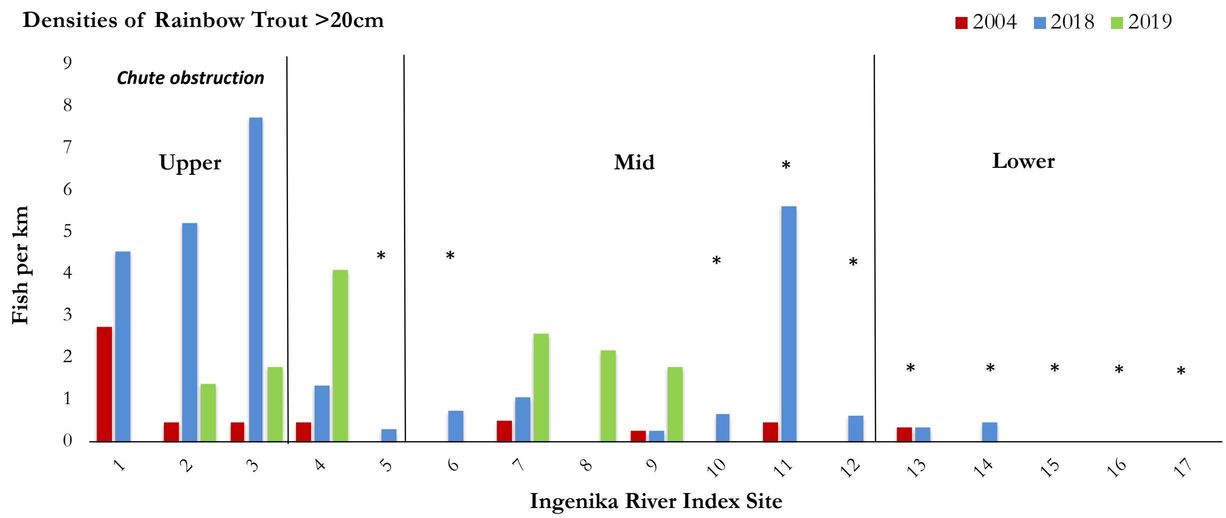

Figure 5.9 Densities (fish/km) of Rainbow Trout >20 cm in index sites along the Ingenika River, 2019 (green) 2018 (blue) and 2004 (red bars). Asterisks represent index sections that were not surveyed in 2019 due to poor visibility.

Mountain Whitefish remained by far the most numerous salmonid observed during the 2019 snorkeling surveys (Table 2), and continued to be present in every site. They also exhibited a change in distribution similar to Rainbow Trout, with densities in the upper index sites being ~50% lower than observed in 2018 (Figure 5.10). Within the middle index sites 8 and 9, densities were also found to be higher by 60% and 20% respectively.

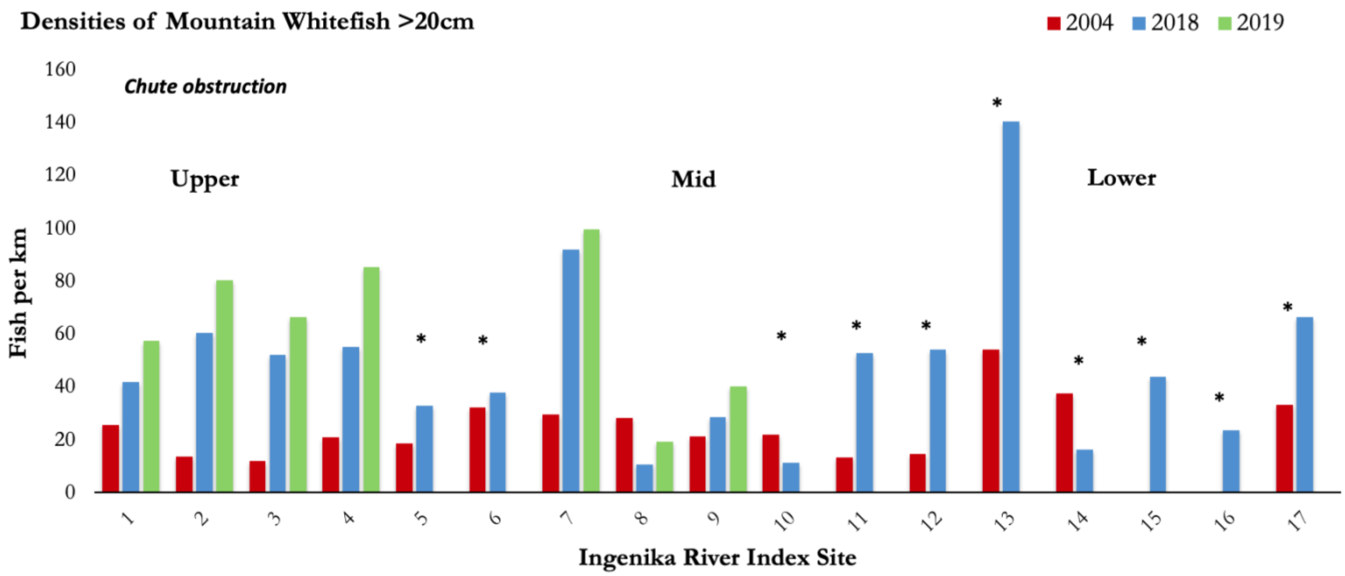

Figure 5.10 Densities (fish/km) of Mountain Whitefish >20 cm in index sites along the Ingenika River, 2019 (green) 2018 (blue) and 2004 (red bars). Asterisks represent index sections that were not surveyed in 2019 due to poor visibility.

6 Feasibility and Recommendations for Snorkeling Counts in the Mesilinka River.

6.1 Background

Between 1992 and 1999, the FWCP funded a fertilization experiment in the Mesilinka River in order to investigate the potential for such projects to compensate for stream habitat lost by the flooding of the Williston Reservoir. Snorkel surveys were established to assess the effect of controlled additions of liquid ammonium polyphosphate and urea-ammonia nitrate on fish abundance, and size from associated increases in primary productivity (Wilson et al. 2008).

The presence of this time series makes the Mesilinka River an enticing candidate to increase the spatial replication of Williston watershed Arctic Grayling monitoring surveys. The Mesilinka River Grayling population is thought to be demographically and genetically distinct from the Ingenika core area, and is assigned instead to the Omineca core area (reviewed in Stamford et al. 2017). Additionally, the Mesilinka River watershed has had a higher intensity of forestry and mining land use when compared to the Ingenika system. Increasing spatial replication of snorkeling surveys will improve assessments of conservation status and limiting factors for Arctic Grayling of the Williston Reservoir watershed as a whole.

6.2 Study design

Three index sections in the lower half of the Mesilinka river were selected in 1992 to facilitate a before and after, control and impacted experimental design. Specifically, the control reach (Blackpine) was located between river km 93 and 100, the upper treatment reach (T1) between river km 55 and 62, and lower treatment reach (T2) between river km 23 and 31 (Figure 6.1). The average wetted widths in these sections are ~40m which are highly comparable to the index sections in the Ingenika River. All index sections required one day for crews to complete, and were swum twice as a measure of repeatability and accuracy. The specific methods used for snorkel surveys are as follows (from Wilson et al. 2008):

> "Six swimmers were assigned a lane (right shore, right near shore, right middle, left middle, left near shore, left shore), and attempted to maintain an equal distance from other swimmers while counting fish to the front and to one side of themselves. The salmonids seen were identified to species and lengths estimated within 10 cm size classes (0-10 cm, 11-20 cm, 21-30 cm, etc.). The 4 mid-lane counts were expanded over the midchannel width, then the shore lane counts were added to provide expanded population estimates. Mark-recapture estimates of fish population were also conducted to compare with the underwater counts, and provided they produce unbiased estimates (Robson and Regier 1964) and a minimum percentage of fish were marked (Vincent

1971), correction factors can be calculated for use in adjusting future snorkel survey results (Slaney and Martin 1987)."

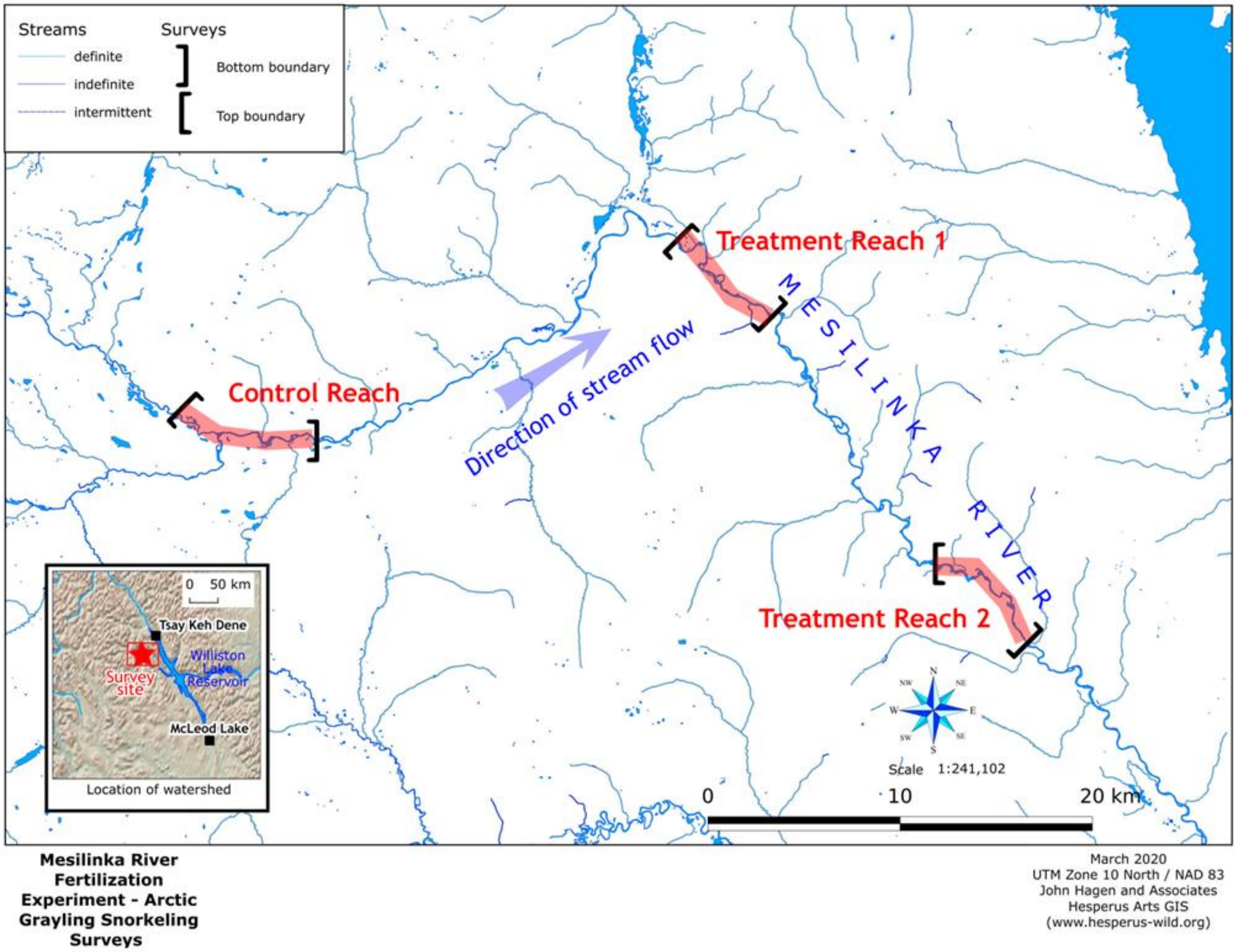

Figure 6.1 Snorkel survey index sections which were used to monitor the effect of stream fertilization experiments between 1992 and 1999.

6.3 Considerations for future surveys

The design of the 1992-1999 Mesilinka River snorkeling study differs from that of the Ingenika study, in several key aspects: 1) decreased spatial replication; 2) temporal replication of snorkeling counts in the same year; 3) double the crew size; and 4) collection of mark-resight data. Decreased spatial replication is a limitation when the data are being used to learn about abundance for the population as a whole, as spatial variation among sites is known to be an important factor affecting uncertainty in population estimates (Hankin 1984; Hankin and Reeves 1988).

Temporal replication (each site was swum twice) is an asset of the time series. When an animal population can be assumed to be closed, count data that are replicated in time can be utilized as an alternative to mark-resight studies for estimating detection probability and abundance. In this no-mark alternative approach, observed counts are assumed to be from a Binomial (*N*, *p*) distribution, where *N* and *p* are abundance (i.e. number of trials) and detection probability, respectively. Using maximum likelihood methods, values for *N* and *p* can then be found that maximize the binomial probability of the count data (Olkin et al. 1981; Royle 2004). A modern alternative to this approach can incorporate prior distributions for *N*, increasing the stability of parameter estimates when count data are sparse or *p* low (*N*-mixture models: Royle 2004; Joseph et al. 2009). Models of *p* and *N* for Arctic Grayling snorkeling count data are being developed by the Eduardo Martins lab at UNBC, and will available in the future for application to replicated snorkeling count data.

Utilizing such a large crew (six swimmers) on the Mesilinka River would pose logistical and capacity challenges, and a smaller crew of 3-4 experienced swimmers may be preferable. A modification of the study protocol for the Mesilinka River has the undesirable potential effect, however, of reducing the comparability of snorkeling count data among years. The solution to this challenge may be adequate replication in each site enabling estimates of *N* and *p* among years using analyses identified in the preceding paragraph. Accounting for varying detection probability in this way may enable more reliable estimates of abundance and trend while keeping program costs in line with the Ingenika monitoring program. Additionally, estimating detection probability in this way would enable us to avoid the method of expanding counts based on subjective estimates of how much of the stream was not surveyed (Slaney and Martin 1987), which is based on untested assumptions.

Mark-resight data were not utilized to expand counts of Arctic Grayling in the Mesilinka River fertilization study but have been compiled in Wilson et al. (2008). Analysis of these data, augmented by new mark-resight data from a 3- or 4-person crew, would enable us to validate the use of replicated snorkeling counts for estimating *N* and *p.* Mark-resight estimates of *N* and *p* could also be directly compared between modern surveys and the surveys conducted between 1992-1999.

Aerial imagery of the study area suggests that most of the survey start and end points should be accessible by road. This could result in significant cost savings when compared to the helicopter access required for monitoring the Ingenika sites. The proximity of the large Mesilinka logging camp also means that all index sites should be within a 1-hour drive from accommodations and a place to dry gear. A day of ground truthing is required to assess the potential of pickup truck-based surveys, and also to evaluate the feasibility of conducting surveys with a smaller crew. We propose to do this during August, 2020, while driving to the Kemess Mine, site of our helicopter staging area for the Ingenika snorkeling study.

In 1995 and 1996, some or all of the Mesilinka River surveys were cancelled due to high flows and low visibility. However, over a span of eight years that seems to be an appropriate level of risk. Like the Ingenika, the Mesilinka also contains a Water Survey of Canada hydrometric monitoring station (07EC003). In August 2018, it recorded a discharge roughly half that of the Ingenika. Some ground truthing will be required to assess the feasibility of swims in low water years, and to what degree those differences in discharge are related to monitoring station location in the watershed.

7 CONCLUSIONS AND RECOMMENDATIONS

Surveys were cancelled in 2019 in the majority of Ingenika River index sites due to poor visibility associated with high rainfall. As such, only a simple investigation of fish abundance and density was possible. Readers are encouraged to review Hagen et al. (2019) for a more thorough assessment of population status based on 2018 and 2004 data.

An FWCP proposal for snorkeling surveys of Ingenika River index sites has been conditionally approved for 2020. The study design will include survey replication in a minimum of 4 sites, and mark-resight estimates of snorkeling detection probability to compare with estimates of detection probability from the replicated count data (see section 6.3).

We recommend continued annual snorkeling surveys in established index sites in the Ingenika River for a minimum of 4 more occasions over the next 15 years (e.g. Humbert et al. 2009),[8] to enable more reliable estimates of Arctic Grayling trend. We have the following additional recommendations for future work:

1. Enable quantitative estimates of snorkeling detection probability and population size by conducting replicated snorkeling surveys (3 replicates) at a minimum of 4 index sections each year. The detection probability model based on the replicated count data will form the basis for estimating Arctic Grayling abundance and its limits of confidence.

2. Estimate snorkeling detection probability directly by conducting a mark-resight study in 2020. Mark-resight studies are a common method of estimating detection probability in snorkeling surveys (Slaney and Martin 1987; Young and Hayes 2001; Hagen and Baxter 2005). Mark-resight studies however may be difficult to implement and/or costly, resulting in inadequate replication of detection probability estimates. A mark-resight study in 2020 will provide important validation of the no-mark methodology described in #1 above, which has not been widely applied to snorkeling count data.

3. Include biological sampling in future study plans, to learn about potential changes in age, life history, and growth. Large Arctic Grayling >40 cm were observed in 2018 and 2019 and validated by angling captures (3 of 5 fish captured in 2018). In contrast, no Arctic Grayling >40 cm were observed or captured in 2004. An increased abundance of large, older Arctic Grayling is an indicator of changed population status, but we require better information before we can make this assessment.

[8] As part of a proposal for 2 years of funding submitted to FWCP for the 2019-2020 funding cycle by Chu Cho Environmental. The proposal recommends that snorkeling surveys be rotated from one year to the next among 3 systems: Ingenika River, Mesilinka River, and a yet-to-be-determined system in the Lower Finlay core area. It would take approximately 15 years to acquire the minimum 5 years' data for each system. Back-to-back years of sampling in the Ingenika were proposed because of logistical considerations and the need to acquire biological and snorkeling accuracy data which were omitted from the 2018 study.

4. Utilize genetic and other analyses to evaluate the degree of genetic and demographic isolation of the Ingenika core area from the nearby Lower Finlay core area. Williston Reservoir is currently believed to be an ecological barrier to movements and gene flow (Stamford et al. 2017). However, recently discovered critical habitat use in surrounding small tributaries draining the eastern slopes of Finlay Arm (FWCP PEA-F20-F-2965: 2018 Williston Arctic grayling monitoring: eDNA monitoring) suggest movements through the reservoir might be an important component of metapopulation dynamics and important demographic connections between core areas (e.g. between Lower Finlay and Ingenika) may exist. Carefully designed studies using genetic and microchemistry data (e.g. assign individuals to their respective natal streams) would better define migratory connections between critical habitats. This would require opportunistic sample collection from the Lower Finlay River to facilitate this comparison.

5. Include snorkeling surveys in the Mesilinka River and lower Finlay River watershed in the long-term study plan for the Tsay Keh Dene traditional territory, to improve knowledge about limiting factors (i.e. those affecting abundance, trend, life history and growth) across a range of physical habitat and ecological conditions. Surveys on 5 occasions over the next 15 years for each of the Ingenika, Mesilinka, and lower Finlay systems are a suggested minimum target.

6. Co-ordinate with Arctic Grayling abundance monitoring elsewhere in the Williston Reservoir watershed (e.g. FWCP project no. PEA-F21-F-3203: 2020 Parsnip Arctic Grayling Abundance and Critical Habitats) to explore opportunities to improve knowledge about limiting factors.

8 ACKNOWLEDGMENTS

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.

Tsay Keh Dene Nation community members are acknowledged for their input and concern expressed during expectations for industry interviews in February 2019, and Science Week. Morgan Hite produced the maps used in the report. Kemess Mine (Centerra Gold Inc.) provided us with accommodation during this study. Silver King Helicopters is acknowledged for accommodating our study within a busy 2019 schedule at Kemess Mine. Lauren Phillips, owner of OVERhang Education Center Ltd (Prince George, BC) was our safety boater, photographer, field data manager, and swiftwater rescue consultant.

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