Ingenika River Arctic Grayling 45 Years Post-Flooding: 2018 Snorkeling Counts in Index sites.

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EXECUTIVE SUMMARY

The Arctic Grayling (*Thymallus arcticus*) is an especially coveted and sought-after sustenance species for the Tsay Keh Dene Nation. Since flooding, Arctic Grayling have disappeared from at least 25 tributaries to Williston Reservoir, and remnant populations are restricted to just six major watersheds containing sufficient habitat for Arctic Grayling to complete their life cycle: Parsnip, Nation, Omineca, Mesilinka, Finlay, and Ingenika. These populations are thought to be isolated from each other by the reservoir, and are referred to as core areas (putative metapopulations). This study assesses the status of the Arctic Grayling population remaining in the Ingenika core area, a watershed of critical interest to the nearby community of Tsay Keh Dene, and confirms critical summer rearing habitats for the population.

The Fish and Wildlife Compensation Program (FWCP) was established to conserve and enhance fish and wildlife resources affected by BC Hydro dam construction. Previous analysis by FWCP has identified two key knowledge gaps limiting the program's ability to initiate conservation and enhancement actions for Ingenika River Arctic Grayling:

1. the lack of monitoring data indicating the population's conservation status (i.e. likelihood of persisting into the future), and
2. the lack of monitoring data indicating critical habitats for key life stages.

Our study has been designed specifically to address two high-priority recommendations of the *Arctic Grayling Synthesis* and *Monitoring Framework* reports produced by FWCP, and is therefore aligned with *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.

The two most important indicators of conservation status are the total abundance of adult individuals, and the population trend. In the Ingenika River watershed, Arctic Grayling abundance has only been assessed previously by FWCP on one occasion in 2004. Low fish densities observed at that time have raised concern for the population's status, but because the surveys were not repeated the population trend is unknown.

In August 2018, we investigated Arctic Grayling abundance in the Ingenika core area and how it has changed over time by conducting snorkeling surveys in 17 index sites distributed along the accessible length of the Ingenika River, in the same locations surveyed in 2004. Minimum estimates for Arctic Grayling abundance in 4 reaches of the Ingenika River mainstem were computed simply by extrapolating reach-specific density estimates to unsurveyed portions of each. Although snorkeling counts were not adjusted for detection probability <1, nor do they account for the use of tributaries by an unknown portion of the population, it nonetheless appears that that the population is very small. The total minimum estimate for the 109 km of the mainstem Ingenika River in 2018 was just 318 Arctic Grayling >20 cm. The snorkeling counts also provisionally indicated stable Arctic Grayling abundance in the Ingenika core area, with the 2018 estimate being within 13% of the 2004 estimate of 282.

The distribution of critical summer rearing habitat for adult and subadult Arctic Grayling described in 2004 was corroborated by the 2018 results. Use of the 41-km Lower reach of the Ingenika River by Arctic Grayling appears to be minimal in late summer. This reach is characterized by low gradient, long

runs, and finer bed material relative to upstream reaches. Currently, land use along the Ingenika River is restricted to this reach. Arctic Grayling were distributed at relatively consistent densities throughout the 49-km-long Mid reach, which is characterized by a frequently-braided channel, relatively low gradient, and fines/gravel/cobble substrate. The most important feature along the Ingenika River affecting the distribution of Arctic Grayling appears to be a chute located approximately 95 km from the mouth, which divides the Upper reach into two distinct sections. Grayling were present upstream of the chute but in extremely low densities, while the density of fish in the site immediately downstream of the chute was the highest recorded, by a large margin, in both 2018 and 2004. This abrupt change in abundance suggests that this chute is a migration obstruction for most Arctic Grayling creating a potentially vulnerable aggregation of fish immediately downstream.

Snorkeling survey results from 2018 have improved our ability to generate categorical estimates of 4 key indicators used to assess conservation status and risk for Arctic Grayling core areas: trend, adult abundance, distribution, and threats. Entering these estimates into the numeric scoring process used previously by FWCP to assess status results in a ranking of 'C2-At Risk' for the Ingenika core area, which corresponds to a core area "at risk because of very limited and/or declining numbers, range, and/or habitat, making the Arctic grayling in this core area vulnerable to extirpation." Key factors in this assessment were the small adult population size and limited distribution of Ingenika Arctic Grayling. Given this situation, further degradation of the conservation status because of a declining trend, a decrease in adult population size below 250, or an increase in threats would all be cause for significant conservation concern in future.

A potential future threat to the Arctic Grayling population of the Ingenika core area would 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. Although the management of forestry and other land use activities on Crown land is a core responsibility of the BC Provincial Government, FWCP can facilitate Arctic Grayling habitat conservation by delivering the scientific data necessary for assessments of conservation status, critical habitats, and limiting factors. To improve the ability of the snorkeling program to contribute some of this scientific data, this report contains the following recommendations:

1. Establish time series comprised of a minimum 5 years snorkeling count data for the Ingenika, Mesilinka, and Lower Finlay watersheds over a 15-year period.
2. Estimate the repeatability of snorkeling counts through replication at a portion of survey sites.
3. Estimate the accuracy of snorkeling counts using mark-resight methods.
4. Include biological sampling in the study plan, to monitor age, life history, and growth.
5. Improve knowledge of genetic and demographic isolation among core areas.
6. Conduct continuous surveys across all potential summer rearing habitats in the Ingenika River watershed at least once in the next 10-15 years.
7. Co-ordinate with Arctic Grayling abundance monitoring elsewhere in the Williston Reservoir watershed to explore opportunities for learning about limiting factors.

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1.0 INTRODUCTION

In their lifetimes, Tsay Keh Dene citizens 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 Tsay Keh Dene Nation. Since flooding, Arctic Grayling have disappeared from most of the direct tributaries to Williston Reservoir outside of six major watersheds containing sufficient habitat for remnant Arctic Grayling populations to complete their life cycle: Parsnip, Nation, Omineca, Mesilinka, Finlay, and Ingenika (Stamford et al. 2017). This study assesses the status of the Arctic Grayling population remaining in the Ingenika River watershed, a watershed of critical interest to the nearby community of Tsay Keh Dene, and identifies critical summer habitats for the population.

The Fish and Wildlife Compensation Program (FWCP) was established to conserve and enhance fish and wildlife resources affected by BC Hydro dam construction. FWCP's *Streams Action Plan* (FWCP 2014a) sets out priorities for the Fish and Wildlife Compensation Program to guide projects within the Peace Basin program area, with a focus on priority species including the Arctic Grayling that use streams for all or part of their life cycle and which have been affected by reservoir creation. In 2016, a major study was conducted by 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 estimate 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

[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).

mammals and birds have generally suggested that an adult 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 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 can be thought of as those which 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.

In the Ingenika River watershed, Arctic Grayling abundance has only been assessed previously by FWCP on one occasion in 2004 (Cowie and Blackman 2012). Low fish densities observed at that time have raised concern for the population's status (Stamford et al. 2017), but because the surveys were not repeated the population trend is unknown. Key questions for FWCP and the Tsay Keh Dene Nation are: What is the status of the Ingenika River Arctic Grayling population now, more than 45 years after it was isolated from other grayling populations by flooding? Where are critical habitats for Arctic Grayling in the watershed located, and are they threatened? Employing the methodology of snorkeling surveys in index sites distributed along the accessible length of the Ingenika River, in the same locations surveyed in 2004, this study makes an important contribution to the longer-term effort to address these questions.

2.0 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*).

Provisional 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.

Our study has been designed specifically to address two high-priority recommendations of the *Arctic Grayling Monitoring Framework* report (ID#1, #2, Table 1; Hagen and Stamford 2017), as described in the previous section (Section *1.0*) and is therefore aligned with *Streams Action Plan* priority action *1b-3* (FWCP 2014a):

> 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.

The 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 a previous survey in 2004.
2. To indicate whether Arctic Grayling abundance has changed since 2004, by comparing counts between the survey periods.
3. To estimate the distribution of summer critical rearing habitats for subadult and adult Arctic Grayling along the Ingenika River mainstem, and whether that distribution is consistent between the 2004 and 2018 survey periods.
4. To communicate the study results directly to members of the Tsay Keh Dene Nation in the winter of 2019.

3.0 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 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 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 Frederikson Creek are 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.' 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 be comprised of 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

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

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 poorly understood (Stamford et al. 2017).

In addition to Arctic Grayling (*Thymallus arcticus*), native salmonids inhabiting the Parsnip River watershed include Bull Trout (*Salvelinus confluentus*), Dolly Varden (*Salvelinus malma*: verified) Rainbow Trout (*Oncorhynchus mykiss*), Mountain Whitefish (*Prosopium williamsoni*), Lake Whitefish (*Coregonus clupeaformis*), and Kokanee (*Oncorhynchus nerka*). Burbot (*Lota lota*), Peamouth (*Mylocheilus caurinus*), Lake Chub (*Couesius plumbeus*), Largescale Sucker (*Catostomus macrocheilus*), Longnose Sucker (*Catostomus catastomus*), White Sucker (*Catostomus commersoni*) and 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).

4.0 METHODS

4.1 Study Design

The design of the Ingenika River Arctic Grayling monitoring program occurred in advance of the 2004 survey (Cowie and Blackman 2012). Following our review of the study design, we elected to replicate the 2004 surveys without modification in 2018. This is because of our judgment that the design was sound, and because a new distribution of sampling sites would introduce extra uncertainty into the comparison between years, related to spatial variation in fish density.

Water quality characteristics and reach habitat characteristics were incorporated into the design of the monitoring program (Cowie and Blackman 2012). Excellent water clarity in the Ingenika River enabled the method of snorkeling counts, which has key advantages including its non-invasive nature and high efficiency (amount of habitat covered for a given cost). High efficiency translates into a potential high sampling fraction (proportion of the total habitat available that is surveyed; Table 1), which means that unwanted effects of spatial variability on population density are reduced for a given cost relative to competing methods like seine netting or electrofishing.

In the 2004 study design, the Ingenika River was stratified into 4 reaches, three of which were sampled (Lower = 5 sites, Mid = 7 sites, Upper = 5 sites, Headwaters = 0 sites; Table 1). Appropriately, the sampling fraction for each of these reaches was related positively to the expected densities of Arctic Grayling. In our inspection of the 2004 density data, it appeared that a further division of the Upper reach into 2 reaches upstream and downstream of a chute obstruction (u/s chute, d/s chute; Table 1) was required because of the strong effect this chute had on Arctic Grayling distribution.

The accuracy and precision of snorkeling counts can vary substantially from system to system. Correlated factors 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). For snorkeling counts in streams to be capable of rapid, sensitive detection of changes in population status, they must be reasonably accurate (unbiased, on average, relative to the true value) and precise (close to the true value during any one survey; Zar 1996). The design for our study in 2018 does not include elements enabling us to estimate the accuracy or precision of snorkeling counts in the Ingenika River. The primary reason for this was our belief that a year's experience in the watershed would improve the design of calibration methods. Recommendations for these study elements for inclusion in future surveys are presented at the end of this report.

4.2 Snorkeling Methods

In 2018 we conducted snorkeling surveys in 17 index sites along the Ingenika River (Figure 1: lower Ingenika River; Figure 2: upper Ingenika River) over the five-day period between August 9-12, similar to the August 10-13 period surveyed in 2004.

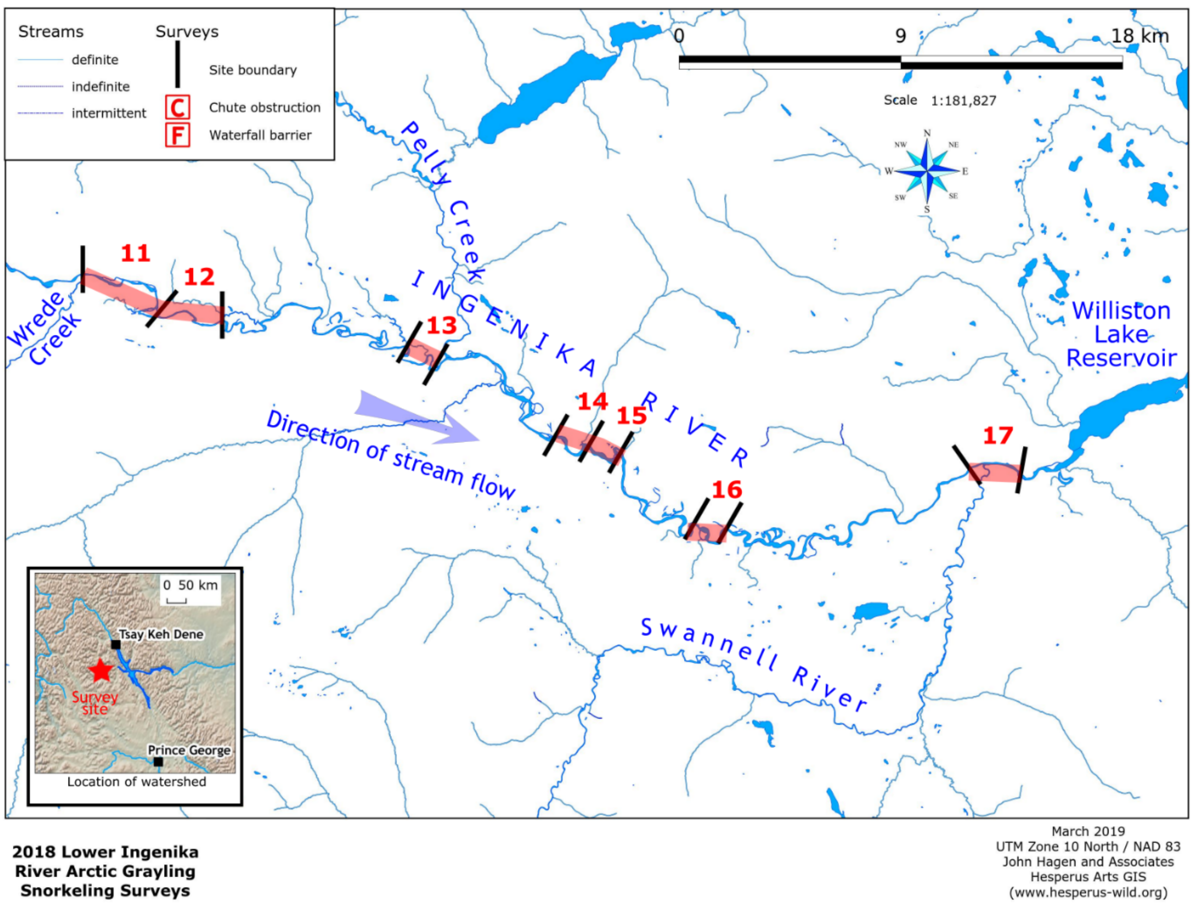


Figure 1. Stream sections (sites) of the lower Ingenika River utilized for snorkeling surveys to monitor Arctic Grayling abundance, 2004 and 2018.

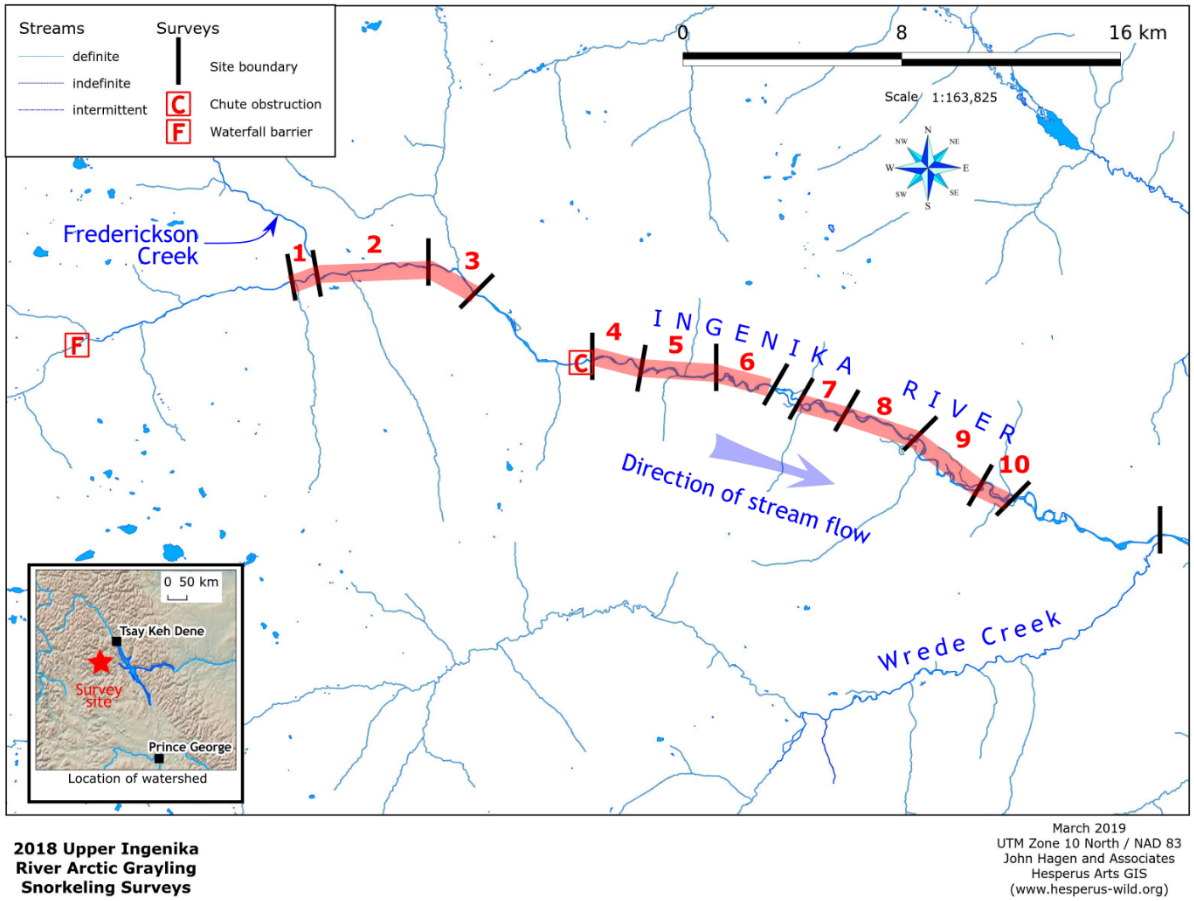


Figure 2. Stream sections (sites) of the upper Ingenika River utilized for snorkeling surveys to monitor Arctic Grayling abundance, 2004 and 2018.

Consistent with methods in 2004 (Cowie and Blackman 2012), snorkeling surveys were conducted by a crew of 3 observers (Figure 3), organized in lanes of width determined by horizontal underwater visibility and estimated habitat suitability (usable wetted width for subadult and adult Arctic Grayling[3]). All observers were experienced in conducting snorkeling surveys, and had received in-the-water training 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). Where possible observers would count fish in a lane extending in front of them and to one side only. When the usable wetted width exceeds the 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

[3]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 2001). In early-to-mid August, the usable width (suitable for subadult and adult fish) of the Ingenika River can be covered effectively by a team of 3 swimming in adjacent lanes (Figure 3).

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, underwater visibility was estimated in two ways: 1) horizontal underwater secchi disk visibility, and 2) horizontal distance at which the species identity of a 30-cm fish model could no longer be discerned. Fish size estimation was practiced on models suspended in the water column at the survey start point, and corroborated in one location by comparing the observed length frequency to lengths in a sample collected by angling (Figures 5, 6).[4]

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). Horizontal underwater visibility in the upper reaches of the Ingenika River was exceptional (up to 19 m), and an observer in the center lane could often see both banks indicating the potential to overcount Arctic Grayling was a concern. To avoid this, observers attempted to count only fish that were in their lane as they past by. However, because fish moved in reaction to the survey team frequent communication was necessary to ensure that double counting did not occur.

Figure 3. Snorkeling survey in the lower Ingenika River, August 2018.

[4] At this site, located downstream of the chute obstruction in section 4 (Figure 2), many fish >40 cm were observed, in contrast to 2004 observations. Angling to corroborate the observations was deemed necessary at this location.

Figure 4. Helicopter basket used to transport the deflated rescue kayak and snorkeling gear.


Figure 5. 410 mm, male Arctic Grayling captured in the Ingenika River, August 2018.

Figure 6. 435 mm, male Arctic Grayling captured in the Ingenika River, August 2018.

4.3 Analysis

The change in Arctic Grayling abundance in the Ingenika River between 2004 and 2018 was assessed in a descriptive manner only, given that just two years of abundance monitoring data have been collected from index sites.

With respect to the total population size for Arctic Grayling >20 cm, ultimately our goal is to combine Arctic Grayling density estimates with estimates of spatial variation, detection probability, and inter-observer variation in a hierarchical analysis that permits a realistic description of uncertainty. Because these other parameters have not been included in the 2018 study design (Section *4.1*), for this year we provide point estimates only for population size of Arctic Grayling >20 cm. Point estimates for abundance of Arctic Grayling >20 cm in each of four survey strata of the Ingenika River (Table 1: Lower, Mid, Upper d/s chute, Upper u/s chute) were estimated simplistically by first computing the mean density across the total distance surveyed in a stratum, then extrapolating this density to the unsurveyed portion. Reach-specific population size estimates were combined to estimate total abundance in the Ingenika River with no adjustments for detection probability <1. Index sites in the Ingenika River watershed are not distributed randomly or systematically across each stratum, instead being clumped in most cases for logistical feasibility (Figures 1, 2). Although this situation is not ideal for deriving unbiased estimates of total population size, it is mitigated in part by the high sampling fraction of 42%-100% in important reaches for Arctic Grayling (Table 1: Upper, Mid).

5.0 RESULTS

5.1 Survey Conditions

Discharge in the lower Ingenika River over the August 8-12 period ranged from 40-43 m^3/s, below the long-term average for the period of approximately 62 m^3/s but higher than the minimum estimate of approximately 32 m^3/s (Water Survey of Canada: Station 07EA004 Ingenika above Swannell River). Low water conditions and excellent underwater visibility were well suited for visual observation methods (e.g. Figure 4, Figure 5). Secchi disk visibility increased with distance from the Ingenika mouth, ranging from 7.0 to 19 m and averaging 15 m. Visibility necessary for identification of Arctic Grayling models ranged from 4.5 m to 9.0 m averaging 7.1 m.

5.2 Critical Adult Summer Rearing Habitat

Snorkeling count data for both 2018 and 2004 indicate a consistent pattern of habitat use for adult/subadult Arctic Grayling in the Ingenika River. Snorkeling observations in index sites distributed along the lower 109 km of the Ingenika River, whether raw counts (Table 2) or standardized as densities of fish >20 cm/km (Figure 7), suggest several distinct zones.

Table 2. August snorkeling counts of Arctic Grayling, Bull Trout, Rainbow Trout, and Mountain Whitefish (GR, BT, RB, MW, respectively) >20 cm in index sits along the Ingenika River, 2004 and 2018.

		Site length	2018 Counts >20 cm				2004 Counts >20 cm*			
Site	**Reach**	**(km)**	**GR**	**BT**	**RB**	**MW**	**GR**	**BT**	**RB**	**MW**
1	Upper u/s chute	1.1	0	11	5	46	0	0	3	28
2	Upper u/s chute	4.4	3	42	23	266	8	1	2	60
3	Upper u/s chute	2.2	2	8	17	115	1	3	1	26
4	Upper d/s chute	2.2	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	8	8	2	175	10	1	1	56
8	Mid	3.2	15	6	0	34	11	1	0	90
9	Mid	3.8	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
Total	*All*	*44.7*	*161*	*292*	*82*	*2198*	*153*	*23*	*12*	*976*

*From Cowie and Blackman (2012).

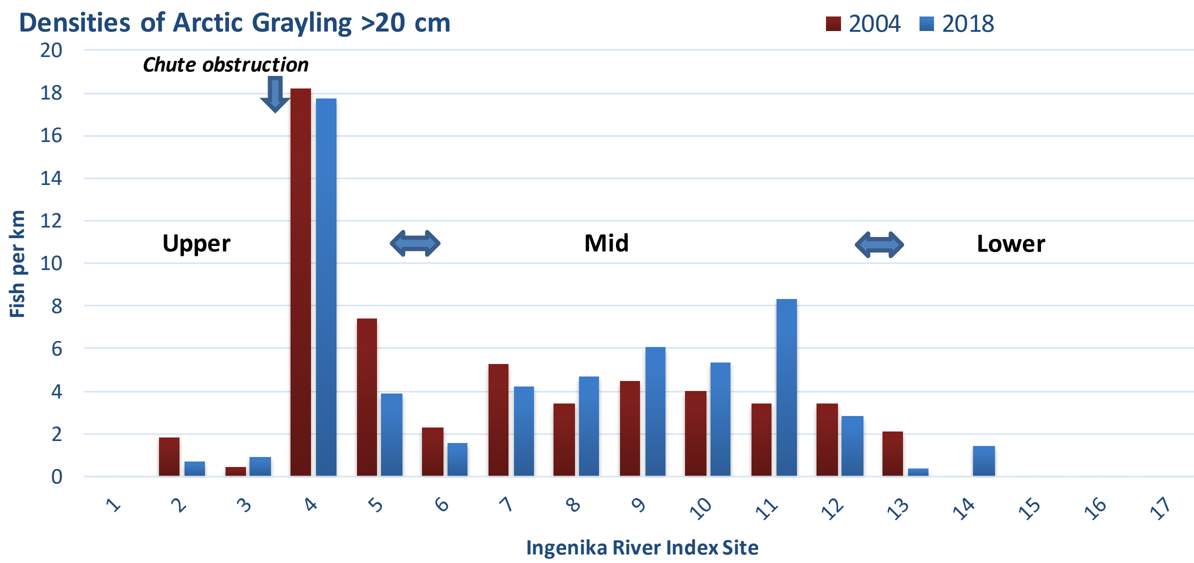


Figure 7. Densities (fish/km) of Arctic Grayling >20 cm in index sites along the Ingenika River, 2018 (blue bars) and 2004 (burgundy bars).

Use of the 41-km Lower reach of the Ingenika River (Sites 13-17) by Arctic Grayling appears to minimal in late summer, with total counts for the reach in 2004 and 2018 of just 4 and 6, respectively in 11.4 km surveyed (Table 2). This reach is characterized by low gradient, long runs, and finer bed material relative to upstream reaches. Currently, land use along the Ingenika River is restricted to this reach.

Arctic Grayling are distributed at relatively consistent, albeit low densities throughout the 49 km of the Mid reach (Figure 7), which is characterized by a frequently-braided channel, relatively low gradient, and fines/gravel/cobble substrate (Table 1).

The most important feature along the Ingenika River affecting the distribution of Arctic Grayling appears to be a chute[5] located approximately 95 km from the mouth, which divides the Upper reach into 'd/s chute' and 'u/s chute' sections (Table 1). Grayling were present upstream of the chute (Sites 1-3) but in extremely low densities, while the density of fish in the site immediately downstream of the chute was the highest recorded, by a large margin, in both 2018 and 2004 (Figure 7, Table 2). This abrupt change in abundance suggests that this chute is a migration obstruction for most Arctic Grayling creating a potentially vulnerable aggregation of fish immediately downstream.

Snorkeling observations in 2018 indicated that relatively large, potentially older Arctic Grayling >40 cm were relatively common in the Ingenika River Arctic Grayling population (Figure 8). Because snorkeling observations of fish body size are potentially vulnerable to overestimation bias related to the underwater magnification of objects, we corroborated observations of fish >40 cm at a

[5] More detailed observations and photographs of this chute are proposed for the 2019 field season.

particular location in Reach 4 with hands-on sampling of fish caught by angling. In a pool where several Arctic Grayling >40 cm had been recorded during the snorkeling survey, 3 of 5 fish subsequently captured by angling were found to exceed this length (Figures 5, 6). A more systematic plan for sampling Arctic Grayling for size and age information is included within the 2019 study proposal (Section *7.0*).

It has been noted elsewhere in northern B.C. that Arctic Grayling are larger in upstream locations (e.g. Baccante 2010). In the Ingenika River watershed, the largest Arctic Grayling >40 cm were not observed above the chute obstruction, nor were fish <30 cm (Figure 8). Large Arctic Grayling >40 cm were distributed throughout the 'Mid' and 'Upper d/s chute' reaches with little evidence of a pattern of increasing proportions of large fish at upstream sites. However, smaller fish <30 cm were more likely to utilize sites closer to the Ingenika's mouth (Figure 8).

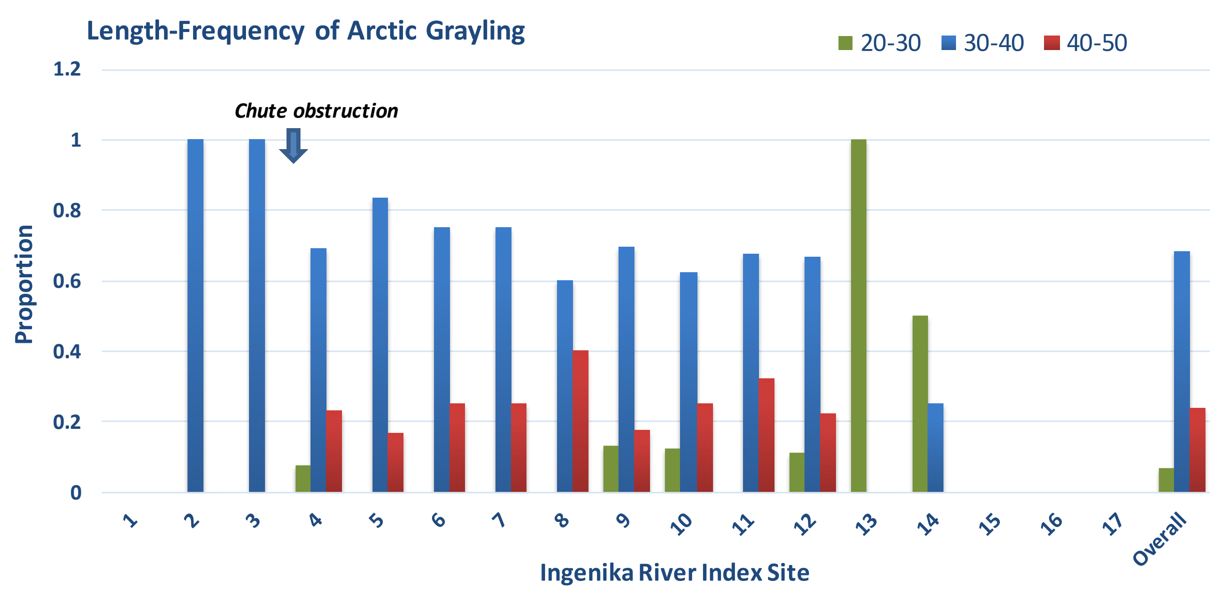


Figure 8. Proportion of observed Arctic Grayling in size classes 20-30 cm (green bars), 30-40 cm (blue bars), and >40 cm (red bars) among sites and overall, Ingenika River snorkeling surveys 2018. Size estimates are based on visual estimates by snorkelers.

Critical habitats for juvenile Arctic Grayling <20 cm in the Ingenika River were not identified during 2018 snorkeling surveys. In fact, only a single Arctic Grayling of this size was observed, in Site 14 in the 'Lower' reach, despite care to search potential juvenile habitats. This is in strong contrast to the 2004 survey, in which a total of 27 Arctic Grayling <20 cm were observed (Cowie and Blackman 2012), suggesting that downstream snorkeling surveys are a poor method for assessing juvenile abundance. Although the reason for the discrepancy between the two years is not clear, juvenile salmonids <20 cm are 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 relative to 2004 (Section *5.4*) is a plausible factor potentially triggering such behaviour. The possibility that reproduction of Arctic Grayling has shifted to another location also cannot be discounted.

5.3 Arctic Grayling Abundance

Point estimates for Arctic Grayling abundance, computed simply by extrapolating reach-specific density estimates to unsurveyed portions of each (Table 3), are not adjusted for detection probability <1 and do not account for the use of tributaries by an unknown proportion of the population (Stamford et al. 2017). Therefore, they should be treated as minimum estimates that are likely to be adjusted upwards in future. It appears nevertheless that the population of Arctic Grayling >20 cm in the Ingenika River watershed is very small.

The abundance and distribution of Arctic Grayling >20 cm is similar for the two years of abundance monitoring data. The total minimum estimate for the 109 km of the mainstem Ingenika River in 2018 was just 318 Arctic Grayling >20 cm, 13% higher than the 282 estimated for 2004 (Table 3). In 2018, 243 and 51 of these fish were estimated to be present in the Mid and Upper d/s chute reaches, respectively, which compares to estimates of 181 and 63 for these same respective reaches in 2004 (Table 3). Given that these estimates are uncertain (Section *4.3*), the relatively small differences in abundance estimates between the two years should not be considered significant at this point in time.

Table 3. Estimated minimum population size of Ingenika River Arctic Grayling >20 cm, 2018.

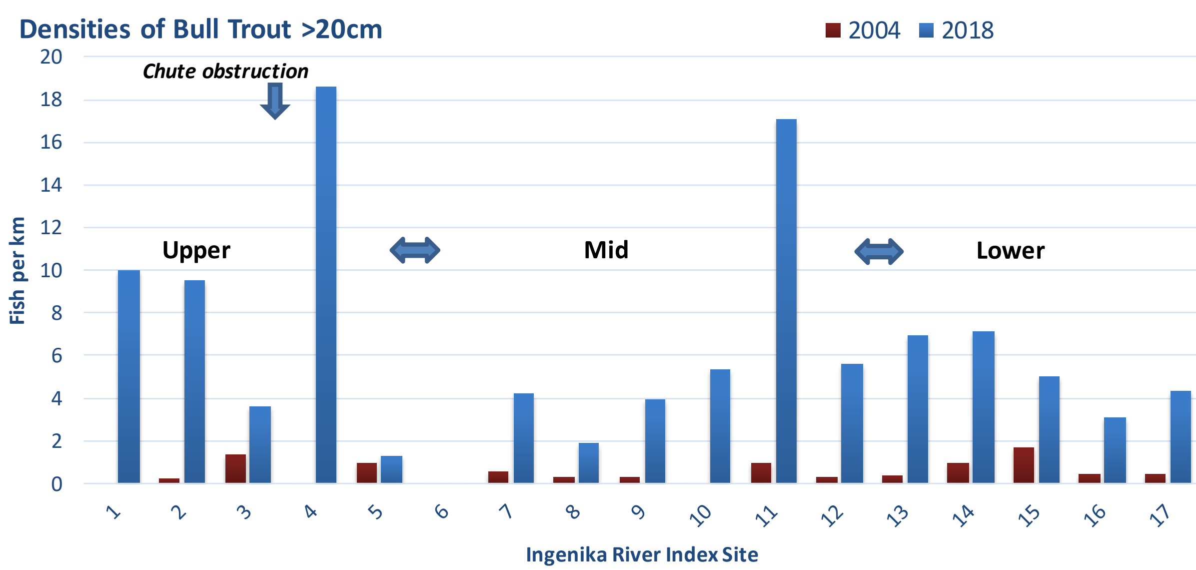
Reach ID	Length (km)	Snorkeling sites	Sampling fraction	GR/km in surveyed portion		Minimum population estimate*	
				2018	2004	2018	2004
Lower	40.6	13-17	28%	0.4	0.5	14	21
Mid	48.9	6-12	42%	5.0	3.7	243	181
Upper d/s chute	5.3	4-5	100%	9.6	11.9	51	63
Upper u/s chute	14.2	1-3	54%	0.6	1.2	9	17
Total	***109***					***318***	***282***

*Unadjusted for snorkeling detection probability <1, or use of tributaries by an unknown proportion of the population

5.4 Other Species

Although Arctic Grayling were the first priority for snorkeling observations, Bull Trout (Figure 9, Table 2), Rainbow Trout (Figure 10, Table 2), and Mountain Whitefish (Figure 11, 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 (Figure 11) should be considered of low precision and accuracy relative to the other 3 species, and the comparison between years may not be reliable.

In 2018, the snorkeling team observed that the mouths of Frederikson Creek (Sites 1 and 2; Figure 2) and Wrede Creek (Site 11; Figure 1), along with the chute obstruction at 95 km (Site 4; Figure 2) were features associated with higher concentrations of adult Bull Trout, potentially indicating an effect of pre-spawning migration behaviour. The Ingenika River watershed is one of the most important Bull Trout systems identified anywhere in the Williston Reservoir watershed, and Frederikson and Wrede Creek are its two most important spawning tributaries (Hagen and Spendlow 2017). Counts of Bull Trout in 2018 are higher by 10-fold than those in 2004. This appears remarkable, but it is important to note that Bull Trout were likely in the middle of their migration to spawning destinations at the time of surveys (2018: August 9-12; 2004: August 10-13). Water height and especially water temperature are potential triggers for migration behaviour, and are also likely to be factors affecting the suitability of pre-spawning staging areas in the mainstem Ingenika versus spawning tributaries. A more reliable methodology for monitoring Bull Trout abundance is through counts of gravel nests, or 'redds' following the completion of spawning.[7]



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[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).

Figure 9. Densities (fish/km) of Bull Trout >20 cm in index sites along the Ingenika River, 2018 (blue bars) and 2004 (burgundy bars).

It is noteworthy that Rainbow Trout >20 cm were at their highest abundance in sites upstream of the 95 km chute in the vicinity of Frederikson Creek (Sites 1-3), and in Site 11 downstream of Wrede Creek (Table 2, Figure 10). Similar to the distribution of Bull Trout, this may reflect that these two tributary watersheds are important to Rainbow Trout populations. In the case of Frederikson Creek at least, a population of Rainbow Trout inhabiting Frederikson Lake at the head of the system is well known anecdotally. Alternatively, the stream habitat located upstream of the chute obstruction may be a relatively open niche for Rainbow Trout, given that interspecific competition with Arctic Grayling would be greatly reduced. The total Rainbow Trout count for the 2018 snorkeling survey was nearly 7-fold higher relative to 2004 (Table 2). Over the longer term, Rainbow Trout abundance is likely 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).

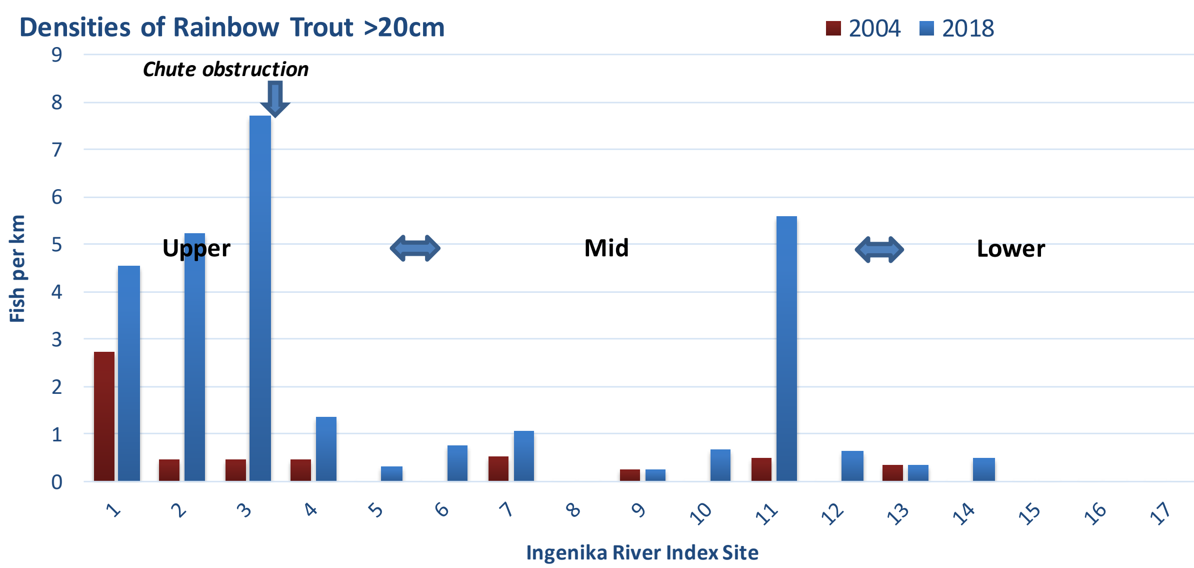

Figure 10. Densities (fish/km) of Rainbow Trout >20 cm in index sites along the Ingenika River, 2018 (blue bars) and 2004 (burgundy bars).

Mountain Whitefish were by far the most numerous salmonid observed during the 2018 snorkeling surveys (Table 2, Figure 11), when they were present in every site. Peaks of Mountain Whitefish density were observed in Sites 7 and 13 (Figure 11), which were not of special importance for other salmonids. Although the Mountain Whitefish count for 2018 is more than double that of 2004, low significance should be placed on this point because of large discrepancies in counts of this species evident among observers in 2004, possibly indicating that Mountain Whitefish counts were not prioritized because of potential interference with counts of Arctic Grayling.

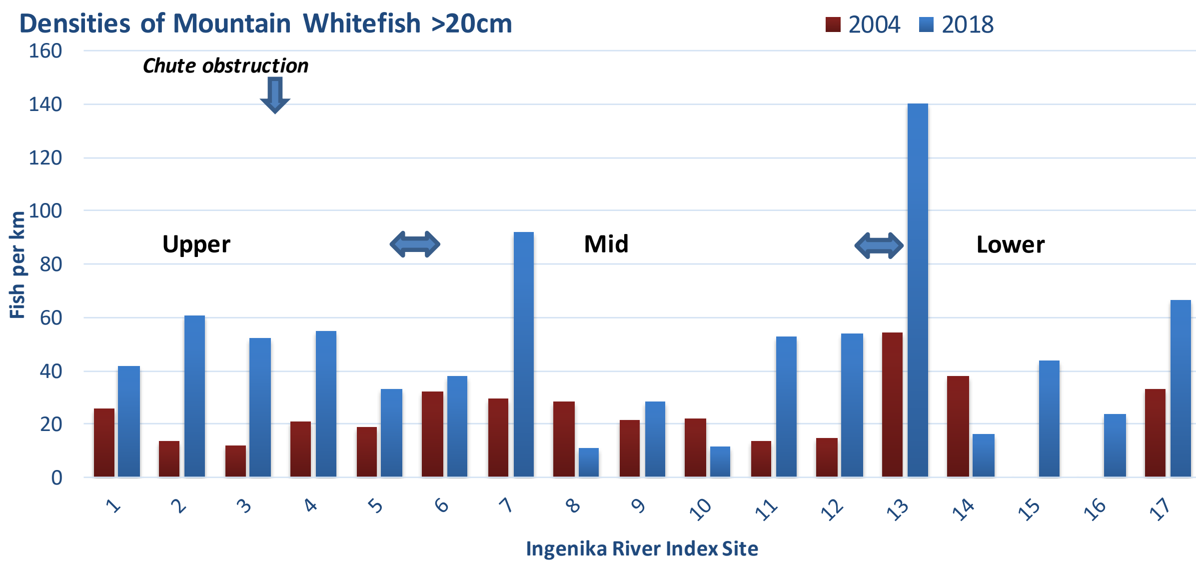

Figure 11. Densities (fish/km) of Mountain Whitefish >20 cm in index sites along the Ingenika River, 2018 (blue bars) and 2004 (burgundy bars).

Non-salmonids were observed but not recorded during the 2018 snorkeling surveys. The primary reason for this was the mental difficulty in keeping track of counts and size estimates for salmonids in between opportunities to record these observations on the dive slate (e.g. at the tails of pools). It was deemed that adding any additional snorkeling observations to the list each snorkeler was responsible for would likely compromise the ability to remember size and count observations for Arctic Grayling, the species of primary focus for this study.

6.0 DISCUSSION

6.1 Conservation Status

The conservation status of a population is its chance of persistence into the future. The first key information gap addressed by this study was the lack of population data since 2004 indicating conservation status of Ingenika River Arctic Grayling (see Section *1.0*).

For Arctic Grayling core areas in the Williston Reservoir watershed, conservation status was evaluated in the FWCP Arctic Grayling synthesis document (Stamford et al. 2017) using the *Core Area Conservation Status and Risk Assessment Methodology* developed by the United States Fish and Wildlife Service (USFWS 2005). The methodology is an indicator-based population viability assessment, rather than a quantitative model of extirpation probability. Although it has not been evaluated for use on Arctic Grayling populations, the methodology is attractive for a number of reasons including: 1) application at a spatial scale relevant to management actions, threats, and extirpation processes, 2) the ability to incorporate information in a variety of standard (population data) and non-standard (anecdotal information, First Nations traditional knowledge, professional judgments) forms, 3) the ability to address threats in a systematic manner, and 4) a standardized process for assigning risk that is likely to produce repeatable results among users (Stamford et al. 2017).

The *Core Area Conservation Status and Risk Assessment Methodology* computes risk to a population based on categorical levels of 4 key indicators of future population viability – trend, adult abundance, distribution, and threats – which are assessed at the spatial scale of metapopulations (i.e. core areas).[8] Snorkeling survey results from 2018 have improved our ability to generate categorical estimates of trend, adult abundance, distribution, and threats for the Arctic Grayling population of the Ingenika core area. Although these estimates remain uncertain, an update to the conservation status assessment for the core area is warranted.

Trend is one of the most important indicators of population viability (McElhany et al. 2000; O'Grady et al. 2004;). To reliably estimate trend, a significant effort applied at the decadal scale is required to acquire the necessary population data (e.g. a minimum of 5 years' abundance data over a minimum 10-year period: Humbert et al. 2009; Kovach et al. 2016). Given that 2018 represents only the second year of snorkeling surveys in index sites in the Ingenika River, the ability to estimate the change in the population over time is obviously limited. For example, the fact that other salmonids in the Ingenika River had 2-fold to 10-fold higher abundance in 2018 relative to 2004 raises the question of whether low water conditions in 2018 may have been a factor affecting the reliability of counts, through elevated detection probability or increased concentration of fish in the index sites. Therefore, any estimate of trend at this point in time should be treated as provisional. Its provisional nature notwithstanding, we consider the best categorical estimate of trend for input into status assessment methodology at this point in time to be 'stable' (Appendix *1* in Stamford et al. 2017) based on comparable counts separated by more than a decade.

The minimum estimate of 318 Arctic Grayling >20 cm in 2018 indicates that adult abundance is likely to be >250, but perhaps only marginally so given the fact that a proportion of the population >20 cm would be immature. Although we consider the '250-1,000' category appropriate for input into the risk assessment methodology (Appendix *1* in Stamford et al. 2017) at this point in time, this assessment is potentially subject to change as more reliable population estimates become available incorporating estimates of detection probability, size estimation bias, and interobserver variability. Estimates of these parameters are a long-term objective of this study program (see Section *7.0*).

The total distribution of Arctic Grayling within the Ingenika core area is likely to be <200 km, consistent with a categorical estimate of '40-200 km' (Appendix *1* in Stamford et al. 2017).

Land use activities and associated roads threaten Arctic Grayling populations because they are correlated with key limiting factors, such as fishing mortality, water temperature, and degradation of stream habitats related to hydrological changes (elevated sediment transport, turbidity, peak flows, reduced summer flows; Stamford et al. 2017). Similar to other authors, we consider road density

[8] See Appedices 1-3 in Stamford et al. (2017) for a complete detailing of the methodology.

(km/km^2) to be suitable for use as a general cumulative effects indicator (Rieman et al. 1997; Foreman and Alexander 1998; Baxter et al. 1999; Trombulak and Frissel 2000; Kovach et al 2016). GIS analysis of road density patterns in Watershed Assessment Units of the Ingenika River watershed indicates moderate road density in the Swannell River watershed and along the Lower reach of the Ingenika River downstream of Pelly Creek, but that critical Arctic Grayling summer rearing habitats in the Upper and Mid reaches are relatively pristine (Hagen and Weber 2019 *in prep*.). These pristine upper reaches have likely played a key role in maintaining suitable water temperature and hydrology for sensitive populations of Arctic Grayling and Bull Trout. We therefore consider an appropriate threats ranking for the Ingenika core area to be 'moderate severity/low scope' (Appendices *1*, *2* in Stamford et al. 2017).

Entering the categorical estimates of trend, adult abundance, distribution, and threats into the *Core Area Conservation Status and Risk Assessment Methodology*'s numeric scoring process results in a ranking of 'C2-At Risk' for the Ingenika core area, which corresponds to a core area "at risk because of very limited and/or declining numbers, range, and/or habitat, making the Arctic grayling in this core area vulnerable to extirpation" (*Appendix 3* in Stamford et al. 2017). It should be noted that the score for the Ingenika core area was at the upper margin for this ranking (i.e. just shy of the more secure ranking 'C3-Potential Risk'). Key factors in this assessment were the small adult population size and limited distribution of Ingenika Arctic Grayling. Given this situation, further degradation of the conservation status because of a declining trend, a decrease in adult population size below 250, or an increase in threats would all be cause for significant conservation concern in future.

6.2 Critical Habitats and Habitat-Based Conservation Actions

A second, key information gap addressed by this study was the lack of information indicating critical (limiting) habitats for key life stages of Ingenika River Arctic Grayling (Stamford et al. 2017). This raises the question of whether subadult/adult summer rearing habitats in the Mid and Upper reaches of the Ingenika River are likely to be limiting to the Arctic Grayling population. It is likely that they are, as discussed below, and given our current level of understanding about adult population size, a drop in the ability of these habitats to produce adult Arctic Grayling may be a significant threat to the population.

For Arctic Grayling in the upper Peace Basin and elsewhere, access to pool habitat within clear stream reaches of moderate gradient appears to be a key habitat requirement for Arctic Grayling. Within accessible reaches, productivity of stream habitats for the subadult/adult life stage has been linked to nutrients, suitable thermal regimes, interspecific competition with other salmonids such as Rainbow Trout, potential predation by Bull Trout, and habitat degradation mechanisms including elevated sediment loads, loss of habitat complexity, elevated peak flows, and loss of connectivity with key spawning and overwintering locations (Stamford et al. 2017 and references therein).

As described in the previous section, land use activities and associated roads threaten the productivity of Arctic Grayling populations when they affect the thermal and hydrological suitability of stream environments. Forestry, in particular, is likely to be the most important source of land use-related threats to Arctic Grayling in the Ingenika River, if expansion occurs into the Mid, Upper, and Headwater reaches of the watershed which are currently pristine.

The management of forestry and other land use activities on Crown land is a core responsibility of the BC Provincial Government and is covered by a number of Provincial Acts. Therefore, the ability of FWCP to conduct habitat conservation on its own may be limited. Unfortunately, with respect to potentially sensitive populations of Arctic Grayling, reliable thresholds for sustainable levels of land use have not been established. It is not clear whether basic provisions for protecting fish habitat outlined in the BC Government's *Forest and Range Practices Act* (FRPA) are adequate for maintaining Arctic Grayling or, like sensitive populations of Bull Trout (an *Identified Wildlife Species at Risk*), these measures are not expected to be enough (BC MWLAP 2004, Hammond 2004).

The most effective habitat conservation actions available, other than legislated reserves of pristine habitat within protected areas, are probably special habitat management objectives delivered through Fisheries Sensitive Watershed (FSW) or Temperature Sensitive Stream (TSS) designations under FRPA. These strong measures, which may potentially operate at the scale of whole watersheds, can be proposed by FWCP but this potentially would be viewed as a core government responsibility. The most important potential role for FWCP in Arctic Grayling habitat conservation may be to deliver the scientific data supporting such designations.[9] Recommendations for acquiring this data are presented in the following section.

7.0 CONCLUSIONS AND RECOMMENDATIONS

In a meeting held at Tsay Keh Dene in March 2019, we heard extensively from community members regarding the conservation of river habitat. Community members have greater hope for the future when species and habitat conservation in their territory is an issue that government and industry take seriously. For members of Tsay Keh Dene Nation, the health of the community is tied to ecosystem health.

To assess the health of Arctic Grayling populations in Tsay Keh Dene traditional territory is to assess their conservation status. In this study, we have renewed the process of conservation status assessment in the Ingenika Arctic Grayling core area after a hiatus of more than ten years. We have found that a population of Arctic Grayling remains in the Ingenika River watershed more than 45 years after it was isolated from the rest of the Finlay River watershed by flooding, and that the mainstem Ingenika River between the Frederikson Creek and Pelly Creek confluences provides critical summer rearing habitat for the population. We have also found that Ingenika River Arctic Grayling may be at risk because of small population size, and that maintaining or improving the

[9] As an example of what is possible, the establishment of FSW designations for the Anzac, Table, Hominka, and Missinka rivers, along with special habitat management rules for forestry, was a key habitat conservation step for Arctic Grayling (and Bull Trout) of the Parsnip River watershed, and was led by MFLNRORD. However, much of the scientific background information enabling the FSW designations came from more than 2 decades of FWCP-funded research into fish population status and critical habitat locations (reviewed in Hagen et al. 2015).

status of the population may require that critical habitats be protected from land use-related habitat degradation.

Within the basin, the most productive critical summer rearing habitats for subadult and adult Arctic Grayling lie in pristine condition beyond the end of the road network. Key habitat elements come together in these locations: cold water flowing from mountainous headwaters, stable flows, and low sediment transport related to undisturbed watershed conditions. The relatively pristine condition of these habitats means that significant opportunities exist for effective habitat conservation action in the Ingenika core area.

As identified in the previous section, the most important first steps required from FWCP to facilitate habitat conservation in the Ingenika River watershed are to improve the scientific data supporting assessments of conservation status, critical habitats, and limiting factors. To improve the ability of the snorkeling program to contribute some of this scientific data, we have the following specific recommendations:

1. Continue 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), to enable more reliable estimates of Arctic Grayling trend. The next survey of the Ingenika is proposed for August 2019.[10]

2. Estimate the repeatability of snorkeling counts by conducting replicated snorkeling surveys at a minimum of three sites in 2019.

3. Estimate the accuracy of snorkeling counts by conducting a mark-resight study of detection probability in 2019.

4. Include biological sampling in the 2019 study plan, to learn about age, life history, and growth.

5. 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

[10] 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.

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. The feasibility of such studies might be evaluated using data already collected for FWCP studies (e.g. variance in allele frequencies, otolith microchemistry among fry rearing locations; Clarke et al. 2005; Shrimpton and Clarke 2012)

6. Improve the accuracy of estimates of population size and critical summer rearing habitats by surveying potentially suitable tributary habitats, and by conducting surveys in sections of the Ingenika River mainstem outside of index sites, on at least one occasion in the next 10-15 years.

7. 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. 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 River are a suggested minimum target.

8. Co-ordinate with Arctic Grayling abundance monitoring elsewhere in the Williston Reservoir watershed (e.g. FWCP project no. PEA-F19-F-2625: Abundance and Critical Habitats of Arctic Grayling of the Parnsip River Watershed) to explore opportunities for learning about limiting factors (e.g. water temperature, turbidity, and flow monitoring paired with biological sampling and abundance monitoring).

8.0 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 a meeting in Tsay Keh Dene in March 2019. Sean Barry provided estimates of road density within the Ingenika River watershed. Morgan Hite produced the maps used in the report. Our pilot for the 2018 study was Ryan Hinds, and Silver King Helicopters is further acknowledged for accommodating our study within a busy 2018 schedule.

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