Trend in Abundance of Arctic Grayling (*Thymallus arcticus*) in Index Sites of the Parsnip River Watershed, 1995-2018.

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EXECUTIVE SUMMARY

Two high-priority knowledge gaps have been identified by the Peace Region Fish and Wildlife Compensation Program (FWCP) that limit the program's ability to initiate conservation and enhancement actions for Arctic Grayling of the Parsnip River watershed. These are: 1) the lack of recent abundance monitoring indicating population trend and total adult population size, key indicators of conservation status, and 2) the lack of monitoring data delineating critical habitats, which is needed for planning conservation and enhancement actions. In this study we address these two information gaps using a snorkeling survey methodology in the Anzac and Table river watersheds, thereby aligning the study with FWCP *Streams Action Plan* (FWCP 2014a) 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 present Parsnip Arctic Grayling abundance monitoring study had three objectives for the 2018 field studies:

1. To conduct replicated snorkeling counts of Arctic Grayling within index reaches using three independent crews, to investigate the repeatability of counts across a realistic range of crew experience levels.

2. To acquire counts of Arctic Grayling and other species in 6 long-term index sites in the Anzac River and Table rivers, using a snorkeling survey methodology consistent with past surveys up to 2007, and to evaluate the trend in abundance over time for Arctic Grayling in the Parsnip River watershed.

3. To acquire counts of Arctic Grayling and other species along the entire accessible length of the Anzac River using a single-pass snorkeling survey methodology, in order to estimate total population size and delineate critical summer rearing habitats for adult and sub-adult grayling.

In three reaches surveyed by three independent crews, repeatability of snorkeling counts of Arctic Grayling >20 cm was relatively high across a broad range of mean snorkeler experience among crews ranging from >20 years to <5 years. The coefficient of variation (*CV*) ranged from 4.1% to 19.9% among the three locations averaging 11.1% (±4.6%). However, size estimation varied widely among crews in replicated reaches. Positive size estimation bias was evident and related to crew experience, indicating the need for improved size calibration using more realistic fish-size models in future swims.

In August 2018, snorkeling counts of Arctic Grayling in long-term index sections of the Parsnip River watershed were the highest on record for 5 of the 6 sites surveyed (all but the lowest Anzac River site between 16 km-12 km; measured along the stream from the mouth). Analysis of population trend with a linear mixed-effects model, with *Year* as the fixed effect and *Stream* and *Site* as nested random effects in the model, indicated a significant increase in the abundance of Arctic Grayling >20 cm in index sites over the 1995-2018 period ($P = 0.014$). However, at this point in time we consider this appearance of a positive trend to be provisional and requiring corroboration in 2019 and beyond, for two important reasons. First, with a hiatus of more than 10 years in the snorkeling count program, the abundance data are not balanced across time and the 2018 data point has high leverage. Second, we have uncertainty about whether the extreme low water conditions observed in August 2018 may have affected counts of Arctic Grayling, perhaps resulting in higher detection probability or increased concentration of individuals in index sites related to these low water conditions.

In addition, we conducted single-pass snorkeling surveys along a continuous section of the Anzac River extending nearly 50 km from 56 km to 5.8 km. These surveys included 8.6 km of stream habitat in which Arctic Grayling were discovered upstream of a chute obstruction at 47 km that was previously thought to be a migration barrier. The core of the Arctic Grayling distribution in 2018, as indicated by consistently high counts in surveyed reaches, extended from the 47 km chute downstream for more than 30 km to 16.6 km, across several distinct zones of channel confinement, stream gradient, and land use. Counts of Arctic Grayling were consistently low in the lower 16.6 km of the Anzac River mainstem, which is characterized by several major braids limiting pool frequency and depth, and a low gradient, meandering channel.

With the resumption of Arctic Grayling population monitoring in the Anzac River and Table River watersheds, we have an improved basis for assessing conservation status. After updating categorical estimates of *Trend*, *Adult abundance*, *Distribution*, and *Threats*, parameters in the *Core Area Conservation Status and Risk Assessment Methodology* (USFWS 2005) used to evaluate status of British Columbia Arctic Grayling populations, we computed a ranking of 'C3-Potential Risk' for the Parsnip core area. This ranking is provisional and depends upon future corroboration of the abundance trend estimate.

Importantly, the core of the Arctic Grayling summer rearing habitat lies adjacent to the existing road network, where intensive forestry and road building activity is now underway. Spruce beetle salvage harvesting is a potential threat to Arctic Grayling populations and has the potential to affect angler access, peak flows, sediment delivery, and water temperature in critical habitats. Therefore, the urgency for continued monitoring, habitat conservation and restoration actions may be high in critical Arctic Grayling rearing habitat of the Parsnip River watershed.

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1.0 INTRODUCTION

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 FWCP to guide projects within the Peace Basin program area, with a focus on priority species that use streams for all or part of their life cycle, and which have been affected by reservoir creation. One such priority species, which is also a priority species for British Columbia's Ministry of Forests, Lands, Natural Resource Operations, and Rural Development (FLNRORD), is the Arctic Grayling (*Thymallus arcticus*).

Losses of critical stream habitats and connectivity among populations resulting from flooding have resulted in major declines of Arctic Grayling in the Williston Reservoir watershed, and extirpation of the species from most of the smaller, direct tributaries to the reservoir. Flooding appears to have isolated remaining populations in seven larger watersheds, with the reservoir potentially acting as an ecological barrier to movements and gene flow (Shrimpton et al 2012; Clarke et al. 2005).

In 2016, a major study was conducted by FWCP to evaluate the existing knowledge base and address *Streams Action Plan* objective *1b-1*.[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.

The lack of regular abundance monitoring indicating trend for Arctic Grayling populations in the Williston Reservoir watershed (Table 1, ID #1 of Hagen and Stamford 2017) is the first of the two high priority knowledge gaps addressed by our study. Trend in abundance is one of the most important indicators of conservation status (along with total adult abundance: O'Grady et al. 2004), which can signal the need for conservation actions, or indicate the sustainability of angling regulations and current habitat management. If trend estimates include other fish species, improved knowledge of ecological interactions with predator (e.g., Bull Trout) and competitor (e.g., Rainbow Trout) species also may have implications for fisheries management and opportunities for human use of fish. Trend data may also indicate the operation of limiting factors, particularly when collected at the decadal scale and combined with other monitoring data from around the Williston Reservoir watershed (e.g. FWCP project no. PEA-F19-F-2647: *Snorkeling to Monitor Ingenika Arctic Grayling*

[1] 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).

Abundance). To address the lack of abundance information indicating Arctic Grayling population trend in the Parsnip River watershed, in this study we resume snorkeling surveys within index sections of the Anzac and Table rivers last surveyed in 2007.

A second, high-priority information gap identified in the *Arctic Grayling Monitoring Framework* was the lack of monitoring data indicating total adult abundance and the distribution of critical habitats for Arctic Grayling populations (Table 1, ID #2; Hagen and Stamford 2017). Total abundance is a second key indicator of conservation status (O'Grady et al. 2004). In this study we conduct single-pass snorkeling surveys along the entire length of streams utilized by Arctic Grayling in the Parsnip River watershed, thereby learning about how counts in index sections relate to total abundance and addressing this important information gap. The focus for the 2018 study was the Anzac River watershed. In addition to enabling estimates of total population size, continuous surveys of whole watersheds permit the identification of critical summer rearing habitats for Arctic Grayling and other species, which is prerequisite information for planning conservation and enhancement actions.

Fish population monitoring data are an essential component of both effective conservation and enhancement projects, as described above. The study partners and collaborators, which include FLNRORD, McLeod Lake Indian Band (MLIB), consultant John Hagen and Associates, and the University of Northern British Columbia (UNBC), believe that Arctic Grayling studies in the Parsnip River watershed are of especially high urgency because:

1. significant habitat loss has resulted from reservoir creation,
2. the reservoir has potentially isolated Parsnip Arctic Grayling from genetic and demographic support from other populations,
3. they face unique ecological challenges associated with being the southernmost population in B.C. (competition with Rainbow Trout, predation from Bull Trout, climate change),
4. because of a rapid expansion of forestry activities in the watershed related to spruce beetle infestation, and
5. close proximity and ease of access for anglers from a large population center (Prince George, BC).

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*).

The goal of FLNRORD in Omineca Region (Fisheries Management Region 7) is to ensure long-term persistence of priority fish species, of which the Arctic Grayling is one, at abundance levels optimizing fishery benefits.

Our study has been designed specifically to address two high-priority recommendations of the *Arctic Grayling Monitoring Framework* report, using the methodology of snorkeling surveys in the Parsnip River watershed. The study therefore is aligned with *Streams Action Plan* priority action *1b-3*[2] (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 sites located in the Anzac and Table rivers, using a snorkeling survey methodology consistent with past surveys, and to evaluate trend over time for Arctic Grayling in the Parsnip River watershed.
2. To conduct replicated snorkeling counts of Arctic Grayling within three index reaches using three independent crews, to investigate the repeatability of counts across a realistic range of crew experience levels.
3. To acquire counts of Arctic Grayling and other species along the entire accessible length of the Anzac River using a single-pass snorkeling survey methodology, in order to estimate total population size and delineate critical summer rearing habitats for adult and sub-adult grayling.

3.0 STUDY AREA

The Parsnip River watershed lies within the traditional territory of the McLeod Lake Indian Band (MLIB), and the Anzac River and Table River watersheds and their natural resources are of critical community interest (Hagen et al. 2015). The mouths of the Anzac and Table rivers are located approximately 30km and 50km southeast of the village of McLeod Lake, respectively (Figure 1). Both rivers also enjoy high popularity amongst the local recreational angler community.

Historically, the Parsnip River flowed roughly 280 km along the Rocky Mountain Trench from near Arctic Lake to its confluence with the Finlay River, where the two rivers joined to form the Peace River. Construction of the 183 m high W.A.C. Bennett Dam, which was completed in 1967, resulted in the formation of Williston Reservoir, which reached full pool in 1972 (Hirst 1991). Impoundment resulted in the permanent loss of over 110 km of critical Arctic Grayling habitats in the Parsnip River mainstem, and the loss of local populations that depended on these habitats (Stamford et al. 2017). Tse'Khene knowledge shared with FWCP indicates that before flooding, Arctic Grayling could be caught by in most tributaries to this section of the river (Pearce et al. 2019).

The post-impoundment Parsnip River system is a 6^{th} order streams that has a watershed area of 5,600 km^2 (Table 1). Major sub-basins of the Parsnip (Misinchinka, Colbourne, Reynolds, Anzac, Table, Hominka, Missinka, Upper Parsnip), range from 290 km^2 to 1,000 km^2 and drain mountainous terrain in the Hart Ranges of the Rocky Mountains, lying to the east of the trench. In contrast, smaller sub-basins on the west side of the Parsnip (95 km^2 to 182 km^2) drain lower elevation areas of the Nechako Plateau (Figure 1; Table 1).

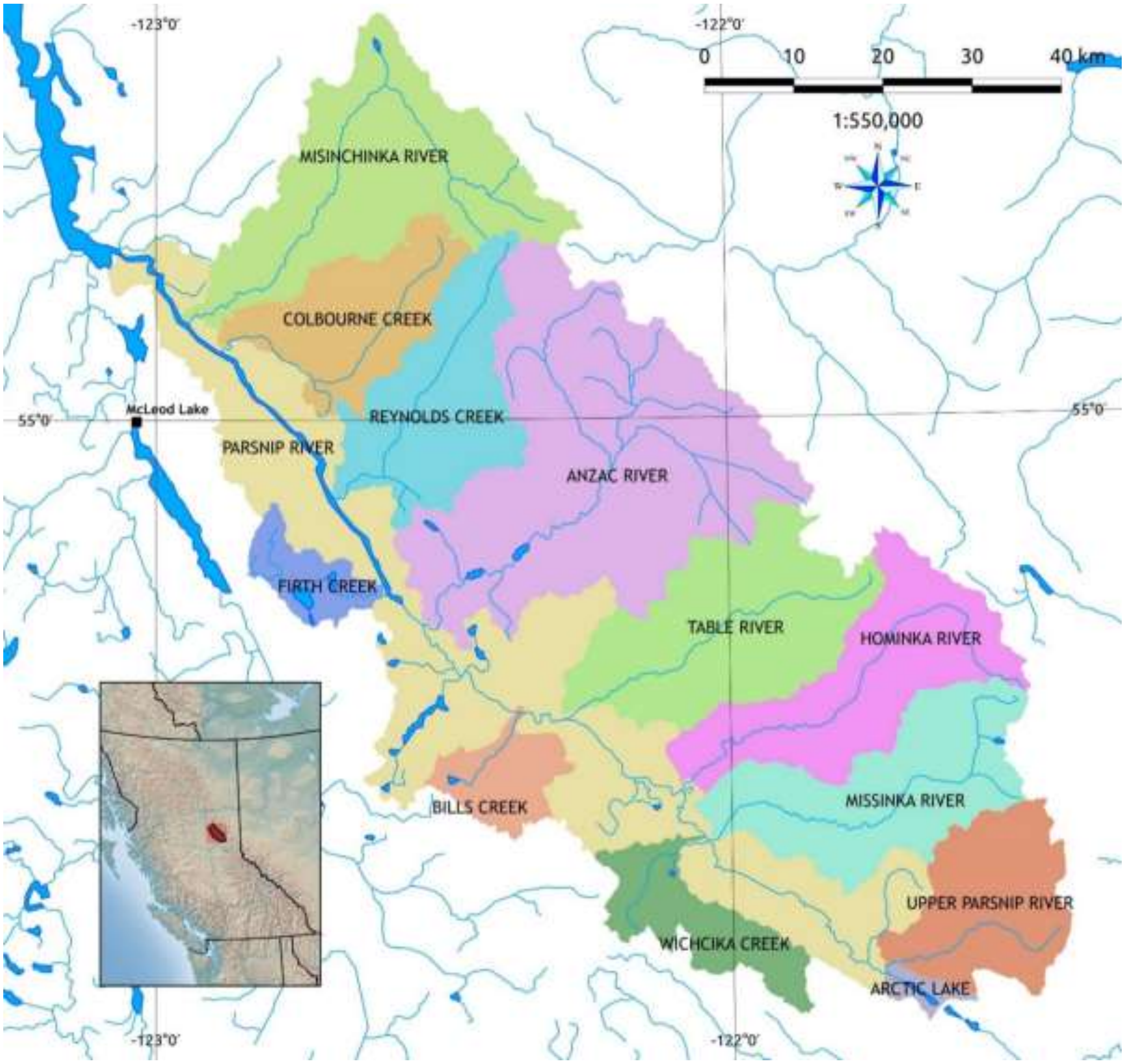

Figure 1. Sub-basins of the Parsnip River watershed (Parsnip mainstem, Misinchinka, Colbourne, Reynolds, Firth, Anzac, Bill's, Table, Hominka, Missinka, Wichcika, Arctic Lake, Upper Parsnip) potentially utilized by Arctic Grayling.

Table 1. Biophysical characteristics of sub-basins potentially utilized by Arctic Grayling within the Parsnip River watershed (adapted from Hagen et al. 2015).

Watershed	Sub-basin	Watershed area (km^2)	Stream order	Fish species present*
Parsnip	Parsnip total	5,612	6	GR, EB, BT, BB, KO, LKC, LT, LW, CSU, LNC, LSU, MW, NSC, PCC, CAS, PW, RB, RSC, CCG, WSU
Parsnip	Misinchinka River	595	4	GR, BT, BB, LSU, MW, RB, CCG
Parsnip	Colbourne Creek	289	4	GR, BT, CSU, LSU, MW, RB, CCG
Parsnip	Reynolds Creek	366	5	GR, BT, BB, LKC, CSU, LNC, LSU, MW, RB, RSC, CCG
Parsnip	Firth Creek	95	3	GR, BB, LKC, LW, LNC, LSU, MW, RB, CCG
Parsnip	Anzac River	1,044	5	GR, BT, BB, LKC, LT, LW, LSU, MW, PCC, CAS, RB, RSC, CCG
Parsnip	Tacheeda Lakes	95	4	BT, KO, LT, LW, LNC, LSU, MW, NSC, PCC, CAS, PW, RB, RSC, WSU
Parsnip	Bill's Creek	122	5	GR, BB, MW, RB, CCG
Parsnip	Table River	504	5	GR, BT, BB, LW, CSU, LSU, MW, NSC, RB, CCG, WSU
Parsnip	Hominka River	433	5	GR, BT, BB, LSU, MW, PCC, RB, CCG, WSU
Parsnip	Missinka River	434	5	GR, BT, BB, LKC, CSU, LNC, LSU, MW, NSC, RB, RSC, CCG
Parsnip	Wichcika Creek	182	5	GR, BT, BB, MW, RT, CCG
Parsnip	Arctic Lake	31	-	GR, BT, KO, LT, LW, LSU, MW, NSC, RB, RSC, WSU
Parsnip	Upper Parsnip	303	-	GR, BT, BB, KO, LT, LW, CSU, LSU, MW, NSC, RB, RSC, CCG, WSU

*From records in databases linked to the BC Geographic Warehouse, accessed January 2015

Streamflow is snowmelt driven, with peak discharge occurring, on average, in late-May to early-June in the Parsnip River watershed.[3] Much of the watershed drains higher elevation, mountainous areas. Consequently, sediment load is relatively high among

[3] Water Survey of Canada, data on file: http://wateroffice.ec.gc.ca/google_map/google_map_e.html?searchBy=p&province=BC&doSearch=Go

sub-basins, as evidenced by turbid water flows in spring, wide channels relative to stream size, and extensive bar development (Bruce and Starr 1985). An important factor positively affecting fish habitat quality in the watershed is the fact that among sub-basins, substantial glacial influence occurs only within the Upper Parsnip sub-basin (Figure 1). Consequently, in most years water clarity is excellent throughout watershed sub-basins throughout much of the year, and by late summer the Parsnip mainstem itself becomes relatively clean in areas downstream of the Missinka River (Anonymous 1978).

4.0 METHODS

4.1 Study Design

Snorkeling surveys have long been used as a research technique in streams (Hagen and Baxter 2005 and references therein). Key advantages of the method are its non-invasive nature and high efficiency, which means that larger areas of habitat can be surveyed for a given cost relative to competing methods like seine netting or electrofishing. However, 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 method of snorkeling counts of adult salmonids in streams has not been extensively evaluated, but results from published accounts suggest that 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). Therefore, the design for our study over its two-year duration includes an evaluation of whether snorkeling counts in the Parsnip River watershed should be considered reliable indicators of population status.

Estimates of population trend and total abundance based on snorkeling counts in index sections depend on 3 important parameters: 1) the repeatability of snorkeling counts (inter-observer variability), 2) spatial variation in fish density and its variance year-to-year, and 3) detection probability (the number of fish seen compared to the number actually present) and its variance from year-to-year.

We assessed the repeatability of snorkeling counts by deploying 3 independent crews to conduct replicate swims in 3 reaches over a 3-day period. For safety and communications purposes, all crews swam the same reach each day, although with a minimum 1-hour delay between start times to minimize the potential effects of site disturbance. The study design calls for 3 additional reaches to be swum with 3 replicates in 2019.

Since the inception of snorkeling surveys in the Parsnip River watershed in 1995, the program has been designed to reduce the unwanted effects of spatial variation in fish density, by utilizing consistent index sites (stream reaches of approximately 4km) each year in the Anzac River and Table River watersheds (Figure 2, 3). However, as such spatial variation has not been previously assessed, we determined a need to explore whether observed densities in index reaches are representative of unsurveyed reaches and can inform estimates of total population size. To assess spatial variation in fish density and acquire total system counts for Arctic Grayling, we conducted 1-pass snorkeling surveys along the entire accessible length (minus the lower 5.8 km due to time constraints) of the Anzac River in 2018. In addition, continuous snorkeling coverage of the Anzac River mainstem was designed to identify critical reaches for adult/subadult Arctic Grayling and other species.

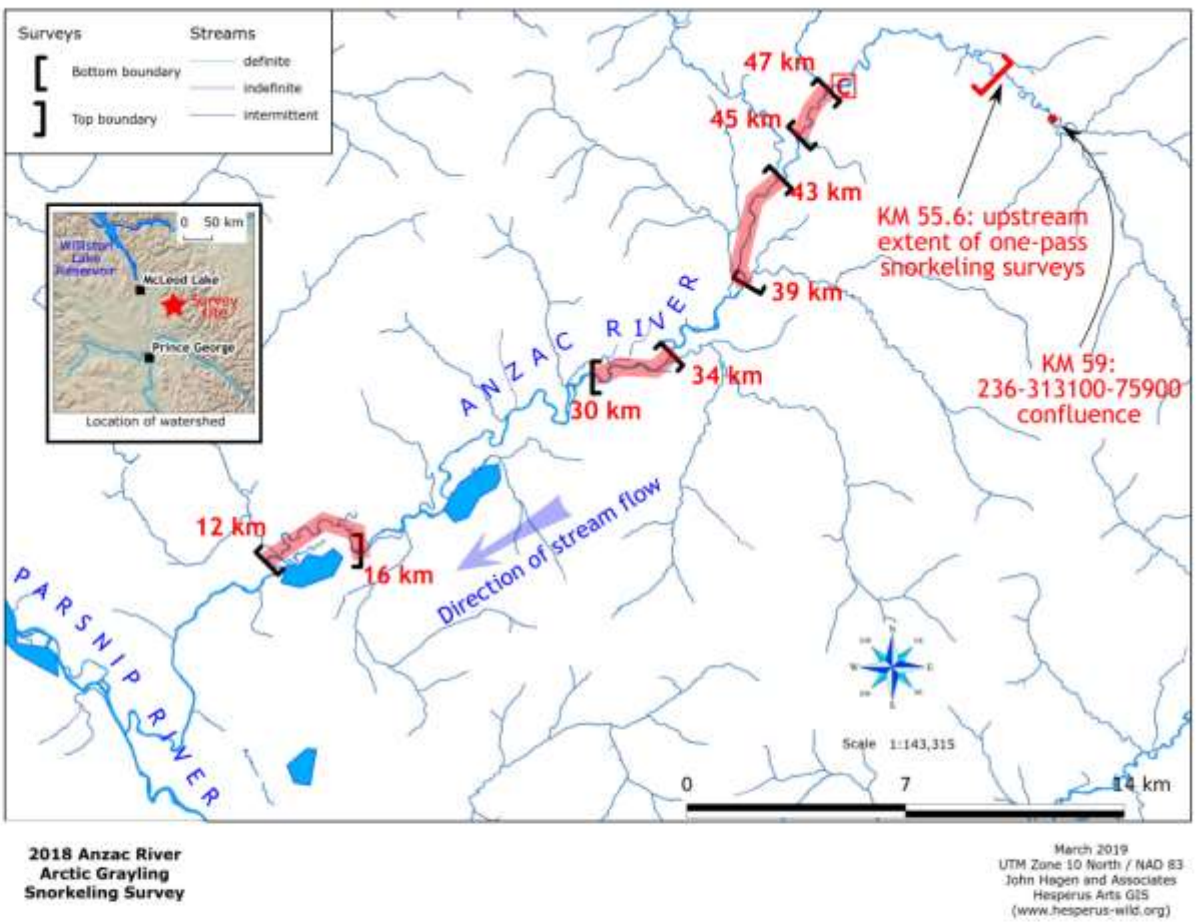

Figure 2. Stream sections of the Anzac River utilized for snorkeling surveys to monitor Arctic Grayling abundance, 1995-2018.

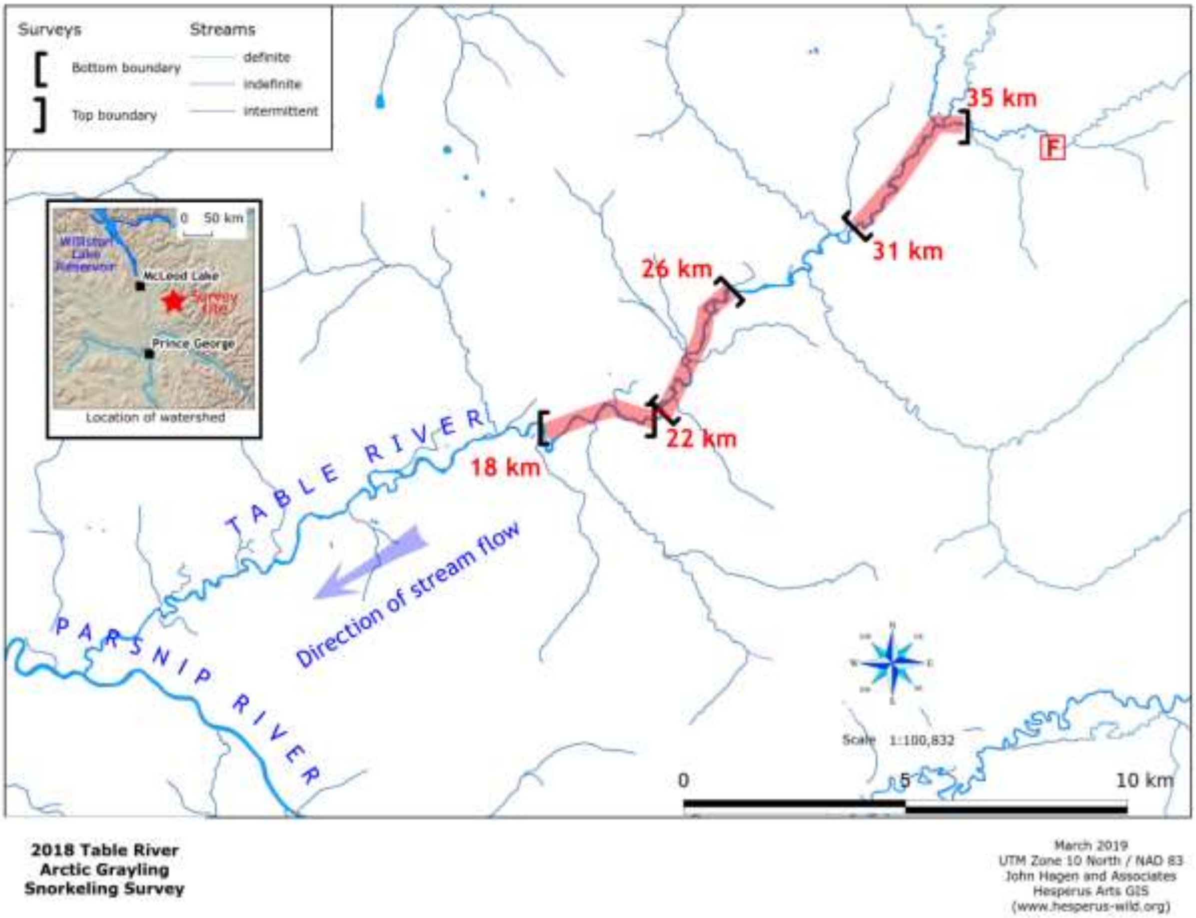

Figure 3. Stream sections of the Table River utilized for snorkeling surveys to monitor Arctic Grayling abundance, 1995-2018.

Mark-recapture estimates of snorkeling detection probability have been attempted previously in these index sites, but the results were not considered reliable because of evidence for post-tagging movements out of index sites prior to the snorkeling surveys (Cowie and Blackman 2012 and references therein). In our study design, estimates of snorkeling detection probability depend on successful collaboration with the UNBC-led acoustic telemetry study (Peace Region Project No. PEA-F19-F-2593) in 2019, when Arctic Grayling bearing both visual tags and surgically-implanted acoustic tags will be present in snorkeling index sites.

4.2 Snorkeling Methods

In 2018 we conducted snorkeling surveys in four index sites in the Anzac River (Figure 2) and two index sites in the Table River (Figure 3) over the four-day period between August 16-19, similar to surveys conducted up to 2007. Continuous snorkeling surveys along the remainder of the Anzac River mainstem between Stream 55.6 km[4] and Stream 5.8 km were conducted between August 20-22.

In a major surprise to the study team, UTM coordinates utilized as survey boundaries for the four Anzac River index sites, which were acquired from a FLNRORD database, were later determined to be inaccurate when compared to a database acquired from FWCP.[5] Fortunately, the fact that the entire length of the Anzac River had been surveyed allowed us to account for the inaccuracies and generate estimates for the true index site boundaries, by interpolating from the continuous snorkeling coverage between 55.6 km and 5.8 km.[6] Index site boundaries for the Table River watershed appeared to be accurate, and no adjustments to snorkeling counts were necessary.

In the field, three independent crews were utilized. Each crew was comprised of two snorkelers in drysuits and one safety boater trained in swiftwater rescue (as per FLNRORD Snorkel Drift Safety Work Procedure, 2018), consistent with methods up to 2007 (Cowie and Blackman 2012). Crews were deployed in the same order in replicated sites (with JH+MS first, RP+IS second, and ZS+NG third).[7]

Adult and subadult Arctic Grayling (Figure 4) in the Parsnip River watershed 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 mid-August, the Anzac and Table rivers are small streams with good underwater visibility (Figure 5). In these circumstances, teams of 2 divers are adequate for surveying across the usable widths of these streams (Figure 6), and the potential for double counting perhaps a greater concern than low detection probability. Protocol for conducting snorkeling surveys, which are discussed in the following paragraph, reflected this concern.

During snorkeling surveys, typically divers surveyed adjacent lanes on either side of the thalweg, and scanned the water ahead of them and to the right or left depending on which side of the stream they were responsible for. Divers attempted to count only fish that were in their lane as they past by, but fish moved in reaction to the divers necessitating frequent communication to ensure that double counting did not occur. In areas where the usable width of the stream was greater than the width of two lanes

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[4] Based on stream segment lengths estimated in the 1990s.

[5] The coordinates acquired from FWCP were compared to maps and site descriptions from snorkeling surveys over the 1995-2007 period and found to be accurate.

[6] Fish density estimates for correct index reach locations were based on the densities for surveys conducted in the same location. If the correct index reach boundaries overlapped with more than one survey in 2018, densities observed during each survey were applied to the corresponding section of the correct index reach.

[7] This order enabled the first (contract) crew to survey a second section on each of these days.

surveyed in this manner, one or both of the divers would extend their lane width and look both ways.

Figure 4. Adult, female Arctic Grayling in the Anzac River, August 2018.

Figure 5. Canyon pool on the Anzac River, August 2018.

Figure 6. Snorkeling team in the upper Anzac River watershed, August 2018.

Observed fish were recorded by species and 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, size estimation was practiced under water using Arctic Grayling models (laminated, trimmed photographs). Underwater visibility was also estimated, in two ways: 1) horizontal underwater secchi disk visibility, and 2) horizontal distance at which the species identity of a 30 cm Arctic Grayling model could no longer be discerned.

During surveys, safety boaters utilized inflatable kayaks (Figure 5) that were capable of navigating the range of stream features encountered and being easily stowed in the basket of the helicopter during transport.

All field crews were experienced in conducting snorkeling surveys, and had received in-the-water training with the study protocol prior to the survey period. However, average snorkeler experience among pairs of divers ranged widely from 20+ years to <5 years, with one member of the field crew in her first year of conducting underwater surveys. This range of experience was considered desirable for the evaluation of snorkeling count repeatability, because of the expectation that it would be representative of the future capacity of FLNRORD or other teams of biologists to conduct major snorkeling field programs.

4.3 Trend Analysis

As the first step in evaluating the 2018 status of Arctic Grayling populations in the Parsnip River watershed, we gathered and compiled present and past snorkeling data (Cowie 2013; FWCP unpublished data) in to a searchable database that will be available for future reference. Then, we described the change in Arctic Grayling abundance over time in index sites in two ways. First, to visually depict changes over time among individual sites, we plotted 2018 counts against 1995-2007 averages for each of the six long-term index reaches in the Anzac and Table rivers.[8] Second, we assessed the change in Arctic Grayling abundance over time for the Parsnip River watershed as a whole using the Stata statistical analysis program (StataCorp, 2009) and the 'xtmixed' function (Rabe-Hesketh and Skrondal 2008) to perform a linear mixed effects analysis. As fixed effects, we entered counts and observation year (without interaction term) into the model. As random effects, we had intercepts for sites nested within streams. Visual inspection of residual plots did not reveal any obvious deviations from homoscedasticity or normality, following square root transformation of the snorkeling count data.

5.0 RESULTS

5.1 Survey Conditions

The summer of 2018 was dry and hot. Discharge in the lower Parsnip River over the August 16-22 period ranged from 46-33 m^3/s at the Water Survey of Canada's Station 07EE007 Parsnip, well below the average of ~74 m^3/s for the Aug 16-22 period across all years since the station's inception. Low flow conditions in the Anzac and Table rivers sometimes resulted in slow rates of travel on the stream, however were considered highly suitable for visual observation methods (e.g. Figure 4, Figure 5). Secchi disk visibility ranged from 7.7 to 10.1 m in two index sites on the Table River, and from 6-12m in reaches distributed along 55 km of the Anzac River. Visibility for identification of Arctic Grayling models ranged from 5.7 m to 7 m in the Table River sites, and from 5-8 m along the Anzac River.

The long-term index site extending from 22 km-18 km in the Table River was the exception to the pattern of good visibility. A large clay slump into the river at the top of the reach reduced visibility to just 3 m, inadequate for reliable snorkeling surveys. The extensive nature of the slump suggested that visibility in the reach would potentially be compromised for years to come. In order to retain a desirable index reach in the middle section of the Table River, in 2018 we surveyed a 4-km reach (26 km-22 km) immediately upstream of the slump instead, and use the resulting count data in the comparison with count data for 22 km-18 km over the 1995-2007 period.

[8] We expected the location of a particular site to have a strong effect on counts of Arctic Grayling over time, with certain sites always being relatively productive and others not so. Missing site data in some years would therefore potentially have a strong effect on average abundance in any given year, if counts were averaged at larger spatial scales such as streams. This could be misleading, hence 2018 counts were plotted only against data from the same sites. The linear mixed-effects model can handle missing data and was therefore suitable for assessing trend at the larger spatial scale of the Parnsip River watershed.

A major factor affecting logistics during the field program in 2018 was the extensive wildfire activity in the Prince George region. Flight travel times were extended due to low visibility caused by wildfire smoke, and the overall duration of the project was extended due to unsafe flying conditions on two days which had to be rescheduled.

5.2 Reliability of Snorkeling Counts

A key objective of the study in 2018 was to investigate the repeatability of snorkeling counts. In three reaches surveyed by three independent crews in 2018 (Anzac 45 km-41.8 km, Anzac 37 km-31.8 km, and Table 35km-31km), repeatability of snorkeling counts of Arctic Grayling >20 cm was relatively high across a broad range of mean snorkeler experience among crews ranging from >20 years to <5 years (Figure 7). Counts were not related to the order of crew deployment. The coefficient of variation (*CV*) ranged from 4.1% to 19.9% among the three locations averaging 11.1 (±4.6)%. It is somewhat counterintuitive that the high estimate for the *CV* of 19.9% corresponded to the site with the least habitat complexity.[9] At this site, perhaps because of the lack of stream habitat complexity, it was noted by one crew that Arctic Grayling were more reactive to the snorkeling team. Observed Arctic Grayling were frequently pushed in front of the line of observers to the tail of long runs, where they would burst back upstream.[10]

High repeatability of snorkeling counts is an important requirement for rapid, sensitive detection of changes in population status for fish populations. Replicate swim data exists for the 1995-2007 period and has been incorporated into the project database. However, over this period replicate counts were not made by independent crews in most cases, and they may underestimate observer error. A quantitative evaluation of 1995-2007 replicates versus those made by independent crews in 2018 and 2019 will occur following the completion of replicate swims in 2019.

For snorkeling observations to provide potentially valuable insights into cohort strength, population age structure, and the abundance of adult fish, visual estimates of fish body sizes must be relatively accurate and precise. Snorkeling crew leaders were aware of underwater magnification effects and the difficulty in attaining reliable estimates of fish size, along with the importance of practice with size estimation. Nonetheless, size estimation varied widely among crews in replicated reaches (Figure 8). Positive size estimation bias was evident and related to crew experience, indicating the need for more realistic models and more practice in future.

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[9] This is a subjective observation only, as detailed habitat data for snorkeling sites have not been compiled. This step is scheduled for the 2019 field season.

[10] This behaviour in Rainbow Trout appeared to be a factor affecting snorkeling count accuracy and precision in the Salmo River, B.C, and was exacerbated by low levels of snorkeling team experience in the first year of the study (Hagen and Baxter 2005).

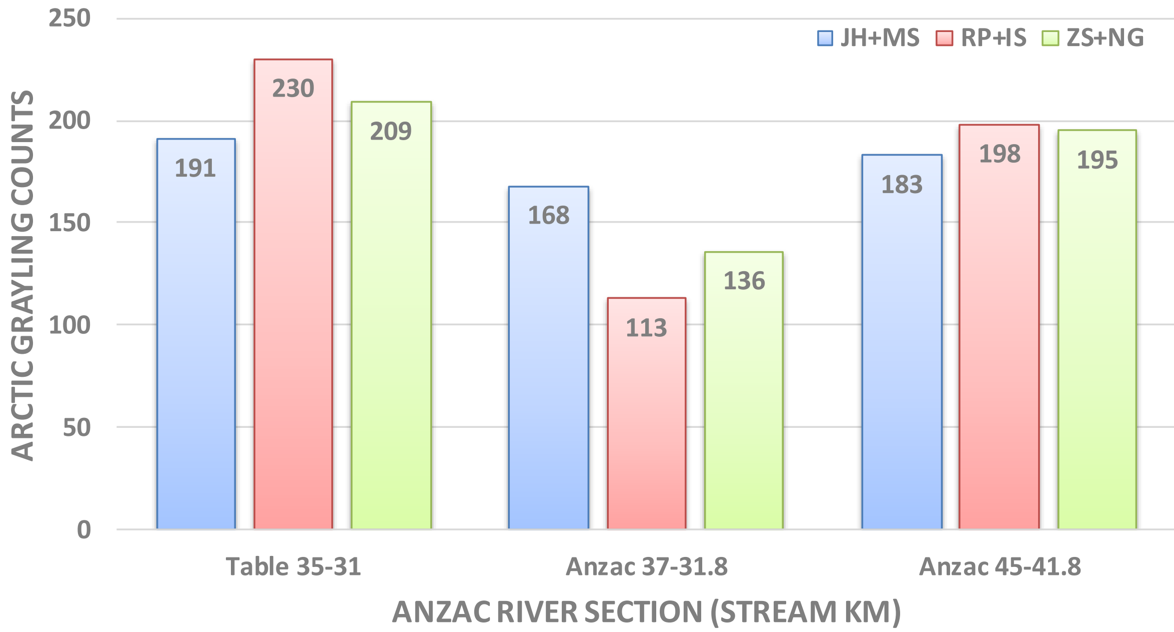

Figure 7. Replicated snorkeling counts of Arctic Grayling >20 cm in three selected sections of the Table River and Anzac River watersheds, August 2018. Site numbers correspond to stream distances from the mouth of the stream to the upper and lower site boundaries.

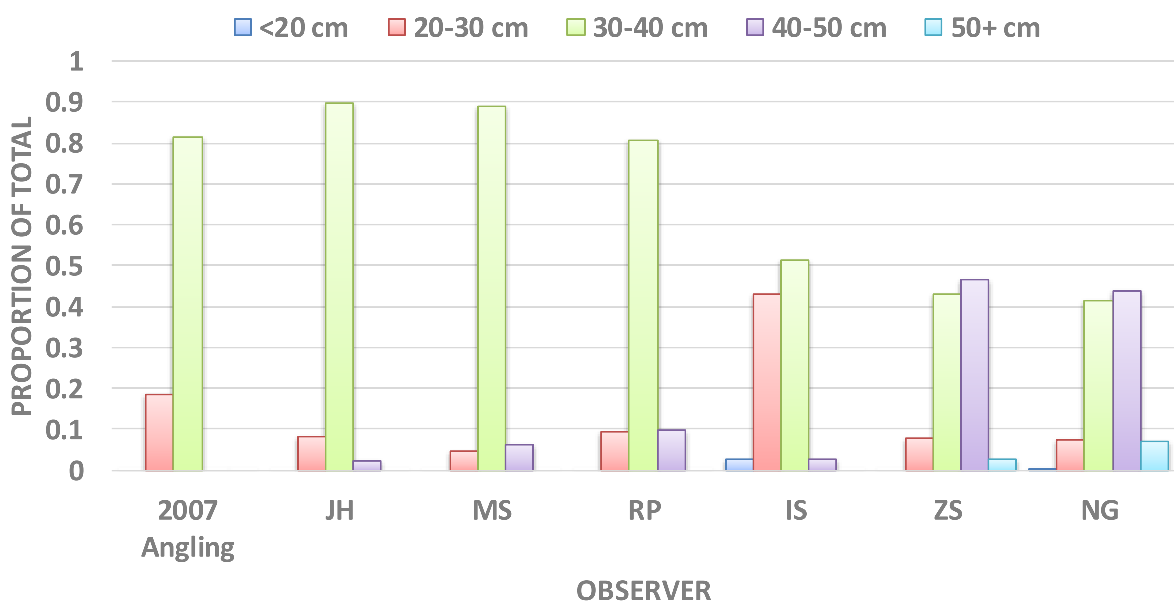

Figure 8. Arctic Grayling length-frequency histograms (proportions) for individual snorkelers based on surveys in replicated stream sections only. The figure depicts 2007 angling data and three crews of 2 (left-to-right pairs) arranged from most to least experienced.

The length-frequency histogram from 2007 angling data does not include any fish >40 cm, potentially suggesting that positive size estimation bias was present for all observers (Figure 8). However, even the most experienced observers were confident that some of the Arctic Grayling present exceeded this size. Earlier in 2018, one of our crews was present in the Ingenika River watershed (FWCP Project No. PEA-F19-F-2647) when an evaluation of underwater size estimation took place. 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 (Hagen et al. 2019) confirming the visual size estimates. Therefore, the potential that an increased presence of larger, older Arctic Grayling >40 cm are present in the Anzac and Table rivers relative to 2007 should not be discounted.

High detection probability (accuracy) of snorkeling counts is likely to be just as important as high repeatability for rapid, sensitive detection of population status changes (Northcote and Wilkie 1963; Hagen and Baxter 2005). An evaluation of detection probability of Arctic Grayling is scheduled for the 2019 field season, when acoustically-tagged fish also bearing visual tags will be present in the study reaches. In 2018, a small number of tagged fish were present in only one study reach, Table River 35 km-31 km. At the time of writing, the preliminary estimates for the number of tagged Arctic Grayling present in the study reach was 5. The average number of tagged Arctic Grayling observed was 4 (80%), provisionally indicating a desirable high detection probability.

5.3 Population Trend

In the Parsnip River watershed in 2018, snorkeling teams counted more Arctic Grayling than had ever been counted before for 5 of the 6 long-term index sites surveyed (all but Anzac River Site 16-12; Table 2). Counts of Arctic Grayling in 2018 ranged from 135% higher to 5% lower than 1995-2007 long-term averages among index sites, with the average being 60% higher (Figure 9, Table 2). Analysis of population trend with the Linear mixed-effects model, with *Year* as the fixed effect and *Stream* and *Site* as nested random effects in the model, indicated a significant increase in the abundance of Arctic Grayling >20 cm in index sites over the 1995-2018 period (P = 0.014).

Table 2. August snorkeling counts of Arctic Grayling >20 cm in index sections of the Table and Anzac rivers, 1995-2018. Counts are averages if more than one replicate swim occurred (*SE* in parentheses).

	Table River Sites			Anzac River Sites			
Year	**Table 35-31**	**Table 26-22***	**Table 22-18**	**Anzac 47-45**	**Anzac 43-39**	**Anzac 34-30**	**Anzac 16-12**
1995	111(4.0)						
1998	136(1.0)		67(7.2)	164(7.0)	136(16)	106(10)	8(5.0)
2000	123(10)		37(2.0)	68(1.0)			
2001	91(11)		42(4.6)	20(5.0)	85(12)	52(3.5)	11(4.5)
2003	137(1.5)		70(3.2)	78(8.7)	166(11)	54(9.5)	23(3.5)
2005	98(3.1)				91(8.0)	79(15)	28.5(2.5)
2007	113(6.1)		45(5.6)			61(14)	45
1995-2007 average	***116(6.7)***		***56(6.8)***	***83(30)***	***120(19)***	***70(10)***	***23(6.6)***
2018	210(11)	76		194	182(4.6)	114(16)	22
% change in 2018	+82%	+35%		+135%	+52%	+62%	-5%

*replacement for Table River section 22-18 in 2018.

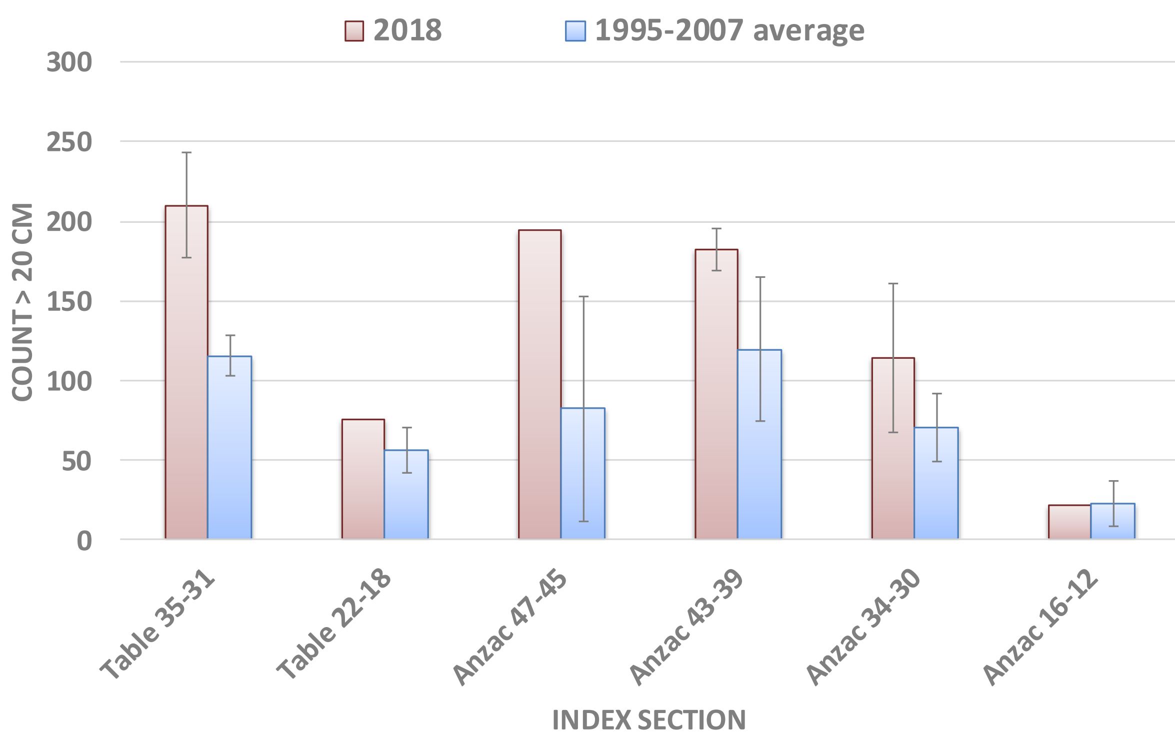

Figure 9. 2018 mean snorkeling counts of Arctic Grayling >20 cm in index sites of the Anzac River and Table River watersheds relative to the mean of mean abundance levels over the 1995-2007 period in each site. Error bars represent limits of 90% confidence. In 2018, Table River section 26-22 was substituted for 22-18 (see text).

5.4 Spatial Variability and Total Abundance in the Anzac River

In 2018, we conducted single-pass snorkeling surveys along a continuous section of the Anzac River extending nearly 50 km from 56 km to 5.8 km (measured along the stream from the mouth; Figure 10). These surveys included 8.6 km of stream habitat in which Arctic Grayling were discovered upstream of a chute obstruction at 47 km (Figure 2, Figure 11) that was previously thought to be a migration barrier (Blackman and Hunter 2001).[11] The lowest 5.8 km of the Anzac River was not surveyed in 2018 because of prior helicopter scheduling commitments related to fire activity. To account for this gap in the snorkeling coverage and provide a continuous picture of Arctic Grayling habitat use in the Anzac River, we substituted counts made in this section during a 1997 reconnaissance survey by FWCP personnel (FWCP unpublished data).

Counts of Arctic Grayling along the Anzac River mainstem exhibit a strong pattern of spatial variation. Although the chute obstruction at 47 km (Figure 11) was not a barrier to Arctic Grayling migration in 2018, the obstruction was correlated with a major change in counts of grayling, which were much lower in 3 stream sections surveyed above it (Figure 10).

The core of the Arctic Grayling distribution in 2018, as indicated by consistently high counts in surveyed reaches, extended from the 47 km chute downstream for more than 30km to 16.6km (Figure 10), across several distinct zones of channel confinement, stream gradient, and land use.

Counts of Arctic Grayling were consistently low in the lower 16.6 km of the Anzac River mainstem (Figure 10), which is characterized by several major braids limiting pool frequency and depth, and a low gradient, meandering channel.

The total count of Arctic Grayling >20 cm in the lower 55.6 km of the Anzac River in 2018 was 1,481. This number is unadjusted for snorkeling detection probability <1, so it is likely to be biased low relative to the true number. Our ability to estimate the number of adult individuals is limited because of uncertainty about the size of first maturity for Williston Reservoir grayling (Stamford et al. 2017), and issues with size estimation among survey teams (Section *5.3*). Nonetheless, it appears likely that an adult population size of 1,000 individuals is present within the system. An adult population size in excess of 1,000 mature individuals for the Anzac and Table rivers together is almost certain, given relatively high abundance of Arctic Grayling in index sections of the Table River as well.

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[11] Because of time constraints, we could not conduct additional surveys to determine the upstream limit of Arctic Grayling distribution in 2018. However, based on consistent habitat characteristics and the lack of further migration obstacles, the distribution likely extends all the way to the headwater fork of the Anzac River at approximately stream km 59 (confluence with unnamed tributary 236-313100-75900) at a minimum.

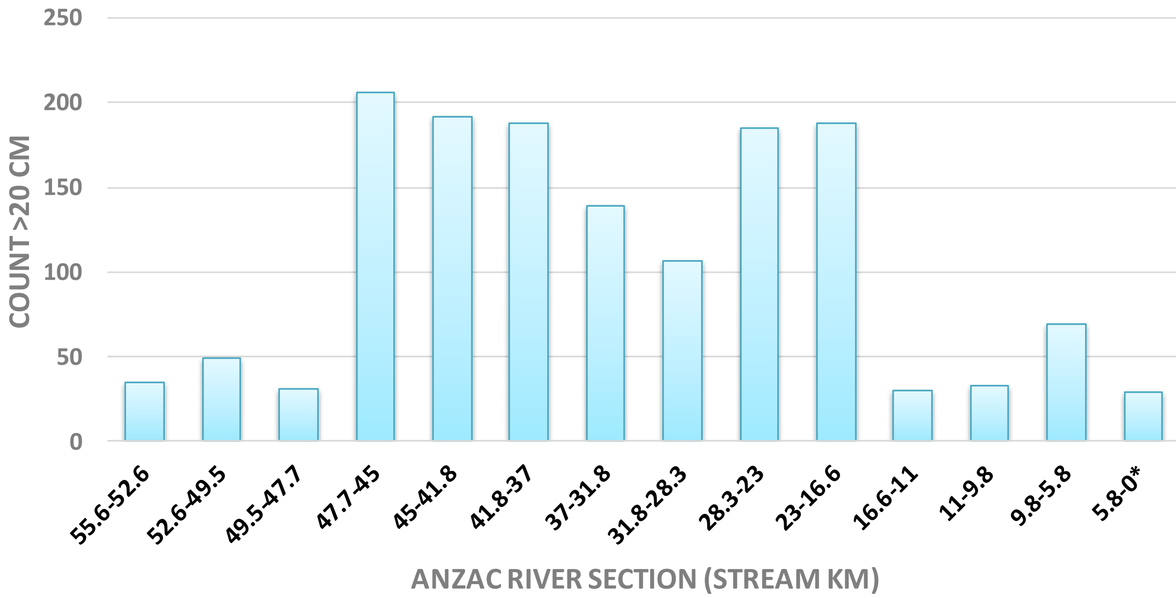

*Figure 10. Counts of Arctic Grayling >20 cm in stream sections of the Anzac River watershed, 2018. Stream section labels correspond to the distance along the stream from the mouth of the Anzac River to the upstream and downstream boundaries of the surveyed reach. *Data for 5.8km-0km based on the 1997 reconnaissance survey (FWCP unpublished data).*

Figure 11. Chute obstruction at 47 km of the Anzac River.

5.5 Other Species

Although Arctic Grayling were the first priority for snorkeling observations, Bull Trout, Rainbow Trout, and Mountain Whitefish were also counted during continuous surveys along the length of the Anzac River (GR, BT, RB: Figure 12; MW: Figure 13), and during snorkeling surveys in index sites of the Anzac and Table rivers (Table 3).[12] Abundance levels for Bull Trout and Rainbow Trout (Figure 12, Table 3) were sufficiently low that they could readily be counted without compromising counts of Arctic Grayling, and we expect counts of these two species to be reliable. Mountain Whitefish, however, were far too numerous to count reliably and were assigned the lowest priority during snorkeling surveys. Therefore, Mountain Whitefish counts (Figure 13, Table 3) should be considered of low precision and accuracy relative to the other 3 species.

In the Anzac River, the cascade obstruction at 47 km was associated with a substantial change in abundance for all species (Figures 12, 13), but the fact that it is a point of difficult passage is not the only factor. The reduction in deep pool habitat and stream discharge upstream of the canyon and unnamed tributary 236-313100-60100, along with the locations of spawning destinations for Bull Trout (Hagen et al. 2015), are also important factors affecting the distribution of salmonids in August.

At the time of the surveys, the Bull Trout distribution was characterized by aggregations of adult fish near the mouths of known spawning tributaries (Hagen et al. 2015), with smaller numbers of subadult and adult fish scattered throughout reaches downstream. Rainbow Trout >20 cm were not abundant in the Anzac River. Peak counts were observed between 31.8 km and 16.6 km (Figure 12), but otherwise the species did not exhibit a strong linear pattern of abundance as surveys proceeded downstream. Mountain Whitefish counts were consistently high between the 47 km chute obstruction and 11 km, reaching a peak between 31.8 km and 23 km (Figure 13).

[12] More detailed information is contained within the Parsnip snorkeling database, available from FWCP and FLNRORD (Omineca Region).

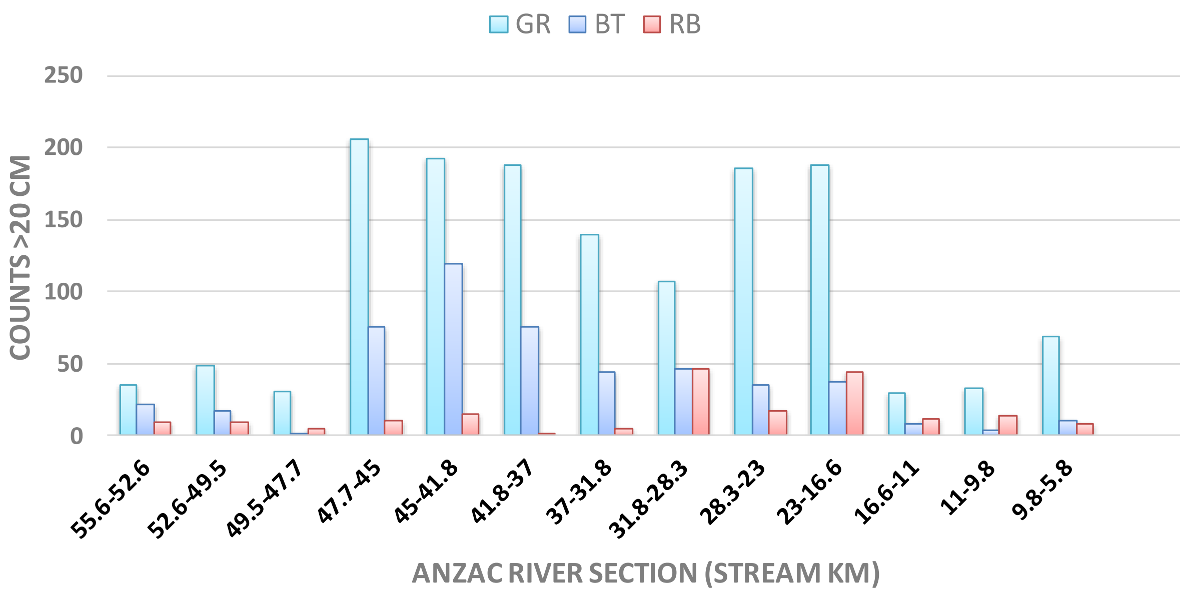

Figure 12. Counts of Arctic Grayling (blue bars), Bull Trout (purple bars), and Rainbow Trout (red bars) >20 cm in stream sections of the Anzac River watershed, 2018. Stream section labels correspond to the distance along the stream from the mouth of the Anzac River to the upstream and downstream boundaries of the surveyed reach.

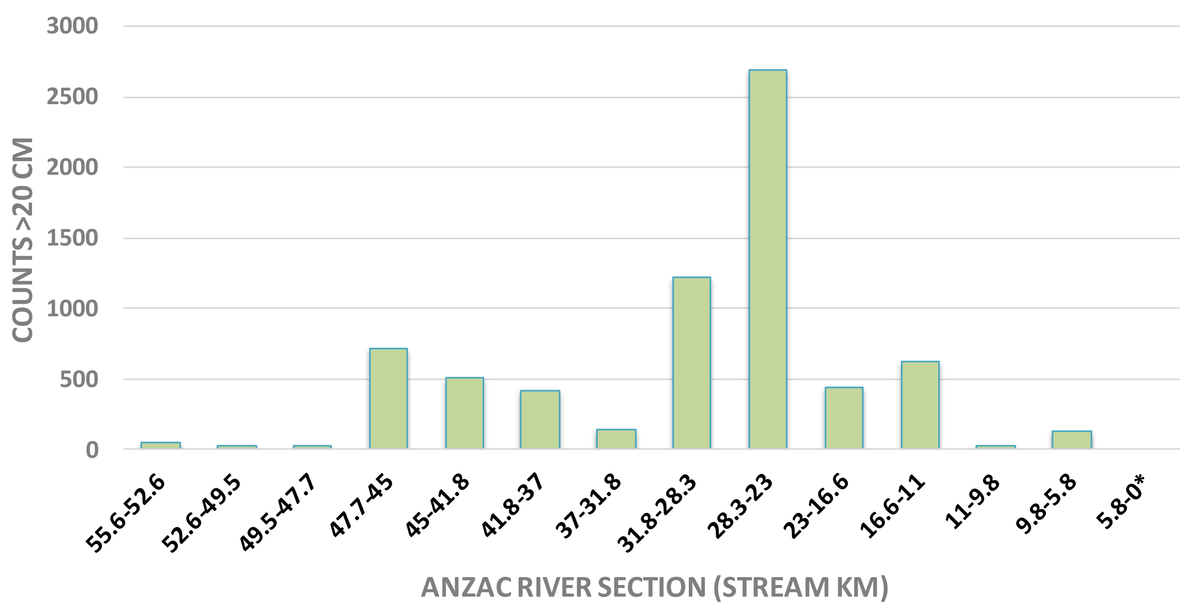

Figure 13. Counts of Mountain Whitefish >20 cm in stream sections of the Anzac River watershed, 2018. Stream section labels correspond to the distance along the stream from the mouth of the Anzac River to the upstream and downstream boundaries of the surveyed reach.

Table 3. August snorkeling counts of salmonids >20 cm in index sites of the Parsnip River watershed, 1995-2018. Counts are averages if more than one replicate swim occurred.

		Table River Sites			Anzac River Sites			
Year	**Species**	**Table 35-31**	**Table 26-22***	**Table 22-18**	**Anzac 47-45**	**Anzac 43-39**	**Anzac 34-30**	**Anzac 16-12**
1995	**GR**	111						
	BT	20						
	RB	12						
	MW							
1998	**GR**	136		67	164	136	106	8
	BT	127		17	29	17	13	10
	RB	83		69	5	6	37	42
	MW	894		105	170	426	8	1
2000	**GR**	123		37	68			
	BT	30		6	16			
	RB	11		30	8			
	MW	636		82	217			
2001	**GR**	91		42	20	85	52	11
	BT	3		1	1	7	10	5
	RB	10		10	3	5	11	10
	MW	991		315	161	700	1272	458
2003	**GR**	137		70	78	166	54	23
	BT	28		12	8	60	6	18
	RB	19		18	4	6	7	29
	MW	1341		320	333	277	641	340
2005	**GR**	98				91	79	29
	BT	8				19	12	20
	RB	4				5	3	14
	MW							
2007	**GR**	113		45			61	45
	BT	21		14			16	20
	RB	15		18			8	29
	MW	1415		394			616	600
1995-2007	***GR***	*116*		*52*	*83*	*120*	*70*	*23*
averages	***BT***	*34*		*10*	*13*	*26*	*12*	*14*
	RB	*22*		*29*	*5*	*6*	*13*	*25*
	MW	*1055*		*243*	*220*	*468*	*634*	*350*
2018	**GR**	210	76		194	182	114	22
	BT	75	14		76	89	42	6
	RB	12	69		8	7	25	9
	MW	730	711		705	433	692	458

*replacement for Table River section 22-18 in 2018.

Other salmonids have not been the primary focus of snorkeling surveys in the Anzac and Table rivers, and the design of the study is not optimized for these other species. This is likely to have a compromising effect on the reliability of assessments of changes in population sizes for Bull Trout, Rainbow Trout, and Mountain Whitefish. Nonetheless, count data from index sites presented in Table 3 are of potential interest over the longer term. Bull Trout counts in index sites are highly variable among years potentially indicating an effect of pre-spawning migration behaviour. Counts of Bull Trout in 2018 are above long-term averages at most index sites, but this may be an artefact of water flow and temperature conditions reducing the suitability of spawning tributaries for staging prior to spawning. A more reliable methodology for monitoring Bull Trout abundance in the Parsnip River watershed is through counts of gravel nests, or 'redds' following the completion of spawning (Hagen et al. 2015).

Snorkeling counts of Rainbow Trout and Mountain Whitefish in 2018 index sites vary from long-term averages, but do not appear to be consistently higher (Table 3). Low Rainbow Trout counts are of interest because of a potential interspecific competition 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).

5.6 First Nations engagement in 2018-19

First Nations engagement and communications for this project were led by FLNRORD. The project goals and objectives were provided to four First Nations (McLeod Lake Indian Band, Saulteau, West Moberly First Nations, and Prophet River First Nations) in May of 2018 to FWCP-provided contacts via email memorandum followed up with phone calls to offer opportunity to discuss the planned project.

A Parsnip Watershed-focused workshop was proposed by the project lead to be held in McLeod Lake in July of 2018, and a FLNRORD First Nations Advisor was engaged to establish the workshop scope, timing, and location with all four First Nations. Accommodating all requests for dates and locations from four First Nations and FLNRORD personnel ultimately proved too great a challenge, and the workshop could not be held prior to the 2018 field season.[13] We wish to acknowledge that it may be overwhelming for First Nations to receive such requests for engagement meetings from a large number of FWCP-funded and other projects. It is equally challenging to accommodate the availability of multiple First Nations to gather in one place for such a workshop. A results workshop encompassing several FWCP projects and involving all participants in the program (First Nations, project leads, and project partners) is a potential means of increasing the efficiency of this important process.

In March 2019, a results review and planning session for Arctic Grayling studies in the Parsnip River watershed was held at FLNRORD offices in Prince George, to which McLeod Lake Indian Band representatives and UNBC collaborators were invited. Project members of the UNBC-led Project PEA-F19-F-2593 *Spatial ecology of Arctic grayling in the Parsnip core area* participated in this meeting and shared insights from

[13] E.g. accommodations included moving the proposed location from McLeod Lake to Chetwynd in response to First Nation's request.

their respective Year 1 of field work. With respect to 2018 results for this project, outreach to First Nations will now be combined with outreach prior to the 2019 field season. This is scheduled for the August 7-9 period, during the Annual General Assembly of McLeod Lake Indian Band.

6.0 DISCUSSION

6.1 Conservation Status

In the *Arctic Grayling Synthesis Report* (Stamford et al. 2017), conservation status for Arctic Grayling populations is assessed at the geographic scale of putative metapopulations (core areas), utilizing the *Core Area Conservation Status and Risk Assessment Methodology* originally developed by the U.S. Fish and Wildlife Service (USFWS 2005).[14] The methodology combines categorical estimates of 4 key indicators of future population viability – *Trend*, *Adult abundance*, *Distribution*, and *Threats* – in a rule- and point-based process to assign conservation status ranks for core areas (Stamford et al. 2017). The methodology has not been quantitatively evaluated for use on Arctic Grayling populations, but has a number of important benefits including: 1) application at a spatial scale relevant to management actions, threats, and extirpation processes, 2) the ability to incorporate information in an 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).

With the resumption of Arctic Grayling population monitoring in the Anzac River and Table River watersheds, we have an improved basis for assessing conservation status. In the following paragraphs, we update the categorical estimates of *Trend*, *Adult abundance*, *Distribution*, and *Threats*, and update the conservation status assessment for the Parsnip core area

Trend is one of the most important indicators of population viability (McElhany et al. 2000; O'Grady et al. 2004;). Snorkeling count data acquired during this study indicate a positive change in abundance over the past two decades for Parsnip Arctic Grayling. However, at this point in time we do not feel comfortable estimating trend as 'increasing,' for two important reasons. The first reason is that with a hiatus of more than 10 years in the snorkeling count program, the abundance data are not balanced across time and the high data point in 2018 has high leverage.[15] Second, we have uncertainty about whether the extreme low water conditions of August 2018 may have

[14] Originally for use with threatened Bull Trout populations of the contiguous United States (USFWS 2005).

[15] Leverage is a measure of how far away the independent variable values of an observation are from those of the other observations.

resulted in positive bias for counts of Arctic Grayling, for example because of higher detection or increased concentration of Arctic Grayling in index sites related to low water conditions. For these two reasons, we consider 'stable' to be a more precautionary estimate of trend for input into the status assessment algorithm (*Appendices 1, 3* in Stamford et al. 2017), with an 'increasing' estimate requiring corroboration from snorkeling counts in subsequent years.

Adult abundance is the second key indicator of population viability (McElhany et al. 2000; O'Grady et al. 2004;). Based on the counts of Arctic Grayling made during continuous surveys along the Anzac River mainstem (Section *5.4*), relatively high counts in index sites of the Table River watershed (Secton *5.2*), and the assumption that a population exists in the Missinka River also, a categorical estimate of '1,000-2,500 km' (*Appendix 1* in Stamford et al. 2017) appears reasonable for this conservation status indicator. A conservative estimate for the *Distribution* indicator within the Parsnip core area is 200 km (*Appendix 1* in Stamford et al. 2017).

Stamford et al. (2017 and references therein) indicate that key limiting factors (i.e. *Threats*) for Arctic Grayling populations are likely to be fishing mortality, water temperature, and degradation of stream habitats related to hydrological changes (elevated sediment transport, turbidity, peak flows, reduced summer flows). Land use activities and associated roads are correlated with all these factors, and because of this road density (km/km^2) has often been used as a general indicator of their cumulative effects (Foreman and Alexander 1998; Trombulak and Frissel 2000; Kovach et al 2016). Existing road density data for the Parsnip River watershed suggest that linear developments and particularly forestry activities have occurred in sub-basins of the Parsnip River watershed, but up until 2018 the sensitive upper reaches of Arctic Grayling streams were mostly pristine. 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. The ongoing outbreak of the spruce bark beetle *Dendroctonus rufipennis* and associated salvage logging is projected by FLNRORD to result in increased road density in upper watersheds adjacent to critical habitats, elevating the level of threats from habitat degradation and increased angler access. We consider a threats ranking of 'low severity/high scope' (*Appendix 2* in Stamford et al. 2017) to be appropriate at this point in time, given that threats related to angler access are partially mitigated through a catch-and-release regulation. Habitat monitoring planned by FLNRORD in the Parsnip River watershed (e.g. a temperature monitoring study initiated in 2018) will allow us to re-evaluate this ranking over the near-to-mid term.

Inputting the updated categorical estimates of *Trend*, *Adult abundance*, *Distribution*, and *Threats* into the numeric scoring process for the *Core Area Conservation Status and*

Risk Assessment Methodology (*Appendix 3* in Stamford et al. 2017) results in a ranking of 'C3-Potential Risk' for the Parsnip core area. The verbal description linked to this ranking is "Core area potentially at risk because of limited and/or declining numbers, range, and/or habitat, even though Arctic Grayling may be locally abundant in some areas."

6.2 Critical Habitats and Conservation Actions

In addition to the objective of improving conservation status monitoring for Arctic Grayling in the Parsnip core area, a second over-arching objective of this study is to improve the accuracy of estimates of critical habitats to the level necessary for planning specific conservation actions. Abundance data and habitat use data acquired across a whole watershed in 2018 have greatly improved accuracy relative to data acquired from subsampling index sites. With respect to Arctic Grayling abundance, extrapolation of mean density estimates from index sites to the entire Anzac River watershed would result in overestimation of total population size by approximately 40%. With respect to critical habitats, important questions about: 1) the maximum extent of Arctic Grayling summer rearing habitats, or 2) where conservation actions should be focused to maintain the productive capacity of the population, also cannot be answered very well based on swim count data from index sites alone.

Snorkeling along the length of the Anzac River has identified the core of subadult and adult summer rearing habitat, which extends from the 47 km chute obstruction (Figure 10) downstream to approximately 16 km (Section *5.4*). Over this 30-km section, the Anzac flows through distinct habitat zones ranging from a swift, entrenched canyon reach to a more open, low gradient channel with broad bars and slower flows. The geographic setting in B.C.'s Rocky Mountain Trench is visually stunning and uniquely located within 2 hours of Prince George, identifying this section of the Anzac River as an exceptional fishery resource within the Williston Reservoir watershed.

Importantly, this core of the Arctic Grayling summer rearing habitat also lies adjacent to the existing road network, where intensive forestry and road building activity is now underway. Spruce beetle salvage harvesting-related activities potentially threaten Arctic Grayling populations if they strongly affect angler access, peak flows, sediment delivery, and water temperature in critical habitats. Therefore, baseline watershed health studies, habitat conservation actions, and further population monitoring are warranted.

Many potential habitat-based conservation actions are core Government responsibilities, but projects qualifying for FWCP funding can also be effective. In fact, distinctions between core Government responsibilities and FWCP opportunities for habitat conservation and restoration may not always be clear cut. For example, Fisheries Sensitive Watershed (FSW) designations have been proposed by FLNRORD

(Ecosystems Section) for the Anzac, Table, Hominka, and Missinka rivers, along with special habitat management rules for forestry. These proposals are under review, but if implemented they should be considered key habitat conservation step for Arctic Grayling (and Bull Trout) of the Parsnip River watershed. Although these proposals for conservation actions were undertaken as a FLNRORD responsibility, 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 as reviewed by Hagen et al. (2015).

Habitat restoration and enhancement actions targeting Arctic Grayling critical habitats are a potential use of FWCP funds in the near-to-mid term. However, to ensure the effectiveness of these actions, the first step for FWCP may need to be monitoring studies to identify: 1) limiting factors affecting Arctic Grayling population productivity, and 2) specific locations where these limiting factors are operating. Systematic monitoring data identifying changes in potential stressors water temperature, turbidity, peak flow, summer low flows, etc., along with data indicating behavioural and demographic responses to theses stressors in populations of fish and benthic invertebrates, may be able to identify limiting factors and target areas for further conservation, restoration, and enhancement actions.

7.0 RECOMMENDATIONS

Our study has begun the process of addressing two high-priority knowledge gaps identified in FWCP's *Arctic Grayling Synthesis Report* (Stamford et al. 2017): 1) the lack of abundance monitoring since 2007 in the Parsnip core area, and 2) the lack of monitoring data delineating critical habitats.

With respect to the first of these two information deficiencies, we consider the six long-term snorkeling index sites located in the Anzac and Table rivers to be key to identifying changes in population abundance over time in the Parsnip core area, and the sustainability of remnant populations of Williston Arctic Grayling following flooding. To improve the ability of the snorkeling program to detect changes in abundance and correlating factors, we have the following 6 recommendations:

1. Continue regular snorkeling surveys in long-term index sites in the Table and Anzac Rivers to achieve balance in the time series and improve estimates of Arctic Grayling abundance trend.
2. Conduct a second year of replicated snorkeling surveys (3 independent crews) at three new locations in 2019, to improve confidence in the repeatability of snorkeling counts among crews with a typical range of experience levels. Thereafter, a single-pass snorkeling program can be utilized to reduce program

costs and/or allocate effort to snorkeling surveys to identify new critical habitats (see following paragraph).

3. Continue to co-ordinate with the crew of the Parsnip Arctic Grayling acoustic telemetry study to ensure that a sample of tagged fish are present during snorkeling counts in 2019, to estimate detection probability at a minimum of 3 index sites.

4. Incorporate new index sections into the Arctic Grayling abundance monitoring program for the Parsnip core area, from at least one watershed outside of the Anzac and Table rivers (e.g. Hominka River, Missinka River), following the identification of critical adult summer rearing habitats in that watershed (see following paragraph).

5. Co-ordinate with Arctic Grayling abundance monitoring elsewhere in the Williston Reservoir watershed (e.g. FWCP project no. PEA-F19-F-2647: *Snorkeling to Monitor Ingenika Arctic Grayling Abundance*) to explore monitoring study modifications for learning about limiting factors (e.g. water temperature, turbidity, and flow monitoring paired with biological sampling and abundance monitoring).

6. Improve dialogue with First Nations to identify opportunities for information exchange, training, and employment.

With respect to the delineation of critical habitats, the value of continuous, whole-watershed snorkeling surveys has been demonstrated during this study by significant improvements in the level of knowledge of core subadult/adult summer rearing habitats in the Anzac River. In August 2019, the study team will apply the methodology within the Missinka River watershed, a potential second hub of Arctic Grayling abundance within the Parsnip core area, to estimate critical habitats and total abundance. Given the potential widespread scope of future spruce beetle salvage logging in the Parsnip River watershed, we also recommend an application of the methodology to other Arctic Grayling streams in the core area beginning with the Table and Hominka Rivers. The clay slump at 22 km affecting underwater visibility in the middle Table River is a factor affecting the feasibility of the methodology, but other techniques could potentially augment the snorkeling surveys in that watershed (e.g. reach-specific detection probability estimates from mark-resight studies, telemetry studies, angling mark-recapture, etc.).

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.

The Freshwater Fisheries Society of B.C. (FFSBC) provided additional study funding enabling the replicated swims in the Anzac and Table rivers. Dawn Cowie, Eduardo Martins, Duncan McColl, Keegan Paterson, Ray Pillipow, Zsolt Sary, Will Schokking, Ian Spendlow, and Mike Stamford provided assistance in the field, and Zsolt also provided photographs used in this report. Dawn Cowie compiled snorkeling data from 1995-2018 in a searchable database, and Benita Kaytor was consulted on the statistical analysis. Sean Barry provided estimates of road density and spruce beetle attack within the Parsnip River watershed. Morgan Hite produced the maps used in the report. Our pilot for the 2018 study was Tom Halbert of Bailey Helicopters Ltd.

9.0 REFERENCES

Anonymous. 1978. Report on environmental studies for the McGregor Diversion Project. Report prepared by Reid, Crowther, and Partners, Ltd. for BC Hydro and Power Authority.

Blackman, B.G. and M.J. Hunter. 2001. Arctic grayling (*Thymallus arcticus*) surveys in the Table, Anzac, and Parsnip Rivers, 1998. PWFWCP Report No. 237.

Blackman, B.G. 2001. An Information Summary on Arctic Grayling from the Williston Reservoir Watershed with Data Gap Analysis and Recommendations. PWFWCP Report No. 258.

Bruce, P.G., and P.J. Starr. 1985. Fisheries resources and fisheries potential of Williston Reservoir and its tributary streams, volume II: fisheries resources potential of Williston Lake tributaries - a preliminary overview. BC Government Fisheries Technical Circular No. 69.

Clarke, A.D., K. Telmer and J.M. Shrimpton. 2005. Population structure and habitat use by Arctic grayling (*Thymallus arcticus*) in tributaries of the Williston Reservoir using natural elemental signatures. Peace/Williston Fish and Wildlife Compensation Program Report No. 300. 62p. + 1 Appendix.

Cowie, D.M. 2013. Compiled files of Arctic grayling swim counts conducted by FWFWCP on the Table, Anzac and Mesilinka Rivers. Memorandum March 2013.

Cowie D.M. and B.G. Blackman. 2012. An Overview and Summary of Methodologies of Arctic grayling (*Thymallus arcticus*) Projects Conducted in the Parsnip, Table, and Anzac Rivers from 1995 to 2007. Fish and Wildlife Compensation Program – Peace Region Report No. 349. 24 pp. plus appendices.

Foreman, R.T.T., and L.E. Alexander. 1998. Roads and their major ecological effects. Annu. Rev. Ecol. Syst. 29:207–31

FWCP. 2014a. Fish and Wildlife Compensation Program – Peace Basin Streams Action Plan. BC Hydro, Fort St. John, BC.

FWCP. 2014b. Fish and Wildlife Compensation Program – Peace Basin Plan. BC Hydro, Fort St. John, BC.

Hagen, J. and J.S. Baxter. 2005. Accuracy of diver counts of fluvial rainbow trout relative to horizontal underwater visibility. North American Journal of Fisheries Management 25:1367-1377.

Hagen, J., and M. Stamford. 2017. FWCP Arctic Grayling Monitoring Framework for the Williston Reservoir Watershed. Prepared for Fish and Wildlife Compensation Program, Peace Region. http://fwcp.ca/app/uploads/2017/07/FWCP-Arctic-Grayling-Monitoring-Framework_Final.pdf

Hagen, J., J. Strohm, M. Tilson, and M. Stamford. 2019 *Draft*. Ingenika River Arctic Grayling 45 Years Post-Flooding: 2018 Snorkeling Counts in Index sites. Report prepared by Chu Cho Environmental for the Fish and Wildlife Compensation Program – Peace Basin, Prince George, BC.

Hagen, J., Williamson, S., Stamford, M.D., and R. Pillipow. 2015. Critical Habitats for Bull Trout and Arctic Grayling within the Parsnip River and Pack River watersheds. Report prepared for: McLeod lake Indian Band, McLeod Lake Indian Band, Sekani Drive, McLeod Lake, BC.

Hawkshaw, S.C.F. and J.M. Shrimpton. 2014. Temperature preference and distribution of juvenile Arctic grayling (*Thymallus arcticus*) in the Williston Watershed, British Columbia, Canada. Fish and Wildlife Compensation Program – Peace Region Report No. 366. 40 pp plus appendices.

Hawkshaw, S.C.F., Gillingham, M.C. and J.M. Shrimpton. 2013. Habitat characteristics affecting occurrence of a fluvial species in a watershed altered by a large reservoir. Ecology of Freshwater Fish, 12pp.

Hirst, S.M. 1991. Impacts of the operations of existing hydroelectric developments on fishery resources in British Columbia, Volume II: inland fisheries. 91. Canada. Department of Fisheries and Oceans. Canadian Manuscript Report of Fisheries and Aquatic Sciences.

Korman, J., R.N.M. Ahrens, P.S. Higgins, and C.J. Walters. 2002. Effects of observer efficiency, arrival timing, and survey life on estimates of escapement for steelhead trout (*Oncorhynchus mykiss*) derived from repeat mark-recapture experiments. Canadian Journal of Fisheries and Aquatic Sciences 59:1116-1131.

Kovach, R.P., R. Al-Chokhachy, D.C. Whited, D.A. Schmetterling, A.M. Dux, and C.C. Muhlfelfd. 2016. Climate, invasive species, and land use drive population dynamics of a cold-water specialist. Journal of Applied Ecology. Doi: 10.1111/1365-2664.12766.

McElhany, P., M.H. Ruckelhaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-42.

McPhail, J.D. 2007. The freshwater fishes of British Columbia. The University of Alberta Press, Edmonton, Alberta.

Northcote, T.G., and D.W. Wilkie. 1963. Underwater census of stream fish populations. Transactions of the American Fisheries Society 92:146-151.

O'Grady, J.J., D.H. Reed, B.W. Brook, and R. Frankham. 2004. What are the best correlates of predicted extinction risk? Biological Conservation 118: 513–520

Parkinson, E., and G. Haas. 1996. The role of macrohabitat variables and temperature in defining the range of bull trout. Province of British Columbia Fisheries Project Report 51.

Parkinson, E.A., E. Lea, and M.A. Nelitz. 2012. A framework for designating "Temperature Sensitive Streams" to protect fish habitat, Part 2: Identifying temperature thresholds associated with fish community changes in British Columbia, Canada. Province of BC, Ministry of Environment, Ecosystem Protection & Sustainability Branch, Fisheries Technical Report No. RD111.

Pearce, T., Lieske, S., Morgan, J., A. Solonas. 2019. First Nations Information Gathering on Kokanee, Bull Trout and Arctic Grayling. Project Number: PEA-F19-F-2866. Prepared for Fish and Wildlife Compensation Program and Tse'Khene Nation (McLeod Lake Indian Band).

Rabe-Hesketh, S., and A. Skrondal. 2008. Multilevel and Longitudinal Modelling Using Stata. 2nd Ed. Stata Press, College Station, TX.

Schill, D.J. and J.S. Griffith. 1984. Use of underwater observations to estimate cutthroat trout abundance in the Yellowstone River. North American Journal of Fisheries Management 4:479-487.

Shrimpton, J.M., S.L. Roberts, and A.D. Clarke. 2012. Genetic analysis of Arctic grayling population structure in the Williston Watershed. Fish and Wildlife Compensation Program – Peace Region Report No. 311. 12 pp plus appendices.

Slaney, P.A. and A.D. Martin. 1987. Accuracy of underwater census of trout populations in a large stream in British Columbia. North Am. J. Fish. Manage. 7:117-122.

Stamford, M.D., Hagen, J. and S. Williamson. 2017. FWCP Arctic Grayling Synthesis Report: Limiting Factors, Enhancement Potential, Conservation Status, and Critical Habitats for Arctic Grayling in the Williston Reservoir Watershed, and Information Gaps Limiting Potential Conservation and Enhancement Actions. Prepared for Fish and Wildlife Compensation Program, Peace Region. http://fwcp.ca/app/uploads/2017/07/FWCP_Grayling_Synthesis_Final.pdf

Stamford, M. D., J. Hagen, and S. Williamson. 2015 (DRAFT). The status of Arctic grayling (*Thymallus arcticus*) in British Columbia: a synthesis of population structure, distribution, abundance, trend, and threat information. Ministry of Environment, Ecosystems Protection & Sustainability Branch, Aquatic Conservation Science Section, Victoria, British Columbia.

StataCorp. 2009. Stata Longitudinal-data/Panel-data Reference Manual, Release 11. Stata Press, College Station, TX.

Trombulak, S.C., and C.A. Frissel. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14(1):18-30.

United States Fish and Wildlife Service (USFWS). 2005. Draft Bull Trout Core Area Conservation Status Assessment. USFWS, Portland, OR.

Young, R.G., and J.W. Hayes. 2001. Assessing the accuracy of drift-dive estimates of brown trout (*Salmo trutta*) abundance in two New Zealand Rivers: a mark-resighting study. New Zealand Journal of Marine and Freshwater Research 35:269-275.

Zar, J.H. 1996. Biostatistical analysis. Prentice Hall, Upper Saddle River, NJ.

Zubik, R.J., and J.J. Fraley. 1988. Comparison of snorkel and mark-recapture estimates for trout populations in large streams. North American Journal of Fisheries Management 8:58-62.