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

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EXECUTIVE SUMMARY

FWCP strategic objectives. The FWCP Streams Action Plan (FWCP 2014) identifies two over-arching strategic objectives for the conservation and enhancement of Arctic Grayling and other priority fish species in the upper Peace Basin:

1. Maintain or improve the conservation status of Arctic Grayling populations.
2. Maintain or improve the integrity and productivity of Arctic Grayling habitats.

This study was initiated by FWCP to evaluate the existing knowledge base relative to these strategic objectives, and fulfill objective *1b-1* of the *Streams Action Plan*:

> 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.

The study has two components to provide guidance to proponents wishing to develop Arctic Grayling study proposals via the FWCP proposal process. This report is the first of these components, and presents extensive background information from past studies of Arctic Grayling in the Williston Reservoir watershed, and from the scientific and management literature. The aim of the report is to identify and prioritize knowledge gaps on a watershed-by-watershed basis, to facilitate a quicker transition to on-the-ground conservation and enhancement actions for Arctic Grayling populations. The second component of this study is a more concise companion document, *Arctic Grayling Monitoring Framework for the Williston Reservoir Watershed* (Hagen and Stamford 2017), which provides a condensed list of recommended monitoring actions for implementation in the near term.

Priority information categories. Information gathering was prioritized according to those types of data most relevant to the FWCP strategic objectives, which include:

1) information indicating potential *limiting factors* for Arctic Grayling populations (e.g. habitat degradation, ecological changes, exploitation),

2) information about the effectiveness of *enhancements* for Arctic Grayling populations,

3) quantitative population data required to assess *conservation status and risk* (population structure, distribution, abundance, trend, threats), and

4) geographic information delineating *critical habitats* (providing habitats for key life history stages and where limiting factors may operate).

In this report, information about conservation status and critical habitats is organized according to conservation units, termed ‘core areas,’ which correspond to the putative

metapopulation structure. Information about limiting factors and enhancements specific for any particular core area in most cases could not be discriminated and are therefore discussed generally for the upper Peace Basin as a whole.

During this assessment of existing information, it was evident that a substantial amount of information exists already that can be applied to Williston Reservoir Arctic Grayling. It was also clear that serious information gaps remain, which probably preclude major FWCP investments in conservation and enhancement actions at this point in time. Data gaps considered of highest immediacy were those likely to be significant obstacles to the initiation of on-the-ground conservation and enhancement actions. These can potentially provide a guide to action in the short-to-medium term, and are summarized below with respect to priority information categories #1-4 listed above.

1) Limiting factors. Relative to pre-impoundment conditions, the most significant factors limiting potential Arctic Grayling productivity in the upper Peace Basin have probably been physical habitat and ecological changes, along with interrupted connectivity among populations, resulting from the flooding of critical habitats. These changes are poorly understood, but probably include flooding of key juvenile rearing and overwintering habitats in low gradient, lower reaches of grayling streams, and high lacustrine predator abundance (e.g. protected Bull Trout populations) in these areas. Studies to address these data gaps are of high immediacy because they may indicate which factors must be addressed and monitored during potential recolonization experiments, and include:

1) inventory studies (e.g. traditional sampling techniques targeting adult and juvenile life stages; environmental DNA) to identify remnant populations that have adapted to the reservoir environment, and physical habitat characteristic of streams or shorelines they inhabit,

2) recolonization experiments, and

3) coordinated Arctic Grayling and Bull Trout monitoring studies in select tributaries, in combination with MFLNRO-led experiments to regulate predator abundance.

2) Enhancements. The most obvious, desirable enhancement would be to facilitate the Arctic Grayling’s recolonization of its former range in small-to-medium sized tributaries of Williston Reservoir. A review of Arctic Grayling recolonization efforts in Montana, where a similar loss of populations following dam construction has occurred, provided the most relevant background information. It appears that recolonization experiments may not succeed if transplanted Arctic Grayling are required to shift their native migratory behaviour (e.g. from adfluvial to fluvial life history), and successful techniques include those providing opportunities for imprinting during key periods of ontogeny. With respect to the potential for recolonization, two key data gaps of high immediacy are:

1) poor understanding of limiting factors that drove extirpation in small-to-medium sized tributaries of Williston Reservoir, and

2) the serious lack of knowledge about spawning areas within the ranges of existing populations and potential sources of gametes.

3) Conservation status and risk. Eight core areas have been delineated for the upper Peace Basin upstream of the W.A.C. Bennet Dam: Parsnip, Nation, Omineca, Ingenika, Williston, Upper Peace, Lower Finlay, and Upper Finlay/Toodoggone. Assessed levels of risk ranged from *Potential Risk* in the relatively pristine Upper Finlay core area, to *High Risk* for the Ingenika, Williston, and Upper Peace core areas. The latter two core areas comprise small-to-medium sized watersheds that are direct tributaries to the reservoir, where Arctic Grayling populations may be largely extirpated or exist only as remnants. The remaining four core areas (Parsnip, Nation, Omineca, Lower Finlay) are considered to be *At Risk*, largely as a result of major habitat loss, diminished connectivity, and population declines over the scale of decades (i.e. the effects of impoundment were included in the analysis). While these assessments corroborate prior levels of conservation concern expressed for upper Peace Basin Arctic Grayling, they were severely limited by a lack of population data with which to estimate adult abundance and trend, which are key conservation status indicators (Arctic Grayling abundance monitoring has not occurred anywhere in the Williston watershed since 2007). A coordinated Arctic Grayling monitoring plan for the Williston Reservoir watershed is urgently needed to address this data gap.

4) Critical habitats. A total of 80 stream segments providing critical habitats for at least one Arctic Grayling life stage (subadult/adult, juvenile, fry) were identified. Among these, information adequacy was estimated to be relatively high in 39 cases, and fair or poor in the remainder. In the analysis of critical habitats, a total of 47 information gaps were identified that potentially limit the ability to initiate conservation and enhancement actions. From these, four categories of high immediacy, recurring data gaps (affecting all core areas) could be discerned:

1) <u>Unknown total distribution of grayling within core areas</u>, and the relative importance of streams within core areas. Potential study techniques include: electrofishing and seining studies targeting fry and juvenile Arctic Grayling, otolith microchemistry, summer habitat use studies targeting adults (e.g. snorkeling surveys, angling), radio telemetry studies, and the promising new technique of environmental DNA. The distribution data gaps of highest immediacy were those for the Williston and Upper Peace core areas, where it is uncertain whether self-sustaining Arctic Grayling populations still exist.

2) <u>Poor understanding of adult migratory behaviour and locations of natal areas</u>. This data gap limits both habitat protection/enhancement efforts and potential collection of gametes. Potential study techniques for addressing this data gap include: radio telemetry, otolith microchemistry, and surveys of newly-emerged fry distribution and abundance.

3) Poor understanding of juvenile (post-young-of-year) habitat use. Habitat use studies are needed to determine if juveniles use a variety of habitats within core areas, and if habitat characteristics are different among populations. Understanding habitat use in small tributaries and the extent they are connected with the mainstem habitats of all core areas will help define limiting factors associated with small tributaries, and perhaps improve understanding of potential limiting factors in the Upper Peace and Williston core areas.

4) Relatively poor understanding of fine-scale population structure and gene flow within and among core areas. Refining estimates of gene flow aimed at dispersal among spawning locations may be important for understanding movements through the reservoir, and for assessing conservation status and risk. Potential studies addressing this recurring information gap would include molecular genetic studies and/or movement and life history studies (e.g. radio telemetry, otolith microchemistry).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

Construction of the 183-m high W.A.C. Bennett Dam was completed in 1967 and resulted in the formation of Williston Reservoir, which reached full pool in 1972 (Hirst 1991). Williston Reservoir flooded roughly 350 km of the Peace, Finlay, and Parsnip river valleys and caused profound changes to the ecologies of these watersheds. The flooding also severely altered traditional patterns of human settlement, resource use, and travel (e.g. Littlefield et al. 2007). Prior to impoundment, Arctic Grayling (*Thymallus arcticus*) were widespread and abundant in tributary streams of these valleys (Withler 1959; Bruce and Starr 1985). In one of the most dramatic and well-known ecological impacts of impoundment, Arctic Grayling were essentially extirpated from the lower reaches of the Parsnip and Finlay rivers and upper reaches of the Peace River, which included most of the tributary streams in which they had formerly thrived (Northcote 1993; Stamford et al. 2015). Self-sustaining populations of Arctic Grayling now appear restricted to just eight of the larger watersheds (Parsnip, Nation, Omineca, Osilinka, Mesilinka, Ingenika, Finlay, Toodoggone).

The Peace Region Fish and Wildlife Compensation Program (FWCP) was initiated in 1988, and is a partnership between BC Hydro, the Province of British Columbia, Fisheries and Oceans Canada, First Nations, and local stakeholders. The FWCP objective is to conserve and enhance fish and wildlife (including their habitats) that have been impacted by BC Hydro hydroelectric dams. The Arctic Grayling is of conservation concern in the province and is currently identified by FWCP as a priority fish species (FWCP 2014). The species provides regionally-important fisheries and is therefore also considered a priority species by the British Columbia Ministry of Environment, Lands, and Natural Resource Operations (FLNRO), the lead agency responsible for Arctic Grayling management and habitat protection.

The FWCP Streams Action Plan (FWCP 2014) identifies two over-arching strategic objectives for the conservation and enhancement of priority fish species in the Peace Basin. Paraphrased below in terms of the Arctic Grayling, these are:

1. Maintain or improve the conservation status of Arctic Grayling populations.
2. Maintain or improve the integrity and productivity of Arctic Grayling habitats.

The successful pursuit of these strategic objectives requires: 1) effective measures and methodologies for monitoring conservation status, and 2) sufficient knowledge to reliably increase the productivity of critical habitats (in this report, ‘critical’ habitats are those that potentially affect the overall productivity of Arctic Grayling populations).

Writing more than 20 years ago, Northcote (1993) identified that reliable predictions of success for Arctic Grayling conservation and enhancement actions in the Williston watershed were not possible at that time, because of serious knowledge gaps with respect to Arctic Grayling biology and critical habitats at the local and regional scales. FWCP has since undertaken significant efforts to better understand Arctic Grayling in the Williston watershed, which include additional literature review (e.g. Northcote 2000; Blackman 2001a), strategic planning (e.g. Blackman 2001b), field studies of life history and habitat use (e.g. Mathias et al. 1998; Blackman and Hunter 2001; Blackman 2002a; Clarke et al. 2005; Hawkshaw et al. 2013; Hawkshaw and Shrimpton 2014), field trials of enhancement methods (e.g. Wilson et al. 2008), genetic studies of population structure (e.g. Stamford and Taylor 2005; Shrimpton et al. 2012; Shrimpton and Clarke 2012), and previous data gap analyses focused on biological information (Blackman 2002b; Ballard and Shrimpton 2009). Additionally, non-FWCP studies have been conducted in the Williston Reservoir watershed, which provide potentially important biological and habitat information (e.g. Beak 1998, ECL Envirowest 1998; Triton 1999; EDI 2000, 2001, 2002a, b; Schell 2002; Hagen et al. 2015).

In 2015, FWCP initiated a directed study to evaluate the existing knowledge base relative to strategic objectives *1* and *2* above. The study has two components to provide guidance to proponents wishing to develop Arctic Grayling study proposals via the FWCP proposal process. This report is the first of these components, and presents extensive background information from past studies of Arctic Grayling in the Williston Reservoir watershed, and from the scientific and management literature. The aim of the report is to identify and prioritize knowledge gaps on a watershed-by-watershed basis, to facilitate a quicker transition to on-the-ground conservation and enhancement actions for Arctic Grayling populations. The second component of this study is a more concise companion document, *Arctic Grayling Monitoring Framework for the Williston Reservoir Watershed* (Hagen and Stamford 2017), which provides a condensed list of recommended monitoring actions for implementation in the near term..

For this report, information gathering was prioritized according to those types of data most relevant to the FWCP strategic objectives, which include:

1. Information indicating potential *limiting factors* for Arctic Grayling populations. These include habitat degradation, ecological changes, and exploitation.
2. Information about the *effectiveness of enhancements* for Arctic Grayling populations.
3. *Quantitative population data* required to accurately assess conservation status: population structure (e.g. among core areas, among tributaries, among spawning locations), distribution, abundance, trend, and threats.
4. Geographic information delineating critical habitats for Arctic Grayling populations, i.e. those locations providing habitats for key life history stages and where limiting factors may operate.

The structure of this report is in accordance with this categorization of key information (points 1 to 4 above), and therefore differs in focus from previous literature summaries (Northcote 1993, 2000; Blackman 2002b; Ballard and Shrimpton 2009). Information about limiting factors and enhancements specific for any particular core area (geographic location) in most cases could not be discriminated, and these are discussed generally for the upper Peace Basin as a whole (sections *2.3, 3.0*). With respect to indicators of conservation status and critical habitats, however, information is structured geographically into report sections that correspond to core areas (Section *5.0*).

2.0 ARCTIC GRAYLING BIOLOGY

2.1 Phylogenetic and ecological diversity in B.C.

Arctic Grayling are widely distributed in Arctic drainages across North America from the west coast of Hudson Bay west through northern British Columbia and Alaska and into northcentral and eastern Russia (Scott and Crossman 1973; McPhail and Lindsey 1970). It is in Eurasia that ancestral genotypes occur, and where taxonomic diversity within *Thymallus* is highest (e.g. Koskinen et al. 2002; Knizhin et al. 2004; 2006; Weis et al. 2006). Arctic Grayling probably first colonized North America during the mid-Pliocene (perhaps 3-5 million years ago) and dispersal likely continued back and forth numerous times across the Bering land bridge during the Pleistocene (Stamford and Taylor 2004; Weis et al. 2006). In North America, there were once two disjunct southern populations located in upper Missouri River in Montana and Great Lakes tributaries (Michigan, Huron, and Superior), the latter extirpated since the 1930s (Vincent 1962).

Diversity within and among North American populations has been addressed, but to a relatively limited extent (e.g. McCart and Pepper 1971; Reed 1973; Bodaly and Lindsey 1977; Hop and Gharrett 1989; Redenbach and Taylor 1999; Stamford and Taylor 2004; Peterson and Ardren 2009). Nonetheless, two major lineages of Arctic Grayling, putatively originating from ‘Beringean’ and ‘Nahanni’ glacial refugia, have so far been resolved in North America based on levels of mitochondrial DNA (mtDNA) divergence among regions (Redenbach and Taylor 1999; Stamford and Taylor 2004). The highly divergent and locally distributed Nahanni lineage appears geographically nested within the range of the widespread Beringian lineage, which includes the disjunct Montana populations. In British Columbia, the distribution of the Nahanni lineage is limited to the lower Liard River system downstream of its Grand Canyon (Stamford et al. 2015). Stamford and Taylor (2004) suggested a relatively recent divergence might also have occurred within the Beringian lineage, giving rise to two polyphyletic mtDNA lineages. ‘North Beringian’ haplotypes are distributed in the far north (Arctic coast), east, and south (including Montana) while ‘South Beringian’ haplotypes are distributed in the west, including the Peace River watershed and the rest of the British Columbia range not occupied by Nahanni Arctic Grayling.

Patterns of molecular genetic and ecological diversity in the Peace River system suggest at least two (possibly three) divergent lineages influenced lower Peace River populations. Populations in the upper Peace Basin, now the Williston Reservoir watershed, remained relatively isolated from such influences (Stamford 2001), however, and are therefore unique within the Peace River system. For example, extensive inventories found Arctic Grayling conspicuously absent in most small lakes within the Williston watershed (http://www.bchydro.com/pwcp/reports2.html; Pollard and Miller 2011), but lake populations exist in the lower Peace watershed and are relatively common throughout the species range in North America (Northcote 1993). Possibly, historical influences from divergent lineages (e.g. a Great Plains haplotype was found in the Burnt River; Stamford et al. 2015) boosted the adaptive potential in the lower Peace and facilitated colonization of novel habitats (Stamford 2001).

At a finer geographic scale, genetic comparisons suggest that Arctic Grayling living among major tributaries to Williston Reservoir are demographically independent from one another, and that this independence preceded the creation of the reservoir (Stamford and Taylor 2005; Shrimpton et al. 2012, Shrimpton and Clarke 2012). An otolith microchemistry study of Clarke et al. (2005) found no evidence that Williston Reservoir is currently used by Arctic Grayling for rearing or overwintering, which suggests that the reservoir might further restrict movements between extant populations. Taken together, these studies suggest that Arctic Grayling populations surviving in major tributaries to the reservoir should be treated as separated conservation units.

In the analysis of Stamford et al. (2015), conservation units based on the putative metapopulation structure are termed 'core areas'.[1] Eight core areas were identified for the upper Peace Basin upstream of the W.A.C. Bennet Dam: Parsnip, Nation, Omineca, Ingenika, Williston, Upper Peace, Lower Finlay, and Upper Finlay/Toodoggone (Figure 1), and the Dinosaur Reservoir watershed comprises a ninth. In this report, we utilize this system of core areas to organize conservation status and critical habitat information (section *5.0*).

Stamford et al. (2015) reviewed Arctic Grayling literature and identified grayling populations living in diverse physical and ecological environments and suggested there might be different migratory behaviours associated with particular landscape features. Also, studies of early life history specializations found divergent juvenile behaviours (rheotaxis and sustained swimming performance, Kaya 1991; Kaya and Jeanes 1995) and growth rates (Haugen and Vøllestad 2000) adapted to their home streams. These heritable traits also appear to be important factors in limiting gene flow between populations, and in promoting higher survival in local streams and suggest Arctic Grayling populations (i.e. core areas) might be locally adapted to their home environment (e.g. Taylor 1991). For example, attempts to transplant populations of Arctic Grayling into novel stream habitat (to recover their historical distribution) using both

[1] Core area: putative metapopulation or group of semi-independent spawning populations linked by gene flow, or the potential for it, and which are independent from other such groupings (Stamford et al. 2015).

fluvial (stream resident) and adfluvial (lake resident) source populations have rarely been successful (Kaya 1992, 2000), possibly because grayling have locally-adapted migration behaviours finely tuned to their native stream (e.g. Kaya 1991).

A conservation strategy should ideally be founded on both historical (phylogenetic) and contemporary (characters of adaptive significance) components of diversity, and important components of genetic diversity include those unique phenotypic characters associated with survival in the diverse environments inhabited by Arctic Grayling. Consequently, Stamford et al. (2015) proposed three putative 'ecotypes[2]' for British Columbia as an additional component of grayling diversity in the province: 'Large Turbid Rivers,' 'Clear Streams,' and 'Lakes,' of which the first two are known to be present in the Williston watershed, and the third is suspected to be present only in the Upper Finlay/Toodoggone core area. Identifying phenotypic expressions associated with these stream features might help define metapopulation structure for Arctic Grayling within watersheds. It is important to note that no studies were found that identify local adaptations associated with populations living in clear streams, which would support distinction from adjacent populations in large turbid rivers[3]. The 'Clear Stream' ecotype is therefore currently somewhat uncertain.

[2] 'Ecotype': populations or population assemblages adapted to specific environmental conditions. Typically among animal and plant species, ecotypes exhibit genetically-based phenotypic differences stemming from environmental heterogeneity, but are still capable of interbreeding with other geographically adjacent ecotypes without loss of fertility or vigor (Turesson 1992; Mager 2012).

[3] Taylor et al. (2013) found significant genetic divergence, however, between adult Arctic Grayling rearing in lower Peace River (large turbid river) and those in adjacent tributaries Pine, Halfway, and Beatton rivers even though recruitment sources associated with the genetic samples were widely distributed in lower Peace watershed (Earthtone and Mainstream 2013).

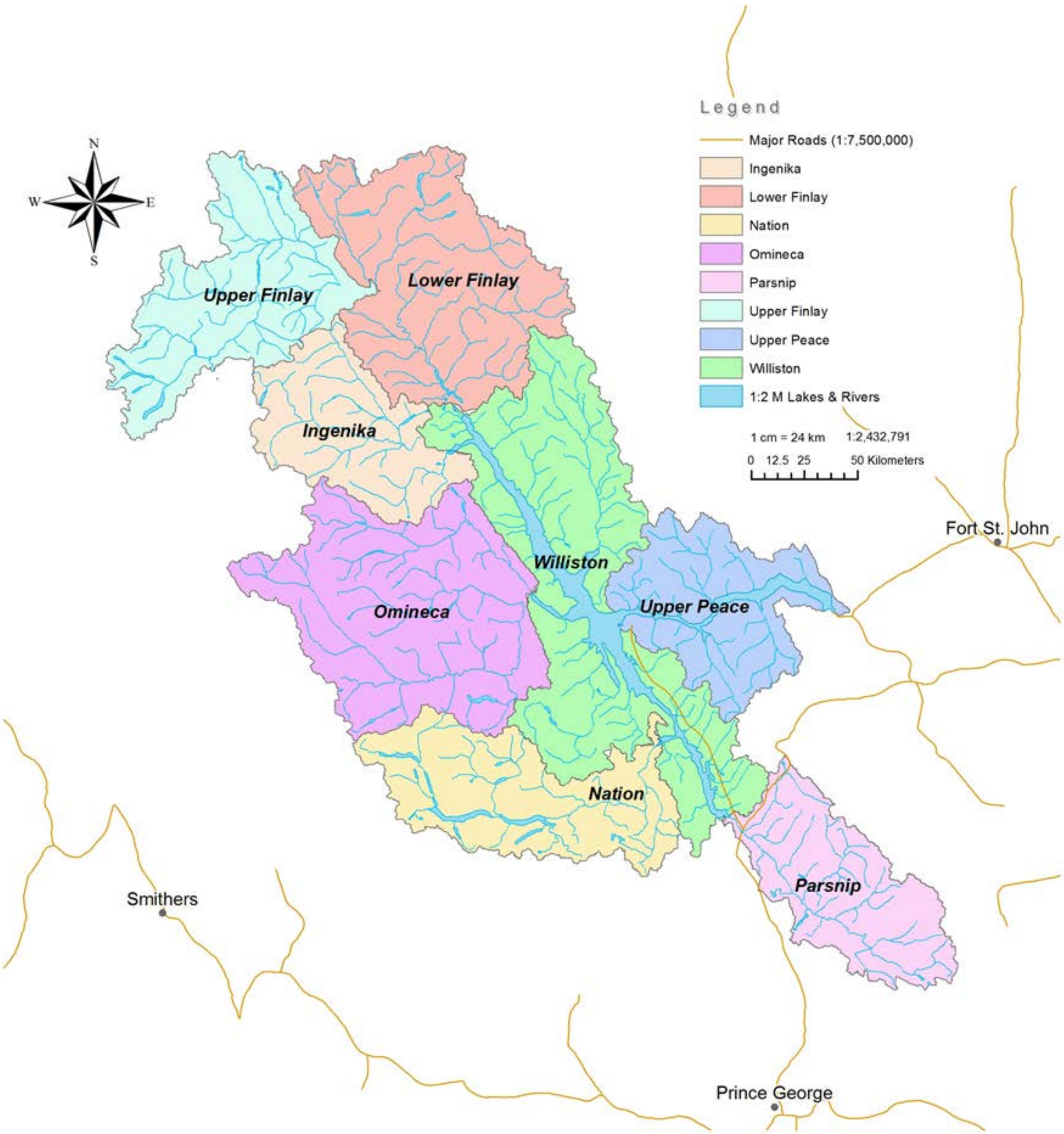

Figure 1. Arctic Grayling 'core areas' (putative metapopulations) comprising the range of Arctic Grayling in the Williston Reservoir watershed.

2.2 Life history

Northcote (1993) presented a conceptual model of Arctic Grayling life history, which is based on a cycle of potentially complex migratory behaviour involving alternation between three major habitat categories: 1) summer feeding habitat, 2) overwinter refuge, and once maturity is reached, 3) suitable spawning habitat. For these three habitat categories, critical habitat locations and physical habitat parameters are distinct and quite narrow for each life history stage (Craig and Poulin 1975; Butcher et al. 1981; Northcote 1993; Stewart et al. 2007a). In some cases these migrations may be at the scale of a single, relatively small watershed, if it is a relatively low gradient stream or lake system (Stewart et al. 2007a) that contains sufficient habitat complexity. In these streams, overwintering, spawning, and summer rearing locations for all life stages can all occur in relatively close proximity to each other. Identifying streams with these habitat characteristics may be pivotal to the success of future efforts to re-introduce grayling in tributaries of the Williston watershed.

Perhaps a more defining characteristic of the Arctic Grayling, however, is its potential for long, complex migrations among critical habitats, which may traverse marginal habitat (e.g. turbid rivers, brackish estuaries) and span hundreds of kilometers between overwintering, spawning and summer feeding areas located in different systems (Armstrong 1986, Northcote 1993; Stewart et al. 2007a). Furthermore, migration timing can be remarkably fine-tuned (water temperature is probably an important trigger) to coincide with the dramatic seasonal changes in local environments (Tack 1980). The focus of the following paragraphs is on the habitat requirements of Arctic Grayling fry, juveniles, and sub/adults that drive these migrations. Information specific to the Williston watershed is utilized where possible.

Incubation and larval development happen quickly and spawning is probably timed so fry (young-of-year) emergence occurs when natal areas are most productive. Generally across the range of Arctic Grayling, all life history stages (young-of-year ‘fry’, age-1+ and age-2+ juveniles, subadults and adults) usually require clear, low gradient, shallow, often warm stream reaches (and including lakes) for rearing (deBruyn and McCart 1974; Craig and Poulin 1975; Stuart and Chislett 1979; Butcher et al. 1981; Northcote 1993; Stewart et al. 2007a). Only a few studies identify rearing in turbid streams (e.g. some Lower Liard tributaries: Stewart et al. 1982; Anderson 2004), but turbid streams seem generally less studied. Natal areas in particular often warm quickly in the spring and provide productive environments for rapid growth. At the southern limit of the Arctic Grayling range in British Columbia, the Williston Reservoir watershed might present a somewhat unique picture, as grayling appear more limited to cooler fifth order streams (Ballard and Shrimpton 2009; Hawkshaw and Shrimpton 2014). Whether this limitation is due to the influence of thermal habitat preferences (e.g. local adaptation) is unknown, as the scientific literature presents limited information with respect to thermal habitat requirements (but see Lohr *et al.* 1996; Haugen and Vollstad 2000; Hawkshaw and Shrimpton

2014), and interspecific competition and predation are also potential factors influencing distribution and habitat use (see section *2.3*).

Newly-emerged grayling fry are weak swimmers, and a key habitat requirement is the availability of low velocity areas along channel margins (and including side channels, back channels, and alcoves) located in relatively close proximity to the spawning area (Stuart and Chislett 1979; Butcher et al. 1981; Stewart et al. 1982; Armstrong 1986; Blackman 2002a; Blackman 2004; Cowie and Blackman 2003; Cowie and Blackman 2004; Nykänen and Huusko 2004). Within the Parsnip River watershed, preferred habitats of newly-emerged grayling are shallow areas (approximately 0.l m) of little or no flow (approximately 0.1 m/s) along the channel margin (Mathias et al. 1998; Blackman 2004). In fry rearing streams of the Parsnip River watershed, the upstream distribution of these habitats corresponds to the shift from gravel to cobble as the dominant stream-bed material, indicating a change in stream energy (Blackman 2004). Initially, fry school. As they grow, however, Arctic Grayling fry undergo behavioural and habitat shifts away from schooling in quiet areas, and move out into deeper faster water along mainstem margins and side channels where they remain for the rest of the summer (Stuart and Chislett 1979; Armstrong 1986). Larger fry become territorial, more solitary, and widely distributed (Kratt and Smith 1979), and the timing of this ontogenetic shift is likely related to first-summer growth rate (Stuart and Chislett 1979; Stewart et al. 1982; Cowie and Blackman 2007).

First summer growth is highly variable among populations, with fall fork lengths ranging from 35mm (McCart *et al.* 1972 cited by deBruyn and McCart 1974) to 120mm (Tack 1980), but young-of-year Arctic Grayling generally appear to attain larger sizes than fall spawning species competing in the same habitat (e.g. mountain whitefish, longnose sucker; Stuart and Chislett 1979; Tack 1980). Water temperature in rearing areas appears to be a key factor regulating fry growth (Schell 2002; Cowie and Blackman 2003; Cowie and Blackman 2007; Ballard and Shrimpton 2009; Hawkshaw and Shrimpton 2014). For instance, the lake-headed Nation River warms quickly in summer and remains about 3^{o}C warmer than other Williston grayling streams, and the mainstem remains warm for longer time periods into the fall (e.g. compared with the Mesilinka River; Langston 1992 through 1996). During late-summer sampling, Nation River grayling averaged 68 mm, versus 38-45 mm in other systems sampled at the same time of year, and this larger size corresponded with a shift to deeper, swifter water and larger stream bed material (Cowie and Blackman 2007). Warm and stable rearing conditions explain at least part of the faster growth rates observed in Nation River fry. Possibly, other factors besides temperature, however, might also influence the divergent growth rates of fry observed among Williston populations (see Species Interactions, Section 2.3.4). Williston Arctic Grayling fry in general appear to have similar temperature preferences (around 16.7^{o}C, Hawkshaw and Shrimpton 2014), and rear during their first summer in locations with similar habitat characteristics (i.e. low gradient, stable summer temperatures, located in middle reaches of larger tributaries; Hawkshaw *et al.* 2013). Grayling fry feed on smaller taxa (e.g. early life stages of aquatic invertebrates), and add drifting nymphs and terrestrial insects to their diet as they grow (Jones *et al.* 2003; Stewart *et al.* 2007b; McPhail 2007).

Arctic Grayling fry are thought to remain in the vicinity of the natal area during the first summer, and by fall they drift or move downstream into larger streams (e.g. large turbid rivers that often run clear during winter) to overwinter (Northcote 2003). These larger streams (e.g. Peace River, Mainstream 2012; Earthtone and Mainstream 2013) are often utilized by juvenile grayling 100-200 mm (age-1+ to age-2+) throughout the year, and the summer rearing habitats and overwintering locations may be in relatively close proximity (Tack 1980; Butcher et al. 1981; Northcote 1993; Stewart et al. 2007a). Rearing locations for juvenile grayling living both in clear stream (e.g. Ingenika River; Cowie and Blackman 2004) and turbid river environments (e.g. Parsnip River; Blackman and Hunter 2001) are primarily quiet margins and low velocity riffles in mainstem rivers. In the Parsnip River watershed, very few juvenile grayling have been observed in areas other than the Parsnip mainstem, where they utilize low velocity areas of approximately 0.4-1.0 m depth (Blackman and Hunter 2001). At this size range (100-200mm), it is possible that the energetic cost of migration to clear habitats further upstream may outweigh benefits, or, alternatively, turbidity in lower reaches may provide a refuge from predation. Overwinter habitat utilized by subadult and adult Arctic Grayling may be in the same reaches utilized by juvenile grayling year-round (e.g. Blackman and Hunter 2001; Blackman 2002a).

Beginning in their second or third year of life, subadult grayling join adults in making migrations from overwintering locations to summer feeding habitat, which depending on the population, may be located in different streams (Tack 1980; Armstrong 1986; Ridder 1994; Blackman 2002a). Clear stream reaches appear to be critical for summer rearing of subadult and adult Arctic Grayling, likely because they are highly dependent on sight for feeding (Birtwell *et al.* 1984; McLeay *et al.* 1987; Ott *et al.* 1998; Stewart *et al.* 2007).

Migrations to summer feeding habitats are typically in an upstream direction, and continue throughout the summer in response to seasonal changes to the stream (Blackman 2002a; Tack 1980). The largest, oldest (i.e. competitively dominant; Hughes and Reynolds 1994; Hughes 1998) individuals usually lead schools around during migrations and dominate optimal feeding habitats (Tack 1980). It is commonly observed that by late summer, larger fish will be distributed further upstream relative to younger, smaller fish rearing in larger habitat downstream (Tack 1980; Northcote 1993; Baccante 2010). Habitat use studies have indicated that larger adult grayling in the Parsnip watershed are distributed further upstream, and that they have a strong preference for pool (>60% of observations) and run habitat and avoid riffles (<1% of observations; Zemlak and Langston 1998; Blackman 2004). Elsewhere, overhanging vegetation cover and pool habitat have been found to be the best physical habitat variables predicting Arctic

Grayling abundance (Big Hole River, Montana; Lamothe and Magee 2004) and distribution (Adsett Creek; Stewart *et al.* 1982) in streams.

Mark-recapture and radio telemetry studies suggest that individual fluvial adults home yearly to the same summer feeding sites, but grayling from different spawning streams may exhibit overlap in summer rearing and/or overwinter habitat (Tack 1980; Buzby and Deegan 2000; Blackman 2002a; Gryska 2006; Earth Tone and Mainstream 2013). For example, radio-tagged adults in the turbid Tanana River, Alaska, migrated from eight different spawning streams to school together in the same rearing stream and 98% of them returned the following summer (Ridder 1998). Subadult and adult grayling consume primarily aquatic and terrestrial insects similar to juvenile grayling, but may also add fish to their diet (Withler 1956; Stewart et al. 1982; Stewart et al. 2007b). Invertebrate prey is foraged primarily from the drift and from the stream surface in summer, while benthically-oriented foraging is more important during the winter months (McPhail 2007).

Mature adult Arctic Grayling migrate in spring to spawning locations and arrive there when water temperature reaches about 4^{o}C (Armstrong 1986; Northcote 1993; Butcher *et al.* 1981). This temperature-associated migration timing has also been observed in Parsnip River grayling (Blackman 2002a). Grayling spawn in a wide variety of habitats, including mainstem rivers, large and small tributaries to streams and lakes, and along lake shores at the mouths of inlets (Tack 1980; Armstrong 1986; Blackman 2002a; Stewart et al. 2007a). Stream reaches that warm quickly in the spring are prime habitat for spawning and early rearing but can also be too small and possibly warm for adult rearing (Tack 1980; Butcher et al. 1981; Ridder 1994, 1998; Stewart et al. 2007a), which may explain why critical habitats for spawning and summer rearing may be located in different streams. Fluvial Arctic Grayling have generally been observed spawning over small pea-sized unembedded gravels in shallow riffles and runs, but also use large cobbles and boulders to incubate their adhesive eggs (Stuart and Chislett 1979; Tack 1980; Armstrong 1986; Stewart et al. 2007a). Relatively precise homing of adults on spawning migrations, and corresponding demographic independence, has been suggested for numerous stream populations (e.g. Tack 1980; Ridder et al. 1993; Ridder 1994, 2000; Blackman 2002a; Gryska 2006), although adults have also been observed moving to different spawning sites sometimes in response to poor spring conditions (Ridder 2000; Stewart et al. 2007).

With respect to Williston Arctic Grayling, adult and subadult movements are known in detail only for populations utilizing the Table and Anzac Rivers within the Parsnip River watershed, which were subjects of a two-year radio telemetry study (Blackman 2002b). From overwintering habitat, which was located almost exclusively along the Parsnip River mainstem, migrations to spawning areas were initiated during the late-April/early-May period, and covered distances ranging from 9 to 71 km. Spawning was estimated to have occurred over the late-May to late-June period.[3] Telemetry data indicated that spawning sites were located mostly in the lower reaches of the Anzac and Table Rivers, and in the Parsnip mainstem, and that multiple-channel and side-channel locations with abundant small gravel were preferentially selected. Migration of radio-tagged grayling to summer feeding areas occurred primarily in July and individuals exhibited high site fidelity, returning to rear in the same locations where they were tagged. The radio telemetry data indicated that downstream movements to overwintering locations occurred in September and October, and may have been triggered by a drop in water temperature (similar to other studies; e.g. Tack 1980; Stewart et al. 1982). Radio tagged individuals moved throughout the winter but remained within the Parsnip River mainstem, frequenting shallow, higher velocity areas associated with riffles, side channels, and islands (Blackman 2002b).

Similar to other fish species, Arctic Grayling exhibit decreasing age-at-maturity and maximum age within more southern populations that grow faster (Armstrong 1986; Northcote 1993). Within the Williston watershed, the maximum recorded age is 9 years, and maximum body size is approximately 400-450 mm among populations and associated with grayling of 6 years and older (Ballard and Shrimpton 2009).[4] Preliminary analysis suggests little difference among Williston grayling populations with the exception of Nation River, which appear to have the highest growth rate and lowest maximum age (age-5+: Cowie and Blackman 2007; Ballard and Shrimpton 2009). For those Williston grayling that have been visually estimated to be mature, minimum and mean sizes are 230 mm and 338 mm, respectively. However, maturity status observations have been based on visual estimation and are potentially uncertain. Because scale ages may also be uncertain (see previous footnote), it remains unclear at what age Williston Arctic Grayling become mature or how long they live (Ballard and Shrimpton 2009). McPhail (2007) suggests, however, that most British Columbia grayling of both sexes mature after their fifth summer.

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[3] While spawning was not observed directly by Blackman (2002a), the spawning period was inferred from the telemetry data and also from back-calculation based on estimated fry emergence dates, observed water temperatures, and an assumption that roughly 128 to 158 degree-days are required for egg development and emergence.

[4] Because these ages are mostly based on scales, caution must be exercised in interpreting the estimates. Decicco and Brown (2006) found that estimates from otoliths and scales were similar up to around age five, and that after age eight and 350mm fork length otolith ages grew much older (up to 29) while scale ages never went higher than 10 years. Stuart and Chislett (1979) reported agreement between scale and otolith ages but examined a small sample size of young specimens (max 7 years).

2.3 Limiting factors

Northcote (1993) noted that over the North American range of Arctic Grayling, subadult/adult abundance ranges over three orders of magnitude from the low 10's to more than 1,000/km. While this range indicates that important factors operate to limit grayling production among watersheds, within the scientific literature it has still not been clearly demonstrated what these factors are. Studies in Alaska suggest, however, that population sizes rarely reach carrying capacity and density independent factors (e.g. stream discharge, temperature, predation) play a larger role in long term survival than density dependent factors (e.g. competition, Clark 1992; Buzby and Deegan 2004). On this spectrum, the abundance of subadult/adult Arctic Grayling observed in the Williston watershed in recent years is low (10-25/km: Stamford *et al.* 2015), suggesting that significant benefits to grayling populations may be possible if limiting factors can be identified and relieved.

2.3.1 Habitat requirements

Important speculation has been made about potential limitation of Arctic Grayling within the Williston watershed and elsewhere in terms of rearing space at key life stages, and during different parts of the year. For stream-dwelling trout, Elliott (1987, 2006) proposed the concept of an 'early critical period' of one to two months following fry emergence when density-dependent population limitation was most intense. As described in the previous section (see Section *2.2*), a key requirement for newly-emerged grayling fry is shallow, low-velocity margin habitat in close proximity to spawning areas. The use of shallow, low-velocity habitat in alcoves, side channels, and back channels has been noted for fry rearing reaches in the Ingenika, Osilinka, Omineca, and Parsnip systems (Mathias et al. 1998; Cowie and Blackman 2003, 2004; Blackman 2004). These may provide key refugia from high spring flows following emergence, and potentially warmer microhabitats promoting faster growth (Blackman 2004). Rearing habitat for larger fry may be widely available in key Williston grayling streams by late summer, when water levels have dropped and young grayling have dispersed along the lengths of rearing reaches (Blackman 2004). Immediately following emergence, however, high and variable flows related to spring freshet might limit the availability of low-velocity rearing space. When this is factored together with the low dispersal capabilities of the tiny grayling fry away from spawning areas, the potential for a significant bottleneck for grayling production is apparent. Tack (1974) noted absence of a whole year class in Chena River following a flood event and Clark (1992) found a significant correlation between recruitment levels and stream flows over a 14-year period. Large numbers of grayling fry have also been observed stranded in pools isolated from the main stream after water levels dropped (de Bruyn and McCart 1974; Cowie and Blackman 2003). The importance of this early critical period in Williston grayling population dynamics, and the factors which affect fry recruitment variation, are unknown. We consider this a significant data gap of moderate immediacy[5] (Data gap *2.3.1a*; Table 1), because this knowledge may help to prioritize enhancement actions directed at this life stage. To address this data gap Blackman (2004) recommended studies examining distribution and abundance of newly-emerged grayling fry, and identified dipnets, fine-mesh seines, and visual observations as potential sampling techniques (Table 1). Such studies could be included within a coordinated monitoring plan for Arctic Grayling within the Williston watershed.

Critical habitat space for older juveniles (and the loss of it following inundation) is potentially a key factor limiting the distribution and abundance of Arctic Grayling within the reservoir environment. It is not only adults, but juveniles also that have been observed migrating directly to productive rearing areas and overwintering locations each year without wasting time searching for alternative locations (Tack 1980; West *et al.* 1992; Buzby and Deegan 2000, 2004; Gryska 2006). Juvenile rearing locations within the Williston watershed tend to be located downstream of spawning reaches in larger mainstem rivers (Blackman and Hunter 2001; Blackman 2004). This pattern of downstream movement during ontogeny, coupled with the flooding of larger mainstem river habitat, is a leading plausible hypothesis for the extirpation of grayling from a minimum of 24 tributaries to Williston Reservoir following inundation (Blackman 2002a; Blackman 2002b; Stamford *et al.* 2015). Having a better understanding of this potential limiting factor is key to successfully re-introducing grayling into these streams. Whether direct tributaries to the reservoir can sustain grayling populations, and particularly whether juvenile grayling can survive there, together form an important data gap potentially limiting enhancement actions (Data gap *2.3.1b*; Table 1), and therefore of high immediacy. Key questions for future research include:

1) What factors affect grayling survival in the reservoir environment?
2) At what life stage(s) does the reservoir survival bottleneck occur?
3) Can steps be taken to mitigate these mortality factors?
4) If reservoir use is untenable, can suitability of candidate streams be assessed for grayling re-introduction using factors such as stream size, unflooded river length (e.g. Hawkshaw *et al.* 2013)?

Access to pool habitat, especially, within clear stream reaches of moderate gradient appears to be a key habitat requirement for adult and subadult Arctic Grayling within the Williston watershed (Blackman 2004; Mathias et al. 1998) and other streams (e.g. Stewart *et al.* 1982; Lamothe and Magee 2004). Intraspecific competition for optimal feeding locations has been

[5] In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions.

documented (see Section *2.2*), and it is plausible that this habitat requirement may play an important role in population limitation in many locations. Pool habitat of this type is, however, present in numerous clear streams from which grayling have been extirpated in the Williston watershed (e.g. Carbon Creek, Clearwater Creek in Peace Reach; Langston and Blackman 1993). Given that subadult/adult densities in remaining grayling streams are at the low end of the observed spectrum (10-25/km; see section *2.0*), it seems likely that adult/subadult rearing space may not be limiting, and the first priorities for study should be other, more likely factors (e.g. juvenile rearing and overwintering areas).

Blackman (2002a) noted a wide variety and distribution of overwinter locations used by Arctic Grayling in the Parsnip River mainstem, and suggested that overwintering habitat may not be limiting the grayling population. Of note, however, was the virtual absence of overwintering juvenile and adult grayling in the lower reaches of the Anzac and Table rivers, which are low gradient reaches with similar characteristics to the overwintering areas used in the Parsnip mainstem (Blackman 2002a; Blackman and Hunter 2001). This potential limiting factor may have played a much more important role in shorter, direct tributaries to Williston Reservoir, where access to overwintering habitats in larger mainstem reaches was cut off by inundation. While the potential for larger rivers providing habitat for juvenile grayling (year-round) has been discussed above, the unknown criteria for adult grayling habitat in winter, especially with regard to the reservoir environment, should also be considered a data gap of relatively high immediacy (data gap *2.3.1c*). For instance, a small remnant population of fluvial grayling currently survives in Maddison River, Montana, possibly because overwintering areas escaped the full impacts from Ennis Reservoir formation (Kaya 2000; USFW 2010). This suggests homing to overwintering areas can be precise and the range of physical habitat preferences narrow, especially when interspecific competition and predation are high. Key questions for future studies, with respect to the feasibility of Arctic Grayling re-introduction in direct tributaries to Williston Reservoir, are the same as questions #1-4 identified above for juvenile grayling.

2.3.2 Aquatic productivity

Whole-stream fertilization experiments in British Columbia have demonstrated that nutrient limitation is a potential factor affecting salmonid production in stream environments (Decker 2010 and references therein). Following treatment, significant increases in production of periphyton and benthic macroinvertebrates have been reported in all cases reviewed by Decker (2010). Studies have typically also reported an initial increase in biomass of salmonids following treatment (including Arctic Grayling, Deegan and Peterson 1992), but not always evidence of increased survival or abundance over the long term. Some long-term studies, for instance, have found no increase in survival of adult fish (e.g. after almost two decades of fertilizing an Arctic Grayling stream; Deegan et al. 1999; Buzby and Deegan 2004) and suggest other environmental factors (e.g. stream temperature, variable discharge) or changes in prey characteristics (Davis *et al.* 2009) can confound benefits from energy flow to higher trophic levels. In the Williston

Reservoir watershed, experimental fertilization of an Arctic Grayling river was evaluated in an eight-year-long FWCP-supported experiment in the Mesilinka River between 1992-1999. Positive responses were observed in three trophic levels, including a 1.5- to 2-fold increase in Arctic Grayling numbers (Slaney 2000; Wilson et al. 2008). Results of this study suggest that nutrients may limit productivity of fish in cool, oligotrophic streams of northern B.C. (similar to Arctic Alaska streams, Deegan and Peterson 1992; Slavik et al. 2004). However, the authors of this and other comparable B.C. studies (Slaney 2000; Decker 2010) also indicate that monitoring for whole-stream fertilization experiments may have been terminated before community equilibriums were reached, both for the fish and benthic macroinvertebrates. We therefore do not consider the role of nutrients in limiting Arctic Grayling productivity within the Williston watershed to have been definitively established. We consider this a data gap of low immediacy (Data gap *2.3.2*; Table 1).

2.3.3 Parasitism and disease

Northcote (1993) indicated that in the North American literature at that time, there were no records of parasitism and disease strongly regulating Arctic Grayling population size in wild populations. The authors therefore do not consider the lack of information about these factors to be an important data gap within the Williston Reservoir watershed.

2.3.4 Species interactions - competition

Detailed studies of whether species interactions such as interspecific competition and predation affect the population dynamics of Williston Arctic Grayling have not been conducted. It is feasible, however, that these potential limiting factors have had important roles in determining historical and contemporaneous distribution and abundance. Upper Peace Basin Arctic Grayling are unique in Canada with respect to the fish community they coexist with. The assemblage of species includes more from the Fraser and other western drainages than from other Arctic drainages, and colonization occurred slowly and to a more limited extent in the Rocky Mountain trench (McPhail 2000 *in* Zemlak 2000). This indicates that species interactions are unique and significant in promoting divergent behaviours in upper Peace Basin Arctic Grayling (and other species).

Rainbow Trout, Bull Trout, and Mountain Whitefish are widespread within the Williston watershed. During electrofishing surveys of the Ingenika, Osilinka, and Table systems, no Arctic Grayling fry were captured in tributaries that were dominated by one of these other species (Mathias et al. 1998; Cowie and Blackman 2003, 2004). Competition for food and space with these species might influence grayling distribution and limit recovery of their historical range in these systems, as has been documented in other systems (e.g. upper Missouri River; Kaya 2000). For example, observed increases of Rainbow Trout in the Burnt River, possibly promoted by stocking, are correlated with declines of Arctic Grayling (Euchner 2010).

Temperature is paramount among environmental parameters for regulating developmental processes and is an important selective factor maintaining variability among salmonid populations (Taylor 1991). Water temperature is therefore likely to be an important factor limiting Arctic Grayling populations, both through direct effects on survival and growth (discussed above in section 2.2, *Life History*), and also through temperature-mediated species interactions. Generally, Arctic Grayling fry do well in warm summer rearing areas where survival is probably linked to rapid growth rate during the first year (Deegan *et al.* 1999; Stewart *et al.* 2007). Fluvial grayling populations in Williston watershed appear to be centered around fry rearing areas located in the low gradient middle reaches of larger (e.g. 4th order and larger) tributaries where stable ambient summer temperatures hover close to16^{o}C (Hawkshaw *et al.* 2013). The extent of local adaptation to these rearing areas remains unclear but grayling are known to rapidly fine tune their growth rates to particular temperatures present in natal areas (Haugen and Vollstad 2000). Temperature preferences for rearing fry were the same (16.7^{o}C), however, between three different natal areas, each derived from distinct spawning locations in warm (two locations, Nation River) and cooler (one location, Table River system; Hawkshaw and Shrimpton 2013) streams. This suggests Williston fry populations might be constrained in their ability to adapt to different local temperatures (e.g. fry in Nation River appear to accumulate in locations that provide a consistently optimal rearing temperature). Adults and older juveniles (1+ and older), however, can show higher growth rates during years when stream discharge is higher and summer water temperatures are lower (e.g. approaching 10°C; Lohr *et al.* 1996; Deegan *et al.* 1999). Despite the potential benefits of warm water conditions on fry survival, the indication of strong local adaptation in Arctic Grayling to local watershed conditions (e.g. Kaya and Jeanes 1995; Haugen and Vollstad 2000, 2001) suggests that failure to maintain natural thermal regimes within critical habitats poses a significant threat.

Similar to the Arctic Grayling, the Rainbow Trout in fluvial environments feeds primarily on aquatic insects, with a strong orientation to the drift and surface feeding modes (McPhail 2007). Interspecific competition with Rainbow Trout, which may be temperature-mediated, may limit Arctic Grayling distribution and abundance. Ballard and Shrimpton (2009) found no records of adult Arctic Grayling captured from water warmer than 14.5°C in the Omineca Region, which suggests their distribution is limited to cooler waters. Adults and fry tend to move away from suboptimal temperatures (i.e. above 16°C for adults, Tack 1980; Lohr *et al.* 1996; above or below 16.7^{o}C for Williston fry, Hawkshaw and Shrimpton 2014) and move into reaches that provide optimal conditions for rearing. Rainbow Trout appear to have more plasticity in responses to their environments and have far wider preferred temperatures than Arctic Grayling (e.g. 7-18^{o}C; McPhail 2007; Nelitz *et al.* 2007), which may explain the absence of grayling from the extensive, low-gradient Pack River watershed, in which Rainbow Trout are abundant and widely distributed (LRDW 2015). In the absence of available niche space (having been filled by Rainbow Trout) Arctic Grayling may be unlikely to recover their historical range. Greater niche separation likely occurs between both of these species and the more benthically-oriented

Mountain Whitefish, with which they co-occur in many parts of their respective ranges (McPhail 2007).

Temperature-mediated competition with non-salmonid species may also limit grayling productivity in warmer systems. Nation River Arctic Grayling fry appear to grow faster than fry in other Williston streams and, consequently, might move into deeper and faster water earlier in the summer (Cowie and Blackman 2007). Although warmer rearing temperatures can explain faster fry growth in salmonid fishes, Cowie and Blackman (2007) postulated the potential for interactive segregation with high densities of juvenile Longnose Dace (*Rhinichthys cataractae*), Northern Pikeminnow (*Ptychocheilus oregonensis*), and suckers (*Catostomus* sp.). Larval stages of all these species occupy the same low-velocity margin habitat preferred by larval grayling in other systems.

The lack of knowledge about the role of competition, and temperature-mediated competition in limiting Arctic Grayling populations is an important data gap, but one which we consider of relatively low immediacy for FWCP (Data gap *2.3.4*; Table 1). The management of watershed development, the primary short-term threat to thermal habitat suitability, is the responsibility of the BC Provincial Government and is covered by a number of Provincial Acts. Acquiring knowledge about how these and other ecological factors relate to Arctic Grayling productivity can best be done as part of a coordinated grayling monitoring plan for the Williston watershed, in which juvenile and adult grayling abundance data would be collected regularly, and these time series related to ecological factors (e.g. water temperature, turbidity, density of competitors, etc.).

2.3.5 Species interactions - predation

The role of predation in Arctic Grayling population dynamics in the Williston watershed is unstudied, but potentially important, as Arctic Grayling are sympatric with significant populations of Bull Trout in all remaining grayling streams. Bull Trout have frequently done well in B.C. reservoirs, especially when naturalized populations of Kokanee (*Oncorhynchus nerka*) are also present (Hagen 2008). Indeed, the Williston Reservoir watershed should probably be considered a stronghold of Bull Trout abundance in the province. Large Bull Trout are primarily piscivorous and consume fish prey of up to one half their own body length (Beauchamp and Van Tassel 2001), meaning that even adult Arctic Grayling do not outgrow the risk of predation. Relatively large Bull Trout populations are likely to utilize streams that are also candidates for Arctic Grayling re-introduction. It is plausible that following inundation, predation by Bull Trout on young and adult Arctic Grayling in Williston Reservoir was a contributing mechanism to the extirpation of grayling from these streams in the first place. It is important to note that unlike some other potential limiting factors, managing Bull Trout abundance (while ensuring conservation) is feasible through angling regulations, provided that appropriate monitoring is in place (R. Pillipow, MFLNRO Prince George, pers. comm. 2015).

Therefore, we consider the lack of knowledge about the role of Bull Trout predation in limiting Arctic Grayling populations to be a data gap of high immediacy (Data gap *2.3.5*; Table 1). Studies of interactions between Bull Trout density and Arctic Grayling density necessarily require the participation of MFLNRO as a study partner, and would also benefit by coordinated monitoring plans for both species.

2.3.6 Habitat degradation

Mechanisms of habitat degradation (in addition to stream temperature effects) related to forest harvesting, road building, and pipeline construction and operation include: 1) losses of riparian vegetation, stream habitat complexity, stream depth and access to critical habitats, 2) increases in water temperature, sediment transport, variation in stream flow and temperature, channel widening and destabilization, and 3) accidental release of hazardous materials (Northcote 1993; Hagen *et al.* 2015 and references therein).

Among threats mechanisms associated with habitat degradation, high sediment transport is one of particular importance to Arctic Grayling. Rearing adults avoid turbid conditions and can apparently migrate to different feeding locations, but fry and juveniles are more restricted in their ability to move and survival depends on rapid growth in natal streams. Adults continue to spawn in streams impacted by elevated sediment loads (possibly due to a strong heritable component to homing behaviour), but young-of-year surviving the high sediment load show reduced growth and some signs of stress (Birtwell et al. 1984; McLeay et al. 1987). Indirect effects of sedimentation, through loss of summer habitat for feeding and reproduction, may more severely affect Arctic Grayling populations than the direct effects of sedimentation on the health and survival of individual fish. Elevated sediment may result from multiple sources (forest harvesting, oil and gas extraction, dam construction, mining, linear developments), but effects from placer mining are of particular concern and have been studied most extensively. Placer mining causes siltation of spawning habitat and reduce growth rate during early rearing, and often destroys habitat in natal streams (Birtwell et al. 1984; McLeay et al. 1987). Arctic Grayling populations may continue to home to spawning sites downstream of placer mines, but offspring suffer increased mortality (alevins), starvation, and reduced growth rates during early rearing (Birtwell et al. 1984; Reynolds et al. 1989). Consequently, reduced recruitment success due to sedimentation impacts can cause population declines over the long term.

Greater variation in discharge following watershed development may be another threats mechanism of particular importance to Arctic Grayling populations. Fry living in streams might be subject to extremely high mortality during flood or drought conditions. Fry are highly susceptible to high flows for two weeks after hatch, a time when spring freshets cause unpredictable flood events (see ‘habitat requirements’ above).

Homing to rearing areas (and possibly overwintering sites) facilitates efficient acquisition of resources during short summers and increases overwinter survival over the long term in a temporally unpredictable environment (Busby and Deegan 2000, 2004). Disturbances to rare natal areas or restricted access (e.g. hanging culverts) to critical spawning and rearing habitat can seriously harm or eliminate Arctic Grayling from a watershed. Habitat alteration and linear developments affecting access should therefore be considered important threats mechanisms affecting the viability of grayling populations, which may originate from any number of potential sources that are associated with road building and physical site disturbance (forest harvest, oil and gas extraction, dam construction, mining, linear developments). Oil and gas developments require vast networks of roads to access numerous drill sites. Poorly installed crossings can restrict access to critical spawning and rearing locations, so this source of threats is of particular concern with respect to access to critical habitats (Sullivan 2000; Anderson 2004).

Habitat degradation from forestry-related activities has been noted within tributary basins of the Williston Reservoir watershed (e.g. Mathias et al. 1998), but systematic investigations of degraded areas, and opportunities for restoration, have only briefly been examined and in few areas (e.g. Mesilinka River – EDI 2001; Osilinka and Misinchinka – EDI 2002a; Table River – EDI 2002b, c). This lack of knowledge is an important data gap of low immediacy (Data gap *2.3.6*; Table 1), but the immediacy ranking would increase if watershed restoration were to be included within the range of acceptable enhancement and conservation actions supported by FWCP. Indicators of cumulative effects from watershed development on aquatic ecosystem health include measures such as road density, road density near streams, stream crossing density, percent riparian disturbance, and equivalent clearcut area (Hagen et al. 2016 *in prep.*). The most efficient and rapid means of acquiring information about potential habitat degradation 'hotspots' may be to utilize these indices of cumulative effects in a GIS-based exercise (e.g. Hagen et al. 2016 *in prep*.). More detailed assessments on the ground, utilizing methods identified in the BC Government's Fish Habitat Assessment Procedures (Johnston and Slaney 1996) would likely be a further step required to identify particular enhancement/restoration possibilities.

2.3.7 Exploitation

Arctic Grayling are highly susceptible to harvest, and such harvest often takes the largest (oldest, most fit; Baccante 2010) individuals from a population. Adult and subadult grayling can be rapidly depleted under even moderate angling pressure (Northcote 1993 and references therein). Angling harvest has resulted in declines in Alberta (e.g. Fitzsimmons and Blackburn 2009; Alberta Sustainable Resource Development 2005), British Columbia (Euchner 2010) and Alaska (Armstrong 1986; Northcote 1993). It is important to note that overexploitation of Arctic Grayling, concentrated at stream mouths following inundation, has been proposed as a plausible hypothesis for extirpation of the species from tributaries to Williston Reservoir (Blackman 2001).

Angler access is a primary factor affecting exploitation levels (Northcote 1993). While the BC Provincial Government regulates angling harvest, watershed development can affect exploitation of Arctic Grayling by providing angler access. Forest harvest and oil and gas development are obvious potential threats sources providing angler access via road and other linear developments (e.g. pipeline right-of-way). Oil and gas developments, in particular, require extensive road networks.

Currently, angling regulations across the Williston watershed do not permit harvest of Arctic Grayling. Monitoring to assess the effects of this regulation on grayling abundance, and the potential effects of catch-and-release and illegal harvest, is not being conducted, and we view this as a significant data gap (Data gap *2.3.7*; Table1). Acquiring knowledge about the sustainability of angling regulations can best be done as part of a coordinated Arctic Grayling monitoring plan for the Williston watershed, based on regular abundance monitoring (e.g. Cowie and Blackman 2012b; Mathias *et al.* 1998; Zemlak and Langston 1998). The need for a coordinated grayling monitoring plan has also been identified above with respect to other potential limiting factors, such as fry recruitment success, water temperature, competition, and predation, and should therefore should be considered of high immediacy.

Table 1. Data gaps affecting understanding of factors limiting distribution and productivity of Arctic Grayling habitats within the Williston watershed, and potential studies to address them.

ID	Limiting factor	Data gap	Potential study(s)	Immediacy
2.3.1a	Habitat requirements, fry	Poor understanding of factors affecting fry recruitment variation	Studies of the distribution and abundance of newly-emerged grayling fry	Moderate[1]
2.3.1b	Habitat requirements, juveniles	Unknown survival potential of juvenile grayling in tributaries to Williston Reservoir	Key questions: 1) factors affecting survival in the reservoir; 2) life stage at which survival bottleneck occurs; 3) can mortality factors be mitigated; 4) stream size and unflooded river length as indices of candidate stream suitability?	High
2.3.1c	Habitat requirements, adults	Unknown overwinter survival potential of adult grayling in tributaries to Williston Reservoir	Key questions: see Data gap *2.3.1b* above	High
2.3.2	Aquatic productivity	Role of nutrients in limiting grayling productivity	Longer-term whole-stream fertilization and monitoring	Low
2.3.4	Species interactions - competition	Role of competition, and temperature-mediated competition, in limiting Arctic grayling populations	Coordinated grayling monitoring plan for Williston watershed, including ecological factors (e.g. water temperature, turbidity, density of competitors, etc.)	Low
2.3.5	Species interactions - predation	Role of predation by bull trout in limiting Arctic grayling populations	Coordinated monitoring plans for both species, participation of FLNRO in experiments mandatory	High
2.3.6	Habitat degradation	No systematic investigation of degraded areas, and opportunities for restoration, in most areas	GIS-based indicators of cumulative effects; BC Government Fish Habitat Assessment Procedures	Low
2.3.7	Exploitation	No subadult/adult population abundance monitoring anywhere in the Williston watershed since 2007	Adult population abundance indices (e.g. snorkeling counts, angling CPUE, mark-recapture)	High

[1] In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions

3.0 ENHANCEMENT

3.1 Review of Arctic Grayling enhancement techniques

Many poorly understood aspects of Arctic Grayling biology continue to limit the success of enhancement efforts. For instance, enhancement techniques that are successful for other salmonid species often fail with Arctic Grayling (Northcote 1993), probably because they do not successfully target limiting factors associated with declines (e.g. Kaya 2000). Northcote (1993) listed numerous enhancement options for Williston Arctic Grayling but strongly recommended that trials be carried out at a small scale and with an investigative research approach.

Enhancement trials must have clear objectives aimed at addressing potential limiting factors. Such studies are more likely to be successful at increasing the productivity and distribution of Williston grayling, and facilitating recolonization of their historic range.

Stream habitat improvements have had some success in creating spawning and juvenile rearing habitats that replace losses resulting from industrial development. In one such instance (e.g. Jones *et al.* 2003), spawning adults were successfully drawn to manufactured spawning structures and their offspring recruited successfully downstream to rear in created habitat. Connectivity to other native habitats (i.e. overwintering, rearing) was maintained so the population could complete their life history (Jones and Tonn 2004). Perhaps more importantly, however, the native migration patterns appear to have been altered only minimally. Although not stated explicitly in their study, the adfluvial adult grayling appear to ascend their natal stream before entering the diversion channel, which lead them directly to constructed habitat structures (Jones *et al.* 2003).

Enhancements are less successful when the Arctic Grayling are required to shift their native migratory behaviour, especially into the fluvial environment. For instance, efforts to re-establish populations in Madison River streams (eastern branch of upper Missouri Basin) where grayling were historically abundant have had almost no success after numerous enhancement actions (e.g. transplants, habitat improvements), and over twenty years of adaptive management efforts aimed at identifying threats and limiting factors (Kaya 1990, 2000; Peterson and Ardren 2009; USFW 2010; MFWP 2014). In contrast, such efforts have had success in the western branch of upper Missouri River, in which fluvial grayling appear to be recovering some of their native range within the Big Hole River watershed (MFWP 2014). Habitat improvements combined with three consecutive years of egg-plants have resulted in returning adult spawners and successful rearing of their wild offspring into Rock Creek. One key to this success has been the use of local brood stock derived from the Big Hole River conservation brood reserve, where careful attention to maintaining genetic diversity, and avoiding domestication without diminishing adult abundance in Big Hole River (Peterson and Ardren 2009). Also, remote site incubators (RSI's) have been used to allow fertilized eggs to incubate at various likely spawning locations. Utilizing the RSI's provides opportunities for imprinting during key periods of ontogeny, a key mechanism behind homing behaviour in salmonid fishes (Dittman and Quinn 1996). The above example suggests that precise homing to spawning locations is an important factor that must be accounted for, in order for efforts at range expansion (e.g. in Williston Reservoir tributaries) to be successful.

Grayling populations in the upper Missouri and upper Peace rivers have key similarities that suggest enhancement actions used in one watershed may be successful in the other. The native populations in both watersheds are predominately fluvial Arctic Grayling of Beringian ancestry that were isolated above barriers by receding glaciers (although probably during different ice ages) at the southern edge of the species' range (Northcote 1993; Kaya 1990; McPhail 2007;

Peterson and Ardren 2009). The initial human-caused declines in both basins stem from reservoir creation, which resulted in habitat loss and imposed restrictions to their native migration patterns, mostly in the downstream large river habitat (Northcote 1993; Kaya 1992, 2000; USFWS 2010). Adult grayling disappeared from the smaller rearing tributaries (angling locations) about a decade later and limiting factors associated with declines were not clearly understood for either watershed. Fluvial Arcitc Grayling that survived the initial decline (after Williston and Ennis reservoirs were created) were in the larger tributaries, presumably those large enough to sustain demographically independent populations (Kaya 1990; Northcote 1993; Hawkshaw *et al.* 2013). Further anthropogenic impacts have resulted in additional range contractions in upper Missouri River, with the result that only one native fluvial population remains in the Big Hole River (Kaya 1990).[6]

In the Williston Reservoir basin, at least six streams continue to sustain demographically-independent Arctic Grayling populations, and the eight identified core areas (Figure 1) represent the minimum geographic scale for conserving biodiversity in the watershed (Stamford *et al.* 2015, and references therein). It is increasingly evident that long-term survival improves when fisheries management strategies promote productivity of numerous, unique, locally-adapted populations (e.g. Hilborn et al. 2003). Consequently, enhancement actions aimed at recovering the range and abundance of upper Peace Basin Arctic Grayling must be compatible with the existing unique biological aspects of Arctic Grayling to be found in each core area.[7] Enhancement action must avoid diminishing this level of diversity (e.g. transplants might dilute the native gene pools) for fear of putting populations further at risk of extirpation.

Exotic species introductions (especially the Brown Trout *Salmo trutta*: Vincent 1962; Kaya 2000) confound the efforts to recover the range of fluvial grayling in upper Missouri River. The loss of genetic diversity also remains a significant concern (Peterson and Ardren 2009). Beyond the success in Big Hole River (see above), transplants of native fluvial and adfluvial Arctic Grayling have so far not established fluvial populations beyond the range of their home stream (e.g. Maddison River; Kaya 2000; MFWP 2014).[8] Once lost from their home stream, fluvial population recovery appears slow, possibly because the source of grayling used for transplanting lack the plasticity in traits (e.g. for temperature preferences, rheotaxis, homing behaviour) that

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[6] Two other small populations possibly of native fluvial ancestry also remain in Maddison River (around ancestral overwintering locations near Ennis Reservoir) and Sun River (in Sunnyslope Canal downstream of Pishkun Dam) and might carry important remnants of fluvial traits that once thrived in upper Missouri River grayling (USFW 2010; FWCP 2014).

[7] These biological attributes are unstudied; e.g. Taylor 2005.

[8] Introduced populations in lakes and ponds, however, are distributed throughout the species range and beyond (e.g. Northcote 1993; Peterson and Ardren 2009).

facilitate adapting to divergent but specific and complex migrations in novel streams (MWFP 2014).

Their wide geographic range suggests that range expansion has been a key aspect to Arctic Grayling ancestry. Higher plasticity in life history traits is presumably a desirable characteristic in potential source populations for recolonization experiments. There is evidence that the extent of plasticity in Arctic Grayling populations is adaptive and reflects the surrounding environment (Salonen and Peuhkuri 2007). Higher water velocity and competition promote greater plasticity in adaptive traits (e.g. morphology, aggression, boldness) in European Grayling (*T. thymallus*) and stream dwelling populations appear to have greater plasticity than adfluvial populations (Salonen 2005). Possibly, Arctic Grayling populations adapted to larger rivers might also have plastic responses to variable conditions relative to those populations adapted to more predictable habitats in low gradient headwater streams and lakes. Long-term persistence and adaptive potential in watersheds might hinge around populations living downstream in the larger river habitats. These types of populations might be ancestral to surrounding subpopulations in headwaters, where selection may favour local adaptation over plasticity. The putative Large Turbid River Ecotype identified both in Lower Finlay and Parsnip core areas (Stamford et al. 2015) are good candidates to examine this hypothetically natural tendency toward higher plasticity in downstream larger river habitats, and may be potential source populations for recolonization experiments.

3.2 Potentially suitable enhancement options for upper Peace Basin

Enhancement actions need clear objectives aimed at recovering Arctic Grayling toward pre-reservoir levels of distribution and abundance, but actions must also improve the conservation status of current populations. One appealing approach is to utilize local genotypes and facilitate range expansions into adjacent habitats where they were once abundant. Persistent observations of Arctic Grayling in some of these small tributaries indicate adults continue to rear there (e.g. Weston Creek, Choweka Creek: Williston core area) and in some instances spawn successfully (e.g. Clearwater River: Peace Core Area; Munro, Rainbow, Sylvester creeks: Nation core area; Hominka River: Parsnip core area). The core areas of origin are less clear for those streams that enter Peace and Williston core areas and might include strays from adjacent core areas (e.g. Parsnip, Lower Finlay). The upstream tributaries are currently assumed to be part of the metapopulations of their respective core areas, Nation and Parsnip. However, the population dynamics around tributary use remains unclear for Arctic Grayling.

Sylvester Creek (Nation core area) and Hominka River (Parsnip core area) are thought to be historically productive Arctic Grayling streams, but now appear to be relatively marginal relative compared to other parts of their respective core areas. Declines in these tributaries stem from factors other than flooding downstream reaches (e.g. exploitation, logging, mining impacts), while declines in Williston and Peace tributaries are much more likely to be associated with flooding and loss of juvenile habitat downstream (Section *2.3.1*).

Tributary use within core areas, and the potential for range expansion, might be influenced by movements within a metapopulation, and furthermore the extent of use may reflect the year-to-year level of abundance overall in the core area. Alternatively, independent and locally-adapted populations need longer recovery times and more intensive enhancement actions to facilitate recovery (e.g. Big Hole River, Section *3.1*; WFWP 2014). Both scenarios are possible among Peace Basin core areas.

A number of data gaps need to be filled before enhancement actions can proceed (listed in Enhancement options *3.2.1a*, *3.2.1b*; Table 2). Studies addressing movements, population structure, and competition will help identify homing behaviour, in particular how much straying happens among spawning locations. As a potential example of a factor that may affect enhancement actions, competition with other species may impede grayling range expansion (e.g. data gap *2.3.5*, Table 1). Physical habitat studies are needed to identify disturbances associated with declines (e.g. in tributaries), identify key habitat factors that remain limiting, and identify at which life stage these habitat factors operate (e.g. almost nothing is known about natal areas, particularly for newly-emerged larval stages; data gap *2.3.1a*, Table 1). Identifying habitat requirements for juveniles and adults in reservoir tributaries are needed to focus enhancement actions (data gaps *2.3.1b*, *2.3.1c*).

Introducing local genotypes into novel streams might promote faster recovery of populations (Enhancement options *3.1.1c*, *d*, *e*; Table 2). Currently, however, besides a few locations in Parsnip core area there is almost no knowledge of spawning areas in any core area including areas where many spawners congregate. Without the establishment of core area-specific genetic reserves capable of providing genetically diverse egg-plants, transplants may be less likely to be successful. Records suggest grayling fry were collected from Finlay River (possibly Toodoggone core area) and established a thriving adfluvial population in upper Sikanni River (Woods 2000). This suggests that the possibly adfluvial Toodoggone Arctic Grayling may be a candidate source population for recovering other Peace Basin populations. Transplanting fish between core areas, however, is less desirable than within a core area due to the potential genetic risk to existing populations.

Fluvial Arctic Grayling population sizes appear in general to remain below carrying capacity, and manipulations that target the carrying capacity of streams (e.g. fertilization) appear to have limited benefit over the long term (Clark 1992; Buzby and Deegan 2004; see Section *2.3.2*).

Table 2. Potential enhancement options for Peace Basin Arctic Grayling and associated key data gaps.

ID	Enhancement Type	Data gap	Potential study(s)	Immediacy
3.2.1a	Habitat Improvements	Poor understanding of habitat degradation in areas (tributaries) where grayling were once abundant	Assess physical habitat in key tributaries (e.g. Weston Creek, Sylvester Creek) where spawning grayling were once abundant (Data gaps *2.3.1b* , *2.3.1c* , *2.3.6*)	High[1]
3.2.1b	Habitat Improvements	Poor understanding of habitat requirments in natal areas surrounding spawning locations	Physical habitat assessments, identify key variables associated with larval rearing around natal areas (e.g. data gap *2.3.1a*)	Moderate
3.2.1c	Introductions using transplants	Almost no knowledge about spawning areas within core areas and potential sources for gametes	Movements between natal areas and adult rearing areas in core areas (e.g. concordant microchemistry and genetic analyses among fry rearing areas; radio telemetry)	High
3.2.1d	Introductions using transplants	Feasibility of creating genetic reserves (e.g. similar to Big Hole River) for future enhancements	Examine details of successes and failures in upper Missouri River. Is the use of genetic reserves most appropriate for Peace Basin?	Low
3.2.1e	Introductions using transplants	Poor understanding of candidate core areas with life histories most likely to survive in the reservoir environment.	Examine differences among core areas for migratory behaviours and habitat use to identify those most appropriate for transplanting (e.g. Toodoggone, Lower Finlay, Parsnip core areas?); Is adfluvial life history most appropriate? Microchemistry, radio telemetry, concordant genetic analyses; habitat descriptions	Low

[1]In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions

4.0 STUDY METHODS

4.1 Conservation status and risk assessment methods

In 2011, following a review of potential alternatives, the *Core Area Conservation Status and Risk Assessment Methodology* developed by the United States Fish and Wildlife Service (USFWS 2005) was proposed for use in British Columbia, for the province's Bull Trout (*Salvelinus confluentus*) populations (Hagen and Decker 2011). The use of the methodology was approved by the BC Ministry of Environment (Hagen and Decker 2011), and has since been applied to Arctic Grayling, as well, across their B.C. range (Stamford *et al.* 2015). The USFWS (2005) risk assessment methodology is an adaptation of the generalized ranking methodology for animal species developed by the Montana Natural Heritage Program (MNHP 2005), which is in turn adapted from a process developed and proposed originally by scientists at NatureServe. The methodology shares definitions and ratings for information fields with NatureServe and IUCN (International Union for Conservation of Nature) criteria (USFWS 2005; MNHP 2005). The methodology is attractive because: 1) it is applied at a spatial scale relevant to management actions, threats, and extirpation processes, 2) it can incorporate information in an a variety of standard (population data) and non-standard (anecdotal information, First Nations traditional knowledge, professional judgments) forms, 3) it has the ability to address threats in a systematic manner, and 4) the rule- and point-based process for assigning risk was felt to be standardized and therefore likely to produce repeatable results.

A key feature of the USFWS (2005) methodology is that conservation status and risk are assessed at the spatial scale of putative metapopulations, which are termed ‘core areas.’ As described in Section *2.1*, genetic and other studies of Arctic Grayling population structure in the Williston Reservoir watershed have been a priority for FWCP (Stamford *et al.* 2015 and references therein), and therefore a relatively good basis exists for delineating the core area structure. We use the eight putative core areas for the upper Peace Basin above W.A.C. Bennett Dam (Figure 1) as the geographic units for summarizing population data and identifying data gaps in Section *5.0*.

Conservation status and risk rankings are based on categorical estimates for four indicators: 1) *Distribution,* 2) *Abundance* of adults, 3) *Trend* in abundance, and 4) *Threats* (Appendix 1). Threat categories include: 1) *Habitat Threats*, as detailed in section *2.3 Limiting Factors*, and 2) *Exploitation Threats* resulting from high angling effort, high vulnerability of the population, or high fishing mortality resulting from existing regulations, catch and release mortality, or illegal harvest. Threats are assessed in terms of severity, scope, and immediacy, and an overall threats score for the core area is assigned based on estimated cumulative effects across all threats (Appendix 2).

As the final step in the core area assessment methodology, alphabetical scores corresponding to categorical estimates of *Abundance*, *Distribution*, *Trend*, and *Threats* are converted to numerical values with positive or negative signs (Appendix 3). The numerical values are summed across categories and added to a baseline value (USFWS 2005). The resulting total is then compared to the range of values corresponding to each of 4 conservation status/risk ranks (C-ranks) in order to assign a rank to the Core Area. The C-ranks are *C1-High Risk*, *C2-At Risk*, *C3-Potential Risk*, and *C4-Low Risk* (Appendix 3). The numeric scoring procedure is compatible with unknown values for the risk factors, and assigns a ‘0’ numeric value for each ‘U’ (unknown) alphabetic value. Unknown values for the conservation status indicators therefore weaken the power of the analysis, and are considered important information gaps in Section *5.0*.

For Williston watershed Arctic Grayling core areas, ‘first-cut’ estimates for the conservation status indicators existed following an ‘expert’s workshop’ exercise conducted over the 2013-2014 period, as part of the provincial risk assessment (Stamford *et al.* 2015). Our information synthesis makes use of this prior information, but also reviews a broader scope of information at a more detailed level, permitting an update to the conservation status and risk assessments for core areas within the Williston Reservoir watershed[9].

4.2 Methods for delineating critical habitats

For the purpose of assessing critical habitats (as well as estimating distribution), the primary information source used was GIS software, ArcGIS 9.3 and the BC Government Fish Observations and Fish Obstacles layers populated from the BC Land and Resources Data Warehouse (LRDW). The LRDW is the primary collection of the Province's natural resource data and integrates all relevant past and present fisheries databases including the BC Field Data Information System (FDIS), the joint BC Environment/Fisheries and Oceans Canada (FOC) Fish Information Summary System (FISS) and Fish Habitat Inventory and Information Program (FHIIP), and the BC Lakes Database. Distribution information from outside the LRDW was also collected during our review of regional Arctic Grayling literature.

As the first step in the information synthesis, the 8 core areas comprising the Williston Reservoir watershed (Figure 1) were subdivided into watershed sub-basins, a finer geographic scale for summarizing critical habitats and comments. This is likely to be the geographic scale that best represents local fish sub-populations nested within core areas (e.g. Anzac, Table and Missinka watersheds within the Parsnip core area: Shrimpton et al. 2012).

[9] Results from the information synthesis presented in this report have been incorporated into the latest draft of the provincial risk assessment (Stamford *et al.* 2015).

Table 3. Watershed sub-basins utilized for summarizing critical habitats assessments and information gaps within Arctic Grayling core areas of the upper Peace Basin, British Columbia.

Core area	**Sub-basin**	**Watershed area (km^2)**	**Stream order**
Parsnip	Misinchinka River	595	4
Parsnip	Colbourne Creek	289	4
Parsnip	Reynolds Creek	366	5
Parsnip	Firth Creek	95	3
Parsnip	Anzac River	1,044	5
Parsnip	Bill's Creek	122	5
Parsnip	Table River	504	5
Parsnip	Hominka River	433	5
Parsnip	Missinka River	434	5
Parsnip	Wichcika Creek	182	5
Parsnip	Arctic Lake	31	-
Parsnip	***Parsnip total***	***5,612***	***6***
Nation	Philip Creek	764	4
Nation	Munro Creek	189	3
Nation	Rainbow Creek	232	4
Nation	Sylvester Creek	288	4
Nation	Suschona Creek	164	4
Nation	***Nation Total***	***6921***	***6***
Omineca	Mesilinka River	3298	6
Omineca	Lay Creek	304	5
Omineca	Osilinka River	2113	5
Omineca	Tenakihi Creek	341	4
Omineca	Silver Creek	403	4
Omineca	Ominicetla Creek	606	4
Omineca	Carruthers Creek	231	4
Omineca	***Omineca Total***	***7,928***	***6***
Ingenika	Wrede Creek	527	5
Ingenika	Swannell River	1053	5
Ingenika	***Ingenika Total***	***5329***	***7***

Table 3 (continued).

Core area	Sub-basin	Watershed area (km^2)	Stream order
Lower Finlay	Pesika Creek	721	4
Lower Finlay	Warneford River	1012	5
Lower Finlay	Fox River	1853	6
Lower Finlay	***Lower Finlay Total***	***9803***	***7***
Upper Finlay	Fishing Lakes	49	-
Upper Finlay	Toodoggone River	7367	5
Upper Finlay	Firesteel River	1690	6
Upper Finlay	Unknown Trib, 239-727000	1	1
Upper Finlay	***Upper Finlay***	***7367***	***5***
Upper Peace	Stott Creek	33	3
Upper Peace	Schooler Creek	269	4
Upper Peace	Carbon Creek	799	6
Upper Peace	Eleven Mile Creek	216	5
Upper Peace	Seven Mile Creek	78	4
Upper Peace	Nabesche River	843	5
Upper Peace	Pardonet Creek	64	4
Upper Peace	Ducette Creek	188	5
Upper Peace	Clearwater Creek	629	5
Upper Peace	Point Creek	100	4
Upper Peace	Bernard Creek	107	3
Upper Peace	Selwyn Creek	153	4
Upper Peace	Wicked River	397	5
Upper Peace	***Peace Reach Total***	***5896***	***8***

Table 3 (continued).

Core area	Sub-basin	Watershed area (km^2)	Stream order
Williston	Weston Creek	101	3
Williston	Scott Creek	210	4
Williston	Six Mile Creek	126	3
Williston	Patsuk Creek	63	3
Williston	Kimta Creek	37	3
Williston	Cut Thumb Creek	145	4
Williston	Tony Creek	108	3
Williston	Tutu Creek	53	3
Williston	Mugaha Creek	205	5
Williston	Mischinsinlika Creek	233	5
Williston	Blackwater River	489	5
Williston	Manson River	1515	5
Williston	Fries Creek	71	3
Williston	Strandberg Creek	146	3
Williston	Ospika River	2972	6
Williston	Lafferty Creek	182	3
Williston	Collins Creek	122	3
Williston	Davis River	483	5
Williston	Chowika Creek	477	5
Williston	***Finlay+Parsnip reaches***	***7738***	-

Records of sampled Arctic Grayling within the LRDW were then utilized to evaluate whether the presence of the species within the watershed sub-basins also indicated the presence of critical habitats, and for which life stage. Indicators of critical habitats for Arctic Grayling fry and juveniles included: 1) the presence of grayling <100 mm and <200 mm, respectively; and 2) a relatively high frequency of occurrence. Adult and subadult grayling critical habitats were indicated by: 1) a relatively high frequency of occurrence of fish >200 mm when sampling frequency was deemed adequate, and when suitable sampling techniques were employed; and 2) indications of habitat use in radio telemetry records.

There are a number of reasons why LRDW records may under-represent Arctic Grayling distribution within core areas, including: i) sampling methods or approaches which do not reliably detect the presence of grayling, ii) low replication of sampling sites, iii) non-random/non-systematic distribution of sampling sites, and iv) sampling programs which do not have Arctic Grayling as their focus (Stamford *et al.* 2015). Consequently, we included past sampling effort directed at all species to identify reaches where Arctic Grayling were not found and gain perspective on their distribution relative to other species within the watershed sub-units. Based on our assessment of the sampling effort, we used professional judgment to assign high, medium, or low levels of ‘sampling adequacy’ to each of the identified critical habitats. For example, critical habitats identified with multiple sampling sites including relatively recent sampling, and/or targeting Arctic Grayling, would be considered to have high information adequacy. Critical habitats identified from a single sampling site, or sampling from the pre-collapse period, would likely be considered to have low information adequacy. Low levels of sampling adequacy in estimated critical habitats, and unknown critical habitats where sampling effort is low or non-existent are potentially important information gaps in our analysis (see Section *5.0*).

Biological data linked to the LRDW fish observation points provided a good starting point for identifying Arctic Grayling critical habitats, and was essential for identifying key references for follow-up. However, it was typical that these data were incomplete relative to written reports (e.g. missing body size and/or abundance data). In almost every case, key references had to be acquired and read manually. Key references in report form had usually been uploaded to the BC Government’s Aquatic Reports Catalogue (http://a100.gov.bc.ca/pub/acat/public/welcome.do), or the Peace/Williston Fish and Wildlife Compensation Program (PWFWCP) report series (https://www.bchydro.com/pwcp/reports.html). In some cases, however, reports had not been uploaded or data were available only in raw form, which required special information requests within the BC Ministry of Environment, or from the personal files of colleagues.

In this report, we define limiting factors to be those that affect Arctic Grayling population productivity (Section *2.3*). Effective enhancement and conservation actions must be specific and target a limiting factor(s), and aim to achieve the FWCP program goal of improving the productivity of critical habitats. To confidently identify the effect of a limiting factor on population productivity, however, detailed monitoring data are frequently required. An exception to this is where critical spawning and juvenile rearing habitats were eliminated by flooding of the reservoir so associated limiting factors responsible for the losses of populations are more obvious. As a consequence, detailed analysis of potential limiting factors within critical habitats is not provided in this report, and our assessment has been made at the larger scale of the Williston watershed (Section *2.3*).

We recognize that in some cases multiple study techniques are needed to address different aspects of the same information gap. For example, to fully understand population structure, studies may be required that examine: 1) how individuals currently move between critical habitats to carry out their life history (e.g. radio telemetry, otolith microchemistry), 2) gene flow between sample groups (e.g. genetic divergence between spawning groups), 3) physical restrictions to current movements and gene flow (distribution data around natural migration barriers), and 4) the deeper ancestry giving rise to current populations (e.g. patterns of post-glacial dispersal possibly linked to larger divergence or distinct phenotypes). Furthermore, improvements and innovations in study methodologies are to be expected over time. Arctic Grayling study techniques proposed in future should be permitted to vary according to 1) the experience and capacity of individuals involved, 2) budget considerations, and 3) innovations in study methodologies. In Section *5.0*, therefore, we do not always specify a particular study methodology corresponding to each data gap, but rather suggest appropriate types of studies and provide examples. We assume that the ability to identify a feasible and effective study methodology, from within a general study type category, is a reasonable requirement from study proponents during proposal writing. This flexibility will promote innovation and efficiency.

5.0 SYNOPSIS BY CORE AREA

5.1 Parsnip core area

5.1.1 Overview of existing information

When interpreting the results of previous studies to delineate critical habitats for fish species, it is important to recognize that 1) fish of a given life stage may be present only at certain times of year, and 2) the probability of detecting these fish may be low even if they are present at the time of sampling. Furthermore, if the distribution of critical habitats is patchy within a watershed, identifying them may require a relatively high level of sampling replication (i.e. more than just one site per stream). Studies that are of particularly high value for identifying critical habitats for broadly distributed species like Arctic Grayling include: 1) studies that target the species of interest (and take into account their life history) and 2) inventory studies that have a broad geographic scope.

The Parsnip core area has received more grayling-focused studies than any other conservation unit in the upper Peace Basin, and inventory and other studies have resulted in widespread sampling (Figure 2). Of particular relevance was a critical fish habitats study in the Parsnip and Pack river watersheds conducted in 2015 by McLeod Lake Indian Band (Hagen *et al.* 2015), which we were able to utilize extensively when identifying Arctic Grayling habitat in the Parsnip River watershed for multiple life stages.

A substantial number of studies have targeted Arctic Grayling life history, migration behaviour, habitat use, and population structure. These have been primarily focused on the Table and Anzac sub-basins and reaches of the Parsnip River mainstem located close to these tributaries (Cowie and Blackman 2012a). Study methods targeting Arctic Grayling have included radio telemetry, Reconnaissance Level Stream Surveys, Level 1 Fish Habitat Assessments, electrofishing surveys, beach seining, snorkeling surveys, and visual observations on foot. Study results have developed a relatively good picture of Arctic Grayling life history and critical habitats for the Table and Anzac populations. Fry initially rear in habitat downstream of the putative spawning locations, then move downstream toward or within the Parsnip River over the summer (Blackman and Hunter 2001; Blackman 2002b). After their first summer 0+ grayling appeared to overwinter in lower reaches of larger tributaries (i.e. Table, Anzac rivers) as well as the Parsnip River. In these studies few age-1+ grayling have been sampled in tributaries, but age-1+ have been sampled extensively in the turbid Parsnip River. A widely distributed and clumped distribution suggests Arctic Grayling move in schools among rearing locations during their second and possibly their third summers (Zemlak and Langston 1996; Mathias et al. 1998; Blackman 2002a; Blackman 2004; Cowie and Blackman 2012; Mackay and Blackman 2012). An important radio telemetry study found that adult grayling moved into various locations in the Parsnip River mainstem to over-winter, then moved to various other locations, including the Parsnip, Anzac, and Table rivers as well as other tributaries during spawning time (Blackman 2002b). After spawning, most adults returned to the same locations where they were tagged the previous summer, which suggest they home to summer feeding habitats.

For the purposes of our analysis, there was a general lack of information about Arctic Grayling life history, migration behaviour, habitat use, and population structure for areas outside of the Table and Anzac rivers and the adjacent sections of the Parsnip River. Consequently, the basis for delineating critical habitats for these other populations came from inventory studies. Arctic Grayling records for the Reynolds Creek, Firth Creek, Bill's Creek, Hominka River, Missinka River, Wichcika Creek, and Arctic Lake sub-basins (Table 3), as well as other areas of the Parsnip River mainstem, were relatively rare, and available from some of the same sources utilized to delineate Bull Trout critical habitats. These were: 1) inventory studies related to dam construction (Langston and Blackman 1993) and a proposed McGregor River diversion project (Anonymous 1978), 2) watershed-wide 2005 inventory sampling focused on the distribution of Arctic Grayling fry (LRDW 2005), which was of particular value, and 3) Reconnaissance (1:20 000) Fish and Fish Habitat Inventory within the Missinka sub-basin (Triton 1999).

Unfortunately, fish sampling data were not available with some older records of grayling in the Misinchinka River and Colbourne Creek sub-basins (LRDW 1977), and for a record at the mouth of the Pack River watershed (LRDW 1971). These records were utilized to delineate uncertain critical habitats within these sub-basins but more sampling is needed to confirm their accuracy.

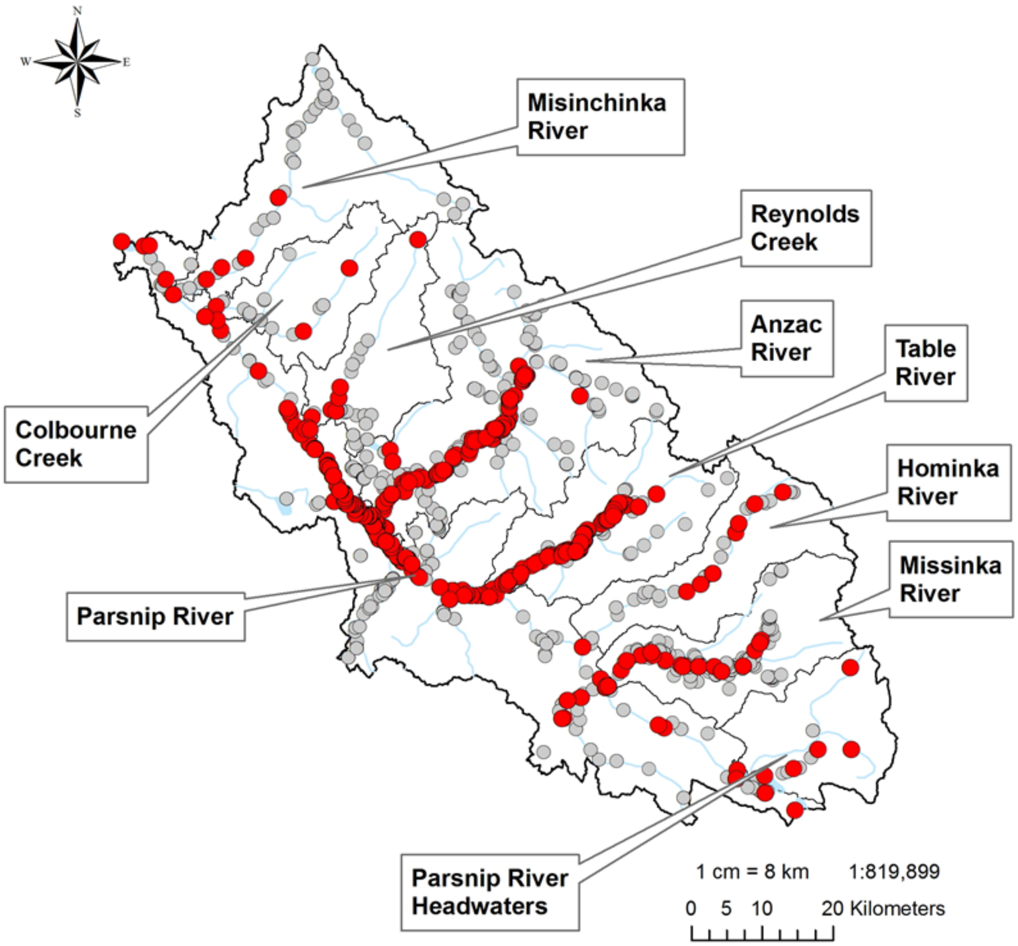

Figure 2. Distribution of records for past sampling of Arctic Grayling (red circles) and all other species (light grey circles) within sub-basins of the Parsnip core area.

5.1.2 Conservation status and risk assessment

Distribution. Distribution of Arctic Grayling within the Parsnip core area has been categorically estimated by Stamford *et al.* (2015) to be 40-200 km (category *C*; Appendix 1). The distribution of grayling within the core area is relatively well understood in the Table and Anzac watersheds and the mainstem Parsnip River in the vicinity of these streams and downstream. However, grayling distribution and habitat use are poorly understood in other areas of the watershed. Several important data gaps with regards to Arctic Grayling distribution within the Parsnip core area are identified in the following section (*5.1.3 Critical habitats*).

Abundance. Adult population size within the Parsnip core area was categorically estimated to be 1,000-2,500 adults (category *D*; Appendix 1), largely based on snorkeling counts of substantial populations in the Table and Anzac rivers (Cowie and Blackman 2012a). The relative importance (i.e. population size) of other local populations (e.g. Missinka sub-basin) is unknown, which constitutes an important data gap affecting both conservation status assessment and planning for enhancement actions (Data gap *5.1.2a*; Table 4). Snorkeling surveys of the Missinka River system, ideally calibrated by mark-recapture (e.g. Slaney and Martin 1987; Mathias et al. 1998; Zemlak and Langston 1998; Hagen and Baxter 2005), would provide comparable data to that collected so far for the Table and Anzac systems, and may identify a second hub of grayling abundance within the Parsnip core area.

Trend. With respect to the assessment of abundance trend within the core area, an important FWCP population monitoring program was developed for adult rearing reaches of the Table and Anzac rivers (Cowie and Blackman 2012a), and was implemented over the 1995-2007 period (Figure 3). Despite evidence of a stable trend in the Table and Anzac systems up to 2007, the categorical estimate for the core area was estimated to be ‘declining’ (category *D*; Appendix 1). This is due largely to evidence that, of 8 streams where fry rearing has previously been identified, the distribution hub for fry rearing remain in only three streams (Table, Anzac, Missinka) while in other tributaries declines have occurred. Although pre-reservoir information is sparse, comparing data collected in 1975 (Bruce and Starr 1985) and 1988 (Langston and Blackman 1993) suggest that a range contraction occurred in the mid-1980s. LRDW (2015) records suggest Arctic Grayling may have disappeared from numerous tributaries that now drain into Parsnip Reach and lower Parsnip River including larger tributaries (e.g. Misinchinka River, Colbourne Creek; Hagen et al. 2015).

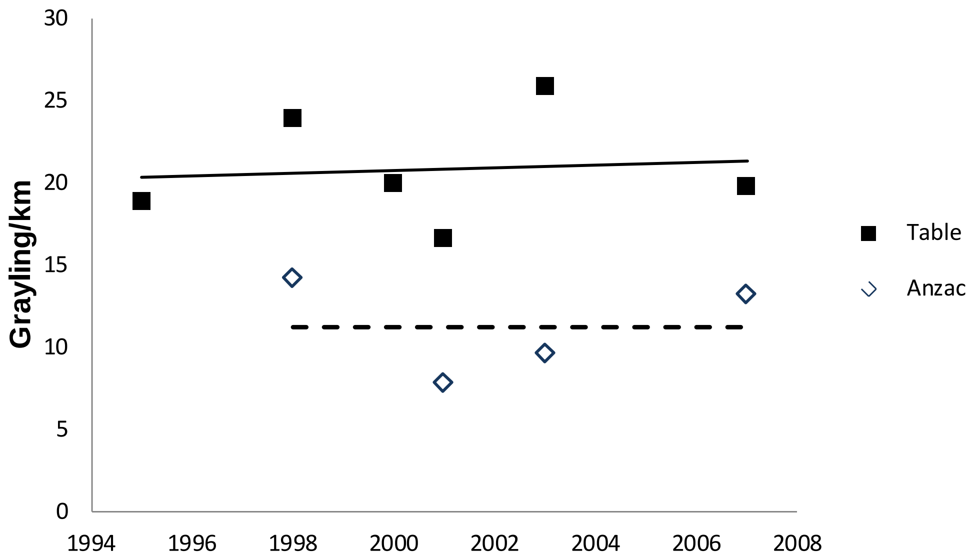

Figure 3. Estimated density of adult Arctic Grayling in index sections of the Table (closed squares) and Anzac (open diamonds) rivers, monitored using snorkeling surveys over the 1995-2007 period (reprinted from Stamford et al. 2015).

Given the relatively high sensitivity of Arctic Grayling to various threats (Section *2.3 Population limitation*), and the serious conservation situation for the species adapting to the reservoir environment, regular monitoring of abundance is warranted within the Parsnip watershed. Density estimates have not been collected since 2007 and is a data gap of high immediacy (Data gap *5.1.2b*; Table 4). The information shortfall can be addressed through the resumption of the grayling monitoring program within the Anzac and Table Rivers, using the same or comparable swim count methodology to that employed prior to 2007 (e.g. Cowie and Blackman 2012a; Mathias et al. 1998; Zemlak and Langston 1998). As identified in Section 2.3, there is a general need for a coordinated grayling monitoring plan across the Williston watershed to assess potential limiting factors, such as fry recruitment success, water temperature, competition, predation, and the sustainability of angling regulations. Knowing trends in adult abundance data measures the influences, relative importance of limiting factors on long-term persistence of grayling populations.

Threats. Threats were estimated to be of moderate scope and severity (category *B*; Appendix 2). This assessment was based on observed habitat impacts related to: flooding and loss of critical juvenile rearing habitats for lower Parsnip River tributaries; habitat degradation from extensive logging; associated exploitation threats resulting from access roads; and habitat degradation and exploitation threats associated with impending pipeline developments (Stamford et al. 2015). The lack of a detailed, quantitative assessment of threats is an information gap that limits the ability to prescribe conservation actions (Data gap *5.1.2c*; Table 4). As described in Section *2.3.6*, a more quantitative, GIS-based assessment of threats is possible using indicators of cumulative effects on aquatic ecosystem health (e.g. Hagen et al. *in prep.*), and the BC Government's Fish Habitat Assessment Procedures (Johnston and Slaney 1996) also provide a potential mechanism for quantifying forestry-related and other threats to stream habitat (e.g. Mathias et al. 1998). These potential studies are probably of low immediacy for FWCP given that the regulation of threats upstream of reservoir influence is the responsibility of the BC Provincial Government.

Table 4. Data gaps limiting conservation status and risk assessments for Arctic Grayling within the Parsnip core area, and potential studies to address them.

ID	Sub-basin(s)	Data gap	Potential study(s)	Immediacy
na	Parsnip mainstem	***Distribution*** . Poor understanding of grayling distribution outside of the Table, Anzac, and lower Parsnip reaches	*See Table 6*	-
5.1.2a	All except Table, Anzac	***Abundance*** . Unknown adult population size/relative importance of watersheds outside of the Table, Anzac systems	Adult population abundance indices (e.g. snorkeling counts, angling CPUE, mark-recapture)	Moderate[1]
5.1.2b	Table, Anzac (Missinka, Hominka)	***Trend*** . Lack of annual abundance monitoring since 2007	Swim count methodology within index sections of Table, Anzac systems (Cowie and Blackman 2012). Possibly include upstream tributaries for concordant data.	High
5.1.2c	All	***Threats*** . Lack of a detailed, quantitative assessment of threats	GIS-based assessment of aquatic ecosystem health indicators of cumulative effects (road density, etc.); Fish Habitat Assessment Procedures	Low

[1]In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions

Conservation status and risk assessment. The categorical estimates for the four conservation status indicators, when factored together (see Appendix 3), corresponded to a ranking of *C2-At Risk* (Stamford *et al.* 2015). According to this ranking, Arctic Grayling of the Parsnip core area are "at moderate risk of extirpation (within the next 100 years) due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors" (Appendix 3).

5.1.3 Critical habitats

Within the Parsnip core area, we delineated 20 stream sections providing critical habitats for at least one Arctic Grayling life stage (fry, juvenile, subadult/adult rearing, overwintering), largely based on the critical fish habitat analysis of Hagen *et al.* (2015). Critical habitats for

Arctic Grayling were distributed among all 12 sub-basins identified within the Parsnip River watershed (Table 5; Figure 4).

The Parsnip River mainstem provides critical habitat for all Arctic Grayling life stages, for spawning, fry (age-0+) and juvenile (1+, 2+) rearing, and subadult and adult migration (among seasonal habitats, possibly some rearing) and overwintering for all life stages (Table 5; Figure 4). Arctic Grayling juveniles (<200 mm) within this core area are found primarily along the Parsnip River mainstem, where they reside year-round probably close to overwintering locations. Adult and juvenile (including fry) Arctic Grayling habitat use within the Parsnip mainstem is poorly understood upstream of the Table River (Data gaps *5.1.3a*, *5.1.3b*; Table 6, Figure 5), but critical habitats likely include mainstem sections downstream of the Missinka River (Figure 4). These data gaps could be addressed through habitat use studies targeting adult and juvenile life stages (Table 6). Examples of appropriate study methodologies for the mainstem environment include radio telemetry (e.g. Blackman 2002a) and beach seining (e.g. Blackman and Hunter 2001; Blackman 2002c; Mackay and Blackman 2012), respectively, which were utilized for comparable research conducted in the vicinity of the Table and Anzac Rivers. Addressing data gaps *5.1.3a* and *5.1.3b* should be considered of moderately high immediacy, because a complete picture is currently not available for population structure, life history, critical habitats, and relative abundance when considering the scale of the entire core area (i.e. are Missinka River grayling demographically independent from downstream populations?). For instance, second summer (1+) habitat is distinct and might often be a survival bottleneck limiting recruitment success in Williston grayling core areas, and influence metapoulation structure (e.g. gene-flow among subpopulations).

The delineation of critical Arctic Grayling habitats within the Misinchinka River and Colbourne Creek sub-basins is based on poor information from 1977 sampling (LRDW 1977: sampling details unavailable). It is currently unknown whether Arctic Grayling are utilizing these systems, as subsequent sampling has not detected their presence (Table 5, Figure 4). This data gap (data gap *5.1.3c*; Table 6, Figure 5) is significant because it affects potential planning of conservation and restoration activities aimed at Arctic Grayling recovery for the Parsnip watershed as a whole. It could be effectively addressed with habitat use studies targeting both juvenile (including fry) and adult life stages within the Misinchinka and Colbourne sub-basins. Potential fish sampling methods for Arctic Grayling fry surveys include electrofishing, visual observations, fine-meshed seines, and small dipnets (e.g. Zemlak and Langston 1998; Mathias et al. 1998; Blackman 2004), while juvenile grayling (most likely to be using downstream reaches of these systems and the lower Parsnip River mainstem) can be sampled using a beach seine methodology (e.g. Blackman and Hunter 2001; Mackay and Blackman 2005). Snorkeling surveys (e.g. Zemlak and Langston 1998; Mathias et al. 1998), and angling are known to be reliable sampling methods for adult Arctic Grayling, at the appropriate time of year and under suitable visibility conditions (Table 6). These studies should employ adequate replication to ensure that even low densities of grayling would be detected (if present), ensure collection of appropriate physical habitat data (Johnston and Slaney 1996; BC FISB 2002), and would be of high immediacy given the serious conservation situation for these sub-basins (potentially extirpated).

Potential recolonization of the Misinchinka and Colbourne sub-basins, through persistent downstream dispersal from other Parsnip locations, is possible. However, recolonization in the Parsnip core area through natural dispersal might be limited if the grayling exhibit high site fidelity to natal areas (i.e. spawning and early rearing) in upstream tributaries [10, 11] (Shrimpton *et al.* 2012). Conservation and enhancement actions that facilitate range expansion are possible, however, but would need to address those limiting factors associated with productivity of critical habitats (e.g. habitat requirements, competition, predation; Table 1). The main distribution of Williston Arctic Grayling is currently among larger streams (i.e. fourth order and larger; Williamson and Zimmerman 2004, 2005) and fry rearing habitats are usually located some distance upstream from the reservoir (Hawkshaw et al. 2013). It appears that passive downstream dispersal from natal areas by juveniles during the first and second summer into fluvial summer and winter habitats is critical for survival of fluvial Arctic Grayling populations (see Section *2.3 Population limitation*). The relatively short lengths of the Parsnip River mainstem downstream of the Misinchinka and Colbourne mouths may currently be insufficient, or unsuitable. Alternatively, or concordantly, disturbances to natal areas further upstream (e.g. EDI 2002), including increased competition and predation on larvae and fry might have resulted in recruitment failure (e.g. rainbow trout and Bull Trout abundance might have increased after flooding).

Sampling of Arctic Grayling fry in Reynolds Creek suggests the presence of a self-sustaining local spawning population (Table 5, Figure 4). Arctic Grayling fry have been found in the relatively small Firth Creek, Bill’s Creek, and Wichcika Creek sub-basins, and far enough upstream (1.7 km to >10 km upstream) to indicate that spawning occurs in these watersheds as well (Table 5; Figure 4). However, habitat use and abundance of adult grayling within all of these systems are unknown (data gap *5.1.3d*; Table 6, Figure 5). This data gap could be addressed in each of these systems by summer habitat use studies targeting adult grayling,

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[10] Impressions from field work suggest Arctic Grayling upstream might be locally adapted to different ecological conditions (Brian Blackman pers. comm. 2014), which might suggest additional Core Areas could be recognized with further study.

[11] Higher levels of population subdivision in the larger Core Areas (Parsnip and Finlay) might reflect lower relative impacts from flooding compared with the smaller streams (e.g. Mesilinka, Osilinka, Ingenika; Shrimpton and Clarke 2012). Alternatively, different hydrological features (e.g. turbid mainstem, gradient) might promote different levels of population subdivision within Core Areas.

utilizing adequate replication/coverage to permit estimates of abundance for the watershed (Table 6), and should probably be considered to be of moderate immediacy. Suitable fish sampling methods for these clear streams would include snorkeling surveys and angling (e.g. Zemlak and Langston 1998; Mathias et al. 1998).

The Anzac River and Table River sub-basins comprise an important hub of post-Williston Reservoir Arctic Grayling distribution in the Parsnip River watershed. These two sub-basins have been the subjects of the majority of grayling-specific study that has been conducted in the Parsnip core area, and life history, migration behaviours, critical habitats, and relative abundance have all been described in detail (Table 5; Figure 4). Furthermore, Level 1 Fish Habitat Assessments have indicated areas of potential forestry-related habitat degradation within the Table River sub-basin (Mathias *et al.* 1998; Zemlak and Langston 1998). As mentioned in the previous section, regular monitoring of grayling abundance is warranted within the Parsnip core area, given the serious conservation situation for the species caused by major declines following the formation of Williston Reservoir. The lack of population abundance monitoring since 2007 within the Anzac and Table Rivers has been identified as a data gap of high immediacy, for which a swim count methodology (e.g. Zemlak and Langston 1998; Mathias *et al.* 1998; Blackman and Hunter 2001; Cowie and Blackman 2012a, b) has already been developed (Section *5.1.2*, data gap *5.1.2b*; Figure 5).

The Hominka River sub-basin appears to be utilized by a population of Arctic Grayling spawners, as a single fry was captured more than 20 km upstream (Table 5; Figure 4). Such low fry density does not indicate a substantial spawning population, but the importance of the stream for adult and subadult grayling rearing is unknown. This data gap could be addressed by a summer habitat use study targeting adult grayling, utilizing snorkeling and/or angling as potential sampling methods (e.g. Zemlak and Langston 1998; Mathias *et al.* 1998). Given the trends found in other core areas (e.g. Nation River) and upper Missouri River (e.g. Kaya 1990) where range contractions include declines from tributaries and headwaters, moderately high immediacy should be given to this system because it is an important indicator for Arctic Grayling productivity in the core area (data gap *5.1.3e*; Table 6, Figure 5). Although few fry in previous sampling efforts suggest marginal habitat, recruitment from natal areas might vary among years but still provide significant components to the Parsnip adult population, and might not spawn every year. Alternatively, abundance of fry around marginal natal areas might correspond with years of high spawning activity in surrounding areas (e.g. Missinka, Parsnip rivers), which can push younger adults into marginal spawning areas (Tack 1980). Monitoring concordant trends in abundance among Parsnip tributaries may be important for understanding metapopulation productivity and core area conservation status.

The Missinka River sub-basin is known, with relatively high confidence, to be utilized by all life stages and is likely a self-sustaining Arctic Grayling population (Table 5; Figure 4), and (possibly together with Hominka basin) may be a second hub of Arctic Grayling distribution in the Parsnip River watershed (in addition to Table/Anzac watersheds). Parsnip grayling show genetic distinctions among adults rearing in tributaries (Anzac, Table, and Missinka sub-basins, Shrimpton *et al.* 2012). This suggests that migratory behaviours and habitat use might also be distinct among local populations, even though Clarke *et al.* (2015) found that movements of individuals through their life span varied widely among adults collected from any given basin (e.g. Table, Anzac basins).[12] Observations in the field also suggest movements might be especially distinct upstream of the Table River (Brian Blackman, retired PWFWCP biologist, pers. comm. 2014). Better knowledge is required about migratory behaviour, population structure, and relative importance (abundance) of the populations using the upstream tributaries, in order to assess the need for conservation actions or opportunities for enhancement (data gaps *5.1.3g, 5.1.3h, 5.1.3i*, respectively; Table 6, Figure 5). These data gaps should be considered of moderately high immediacy, and potential study methodologies include: 1) adult movement studies employing radio telemetry (e.g. Blackman 2002b) or otolith microchemistry (e.g. Clarke et al. 2005), 2) population structure studies employing genetic analysis (e.g. Stamford and Taylor 2005; Shrimpton and Clarke 2012); and 3) adult abundance monitoring studies employing snorkeling surveys calibrated by mark-recapture (e.g. Zemlak and Langston 1998; Mathias *et al.* 1998) as a fish sampling method (Table 6).

Arctic Grayling were captured in Arctic Lake in 1978, but the extent of lake use is unknown (Table 5; Figure 4). It is possible, for example, that the population is primarily fluvial and utilizing the lake outlet area because of growth and survival benefits during spawning and early rearing life phases. This uncertainty, combined with the lack of more recent sampling, does not permit current critical habitats to be delineated with confidence. An adfluvial population would represent a significant component of the overall diversity within the Parsnip watershed, given that life history adaptations in Arctic Grayling frequently have a genetic basis. Resolving uncertainty about life history, critical habitats, and abundance for this population would require inventory studies targeting both lake and stream environments, and both juvenile and adult life stages (Data gap *5.1.3i*; Table 6, Figure 5). This data gap is of low immediacy.

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[12] Some were resident while others moved widely among adjacent streams (Clark et al. 2015).

Table 5. Critical habitats delineated for Arctic Grayling populations inhabiting sub-basins of the Parsnip core area (adapted from Hagen et al. 2015). Sampling methods EF, SN, VO, SW, GN, AN, and RT refer to electrofishing, seine netting, visual observation, swim counts, gillnetting, angling, and radio telemetry, respectively. ID numbers facilitate identification of critical habitats in Figures 4.

ID	Sub-basin	Reach	Life stage	Sampling methods	Information adequacy	UTM bottom; UTM top	Key reference(s)
1	Parsnip mainstem	Lower	Juveniles	SN, EF	Good	10 U 496205 6113471; 10 U 546738 6061936	Anonymous 1978; Murphy and Blackman 2012; Mackay and Blackman 2012; LRDW 2005 (PWFWCP unpublished)
	<u>Critical habitat comments</u>: Juveniles widely distributed in Parsnip mainstem between Table R and mouth, but clumped distribution; inadequate sampling upstream of Table River; fry and juveniles co-occur in some sites						
2	Parsnip mainstem	Upper	Juveniles	SN, EF	Poor	10 U 546738 6061936; 10 U 561820 6048346	Anonymous 1978; LRDW 2005 (PWFWCP unpublished)
	<u>Critical habitat comments</u>: Juveniles present below Missinka; sampling elsewhere inadequate to identify critical habitats; rearing in upper Parsnip River documented by catches at one location in 1977 only (very low abundance); very low adult use upstream of Missinka						
3	Misinchinka River	mainstem	na	na	Poor	10 U 502803 6106383; 10 U 515967 6115924	LRDW 1977; LRDW 2005 (PWFWCP unpublished); Langston and Blackman 1993
	<u>Critical habitat comments</u>: 1977 sampling details n/a; grayling not sampled in 1993 or 2005 despite significant effort						
4	Colbourne Creek	mainstem	na	na	Poor	10 U 507080 6103106; 10 U 524141 6103972	LRDW 1977; LRDW 2005 (PWFWCP unpublished)
	<u>Critical habitat comments</u>: 1977 sampling details n/a; grayling not sampled in 2005 despite significant effort						
5	Reynolds Creek	mainstem	Fry	EF	Good	10 U 520022 6085801; 10 U 525931 6092203	LRDW 2005 (PWFWCP unpublished)
	<u>Critical habitat comments</u>: >3000s electroshocking distributed among seven sites found only 10 GR fry; suggests low abundance. Fry found 11.9km upstream indicates spawning in stream						
6	Firth Creek	mainstem	Fry, Juvenile	EF	Good	10 U 525792 6076619; 10 U 524399 6076112	LRDW 2005 (PWFWCP unpublished)
	<u>Critical habitat comments</u>: Seven grayling records including fry and juveniles (68-90mm) collected and far enough upstream (2.6 km) to indicate spawning occurred in stream; lake headed tributary						
7	Anzac River	mainstem	Fry	EF	Good	10 U 526238 6075638; 10 U 541486 6081631	Blackman 2004; Cowie and Blackman 2012a
	<u>Critical habitat comments</u>: Extensive fry sampling and monitoring						
8	Anzac River	mainstem	Adult	AN, SW	Good	10 U 526238 6075638; 10 U 547728 6085389	Blackman and Hunter 2001; Blackman 2004; Cowie and Blackman 2012a
	<u>Critical habitat comments</u>: Adults move among locations including tributaries (e.g. Crocker Creek, North Anzac River) during summer so considered downstream limit as mouth. Upstream distribution limited by falls						
9	Anzac River	mainstem	Juveniles	SN, EF	Good	10 U 526238 6075638; 10 U 541486 6081631	Blackman and Hunter 2001; Blackman 2004; Cowie and Blackman 2012a
	<u>Critical habitat comments</u>: Juveniles rare in watershed, assume similar distribution to fry						
10	Anzac River	Destilda Creek	Fry, Adult	na	Poor	10 U 534315 6077955; 10 U 531943 6082465	LRDW 1977; Anonymous 1978
	<u>Critical habitat comments</u>: No recent sampling, potential spawning inferred from either presence of fry or spent adults						

Table 5, continued. Critical habitats delineated for Arctic Grayling populations inhabiting sub-basins of the Parsnip core area (adapted from Hagen et al. 2015).

ID	Sub-basin	Reach	Life stage	Sampling methods	Information adequacy	UTM bottom; UTM top	Key reference(s)
11	Bill's Creek	mainstem	Fry, Adult	EF	Fair	10 U 540561 6062762; 10 U 540158 6061619	Anonymous 1978; LRDW 2005 (PWFWCP unpublished)
	<u>Critical habitat comments</u>: Only one fry collected in 2005 but far enough upstream (1.7 km) to indicate spawning may have occurred in stream; lake headed tributary; no adult sampling effort (e.g. AN) found						
12	Table River	mainstem	Fry	EF	Good	10 U 545547 6061836; 10 U 560114 6070554	Zemlak and Langston 1998
	<u>Critical habitat comments</u>: Extensive fry sampling and monitoring						
13	Table River	mainstem	Adult	AN, SW, RT	Good	10 U 545547 6061836; 10 U 567666 6073730	Blackman 2002b; Cowie and Blackman 2012a
	<u>Critical habitat comments</u>: Adults move among locations including tributaries during summer so downstream limit considered to be mouth						
14	Table River	mainstem	Juvenile	EF, SN	Good	10 U 545547 6061836; 10 U 554367 6067036	Mathias et al. 1998; Zemlak and Langston 1998; Blackman and Hunter 2001
	<u>Critical habitat comments</u>: Juveniles rare in watershed, assume similar distribution to fry						
15	Hominka River	mainstem	Fry	EF	Good	10 U 558750 6054109; 10 U 572137 6061263	LRDW 2005 (PWFWCP unpublished)
	<u>Critical habitat comments</u>: Only one fry collected but far enough upstream (>20 km) to indicate spawning occurred in stream; significant sampling effort suggests low abundance						
16	Hominka River	mainstem	Adult	AN	Good	10 U 558750 6054109; 10 U 577686 6063661	LRDW 2005 (PWFWCP unpublished)
	<u>Critical habitat comments</u>: 2005 sampling captured two adults only by AN						
17	Missinka River	mainstem	Fry	EF	Good	10 U 561781 6048217; 10 U 578365 6049817	Triton Environmental Consultants, Ltd. 1999; LRDW 2005 (PWFWCP unpublished)
	<u>Critical habitat comments</u>: Many fry collected up to 18km upstream indicates spawning in stream						
18	Missinka River	mainstem	Adult	EF, AN, SW	Good	10 U 561781 6048217; 10 U 583229 6052577	Triton Environmental Consultants, Ltd. 1999; LRDW 2005 (PWFWCP unpublished)
	<u>Critical habitat comments</u>: Upstream distribution limited by falls. Adults and juveniles observed and sampled						
19	Wichcika Creek	mainstem	Fry	EF	fair	10 U 558238 6046963; 10 U 555396 6044115	Anonymous 1978; LRDW 2005 (PWFWCP unpublished)
	<u>Critical habitat comments</u>: Eight fry collected among three sites in 2005, furthest upstream >10km indicates spawning in stream; possible use of numerous lake headed tribs; high sampling effort suggests low abundance; inadequate sampling targeting juveniles, adults						
20	Arctic Lake		na	na	Poor	10 U 583771 6032384; 10 U 587947 6029830	Partial Lake Inventory 1965; Anonymous 1978
	<u>Critical habitat comments</u>: Present in Arctic Lake in 1977; extent of lake use unknown; possibly fluvial						

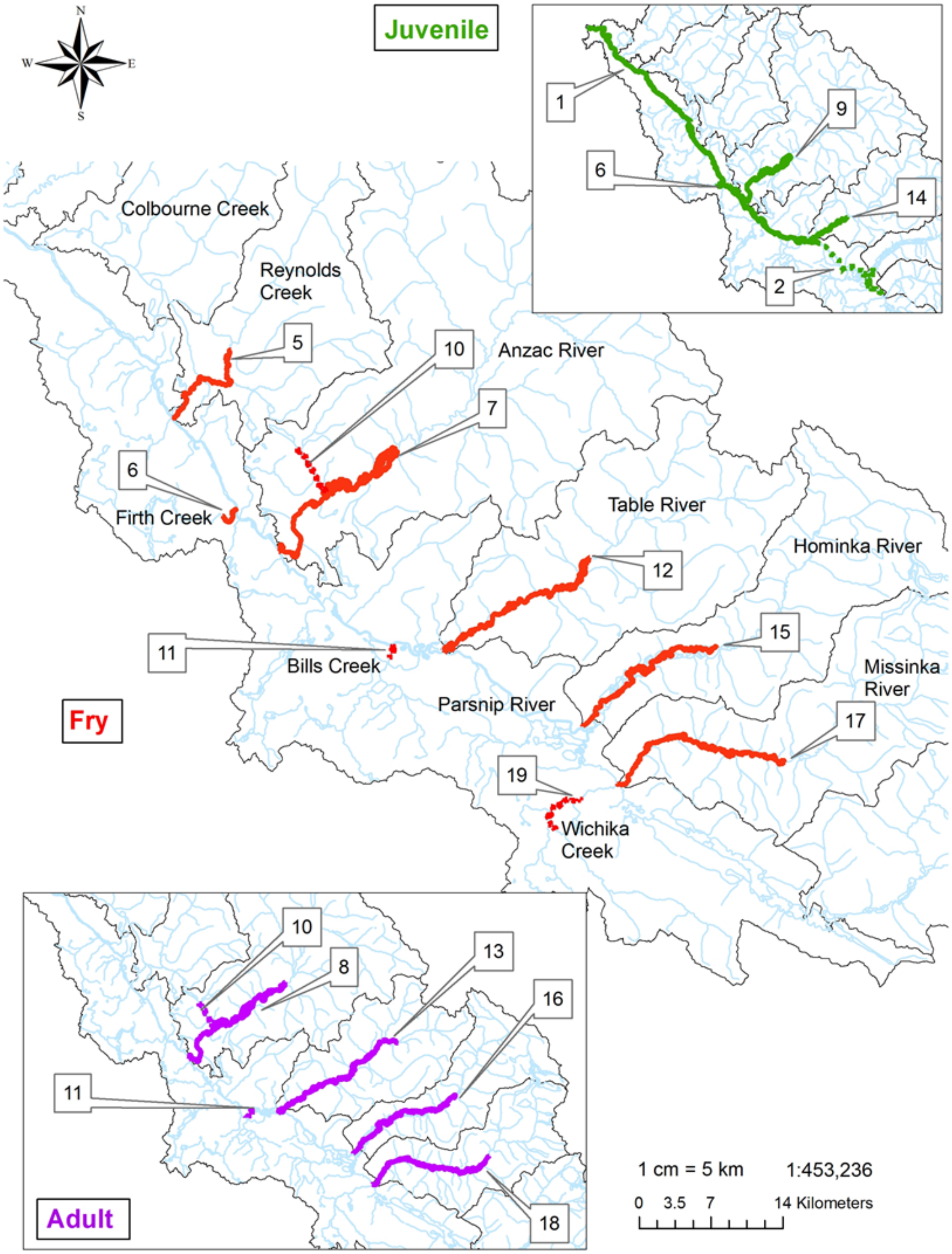

Figure 4. Critical habitats delineated for subadult/adult rearing (lower figure), fry (young-of year) rearing (middle figure), and juvenile (age-1+, age-2+) rearing (upper figure) for Arctic Grayling within sub-basins of the Parsnip core area. Continuous lines indicate good information adequacy, while dashed lines indicate fair or poor information adequacy. ID numbers correspond with critical habitats described in Table 5.

Table 6. Data gaps limiting assessments of critical habitats for Arctic Grayling within sub-basins of the Parsnip River watershed, and potential studies to address them.

ID	**Sub-basin(s)**	**Data gap**	**Potential study(s)**	**Immediacy**
5.1.3a, 5.1.3b	Parsnip mainstem	Poor understanding of 1) adult and 2) juvenile grayling habitat use in the Parsnip mainstem upstream of Table R	1) Adult movement studies (e.g. radio telemetry) and 2) juvenile sampling (e.g. beach seining), respectively	Moderate[1]
5.1.3c	Misinchinka, Colbourne	Unknown whether Arctic grayling are still utilizing these systems	Habitat use studies targeting both juvenile (e.g. electrofishing, visual observations, seines) and adult life stages (e.g. snorkeling, angling)	High
5.1.3d	Reynolds, Firth, Bill's, Wichcika	Unknown habitat use and abundance of adult grayling	Summer habitat use studies targeting adult grayling (e.g. calibrated snorkeling surveys)	Moderate
5.1.3e, 5.1.3f	Hominka	Unknown importance for: 1) adult, subadult, and 2) juvenile grayling rearing.	1) Summer habitat use studies targeting adult grayling (e.g. calibrated snorkeling surveys) and 2) juvenile sampling (e.g. electrofishing, seining).	Moderate
5.1.3g, 5.1.3h, 5.1.3i	Missinka	Better knowledge required of 1) migration behaviours, 2) genetic distinctness, and 3) relative importance (abundance) of this grayling population	1) Movement studies, 2) further genetic study, and 3) adult abundance monitoring studies, respectively	Moderate
5.1.3j	Arctic Lake	Uncertain life history, critical habitats, and abundance	Inventory studies targeting both lake and stream environments, and both juvenile and adult life stages	Low

[1]In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions

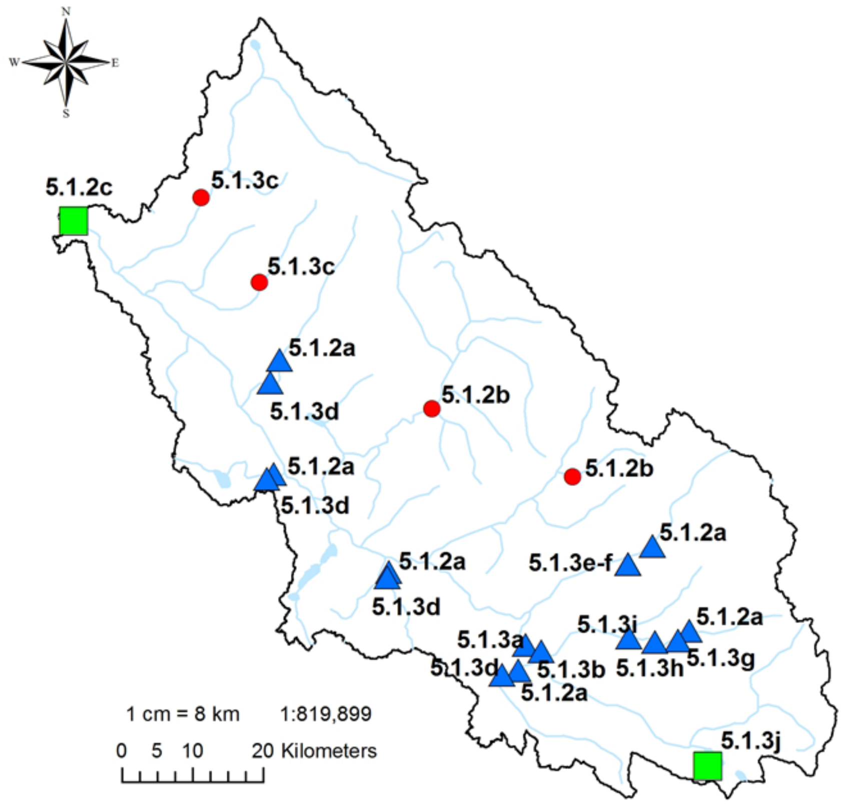

Figure 5. Locations within the Parsnip core area where data gaps limit understanding of conservation status and critical habitats for Arctic Grayling (high immediacy = red circles; moderate immediacy = blue triangles; low immediacy = green squares). Labels correspond with data gap IDs in Table 6.

5.2 Nation core area

5.2.1 Overview of existing information

Numerous inventories throughout Nation watershed, including Grayling-directed sampling for otolith microchemistry (Clarke et al. 2005), genetic (Stamford and Taylor 2005; Shrimpton and Clarke 2012), adult distribution (LRDW 1992), and fry distribution data (Cowie and Blackman 2007), suggest the Arctic Grayling distribution is restricted to stream reaches downstream of Chuchi Lake (Figure 6). While the distributions of fry and adult summer rearing habitats in the mainstem Nation River are known from adequate sampling data, data are very limited with respect to temporal changes in this distribution, the distribution of juveniles (<200mm), and the extents of tributary use (LRDW 1998; Hawkshaw and Shrimpton 2014). There are no data describing overwintering, spawning, abundance, and movements throughout the core area.

Distribution data indicates all life history stages of Arctic Grayling in the Nation River mainstem, and adults and fry rearing and spawning in tributaries. Overwintering for all life stages is assumed to be in the Nation River, but there are no data to validate this. Rearing areas in the Nation River appear to be associated with tributary confluences, especially for fry, and suggest they provide rearing and possibly spawning habitats (e.g. temperature, substrates; Cowie and Blackman 2007; Hawkshaw and Shrimpton 2014). Critical habitats in tributaries are based on only a few records of fry and adults during grayling-directed sampling (LRDW 1998; Hawkshaw and Shrimpton 2014) and their absence in stream and lake inventories (e.g. Burns and Philip 1978; Grant 1985b; Hunter 1996 a, b, c; Langston and McLean 1999; Langston 1999b) suggests the tributary reaches near Nation confluence are most important. Fry occur far enough upstream to indicate spawning in at least two lake headed tributaries (Philip River, Sylvester Creek) and spawning in other tributaries (Munro, Rainbow, Suschona creeks) is also possible. Historical records (and local knowledge) suggest Arctic Grayling were once more abundant in tributaries, and possibly the current distribution has contracted (and abundance declined) in the core area. The limiting factors associated with small tributary use and their influences on population productivity in the core area are poorly understood and an important data gap for Peace Basin (e.g. data gap *2.3.1 a*, *b*, *c*; Table 1). Interactions with other species (e.g. rainbow trout are abundant in tributaries) might also limit tributary use in the Nation River (e.g. data gaps *2.3.4*, *2.3.5*; Table 1).

The unknown ability for adults to move upstream past cascades in the middle river (i.e. upstream of Philip River; see Cowie and Blackman 2007) remains a major data gap with important conservation implications. Restricted access upstream promotes creation of demographically independent headwater grayling populations, and adult movements and abundance estimates are needed to determine if an additional core area exists upstream in Nation River (i.e. similar to Upper Finlay core area). Independent upstream populations (e.g. <10% of the population are immigrants; Hastings 1993) are not only of conservation concern but also provide unique opportunities to study Arctic Grayling population viability. For instance, fry rear in Nation River just upstream and downstream of the cascades (putative barrier; Cowie and Blackman 2007) and might suggest effective dispersal from upstream improves the viability downstream. Alternatively, habitats both upstream and downstream are sufficiently distinct and complex to sustain two demographically independent populations so movements past cascades are not required to sustain Nation grayling over the long term.

There is an absence of any directed sampling effort toward juveniles (1+) and the few records are incidental catches during electrofishing and angling. Rare occurrence of juveniles in the LRDW may not accurately reflect low relative abundance and restricted distribution in the mainstems of Nation and Philip rivers. Possibly, Nation River provides optimal growing conditions so especially large juveniles migrate into larger river habitats to rear together with adults earlier in life (e.g. during their second summer; Cowie and Blackman 2007).

Alternatively, juveniles rear in distinct but diverse habitats (e.g. boggy areas, ponds, stream margins, shallow riffles) and their rare occurrence in the mainstem reflect the limited sampling effort.

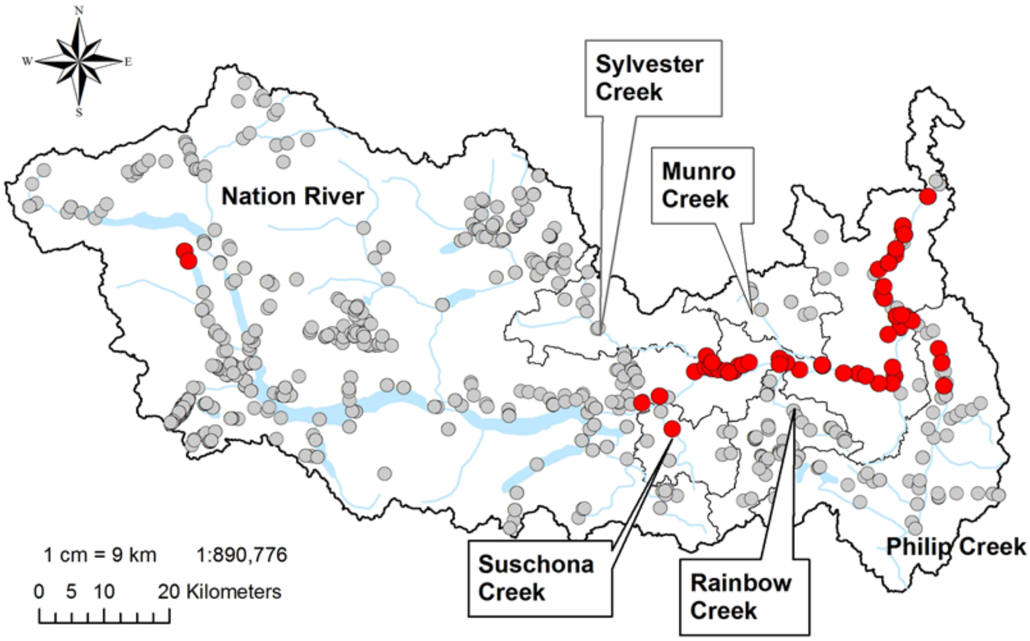

Figure 6. Distribution of records for past sampling of Arctic Grayling (red circles) and all other species (light grey circles) within sub-basins of the Nation core area.

5.2.2 Conservation status and risk assessment

Distribution: Distribution of Arctic Grayling within the Nation core area has been categorically estimated by Stamford et al. (2015) to be 40-200 km (category *C*; Appendix 1) and assumes a continuous distribution from the outlet of Chuchi Lake to Williston Reservoir (~90km). However, their distribution, habitat use, and movements past a series of cascades near Philip Creek are poorly understood and several data gaps are identified in the following section (*5.2.3 Critical Habitats*).

Abundance: Adult population size within the Nation core area was categorically estimated to be 250 -1000 adults (category *C*; Appendix 1), but the estimate was based on impressions from field observations (i.e. no adult abundance data were found; Stamford et al. 2015). This is an important data gap of high immediacy affecting both conservation status assessment and planning for enhancement actions (Data gap *5.2.2a*; Table 4). Snorkeling surveys in Nation River mainstem, ideally calibrated by mark-recapture (e.g. Slaney and Martin 1987; Mathias et al.

1998; Zemlak and Langston 1998, Hagen and Baxter 2005), may provide reliable estimates of abundance assuming suitable conditions. Given the possible restriction to movements imposed by cascades upstream of Philip Creek two sections are recommended to compare abundance upstream of the cascade (e.g. between Sylvester Creek and Munro Creek) and a downstream section of Nation mainstem. Understanding the movements of adults (e.g. radio telemetry, microchemistry) is also key to understanding demographic independence of Arctic Grayling upstream of the cascades.

Trend: Arctic Grayling in Nation River were categorically estimated to be declining (category *D*; Appendix 1) primarily due to an apparent range contraction from tributaries. For instance, historical records suggest Sylvester Creek once had abundant grayling (LRDW 1956) and local knowledge suggests both Suschona Creek and Sylvester Creek once provided good angling opportunities for Arctic Grayling (Langston and Zemlak 1996). More recent records in Munro Creek, Sylvester Creek, and Philip River indicate spawning and rearing for adults and fry continues in some tributaries (LRDW 1998; Cowie and Blackman 2007; Hawkshaw and Shrimpton 2014). Temporal sampling suggests, however, that fry rear mainly in the mainstem (LRDW 1998; Cowie and Blackman 1997; Hawkshaw and Shrimpton 2014). Impressions from field-work suggest the population has recovered from a 1992 removal of 87 adults (transplanted upstream to Calais Lake; Brian Blackman pers. com.).

Adult density estimates have not been collected from Nation River and is a data gap of high immediacy (Data gap *5.2.2b*; Table 7). The information shortfall can be addressed through a grayling monitoring program within two sections of Nation River, one located upstream and one downstream of the cascade near Philip Creek, using the comparable swim count methodology to that employed in Table and Anzac rivers (e.g. Cowie and Blackman 2012; Mathias et al. 1998; Zemlak and Langston 1998).

Threats: Threats were estimated to be of high scope and low severity (category F, Appendix 2). Scope was high due to the possible restricted movements imposed by cascades on the mainstem. Exploitation was considered significant and could explain the decline in abundance in tributaries in the upstream section of Nation River. Historical and current industrial developments were also identified significant and might limit recovery in tributaries. The associated linear developments increase the exploitation risk, and since adults likely home to rearing areas recovery potential is limited and might explain the currently rare tributary use. Similarly, competition with other species (e.g. Rainbow Trout) might limit range expansion into their historical range. Possibly, recovery from range contractions depends on dispersal from mainstem spawning population(s) into tributaries. Alternatively, observed fluctuating low abundance of fry rearing in tributaries might be due to variable recruitment success and generally low spawner abundance (e.g. adults might not spawn every year) in the core area during certain years. Currently, increased angler compliance to catch and release regulation, and geographic isolation (jet boat access only to most of the core area) has apparently decreased severity of exploitation from historical levels. Severity remains significant due to a possible restricted distribution upstream of cascades. Population numbers might be recovering (Brian Blackman pers com.; Cowie and Blackman 2007). Linear developments might be especially harmful to critical habitat in tributaries. Similar to Parsnip core area the lack of a quantitative assessment of threats is an information gap that limits the ability to prescribe conservation actions (data gap 5.2.2c, Table 7) and is described above (section 5.1.2).

Table 7. Data gaps limiting conservation status and risk assessments for Arctic Grayling within the Nation core area, and potential studies to address them.

ID	**Sub-basin(s)**	**Data gap**	**Potential study(s)**	**Immediacy**
na	Nation mainstem	***Distribution*** . Poor understanding of grayling distribution and movements past barriers and in and out of tributaries.	*see Table 9*	-
5.2.2a	Nation mainstem, upstream and downstream sections	***Abundance*** . Unknown adult population size.	Adult population abundance indices (e.g. snorkeling counts, angling CPUE, mark-recapture) estimated both upstream and downstream of cascades.	High[1]
5.2.2b	Nation mainstem, upstream and downstream sections	***Trend*** . Lack of annual abundance monitoring.	Swim count methodology within one upstream and one downstream index sections of Nation mainstem. Paired estimates to evaluate concordance.	High
5.2.2c	All	***Threats*** . Lack of a detailed, quantitative assessment of threats	GIS-based assessment of aquatic ecosystem health indicators of cumulative effects (road density, etc.); Fish Habitat Assessment Procedures	Low

[1]In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions

Conservation status and risk assessment: The categorical estimates for the four conservation status indicators, when factored together (see Appendix 3), corresponded to a ranking of *C2-At Risk* (Stamford et al. 2015). According to this ranking, grayling of the Nation core area are "at moderate risk of extirpation" (within the next 100 years) due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors" (Appendix 3).

5.2.3 Critical habitats

Within the Nation core area we delineated 16 stream sections estimated to provide critical habitat for at least one Arctic Grayling life history stage (fry, juvenile, subadult/adult, overwintering) and these were distributed among five sub-basins and two sections of the Nation River mainstem (Table 8, Figure 6).

Two mainstem sections provide critical habitat for all life history stages including fry, juvenile, and adult rearing, overwintering, and spawning (Table 8, Figure 6). All life history stages probably remain in the mainstem year round but adult movements and tributary uses are poorly understood. For instance, a series of cascades, which end upstream of Philip Creek, might restrict adult movements upstream (see Cowie and Blackman 2007 for putative barrier locations). Thus a demographically independent population might exist upstream between the cascades and Chuchi Lake outlet.[13] No studies have specifically examined possible divergence between putative populations living upstream and downstream of the cascades in Nation River. However, data from two independent genetic studies (Stamford and Taylor 2005 and Shrimpton et al. 2012) suggest that fish upstream of the cascade are especially divergent (isolated) compared with other Williston core areas, while adult fish collected from Philip Creek (i.e. downstream of the cascade) appear less divergent possibly linked to more recent gene flow with adjacent streams (e.g. Osilinka, Mesilinka; Omineca Core Area). Microchemistry analyses examined the adults rearing near Philip Creek, however, and could not rule out possible connections with rearing locations upstream of the cascades (Clarke et al. 2005). Even though cascades might restrict upstream movements, the downstream dispersal is possible (e.g. fry rear at the base of the cascades) and might provide recruitment to the downstream section.

Studies of movements of adults in the Nation River mainstem together with abundance monitoring in upstream and downstream sections will help assess potential demographic connections and vulnerability to threats (data gaps *5.2.3a*, *b*, *c*; Table 9).

Juveniles (i.e. <200mm) appear rare in the Nation River (Figure 7) but directed sampling is lacking and the few records are incidental catches during angling surveys (Table 8). Consequently, juvenile abundance and their distribution (e.g. do they occur in tributaries?) are poorly understood (data gap *5.2.3d*). As described above (Parsnip core area), appropriate study methodologies for the mainstem environment include radio telemetry (e.g. Blackman 2002a) and beach seining (e.g. Blackman and Hunter 2001; Blackman 2002c; Mackay and Blackman 2012), to examine movements and habitat use for adults and juveniles, respectively. Although juveniles appear to rear together with adults in Nation River mainstem, their habitat requirements are usually distinct and further sampling is needed to understand their distribution and abundance. Addressing data gaps *5.2.3a, b, c, d* should be considered of high immediacy to gain a complete

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[13] Adults previously observed upstream of Chuchi Lake were thought to be individuals returning (homing) to their native rearing areas after they were transplanted into Calais Lake, but a self-sustaining population does not appear to have been established (Langston 1999; Langston and McLean 1999; Cowie and Blackman 2007).

picture of population structure, life history, critical habitats, and relative abundance between upstream and downstream sections.

Nation grayling continue to spawn in at least two tributaries (Sylvester Creek, Philip River) and are reputed to spawn in others (Suschona Creek, Rainbow Creek, Munro Creek) but the extent to which they provide recruitment in the core area is poorly understood. Tributary confluences appear to provide optimal rearing conditions for dispersing fry derived from Nation mainstem spawning locations (Hawkshaw and Shrimpton 2014) and both fry and adults congregate at tributary confluences during the warmest summer periods (Cowie and Blackman 2007). It remains unclear, however, how many of the fry that accumulate at tributary confluences are derived from tributary spawners and how many are derived from mainstem spawning. It is also unclear if precise homing to natal areas (e.g. tributaries) is promoting higher levels of population subdivision within Nation River grayling. Sampling suggests spawning continues in upstream tributaries (e.g. Sylvester Creek) and Philip River appears to be an important recruitment source and rearing area for Arctic Grayling in the downstream section of Nation River (Table 8, Figure 7). A habitat use study(s) in tributaries aimed at all life history stages (as described in section *5.1.3*) is needed to confirm absence of Arctic Grayling use in some upstream tributaries (data gap *5.2.3e*; Table 9, Figure 8) and habitat use studies are needed to monitor and assess abundance of grayling life history stages in Sylvester Creek and the Philip River (data gaps *5.2.3f, g*).

Table 8. Critical habitats delineated for Arctic Grayling populations inhabiting sub-basins of the Nation core area. Sampling methods EF, SN, VO, SW, GN, AN, and RT refer to electrofishing, seine netting, visual observation, swim counts, gillnetting, angling, and radio telemetry, respectively. ID numbers facilitate identification of critical habitats in Figures X.

ID	Sub-basin	Reach	Life stage	Sampling methods	Information adequacy	UTM bottom; UTM top	Key reference(s)
1	Nation Mainstem	Lower	Adult	AN, SW	Good	10 U 464000 6147000; 10 U 418472 6117173	LRDW 1992; Langston and Blackman 1993; Clark et al. 2005; Cowie and Blackman 2007
	<u>Critical habitat comments</u>: Adults appear to move in and out of Philip Creek to rear.						
2	Nation Mainstem	Lower	Juvenile	AG, EF, SW, GN	Poor	10 U 464000 6147000; 10 U 458321 6128960	LRDW 1992; Langston and Blackman 1993; Clark et al 2005;
	<u>Critical habitat comments</u>: Juveniles present but appear rare compared with adults and fry; sampling methods focused on adults and fry, juveniles captured incidentally.						
3	Nation Mainstem	Lower	Fry	EF, SN	Good	10 U 456300 6136500; 10 U 455926 6118042	Langston and Blackman 1993; Cowie and Blackman 2007; Hawkshaw and Shrimpton 2014
	<u>Critical habitat comments</u>: Fry abundance appears higher downstream of Philip Creek; rearing locations seem to be consistent among years. Upstream range is among cascades; possibly drifting down from upper reach.						
4	Nation Mainstem	Upper	Adult	AG	Good	10 U 446588 6121888; 10 U 418472 6117173	LRDW 1992; Langston and Blackman 1993; Cowie and Blackman 2007
	<u>Critical habitat comments</u>: Population assumed to migrate between Chuchi Lake outlet and cascade barriers downstream. Independence between upper and lower reaches uncertain.						
5	Nation Mainstem	Upper	Juvenile	AG	Poor	10 U 446671 6121890; 10 U 440200 6122800	Langston and Blackman 1993; LRDW 1998 (Stamford 2000 unpublished); Hawkshaw and Shrimpton 2014
	<u>Critical habitat comments</u>: Juvenile abundance in samples rare relative to adults and fry but sampling limited, none targetting juvenile stage (e.g. SN); distribution might be wider.						
6	Nation Mainstem	Upper	Fry	EF, SN	Good	10 U 455068 6118644; 10 U 422559 6117945	Langston and Blackman 1993; LRDW 1998 (unpublished Stamford 2000); Cowie and Blackman 2007; Hawkshaw and Shrimpton 2014
	<u>Critical habitat comments</u>: Fry appear to drift downstream to maintain optimal rearing conditions, often associated with tributary confluences; rate of effective dispersal downstream into Lower Reach unknown but distribution of ry suggests						
7	Philip Creek	mainstem	Adult	AG	Good	10 U 458321 6128960; 10 U 465213 6117852	Cowie and Blackman 2007; Clark et al. 2005;
	<u>Critical habitat comments</u>: Possible local migration behaviour promoted by presence of headwater lakes should be						
8	Philip Creek	mainstem	Juvenile	AG	Poor	10 U 458344 6128925; 10 U 458999 6129170	Cowie and Blackman 2007; Clark et al. 2005
	<u>Critical habitat comments</u>: Limited sampling directed at this life stage. Possible rearing locations upstream near lake						

Table 8 (Continued):

ID	Sub-basin	Reach	Life stage	Sampling methods	Information adequacy	UTM bottom; UTM top	Key reference(s)
9	Philip Creek	mainstem	Fry	EF	Good	10 U 458344 6128925; 10 U 462729 6111811	Clark et al. 2005; Cowie and Blackman 2007; Hawkshaw and Shrinpton 2014
	<u>Critical habitat comments</u>: Assuming fry distribution to the mouth, but appears patchy further upstream. Hawkshaw and Shrimpton (2014) sampling has extended the range of fry further upstream; lake inventories suggest no grayling rearing in Philip Lakes but outlets should be assessed.						
10	Munro Creek	mainstem	Fry	EF	Good	10 U 446592 6121939; 10 U 446564 6122196	LRDW 1998 (Stamford 2000 unpublished); Cowie and Blackman 2007
	<u>Critical habitat comments</u>: Stamford 2000 found rearing fry ~100m upstream in Munro, which suggests spawning occurred upstream. Fry absence in other years (Cowie and Blackman 2007) suggests variable recruitment success in tributary among years. Alternatively, fry exit tributaries early during the summer to rear in Nation mainstem.						
11	Rainbow Creek	mainstem	Adult, Juveniles	EF, AG	Good	10 U 440039 6123059; 10 U 440112 6122794	LRDW 1998 (Stamford 2000 unpublished); Cowie and Blackman 2007
	<u>Critical habitat comments</u>: Adults and juveniles observed rearing in deep pool near the mouth. Movements upstream during summer flows likely restricted by beaver dams						
12	Rainbow Creek	mainstem	Fry	EF	Good	10 U 440039 6123059; 10 U 440112 6122794	LRDW 1998; Cowie and Blackman 2007
	<u>Critical habitat comments</u>: Fry captured close to Nation confluence both in 1998 and 2005. Possibly fry move in from Nation River spawning sites						
13	Sylvester Creek	mainstem	Adults	EF, AG, SW	Good	10 U 429187 6122487; 10 U 417329 6127090	Hawkshaw and Shrimpton 2014; Cowie and Blackman 2007; LRDW 1998 (Stamford 2000 unpublished); LRDW 1952 (UBC Fish Museum)
	<u>Critical habitat comments</u>: Historical lethal sampling (rotenone) suggest GR once abundant in stream. Adult observed rearing ~200 m upstream in 1998 but stream dominated by RB.Upstream coordinates from 1952 sampling.						
14	Sylvester Creek	mainstem	Fry	EF, SN	Good	10 U 429187 6122487; 10 U 426254 6124870	See Critical Habitat #13 above
	<u>Critical habitat comments</u>: Upstream coordinates from Hawkshaw and Shrimpton (2014). Fry samples collected ~200 meters upstream indicate spawning still occures. Abundant fry downstream at confluence might originate from both Sylvester Creek and upstream in Nation River (Hawkshaw and Shrimpton 2014). Absence in other sampling (Cowie and Blackman 2007) suggest fry abundance low.						
15	Suschona Creek	mainstem	Adult, Juvenile	AG, SN	Poor	10 U 422478 6117790; 10 U 422491 6117664	LRDW 1998 (Stamford unpublished); Cowie and Blackman 2007; Hawkshaw and Shrimpton 2014
	<u>Critical habitat comments</u>: Grayling samples at the confluence with Nation; use upstream is uncertain. Possibly a temperature refuge from warm summer mainstem. Spawning never confirmed in this stream.						
16	Suschona Creek	mainstem	Fry	EF, SN	Poor	10 U 422478 6117790; 10 U 422491 6117664	Hawkshaw and Shrimpton 2014; LRDW 1998 (Stamford 2000 unpublished).
	<u>Critical habitat comments</u>: SN confirmed GR presence in Suschona Creek and at the confluence with Nation River. Classified as juvenile habitat in micro and macro habitat analyses (Hawkshaw and Shrimpton 2014). EF sampling found no grayling fry (LRDW 1998).						

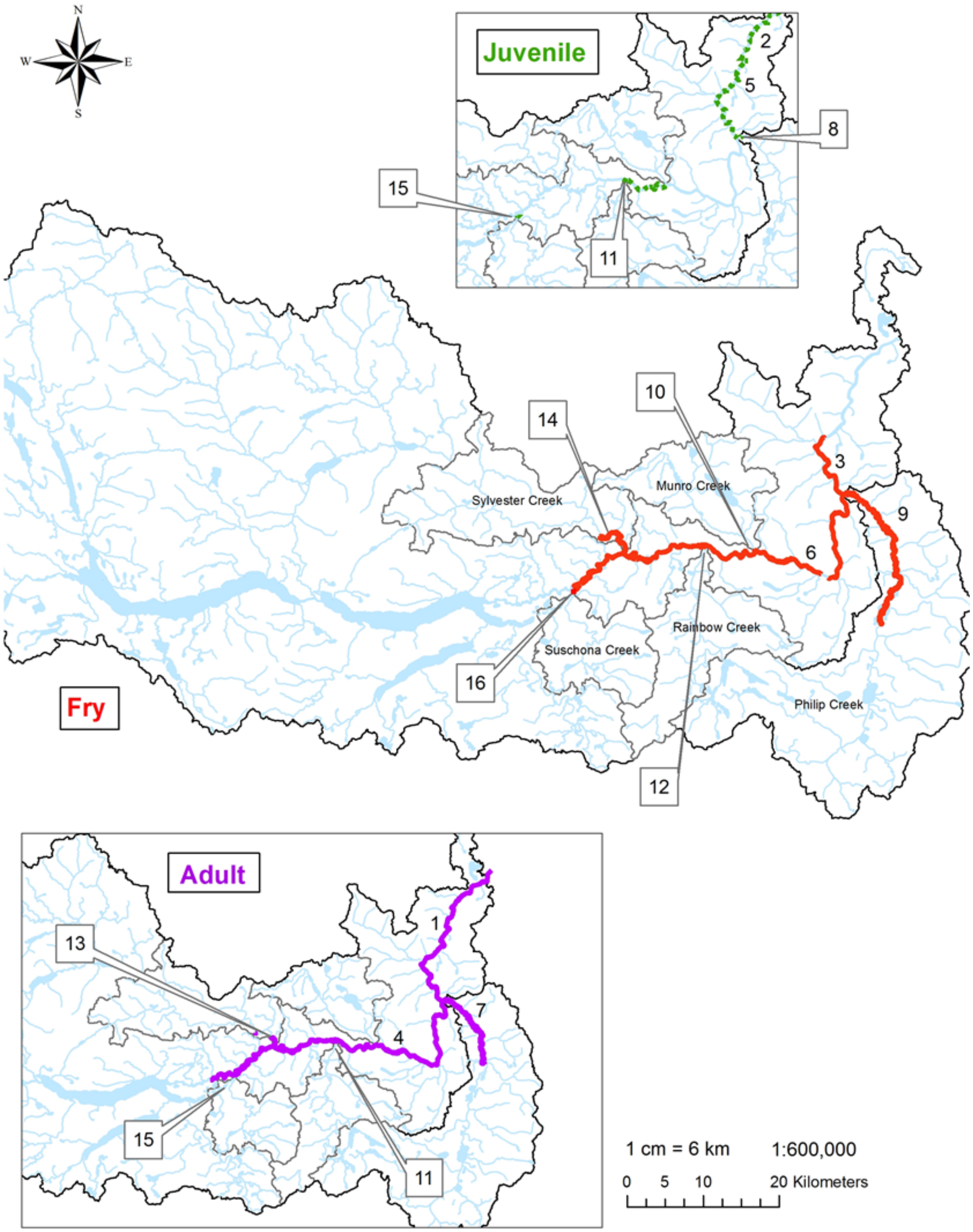

Figure 7. Critical habitats delineated for subadult/adult rearing (lower figure), fry (young-of-year) rearing (middle figure), and juvenile (age-1+, age-2+) rearing (upper figure) for Arctic Grayling within sub-basins of the Nation core area. Continuous lines indicate good information adequacy, while dashed lines indicate fair or poor information adequacy. ID numbers correspond with critical habitats described in Table 8.

Table 9. Data gaps limiting assessments of critical habitats for Arctic Grayling within sub-basins of the Nation River watershed, and potential studies to address them.

ID	Sub-basin(s)	Data gap	Potential study(s)	Immediacy
5.2.3a, 5.2.3b, 5.2.3c	Nation mainstem, upstream and downstream sections	Better knowledge required of 1) migration behaviours, 2) genetic distinctness, and 3) realtive abundance in these sections.	1) Movement studies, 2) further genetic study, and 3) adult abundance monitoring studies, respectively	High[1]
5.2.3d	Nation mainstem	Poor understanding of juvenile grayling habitat use.	Juvenile sampling (e.g. beach seining)	High
5.2.3e	Suschona, Rainbow, Munro creeks.	Unknown extent that Arctic grayling are still utilizing these systems.	Habitat use studies targeting fry, juvenile (e.g. dip nets, electrofishing, visual observations, seines) and adult life stages (e.g. snorkeling, angling).	Moderate
5.2.3f, 5.2.3g	Sylvester Creek, Philip River	Better knowledge of habitat use and temporal changes in abundance of: 1) adults and juveniles, 2) fry, especially early emergent.	Habitat use and monitoring studies targeting 1) adult and juvenile (e.g. snorkeling, angling), 2) fry (electrofishing, beach seining, dip netting)	Moderate

[1]In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions

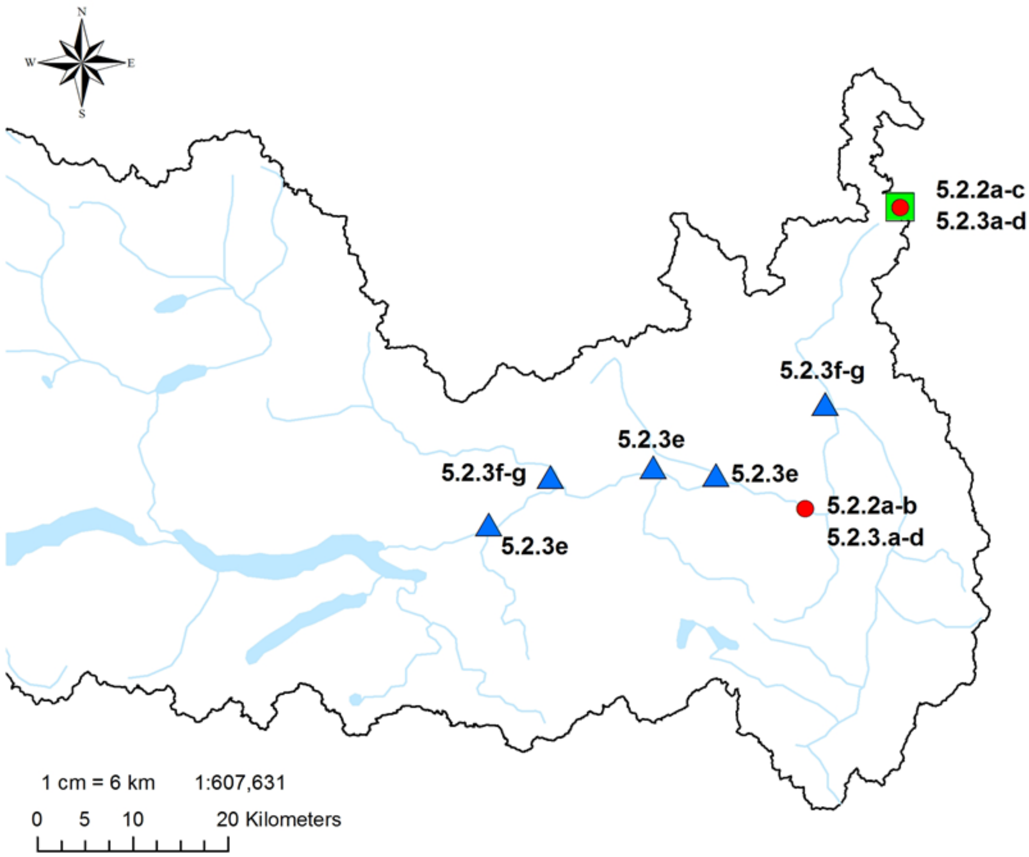

Figure 8. Locations within the Nation core area where data gaps limit understanding of conservation status and critical habitats for Arctic Grayling (high immediacy = red circles; moderate immediacy = blue triangles; low immediacy = green squares). Labels correspond with data gap IDs in Table 9.

5.3 Omineca core area

5.3.1 Overview of existing information

Numerous forestry and fisheries related inventory and habitat assessments (Hunter 1996d; Envirowest 1998; Beak International 1998; EDI 2000, 2001, 2002a; Wilson et al. 2008) together with grayling directed sampling (Schell 2002; Cowie and Blackman 2003) describe the summer distributions for Arctic Grayling fry, juveniles, and adults in the Omineca core area. Abundance trends over eight years (1992-1998) has been estimated in Mesilinka River (Wilson et al. 2008) and their movements over the short term described from otolith microchemistry analyses (Clarke et al. 2005) and over longer (perhaps evolutionary) time with genetic analyses (Shrimpton and Clarke 2012).

Omineca is a large core area, and critical habitats for spawning, fry and adult rearing are distributed among three major sub-basins (Omineca, Osilinka, Mesilinka rivers). Juvenile

(<200mm) summer rearing appears to be most abundant in the middle reaches of Omineca River but this might be a reflection of different sampling efforts directed a this life history stage (i.e. beach seining; Schell 2002). Similar to other core areas, however, lower abundance and spotty distribution of juveniles in Mesilinka River and their apparent absence in Osilinka might also suggest that juveniles utilize different habitats that require different types of sampling (e.g. angling, gill netting in deep meandering lower reaches; EDI 2001). These rivers (Mesilinka, Osilinka, Omineca) appear to have divergent landscape characteristics, which might promote distinct migratory behaviours and demographic independence between them. Levels of genetic divergence support this hypothesis (Shrimpton and Clarke 2012) yet microchemistry analyses and mark recapture information show adult movements between summer rearing areas in Osilinka, Mesilinka and lower Omineca rivers (LRDW 1996; Clarke et al. 2005). There is no evidence for movements in or out of upper Omineca River (Clarke et al. 2005). Possibly, higher disturbances to the downstream sections of Omineca core area (i.e. reservoir flooding, forest extractions) have influenced the current population structure and migratory behaviour. Alternatively, effective dispersal occurs throughout the Omineca watershed (as the current core area structure suggests) and threats to downstream habitat are mitigated by immigration from the more pristine upper Omineca. Understanding adult movements throughout the core area (e.g. radio telemetry, microchemistry) together with abundance monitoring (e.g. calibrated snorkel counts index locations in Mesilinka, Osilinka, and upper Omineca rivers) is key to distinguishing between these hypotheses and improving estimates of conservation status.

The relatively pristine upper Omineca also provide an opportunity to examine limiting factors associated with spawning and recruitment from small tributaries (Silver, Ominicetla creeks).

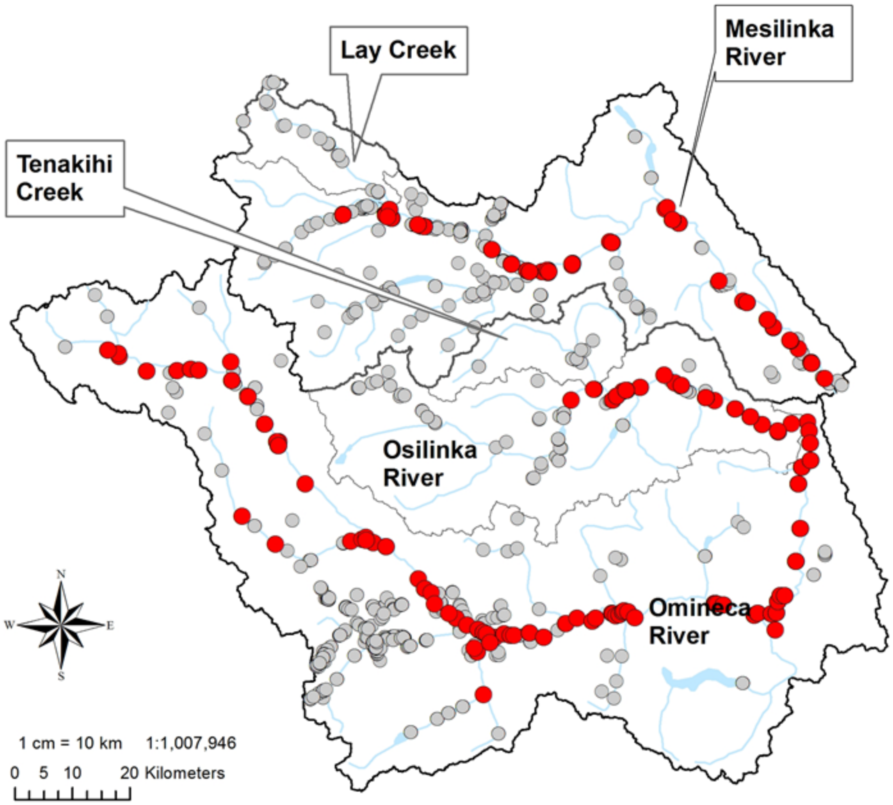

Figure 9. Distribution of records for past sampling of Arctic Grayling (red circles) and all other species (light grey circles) within sub-basins of the Omineca core area.

5.3.2 Conservation status and risk assessment

Distribution: Distribution of Arctic Grayling within the Omineca core area was categorically estimated by Stamford et al. (2015) to be 200-1000 km (category *D*; Appendix 1). The distribution and habitat use of grayling within the core area is somewhat understood in the Mesilinka, Osilinka, and upper portion of Omineca watersheds but less understood in the lower Omineca in the vicinity of Mesilinka and Osilinka rivers. Several important data gaps with regards to Arctic Grayling distribution within the Omineca core area are identified in the following section (*5.3.3 Critical habitats*).

Abundance: Adult population size within the Omineca core area was estimated to be in the upper end of the range 250-1000 adults (category *C*; Appendix 1), based roughly on snorkeling counts of adults in Mesilinka River (Wilson et al. 2008). The relative importance (i.e. population size) of other local populations (e.g. Omineca, Osilinka sub-basins) is unknown, which constitutes an important data gap affecting both conservation status assessment and planning for enhancement actions (Data gap *5.3.2a*; Table 10). Snorkeling surveys of the Osilinka and Omineca river systems, ideally calibrated by mark-recapture (e.g. Slaney and Martin 1987;

Mathias et al. 1998; Zemlak and Langston 1998; Hagen and Baxter 2005), would provide comparable data to that collected from the Mesilinka system. Because human disturbances from industrial developments are higher in both the Osilinka and Mesilinka systems (Stamford et al. 2015), monitoring densities in the more pristine upper Omineca system might provide a context for natural density changes (e.g. variance due to population dynamics, seasonal conditions) and help tease out a response resulting from human caused disturbances. Understanding movements in the core area (e.g. estimating movements of adults among natal, rearing, overwintering areas) together with abundance estimates is key to understanding current patterns of diversity and metapopulation structure (e.g. Schick et al. 2007; see Critical Habitats Section 5.3.3).

Trend: Assessment of adult abundance trend within the core area was carried out between 1992 and 1999 in a FWCP-funded assessment of changes resulting from fertilization in the Mesilinka system (Wilson et al. 2008). The assessment provided evidence of a stable trend in abundance in the control reach (Figure 10) and minimal declines in the experimental reach, possibly resulting from increased competition with rainbow trout (Wilson et al. 2008). Arctic Grayling in the core area were, nonetheless, assessed to be declining (category D, Appendix 1) mainly due to habitat losses resulting from flooding in the lower reaches of Omineca River, combined with large disturbances and habitat loss resulting from industrial developments mostly in Osilinka and Mesilinka systems (EDI 2002). Apparent range contractions from tributaries in sub-basins (e.g. Osilinka, Mesilinka) and other core areas (Nation, Ingenika, Peace, Williston) are assumed to signify population declines resulting from disturbances (Stamford et al. 2015). Since the mid 1990's, however, forestry practices have improved and impacts to habitat have probably diminished (e.g. riparian vegetation has probably grown back, stream structure has probably improved; EDI 2002), but no notions have been put forward of what has happened to the grayling (e.g. is it the juvenile 1+ habitat that was impacted and thus recently improved?).

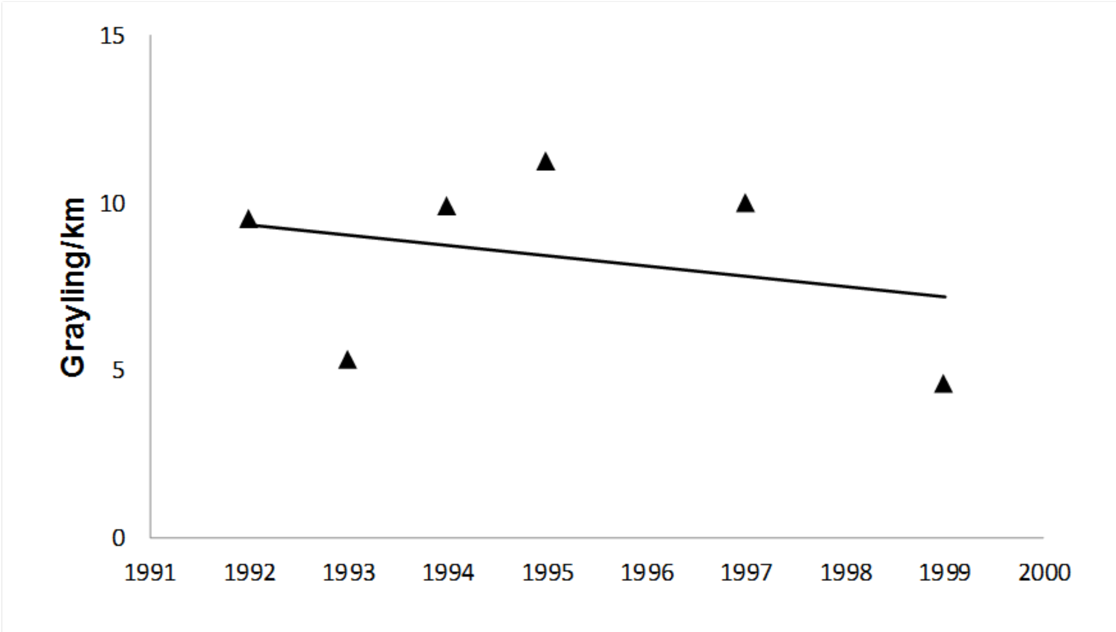

Figure 10. Estimated density of adult Arctic Grayling in a control reach of the Mesilinka River, monitored using snorkeling surveys during the 1992-1999 stream fertilization experiment (derived from Wilson et al. 2008).

Density estimates have not been collected from Mesilinka River since 1999 so any changes in Omineca Arctic Grayling abundance (based on one sub-basin) are unknown (data gap *5.3.2b*, Table 10). The population is adapting to both the flooding and habitat disturbances in the lower Omineca so changes are expected (e.g. what is the significance of low densities during years 1993 and 1999; Figure 10). By resuming similar calibrated snorkel counts (methods and locations) as that used in the Mesilinka River fertilization assessment (Wilson et al. 1999) the abundance can be compared with those prior years (Figure 10). Also, given the large size of the core area, potentially long and diverse migration distances observed among adult grayling, and regionally different levels of disturbances, density estimates from other rivers (e.g. other adult rearing areas in the relatively disturbed Osilinka and relatively pristine upper Omineca) would also be valuable (e.g. resolving natural fluctuations in abundance from those result from human disturbances; improved understand of demographic linkages within the core area). Abundance information would comprise an important component of a coordinated, grayling monitoring plan across the Williston watershed (introduced in Sections *2.3* and *5.1.2*) and is ranked high immediacy.

Threats: Threats within the Omineca core area overall were estimated to be of moderate scope and low severity (Category F, Appendix 2). Flooding of Williston Reservoir removed about 30 km of fluvial habitat from the lower Omineca River and inundated upstream past the confluence with Mesilinka River. Exploitation has likely had an impact due to the extensive linear developments in the lower parts of Mesilinka and Osilinka rivers since the 1970's (EDI 2000). Habitat disturbances from logging (e.g. loss of riparian cover, diminished bank stability and stream structure; EDI 2000, 2002) are most pronounced in the lower Mesilinka River (e.g. juvenile rearing) and Tenakihi Creek (possible spawning stream). Populations in upper Mesilinka and upper Omineca are less impacted with some protection in parkland (see Omineca Provincial Park and Protected Area; http://www.env.gov.bc.ca/bcparks/explore/parkpgs/omineca/). There are no recent quantitative assessments of threats (data gap *5.3.2c*, Table 10), although evaluation of threats is given low immediacy given that management of these threats is the responsibility of the Provincial Government. However, these data would be of particular interest in Omineca core area if taken together with evaluations of abundance trends in the three main sub-basins (Omineca, Osilinka, Mesilinka), where divergent levels of threats and disturbances occur.

Table 10. Data gaps limiting conservation status and risk assessments for Arctic Grayling within the Omineca core area, and potential studies to address them.

ID	Sub-basin(s)	Data gap	Potential study(s)	Immediacy
na	Mesilinka, Omineca, Osilinka	***Distribution*** . Poor understanding of demographic independence between Mesilinka, Omineca, and Osilinka.	*See Table 6*	-
5.3.2a	All except Mesilinka	***Abundance*** . Unknown adult population size/relative importance of watersheds outside of the Mesilinka sub-basin	Adult population abundance indices (e.g. snorkeling counts, angling CPUE, mark-recapture)	High[1]
5.3.2b	Mesilinka (Osilinka, Omineca)	***Trend*** . Lack of annual abundance monitoring since 1999	Swim count methodology within index sections of Mesilinka systems (Wilson et al. 2008). Best to include Osilinka and an upstream section of Omineca for concordant data.	High
5.3.2c	All	***Threats*** . Lack of a detailed, quantitative assessment of threats	GIS-based assessment of aquatic ecosystem health indicators of cumulative effects (road density, etc.); Fish Habitat Assessment Procedures	Low

[1]In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions

Conservation status and risk assessment. The categorical estimates for the four conservation status indicators, when factored together (see Appendix 3), corresponded to a ranking of *C2-At Risk* (Stamford et al. 2015). According to this ranking, grayling of the Omineca core area are "at moderate risk of extirpation" (within the next 100 years) due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors" (Appendix 3).

5.3.3 Critical habitats

Within the Omineca core area, we delineated 13 stream sections providing critical habitats for at least one Arctic Grayling life stage (fry, juvenile, subadult/adult rearing, overwintering). Critical habitats for Arctic Grayling were distributed among eight sub-basins within the core area (Table 11, Figure 11).

The Omineca and Mesilinka mainstems provide critical habitat for all Arctic Grayling life stages, for spawning, and rearing for fry (age-0+), juveniles (1+, 2+), subadults, and adults. The Osilinka provides spawning, fry and adult rearing, but no records of juveniles were found.

Arctic Grayling adult records (summer rearing habitats) are widely distributed throughout the whole core area but appear most abundant in the upstream reaches of the three main sub-basins, Omineca, Osilinka, and Mesilinka, including tributaries. Otolith microchemistry analysis found adult movements highly variable, with some adults remaining in their natal sub-basins their whole life (upper Mesilinka near Lay Creek) while others moved to distant rearing areas (lower Omineca), but no suggestions of movements outside the core area (Clarke et al. 2005). Microchemical profiles also suggest adults home to natal areas during spawning time, and levels of genetic divergence among rearing adults suggest the three main sub-basins might sustain demographically-independent populations (Shrimpton et al. 2012). The extent that adults move among sub-basins in Omineca core area is poorly understood (e.g. movements between the upper Omineca and other sub-basins is unknown; LRDW 1996, Clarke et al. 2005; Shrimpton and Clarke 2012), however, and is an important data gap of moderate immediacy (data gap *5.3.3a*; Table 12, Figure 11). Radio telemetry (e.g. Blackman 2002a) is a potentially appropriate study methodology for assessing adult grayling movements and habitat use in mainstem environments of the Omineca core area.

Juveniles (<200 mm) are widely distributed but patchy in both Omineca and Mesilinka mainstems (Langston and Blackman 1993; Larkin et al. 1999; LRDW 1997; EDI 2001; Schell 2002; Cowie and Blackman 2003; Clarke et al. 2005). Recruits from Osilinka River, where juveniles have not been captured, might overwinter downstream in the lower Omineca or Mesilinka then rear there during their second summer (Table 11, Figure 11). More directed sampling is needed to better identify productive areas and critical habitat boundaries (data gap *5.3.3b*; Table 12, Figure 11). Beach seining is a potential methodology for studying juvenile grayling habitat use in the mainstem environments of the Omineca core area (e.g. Blackman and Hunter 2001; Schell 2002; Blackman 2002c; Mackay and Blackman 2012).

Fry sampling in Omineca and Osilinka mainstems has been grayling-directed and relatively extensive, with many sample sites located well beyond the end of the grayling distribution (two episodes in upper Omineca River; Schell 2002; Cowie and Blackman 2003). Most fry rearing areas in the mainstems of upper Omineca and Osilinka sub-basins appear strongly associated with certain tributary confluences (similar to Nation Core Area). Similarly, Mesilinka River fry records show temporally-consistent fry collections close to tributary confluences (Table 11, Figure 11). In the more pristine upper Omineca sub-basin fry records are far enough upstream to indicate tributary and headwater spawning, but neither Osilinka nor Mesilinka rivers show any records of fry rearing in tributaries or headwaters. Local movements of adults and presence of juveniles near Lay Creek (LRDW 1997; Clarke et al. 2005), hint that Mesilinka headwaters might sustain an independent population. Similar to Nation River, the factors that limit recruitment (productivity) in tributaries and headwaters remains unclear. The relative importance of tributary and mainstem spawning to recruitment and promoting diversification in Arctic Grayling is an important data gap for the species in general (data gap *5.3.3c*; Table 12), and understanding these associations may be important for gaining perspective of diversity among Williston core areas. Chemical signatures from fry otoliths can potentially distinguish among natal and rearing areas (given distinct chemical signatures among habitats) and are particularly good at distinguishing tributary and mainstem uses (Clarke et al. 2005; Earth Tone and Mainstream 2013). Considering that the unknown importance of tributary use is a consistent data gap among core areas, data gap *5.3.3c* has been given high immediacy.

Genetic analyses comparing among adult rearing areas has had attention (Stamford and Taylor 2005; Shrimpton and Clarke 2012) although linking the data directly with movements (e.g. otolith microchemistry, radio telemetry) has the potential to examine population structure with finer brush strokes (e.g. homing to natal areas; Quinn et al. 1999) within the Omineca core area. Combined otolith and tissue sample collection (for microchemistry and genetic analyses, respectively), aimed at addressing movements over ecological and evolutionary time scales, could address these data gaps (*5.3.3c* and *d*; Table 12, Figure 11).

Sampling of Arctic Grayling fry in two Omineca tributaries, Silver Creek and Ominicetla Creek, suggests the possible presence of a self-sustaining local spawning population (Table 11, Figure 11). Arctic Grayling fry have not been found in any other tributary in Omineca core area and suggests self-sustaining tributary populations are rare. Adult and juvenile use in these streams is limited to a few records of adults in Ominicetla Creek but no records of second summer juveniles were found. Further sampling is needed to better understand the extent of adult and juvenile habitat use (data gaps *5.3.3e* and *f*, Table 12). These data gaps could be addressed by a summer habitat use study targeting adult and juvenile grayling, utilizing snorkeling and/or angling as potential sampling methods (e.g. Zemlak and Langston 1998; Mathias et al. 1998). Given the trends found in other core areas (e.g. Nation, Williston, Upper Peace) and upper Missouri River (e.g. Kaya 1990) where range contractions appear to include losses from small tributaries and headwaters, high immediacy should be given to these systems because it is an important indicator for Arctic Grayling productivity in the core area.

Table 11. Critical habitats delineated for Arctic Grayling populations inhabiting sub-basins of the Omineca core area. Sampling methods EF, SN, VO, SW, GN, AN, and RT refer to electrofishing, seine netting, visual observation, swim counts, gillnetting, angling, and radio telemetry, respectively. ID numbers facilitate identification of critical habitats in Figures X.

ID	Sub-basin	Reach	Life stage	Sampling methods	Information adequacy	UTM bottom; UTM top	Key reference(s)
1	Mesilinka River	Mainstem	Fry	EF	Good	10 V 383182 6252361; 10 V 359900 6245113	Koning et al. 1992; Larkin et al. 1999; LRDW 1997
	Critical habitat comments: Fry rearing in low gradient sections and appear to be associated with lake headed tributaries Carina Creek and Tutezika River. Repeat sampling in Mesilinka show consistent rearing locations used by fry among years.						
2	Mesilinka River	Mainstem	Juvenile	EF, SN, AG, SW	Poor	10 V 405227 6227185; 10 V 332446 6255652	Langston and Blackman 1993; Larkin et al. 1999; LRDW 1997; EDI 2001; Clark et al. 2005
	Critical habitat comments: Juveniles widely distributed but patchy and few occurrences relative to adults and fry. Low abundance possibly a sampling artefact (i.e. limited SN effort especially in lower reaches). Habitat descriptions in lower reaches suggest good juvenile habitat.						
3	Mesilinka River	Mainstem	Adult	AG, EF, SN, SW	Good	10 V 408900 6221600; 10 V 324646 6256322	Koning et al. 1992; Langston and Blackman 1993; Larkin et al. 1999; LRDW 1997; Clark et al 2005
	Critical habitat comments: Adults distributed from mouth to headwaters around Aiken Lake. Migrations variable with some individuals remaining in Mesilinka whole lives, others migrate into Omineca River for some portion of their lives. Adults tagged in Mesilinka recovered in Osilinka following years. Repeat sampling in Mesilinka show consistent rearing locations used by adults among years and rearing site fidelity.						
4	Mesilinka River, Lay Creek	mainstem	Adult	AG	Good	10 V 332107 6256081; 10 V 332776 6256852	LRDW 1997; Clark et al. 2005
	Critical habitat comments: Adult rearing in lower reaches near Mesilinka confluence.						
5	Mesilinka River, Kliyul Creek	Mainstem	Adult	AG	Good	10 V 325044 6256491; 10 V 324688 6256432	LRDW 1997; Beak Industrial 1998
	Critical habitat comments: Adult rearing near headwaters						
6	Osilinka River	Mainstem	Fry	EF	Good	10 V 404195 6216801; 10 V 370308 6222153	Stamford 1998 (unpublished); Cowie and Blackman 2003
	Critical habitat comments:Fry consistently found in low gradient section downstream of Tenakihi Creek (~38km of river) but habitat extends to stream mouth. Often large schools observed trapped in isolated pools (e.g. 85% of GR Fry captured by Cowie and Blackman 2003). No fry found in tributaries but some might be used for spawning (e.g. Tenakihi, Wasi, data gap). Absence of juveniles (>100mm) in the data suggests they might rear in Omineca River (data gap).						
7	Osilinka River	Mainstem	Adult	AG	Good	10 V 404195 6216801; 10 V 363114 6222447	LRDW 1998 (Stamford unpublished); Cowie and Blackman 2003; Clark et al 2005
	Critical habitat comments: Adults distributed throughout mainstem from Omineca confluence; some probably move among rearing locations throughout their life history in Mesilinka and Omineca based on mark recapture of tagged adults and microchemistry analyses.						

Table 11, continued:

ID	Sub-basin	Reach	Life stage	Sampling methods	Information adequacy	UTM bottom; UTM top	Key reference(s)
8	Omineca	Mainstem	Fry	EF, SN	Good	10 V 407699 6221202; 9 V 654761 6231867	Schell 2002; Cowie and Blackman 2003
	<u>Critical habitat comments</u>: Wide distribution of fry throughout Omineca mainstem well represented by extensive sampling effort (e.g. GR present in 63 of 105 sites sampled by Cowie and Blackman 2003). Distribution appears clustered around four sections, possibly associated with headwaters and tributaries.						
9	Omineca	Mainstem	Juvenile	EF, SN	Fair	10 U 365712 6184399; 10 U 335039 6192554	Schell 2002; Cowie and Blackman 2003
	<u>Critical habitat comments</u>: Abundance and distribution of juveniles appears small relative to adults and fry and appears limited to middle reaches of Omineca River. However, all samples were collected using SN, and suggests more sampling effort directed at this life history stage (e.g. SN, AG) might reveal wider distribution and possibly higher abundance.						
10	Omineca	Mainstem	Adult	EF, AG	Fair	9 V 685225 6217231; 9 V 656559 6231361	Schell 2002; Cowie and Blackman 2003; Clark et al. 2005
	<u>Critical habitat comments</u>: Current sampling shows adults rearing close to headwaters, upstream of all juvenile records but downstream of fry record. More effort directed at adults (e.g. AG) might extend the range further upstream, and						
11	Omineca, Silver Creek	Mainstem	Fry	EF, SN, AG	Good	10 U 348090 6181795; 10 U 345668 6171766	Schell 2002; Cowie and Blackman 2003
	<u>Critical habitat comments</u>: Two episodes (2002, 2003) of EF and SN sampling found fry rearing in lower reaches, suggests temporally consistent recruitment. No adults or juveniles found.						
12	Omineca, Ominicetla Creek	Mainstem	Fry, Adults	EF, SN, AG	Good	10 U 326388 6199680; 9 U 679405 6204039	Schell 2002; Cowie and Blackman 2003
	<u>Critical habitat comments</u>: Adults rearing upstream toward headwaters, fry rearing downstream close to Omineca confluence.						
13	Omineca, Carruthers Creek	Mainstem	Adult	EF, AG	Good	9 V 677110 6226929; 9 V 676252 6230765	Schell 2002; Cowie and Blackman 2003
	<u>Critical habitat comments</u>: Rearing adults present (Cowie and Blackman (2003), but maybe not every year (Schell 2002). Fry rearing in Omineca maninstem both upstream and downstream on confluence.						

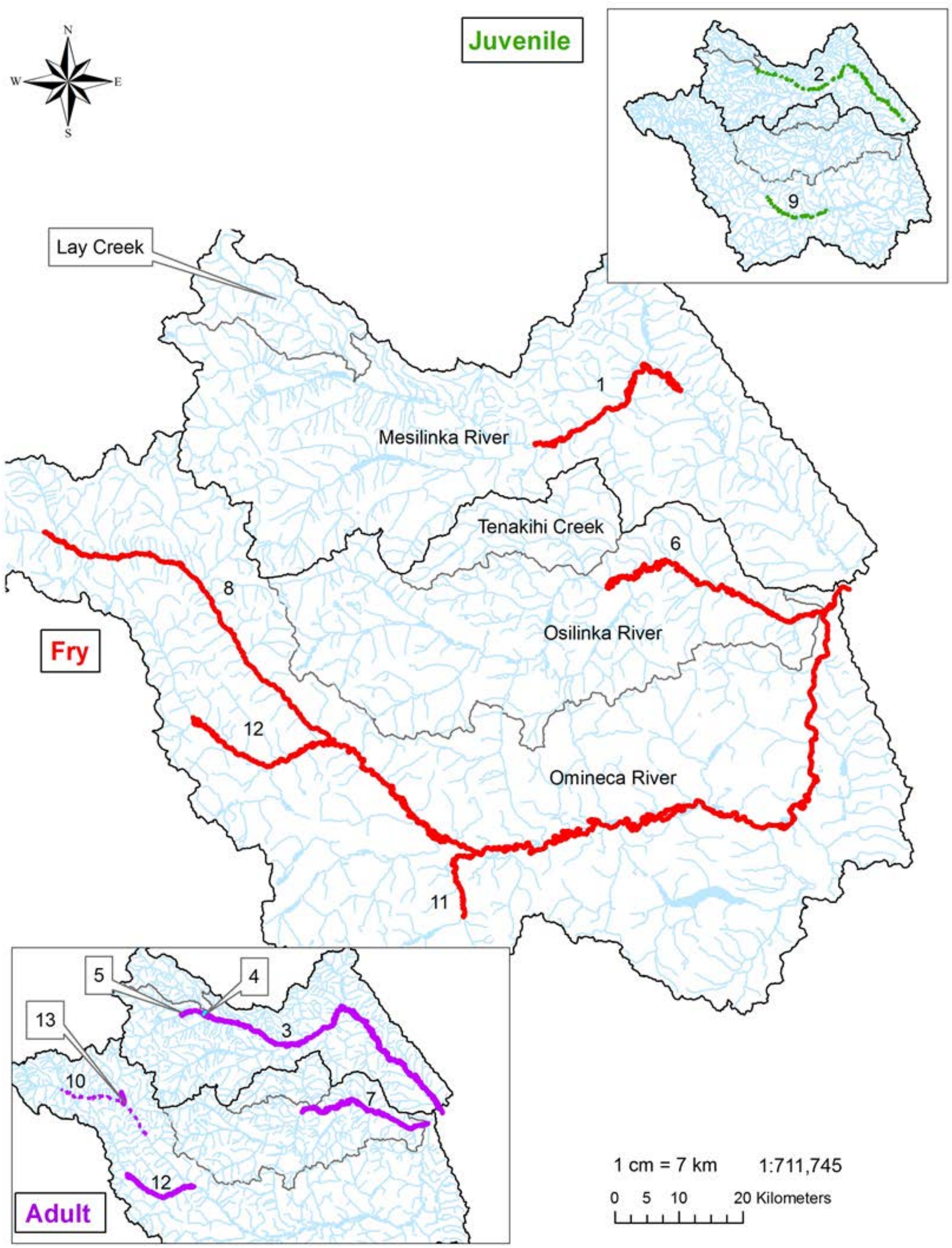

Figure 11. Critical habitats delineated for subadult/adult rearing (lower figure), fry (young-of year) rearing (middle figure), and juvenile (age-1+, age-2+) rearing (upper figure) for Arctic Grayling within sub-basins of the Omineca core area. Continuous lines indicate good information adequacy, while dashed lines indicate fair or poor information adequacy. ID numbers correspond with critical habitats described in Table 11.

Table 12. Data gaps limiting assessments of critical habitats for Arctic Grayling within sub-basins of the Omineca River watershed, and potential studies to address them.

ID	**Sub-basin(s)**	**Data gap**	**Potential study(s)**	**Immediacy**
5.3.3a, 5.3.3b	Omineca, Osilinka, Mesilinka	Poor understanding of 1) adult and 2) juvenile grayling habitat use in the Omineca, Osilinka, Mesilinka mainstems.	1) Adult movement studies (e.g. radio telemetry) and 2) juvenile sampling (e.g. beach seining), respectively	Moderate[1]
5.3.3c	Omineca, Osilinka, Mesilinka	Unknown relative importance of mainstem and tributariesfor providing spawning and early rearing and dispersal of fry from natal areas.	Fry movement studies (e.g. otolith microchemistry analyses).	High
5.3.3d	Omineca core area	Unknown extent of homing to spawning locations, natal site fidelity within and among sub-basins.	Genetic comparisons among sub-basins using fry tissue samples. Combine with movement estimates (e.g. otolith microchemistry).	Moderate
5.3.3e, 5.3.3f	Silver Creek, Ominicetla Creek, Omineca headwaters	Unknown importance for: 1) adult, subadult, and 2) juvenile grayling rearing.	1) Summer habitat use studies targeting adult grayling (e.g. calibrated snorkeling surveys) and 2) juvenile sampling (e.g. electrofishing, seining).	Moderate

[1]In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions

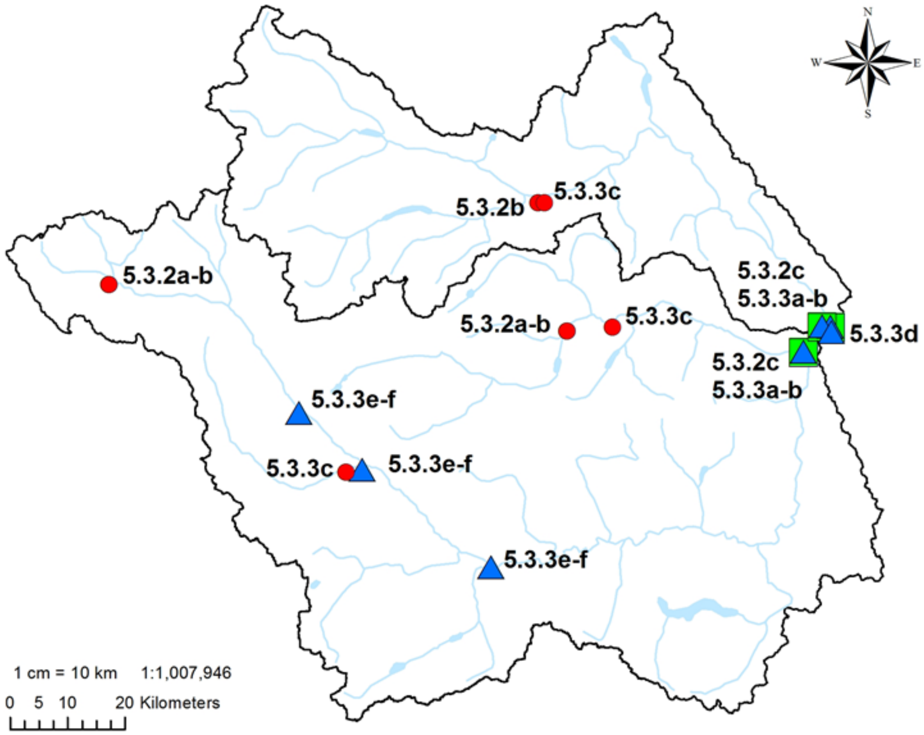

Figure 12. Locations within the Omineca core area where data gaps limit understanding of conservation status and critical habitats for Arctic Grayling (high immediacy = red circles; moderate immediacy = blue triangles; low immediacy = green squares). Labels correspond with data gap IDs in Table 12.

5.4 Ingenika core area

5.4.1 Overview of existing information

The distribution of critical habitats in Ingenika core area has been characterized mostly with two sampling episodes directed at Arctic Grayling fry (Cowie and Blackman 2004) and adults (Cowie and Blackman 2012b). Both studies also show juvenile rearing locations and describe habitat characteristics that resemble those for Parsnip River (i.e. slow riffles and about a meter depth; see Section *2.2*). Other sampling shows adults rearing in two tributaries (Bruce and Starr 1985; LRDW 1998) but use might only be periodical (Cowie and Blackman 2004). Grayling were not found at numerous sampling locations in tributaries (e.g. Pelly Creek and Pelly Lake; Tupniak and Abelson 1981; Cowie and Blackman 2004) and upstream reaches of the Ingenika River (Cowie and Blackman 2004; Figure 13). A single swim count exists (Cowie and Blackman 2012b) with which to estimate grayling density, an indicator of population status (Section *5.4.2*). Cowie and Blackman (2004) found fry widely distributed along about 76 kilometers of the mainstem, and mostly in off channel habitats and isolated pools in the middle reaches around confluences with Cutbank and Pelly creeks.

Microchemistry signatures from four adults were estimated to complete their life history in the Ingenika River (Clarke et al. 2005) and might suggest a demographically independent population inhabits the watershed. The close genetic connections with lower Finlay River grayling (Shrimpton and Clarke 2012) may therefore reflect recent ancestral connections that no longer exist. Alternatively, gene flow continues between Finlay and Ingenika watersheds and might improve population viability in both systems.

Demographic connections between core areas can be addressed with movement studies (e.g. radio telemetry, microchemistry) aimed at comparing between natal areas, but also need to include estimates of abundance for adults sustained by those natal areas to gauge demographic independence (data gaps 5.4.3 a, b, c; Table 15).

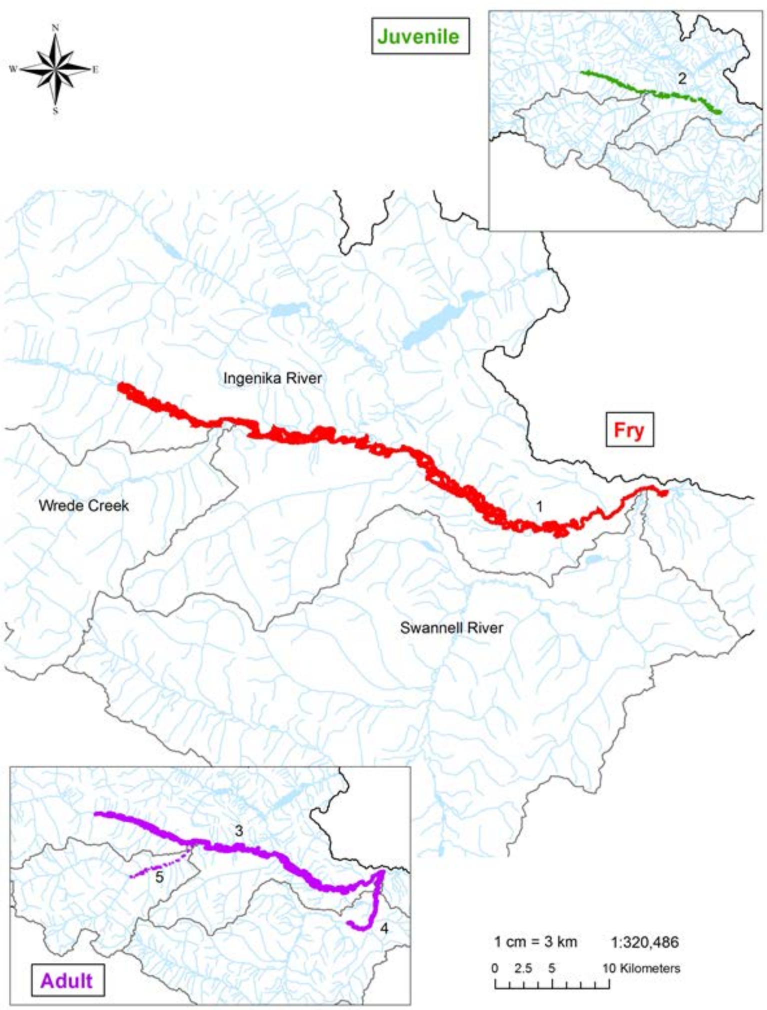

Figure 13. Distribution of records for past sampling of Arctic Grayling (red circles) and all other species (light grey circles) within sub-basins of the Ingenika core area.

5.4.2 Conservation status and risk assessment

Distribution: The distribution of Arctic Grayling within the Ingenika core area was estimated by Stamford et al. (2015) to be 40-200 km (category *C*; Appendix 1). The distribution and habitat use of grayling within the core area is moderately well understood with recent sampling and suggests a mainstem population with periodic use of tributaries by rearing adults, and possibly spawning. Several important data gaps associated with distribution within the Ingenika core area are identified in the following section (*5.1.3 Critical habitats*).

Abundance. Adult population size within the Ingenika core area was categorically estimated to be in the range 250-1000 adults (category *C*; Appendix 1), based roughly on a single snorkeling count that targeted most of the prime adult rearing habitat in the river (Cowie and Blackman 2012b). Sampling suggests tributary use by rearing adults is temporally inconsistent, however, a possible sign that adult abundance might be declining, or fluctuate among years, or homing behaviour is not precise (Data gap *5.4.2a*; Table 13). Snorkeling surveys in Ingenika river, ideally calibrated by mark-recapture (e.g. Slaney and Martin 1987; Mathias et al. 1998; Zemlak and Langston 1998; Hagen and Baxter 2005) and linking with previous methods (Cowie and Blackman 2012b), would provide a better understanding of adult abundance.

Trend. There are no data to say much about the abundance trend in Ingenika core area. Temporal sampling suggests that the range of adult rearing might have contracted away from tributaries and the core area was assessed to be declining (category D, Appendix 1). Density estimates from Ingenika River are unknown although a single snorkel count (Cowie and Blackman 2012b) suggests the population is small (~4 GR/km) relative to other Peace Basin Core Areas (data gap *5.4.2b*; Table 13). The population has been forced to adapt to habitat loss and disturbances stemming from flooding, linear developments, and logging activities in lower reaches of the river. Genetic analyses also suggest that the population might benefit from geneflow with lower Finlay River core area. Calibrated snorkel counts, ideally as part of a coordinated grayling-monitoring plan across the Williston watershed (introduced in sections *2.3* and *5.1.2*) would allow estimates of abundance and trend and are considered to be of high immediacy.

Threats: Threats were estimated to be of moderate severity and scope (Stamford et al. 2015) (Category B, Appendix 2). Flooding of Williston Reservoir removed about 12 km of low gradient mainstem habitat from the lower Ingenika River that probably was important for first and second summer rearing juveniles and possibly overwintering areas. Prior demographic or ecological connections (e.g. gene flow, overlapping habitat uses) with lower Finlay River are likely to have been disturbed by the flooding (Shrimpton and Clarke 2012). Exploitation has likely had an impact due to linear developments in the lower river and jet boat access from downstream. Habitat disturbances from logging are most pronounced in Swanell River (adult rearing area). Most of the remaining population (all life history stages) rears upstream in more pristine habitat (Cowie and Blackman 2004, 2012b). There are no recent quantitative assessments of threats (data gap 5.4.2c; Table 13), however, and evaluation of threats is given low immediacy given that management of most threats is the responsibility of the Provincial Government.

Table 13. Data gaps limiting conservation status and risk assessments for Arctic Grayling within the Ingenika core area, and potential studies to address them.

ID	Sub-basin(s)	Data gap	Potential study(s)	Immediacy
na	mainstem	***Distribution*** . Poor understanding of grayling distribution in tributaries.	*See Table 6*	-
5.4.2a	Ingenika mainstem	***Abundance*** . Adult population size estimatedroughly with only one count.	Adult population abundance indices (e.g. snorkeling counts, angling CPUE, mark-recapture)	High[1]
5.4.2b	All	***Trend*** . Lack of annual abundance monitoring besides one count (n=1).	Swim count methodology within index sections of Ingenika system (Cowie and Blackman 2012).	High
5.4.2c	All	***Threats*** . Lack of a detailed, quantitative assessment of threats	GIS-based assessment of aquatic ecosystem health indicators of cumulative effects (road density, etc.); Fish Habitat Assessment Procedures	Low

[1]In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions

Conservation status and risk assessment. The categorical estimates for the four conservation status indicators, when factored together (see Appendix 3), corresponded to a ranking of *C1-High Risk* (Stamford et al. 2015). According to this ranking, Ingenika grayling are “at high risk of extirpation” (within the next 100 years) due to a restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors” (Appendix 3). Factors influencing this assessment include a significant loss of low gradient habitat due to Wiiliston Reservoir formation, small population size with close genetic affinities with the adjacent lower Finlay core area. It was precautionary to assume that Ingenika Arctic Grayling are demographically independent despite the close genetic connections with lower Finlay River grayling, relative to other core areas, because ancestral connections are often broken in current-day metapopulation dynamics.

5.4.3 Critical habitats

Five stream sections were delineated for providing critical habitats for at least one Arctic Grayling life stage (fry, juvenile, subadult/adult rearing, overwintering). These were distributed mostly in the mainstem but adult records also occur in two sub-basins within Ingenika River watershed (Table 14; Figure 14).

The Ingenika River mainstem provides critical habitat for all life stages, for spawning, fry (age-0+), juvenile (1+, 2+), subadult, and adult rearing, as well as migration among seasonal habitats for all life stages (Table 14; Figure 14). The distributions of rearing habitats overlap among life stages. Adults follow a classic grayling distribution with larger adults further upstream (Cowie and Blackman 2004, 2012b). Fry and juvenile (<200 mm) habitats predominate in the middle and downstream reaches with abundant fry rearing in a low gradient 26km section around Pelly River confluence (Cowie and Blackman 2004). Juveniles appear to school among slow riffles in about a meter of water (Cowie and Blackman 2004, 2012b). Overwintering locations have never been identified but likely occur in the Ingenika mainstem. While the rearing areas have been described briefly (Cowie and Blackman 2004, 2012b), better knowledge is required about migratory behaviour, genetic distinction from adjacent core areas, and abundance to assess the need for conservation actions or opportunities for enhancement (Data gaps *5.4.3a, 5.4.3b, 5.4.3c*; Table 15, Figure 15). These data gaps should be considered of high immediacy, and potential study methods include: 1) adult movement studies employing radio telemetry (e.g. Blackman 2002a) or additional otolith microchemistry (e.g. Clarke et al. 2005), 2) population structure studies aimed at comparing between natal areas; and 3) adult abundance monitoring studies employing snorkeling surveys calibrated by mark-recapture (e.g. Zemlak and Langston 1998; Mathias et al. 1998) and utilizing previous methods and locations (Cowie and Blackman 2012b). The aim of further study should consider improving perspectives on possible demographic connections with Finlay River as suggested by low genetic distance (Shrimpton and Clarke 2012). For instance, records suggest that Ingenika and lower Finlay/ Fox rivers continue to produce abundant fry (LRDW 2006; Cowie and Blackman 2004) but juveniles appear relatively rarely in both core areas. Flooding probably removed extensive juvenile rearing and overwintering habitats; areas that once overlapped extensively when Ingenika River was a tributary of Finlay River. The current migratory behaviour and abundance continues to adapt to the new conditions but the viability of Ingenika grayling is poorly understood.

Juvenile habitat characteristics and abundance are poorly understood in the Ingenika core area (data gap *5.4.3d*; Table 15, Figure 15). Current records suggest that juvenile abundance is low relative to fry and adults (e.g. Cowie and Blackman 2004, 2012b) but the counts come from incidental catches from sampling methods directed at either fry or adults (e.g. there is an absence of seining effort in the Ingenika core area).

Similar to other core areas, the relative importance of tributaries for spawning and early rearing needs investigating (Data gap *5.4.3e*; Table 15, Figure 15).

Table 14. Critical habitats delineated for Arctic Grayling populations inhabiting sub-basins of the Ingenika core area. Sampling methods EF, SN, VO, SW, GN, AN, and RT refer to electrofishing, seine netting, visual observation, swim counts, gillnetting, angling, and radio telemetry, respectively. ID numbers facilitate identification of critical habitats in Figures X.

ID	Sub-basin	Reach	Life stage	Sampling methods	Information adequacy	UTM bottom; UTM top	Key reference(s)
1	Ingenika	Mainstem	Fry	EF	Good	10 V 373657 6289082; 10 V 326287 6300504	Cowie and Blackman 2004
	Critical habitat comments: *Fry distributed in lower 76 km of river with core rearing areas occurring in braided channel habitat upstream and downstream of Pelly Creek River (~26km section). No association with substrate, fry distribution assumed to be associated with spawning locations. Fry NOT found in tributaries; many (46%) found stranded in isolated poolsor (36%) in backchannels and side channels on mainstem. Only 18% of fry were captured free swimmming in mainstem.*						
2	Ingenika	Mainstem	Juvenile	EF, AG, SW	Fair	10 V 356773 6289814; 9 V 682082 6303047	LRDW 1998 (Stamford unpublished); Cowie and Blackman 2004, 2012
	Critical habitat comments: *Minimal effort directed at this LH stage, juveniles collected while angling particular shallow riffle habitat and observed during snorkel survey. Juveniles (<200mm) made up 15% of the SW count.*						
3	Ingenika	Mainstem	Adult	EF, AG, SW	Good	10 V 371781 6289505; 9 V 669111 6305246	Clark et al. 2007; Cowie and Blackman 2004, 2012
	Critical habitat comments: *Microchemistry analyses indicate local migration behaviour; SW counts show rearing adults more abundant in upstream reaches (between 60 and 100 km upstream from mouth),*						
4	Swannell River	Mainstem	Adult	AG, SW	Good	10 V 371629 6289457; 10 V 364597 6279830	LRDW 1998 (Stamford unpublished); Cowie and Blackman 2004
	Critical habitat comments: *Adults observed rearing in deep pool upstream of bridge crossing at base of cascade barrier in 1998; subsequent sampling in 2004 found no Arctic grayling. Possibly evidence for decline; alternatively, ephemeral use by rearing adults. No evidence for spawning or juvenile rearing but significant EF effort in stream.*						
5	Wrede Creek	Mainstem	Adult	Obs	Poor	10 V 335061 6297168; 10 V 322196 6290719	Bruce and Star 1986; Cowie and Blackman 2004
	Critical habitat comments: *Arctic grayling observed in mid 1970's but not since; limited sampling effort in the creek. Possibly spawning activity associated with this location, at upstream edge of 'core fry rearing' area. Two EF sites found no GR Fry; upstream boundary arbitrary placement at first major tributary confluence.*						

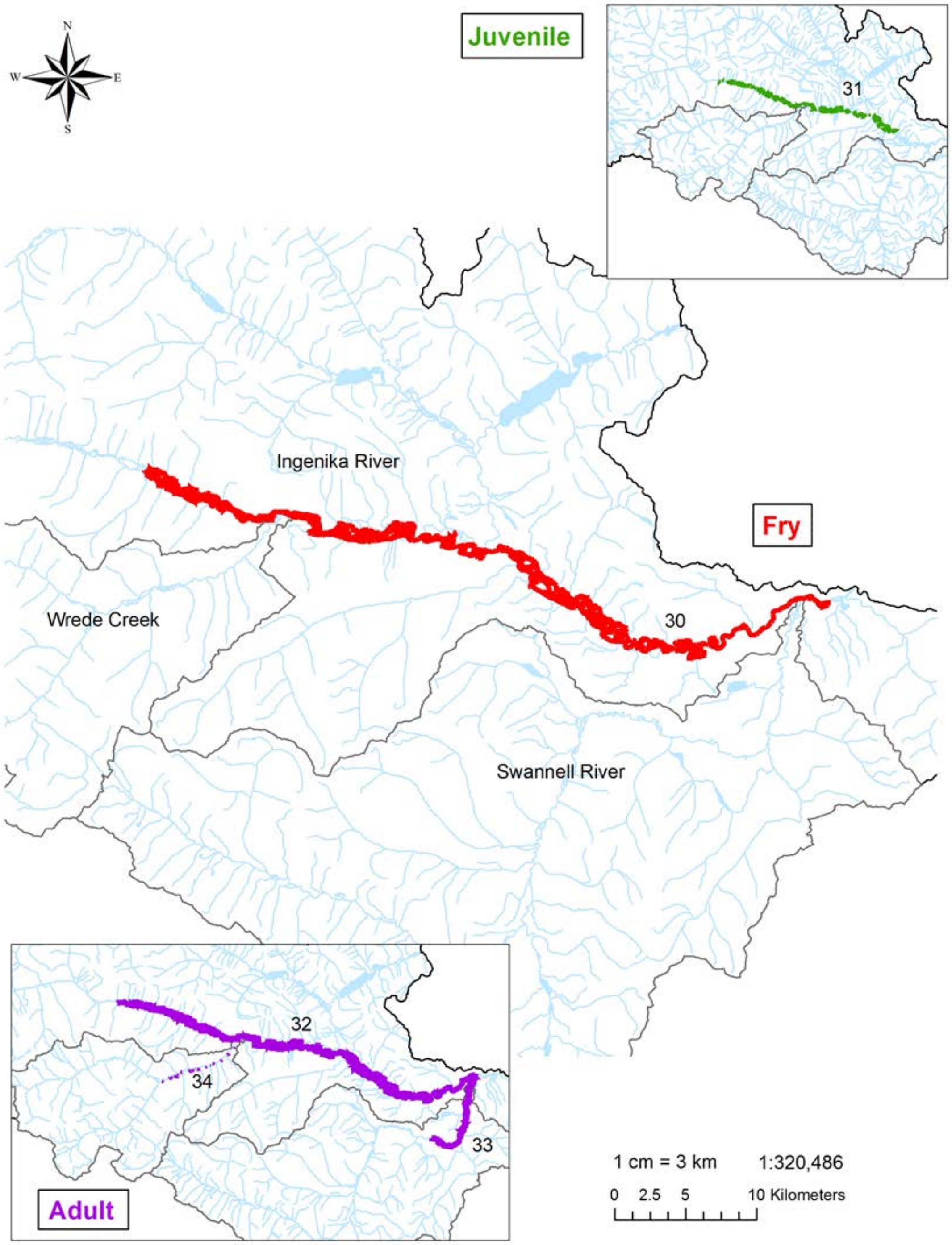

Figure 14. Critical habitats delineated for subadult/adult rearing (lower figure), fry (young-of year) rearing (middle figure), and juvenile (age-1+, age-2+) rearing (upper figure) for Arctic Grayling within sub-basins of the Ingenika core area. Continuous lines indicate good information adequacy, while dashed lines indicate fair or poor information adequacy. ID numbers correspond with critical habitats described in Table 14.

Table 15. Data gaps limiting assessments of critical habitats for Arctic Grayling within sub-basins of the Omineca River watershed, and potential studies to address them.

ID	**Sub-basin(s)**	**Data gap**	**Potential study(s)**	**Immediacy**
5.4.3a, *5.4.3b*, *5.4.3c*	Ingenika	Better knowledge required of 1) migration behaviours (e.g. immigrants, emigrants, from other core areas), 2) genetic distinctness, and 3) abundance	1) Movement studies (e.g. additional microchemistry), 2) Finer brush stroke genetic study (e.g. fry samples), and 3) adult abundance monitoring studies, respectively	High[1]
5.4.3d	Ingenika	Better knowledge required about juvenile habitat use: 1) abundance and distribution, 2) habitat descriptions.	Juvenile sampling (e.g. snorkel counts, electrofishing, seining).	Moderate
5.4.3e	Ingenika	Unknown relative importance of tributaries for providing spawning and early rearing,	Fry movement studies (e.g. otolith microchemistry),	Moderate

[1]In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions

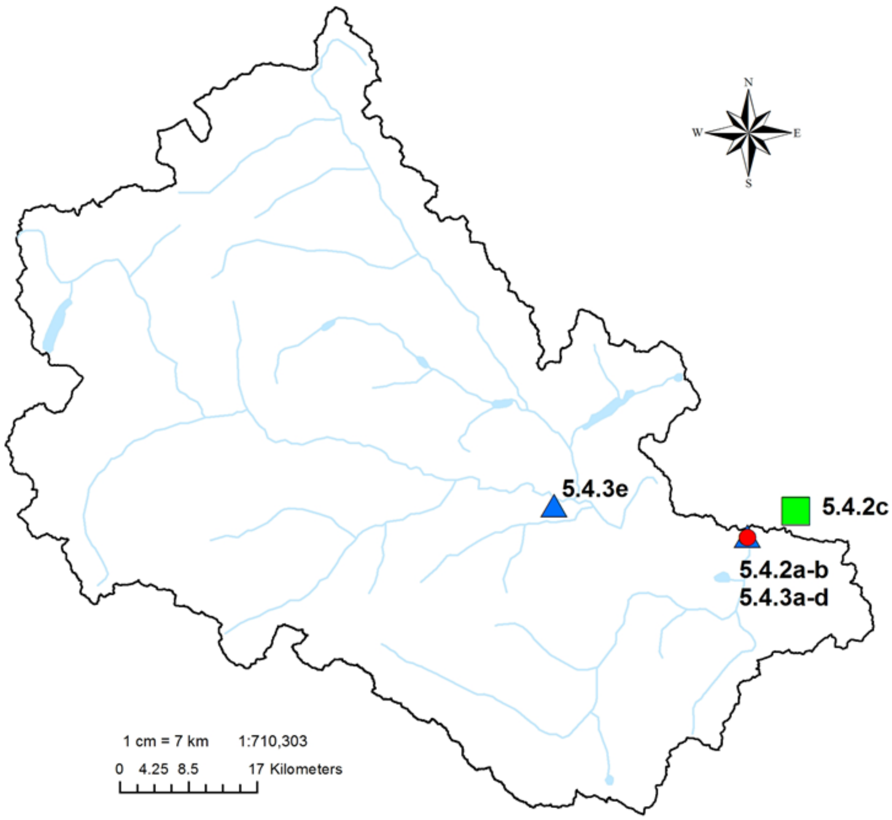

Figure 15. Locations within the Ingenika core area where data gaps limit understanding of conservation status and critical habitats for Arctic Grayling (high immediacy = red circles; moderate immediacy = blue triangles; low immediacy = green squares). Labels correspond with data gap IDs in Table 15.

5.5 Lower Finlay core area

5.5.1 Overview of existing information

Arctic Grayling critical habitats were identified using sampling records from three fish and fish habitat inventory assessments (RL&L 2000; Triton 2005, 2006), two kokanee spawning surveys (Fielden 1991, 1992), and a grayling-directed FWCP survey, which targeted fry and adults (LRDW 2006). The Arctic Grayling appear to be fluvial and most common in the Fox River and upstream reaches of the Finlay River to the base of Long Canyon Rapids. Records suggest that Arctic Grayling are rare in the Kwadacha River (one fry found in the Warneford River) and appear not to use downstream tributaries (a recent inventory in the Akie River found no grayling; LRDW 2007a). However, grayling studies of tributaries are needed to investigate rare occurrences and might broaden their range in the core area (e.g. grayling were present in Akie River before flooding; LRDW 1963). Similarly, juvenile (1+, 2+) grayling records are exceedingly rare but sampling has not been sufficient to give even an impression of abundance.

Adult abundance and their movements in the core area are also little more than a guess based on existing information (e.g. brief snorkeling in Fox River; Triton 2005).

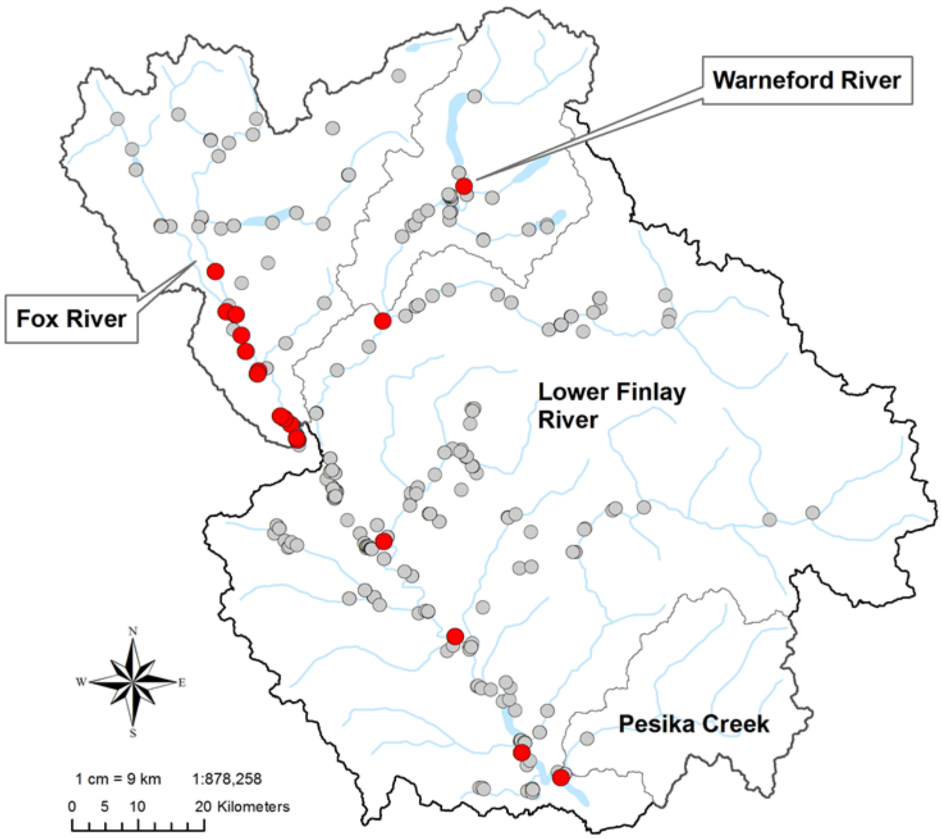

Figure 16. Distribution of records for past sampling of Arctic Grayling (red circles) and all other species (light grey circles) within sub-basins of the Lower Finlay core area.

5.5.2 Conservation status and risk assessment

Distribution: The distribution of Arctic Grayling within the Lower Finlay core area was estimated by Stamford et al. (2015) to be 40-200 km (category *C*; Appendix 1). The distribution and habitat use are reasonably well understood, drawing from inventory assessments (Miller and Kuma 1972; Triton 2005, 2006; LRDW 2006; Zemlak and Cowie 2013), kokanee studies (McLean and Blackman 1991; Fielden 1991, 1992) and grayling directed sampling (LRDW 2006). The records suggest a mainstem population distributed mainly in Fox and Finlay rivers. The upstream boundary of the core area is at “Long Canyon” rapids, which is assumed to be a barrier to upstream dispersal (based on genetic divergence from Upper Finlay core area; Shrimpton and Clarke 2012). Two lake-headed tributaries in Fox and Kwadacha watersheds (McCook and Warneford rivers, respectively) also provide spawning and rearing habitats but adult and juvenile (1+, 2+) habitat use remains poorly understood; several important data gaps associated with distribution within the Lower Finlay core area are identified in the following section (*5.5.3 Critical habitats*).

Abundance. The lack of monitoring data for estimating grayling abundance in the Finlay core areas is an important data gap of high immediacy (Data gap *5.5.2a*; Table 16). Adult population size within the Lower Finlay core area was nonetheless estimated roughly to be in the range 1000-2500 adults (category *C*; Appendix 1), based on impressions from adult distribution records and inventory reports. Abundance is assumed to be higher than in the Ingenika core area because the distribution is wider but all life history stages appear clumped into small rearing groups. Snorkeling surveys in index locations (e.g. Fox River, Bower Creek), ideally calibrated by mark-recapture (e.g. Slaney and Martin 1987; Mathias et al. 1998; Zemlak and Langston 1998; Hagen and Baxter 2005), would provide a better understanding of adult abundance. Possible index sites would need to be evaluated first with habitat use studies (see below Section *5.5.3*).

Trend. There are no data related to the abundance trend in Lower Finlay core area. The hub of the metapopulation appears to be in Fox and upper reaches of lower Finlay rivers, which are relatively pristine and escaped impacts from flooding. Consequently, the current population trend was considered no longer declining and assessed stable (category E, Appendix 1). The population is still probably adapting to habitat losses and disturbances stemming from flooding and linear developments in lower reaches of the river. Genetic analyses also suggest recent connections with Ingenika core area and possible linkage by gene flow is possible. The lack of monitoring data for estimating grayling trend in the Finlay core areas is an important data gap of high immediacy (Data gap *5.5.2a*; Table 16), which should be addressed as part of a coordinated grayling monitoring plan for the Williston watershed (introduced in Sections *2.3* and *5.1.2*). This data gap is considered to be of high immediacy.

Threats: Threats were assessed by Stamford et al. (2015) to be of moderate scope and severity (Category B, Appendix 2). Flooding of Williston Reservoir removed about 100 kilometers of fluvial habitat from Finlay River, but the prior distribution of the extant population (e.g. virgin state; Schick et al. 2007) is unknown. Loss of low gradient mainstem habitat in the lower Finlay River was probably used by second summer rearing juveniles and possibly for overwintering. Demographic or ecological connections with other streams (e.g. Ingenika River; Shrimpton and Clarke 2012) were likely disturbed by the flooding. Exploitation has likely had some increase due to linear developments but generally isolation of the Arctic Grayling populations was considered to be a factor reducing threats. There are no recent quantitative assessments of threats (data gap *5.5.2c*; Table 16), but this data gap is assigned low immediacy given that managing threats is the responsibility of the Provincial Government.

Table 16. Data gaps limiting conservation status and risk assessments for Arctic Grayling within the Lower Finlay Core Area, and potential studies to address them.

ID	Sub-basin(s)	Data gap	Potential study(s)	Immediacy
na	Lower Finlay, Kwadacha, Fox.	***Distribution*** . Poor understanding of grayling distribution	*See Table 18*	-
5.5.2a	All	***Abundance*** . Unknown adult population size.	Adult population abundance indices (e.g. snorkeling counts, angling CPUE, mark-recapture).	High[1]
5.5.2b	All	***Trend*** . Lack of abundance monitoring.	Swim count methodology within index sections of Fox and lower Finlay systems (e.g. Cowie and Blackman 2012).	High
5.5.2c	All	***Threats*** . Lack of a detailed, quantitative assessment of threats	GIS-based assessment of aquatic ecosystem health indicators of cumulative effects (road density, etc.); Fish Habitat Assessment Procedures	Low

[1]In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions

Conservation and risk assessment. Factoring the four conservation status indicators together (see Appendix 3) corresponded to a ranking of *C2-At Risk* (Stamford et al. 2015). According to this ranking, Lower Finlay grayling are "at moderate risk of extirpation" (within the next 100 years) due to a restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors" (Appendix 3). Factors influencing this assessment include a significant loss of low gradient habitat due to Williston Reservoir formation, possible small population size with significant genetic distance from the adjacent upper Finlay (Toodogonne) core area. The population seems most productive upstream of Kwadacha River, including Fox River, which receives some protection from development in Muskwa-Kechika Management Area (M-K; zoned special management). The grayling in Kwadacha River also protected by this M-K management (zoned protected). However, the grayling downstream of Kwadacha confluence are outside M-K management boundaries and, since demographic connections with upstream populations are unclear, recovery from flooding is uncertain.

5.5.3 Critical habitats

Within the Lower Finlay core area, we delineated eight stream sections providing critical habitats for at least one Arctic Grayling life stage (fry, juvenile, subadult/adult rearing, overwintering). Critical habitats for Arctic Grayling were distributed among three sub-basins within the core area (Table 17, Figure 17).

Wide distributions of critical habitats throughout the core area and including tributaries (Fox and Kwadacha rivers) suggest the Arctic Grayling are abundant (see *Abundance* in section *5.5.2*). The assessment that critical fry habitat distributed continuously throughout the core area was derived from small sample sizes, however, and suggests small pockets of fry rear near tributary confluences. Possibly, these fry are locally distributed around spawning habitats associated with these tributaries. Alternatively, fry rearing in downstream sections of Finlay River dispersed from hubs of fry production upstream in Fox and Finlay rivers. Fry sampling is insufficient to distinguish between these hypothetical recruitment sources. Similarly, adults are distributed throughout the core area but sampling is insufficient to identify the most important rearing locations beyond Fox and upper Finlay rivers. Similar to other core areas, better knowledge is required of migration behaviours, population structure, and relative abundance in order to identify key limiting factors and opportunities for conservation and enhancement (data gaps *5.5.3a*, *b*, *c*; Table 18, Figure 18).

Juvenile records are sparse (only two records each in Fox and lower Finlay rivers), which suggests they are rare relative to adults and fry. As in other core areas, however, there is an absence of directed sampling toward this life history stage. Some seining effort exists, but sample sites chosen for the overview assessment were not optimal for this method (e.g. large substrate; Triton 2005) or sites were dominated by other species (e.g. pygmy whitefish, *Prosopium coulteri*; Triton 2006). Arctic Grayling juveniles might rear in distinct locations that require alternative sampling techniques (e.g. deep canyon pools, ponds, deep back channels, off channel boggy areas). Possibly interactions with other fish species (pygmy whitefish, kokanee) affect the distribution of critical habitat for Arctic Grayling rearing in their second and third summers. Poor understanding of juvenile abundance and the types of rearing habitats they utilize (data gap *5.5.3d*; Table 18, Figure 18) is an important data gap with implications for limiting factors and conservation actions throughout the Peace basin, and should be considered of moderately high immediacy.

Fry records far upstream in two lake headed tributaries indicate natal areas associated with the outlets of Quentin and Weisner lakes (Triton 2005, LRDW 2006). No other records of grayling were found despite a significant sampling effort (Hazelwood 1976; Miller and Kumka 1982; Triton 2005, 2006). None of these efforts were directed at Arctic Grayling, however, so more sampling is required to determine the extent these tributaries (and the lakes) are used by Artic grayling (data gap *5.5.3 e*, *f*; Table 18, Figure 18). Studies aimed at filling these gaps should consider the possible influences lakes have on promoting locally-adapted migratory behaviour in Arctic Grayling and possible finer levels of population subdivision (demographic independence) within the core area.

Table 17. Critical habitats delineated for Arctic Grayling populations inhabiting sub-basins of the Ingenika core area. Sampling methods EF, SN, VO, SW, GN, AN, and RT refer to electrofishing, seine netting, visual observation, swim counts, gillnetting, angling, and radio telemetry, respectively. ID numbers facilitate identification of critical habitats in Figure 17.

ID	Sub-basin	Reach	Life stage	Sampling methods	Information adequacy	UTM bottom; UTM top	Key reference(s)
1	Lower Finlay	Mainstem	Fry	EF	Fair	10 V 370771 6321036; 10 V 330184 6368054	LRDW 2006, 2007b; Shrimpton and Clark 2012
	<u>Critical habitat comments</u>: Records indicate multiple fry rearing locations might suggest pockets of rearing habitat and possible associations with tributaries (e.g. Akie River, McGraw Creek, Paul River, Fox River, Bower Creek), but temporal sampling not sufficient to see consistencies in rearing locations among years. Distributed upstream and downstream of Fox River; downstream coordinates at mouth but lowest record near Akie confluence. Genetic analyses found significant divergence between Fox River and upper Finlay grayling (suggests Long Canyon rapids restricts upstream dispersal) but effective dispersal might occur downstream into lower Finlay. Fry rearing locations near Bower Creek might originate from upstream (e.g. Toodoggone); alternatively they are part of lower Finlay population (i.e. downstream of Long Canyon rapids). Genetic comparisons among fry rearing locations together with estimates of movements (e.g. microchemistry) will improve rigour in measures of population subdivision in Finlay River grayling.						
2	Lower Finlay	Mainstem	Juvenile	EF, AG	Poor	10 V 381622 6307329; 10 V 334671 6367543	Fielden 1991;1992; LRDW 2006, 2007
	<u>Critical habitat comments</u>: Downstream end put at Finlay mouth even though furthest downstream record (one of two) is near Akie confluence; the other record found upstream of Fox River, both caught AG. Limited effort directed at this LH stage (e.g. SN in mainstem during summer low flows; off channel bogs, tributaries) needed to better understand distribution and location of critical habitats. Interactions with native kokanee should be examined; possible competitors in mainstem rearing areas; possible additional food supply from spawning KO adults and rearing fry. SN and GN efforts aimed at kokanee spawning migration (during high fall flows) did not find any Arctic grayling juveniles in sloughs and back channels (only adults in mainstem).						
3	Lower Finlay	Mainstem	Adult	AG	Fair	10 V 381622 6307329; 10 V 322196 6371088	Fielden 1991; 1992; LRDW 2006, 2007; Shrimpton and Clark 2012
	<u>Critical habitat comments</u>: Downstream end at mouth even though furthest downstream record is upstream in Deserters Canyon. Upstream end in Bower Creek (suggests an important grayling rearing stream). Records indicate adult use in lower reaches where kokanee spawners are abundant. Possibly adults rear in Akie River (UBC Fish Museum 1963), but no confirmed records in Pesika River (e.g. Langston and Blackman 1993). Interactions between kokanee and grayling might influence GR rearing behaviour (e.g. similar to Bristol Bay populations), and KO fry might provide forage in Finlay Reach and explain some recent records (e.g. adults rearing in Chowika Creek mouth). Genetic analyses suggest gene flow between adults that rear in Ingenika, lower Finlay, and Fox rivers.						
4	Kwadacha River	Warneford River	Fry	EF	Fair	10 V 352552 6387313; 10 V 365757 6407169	Triton 2006
	<u>Critical habitat comments</u>: Single fry record indicates a natal area downstream of Quentin Lake outlet; Gr absent in 61 other EF sites in generally higher gradient portions of Kwadacha River, but also absent in 14 sites downstream in Warneford River. Neither juveniles nor adults were collected in Kwadacha watershed but Triton (2006) suggest further sampling required to improve understanding their distribution. Habitat descriptions for fluvial pygmy whitefish in turbid Kwadacha River seem similar to that used by juvenile (1+) grayling; possible species interactions affect their distributions. Downstream coordinates at Warneford mouth to include probable additional nursery areas, juvenile and adult rearing, overwintering: further sampling needed to evaluate distribution of juveniles and adults.						
5	Fox River	mainstem	Fry	EF,	Fair	10 V 339009 6368529; 10 V 330225 6389240	Triton 2005; LRDW 2006; Shrimpton and Clark 2012.
	<u>Critical habitat comments</u>: Upstream coordinates associated with record downstream of McCook River, and numerous records located downstream to Finlay confluence (mouth). GR absent in samples upstream of McCook Creek; possible species interactions limit GR rearing areas near Fox Lake. Fry abundance appears to increase further downstream; probably multiple spawning locations including mainstem and tributaries						

Table 17 (continued):

ID	Sub-basin	Reach	Life stage	Sampling methods	Information adequacy	UTM bottom; UTM top	Key reference(s)
6	Fox River	Mainstem	Juvenile	EF, SW	Poor	10 V 339009 6368529; 10 V 333165 6380149	RL&L 2000; Triton 2005; LRDW 2006
	Critical habitat comments: Only two records of juvenile GR both in mainstem Fox River but needs further efforts aimed at this LH stage (e.g. SN during summer low flows, off channel bogs, tributaries, e.g. toward Weisner Lake).						
7	Fox River	Mainstem	Adult	AG	Poor	10 V 339009 6368529; 10 V 330918 6386068	RL&L 2000; Triton 2005; LRDW 2006; Shrimpton and Clark 2012
	Critical habitat comments: Records show adults at three locations only; limited effort aimed at this LH stage (e.g. AG, SW), Greater effort aimed at adults might extend their distribution further upstream.Minimal understanding of movements in Fox River but lower reaches apparently provide optimal habitat. Genetic analyses suggest Fox and lower Finlay adults are similar to Ingenika adults; possibly adults move among rearing areas in these streams.						
8	Fox River	McCook River	Fry	EF	Good	10 V 328839 6389876; 10 V 327407 6395913	Triton 2005; LRDW 2006
	Critical habitat comments: Single fry collected during electrofishing (FWCP 2005) suggests GR natal area in McCook River downstream of Weisner Creek, but sampling efforts suggests GR rare in this stream (e.g. sampling upstream found no GR, Triton 2005).						

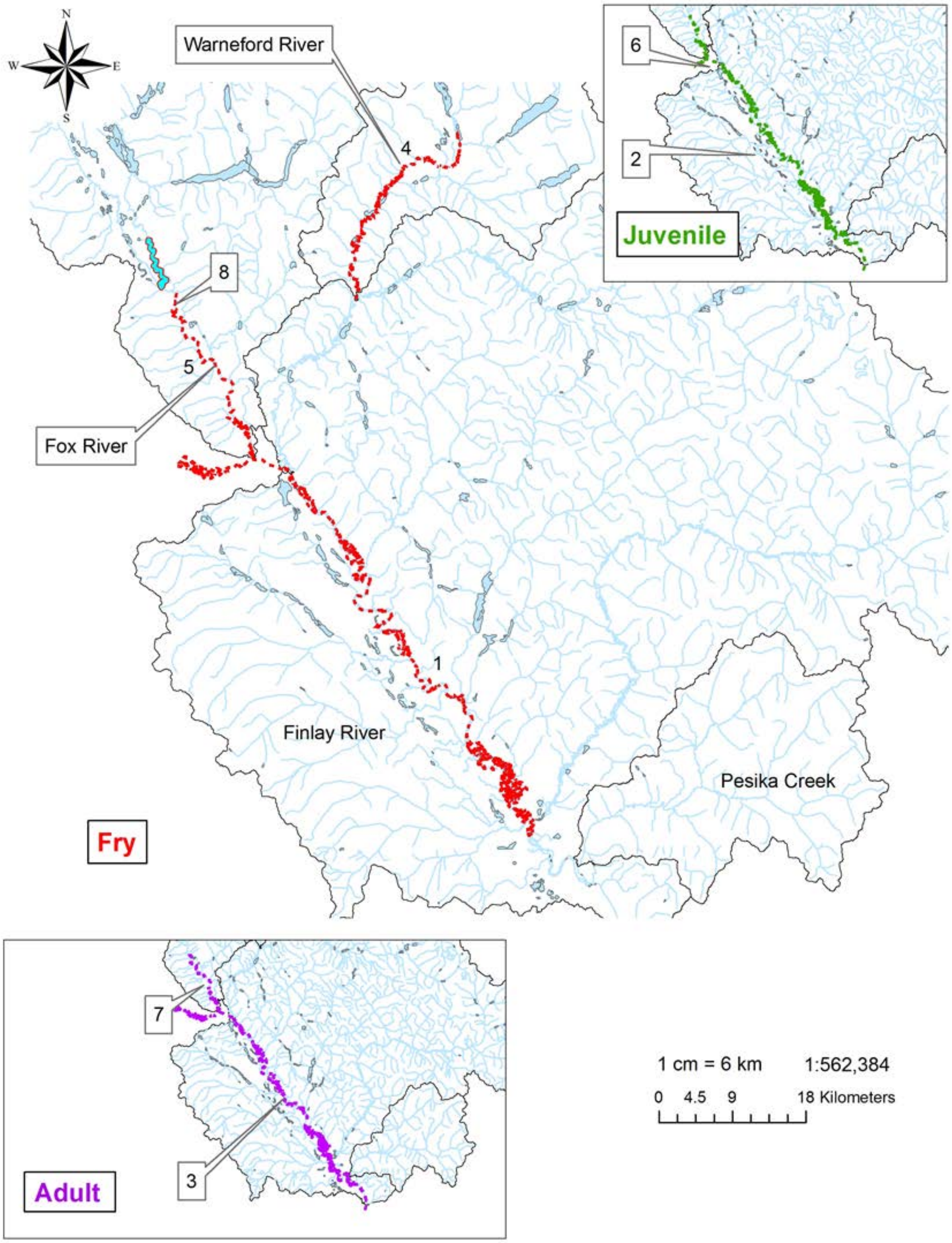

Figure 17. Critical habitats delineated for subadult/adult rearing (lower figure), fry (young-of year) rearing (middle figure), and juvenile (age-1+, age-2+) rearing (upper figure) for Arctic Grayling within sub-basins of the Lower Finlay core area. Continuous lines indicate good information adequacy, while dashed lines indicate fair or poor information adequacy. ID numbers correspond with critical habitats described in Table 17.

Table 18. Data gaps limiting assessments of critical habitats for Arctic Grayling within sub-basins of the Omineca River watershed, and potential studies to address them.

ID	Sub-basin(s)	Data gap	Potential study(s)	Immediacy
5.5.3a, 5.5.3b, 5.5.3c	Lower Finlay, Fox, Kwadacha, Akie rivers	Better knowledge required of 1) migration behaviours, 2) population structure, and 3) abundance	1) Movement studies (e.g.radio telemetry, microchemistry), 2) Finer brush stroke genetic study (e.g. fry samples), and 3) Summer habitat use studies targeting adult grayling (e.g. calibrated snorkeling surveys).	High[1]
5.5.3d	Whole core area	Better knowledge required about juvenile habitat use: 1) abundance and distribution, 2) habitat descriptions.	Juvenile sampling (e.g. snorkel counts, electrofishing, seining, angling, gillnetting).	Moderate
5.5.3e, 5.5.3f	Warneford, McCook rivers	Better knowledge of habitat use and distribution: 1) adults and juveniles, 2) fry, including early emergent.	Habitat use and monitoring studies targeting 1) adult and juvenile (e.g. snorkeling, angling, seining), 2) fry (electrofishing, beach seining, dip netting)	Moderate

[1]In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions

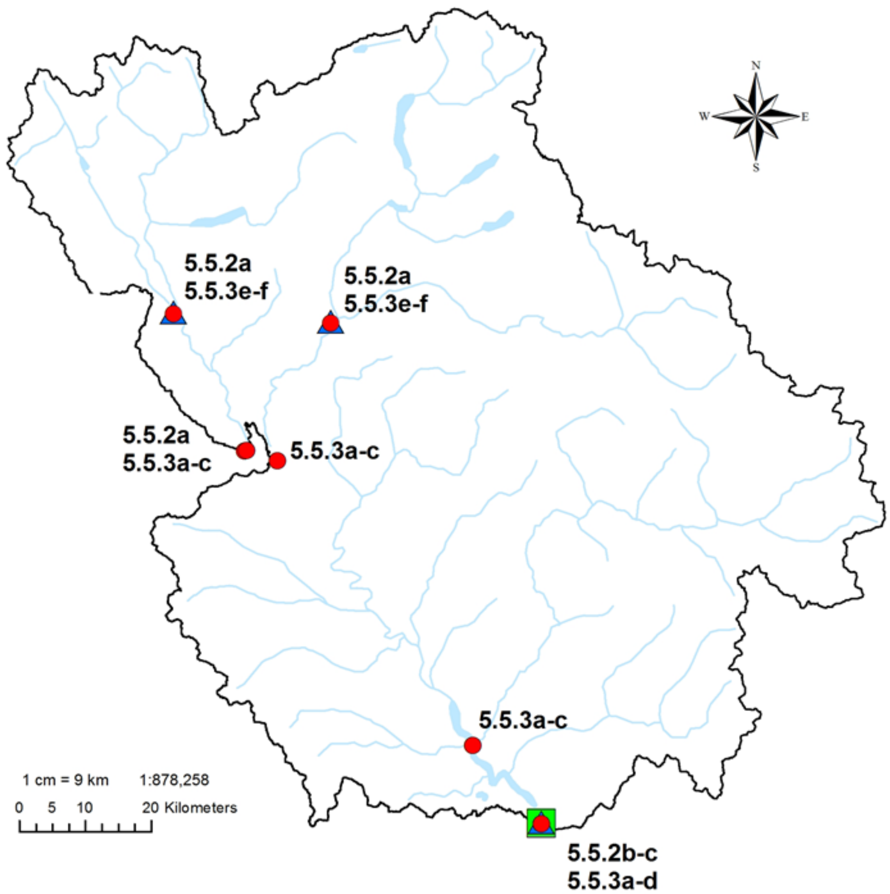

Figure 18. Locations within the Lower Finlay core area where data gaps limit understanding of conservation status and critical habitats for Arctic Grayling (high immediacy = red circles; moderate immediacy = blue triangles; low immediacy = green squares). Labels correspond with data gap IDs in Table 18.

5.6 Upper Finlay (Toodoggone) core area

5.6.1 Overview of existing information

Inventory assessments (Norcol Environmental Consultants 1986; Norris 1987; RL&L 2000, 2002), a lake trout survey (Zemlak and Langston 1994), and grayling directed sampling (LRDW 2007b) provide a perspective on the distribution of all life history stages of Arctic Grayling (Figure 19). Juveniles are distributed in both the Finlay mainstem (mostly Fishing Lakes area) and small tributaries but as in most other core areas, there is no directed sampling for this life history stage, which is likely more widely distributed and abundant. The distribution of fry rearing in patches throughout the core area suggest they derive from numerous natal areas and might suggest juveniles are also diverse in their preferred habitat (e.g. Toodoggone Lake). Movements of Arctic Grayling are also unknown, so the extent that demographic independence might promote distinct habitat uses (e.g. local adaptation) is unknown. Migration barriers at

Cascadero Falls and in the Firesteel River limit the upstream distribution in this core area, and genetic analyses suggest gene flow with Lower Finlay grayling is restricted by Long Canyon rapids (Shrimpton and Clarke 2012). The core area appears to have escaped the impacts from flooding so demographic associations between adult rearing areas (e.g. Toodoggone, Firesteel, Finlay rivers) has remained relatively undisturbed and provide an example of the native (virgin state) metapopulation structure. Arctic Grayling from this core area might have been founded first during postglacial dispersal (Stamford and Taylor 2004) so hypothetically could contain relatively high genetic diversity (and associated adaptive potential) relative to other upper Peace core areas. Some evidence suggests Finlay River grayling might have been successfully transplanted into other watersheds where established adfluvial populations exist today (e.g. upper Sikanni Chief River; Woods 2000). Therefore, this pristine core area may provide an important source population for grayling recolonization experiments in the Williston and Upper Peace core areas.

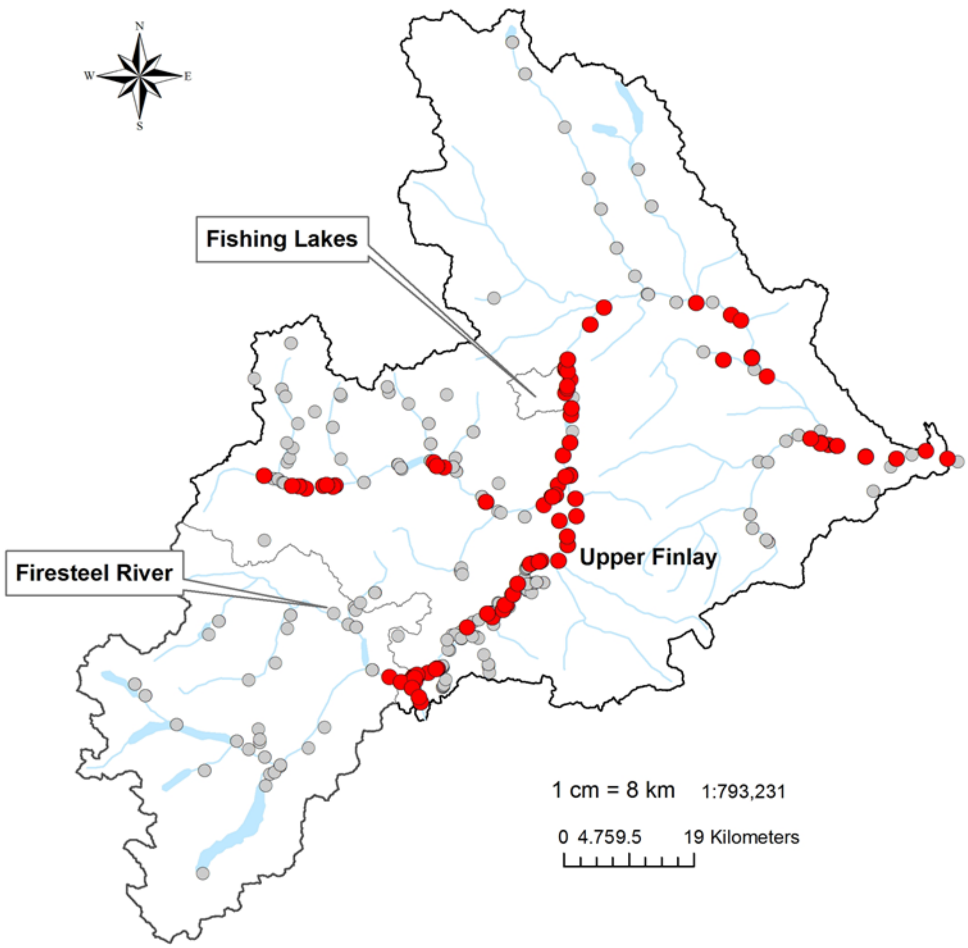

Figure 19. Distribution of records for past sampling of Arctic Grayling (red circles) and all other species (light grey circles) within sub-basins of the Upper Finlay core area.

5.6.2 Conservation status and risk assessment

Distribution: The distribution of Arctic Grayling within the Upper Finlay (Toodoggone) core area was estimated to be 40-200 km (category *C*; Appendix 1). The distribution and habitat use suggest spawning and early rearing occurs in numerous locations in the Finlay and Toodoggone rivers. Their distribution in tributaries is less understood. Several important data gaps associated with distribution within the core area are identified in the following section (*5.6.3 Critical habitats*).

Abundance. Adult population size within the Upper Finlay core area was roughly estimated to be in the range of 1,000-2,500 adults (category *D*; Appendix 1), based on impressions from adult distribution records and inventory reports. There are no abundance estimates (data gap *5.6.2a*; Table 19) but snorkeling surveys in potential index locations (e.g. Toodoggone River, upper Finlay River, Firesteel River), ideally calibrated by mark-recapture (e.g. Slaney and Martin 1987; Mathias et al. 1998; Zemlak and Langston 1998; Hagen and Baxter 2005) can potentially be utilized to address this data gap of high immediacy.

Trend. There are no data to estimate abundance trend in Toodoggone core area (data gap *5.6.2b*; Table 19, Figure 20). The hub of the metapopulation appears to reside around natal areas in upper Toodoggone, upper Finlay, and Firesteel rivers although natal areas also occur in the downstream end of the core area (just upstream from Long Canyon). The core area is relatively pristine and escaped impacts from flooding so the population trend was considered stable (category E, Appendix 1). As mentioned in the preceding paragraph, abundance monitoring to assess population size and trend is required.

Threats: Threats have been assessed by Stamford et al. (2015) to be of low severity and scope (Category G, Appendix 2). A proposed mine development around Lawyers Creek might threaten Toodoggone River but threats were generally considered low since much of the core area has been zoned protected in the Muskwa-Kechika Management Area (Stamford et al. 2015). Some potential exploitation from guide outfitters considered a minimal threat. There are no recent quantitative assessments of threats (data gap *5.6.2c*; Table 19), however.

Table 19. Data gaps limiting conservation status and risk assessments for Arctic Grayling within the Upper Finlay core area, and potential studies to address them.

ID	Sub-basin(s)	Data gap	Potential study(s)	Immediacy
na	All	***Distribution*** . Poor understanding of grayling distribution	*See Table 18*	-
5.6.2a	Toodogonne, Firesteel, Finlay rivers	***Abundance*** . Unknown adult population size.	Adult population abundance indices (e.g. snorkeling counts, angling CPUE, mark-recapture).	High[1]
5.6.2b	Toodogonne, Firesteel, Finlay rivers	***Trend*** . Lack of abundance monitoring.	Swim count methodology within index sections of Finlay and Toodogonne systems (e.g. Cowie and Blackman 2012).	High
5.6.2c	All	***Threats*** . Lack of a detailed, quantitative assessment of threats	GIS-based assessment of aquatic ecosystem health indicators of cumulative effects (road density, etc.); Fish Habitat Assessment Procedures	Low

[1]In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions

Conservation and risk assessment. The estimates from the four conservation status indicators factored together (see Appendix 3), corresponded to a ranking of 'C3-Potential Risk' (Stamford et al. 2015). According to this ranking, Upper Finlay grayling are "potentially at risk of extirpation" (within the next 100 years) due to a restricted range, possibly few populations or occurrences, threats, or other factors" (Appendix 3). Factors influencing this assessment include uncertainties around population abundance and extents of demographic independence among spawning locations (i.e. metapopulation structure). A significant genetic distance from the adjacent Lower Finlay core area, together with possibly distinct phenotypic characters (i.e. spotting pattern and colouration; adfluvial migratory behaviour; Brian Blackman pers. com. 2012) suggest the Arctic Grayling might be especially unique among other Peace basin core areas.

5.6.3 Critical habitats

Within the Upper Finlay core area, we delineated nine stream sections providing critical habitats for at least one Arctic Grayling life stage (fry, juvenile, subadult/adult rearing, overwintering). Critical habitats for Arctic Grayling were distributed among three sub-basins within the core area (Table 20, Figure 20).

Fry rearing habitat appears to have a patchy distribution in lower, middle, and upstream reaches of the Finlay and Toodoggone Rivers (over 100 river kilometers), potentially suggesting multiple recruitment sources (i.e. spawning and natal areas; Table 20, Figure 20). The locations of natal areas, the extents of fry dispersal, and the movements of adults within the core area are all unknown. These data gaps pertaining to migratory behaviours, habitat use, and relative importance among critical habitats are of relatively high immediacy and would ideally be addressed with adult and fry movement studies (e.g. radio telemetry, microchemistry), accompanied by adult abundance monitoring in key rearing locations (data gaps *5.6.3 a*, *b*; Table 21). Understanding adult abundance and their movements around natal areas in this core area are important for understanding population viability and metapopulation structure (i.e. demographic connections among spawning locations), and for designing conservation and enhancement actions.

Juvenile records are rare relative to adults and fry and, similar to other core area, there is an absence of directed sampling toward this life history stage. Incidental catches of Arctic Grayling juveniles suggest locations close to the upper Finlay River mainstem provide critical habitat but further sampling is needed to identify productive locations. For instance, the few records might suggest that smaller juveniles tend to rear in tributaries (e.g. Delta Creek) and larger juveniles rear in the mainstem (e.g. Fishing Lakes; Table 20), possibly signifying an ontogenetic niche shift. Alternatively, growth rates are different among demographically independent subpopulations and each utilizes distinct types of rearing areas. Further study is needed to distinguish between these hypothetical scenarios for second and third summer rearing habitats. Poor understanding of juvenile abundance and the types of rearing habitats they utilize (data gap *5.6.3c*, Table 21) is an important data gap limiting understanding of limiting factors surrounding juvenile habitat use. Understanding these factors may facilitate future conservation actions aimed at recovering populations toward their historic range in Peace basin (Table 1), and are therefore of moderately high immediacy (Table 21).

Adult and juvenile habitat uses in small tributaries is poorly understood and further sampling is needed to identify the important rearing areas (data gap *5.6.3d*) and natal areas (*data gap 5.6.3e*; Table 21). Summer habitat use studies in known (e.g. Delta Creek, unnamed Creek) and suspected grayling tributaries (Figure 16) are needed to understand the relative importance in the core area. Fry sampling could build on current records in Finlay mainstem and examine temporal consistency of rearing locations, and possibly use otolith microchemistry to help identify spawning locations and fry dispersal patterns (e.g. tributary use).

Sinking gill net sets in Toodoggone Lake have previously failed to capture Arctic Grayling (Norris 1987), but the inlet is a natal area, and surface oriented rearing adult Arctic Grayling often avoid capture in sinking nets (e.g. Withler 1956). Further sampling directed at Arctic Grayling is warranted in Toodoggone Lake, because it may contain a unique example of an adfluvial life history in the Williston Reservoir watershed, with potential implications for recolonization efforts in direct tributaries to the reservoir. Sampling should include shallow littoral areas where aquatic and terrestrial invertebrates frequently attract schools of rearing grayling (data gap *5.6.3f*; Table 21). Sampling for this data gap could be included in studies addressing other high priority data gaps (e.g. *5.6.3a*, *b*; Table 21) and is considered to be of moderate immediacy here.

The Arctic Grayling of the Upper Finlay core area might have appropriate adaptive potential for colonizing Williston tributaries. Addressing the data gaps identified above, taken together with those in other core areas, will improve understanding of the diversity of Arctic Grayling life history in Peace Basin (e.g. Taylor 2005), and potentially inform conservation actions aimed at improving population viability.

Table 20. Critical habitats delineated for Arctic Grayling populations inhabiting sub-basins of the Toodogonne core area. Sampling methods EF, SN, VO, SW, GN, AN, and RT refer to electrofishing, seine netting, visual observation, swim counts, gillnetting, angling, and radio telemetry, respectively. ID numbers facilitate identification of critical habitats in Figure20.

ID	Sub-basin	Reach	Life stage	Sampling methods	Information adequacy	UTM bottom; UTM top	Key reference(s)
1	middle Finlay	mainstem	Fry	EF	Fair	9 V 671241 6388012; 9 V 664654 6390274	LRDW 2007b; Shrimpton and Clark 2012
	Critical habitat comments: Downstream fry rearing habitat in low gradient braided section near Spinel Creek and downstream of cascades near Thudaka Creek confluence. Only one sampling episode but genetic analyses suggest geneflow occurs between Finlay and Toodoggone rivers. Tributary influence on spawning and rearing locations unknown; adults found rearing upstream in bedrock canyon.						
2	upper Finlay	mainstem	Fry	EF	Fair	9 V 648458 6358450; 9 V 626577 6331014	RL&L 2002; LRDW 2007b; Shrimpton and Clark 2012
	Critical habitat comments: Habitat distributed in low gradient braided sections between Toodoggone River and the base of Cascadero falls. Records appear clustered into two low gradient sections upstream and downstream of a bedrock canyon (293m long) and suggests at least two spawning locations but needs further sampling (e.g. unknown if temporally consistent, missing habitat discriptions) to verify. Mainstem side channels suggested as potential natal areas (RL&L 2001) although associations with tributaries (e.g. Delta Creek, Firesteel River) needs to be better examined. Genetic analyses suggest geneflow probably high between 'mid Finlay', 'upper Finlay', and 'Toodoggone' but clustering among these locations might also suggest high degrees of homing to spawning areas. Further investigations into movements between natal areas within this core area are needed.						
3	upper Finlay	mainstem	Juvenile	GN, EF, AG	Poor	10 V 321340 6376776; 9 V 626715	Zemlak and Langston 1994; RL&L 2002; LRDW 2007b
	<u>*Critical habitat comments*</u>*: Habitat widely distributed assuming juveniles move throughout mainstem of upper Finlay from Long Canyon (to include a record near Cutoff Creek) upstream to Cascadero Falls (include a record near Firesteel River). Additional sampling effort directed at this LH stage needed to better define locations of critical habitats (e.g. sampling in canyons seems limited) and abundance. GN indicate Fishing Lakes are important for rearing and EF and AG indicate tributaries used by smaller yearlings; suggests ontogenic shifts between tributaries and mainstem might occur. Abundance seems lower than adults and fry but this might be a sampling artefact (e.g.limited sampling directed at juveniles). Upper Finlay River appears to provide rearing habitat for juveniles derived from many populations (similar to Parsnip).*						
4	upper Finlay	mainstem	Adult	AG	Fair	10 V 321340 6376776; 9 V 626715	Zemlak and Langston 1994; RL&L 2001; LRDW 2007b
	<u>*Critical habitat comments:*</u> *Downstream end at long canyon rapids, with records in and around Cutoff Creek, upstream end at Cascadero Falls. Movements of adults unknown but based on other studies adults from numerous spawning locations probably gather (and home) to rear together in the same locations. Genetic analyses comparing among rearing adults hint at population subdivision possibly promoted by strong homing behaviour, but migratory behaviour needs further study (e.g. microchemistry, mark recapture). Adults seem to be abundant but needs assessment (e.g. calibrated annual SW counts).*						
5	upper Finlay	Delta Creek	Fry, Juvenile	EF	Poor	9 V 646113 6352601; 9 V 646107 6351772	LRDW 2007b
	<u>*Critical habitat comments*</u>*: EF indicate downstream reach used by fry and smaller yearlings. Need investigations into habitat variables associated with GR presence in tributaries;other species present include BT.Records indicate single sampling episode one location, more sampling needed.*						
6	upper Finlay	239-761400	Juvenile	EF, AG	Poor	9 V 636514 6343814; 9 V 636819 6343147	RL&L 2001; LRDW 2007b
	<u>*Critical habitat comments*</u>*: EF and AG indicate downstream reach used by smaller yearlings. Need investigations into habitat variables associated with GR presence; other species include BT, MW. Records include single sampling episode, two locations; more sampling needed.*						

Table 20, continued.

ID	Sub-basin	Reach	Life stage	Sampling methods	Information adequacy	UTM bottom; UTM top	Key reference(s)
7	Toodoggone	mainstem, upstream of Toodoggone Lake	fry	EF, SN	Good	9 V 620085 6364027; 9 V 602489 6362316	Norecol Environmental Consultants Ltd. 1986; Norris 1987; LRDW 2007b; Shrimpton and Clark 2012.
	Critical habitat comments: Records suggest fry abundant upstream of Toodoggone Lake and this inlet population might have distinct migratory behaviours from Finlay River downstream; demographic independence might be promoted by homing and local adaptation to this natal area. Habitat descriptions suggest optimal GR habitat and no fry records occur downstream of Toodoggone Lake. Local knowledge suggest Gr use lake but none cought in GN inventory; possibly overwintering only. Genetic analyses hint at population subdivision between Finlay and Toodoggone GR (Shrimpton and Clarke 2012) but possible demographic independence needs further study.						
8	Toodoggone	mainstem	Adult	AG	Fair	9 V 647251 6364249; 9 V 602489 6362316	Norecol Environmental Consultants Ltd. 1986; Norris 1987; LRDW 2007b; Shrimpton and Clark 2012.
	Critical habitat comments: Adults rear throughout the stream both upstream and downstream of Toodoggone Lake and might use the lake for overwintering; absence of GR in lake inventory (GN; Coombs 1987). Absence of juvenile records suggests rearing might be downstream in Finlay River and adults might also move extensively in and out of the rivers, but this needs more study. Juvenile directed sampling effort seems low and lacking estimates of abundance. Possibly Toodoggone Lake might promote a local migratory behaviour.						
9	Firesteel	mainstem	Adult	AG	Fair	9 V 625705 6334003;	LRDW 2007b
	Critical habitat comments: Records suggest only adults rear in downstream reach. Possible spawning location, fry rear at confluence with Finlay River.						

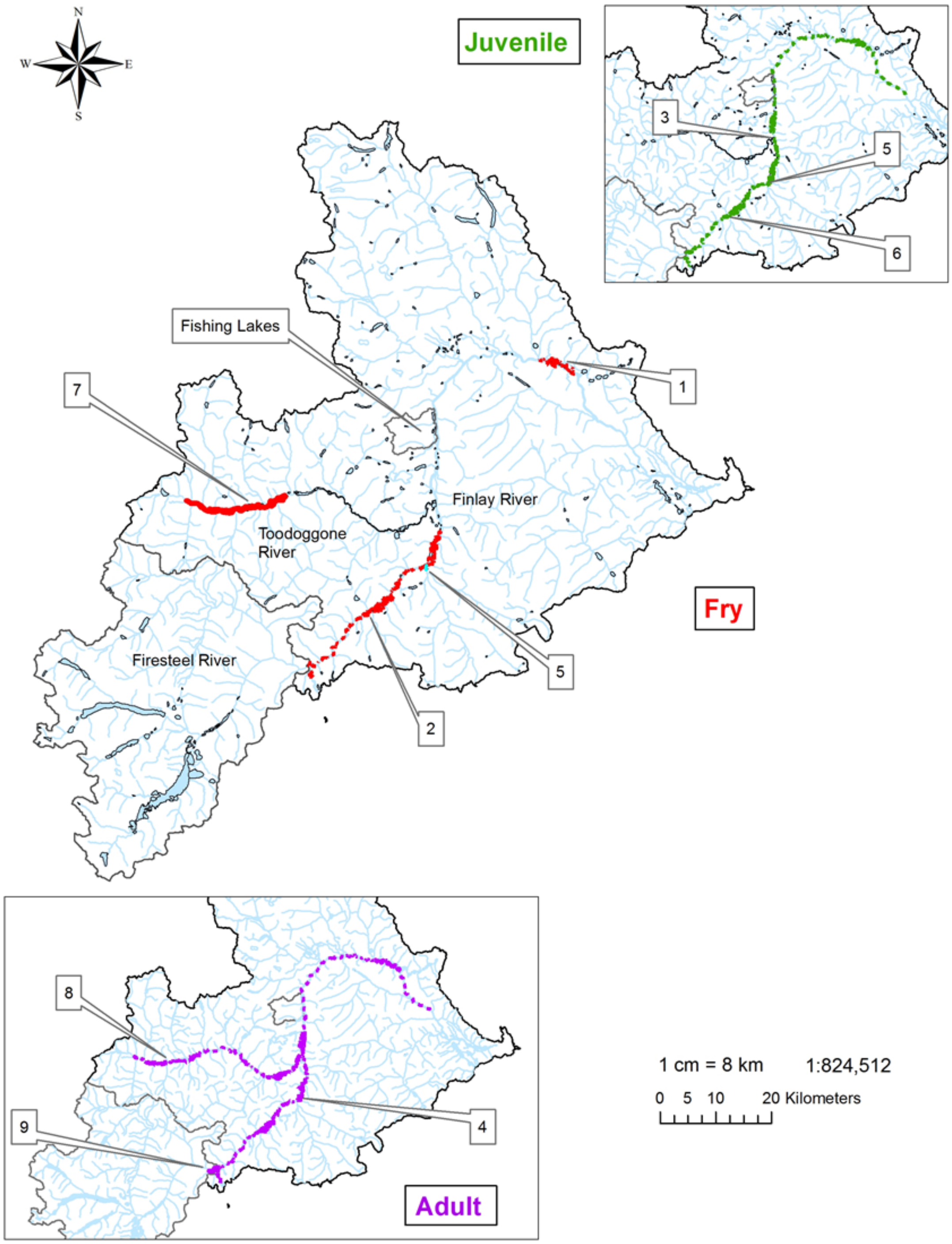

Figure 20. Critical habitats delineated for subadult/adult rearing (lower figure), fry (young-of year) rearing (middle figure), and juvenile (age-1+, age-2+) rearing (upper figure) for Arctic Grayling within sub-basins of the Upper Finlay core area. Continuous lines indicate good information adequacy, while dashed lines indicate fair or poor information adequacy. ID numbers correspond with critical habitats described in Table 20.

Table 21. Data gaps limiting assessments of critical habitats for Arctic Grayling within sub-basins of the upper Finlay River watershed, and potential studies to address them.

ID	Sub-basin(s)	Data gap	Potential study(s)	Immediacy
5.6.3a, 5.6.3b	Toodogonne, Upper Finlay/Firesteel, Finlay mainstem	Better knowledge required of: 1) migration behaviours and demographic independence among natal areas, and 2) relative importance (abundance) of rearing areas	1) Movement studies (e.g.radio telemetry, microchemistry), and 2) adult abundance monitoring studies.	High[1]
5.6.3c	Whole core area	Better knowledge required about juvenile habitat use and limiting factors	Juvenile sampling (e.g. snorkel counts, electrofishing, seining, angling, gill netting).	Moderate
5.6.3d, 5.6.3e	Small Finlay tributaries: e.g. Delta Creek, Unnamed Creek, Spinel Creek	Better knowledge of habitat use and abundance: 1) adults and juveniles, 2) fry, including early emergent.	Habitat use studies targeting 1) adult and juvenile (e.g. snorkeling, angling, seining), 2) fry (electrofishing, beach seining, dip netting, microchemistry)	Moderate
5.6.3f	Toodogonne Lake	Uncertain Arctic grayling use for 1) Overwintering, 2) rearing	Adult and Juvenile habitat use (angling, floating and sinking gill nets, seining)	Moderate

[1]In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions

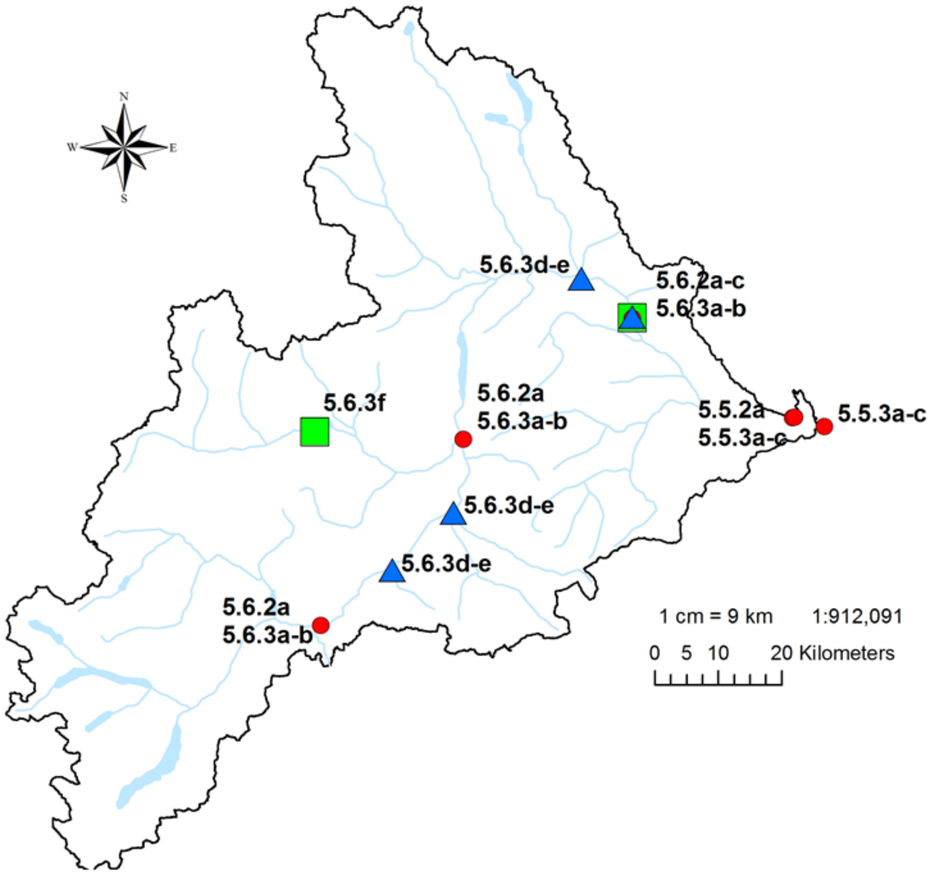

Figure 21. Locations within the Upper Finlay core area where data gaps limit understanding of conservation status and critical habitats for Arctic Grayling (high immediacy = red circles; moderate immediacy = blue triangles; low immediacy = green squares). Labels correspond with data gap IDs in Table 21.

5.7 Williston and Upper Peace core areas

5.7.1 Overview of existing information

Sampling during the mid-1970's identified abundant Arctic Grayling rearing in Williston Reservoir and in most small and large tributaries (BC Research 1975a, b; Bruce and Star 1985; Barrett and Halsey 1985). Gill netting, trawling, and hydroacoustic surveys (Blackman 1992a; Pillipow and Langston 2002), and stream surveys (Langston and Blackman 1993) beginning in 1988 (i.e. post crash; Blackman 1992a) show rare accounts of rearing grayling but suggest the reservoir and small tributaries continued to provide habitat for grayling in Williston and Peace core areas (Figures 22, 23). More recent analyses of habitat requirements and reviews of sampling in Williston watershed (Williamson and Zimmerman 2004, 2005; Clarke et al 2005; Hawkshaw et al. 2013), suggest, however that extant populations require larger (5^{th} order and larger) streams to complete their life history and spawning appears constrained to locations some distance upstream from the reservoir. Combined impacts from habitat loss, excessive exploitation during the 1970's and 1980's, and changing conditions in the reservoir resulted in a population crash in Williston and Peace core areas during early 1980's (reviewed by Blackman 2001). Records from between 1988 until 2002 show adults, fry, and juveniles rearing in small tributaries and adults rearing in the reservoir (see Section *5.7.3 Critical habitats*). The nature of these putative populations (i.e. of unknown natal area of origin), and the extent that the reservoir environment is used for migration between critical habitats remains unknown because no studies directed at Arctic Grayling were found for these core areas.

However, genetic and microchemistry studies suggest that those populations lost due to flooding in Upper Peace/Williston core areas may have been largely demographically distinct from those that survive today in other core areas (Stamford et al. 2015). Generally for the species, large rivers provide important demographic connections between far reaching habitats, which include critical habitats for juveniles rearing in their second summer (see data gaps *2.3.1a, b, c*; Table 1). Persistent records of rearing adults in small tributaries suggest some of the ancestral tendencies to home to distant habitats (e.g. chemical cues guiding movements between Core Areas; Dittman and Quinn 1996) might still persist in Peace Basin – a migratory behaviour that could inform future enhancement actions. In other words, populations that might persist in Upper Peace and Williston core areas may retain a migratory behaviour tuned to survival in the reservoir environment. Identifying such populations, and estimating their abundance and distributions, is a key to conserving the adaptive potential in Peace Basin grayling and managing for their survival into the future.

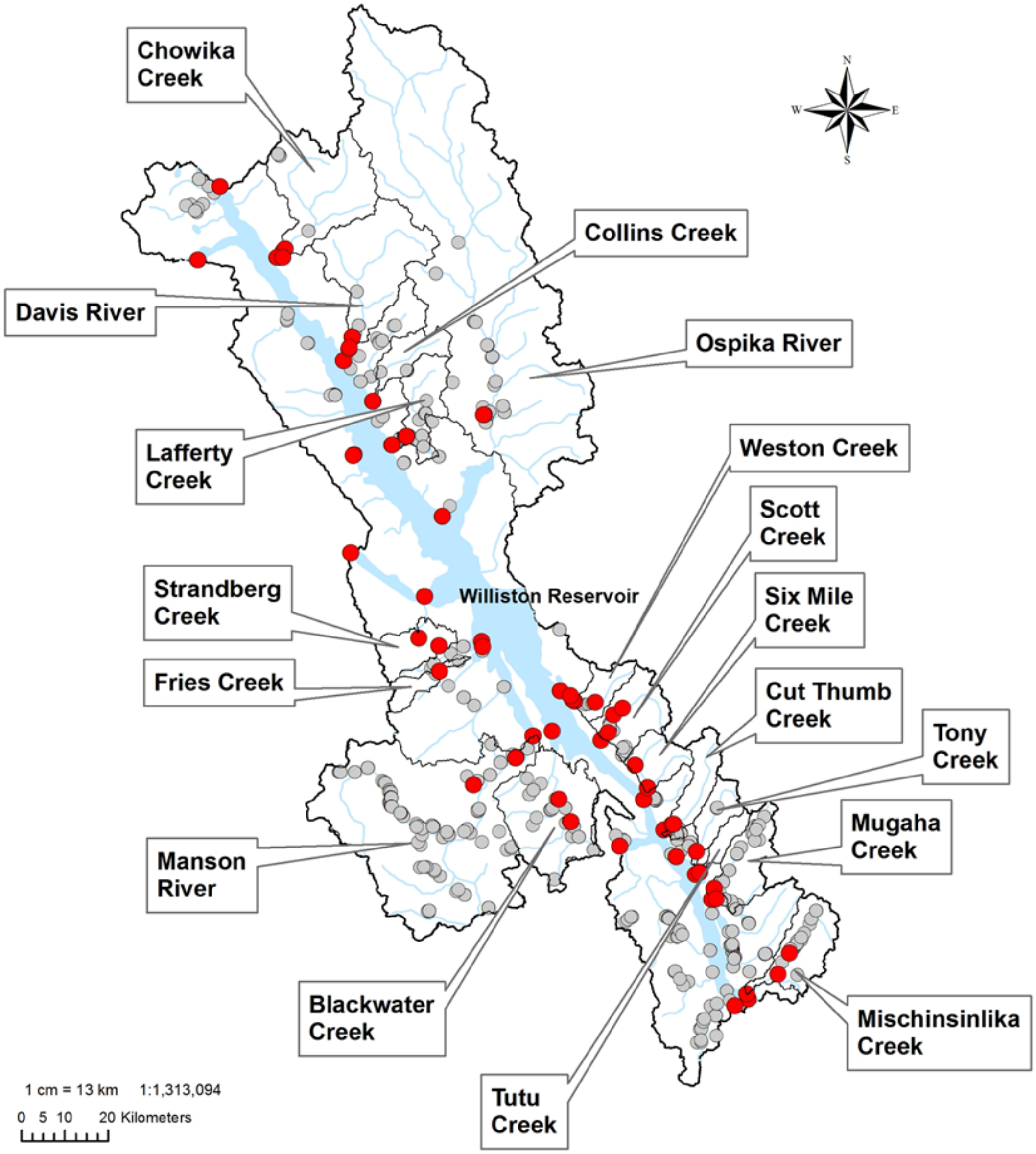

Figure 22. Distribution of records for past sampling of Arctic Grayling (red circles) and all other species (light grey circles) within sub-basins of the Williston core area.

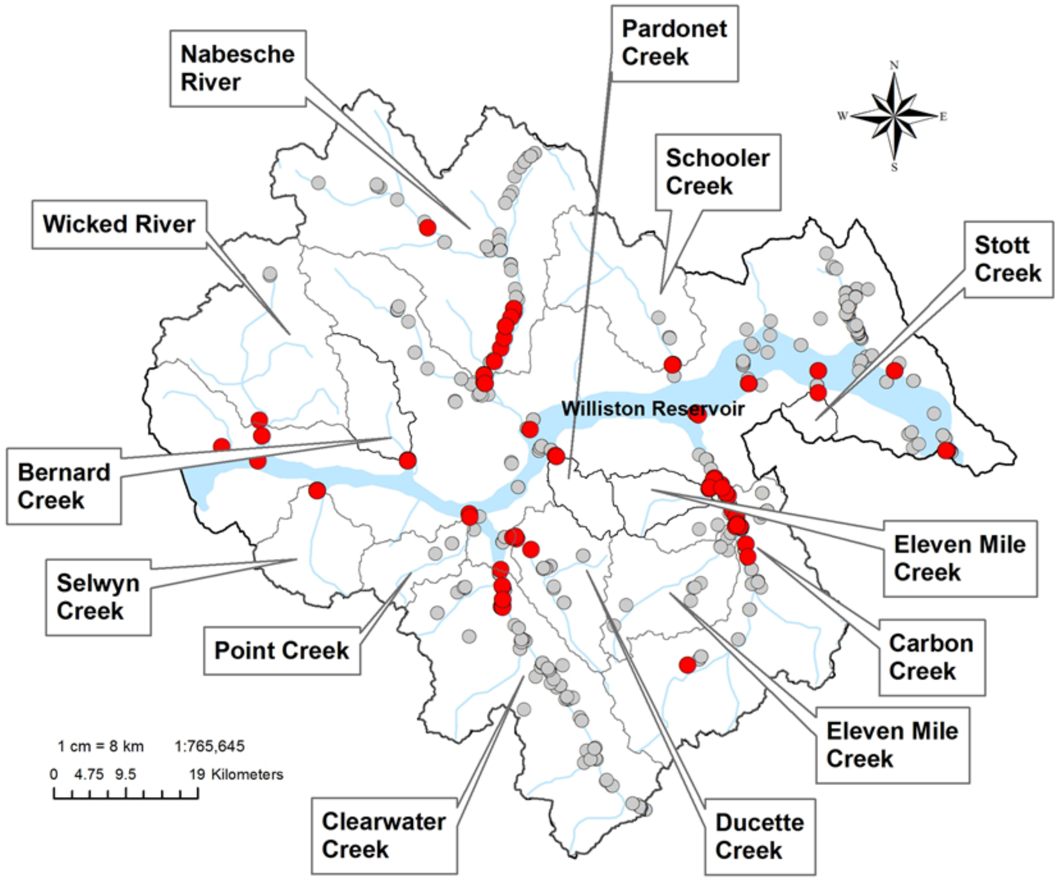

Figure 23. Distribution of records for past sampling of Arctic Grayling (red circles) and all other species (light grey circles) within sub-basins of the Upper Peace core area.

5.7.2 Conservation status and risk assessment

Distribution: The distribution of Arctic Grayling within the Williston and Peace core areas was estimated to be less than four kilometers (category A; Appendix 1), assuming critical habitats consisted of the lower reaches of only six tributaries. Arctic Grayling were assumed not to utilize the reservoir environment (Clarke et al. 2005; Ballard and Shrimpton 2009; Hawkshaw et al. 2013). Williston and Peace core areas include all flooded areas and tributaries where Arctic Grayling appear to have been extirpated (Blackman 2001; Williamson and Zimmerman 2004, 2005), but also include one larger watershed (Manson River) and seven smaller tributaries that may continue to provide adult rearing habitats (see Section *5.7.3*). The origin of these individuals is unknown and they might stray from other core areas. A baseline of distribution information in the Williston and Upper Peace core areas is urgently needed (data gap *5.7.2a*; Table 24). If existing populations are identified, an assessment of their source natal areas is required, which might be accomplished using movement studies including otolith microchemistry (assuming unique chemical signatures among tributaries; data gap *5.7.2b*; Table 22). Lethal sampling should be minimized, given the potentially severe conservation situation for these fish. Therefore, the potential use of fin rays for microchemistry analysis (Clarke et al. 2005) should be explored.

Additional data gaps associated with distribution within these core areas are identified in the following section (*5.7.3 Critical habitats*).

Abundance. Adult population size was unknown in the Williston/Peace core areas (category *U*; Appendix 1), but some broad scale sampling efforts suggest that since mid-1980s Arctic Grayling are exceedingly rare in the reservoir and small tributaries (e.g. Blackman 1992; Langston and Blackman 1993). More recent sampling efforts aimed at Arctic Grayling are insufficient, however, to provide any estimate of abundance (Williamson and Zimmerman 2004, 2005). Possibly, the post-reservoir crash signifies the extirpation of Arctic Grayling from Upper Peace and Williston core areas, and the few recent records of rearing adults are individuals wandering from other core areas. Alternatively, some natal areas may have survived the flooding (e.g. lower reaches of other core areas, Clearwater River, Langston and Blackman 1993; Fries Creek near Manson River, LRDW 1996) and offspring continue their ancestral migratory behaviour, which includes movements through the reservoir to rearing areas in small tributaries. As discussed above, an assessment of source natal areas is required to discriminate between these possibilities. Where adult grayling are found to be utilizing the streams of these two core areas, abundance needs assessment possibly using a combination of methods; e.g. swim count methodologies, angling with CPUE, creel surveys (data gap *5.7.2c*; Table 24).

Trend: (category U, Appendix 1). Infrequent records suggest the possibility that spawning continues in some tributaries (e.g. fry in Clearwater River: Langston and Blackman 1993; juveniles in Fries Creek: LRDW 1996) and sightings continue to suggest rearing occurs in the lower reaches of some tributaries where they were once abundant (Section *5.7.3*). Abundant records from the mid-1970s (BC Research 1976a, b; Bruce and Star 1985) also suggest natal areas in some small tributaries survived after flooding (e.g. Carbon Creek, Clearwater River, possibly Manson River area) and recent sampling effort directed at Arctic Grayling is insufficient to assume they no longer exist today (Brian Blackman pers. com. 2014). Data do not exist with which to evaluate trend in abundance or whether recent range expansion has occurred in tributaries to the reservoir environment (data gap 5.7.2*d*, Table 22). A baseline of distribution and abundance information is urgently needed to begin this evaluation, as discussed above.

Threats: Threats were assessed by Stamford et al. (2015) as being of high severity and scope (Category A, Appendix 2). Formation of Williston Reservoir appears to have removed almost the entire Arctic Grayling habitat that existed before flooding, and severed a complex array of demographic and ecological connections between populations.[14]

Previous conservation and enhancement actions aimed at other species, including spawning channel construction, hatchery introductions (e.g. Kokanee, Rainbow Trout; Blackman 1992b; Triton 2012), and Bull Trout non-retention, may also threaten recovery of Arctic Grayling in the reservoir (e.g. increased competition, predation; see Section *2.3*). Identifying threats to remaining grayling within the Williston and Upper Peace core areas in more detail (data gap *5.7.2e*; Table 22) will first require that the current distribution be identified (see above for *distribution*).

Table 22. Data gaps limiting conservation status and risk assessments for Arctic Grayling within the Upper Peace and Williston core areas, and potential studies to address them.

ID	**Sub-basin(s)**	**Data gap**	**Potential study(s)**	**Immediacy**
5.7.2a	All	***Distribution*** . Extremely poor knowledge of a) current distribution and b) natal source populations	a) Inventory studies targeting adult and juvenile life stages, and b) movement studies aimed at natal areas (e.g. microchemistry, genetics, radio telemtry).	High[1]
5.7.2c	Weston, Chowika, Carbon, Fries creeks, Clearwater, Nabesche, Manson rivers	***Abundance*** . Unknown relative importance (adult abundance) of these systems for grayling	Adult population abundance indices (e.g. snorkeling counts, angling CPUE).	High
5.7.2d	Weston, Chowika, Carbon, Fries creeks, Clearwater, Nabesche, Manson rivers	***Trend*** . Lack of abundance and distribution monitoring.	Baseline of abundance and distribution required: see studies identified above	High
5.7.2e	Weston, Chowika, Carbon, Fries creeks, Clearwater, Nabesche, Manson rivers	***Threats*** . Lack of detailed, quantitative assessment of threats;	GIS-based assessment of aquatic ecosystem health indicators of cumulative effects (road density, etc.); Fish Habitat Assessment Procedures	Moderate

[1]In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions

[14]The metapopulation structure that once existed in these core areas can probably be inferred from other populations (e.g. lower Peace core area; Earth Tone and Mainstream 2013; Taylor et al. 2013).

Conservation and risk assessment: Factoring the four conservation status indicators together (see Appendix 3) corresponded to a ranking of *C1-High Risk* (Stamford et al. 2015). According to this ranking, Upper Peace/Williston grayling are "at high risk of extirpation" (within the next 100 years) due to a restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors" (Appendix 3). Factors influencing this assessment include a significant loss of low gradient habitat due to Williston Reservoir formation, small population size and apparent demographic independence from all other core areas. Recovery from flooding is uncertain.

5.7.3 Critical habitats

In Upper Peace and Williston core areas, we delineated seven stream sections and two reservoir areas which, are potentially providing critical habitats for at least one Arctic Grayling life stage (fry, juvenile, subadult/adult rearing, overwintering, migration). Critical habitats for Arctic Grayling were distributed among nine sub-basins within the core areas (Table 23, Figure 24).

Better knowledge of the distribution of rearing (all life stages) and possible spawning habitats in small tributaries is a significant data gap of high immediacy (data gaps *5.7.3a, b*; Table 24, Figure 25). High sampling intensity and effort may be needed to reliably assess distribution and abundance because grayling appear rare in these streams. Sample collection methods targeting grayling microhabitats (e.g. draw from studies of limiting factors *2.3.1a, b, c*; Table 1) and using specialized sampling methods (e.g. Schell 2002; Cowie and Blackman 2004, 2012a, b) will raise likelihood of sampling rare occurrences. Another promising potential methodology is the use of environmental DNA assay, which appears to successfully identify tributaries used by Arctic Grayling using only water samples (Carim et al. 2016).

Understanding metapopulation structure improves confidence in adult abundance estimates (e.g. how many natal areas recruit to the same rearing areas) and provides direction for conservation management actions (e.g. Schick et al. 2007). In Peace and Williston core areas there is no knowledge of the locations of natal areas for the adults rearing in small tributaries and reservoir, which constitutes an important data gap as discussed in the previous section (data gap *5.7.2b*; Table 24).

Juvenile habitat is poorly understood in Upper Peace and Williston core areas – flooding of former juvenile rearing habitat may be a key limiting factor surrounding this life stage (see Section *2.3*, Table 1). A single record in Fries Creek suggests the low gradient drainage areas along the western shore of Williston Core Area (e.g. between Nation and Ingenika rivers) may continue to provide rearing habitat (Table 23), and follow up sampling is needed to determine distribution and abundance (data gap *5.7.3c*; Table 24). This record and some from other C core areas (e.g. near Aiken Lake, Fishing Lakes, tributaries of upper Finlay River) suggest second summer rearing habitat includes types other than mainstem rivers (e.g. described for Parsnip

River, Omineca River, Ingenika River) but habitat descriptions remain poorly understood in general for juveniles in Peace Basin. Improved understanding of the existing juvenile habitat uses (e.g. smaller gill raker spacing in juveniles might facilitate planktivory; Stewart et al. 2007b) in these Core Areas, and in comparison with those in other core areas, may facilitate further actions that might promote range expansion while preserving the native diversity in Peace Basin (Taylor 2005; McPhail 2007).

Utilization of the reservoir environment by adult Arctic Grayling for rearing, overwintering, and migration is also poorly understood in Upper Peace and Williston core areas (data gap *5.7.3d*) – flooding may be a key limiting factor for this life stage (see Section *2.3*, Table 1). Records suggest adults continue to rear in the reservoir (Table 23) but overwintering use remains unknown.

Table 23. Critical habitats delineated for Arctic Grayling populations inhabiting sub-basins of the Upper Peace and Williston core areas. Sampling methods EF, SN, VO, SW, GN, AN, and RT refer to electrofishing, seine netting, visual observation, swim counts, gillnetting, angling, and radio telemetry, respectively. ID numbers facilitate identification of critical habitats in Figures 22.

ID	Core Area	Sub Basin	Life stage	Sampling methods	Information adequacy	UTM bottom; UTM top	Key reference(s)
1	Upper Peace	Clearwater River	F	EF	Poor	10 U 490039 6195146; 10 U 490000 6190200	Langston and Blackman 1993
	Critical habitat comments: Follow up sampling effort directed at grayling is needed to confirm Arctic grayling continue to spawn in this stream. Use by other LH stages needs investigating.						
2	Upper Peace	Carbon Creek	A	SW	Poor	10 U 519605 6205637; 10 U 520456 6203831	Langston and Blackman 1993
	Critical habitat comments. A single sampling event identified a rearing grayling in 1988. Two follow surveys found no GR in lower reaches and tributaries (Aquatic Resources 1997; LRDW 2012), but grayling directed sampling needed to confirm absence. Gr appear to continue rearing in Carbon Arm (Blackman 1992a) and fry were still rearing in lower reaches during mid 1970's (BC Research 1975; Bruce and Star 1985).						
3	Upper Peace	Nabesche River	A	AG	Poor	10 V 489673 6218946; 10 V 490250 6222700	FWCP 1991
	Critical habitat comments: Sampling effort since 1991 seems limited (absent?); further grayling directed sampling required to determine habitat use and natal origin of rearing adults.						
4	Upper Peace	Peace Arm	A	GN, AG	Poor	10 V 551488 6208529; 10 V 453564 6212207	LRDW 1989, 1991; Blackman 1992; Langston and Blackman 1993.
	Critical habitat comments: Only two records of reservoir rearing adults since 1970's; angler reports suggest GR might still be present (LRDW 1989, 1991). Natal origin of adults unknown.						
5	Williston	Weston Creek	A	EF, AG	Fair	10 U 457452 6185885; 10 U 457819 6184998	Langston and Blackman 1993; LRDW 1996
	Critical habitat comments: Repeat sampling suggest adults might return (home) to rear in this stream. Electrofishing effort failed to find fry; natal areas for rearing adults unknown.						
6	Williston	Manson River	A	SW	Fair	10 U 448339 6176775; 10 U 434122 6166261	LRDW 1998, 2002; Hawkshaw and Shrimpton 2014.
	Critical habitat comments: Downstream end at mouth. Natal origin of adults not known, but repeat sampling suggest they might return each year to rear. Possible natal areas present needs confirming (e.g. Hawkshaw and Shrimpton 2014).						
7	Williston	Fries Creek	J	EF	Poor	10 U 434783 6195788; 10 U 427289 6192869	LRDW 1996
	Critical habitat comments: Single record but indicates juvenile rearing habitat. Natal origin or temporal abundance unknown.						
8	Williston	Chowika Creek	A	AG	Poor	10 V 394176 6289949; 10 V 394796 6290303	LRDW 1996
	Critical habitat comments: Adults collected during 1996 tissue (DNA) sampling. Natal origin of rearing adults unknown. More sampling required to determine possible temporal usage.						
9	Williston	Finlay and Parsnip arms	A	GN	Poor	10 U 495557 6114125 (Pars Arm); 10 V 381349 6309026 (Fin Arm)	Blackman 1992
	Critical habitat comments: Coordinates between Parsnip and Finlay confluences. Only one record located near Teare Creek on Finlay Arm. Whole reservoir appears to provide migratory connections to rearing areas in small tributaries, and possibly between core areas.						

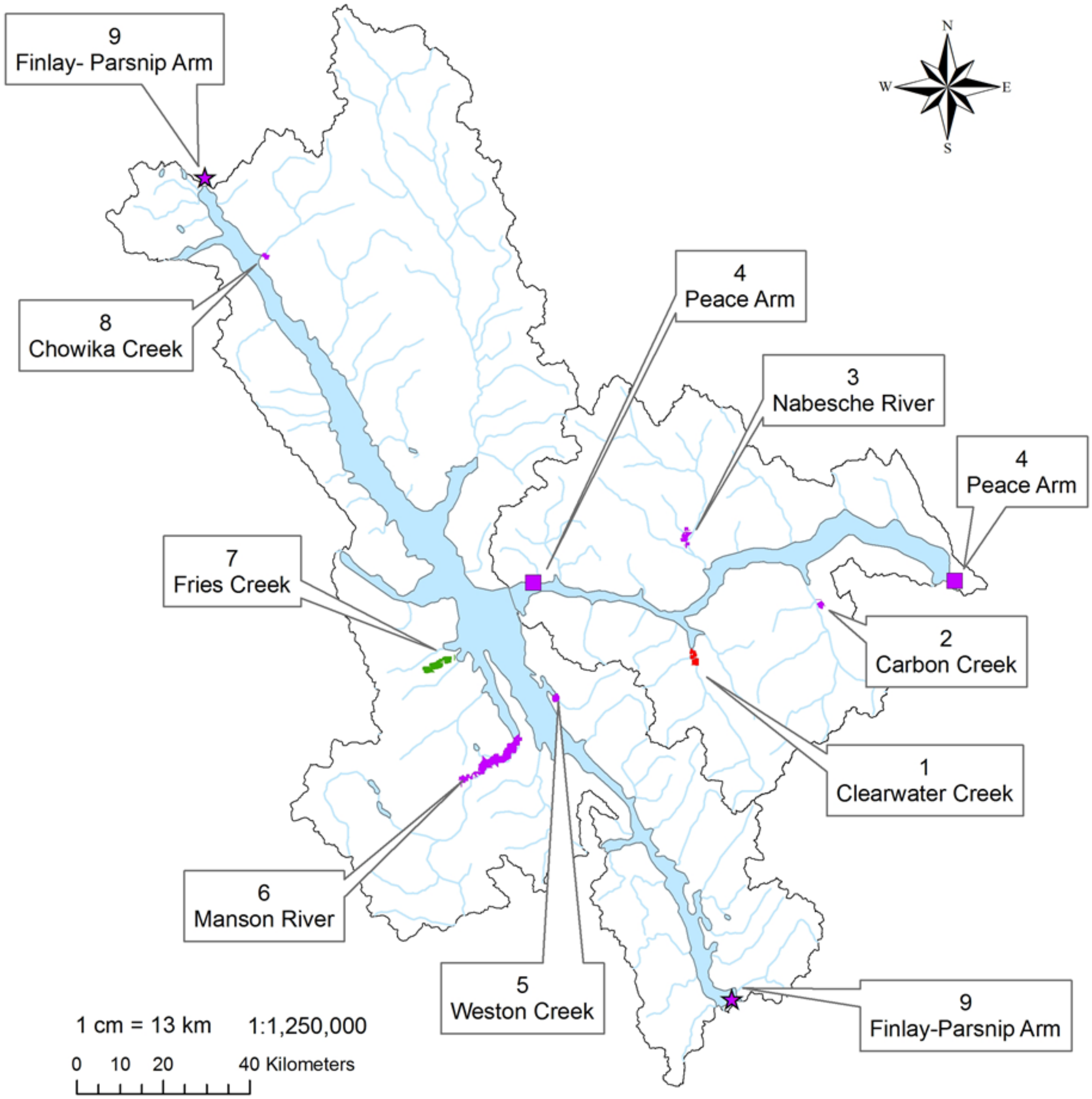

Figure 24. Critical habitats delineated for subadult/adult rearing (purple marker or line), fry (young-of year) rearing (red marker or ling), and juvenile (age-1+, age-2+) rearing (green marker or line) for Arctic Grayling within sub-basins of the Upper Peace and Williston core areas. Dashed lines indicate fair or poor information adequacy, while markers delineate extent of potential habitat in the reservoir. ID numbers correspond with critical habitats described in Table 23.

Table 24. Data gaps limiting assessments of critical habitats for Arctic Grayling within sub-basins of the Peace Basin watersheds, and potential studies to address them.

ID	Sub-basin(s)	Data gap	Potential study(s)	Immediacy
5.7.3a, 5.7.3b	Weston, Chowika, Carbon, Fries creeks, Clearwater, Nabesche, Manson rivers	Better knowledge of habitat use and abundance: a) adults and juveniles, b) fry, including early emergent.	Habitat use and monitoring studies targeting a) adult and juvenile (e.g. snorkeling, angling, seining, environmental DNA), b) fry (electrofishing, beach seining, dip netting, microchemistry, eDNA)	High[1]
5.7.3c	All	Poor knowledge of juvenile habitat use and requirements.	Juvenile sampling around existing distribution (e.g. snorkel counts, electrofishing, seining, angling, gill netting).	High
5.7.3d	All	Uncertain Arctic grayling use of reservoir for overwintering and rearing	Adult habitat use (angling, floating and sinking gill nets, seining); movement studies from small tributaries and other core areas (e.g. radio telemetry, microchemistry)	High

[1]In this report we rate immediacy based on the expected consequences of not doing the proposed action, in terms of the ability of FWCP to conduct conservation and enhancement actions

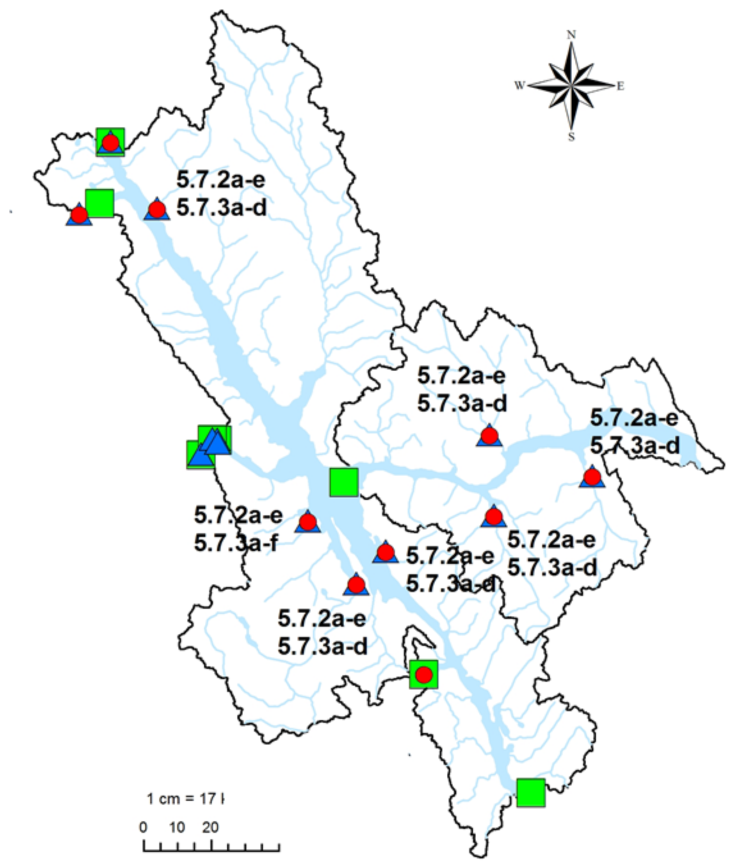

Figure 24. Locations within the Williston and Upper Peace core areas where data gaps limit understanding of conservation status and critical habitats for Arctic Grayling (high immediacy = red circles; moderate immediacy = blue triangles; low immediacy = green squares). Labels correspond with data gap IDs in Table 24. Note that unlabeled data gap markers are in other, adjacent core areas and are depicted in greater detail elsewhere.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Arctic Grayling distribution and abundance in the upper Peace Basin have been severely impacted by the construction of the W.A.C. Bennett Dam and creation of Williston Reservoir, with extirpation apparently the fate of most populations from smaller, direct tributaries of the reservoir. As identified in the Strategic Objectives of the Streams Action Plan (FWCP 2014), FWCP wishes to address this serious conservation situation by maintaining or improving the conservation status of grayling populations, and maintaining or improving the integrity and productivity of grayling habitats. However, for conservation and enhancement actions targeting Arctic Grayling to be successful, a prior knowledge base is required which includes accurate information about:

1) Arctic Grayling biology and limiting factors,
2) enhancement techniques suitable for Arctic Grayling, and realistic expectations for success,
3) indicators of conservation status and risk (distribution, abundance, trend, and threats), and
4) locations of critical habitats (i.e. those that potentially limit population productivity at one or more life stages).

In evaluating this knowledge base for FWCP, we have identified that a substantial amount of information exists already that can be applied to Williston Reservoir grayling. Of equal importance, however, is our finding that serious information gaps exist, which probably preclude major FWCP investments in conservation and enhancement actions at this point in time. In the preceding analysis, data gaps of highest immediacy were those which are likely to be significant obstacles to the initiation of on-the-ground conservation and enhancement actions. These can potentially provide a guide to action in the short-to-medium term, and are summarized below with respect to key information categories #1-4 listed above.

***Arctic Grayling biology and limiting factors*.** Relative to pre-impoundment conditions, the most significant factors limiting potential grayling productivity in the upper Peace Basin have probably been physical habitat and ecological changes, along with interrupted connectivity among populations, resulting from the flooding of critical habitats. These changes are poorly understood, but probably include flooding of key juvenile rearing and overwintering habitat in low gradient, lower reaches of grayling streams, and high lacustrine predator abundance (i.e. protected Bull Trout populations) in these areas (reservoir-stream interface). Studies to address these data gaps are of high immediacy because they may indicate which factors must be addressed and monitored during potential recolonization experiments, and include:

4) inventory studies (traditional sampling techniques targeting adult and juvenile life stages, or environmental DNA) to identify remnant populations that have adapted to the reservoir environment, and physical habitat characteristic of streams or shorelines they inhabit,
5) recolonization experiments, and
6) coordinated Arctic Grayling and Bull Trout monitoring studies in select tributaries, in combination with MFLNRO-led experiments to regulate predator abundance.

***Enhancements*.** In this analysis, we have identified that an obvious and significant enhancement objective of high immediacy would be to facilitate grayling recolonization of their former range in small-to-medium sized tributaries of Williston Reservoir. Our review of key studies of Arctic Grayling recolonization efforts in Montana, where a similar loss of grayling populations following dam construction has occurred, provided the most relevant background information. It appears that recolonization experiments may not succeed if transplanted grayling are required to shift their native migratory behaviour (e.g. from adfluvial to fluvial life history), and techniques include those providing opportunities for imprinting during key periods of ontogeny. With respect to the potential for recolonization, the two key data gaps of high immediacy are:

1) poor understanding of limiting factors that drove extirpation in small-to-medium sized tributaries of Williston Reservoir – this data gap and potential studies are described in the preceding paragraph, and
2) the serious lack of knowledge about spawning areas within the ranges of existing populations and potential sources of gametes.

Present-day Arctic Grayling core areas in the Williston Reservoir watershed include the larger watersheds, each with a relatively substantial stream length upstream of the reservoir influence. Following inundation, shorter (<5th order) tributaries to the reservoir in the Williston and Upper Peace core areas (and Dinosaur Reservoir) have lost larger proportions of potentially critical, low gradient habitats in their lower reaches, which were likely important to migrating juveniles and overwintering adults. It is currently uncertain if these tributaries contain sufficient habitat to sustain Arctic Grayling populations. Other potential mortality bottlenecks include competitor abundance and predation of juveniles in the stream and reservoir environments. Studies to identify suitable candidate streams for re-colonization experiments need to address at least four key questions: i) factors affecting survival in the reservoir? ii) life stage at which survival bottleneck occurs? iii) can mortality factors be mitigated? and iv) stream size and unflooded river length as indices of candidate stream suitability? Other studies estimating the abundance of key competitor (rainbow trout) and predator (Bull Trout) species together with a review of pre-reservoir and/or recent evidence of grayling populations within Williston, Upper Peace, and Dinosaur core areas will be needed to evaluate candidate streams.

In this report, we have suggested that the Parsnip and/or Finlay core areas have potentially suitable traits as donor populations for recolonization experiments, if Arctic Grayling in these large river systems have more plastic life history responses to variable conditions relative to other populations. We have also suggested that the Upper Finlay Arctic Grayling populations appear to have successfully been established by transplanting into headwaters in other core areas outside the upper Peace Basin (upper Sikanni Chief River, upper Prophet River, upper Halfway River). Possibly, the Finlay River population was founded first during postglacial dispersal (Stamford and Taylor 2004), and might contain higher genetic variance (and associated adaptive potential) than other Peace Basin core areas. Such adaptive potential could make this population a suitable potential donor population. Actions must not, however, threaten the conservation status of the donor core area(s). Indicators of potential suitability may include: i) relatively secure conservation status, ii) knowledge of critical adult grayling aggregations permitting efficient brood stock collection, iii) genetic and life history diversity, and iv) evidence of survival/movements in the reservoir environment, or in lacustrine environments (especially lacustrine environments with a similar community of predators/competitors; e.g. Upper Finlay core area). The lack of knowledge about spawning areas also limits the potential to protect and enhance these critical spawning habitats (see following paragraphs), so studies to identify critical spawning habitats throughout the Williston Reservoir watershed should be considered of high immediacy.

***Conservation status and risk*.** Conservation status and risk among core areas was assessed during the analysis of Stamford et al. (2015). Assessed levels of risk ranged from *Potential Risk* in the relatively pristine Upper Finlay core area, to *High Risk* for the Ingenika, Williston, and Upper Peace core areas. The latter two core areas comprise small-to-medium sized watersheds that are direct tributaries to the reservoir, where grayling populations may be largely extirpated or exist only as remnants. The remaining four core areas (Parsnip, Nation, Omineca, Lower Finlay) are considered to be *At Risk*, largely as a result of major habitat loss, diminished connectivity, and population declines over the scale of decades (i.e. the effects of impoundment were included in the analysis). While these assessments corroborate the conservation concern expressed with previous red listing of Upper Peace Arctic Grayling, they were severely limited by a lack of population data with which to estimate adult abundance and trend, which are key conservation status indicators (Arctic Grayling abundance monitoring has not occurred anywhere in the Williston watershed since 2007).

A coordinated Arctic Grayling monitoring plan for the Williston Reservoir watershed is urgently needed. We recommend that it be considered of high immediacy and a top priority for action in the near-to-medium term. Given the general sensitivity of grayling to threats, serious conservation concern for Williston grayling following reservoir creation, and presence of small, isolated populations which may be particularly vulnerable to extirpation (e.g. Ingenika core area), regular monitoring of grayling abundance is warranted to better assess conservation status. Population data are also required to assess the positive and negative effects of conservation actions, such as habitat creation, or removal of gametes for use in recolonization experiments. Arctic Grayling population data, along with population data from potential competitors and predators (e.g. Rainbow Trout, Bull Trout, Lake Trout), are required to assess the importance of species interactions in limiting Arctic Grayling distribution and abundance. A proven study technique in clear stream reaches of the Williston Reservoir waterhshed has been calibrated (via mark-recapture) snorkeling surveys targeting adult and subadult grayling. Reliable results from population monitoring studies require experienced crews and a significant commitment of resources, and population monitoring may not be feasible in all core areas. In setting priorities for monitoring, coordination with the Bull Trout monitoring program to identify suitable watersheds for monitoring of both species is desirable.

***Critical Habitats*.** A total of 80 stream segments providing critical habitats for at least one Arctic Grayling life stage (subadult/adult, juvenile, fry) have been delineated in the tables of this report. Among these, information adequacy was estimated to be relatively high in 39 cases, and fair or poor in the remainder. In the analysis of critical habitats, a total of 47 information gaps were identified that potentially limit the ability to initiate conservation and enhancement actions. While this is a large number, the picture can be greatly simplified by generalizing a pattern of recurring data gaps affecting all core areas, and identifying those estimated to be of high immediacy.

The first recurring data gap of high immediacy with respect to critical habitats is the unknown total distribution of grayling within core areas, and the relative importance of grayling streams within the core area. While these data gaps range from high to low immediacy, it can generally be said that inventory studies targeting adult and juvenile life stages can be of value in better defining the existing range of Arctic Grayling in each core area. Knowledge of critical habitats throughout the life cycle is also essential for identifying: i) potential threats to grayling populations, ii) potential limiting factors for each life stage, iii) appropriate locations for conservation and enhancement actions, and iv) life history within a core area. Potential study techniques include: electrofishing and seining studies targeting fry and juvenile grayling, otolith microchemistry, summer habitat use studies targeting adult grayling (e.g. snorkeling surveys, angling), radio telemetry studies, and the promising new technique of environmental DNA. Because the need for inventory and abundance data is widespread, prioritization will obviously be of importance. In the tables of this report, the distribution data gaps of highest immediacy are those for the Williston and Upper Peace core areas, where it is uncertain whether self-sustaining Arctic Grayling populations still exist. If populations can be identified that have adapted to life in partially-inundated tributary systems, their study may hold the key to understanding the potential for recolonization efforts in these core areas.

The second recurring, critical habitat data gap is the poor understanding of adult migratory behaviour and locations of natal areas. This corresponds to the data gap identified above with respect to enhancement (lack of knowledge about spawning areas within the ranges of existing populations and potential sources of gametes). Early rearing success in natal areas may be an important bottleneck limiting grayling populations, so conservation and enhancement actions targeting this life stage and the critical habitats may potentially be important.[15] Potential study techniques for understanding adult migratory behaviour are listed for every core area and include: radio telemetry, otolith microchemistry, and surveys of newly-emerged fry distribution

[15] Enhancement techniques targeting the early critical period following emergence have yet to be identified and/or evaluated, which might limit successful actions. Characterizing habitat requirements for early rearing requires study of these habitats, which will be required before enhancements can be designed (e.g. low velocity margin habitat structures suitable for high water conditions; improvements/restoration of stream passage to permit adult grayling to access suitable habitats).

and abundance. As mentioned above, this is also a key enhancement data gap with respect to potential reservoir recolonization experiments, because the lack of knowledge of spawner distribution and abundance means that potential source populations for gametes have not been characterized.

A third general critical habitat data gap of high immediacy in every core area is the poor understanding of juvenile (post-young-of-year) habitat use. The sparse records that do exist suggest the types of critical habitats might be variable. For instance, juveniles have been observed in mainstem riffles in the Parsnip, Omineca, and Ingenika core areas, yet critical habitats also include off channel habitats and small tributaries. Habitat use studies are needed to determine if juveniles use a variety of habitats within core areas, and if habitat characteristics are different among populations. Understanding habitat use in small tributaries and the extent they are connected with the mainstem habitats of all core areas (e.g. data gap *5.3.3c*, *d*, Table 12) will help define limiting factors associated with small tributaries, and perhaps improve understanding of potential limiting factors associated with the Upper Peace and Williston core areas.

The fourth recurring data gap is the relatively poor understanding of fine-scale population structure and gene flow within and among core areas. Population structure data exist for Williston Arctic Grayling, but provide fairly broad-brush stroke descriptions of population subdivision mostly among groups of rearing adults. The extents that landscape features (e.g. gradient, presence of tributaries) influence gene flow both within and between core areas remains unclear. Gene flow estimates may improve abundance estimates (e.g. do rearing adults derive from a single metapopulation or are their spawning locations demographically independent?) and may be important for understanding movements through the reservoir. Potential studies addressing these information gaps include molecular genetic studies and/or movement and life history studies (e.g. radio telemetry, otolith microchemistry).[16]

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[16] Addressing this data gap requires a rigorous characterization of the genetic profile of natal areas. From this the adults and juveniles of unknown natal origin can be assigned to their respective natal streams based on their individual genetic variance. More accurate and powerful models have larger sample sizes of fry from each natal stream (i.e. between 30 and 50 individuals) and have samples from all possible natal areas. Attaining such a data set requires a significant amount of sampling effort, yet tissue sample collection is non-lethal and relatively simple once fish are collected. Consequently, it is highly recommended that tissue samples be collected from all Arctic Grayling that are collected during FWCP-funded projects. Tissue samples can be small (1/4 of a thumbnail) and best clipped from the distal edge of a fin (e.g. dorsal lobe of the caudal fin) where the fin clip is more likely to regenerate. Fin clips need to be completely immersed in 95% pure ethanol (denatured alcohol damages the DNA) and stored in a sealed and labeled vial (e.g. 2ml microcentrifuge tube). Data accompanying each labelled tissue sample must include: Sample date; Location (e.g. UTM); Stream name. Tissue sample vials are then submitted to FWCP who then passes them on to a storage facility (e.g. Shrimpton Lab, UNBC; Beatty Biodiveristy Museum, UBC).

Among the information gaps identified above for limiting factors, enhancements, conservation status and risk, and critical habitats, some overlap occurs as noted (e.g. the lack of knowledge about adult migratory behaviours, natal areas, and potential sources of gametes limits both potential enhancement activities and also conservation of critical habitats). With redundant data gaps merged into a single list, eight data gaps of high immediacy can be discerned (Table 25). This list provides the basis for recommended monitoring actions presented in the companion document to this report, the *Arctic Grayling Monitoring Framework for the Williston Reservoir Watershed* (Hagen and Stamford 2017). It is our intention that this list will provide a helpful and relatively concise recommendation for Arctic Grayling science within core areas of the Williston Reservoir watershed, over the near-to-medium term.

Table 25. Recurring information gaps of high immediacy that limit the ability of FWCP to initiate conservation and enhancement actions for Arctic Grayling in the Williston Reservoir watershed, and potential monitoring studies to address them.

ID	Core area	Information gap	Monitoring action	Report section	Link to conservation/ enhancement actions
1	Parsnip, Ingenika	Lack of population data for assessing total adult abundance and trend (since 2007).	Estimate total abundance, and trend within existing index reaches (snorkeling surveys).	*5.1.2* (Parsnip); *5.4.2* (Ingenika)	Will enable: 1) conservation status assessment for core area; 2) prioritization among core areas and sub-basins for conservation/ enhancement actions; 3) identification of index reaches for monitoring trend; 4) delineation of summer-rearing critical habitats for conservation and enhancement actions (e.g. stream fertilization, land securement); 5) improved knowledge of ecological interactions with predators (if coordinated with Bull Trout monitoring locations).
2	Parsnip (upstream of Table R), Nation, Omineca, Ingenika, Lower Finlay	Lack of population data for assessing total adult abundance and trend, and for delineating critical habitats for subadult/adult rearing; unknown feasibility for abundance monitoring.	Feasibility study of potential for adult grayling abundance monitoring (e.g. underwater visibility, snorkeling detection probability estimates), combined with estimation of critical summer rearing habitats	*5.1.2* , *5.1.3* (Parsnip); *5.2.2* , *5.2.3* (Nation); *5.3.2* , *5.3.3* (Omineca); *5.4.3* (Ingenika); *5.5.2* , *5.5.3* (Lower Finlay)	Will enable: 1) conservation status assessment for core area; 2) prioritization among core areas and sub-basins for conservation/ enhancement actions; 3) identification of index reaches for monitoring trend; 4) delineation of summer-rearing critical habitats for conservation and enhancement actions.
3	All	Lack of assessment of aquatic ecosystem health (habitat threats).	GIS indicator-based assessment of aquatic ecosystem health; Fish Habitat Assessment Procedures.	*5.1.2, 5.2.2, 5.3.2, 5.4.2, 5.5.2, 5.6.2, 5.7.2*	Will enable: 1) conservation status assessment for core area; 2) prioritization among core areas and sub-basins for restoration/ enhancement actions (e.g. riparian restoration, road deactivation)

Table 25, continued.

ID	Core area	Information gap	Monitoring action	Report section	Link to conservation/ enhancement actions
4	All	Lack of critical habitat information for key life stages: spawning/natal areas.	Movement studies (e.g. radio telemetry); studies of newly-emerged fry distribution.	*5.1.3, 5.2.3, 5.3.3, 5.4.3, 5.5.3, 5.6.3, 5.7.3*	1) Enhancements of low-velocity margin habitats may target a key factor limiting recruitment; 2) will enable spawning habitat protection; 3) identification of potential sources of gametes for recolonization experiments.
5	All	Lack of critical habitat information for key life stages: juvenile rearing/ overwintering.	Inventory methods targeting juvenile life stage (100-200 mm): seine netting, electrofishing, snorkeling; otolith microchemistry.	*5.1.3, 5.2.3, 5.3.3, 5.4.3, 5.5.3, 5.6.3, 5.7.3*	Loss of juvenile rearing/overwintering habitat due to flooding is a leading plausible explanation for extirpation of grayling from Williston Reservoir streams. A good understanding of juvenile habitat requirements in other core areas is key to identifying candidate streams and enhancements that will enable successful recolonization.
6	All	Relatively limited understanding of fine-scale population structure and gene flow within and among core areas.	Molecular genetic studies (tissues to be collected during studies identified above); movement studies (e.g. otolith microchemistry).	*5.1.2, 5.2.2, 5.3.2, 5.4.2, 5.5.2, 5.6.2, 5.7.2, 6.0*	Will enable: 1) more accurate knowledge of core area boundaries and conservation status; 2) better understanding of potential for movements within the reservoir.
7	Williston, Upper Peace	Unknown present-day distribution of grayling	Inventories targeting adult and juvenile life stages; environmental DNA (requires feasibility assessment).	*5.7.2, 5.7.3*	Will enable: 1) conservation actions to protect remnant populations, if present; 2) studies of key habitat requirements necessary for recolonization (to inform future enhancements); 3) identification of potential sources of gametes for recolonization experiments.
8	Williston, Upper Peace	Poor understanding of factors driving extirpation in small-to-medium size tributaries to the reservoir	Recolonization experiments in candidate streams, in combination with studies of habitat use and predator abundance.	*5.7.2, 5.7.3*	Recolonization of the lost range in Williston Reservoir tributaries would potentially be the single most significant enhancement, but actions must not threaten the conservation status of existing populations

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Appendix 1. Codes and associated definitions for categorical estimates of population size (mature adults), distribution, trend, and threats, for use in the USFWS (2005) *Core Area Conservation Status and Risk Assessment Methodology* (see Section *4.1*).

1. 'Population Size' codes

A 1-50 adults
B 50-250 adults
C 250-1,000 adults
D 1,000-2,500 adults
E 2,500-10,000 adults
U Unknown

2. 'Distribution' (area of occupancy within core area expressed as stream length) codes

A <4 km
B 4-40 km
C 40-200 km
D 200-1,000 km
E 1,000-5,000 km
U Unknown

3. 'Trend' (within 25 years) codes

A Severely declining. Decline of >70% in population, distribution, or number of occurrences
B Very rapidly declining. Decline of 50-70% in " " "
C Rapidly declining. Decline of 30-50% in " " "
D Declining. Decline of 10-30% in " " "
E Stable. Population, distribution, or number of occurrences unchanged or remaining within +/- 10% fluctuation
F Increasing. Increase of >10% in population, distribution, or number of occurrences
U Unknown

4. 'Threats'

Severity

High: Loss of population or destruction of species' habitat in area affected, with effects irreversible or requiring long-term recovery (>100 yrs)
Moderate: Major reduction of species population or long-term degradation or reduction of habitat in the core area, requiring 50-100 yrs for recovery
Low: Low but significant reduction of species population or reversible degradation or reduction of habitat in area affected, with recovery expected in 10-50 yrs
Insignificant: Essentially no reduction of population or degradation of habitat or ecological community due to threats, or recovery from minor temporary loss possible within 10 yrs (effects of locally sustainable levels of fishing are considered insignificant as defined here).

Scope

High: >60% of total population or area affected
Moderate: 20-60% of total population or area affected
Low: 5-20% of total population or area affected
Insignificant: <5% of total population or area affected

Immediacy

High: Threat is happening now or imminent
Moderate: Threat is likely to be operational within 2-5 yrs
Low: Threat is likely to be operational within 5-20 years
Insignificant: Threat is not likely to be operational within 20 yrs

Appendix 2. Calculation of overall threats values from values for severity, scope, and immediacy subfactors (USFWS 2005; see Appendix 1 and Section *4.1* for details).

SEVERITY	***SCOPE***	***IMMEDIACY***	***VALUE***	***DESCRIPTION***
High	High	High	A	Moderate to severe, imminent threat for most (>60%) of population, occurrences, or area
High	High	Moderate		
Moderate	High	High		
Moderate	High	Moderate		
High	Moderate	High	B	Moderate to severe imminent threat for a significant proportion (20-60%) of population, occurrences, or area
High	Moderate	Moderate		
Moderate	Moderate	High		
Moderate	Moderate	Moderate		
High	High	Low	C	Moderate to severe, nonimminent threat for significant proportion of population, occurrences, or area
Moderate	High	Low		
High	Moderate	Low	D	Moderate to severe, nonimminent threat for a significant proportion of population, occurrences, or area
Moderate	Moderate	Low		
High	Low	High	E	Moderate to severe threat for small proportion of population, occurrences, or area
High	Low	Moderate		
High	Low	Low		
Moderate	Low	High		
Moderate	Low	Moderate		
Moderate	Low	Low		
Low	High	High	F	Low severity threat for most or significant proportion of population, occurrences, or area
Low	High	Moderate		
Low	High	Low		
Low	Moderate	High		
Low	Moderate	Moderate		
Low	Moderate	Low		
Low	Low	High	G	Low severity threat for a small proportion of population, occurrences, or area
Low	Low	Moderate		
Low	Low	Low		
Two of three insignificant			H	Unthreatened. Threats are minimal or very localized
Two of three unknown or not assessed			U	Unknown. The available information is not sufficient to assign a degree of threat

Appendix 3. Numeric scoring procedure for assessing risk to Arctic Grayling populations in core areas for which categorical estimates of population data and threats indicators exist, and descriptions of levels of assessed risk (adapted from USFWS 2005).

Core Area Numeric Scoring (USFWS 2005, Appendix A)

(Starting value = 3.5)

Categorical value	Population Size	Distribution*	Trend	Threats
U	0	0	0	0
A	-1	-1	-1	-1
B	-0.75	-0.75	-0.75	-0.75
C	-0.5	-0.5	-0.5	-0.5
D	-0.25	-0.25	-0.25	-0.25
E	-0.25	0	0	0
F	0	-	+0.25	0
G	-	-	-	+0.75
H	-	-	-	+1.0

* lower score by one rank (i.e. reduce risk) if anadromous or adfluvial

Points (P)	C-rank	Description
P≤1.5	C1	**HIGH RISK** - Core area at high risk because of extremely limited and/or rapidly declining numbers, range, and/or habitat, making the Arctic grayling in this core area highly vulnerable to extirpation
1.5<P≤2.5	C2	**AT RISK** - 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
2.5<P≤3.5	C3	**POTENTIAL RISK** - 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 of the core
3.5<P≤4.5	C4	**LOW RISK** - Arctic grayling common or uncommon, but not rare, and usually widespread throughout the core area. Apparently not vulnerable at this time, but may be cause for long-term concern.
N/A	CU	**UNRANKED** - Core area currently unranked due to lack of information or due to substantially conflicting information about status and trends.
N/A	CX	**EXTIRPATED** - Core population extirpated; not a viable core area.