Limiting Factors, Enhancement Potential, Critical Habitats, and Conservation Status for Bull Trout of the Williston Reservoir Watershed: Information Synthesis and Recommended Monitoring Framework

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EXECUTIVE SUMMARY

The Bull Trout (*Salvelinus confluentus*) is one of the most highly-valued fish species in the upper Peace Basin, and is also one of British Columbia's most sensitive species. This study reviews the existing knowledge base for Bull Trout of the Williston Reservoir and Dinosaur Reservoir watersheds, assesses the status of populations of large-bodied, migratory Bull Trout that are of particularly high value and conservation concern, and recommends monitoring studies that will enable habitat-based conservation actions and improved status assessments in future.

The purposes of this study are: 1) to evaluate the existing knowledge base relative to FWCP's strategic objectives of maintaining or improving habitat productivity, the status of populations, and opportunities for sustainable use of fish, and building and maintaining relationships with stakeholders and aboriginal communities; and 2) to identify monitoring study needs to potential proponents wishing to develop Bull Trout project grant applications via the FWCP grant application process. The study thereby fulfils Objective *1c-1* of the *Streams Action Plan* (FWCP 2014):

> Action *1c-1*: Review existing information (including provincial management plan), summarize status and trends of Bull Trout 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.

This report has two main components, reflecting the dual purposes of the study as specified above. The first is a synthesis of available information from the Williston Reservoir watershed and the broader scientific literature, highlighting key information types necessary for FWCP to move forward on habitat conservation and enhancement projects. The final component of this report is comprised of the conclusions from the information synthesis along with recommendations for Bull Trout monitoring in the Williston Reservoir watershed, and can be read as a stand-alone document to gain a quicker perspective on information gaps and monitoring priorities.

Small-bodied, stream resident and large-bodied, migratory life histories are both common for Bull Trout of the Williston Reservoir watershed. Populations of the large-bodied, migratory form of the Bull Trout are of highest value to people, at highest risk, and potentially impacted by the creation of Williston Reservoir, so these populations are the primary focus for this report. With respect to the biology of the Bull Trout in the Williston Reservoir watershed, the lack of knowledge about 1) population structure in the Williston Reservoir watershed and 2) changes in age, growth and life history over time are key data gaps.

Because of conservation concern for Bull Trout across its range, studies of limiting factors have been ongoing since the 1990s. Elevated water temperatures in juvenile and adult habitats, land use-related habitat degradation, interrupted connectivity, the presence of non-native interspecific competitors in adult rearing environments, and angling exploitation appear to be the most important factors limiting the distribution and abundance of Bull Trout. The most important

information gaps with respect to limiting factors are probably the lack of knowledge about: 1) baseline water temperature conditions in critical habitats, 2) sustainable thresholds for land use activities, 3) the threat posed by increasing Lake Trout populations in Williston Reservoir, and 4) exploitation rates in subsistence fisheries.

Enhancements that have been successfully applied to other species may not be suitable for application to Bull Trout in the Williston Reservoir and Dinosaur Reservoir watersheds, so enhancements should be treated as experiments with commensurate standards for monitoring. The most promising potential enhancements to Bull Trout habitat may be: 1) stream fertilization, 2) fish access improvement, 3) side channel development, and 4) riparian restoration. An experimental trial(s) is needed in the Williston Reservoir watershed to confirm potential benefits to Bull Trout from natal stream fertilization, while for other enhancement techniques the principal information shortfall is the lack of systematic surveys (or a review of prior assessments) to identify candidate locations.

Information about conservation status and critical habitats is summarized in this report at the spatial scale of ‘core areas’ (putative metapopulations comprised of fish that are genetically similar and demographically linked). Conservation status was evaluated using the *Core Area Conservation Status and Risk Assessment Methodology* developed by the U.S. Fish and Wildlife Service, using indicators *distribution, adult abundance, population trend*, and *threats*. *Low Risk* core areas were the pristine Upper Finlay core area and the Finlay Reach core area which is home to major populations in the Davis and Ingenika watersheds. *Potential Risk* core areas were the Lower Finlay and Omineca core areas, which had relatively low habitat threats. The Parsnip, Parsnip Reach, and Peace Reach core areas all estimated to be *At Risk*, with the most important factor affecting the ranking being small adult population size. The Dinosaur core area was considered to be at *High Risk* of extirpation due to limited habitat availability and a small, declining population; the remnant population isolated between the Peace Canyon and W.A.C Bennett dams may not be self-supporting and may depend on entrainment through the W.A.C. Bennett Dam for future viability.

A total of 91 stream segments across 6 core areas were delineated as critical habitats for spawning and/or juvenile Bull Trout, along with 34 information gaps limiting FWCP’s ability to assess conservation status and move forward with conservation and enhancement actions. Most data gaps were related to imprecise or missing information about critical habitats, and limited or missing population data (adult abundance, population trend). For core areas that have received prior surveys of critical habitats and abundance (Parsnip, Omineca, Peace Reach/Dinosaur, Finlay Reach), it is important to refine estimates of distribution of spawning and juvenile rearing, using redd count- and electrofishing-based survey methods, respectively, to enable habitat conservation and enhancement actions. For core areas that have not had reconnaissance spawning surveys (Parsnip Reach, Lower Finlay, Upper Finlay), it is important to identify key natal watersheds utilized by populations of large-bodied, migratory Bull Trout, their relative importance, and the locations of critical habitats. Movement studies (telemetry, otolith microchemistry) and a reconnaissance aerial redd count methodology developed by FLNRORD and FWCP are proven, albeit expensive, methods for acquiring this information.

In the report's final section, a monitoring framework is presented to enable potential proponents to fulfill actions 1c-2, 1c-3, and 1c-4 of the *Streams Action Plan*:

> Action *1c-2*: Implement high priority habitat restoration options for Bull Trout.
>
> Action *1c-3*: Undertake Bull Trout monitoring as per recommendations of the monitoring program and develop specific, prioritized recommendations for habitat- based actions which correspond to the monitoring results.
>
> Action *1c-4*: Review Bull Trout monitoring results, refine and implement specific plans in response, as needed; Identify limiting factors to direct conservation and enhancement efforts.

The monitoring framework is comprised of:

1) a list of key types of information facilitating conservation status assessments and habitat-based conservation actions,
2) a recommended sequence of monitoring actions,
3) a summary of potential monitoring techniques to address identified data gaps,
4) an update on recent monitoring developments in the watershed, and
5) a list of sources of key background information for proponents wishing to propose monitoring studies through FWCP's grant application process including: 1) the *Streams Action Plan*, 2) the information synthesis presented in this report, 3) First Nations knowledge reports prepared for FWCP during spring 2019, and 4) yearly guidance from FWCP.

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1.0 INTRODUCTION

The Bull Trout (*Salvelinus confluentus*) is one of the most highly-valued fish species in the upper Peace Basin. Migratory Bull Trout, which grow to sizes of 80 cm or more on a piscivorous diet, provide the only opportunity to catch big fish in streams of the Williston Reservoir watershed, and are targeted in both subsistence and recreational fisheries. The Bull Trout is also among the most sensitive of British Columbia's wildlife species. This study reviews the existing knowledge base for Bull Trout of the Williston Reservoir watershed in northcentral British Columbia, assesses the status of populations of large-bodied, migratory fish that are of particularly high value and conservation concern, and recommends monitoring studies that will enable conservation actions and improved status assessments in future.

Bull Trout populations have declined in many areas of their native range, particularly in the United States and in southern parts of their Alberta and British Columbia distributions. Population declines appear to be due to the cumulative effects of habitat degradation, non-native species introductions, overharvest, and fragmentation of watersheds caused by dam construction (Rieman and McIntyre 1993; Rieman et al. 1997; Paul and Post 2001; Post and Johnston 2002; High et al. 2009; Rodtka 2009; Hagen and Decker 2011; Kovach et al. 2016). Loss of the migratory form (adfluvial, fluvial) in particular is evident in many populations, and many remaining populations in the U.S.A. persist only as small-bodied residents isolated in headwater streams (Nelson et al. 2002).

Because of these human-caused population declines, along with naturally small population sizes, limited or declining distributions, and elevated threats, the Bull Trout is considered a species of conservation concern throughout its distribution in the contiguous United States, Alberta, and British Columbia. In the United States, listing of populations as 'Threatened' under the *Endangered Species Act* commenced in June 1998, starting with the Columbia system, and all populations of the contiguous U.S. had been listed by November 1999 (Lohr et al. 2000). In Canada, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2012) listed Bull Trout populations in the Western Arctic and South Coast British Columbia 'Designatable Units' (DUs)[1] as 'Special Concern', and populations of the Saskatchewan – Nelson Rivers DU as 'Threatened' following status assessments in Alberta (Rodtka 2009) and British Columbia (Hagen and Decker 2011) conducted at the spatial scale of putative metapopulations ('core areas'[2]). Special management of Bull Trout populations in British Columbia predates the

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[1] Infraspecific units that are distinguishable from, and have different extinction probabilities than, the species as a whole (Green 2005 as cited in McPhail 2007).

[2] Core area: group of populations interconnected or potentially interconnected through gene exchange (USFWS 2005; Hagen and Decker 2011).

COSEWIC listing and has been ongoing since 1994, when the species was blue-listed as a 'Species of Special Concern' by the BC Conservation Data Center (Cannings and Ptolemy 1998). Importantly, they have also been listed as an 'Identified Wildlife Species at Risk' under British Columbia's *Identified Wildlife Management Strategy* (BC MWLAP 2004; Hammond 2004), which enables special habitat protection measures unavailable to other species.

Williston Reservoir, which reached full pool in 1972 (Hirst 1991), flooded approximately 350 km of the Peace, Finlay, and Parsnip river valleys resulting in drastic changes to the ecologies of these watersheds and patterns of human settlement and land use. Diverse stream habitats in adult rearing environments for Bull Trout were replaced by a single, monomorphic reservoir, which eventually became populated with a different fish community including new prey and competitor species such as Kokanee (*Oncorhynchus nerka*) and Lake Trout (*Salvelinus namaycush*), respectively. Reservoir creation facilitated widespread forestry in formerly inaccessible watersheds, and the flooding also severely altered traditional patterns of human settlement, resource use, and travel (Herkes and Kurtz 2014).

The Fish and Wildlife Compensation Program (FWCP) was established to conserve and enhance fish and wildlife resources affected by BC Hydro dam construction. FWCP's *Streams Action Plan* (FWCP 2014) sets out priorities for FWCP to guide projects within the Peace Basin program area, with a focus on priority species including the Bull Trout that use streams for all or part of their life cycle and which have been affected by reservoir creation. As described above, the Bull Trout is also a priority species for British Columbia's Ministry of Forests, Lands, Natural Resource Operations, and Rural Development (FLNRORD), the lead agency responsible for inland fisheries management and habitat protection.

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

> **Conservation** – Maintain or improve the conservation status of species or ecosystems of concern.
>
> **Conservation** – Maintain or improve the integrity and productivity of ecosystems and habitats.
>
> **Sustainable use** – Maintain or improve opportunities for sustainable use, including harvesting and other uses.
>
> **Community engagement** – Build and maintain relationships with stakeholders and aboriginal communities.

The purposes of this study are: 1) to evaluate the existing knowledge base relative to these strategic objectives, and 2) to identify monitoring study needs to potential proponents wishing to develop Bull Trout study proposals via the FWCP proposal process. The study thereby fulfils Objective *1c-1* of the *Streams Action Plan* (FWCP 2014):

> Review existing information (including provincial management plan), summarize status and trends of Bull Trout 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.

This report has two main components, reflecting the dual purposes of the study as specified above. The first is a synthesis of available information from the Williston Reservoir watershed and the broader scientific literature, highlighting key information types necessary for FWCP to move forward on habitat conservation and enhancement projects. The structure of the information synthesis reflects the fact that some information is broadly applicable throughout the upper Peace Basin, and other information is population-specific. Information about Bull Trout biology, limiting factors and potential enhancement/conservation actions is in the former category and is discussed in Sections *2.0-3.0*. 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*). Information gaps limiting FWCP's ability to initiate conservation and enhancement actions, along with potential types of studies to address them, are tabulated at the end of each section.

The final component of this report is comprised of the conclusions from the information synthesis along with recommendations for Bull Trout monitoring in the Williston Reservoir watershed (Section *6.0 Conclusions and Recommended Monitoring Framework*). In this section, a strategy for Bull Trout monitoring is proposed that addresses critical information gaps and supports conservation and enhancement actions. The information synthesis is a detailed treatment of the many topics covered, and is meant to be a resource for proponents developing FWCP grant applications for Bull Trout-related studies. To enable a quicker assessment of information gaps and monitoring priorities, the Section *6.0 Conclusions and Recommended Monitoring Plan* has been designed such that it can also be read as a short, stand-alone document.

2.0 BULL TROUT BIOLOGY

2.1 Taxonomy and distribution

Prior to 1978, the Bull Trout was taxonomically included in the Dolly Varden species complex, which had a distribution around the entire arc of the North Pacific from the Sea of Japan to Northern California, and also north in Alaska to its border with the Arctic Ocean (Cavender 1980). This group had received considerable attention up to that time (McPhail 1961, Morton 1970, Behnke 1972), but the Bull Trout form was not distinguished until 1978 because of its similarities to the Dolly Varden both in appearance and also in the morphological characters typically used in char taxonomy (Cavender 1978). Morphological differences eventually utilized to discriminate the species were summarized as adaptations, in terms of mouth morphology particularly, to 'piscivory specialist' and 'generalist' feeding niches by Bull Trout and Dolly Varden, respectively (Cavender 1978; Haas and McPhail 1991).

In western North America, the portion of the geographic range formerly ascribed to Dolly Varden but that is actually occupied by Bull Trout encompasses areas south of 47° N, and interior regions between 47° N and approximately 60° N. Dolly Varden are found in coastal areas north of 47° N. The two species exhibit overlapping distributions along the coastal mountains in British Columbia (Haas and McPhail 1991), with this overlap being at its greatest in northwestern British Columbia where it extends well into the interior to the headwaters of major North Coast drainages, and beyond into the headwaters of the Liard, Peace, and Nechako watersheds which Dolly Varden appear to have colonized via headwater capture (McPhail 2007).

Overlapping distributions of Bull Trout and Dolly Varden form a bimodal hybrid zone where F1 hybrids and backcrosses are viable and fertile (McPhail and Taylor 1995; Baxter et al. 1997), but the two species nonetheless have distinct gene pools which are maintained through a remarkable interactive segregation (Haas and McPhail 1991; Redenbach and Taylor 2002, 2003). In these areas, Dolly Varden populations express a stream resident life history, while Bull Trout populations almost exclusively exhibit a large-bodied migratory life history (McPhail and Taylor 1995; Hagen and Taylor 2001; McPhail 2007; Taylor 2015).

Within Bull Trout, molecular genetic and morphological studies indicate the existence of two major evolutionary lineages (Taylor et al. 1999; Haas and McPhail 2001): interior and coastal clades that appear to reflect utilization of Columbia and Chehalis refugia, respectively, during the Wisconsin glaciation (McPhail 2007). The present distribution of the coastal lineage limited to the lower Fraser (below Hell’s Gate), upper Skagit (Puget Sound), and Squamish (South Coast) drainages. In Canada, the interior clade has crossed the continental divide into Alberta and Northeastern B.C., and reaches the central and northern B.C. coasts in large river systems that penetrate through the Coast Mountains (e.g., Homathko, Klinaklini, Skeena; Haas and McPhail 1991; McPhail 2007).

Phylogeographic and population genetic data collected for Canadian Bull Trout have been utilized by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) to recognize five ‘Designatable Units’ (DUs) for conservation assessments and listing under the Species at Risk Act (SARA) (COSEWIC 2012; Taylor 2015). The coastal lineage comprises the ‘South Coast’ DU, while the remaining four DUs make up the interior lineage: ‘Pacific,’ ‘Western Arctic,’ ‘Upper Yukon Watershed,’ and ‘Saskatchewan-Nelson Rivers’ (COSEWIC 2012). Bull Trout populations of the Williston Reservoir watershed are included within the Western Arctic DU, which received a ranking of ‘Special Concern’ by COSEWIC in 2012.

At a finer geographic scale, molecular genetic and movement data from Canada suggest Bull Trout population structure is strongly affected by migration barriers and distance (Taylor et al.

1999; Burrows et al. 2001; O'Brien 2001; Oliver 2001; Bahr 2002; Latham 2002; Costello et al. 2003; Pillipow and Williamson 2004; Westover and Heidt 2004; Taylor and Clarke 2007; Taylor and Costello 2006; Warnock et al. 2010; E.B. Taylor, unpublished data 2011 as cited in Hagen and Decker 2011), and that groups of geographically adjacent local populations are likely to be genetically similar and demographically linked, i.e. metapopulations.[3] For Bull Trout across their range in the United States, British Columbia, and Alberta, such groups of local populations are termed 'core areas' (USFW 2005; Rodtka 2009; Hagen and Decker 2011; COSEWIC 2012).

A putative core area structure for B.C. was suggested during a conservation status assessment in 2011 (Hagen and Decker 2011), which has now been incorporated in to the draft *Provincial Bull Trout Management Plan* (Pollard et al. 2015). In this plan, the system of core areas is a proxy for the putative metapopulation structure (Hanski and Gilpin 1991; Dunham and Rieman 1999) and provides the most basic conservation units for assessing population status (and for which a conservation status assessment methodology has been developed – see Section *4.2*). Seven Bull Trout core areas have been identified for the upper Peace Basin upstream of the W.A.C. Bennett Dam: Parsnip, Parsnip Reach, Omineca, Peace Reach, Finlay Reach, Lower Finlay, and Upper Finlay (Figure 1), and the Dinosaur Reservoir watershed comprises an eighth. In this report, we utilize this system of core areas to organize critical habitat and conservation status information (section *5.0*).

In contrast to the situation for Arctic Grayling, genetic and movement data do not appear to exist for evaluating the core area structure for Bull Trout in the Williston Reservoir watershed, and therefore the validity of these conservation units remains in doubt. This is a fundamental information gap of high immediacy (**Data gap *2.1***, Table 2.1) which requires resolution using genetic and/or movement studies, because conservation status is meant to be assessed at the spatial scale of demographically-linked populations (Note: throughout this report, information gaps limiting FWCP's ability to initiate conservation and enhancement actions are tabulated at the end of each major section).

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Figure 2.1. Bull Trout 'core areas' (putative metapopulations) comprising the range of the species potentially impacted by the creation of Williston and Dinosaur reservoirs.

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[3] i.e. a population of populations, with the individual local populations being interconnected by the migrations of individuals (Levins 1969; Hanski and Gilpin 1991; Dunham and Rieman 1999).

Table 2.1. Data gaps affecting understanding of population structure and conservation units in the upper Peace Basin.

ID	*Core area*	*Data gap*	*Potential study(s)*	*Immediacy*[1]
2.1a	All	Lack of genetic and/or movement data supporting existing core area boundaries	Genetic studies to identify population structure; movement studies to estimate migration	High[1]

[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

2.2 Life history[4]

2.2.1 Life history forms

In interior regions of western North America, there are three general life history forms of Bull Trout: stream resident, fluvial (migrations of juveniles from natal streams to subadult/adult rearing habitats in larger rivers), and adfluvial (migrations to and from lakes). For Bull Trout of the coastal evolutionary lineage, limited movements into saltwater also occur (anadromy), although relatively little is known about the extent of these movements (McPhail 2007). Stream resident Bull Trout spend their entire life cycle within individual streams or stream reaches, but movements and size-at-maturity appear to vary depending on the sizes of streams and connectivity among suitable habitats. Small stream resident fish with limited opportunities for movement may mature at small body sizes of just 115 mm with few fish in the population >200 mm, but fish exhibiting a restricted fluvial life history with greater movement opportunities may attain body sizes of up to 315 mm and reach ages of up to 8 years (Goetz 1989; Triton 1993; McPhail and Baxter 1996; Chris Schell Consulting 2002; Ladell 2003).[5] Stream resident populations may be separated from migratory populations by a barrier to migration, which may be physical (e.g. waterfalls, dams; Latham 2002; Ladell 2003), physiological (e.g., unfavorably high temperatures; Rieman and McIntyre 1993; Rieman et al. 1997), or biological (e.g. presence of non-native competitor species; Paul and Post 2001; Nelson et al. 2002). However, this is not always the case. Stream resident Bull Trout populations have been identified in reaches of the Omineca core area in the absence of migration barriers, in streams not utilized by large-bodied, migratory fish (Chris Schell Consulting 2002; Hagen and Spendlow 2019). In such cases, the combined productivity of juvenile rearing and adult/subadult habitats may be inadequate to

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[4] This section relies heavily on a previous review by co-author Hagen for FWCP in 2008 (Hagen 2008).

[5] We found records for adult, stream resident Bull Trout up to 264 mm (Chris Schell Consulting 2002) for the Williston Reservoir watershed, but were not able to estimate maximum age.

sustain a minimum viable population size for the migratory life history form (Hagen and Spendlow 2019).

Fluvial and adfluvial Bull Trout rear in natal tributaries for 1-4 years before undergoing migrations downstream to larger rivers and lakes, respectively (McPhail and Murray 1979; Oliver 1979; Shepard et al. 1984; Pratt 1992; Downs et al. 2006).[6]

In large lake and reservoir environments (e.g. Williston Reservoir) in B.C., adfluvial Bull Trout can reach sizes of up to 970 mm and 13.6 kg, and live to 17 years (Langston and Blackman 1993; Hagen 2008; D. Bustard unpublished data for Thutade Lake watershed). Otolith- or fin ray-derived ages for mature Bull Trout in the Williston Reservoir watershed have ranged from 7-15 years averaging approximately 10 years, and this pattern was relatively consistent between sampling events separated by more than a decade (Langston and Blackman 1993; Langston and Cubberley 2008). Williston Reservoir's adfluvial Bull Trout are large, attaining body sizes up to 813 mm and probably larger (Langston and Blackman 1993; O'Brien and Zimmerman 2001; Langston and Cubberley 2008). Although fewer descriptions are available for comparative purposes, it appears that among fluvial populations there exists a greater range of adult body size. Means from several northwestern British Columbia populations range from 380-480 mm (McPhail and Baxter 1996; Bustard and Schell 2002), while fluvial fish utilizing the Peace River below Peace Canyon dam and the upper Kootenay River above Lake Koocanusa can be as large as those belonging to adfluvial populations (up to 900 mm and 9.1 kg or more; McPhail and Baxter 1996; Westover and Heidt 2004).

Given ecological changes in Williston Reservoir over time (e.g. naturalization of Lake Trout; introduction of Kokanee), changes in Bull Trout age-at-maturity and growth may have occurred. These parameters are related to the productivity of populations, but cannot be systematically compared across time for Williston Reservoir Bull Trout. In part, this is because past sampling has been biased towards fish large enough to radio tag (O'Brien and Zimmerman 2001; Langston and Cubberley 2008) or includes a mix of mature and immature fish on foraging migrations (e.g. recent tissue metals sampling; Azimuth 2018). This lack of time series data for age-at-maturity and growth for adfluvial, Williston Reservoir Bull Trout is an important information gap (**Data gap *2.2a***; Table 2.2), which should be addressed by systematic sampling across multiple spawner populations (e.g. one per core area) and across time (e.g. on a once-per-decade time scale). This

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[6] Age-0+ fry may also emigrate from spawning tributaries, but their survival to adulthood appears to be extremely poor. For example, substantial numbers of age-0+ adfluvial Bull Trout emigrate from a spawning tributary to Lake Pend Oreille, Idaho, but otolith microchemistry has suggested that age-0+ emigrants do not make a significant contribution to adult returns. In a sample of 47 adults, most of the Bull Trout entered the lake at age-3 or age-4, and none entered at age-0+ (Downs et al. 2006).

can potentially occur concurrently with genetic sampling or movement studies to improve estimates of core area boundaries (Table 2.1).

2.2.2 Early life history

Egg development and hatching are related to water temperature, with optimal development and survival for Bull Trout occurring at 2-4ºC (McPhail and Murray 1979). In a laboratory setting, alevins emerged from the gravel approximately three weeks after hatching, which occurs in spring in the mountainous tributary watershed utilized by Bull Trout in British Columbia (McPhail and Murray 1979). Emergence success is negatively related to the proportion of fine substrates present in the redd site, suggesting a sensitivity of the species to sedimentation. However, where present, groundwater or streambed recharge may compensate for the negative effects of fines (Pratt 1992). In the Halfway River watershed in northern B.C., areas of groundwater were experimentally shown to result in significantly higher egg-to-alevin survival relative to randomly available sites (Baxter 1997). Newly-emerged fry, observed by McPhail and Murray (1979) in the laboratory, did not fill their swim bladders and acquire neutral buoyancy until approximately 3 weeks post-emergence, which the authors suggested may be an adaptation to maintain station in the swift streams typically utilized by Bull Trout for spawning and rearing.

Young-of-year Bull Trout (also referred to as fry, age-0+) use shallow, slow areas along channel margins irrespective of whether they occur in pools or riffles (Saffel and Scarnecchia 1995), with low velocity side channels being particularly valuable for fry (McPhail and Murray 1979; Saffel and Scarnecchia 1995; Bustard 2004). Age-0+ fry studied by Baxter (1995) preferred areas of 10-18 cm depth, and were generally found in less than 40 cm of water, while preferred velocities have been suggested to be less than 15 cm/s, with an upper limit of approximately 30 cm/s (Baxter and McPhail 1996). Age-1+ and older juveniles, and stream resident fish of comparable size, prefer pools and pocket pools along the main channel and side channels (McPhail and Murray 1979; Saffel and Scarnecchia 1995; Hagen and Taylor 2001). Preferred depths and velocities for these older juveniles appear to be approximately 20-45 cm and 5-35 cm/s, respectively (Baxter and McPhail 1996; Hagen and Taylor 2001). Low velocity areas along channel margins may be even more important than is apparent from typical daytime sampling, as juvenile Bull Trout make diel movements from main channel areas with cover to shallow, calm water at the channel margin or in side channels at night (Thurow 1997; Hagen and Taylor 2001; Muhlfeld et al. 2003; Decker and Hagen 2007).

Large, unembedded substrate appears to be the most important cover variable among studies (Oliver 1979; Pratt 1992; Baxter and McPhail 1996), particularly with respect to winter habitat when daytime concealment occurs (Thurow 1997; Bonneau and Scarnecchia 1998), although instream wood cover is also important (Fraley and Graham 1981; Fraley and Shepard 1989; Baxter 1995; Jakober et al. 1998). Wood debris cover is likely to be a more important cover component in smaller Bull Trout streams that do not undergo major fluctuations in water level throughout the year, and smaller reaches above barriers that may be occupied by resident populations (Ladell 2003). The importance of wood debris in larger streams may lie in its role in promoting channel complexity (Ralph et al. 1994).

Juvenile Bull Trout are closely associated with the stream bottom (McPhail and Murray; Baxter and McPhail 1996; Hagen 2000), and feed primarily on aquatic insects (Shepard et al. 1984; Hagen 2000). Fish make up a small portion of the diet (<1%; Hagen 2000) for juveniles greater than approximately 100 mm (Shepard et al. 1984; McPhail and Baxter 1996; Hagen 2000). The fact that consumed fish are frequently conspecifics (Hagen 2000) may play a role in the overall population dynamics of the species. Bull Trout maintain and defend feeding stations in areas of flow, feeding from the drift, but also move about in low velocity areas and feed from the benthos, particularly at night (Nakano et al. 1992; Hagen 2000).

At the end of their first, second, and third years of life, juvenile Bull Trout in the non-glacial Flathead River Basin had mean sizes of 50-70 mm, 100-120mm, and 150-170 mm, respectively (Shepard et al. 1984). Juvenile Bull Trout from the glacial Incomappleaux and Illecillewaet systems in southern B.C. were of comparable size at the end of their second and third growing seasons, averaging 118 and 156 mm, respectively (derived from Decker and Hagen 2007). Sampling data from the Thutade Lake watershed, which is isolated from the rest of the Williston Reservoir watershed above Cascadero Falls on the upper Finlay River, are not directly comparable because they were collected in late-August, but suggest slower growth in this northern, relatively high elevation environment. Mean lengths of sampled Bull Trout over the 1994-2017 period ranged from 34-52 mm among reaches for 0+ Bull Trout, and from 74-88 mm for 1+ fish (Bustard 2017). Juvenile Bull Trout aging data compiled in Langston and Blackman (1993) for the Williston Reservoir watershed do not appear to be reliable, with numerous ages of 0+ assigned to fish >100 mm. The lack of age, life history, and growth information from critical natal habitat for adfluvial, Williston Reservoir Bull Trout is an important data gap (**Data gap *2.2b***, Table 2.2) that can be addressed using electrofishing surveys, which would ideally be paired with adult sampling programs as discussed above (**Data gap *2.2a***, Table 2.2). Such electrofishing surveys can simultaneously be utilized to refine estimates of critical early rearing habitats (Section *5.0*) and improve knowledge of habitat preferences.

For fluvial and adfluvial populations, emigration of juveniles from critical natal streams at the end of tributary residence occurs throughout the summer from May through to the fall (Fraley and Shepard 1989; McPhail and Murray 1979; Oliver 1979).

2.2.3 Sub adult and adult life history

In large riverine and lacustrine environments Bull Trout eat primarily fish, with individuals becoming progressively more piscivourous with increasing size. Bull Trout of all sizes are capable of eating prey of up to 50% of their own length (Beauchamp and Van Tassell 2001. Other salmonids (e.g. Kokanee, Mountain Whitefish) appear to be the most important fraction of the diet in lacustrine environments, although cottids, cyprinids, catostomids are also consumed (Shepard et al. 1984; Pratt 1992; Beauchamp and Van Tassell 2001). In rivers Mountain Whitefish appear to be a highly important prey source for fluvial Bull Trout (Boag 1987; Swanberg 1997). In Lake Billy Chinook, Oregon, cannibalism on smaller Bull Trout (age-0+ and age-1+) was detected in the stomachs of Bull Trout of <450 mm, but not in larger fish (Beauchamp and Van Tassell 2001). Kokanee are now seasonally present in large numbers in tributaries to Williston Reservoir watershed, during their spawning migrations. Large numbers of Williston Reservoir Bull Trout undertake foraging migrations to take advantage of this potentially important prey source (J. Hagen and I. Spendlow, unpublished data).

The distribution of subadult and adult Bull Trout in rivers and lakes also appears to be strongly affected by water temperature. Bull Trout tend to avoid areas where water temperatures exceed 15ºC for extended periods (Pratt 1992; McPhail and Baxter 1996). Water temperature influences the movements of fluvial Bull Trout as well, probably affecting the timing of migrations into tributaries, which may occur two months before spawning, and influencing movements by non-spawning fish into both spawning and non-spawning tributaries (Swanberg 1997; Westover and Heidt 2004).

The timing of movements of adult Bull Trout to spawning areas also appears to be influenced by the distance to be traveled. In Flathead Lake, where individual Bull Trout migrate up to 200 km or more to spawn, movements from winter locations are initiated between April and June (Fraley and Shepard 1989). In contrast, Bull Trout spawners returning to the Davis River in the Finlay Reach watershed and Attichika Creek in the upper Finlay River watershed, which have a shorter migration distances to spawning areas, leave the lake environment primarily in July (O'Brien and Zimmerman 2001; Hagen and Strohm 2019).

In the Flathead Basin of Montana, adfluvial Bull Trout preferentially select larger, lower gradient tributary reaches for spawning that have abundant gravel and cobble substrates (Graham et al. 1981). In the Williston Reservoir watershed, the most important individual spawning reaches for large-bodied, Williston Reservoir Bull Trout appear to be medium-sized reaches/tributaries of 5th and 6th order streams with stable channels and in relatively pristine condition (Hagen et al. 2015; Hagen and Spendlow 2016, 2017, 2018, 2019; Euchner 2017a, 2018). Small tributaries are also utilized, but generally by smaller populations and for shorter distances. It is possible that the viability of spawning populations of large-bodied, migratory fish in these smaller tributaries may depend on demographic and genetic support from other spawning locations located nearby, whereas larger, premium spawning reaches may be productive enough to support viable populations with less support from migration (Dunham and Rieman 1999; Nelson et al. 2002; Hagen and Spendlow 2019). In less productive tributaries of the Williston Reservoir that are somewhat or completely isolated by migration barriers or by distance from other populations of large-bodied, migratory fish, the stream resident life history may be favoured (Nelson et al. 2002; Hagen and Spendlow 2019).

Spawning sites (redds) are not necessarily directly associated with cover, but cover in the form of pools, large wood debris, undercut banks, and overhead vegetation is nevertheless an important attribute of spawning streams, as adult Bull Trout may hold for up to a month or more in tributaries prior to spawning (McPhail and Murray 1979; Graham et al. 1981; Baxter 1995; Hagen and Strohm 2019). Bull Trout generally do not appear to spawn in large mainstem reaches, such as lower reaches of major tributaries Ingenika, Mesilinka, Osilinka, and Omineca rivers in the Williston Reservoir watershed, or the mainstem Kootenay and Columbia Rivers (McPhail and Baxter 1996; Golder Associates 2004; Westover and Heidt 2004; Hagen and Spendlow 2017, 2018, 2019).

Bull Trout spawning generally takes place between mid-August and mid-October (McPhail and Baxter 1996), although spawning as early as July has been observed in Oregon (Ratliff 1992). In the upper Peace Basin, spawning for fluvial and adfluvial stocks appears to occur between late-August and mid-September (Hagen and Taylor 2001; O’Brien and Zimmerman 2001; Langston and Cubberley 2008). Water temperatures of 9ºC have been associated with the onset of spawning (McPhail and Murray 1979; Fraley and Shepard 1989), although this does not appear to be a precise predictor of spawning timing at many locations (J. Hagen, personal observation).

Stream substrate at spawning sites averages 25-60 mm, and is probably related to availability and the size of spawners (McPhail and Murray 1979; Hagen and Taylor 2001). Spawning site selection may be highly specific, and redd superimposition may occur. In larger streams spawning sites are often associated with aggrading areas and areas of groundwater infiltration (Oliver 1979; Graham et al. 1981; Fraley and Shepard 1989; Baxter 1995; Baxter et al.1999; Oliver 2001), while in some smaller streams all pockets of suitable looking substrate have been used (J. Hagen, personal observation). Depths at redd locations average 24-58 cm, and appear to always be less than 90 cm, while velocities average 14-52 cm/s and are typically 65 cm/s or less (reviewed in Baxter and McPhail 1996).

Migratory Bull Trout do not appear to deviate greatly from a 1:1 sex ratio (McPhail and Baxter 1996). Spawning behaviours, sexual dimorphism, and fecundities are described in detail in McPhail and Murray (1979), Leggett (1980), and (Goetz 1989). In brief, a spawning event involves: excavating an egg pocket by the female, release of gametes by the paired adult Bull Trout, fanning of the fertilized eggs to settle them into interstitial spaces of the gravel, and the sweeping by the female of additional gravel from immediately upstream of the excavation to cover the eggs. During the covering of the eggs a second egg pocket is excavated immediately upstream of the first, and additional spawning events may occur at the same location over a period of several days. The entire excavated area is termed a redd, the size of which can range from 0.5 m^2 (McPhail and Murray 1979) to 3.0 m^2 (Baxter 1995) on average, depending on the size of the female and the nature of the substrate being utilized. The redds of large-bodied, adfluvial Bull Trout in tributaries to the Williston Reservoir average approximately 2.4 m^2 (J. Hagen and I. Spendlow, unpublished data). It also appears that a single female can spawn in more than one redd if gravel accumulations at the first location are of limited size (Leggett 1980). Precocious males have been observed in the upper Columbia Basin (McPhail and Murray 1979) and in tributaries of the Peace system (Baxter 1997), but it is unknown how widespread this life history strategy is. Female Bull Trout leave for downstream lacustrine or fluvial habitats shortly after spawning, but a small number of fish (especially males) may remain at spawning sites in the upper Peace Basin until late September or early October (O'Brien and Zimmerman 2001; Langston and Cubberley 2008; Hagen and Strohm 2019; J. Hagen personal observation).

Bull Trout are iteroparous (capable of spawning in more than one year) and survival following spawning appears to be relatively high. It appears common that populations of large-bodied, migratory Bull Trout spawners in British Columbia contain a mix of both every-year and alternate-year spawning strategies with the majority of fish employing an every-year strategy (Goetz 1989; Pratt 1992; Baxter et al. 2000; Hagen and Strohm 2019). Consequently, the total size of an adult Bull Trout population would be expected to be greater than the mean number of spawners annually.

Table 2.2. Data gaps affecting understanding of Bull Trout life history in the Williston Reservoir watershed.

ID	*Core area*	*Data gap*	*Potential study(s)*	*Immediacy*
2.2a	All	Lack of time series data for age-at-maturity, population age structure, and growth	Systematic biological sampling across multiple populations and core areas	High[1]
2.2b	All	lack of age, life history, and growth information from critical natal habitat	Foot survey-based redd counts; electrofishing surveys	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

2.3 Limiting factors

2.3.1. Density-dependent survival in juvenile rearing habitat

'Productivity' is one of several potential terms referring to the maximum survival of juvenile fish, which occurs at small population sizes when intraspecific compensation is least (Ricker 1975; Walters and Hilborn 1992; Chudnow et al. 2018). At high population sizes, the high intensity of intraspecific competition limits production of juveniles to a maximum number or density, termed the 'carrying capacity' (Ricker 1975; Hilborn and Walters 1992).

Survival of juvenile Bull Trout appears to be strongly density-dependent in the first year of life (Johnston et al. 2007; Bustard 2017; Chudnow et al. 2018), and density-independent for older age classes from age-1+ to the age of first spawning (Johnston et al. 2007). This strong level of density dependence means that even when abundance of spawners is low, juvenile rearing habitat may be productive (provided that the habitat remains suitable – see following paragraphs) and the population may be able to rebound quickly once the factors forcing low adult abundance are alleviated (e.g. Johnston et al. 2007; Erhardt and Scarnecchia 2014).

Within the existing distribution of Bull Trout, the rearing capacity of streams for age-1+ and older Bull Trout parr (post-young-of-year juveniles) appears to be an important bottleneck limiting populations overall. Within core juvenile rearing habitats, density-dependent survival appears to limit production of parr to mean densities of approximately 8-10 fish/100 m^2 or less (Pratt 2003; Hagen 2008 and references therein). This carrying capacity may also be influenced by stream nutrients.[7]

The lack of paired spawner abundance and juvenile recruitment data from anywhere in Williston Reservoir watershed is a data gap limiting our ability to understand the productivity of juvenile and adult rearing environments in the Williston Reservoir watershed, and to identify where bottlenecks limiting the populations lie (**Data gap *2.3a***, Table 2.3). The only time series of stock-recruitment data available from northern B.C. comes from the Thutade Lake watershed, where monitoring has been ongoing since 1994 (Bustard 2017; Chudnow et al. 2018). This population is isolated from the rest of the Williston Reservoir watershed by Cascadero Falls, however, with unique ecological and habitat conditions relative to populations in direct tributaries to the reservoir.

The distribution of core rearing habitat may comprise a relatively small proportion of the total available stream habitat (McPhail and Baxter 1996; Bustard and Schell 2002; Decker and Hagen 2007), related to a number of potential limiting factors as discussed in the following sections. The lack of knowledge about the distribution of critical natal habitats in the Williston Reservoir watershed is an important data gap that is addressed in Section *5.0*.

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[7] A stream fertilization experiment conducted in the Salmo River watershed, B.C., over the 2001-2009 period resulting in more and larger Bull Trout at age-2+, at the end of their natal stream residency period (Decker 2010). Stream nutrient levels have also been related to observed levels of fish production generally in B.C. (Ptolemy 1993). This will be discussed further in Section *3.0 Enhancements*.

2.3.2. Water temperature

In the broadest assessment to date of factors driving population trends in large-bodied, migratory Bull Trout, in which time series of redd[8] count data from 92 populations were analyzed, water temperature was one of the three key factors analyzed that were negatively related to population status, along with land use in natal watersheds (as indicated by road density) and the presence of non-native competitor species in adult rearing environments (Kovach et al. 2016).

Water temperature has been widely related to patterns of Bull Trout distribution and abundance. Water temperature and temperature-mediated interspecific competition have long been known to be key determinants of Bull Trout distribution and abundance, and Bull Trout are generally not present in streams where maximum temperatures exceed 15-16°C. (Fraley and Shepard 1989; Saffel and Scarnecchia 1995; Parkinson and Haas 1996; Haas 2001; Gamett 2002; Essig et al. 2003; Pratt 2003; Benjamin et al. 2016). The distribution of sub-adult and adult Bull Trout in lakes, reservoirs, and larger streams also appears to be strongly affected by water temperature: areas where water temperatures exceed 15°C for extended periods are generally avoided (Pratt 1992; Swanberg 1997; Westover and Heidt 2004). The notion that water temperature can limit Bull Trout distribution and abundance is consistent with laboratory trials demonstrating that Bull Trout have among the lowest upper thermal limits and growth optima of North American salmonids, and that physiological stress begins to occur at constant temperatures of 14-16°C (Selong et al. 2001).

Water temperature thresholds have been delineated throughout the species' range (Fraley and Shepard 1989; Saffel and Scarnecchia 1995; Parkinson and Haas 1996; Haas 2001; Essig et al. 2003; Pratt 2003; Rodtka and Volpe 2007). This step has been taken for British Columbia, where a threshold of 11°C Maximum Weekly Average Temperature (MWAT) has been suggested to delineate the upper limit of thermal suitability for the species (Parkinson et al. 2012). Parkinson et al. (2012) noted that geographic variability in this threshold may occur, and data from the Williston Reservoir watershed were not included in their analysis. Therefore, the lack of confidence about the upper limit of thermal suitability for critical natal habitats in the upper Peace Basin is an information gap with important implications, which could be addressed with a well-designed temperature study(s) encompassing a representative sample of critical habitats (**Data gap *2.3b***, Table 2.3). The lack of knowledge about baseline thermal conditions in critical natal watersheds of the Williston Reservoir watershed is an even more important information gap of high immediacy (**Data gap *2.3c***, Table 2.3), because increased land use adjacent to streams is known to result in increased water temperature. A substantial body of literature, which includes

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[8] Redd: gravel nest excavated into the stream bottom by a female Bull Trout, in which the fertilized eggs are laid.

results from the interior of British Columbia, demonstrates that forestry activities in particular are typically associated with increases in summer water temperature in streams (Beschta and Taylor 1988; Brownlee et al. 1988; Hartman et al. 1996; Johnson and Jones 2000; Johnson 2004; Macdonald et al. 2003; Moore et al. 2005).

Climate is an important factor affecting water temperature, and global climate change is therefore a threat to the future viability of Bull Trout populations. Even small shifts in stream temperature regimes of 1-3°C may be highly significant with respect to habitat suitability for Bull Trout, with a replacement of Bull Trout by a warmer-water fish community to be expected if thermal thresholds are surpassed (Parkinson et al. 2012). Water temperature increases of this magnitude due to climate change are an expectation in many areas of the species' range in British Columbia, and Bull Trout natal streams away from mountainous headwater areas may be severely threatened in this century (Porter and Nelitz 2009; Nelitz et al. 2010). A tool for forecasting the locations of streams where Bull Trout would be viable in a warmer climate would be valuable for habitat conservation, because it would assist in prioritizing among watersheds for potentially-costly conservation and enhancement actions. A major initiative led by the U.S. Forest Service,[9] termed the *Coldwater Climate Shield*, (Isaak et al. 2015, 2016) has integrated temperature and biological databases, along with a U.S. Geological Survey-run regional climate model, to describe warming trends throughout more than 200,000 kilometers of streams in the northwestern United States, and make predictions for the future. A similar approach has been initiated by FLNRORD within the Omineca Region, and application within the Williston Reservoir watershed will be possible once model selection and validation is complete (Nikolaus Gantner, FLNRORD Prince George, pers. comm. 2019).

2.3.3 Land use-related habitat degradation.

A defining characteristic of the Bull Trout is the species' high sensitivity to human-caused environmental change in natal streams. This sensitivity is recognized by the BC Provincial Government through listing of the Bull Trout as an 'Identified Wildlife Species at Risk' under the *Identified Wildlife Management Strategy* (BC MWLAP 2004; Hammond 2004), which recognizes that normal provisions for fish habitat protection in the Forest and Range Practices Act (FRPA) are not expected to be enough to maintain the status of populations in areas where intensive land use is occurring. Habitat degradation has been implicated as a major factor driving declines of Bull Trout and reduced population viability across the species' range (Rieman et al. 1997; Baxter et al. 1999; Dunham and Rieman 1999; Hagen et al. 2011; Kovach et al. 2016).

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[9] in collaboration with the U.S. Geological Survey, National Ocean and Atmospheric Administration, University of Georgia and the Queensland University of Technology.

In past analyses of Bull Trout status, road density has often been used as the sole indicator of the cumulative effects of land use within Bull Trout watersheds. Within the range of Bull Trout, the presence of roads is highly correlated with changes in species composition, population sizes, and hydrologic and geomorphic processes that affect the productivity of riparian and aquatic ecosystems (Eaglin and Hubert 1993; Rieman and McIntyre 1993 and references therein; Rieman et al. 1997; Baxter et al. 1999; Dunham and Rieman 1999; Trombulak and Frissell 2000; Kovach et al. 2016). Roads affect aquatic ecosystems through a number of potential mechanisms, including: 1) increases in runoff resulting in increased peak flows, flooding, and reduced stability of riparian areas, stream channels, and sediment deposits; 2) increases in fine and coarse sediment inputs from road surfaces, cutbanks, fillslopes, bridge/culvert sites, and ditches; 3) alterations to streams and channel migration potential at crossings, and increased angler access; and 4) interception or alteration of groundwater flows (Eaglin and Hubert 1993; Forman and Alexander 1998; Trombulak and Frissell 2000; BC Ministry of Forests 2001; Daust 2015).

Although road density appears to be a reliable indicator of habitat degradation within Bull Trout critical habitats, it can be difficult or impossible to separate the direct ecological effects of roads from those of the accompanying land-use activities (Trombulak and Frissel 2000). Furthermore, it is not clear which specific mechanisms of habitat degradation (other than water temperature increases – see preceding section[10]) are most important for Bull Trout. Potential mechanisms of habitat degradation related to forest harvesting, road building, and pipeline construction and operation include: decreases in riparian vegetation, stream habitat complexity, stream depth, and accessibility to critical habitats, increases in stream temperature, peak flows, fine sediment, channel width, channel instability, and frequency of landslides, alteration of surface and subsurface flows, and accidental release of hazardous materials (Fraley and Shepard 1989; Meehan 1991; Peterson et al. 1992; Saffel and Scarnecchia 1995; Eaglin and Hubert 1993; Forman and Alexander 1998; Trombulak and Frissel 2000; CAPP et al. 2005). Increased access for anglers is an additional threat associated with these watershed developments.

The scientific literature does not provide adequate guidance as to how much land use is sustainable in critical natal watersheds for Bull Trout, and threshold levels resulting in increased risk have not been described.[11] The lack of knowledge about target levels of land use for critical

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[10] In the analysis of Kovach et al. (2016), land use (as indicated by road density) and water temperature had additive negative effects. In other words, Bull Trout are threatened both when water temperatures exceed thresholds of suitability, even in undegraded habitat, and also in degraded habitats when water temperatures remain suitable. When high water temperature and habitat degradation are both indicated, the threat is increased proportionally.

[11] Other than to indicate that a road density of 1.6 km/km^2 or more, which was associated with a 7-fold lower likelihood of having 'strong' status in natal streams of the Columbia and Klamath Basins of the U.S.A. (Rieman et al. 1997), is clearly too high.

Bull Trout watersheds, and about specific mechanisms of habitat degradation most threatening to Bull Trout, are data gaps of high importance which have significant potential consequences to fish populations and to the forestry economy (**Data gaps *2.3.d, 2.3e,*** respectively; Table 2.3). The immediacy levels of these data gaps are high given that the road network is currently expanding in critical natal watersheds for Bull Trout due to salvage logging related to the outbreak of the spruce beetle *Dendroctonus rufipennis*. The most important and time-sensitive knowledge required to mitigate land use-related threats may be information about the locations of critical habitats for key populations of large-bodied, migratory Bull Trout. Data gaps associated with missing critical habitat knowledge are addressed in Section *5.0*.

2.3.4 Species interactions

Competition and hybridization with Brook Trout (*Salvelinus fontinalis*) have been identified as factors threatening Bull Trout populations in the United States and Alberta (Rieman and McIntyre 1993; Paul and Post 2001; Rich et al. 2003), but are not currently thought to be threatening Bull Trout populations in the upper Peace Basin. The current distribution of Brook Trout is limited, and fish stocking policy in B.C. has been changed to minimize the risks to Bull Trout populations.

In contrast, Lake Trout (*Salvelinus namaycush*), which have colonized Williston Reservoir naturally by dispersing from populations upstream, may pose a significant long-term threat to Bull Trout of the Williston Reservoir watershed. The presence of Lake Trout and/or non-native species in adult/subadult foraging habitats appears to be among the most important factors driving declines in Bull Trout across the species' range (Kovach et al. 2016). When introduced in to lake and reservoir environments utilized by Bull Trout, Lake Trout in particular are known to competitively displace Bull Trout over the medium-to-long term (Donald and Alger 1993). This competitive exclusion appears to have occurred naturally across northern B.C.: many larger lakes should support large populations of Bull Trout based on trophic and temperature suitability, but instead they are dominated by Lake Trout (e.g. Quesnel Lake). Poor understanding of the potential threat posed by increasing Lake Trout populations in the Williston Reservoir watershed is a major information gap (**Data gap *2.3f***, Table 2.3), and monitoring of Lake Trout abundance and habitat use (e.g. Euchner 2017b – FWCP Project No. PEA-F17-F-1472) will improve this situation.

The composition of prey fish communities may also be a factor affecting the productivity of subadult/adult rearing environments. A small amount of information from the upper Columbia Basin suggests that the composition of prey fish communities affects Bull Trout growth and survival, and that the introduction of non-native Kokanee to lacustrine environments may enhance their productive capacity for Bull Trout and/or competitors such as Lake Trout (Hagen 2008 and references therein).[12] For example, Bull Trout spawners captured in 1996 in the Wigwam River were more abundant and 140 mm longer on average than those captured in 1978, when introduced kokanee were not yet established in Koocanusa Reservoir (Westover and Conroy 1997). Stable isotope analysis is a potential tool to assess the importance of Kokanee and other species in the Bull Trout diet. This methodology and has been incorporated into the UNBC-led FWCP Project PEA-F19-F-2593 *Spatial ecology of Arctic grayling in the Parsnip core area* (Eduardo Martins, UNBC, pers. comm. 2019).

2.3.5 Dam construction

Dam construction has had a major impact on Bull Trout populations throughout their range (Rieman et al. 1997; Post and Johnston 2002; Hagen 2008). Many of the dams that have been constructed in watersheds occupied by Bull Trout in the United States and Canada, such as W.A.C Bennett Dam, lack provisions to allow for the passage of migrating adults or juveniles. This has resulted in population fragmentation, where barriers separate productive juvenile and adult rearing environments (Hagen 2008), and population isolation, which may compromise a population's chance of long-term survival due to the loss of demographic support and genetic exchange from adjacent populations (Rieman and McIntyre 1993; Hagen and Nellestijn 2015). In the Salmo River watershed of southern British Columbia, which lies within the footprint impact area of BC Hydro's Seven Mile Dam on the Pend d'Oreille River, Bull Trout are in decline and threatened with extirpation despite a total closure of Bull Trout angling, due to reduced productivity of subadult/adult rearing habitats (Hagen and Nellestijn 2015). Prior to dam construction, Salmo River Bull Trout would have had connectivity with colder water habitats and a diverse prey fish base, whereas now the run-of-the-river Seven Mile Reservoir is thermally unsuitable for part of the year and filled with non-native predators and competitors.

Some Bull Trout populations in B.C. have adapted well to living in large reservoirs. In some cases where kokanee have been introduced as a prey fish, base growth and survival may be greater than in pre-existing riverine conditions (Westover and Conroy 1997; Hagen 2008). However, in reservoirs such as Williston Reservoir, impoundment has resulted in the replacement of hundreds of kilometers of diverse stream habitats by a single, monomorphic reservoir environment. Genetic evidence from the upper Columbia Basin suggests this can result in breakdown of population structure and loss of genetic diversity (Hagen 2008).

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[12] We are aware that the introduction of Kokanee to the Williston Reservoir watersheds is poorly viewed by members of First Nations communities (Pearce et al. 2019a, 2019b, 2019c, 2019d).

The effects of dam construction on genetic diversity and population structure in the Williston Reservoir and Dinosaur Reservoir watersheds are unknown, because of the lack of movement data or genetic data to assess movements of Bull Trout through the reservoir. Because of the presence of Lake Trout in the reservoirs and knowledge that this species can competitively displace Bull Trout (Section *2.3.4*), it is even plausible that Williston Reservoir may act as an ecological barrier to foraging migrations and gene flow, which is hypothesized for Arctic Grayling populations (Stamford et al. 2017). This important data gap would be addressed during genetic and movement studies to delineate population structure and conservation units, as described in Section *2.1* (**Data gap *2.1***, Table 2.1), provided that genetic studies were carefully designed to permit assignment of individual fish to known natal watersheds.

Entrainment of Bull Trout through the W.A.C. Bennett and Peace Canyon dams may also be a factor limiting the productivity of Bull Trout populations. FWCP's mandate is to address footprint impacts resulting from the construction of dams, rather than impacts associated with their operation such as entrainment. Although entrainment studies do not fall within FWCP's mandate, it is important to note that BC Hydro has initiated a research program on Williston Reservoir to assess BT entrainment at WAC Bennett Dam and in the Dinosaur Reservoir for entrainment at Peace Canyon Dam. The objectives of the program are to: 1) assess the entrainment rate of Bull Trout at the dams, 2) determine whether there is an effect on the Bull Trout population, and 3) identify potential mitigation measures if possible (M. Casselman, BC Hydro, pers. comm. 2019).

2.3.6 Exploitation

Bull Trout are susceptible to even relatively modest levels of fishing effort because of their aggressive feeding behavior, their tendency to concentrate in specific areas for lengthy periods during their spawning migrations, and the fact that they are relatively slow growing and late maturing (Post and Johnston 2002; McPhail 2007). Overharvest has been implicated in past population declines in British Columbia, Alberta, and the United States (Rieman et al. 1997; Post and Johnston 2002; Hagen and Decker 2011), although populations may rebound quickly when more restrictive regulations are implemented (Johnston et al. 2007; Erhardt and Scarnecchia 2014). The introduction of catch-and-release regulations beginning in the 1990s has also been associated with positive trends in some B.C. Bull Trout populations (Hagen and Decker 2011; Hagen and Spendlow 2019).

Overharvest from recreational angling is not currently thought to be a major threat to Bull Trout populations in the Williston Reservoir Basin because catch-and-release regulations are in place on all streams, and angler harvest of larger individuals >50 cm is not permitted in Williston

Reservoir.[13] In contrast, the harvest rates associated with First Nations subsistence fisheries are unknown. If these are unsustainable, they may threaten the status of some populations. The lack of knowledge of harvest rates in First Nations fisheries is an important data gap that can be addressed using First Nation-led surveys supported by quantitative analysis (**Data gap *2.3g***, Table 2.3).

Table 2.3. Data gaps affecting understanding of limiting factors for Bull Trout life populations in the Williston Reservoir watershed.

ID	***Core area***	***Data gap***	***Potential study(s)***	***Immediacy***
2.3a	All	Lack of data to estimate productivity in juvenile versus adult rearing habitat	Paired spawner abundance (e.g. redd counts in index sections) and juvenile recruitment (e.g. quantitative electrofishing studies) data	Moderate[1]
2.3b	All	Lack of confidence in estimated upper limits of thermal suitability for natal watersheds	Temperature study across multiple natal watersheds	Moderate
2.3c	All	Lack of knowledge about baseline thermal conditions in critical habitats of upper Peace Basin	Temperature monitoring in critical habitats	High
2.3d	All	Lack of knowledge about sustainable levels of land use in critical natal watersheds	Abundance and trend monitoring across a range of land use levels	High
2.3e	All	Inadequate knowledge about specific mechanisms by which land use threatens Bull Trout (in addition to temperature)	Laboratory or field experiments	Moderate-to-high

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[13] Unintentional harvest of Bull Trout due to potential misidentification with other trout and char species is a problem of unknown severity.

2.3f	All	Poor understanding of threat posed by increasing populations of Lake Trout in Williston Reservoir	Monitoring of Lake Trout abundance and habitat use	High
2.3g	All	Unknown harvest rates in First Nations subsistence fisheries	First Nation-led surveys supported by quantitative analysis	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

Some enhancement methods potentially applicable to the Williston Reservoir watershed, which include a diversity of compensation measures applied in both stream and reservoir environments, are reviewed in the following sections. Relatively little research has been done on the suitability of typical enhancement measures for Bull Trout specifically. In the following discussion, therefore, consideration is given to how the unique biology of the species should affect the priority of each as a potential tool to improve the status of populations, the productivity of their habitats, and human opportunities for use of fish (*Streams Action Plan* strategic objectives; see Section *1.0*).

3.1. Artificial propagation

Artificial propagation of Bull Trout, using a hatchery specifically designed for Bull Trout, has had a two-decade experimental trial in the Arrow Lakes Reservoir in British Columbia. The hatchery program was conducted between 1982-2000, after which it was stopped because of poor contributions to the fishery and concerns about population declines in donor streams (Winsby and Stone 1996; Sebastian et al. 2000; Arndt 2004). In addition to these poor results, additional arguments against a trial of hatchery augmentation in the Williston Reservoir watershed are the high cost of the method, along with threats posed to wild populations by potential genetic change and intraspecific competition.

In a situation of extreme conservation concern, it is conceivable that the use of artificial propagation may be justified to meet recovery criteria (USFWS 2002). The Montana Bull Trout Scientific Group evaluated potential strategies for utilizing hatchery practices for Bull Trout conservation, and concluded that potentially valuable approaches included the establishment of genetic reserves for declining populations, restoration stocking, and research activities such as the evaluation of hybridization (MBTSG 1995). The use of artificial propagation, however, must be authorized by the BC Provincial Government. Artificial propagation is not consistent with the emphasis on wild fish populations specified in the BC Government *Fisheries Program Plan* (MOE 2007) and the *Provincial Bull Trout Management Plan* (Pollard et al. 2015). Therefore, this potential enhancement method is unlikely to receive Government support at this point in time, especially given that Bull Trout are widely distributed in the Williston Reservoir watershed and many strong populations occur (Section *5.0*).

3.2 Reservoir fertilization

There is now a relatively extensive body of research about fertilization of large lakes and reservoirs in British Columbia and around the world, and it appears that boosting the primary productivity of pelagic environments in these large water bodies has become an established enhancement methodology (Ashley et al. 1999 and references therein; Schindler et al. 2006).

Because large-bodied, migratory Bull Trout are mostly piscivorous after leaving natal rearing streams (Section *2.2*), the mechanism by which primary productivity changes in lacustrine or fluvial environments would affect survival and growth is through changes to prey fish communities or conditions for foraging. In British Columbia, the best-studied examples of how primary productivity changes affect prey fish communities such as Kokanee lie within the upper Columbia Basin in the province's Kootenay Region. Dams upstream of the largest natural lakes in the upper Columbia Basin, Kootenay and the Upper and Lower Arrow lakes, now catch spring runoff in reservoirs, reducing turbidity and nutrient content of outflow waters (Moody et al. 2007). Kokanee populations showed a delayed response to these changes following dam construction, but had declined to a fraction of pre-impoundment abundance by the late 1980s in Kootenay Lake (Ashley et al. 1999), and by the mid-to-late 1990s in Arrow Lakes Reservoir (ALR) (Arndt 2008). By the late-2000s, experimental fertilization conducted by FWCP, which began in 1992 on Kootenay Lake and in 1999 on the ALR, appeared to have been able to reverse these declines (Schindler et al. 2006; Schindler et al. 2007; Arndt 2008).

Assessing the Bull Trout population responses to fertilization of Kootenay Region reservoirs has been more difficult. At the time of the late 2000s, reliable Bull Trout abundance estimates (e.g. redd counts) were not available to relate to the kokanee abundance time series (Hagen 2008), and the only available information about Bull Trout status was in the form of creel survey and angler questionnaire data from the ALR and Kootenay Lake (Arndt 2004; Andrusak 2007).[14] Angler catch data generally appeared to indicate increased Bull Trout abundance following fertilization. In the ALR, angling effort targeting Bull Trout, Bull Trout catch and harvest, and Bull Trout condition (weight for a given size) all improved in the period immediately following fertilization indicating improved conditions for Bull Trout growth and survival (Arndt and Schwarz 2011).

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[14] Quantitative Bull Trout population monitoring using redd counts has also been initiated in both the ALR and Kootenay Lake watersheds (Decker and Hagen 2007; Hagen and Decker 2009; Andrusak and Andrusak 2012; Hagen and Arndt 2014) since the late 2000s. These time series are still of limited duration and do not include data from the pre-fertilization period, or the period immediately following fertilization when a positive response in angler catch data was evident.

Since that time, angler catch metrics for Bull Trout in the ALR have declined and are more comparable to the pre-fertilization period (Arndt 2018), suggesting that interactions within the trophic ecology of the ALR are complex and not completely understood. The unforeseen and unpredictable consequences of nutrient enrichment on ecosystem structure and productivity may even be a significant potential threat (e.g. Davis et al. 2009). In Kootenay Lake, despite ongoing fertilization, a major Kokanee population crash has occurred resulting in record low abundance over the 2014-2017 period and fears of extirpation of the native Kokanee stock (Burrows and Neufeld 2018).

Results from the Kootenay Region's fertilization experiments do not inspire confidence at this point in time, and indicate a limited understanding of the potentially complex ecology driving the population dynamics. A quantitative analysis of these dynamics would be a major study in its own right, and beyond the scope of this report. Proponents of reservoir fertilization in the upper Peace Basin will need to undertake a much more comprehensive review of fertilization results from the Kootenay Region and elsewhere. This need comprises a serious information gap affecting the future management of FWCP-funded reservoir fertilization programs (**Data gap *3.2***; Table 3.0b).

Two additional, major disincentives exist with respect to reservoir fertilization as an enhancement technique for the Williston Reservoir watershed. The first of these is the high cost of reservoir fertilization. Currently, fertilization of the ALR and Kootenay Lake reservoirs takes up a major portion of the FWCP – Columbia Basin budget, which means that the budget for other conservation and enhancement actions is limited. The cost of Williston Reservoir fertilization is expected to be much higher, given the large size of the reservoir and its remoteness. Consequently, fertilization of bays (e.g. Omineca Bay) or a portion of the reservoir has been presented as an alternative to whole reservoir fertilization (Moody et al. 2007; R. Zemlak, BC Hydro, pers. comm. 2019), but this would necessitate studies to learn more about habitat use in Williston Reservoir by adfluvial Bull Trout (e.g. Euchner 2017b: FWCP – Peace Project No. PEA-F17-F-1472).

The second disincentive would be the fact that the major beneficiaries of reservoir fertilization may be non-native Kokanee and naturalized Lake Trout populations. Enhanced levels of Kokanee would be counter to the wishes of all First Nations whose traditional territories border Williston Reservoir, to whom Kokanee appear to be an invasive species with potentially undesirable effects on aquatic and terrestrial ecology (Pearce and Abadzadesahraei 2019; Pearce et al. 2019a, b, c, d). Lake Trout are a serious competitor species for Bull Trout who may be better able to take advantage of enhanced Kokanee in the pelagic zone of the reservoir, eventually forcing population declines in Bull Trout as discussed in Section *2.3 Limiting factors*. One conceivable benefit of increased Kokanee abundance may be a large, seasonally-available food source for Bull Trout potentially displaced from pelagic habitat in Williston Reservoir (by Lake Trout) and forced into the reservoir's littoral zones and rivers (Donald and Alger 2003).

3.3 Stream fertilization

Stream fertilization in British Columbia has been evaluated as a potential fish habitat enhancement, including streams of the Williston Reservoir watershed, and significant positive benefits may be possible for Bull Trout (Ashley and Stockner 2003; Moody et al. 2007 and references therein; Wilson et al. 2008; Decker 2010). Stream fertilization is a potentially attractive technique for boosting the productivity of critical Bull Trout habitats, in that demographic and genetic processes in Bull Trout are not threatened (unlike artificial propagation), and the method can be applied to the dynamic, high-energy stream channels utilized by Bull Trout in the Williston Reservoir watershed.

However, existing patterns of Bull Trout habitat use must be taken into account to ensure that benefits extend to this species. Fertilization of Mesilinka River in the Williston Reservoir watershed (Wilson et al. 2008) does not appear to be a cost-effective enhancement for Bull Trout – results were mixed – but this is perhaps to be expected given that critical natal habitats for Bull Trout are frequently located in smaller tributaries rather than large, mainstem reaches (Section *5.0*).

Importantly, stream fertilization has been experimentally evaluated specifically for use as an enhancement for Bull Trout within critical juvenile rearing habitats.[15] Stream fertilization was evaluated by BC Hydro over the 2001-2009 period in the Salmo River watershed of B.C.'s Kootenay Region (Seven-Mile Reservoir watershed), as a compensation option for Bull Trout potentially impacted from the addition of the fourth turbine unit at the Seven Mile Generating Station (Decker 2010). Utilizing a before-after, control-impact (BACI) experimental design, Decker (2010) monitored productivity of periphyton, benthic macroinvertebrates, and fish in fertilized (Sheep Creek) and control (South Salmo River) streams for three years pre-treatment (2001-2003) and four years post-treatment (2005-2007, 2009).[16] Nutrient addition had a statistically significant and large effect on periphyton biomass in Sheep Creek, typical of fertilization studies reviewed by the author, and also a significant, large effect on total invertebrate biomass and abundance, with increases relative to the pre-treatment period averaging 2.0-fold and 2.9-fold, respectively. The macroinvertebrate community composition shifted immediately following the onset of treatment, with Diptera (mostly chironomids) responding most rapidly. Following declines in this taxon in 2005, other taxa rebounded so that

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[16] Sheep Creek was fertilized for six consecutive years (2004-2009), but monitoring did not occur every year during the treatment period.

by 2007 the proportional abundance of the four major orders (Diptera, Trichoptera, Ephemeroptera, and Plecoptera) was similar to that of the pre-treatment period (Decker 2010). Fertilizer addition to Sheep Creek led to a substantial increase in Bull Trout biomass, mainly as a result of increases in fish size. The most important result of the study, however, was that age-2+ Bull Trout at the end of their natal stream residence period were larger and 71% more abundant post-treatment, indicating bottom-up control of productivity at each trophic level in this stream (Decker 2010). Given the importance of body size of juvenile salmonids for survival in subsequent life stages (Ward and Slaney 1988; Holtby et al. 1990), it also appears likely that stream fertilization also had a positive effect on productivity of the population overall, which appears to be reflected in subsequent redd count data for the treatment and control streams (Scott Decker, pers. comm. 2019).

Given the high potential cost of stream fertilization in northern British Columbia, uncertainty about the potential effectiveness of this enhancement method in the Williston Reservoir watershed constitutes an important data gap (**Data gap *3.3***, Table 3.0b) which should be addressed with an experimental trial similar to the carefully-designed Decker (2010) study. The promising nature of those earlier results suggest that this should be a priority action for FWCP. The potential for benefits to extend to a sympatric Arctic Grayling population should also be considered, although overlap between critical Bull Trout rearing and Arctic Grayling summer rearing habitat may be limited to a few, cold-water mainstem locations (e.g. Ingenika River, Anzac River). It is important to note that stream fertilization trials will require engagement with FLNRORD, the lead agency responsible for fish habitat.

Kokanee die after spawning, and decomposing bodies potentially provide a source of nutrients to tributary streams where Kokanee spawn (Coxson et al. 2019). Potential nutrient contributions of spawning Kokanee to streams should be considered by proponents if developing an experiment.

3.4 Fish access improvement

If high quality, coldwater habitats exist upstream of an existing migration barrier, the modification of the obstruction to permit passage of large-bodied, migratory Bull Trout can be an extremely cost-effective enhancement measure, which has the desirable attribute of not requiring artificial, in-stream manipulations to healthy stream reaches which may be neither durable nor effective (see Section *3.6*). In the upper Columbia Basin in British Columbia, approximately 2,400 adult Bull Trout now spawn above breached barriers on the Kaslo, Halfway, and Illecillewaet rivers. These measures have relatively effective compensation for footprint impacts of BC Hydro dams, for the Arrow Lakes Reservoir in particular where spawning habitat for an estimated 1,950 adult Bull Trout was cut off by the construction of Revelstoke Dam (Hagen 2008).

The distribution of critical Bull Trout natal habitats, where spawning, egg incubation, and early juvenile rearing take place, is limited by migration barriers (rather that unsuitable habitat) in many locations in the Williston Reservoir watershed. Barriers documented during Bull Trout spawner studies since 2012 (Hagen and Pillipow 2013, 2014; Hagen and Spendlow 2016-2019; Hagen et al. 2015; Euchner 2016, 2017a, 2018) are listed in Table 3.0a. The Fish Obstacles layer linked to the BC Geographic Warehouse (BCGW) includes location data for many more, although in many cases these have not been evaluated for the likelihood of passage by large-bodied, migratory Bull Trout.

Moving adult Bull Trout above migration barriers is a variation of fish access improvement. A waterfall on lower Gething Creek, the only known natal stream for Bull Trout of the Dinosaur core area isolated between W.A.C. Bennett and Peace Canyon dams, restricts habitat use to just the lower 950 m of this stream. In the 1990s, FWCP conducted an experiment with the aim of establishing a resident population above this waterfall. Such a population was presumed to be a potential source of recruitment for the Dinosaur Reservoir Bull Trout population (Langston 2008; Euchner 2011). Adult Bull Trout in spawning condition were captured below the Gething Creek falls and translocated by helicopter above impassable barriers to selected reaches of upper Gething Creek in 1993, 1997 and 1999 and Gaylard Creek in 1994. Although it appears that translocated Bull Trout spawned successfully and juvenile rearing to age-3 was documented, a resident population did not appear to naturalize in the creek above the waterfall resulting in the discontinuation of the program (Langston 2008). Of greater interest may be whether downstream juvenile migrants successfully recruited to the Dinosaur reservoir adfluvial population, confirming the approach as potential (albeit expensive) enhancement. Subsequent adult monitoring data are insufficient to evaluate this possibility (Langston 2008; Euchner 2011; Euchner 2016).

Breaching of natural migration barriers, however, allows adfluvial Bull Trout access into areas that may be inhabited by stream resident Bull Trout (Section *2.2*), unless the reach is barren of fish. Resident Bull Trout populations are highly invasible by adfluvial genotypes (Latham 2002), meaning that production benefits for the migratory life history form are likely to be offset by a loss of genetic diversity. The large-bodied, migratory life history form of Bull Trout is most at risk, because of i) serious threats posed by native and non-native competitors in adult/subadult habitats, ii) exploitation in recreational and subsistence fisheries, and iii) greater levels of land use in critical habitats, which are located within more accessible portions of watershed (see *4.0 Study Methods*). Therefore, barrier removal is perhaps justifiable for circumstances of high conservation concern for the migratory life history form, but otherwise the presence of a resident population above a migration barrier should probably preclude barrier removal. The lack of knowledge about potential candidate reaches for barrier removal (or translocation experiments similar to Gething Creek) is an information gap limiting the potential application of this enhancement technique (**Data gap *3.4a***, Table 3.0b). Addressing this information gap requires knowledge of an existing barrier(s) limiting large-bodied, migratory Bull Trout, as well as a biophysical assessment of fish and fish habitat upstream of the candidate location.

Cost-effective, and consistent with the goal of conserving genetic diversity, is the re-establishment of access blocked by anthropogenic structures such as small dams, culverts, logging debris, or reservoir debris. Assessments of road crossings and debris jams, and remediation measures where appropriate, has been a focus of stream compensation activities conducted by the FWCP in the upper Columbia Basin (reviewed in Hagen 2008). Existing assessments of potential candidate locations for restoring access within the Williston Reservoir watershed (e.g. EDI 2002a) were not reviewed as part of this information assessment, because of time limitations. Given the potential for immediate, cost-effective action by FWCP, the lack of a review of opportunities for restoring fish access is an important information gap of high immediacy (**Data gap *3.4b***, Table 3.0b). Given the ephemeral nature of smaller barriers, the low cost associated with remediation, and potential for community involvement, connectivity should be assessed periodically rather than just once, and annual remediation may we warranted when cost-effective. More specific guidance for fish passage projects was developed by FWCP in 2018, and is presented at:

http://fwcp.ca/app/uploads/2018/08/Grant-Information-Kit-How-to-apply-for-a-2018-FWCP-grant-FINAL-Sept-20-2018.pdf

The 2019 info kit will be available at:

http://fwcp.ca/info-kit-for-grant-applicants/

Table 3.0a. Migration barriers evaluated during Bull Trout spawning surveys since 2012.

Core area	***Watershed***	***Section***	***Barrier type***	***Height***	***UTM***	***Reference***
Parsnip	Misinchinka	236-073000-78200	Chute impassable	3.0	10 U 533337 6120161	Hagen and Spendlow 2019
Parsnip	Anzac	Crocker	Waterfall impassable	5.0	10 U 550473 6082976	Hagen et al. 2015
Parsnip	Anzac	236-313100-60100	Canyon impassable	na	10 U 551261 6094410	Hagen et al. 2015
Parsnip	Anzac	236-313100-42700-17700	Waterfall impassable	9.0	10 U 547921 6081215	Hagen et al. 2015
Parsnip	Anzac	236-313100-75900	Waterfall impassable	5.0	10 U 562969 6086809	Hagen et al. 2015
Parsnip	Anzac	236-313100-49600	Waterfall impassable	3.0	10 U 550223 6087111	Hagen et al. 2015
Parsnip	Colbourne	Mainstem	Waterfall impassable	3.0	10 U 528010 6109604	Hagen et al. 2015
Parsnip	Hominka	Mainstem	Chute impassable	6.0	10 U 590966 6073818	Hagen et al. 2015
Parsnip	Hominka	236-545600-74300	Waterfall impassable	3.0	10 U 587562 6074994	Hagen et al. 2015
Parsnip	Hominka	236-545600-64800	Waterfall impassable	4.0	10 U 583636 6071283	Hagen et al. 2015
Parsnip	N Anzac	Mainstem	Waterfall impassable	5.0	10 U 543757 6105576	Hagen et al. 2015
Parsnip	N Anzac	236-313100-54800-62300	Waterfall impassable	5.0	10 U 542264 6105013	Hagen et al. 2015
Parsnip	N. Anzac	236-313100-54800-52700	Chute impassable	5.0	10 U 539272 6101506	Hagen et al. 2015
Parsnip	Table	236-450800-61000	Chute impassable	3.0	10 U 566262 6076873	Hagen et al. 2015
Parsnip	Table	236-450800-49600	Waterfall impassable	8.0	10 U 574778 6070444	Hagen et al. 2015
Parsnip	Table	236-450800-52700	Waterfall impassable	5.0	10 U 561560 6072419	Hagen et al. 2015

Parsnip	Missinka	Mainstem	Waterfall impassable	5.0	10 U 586324 6055194	Hagen et al. 2015
Parsnip	Missinka	236-614900-62500	Chute impassable	5.0	10 U 585442 6057573	Hagen et al. 2015
Parsnip	Parsnip	236-953600	Waterfall impassable	4.0	10 U 593814 6047163	Hagen et al. 2015
Parsnip	Parsnip	Mainstem	Waterfall impassable	4.0	10 U 595494 6043202	Hagen et al. 2015
Parsnip Reach	Scott	Mainstem	Waterfall impassable	3.0	10 U 471368 6184252	Hagen and Pillipow 2013
Omineca	Big	Mainstem	Waterfall impassable	3.0	10 V 399698 6207595	Hagen and Spendlow 2019
Omineca	20 Mile	Mainstem	Waterfall impassable	2.5	10 U 370899 6183410	Hagen and Spendlow 2019
Omineca	Ominicetla	Johns L Trib	Waterfall impassable	3.5	10 U 315273 6191474	Hagen and Spendlow 2019
Omineca	Detni	Mainstem	Waterfall impassable	3.5	10 V 313819 6214246	Hagen and Spendlow 2019
Omineca	Quartz	Mainstem	Waterfall impassable	4.0	10 U 334842 6180847	Hagen and Spendlow 2019
Omineca	Fall	Mainstem	Waterfall impassable	10	10 U 333871 6180730	Hagen and Spendlow 2019
Omineca	Mesilinka	Hornway	Waterfall impassable	10	10 V 324675 6237564	Hagen and Spendlow 2018
Omineca	Mesilinka	Unnamed Trib5	Waterfall impassable	4.0	10 V 339131 6228845	Hagen and Spendlow 2018
Omineca	Mesilinka	Unnamed Trib2	Waterfall impassable	4.0	10 V 386134 6247798	Hagen and Spendlow 2018
Omineca	Osilinka	Thane	Waterfall impassable	5.0	10 V 350540 6222316	Hagen and Spendlow 2018
Peace Reach	Carbon	230-846900-42700	Waterfall impassable	na	10 U 523382 6184621	Euchner 2018
Peace Reach	W Nabesche	230-860600-55200	Waterfall impassable	2.5	10 V 477824 6230292	Euchner 2018
Peace Reach	W Nabesche	230-860600-55200	Waterfall impassable	6.0	10 V 477859 6230331	Euchner 2018
Peace Reach	Carbon	Mainstem	Waterfall impassable	4.0	10 U 511061 6180716	Euchner 2018
Peace Reach	Carbon	Mainstem	Waterfall impassable	7.0	10 U 511751 6181388	Euchner 2018
Peace Reach	Carbon	Mainstem	Waterfall impassable	8.0	10 U 511937 6181381	Euchner 2018
Peace Reach	Doucette	Mainstem	Waterfall impassable	10	10 U 494585 6196690	Euchner 2018
Peace Reach	Dunlevy	Mainstem	Waterfall impassable	5.0	10 V 537227 6228687	Euchner 2018
Peace Reach	Carbon	Eleven Mile	Waterfall impassable	5.0	10 U 521243 6199561	Euchner 2018
Peace Reach	Carbon	Eleven Mile	Waterfall impassable	5.0	10 U 520226 6198647	Euchner 2018
Peace Reach	Lost Cabin	Mainstem	Waterfall impassable	4.0	10 V 453642 6212947	Euchner 2018
Peace Reach	Nabesche	Mainstem	Waterfall impassable	4.0	10 V 493175 6229557	Euchner 2018
Peace Reach	Carbon	Nine Mile	Waterfall impassable	10	10 U 519952 6203004	Euchner 2018
Peace Reach	Pardonet	Mainstem	Waterfall impassable	25	10 V 498304 6208093	Euchner 2018
Peace Reach	Point	Mainstem	Waterfall impassable	7.0	10 U 478358 6197136	Euchner 2018
Peace Reach	Selwyn	Mainstem	Waterfall impassable	2.0	10 U 464629 6199124	Euchner 2018
Peace Reach	Stott	Mainstem	Waterfall impassable	na	10 V 532986 6216823	Euchner 2018
Peace Reach	W Nabesche	Mainstem	Waterfall impassable	5.0	10 V 476147 6230610	Euchner 2018
Peace Reach	Wicked	Mainstem	Waterfall impassable	3.0	10 V 458806 6216222	Euchner 2018
Dinosaur	Gething	Mainstem	Waterfall impassable	6.0	10 V 547228 6206592	Langston 2008
Finlay Reach	Davis	Mainstem	Waterfall impassable	na	10 V 425776 6292313	Hagen and Spendlow 2016
Finlay Reach	Davis	230-966200-41000-65700	Waterfall impassable	3.5	10 V 408969 6293347	Hagen and Spendlow 2016
Omineca	Ominicetla	Mainstem	Waterfall impassable	6.0	9 V 674149 6214058	Hagen and Spendlow 2019

Omineca	Omineca	Mainstem	Waterfall impassable	5.0	9 V 656746 6232233	Hagen and Spendlow 2019
Finlay Reach	Ingenika	Mainstem	Waterfall impassable	15	9 V 661477 6302342	Hagen and Spendlow 2017
Finlay Reach	Flameau	Mainstem	Waterfall impassable	5.0	9 V 674260 6312472	Hagen and Spendlow 2017
Finlay Reach	Frederikson	LaForce	Waterfall impassable	4.0	9 V 660110 6328638	Hagen and Spendlow 2017

3.5 Side channel developments

Side channels have been found to be particularly important for juvenile Bull Trout production. Mean parr abundance for side channels along the mainstem of Kemess Creek, in the Thutade watershed, averaged 11.8/100 m^2 (derived from Bustard 2004), higher than the most productive mean reach densities observed in other streams (reviewed in Hagen 2008) and twice the density of adjacent mainstem areas. Side channel developments are typically located in old side channel tracks, which receive habitat structures, then are armoured and excavated at their top end to provide year-round flow (Moody et al. 2007). It is important to note that side channel developments require careful design and regular maintenance (considerations for which are summarized in Moody et al. 2007), which probably limits their deployment to road accessible sites. Although the range of juvenile fish densities attained for other species probably cannot be assumed for Bull Trout, a side channel development in the Thutade Lake watershed averaged 13 age-1+ and older juveniles /100 m^2 in the period following its construction (Bustard 2007), and this may be a realistic target.

An advantage of side channel developments is that projects are manageable relative to those in high-energy mainstems, suggesting they may be feasible within the generally steep, high energy systems utilized by Bull Trout throughout their range. They are probably not suited for glacial systems with high bedload movement, in which intake structures have a high likelihood of being buried or stranded, as occurred for a rearing channel development adjacent to Tenderfoot Creek in the Lardeau River watershed of the upper Columbia Basin (H. Andrusak, Redfish Consulting, Nelson, pers. comm. 2006). Experimental side channel developments are likely to be feasible within the Williston Reservoir watershed, but the lack of knowledge about candidate locations is an important data gap limiting the application of this potential enhancement technique (**Data gap *3.5***, Table 3.0b). Candidate locations should be located within the distribution of critical juvenile Bull Trout rearing habitat in the Williston Reservoir watershed, either known (Section *5.0*) or estimated on the ground using juvenile-oriented sampling methods.

3.6 Instream structures

Fish production increases from the introduction of large wood and rock structures into stream channels can be significant if they result in increases in cover or pool habitat, but this enhancement technique may not be appropriate for widespread use in the Williston Reservoir watershed as discussed below.

Reviews of instream structure performance suggest that installations in large streams are more prone to failure (Roper 1998), and that structures are unlikely to be durable or function properly over the longer term in streams with high or elevated sediment loads, high peak flows, or highly erodable bank material (Frissell and Nawa 1993). In mountainous watersheds of British Columbia utilized as critical habitats by Bull Trout, high energy flows associated with snowmelt, glacial runoff, and heavy rainfall are amplified since watersheds are relatively steep, and few lakes are present to moderate flows (Triton 1992; Hagen 2008). This suggests that instream structures may be inappropriate as long-term compensation.

Instream habitat structures have previously been recommended by Moody et al. (2007) as a compensation approach for the upper Columbia Basin in British Columbia, albeit only in streams ≤ 2 % gradient. However, the performance of instream structures even in lower gradient streams of the upper Columbia Basin and upper Peace Basin has been poor. For example, wood debris structures placed in the glacial Bull Trout streams Bluewater Creek and the Bull River experienced a very high rate of failure (Hagen 1993; R.L. and L. 1997) within a relatively short time period following their installation. In non-glacial Camp Creek, a tributary of Kinbasket Reservoir, 47 habitat treatments were evaluated by Bray and Mylechreest (2003). Of these, 12 (26%) had failed completely, 17 (36%) had impaired function, and 18 (38%) were considered to be functioning well less than ten years after their installation in 1994. Although boulder placements were more durable than wood structures, they were frequently filled in with sediment instead of creating scour as intended. With the exception of rainbow trout at one enhanced site, all other species and life stages appear to either decline at treated versus control sites (rainbow trout 0+ and cottids) or show very little difference (Bull Trout 0+ and juveniles; Bray and Mylechreest 2003). In the upper Peace Basin, instream structures placed in streams of the Dinosaur Reservoir watershed have also performed poorly without continuous maintenance, and are no longer functioning as originally intended (Zemlak 2018).).

Thompson (2002) indicated that a risk of locally degraded habitats, including localized channel widening and associated bank erosion, loss of streamside vegetation, and loss of overhead and undercut bank cover, also accompanies structure deployment when evaluated over longer time horizons. Recently a consensus appears to have emerged among scientists evaluating structure performance, which is that structures can be effective in appropriate settings at enhancing fish production, but that their appropriate role is as a short-term restoration to be applied while natural ecosystem processes re-establish themselves (Kauffman et al. 1993, 1997; Roni et al. 2002; Binns 2004). Employing instream structures as long-term enhancements to streams that may already be in good ecological condition exceeds the scope of this recommended role, except in cases where remaining stream habitats are degraded, are of low gradient, and experience low bed material transport. We recommend that a hydrological assessment accompany any such proposal for adding structures to streams of the Williston Reservoir watershed, to reduce risk, and that any such deployment be treated as an experiment with appropriate monitoring. The lack of knowledge about potential durability issues, potential benefits, and suitable locations in the Williston Reservoir watershed meeting the above criteria is a data gap limiting potential application of this enhancement methodology (**Data gap *3.6***, Table 3.0b).

3.7 Riparian restoration

Riparian restoration is accorded a high priority by stream restoration scientists (Frissel and Nawa 1992; Roni et al. 2002), and may have the highest potential for salmonid habitat enhancement among existing techniques (Kauffman et al. 1993). This method is also likely to be particularly important for Bull Trout, because water temperature increases, which are linked to the loss of riparian vegetation, are a key limiting factor for the species (Reviewed in sections *2.3.2*, *2.3.3*).

Loss of riparian shading is a known impact of forest harvesting close to streams. Forest harvesting without riparian buffers may result in substantial increases in maximum temperature ranging up to 13°C, and with increases in summer daily temperature ranges compared to pre-logging ranges (Beschta and Taylor 1988; Brownlee et al. 1988; Hartman et al. 1996; Johnson and Jones 2000; Moore et al. 2005). A primary mechanism of increased water temperature in these stream reaches is direct solar radiation (Johnson 2004; Moore et al. 2005). Forest harvesting with riparian buffers reduces but does not entirely protect against increases in summer temperature (Moore et al. 2005). In the central interior of BC, a range of riparian treatments designed to mimic best practices guidelines of BC's Forest Practices Code, including partial retention and full buffers, have previously been evaluated in small, headwater streams of the Stuart Takla watershed. Five years after treatment, summer maximum mean weekly temperatures rose by up to 4-6°C, and daily temperature ranges nearly doubled following harvesting, with greatest effects observed for the partial retention relative to the high-retention treatments (Macdonald et al. 2003). Subsequent blowdown within riparian buffers appears to have been a significant factor affecting the study results.

Riparian restoration methods include planting and maintenance of trees at disturbed locations, livestock exclosure fencing (where applicable), and accelerating rates of growth of existing immature and young forests in riparian areas (Koning 1999, as cited in Moody et al. 2007). Riparian restoration methods are of low risk to Bull Trout and are recommended for application in the Williston Reservoir watershed. Prior studies assessing riparian habitat condition in the Williston Reservoir watershed (e.g. EDI 2000, 2001, 2002b) were not reviewed as part of this information synthesis, due to time constraints. Therefore, the lack of knowledge about potential candidate reaches for riparian restoration is an information gap limiting the potential application of this enhancement technique (**Data gap *3.7***, Table 3.0b).

An ongoing, FWCP-funded riparian and wetland mapping project has the potential to provide assistance to proponents wishing to develop riparian restoration proposals. A preliminary map/model developed by the BC Ministry of Environment and Climate Change Strategy (MOECCS) is available at:

https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=54822

An upcoming iteration of the model is expected to have a threats assessment layer, which could be used to support prioritizing potential enhancement sites.

3.8 Habitat conservation

The most effective and efficient technique that conservation scientists can employ to attain the strategic goals of maintaining habitat productivity and population status is to preserve existing, high quality habitats and their populations (Roni et al. 2002). This is particularly true for Williston Reservoir Bull Trout, because of the high sensitivity of the species to habitat degradation (Section *2.3.3*), and because of the expected difficulty in locating suitable, accessible sites for enhancements.

The most significant challenge facing FWCP with respect to habitat conservation is that very little of the Williston Reservoir watershed is private land, precluding some land securement options (e.g. property purchase). In watersheds utilized by Bull Trout in the Williston Reservoir watershed, forestry is the dominant land use and is regulated through the BC Government's *Forest and Range Practices Act* (FRPA), which already contains a number of standard provisions for fish habitat protection (e.g. riparian buffer strips on most fish-bearing stream reaches). The Act also recognizes that some wildlife species require specific habitat management, in addition to the general protective measures incorporated into the Act, in order to ensure their conservation status is maintained or improved. An important mechanism for addressing the additional habitat requirements of these wildlife under FRPA is the *Identified Wildlife Management Strategy* (IWMS). As part of IWMS, the Minister of Forests, Lands, and Natural Resources Operations has the authority to designate wildlife species as *Identified Wildlife* when they can be considered to be 1) a Species at Risk in British Columbia, or 2) Regionally Important Wildlife (BC MWLAP 2004). As one such species, the Bull Trout has been designated as an *Identified Wildlife* under FRPA.

Under FRPA, planning of forestry activities at the watershed scale is primarily the responsibility of licensees. FRPA has provisions, however, in the form of special watershed designations, through which FLNRORD and non-government proponents can bring forward proposals for habitat protection for Bull Trout:

1) ***Wildlife Habitat Areas***. A Wildlife Habitat Area (WHA) is defined within the Identified Wildlife Management Strategy as a geographic area delineated to meet the habitat requirements of a category of species at risk or regionally important wildlife the critical habitat requirements of an Identified Wildlife population, and which is managed to limit the impacts of human activity on that population.[17] The specified purpose of a WHA is "to

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[17] In FRPA: Government Actions Regulation, Section 10.

conserve those habitats considered most limiting to a given Identified Wildlife element[18]" (BC MWLAP 2004). In practice, WHA designations for Bull Trout in central and northern BC so far have been saved for critical spawning reaches within natal watersheds, as delineated by the distribution of redds, but critical juvenile rearing habitats usually have a similarly-restricted distribution and should also be considered in future. Wildlife Habitat Areas for Bull Trout in the Williston Reservoir watershed would be most effective if utilized for habitat reserves around critical habitats for key populations. To date, this tool has not been applied anywhere in the Williston Reservoir watershed or Dinosaur Reservoir watershed. Sufficient habitat data has now been collected by FWCP to proceed with several WHA proposals (Section *5.0*).

2) ***Temperature Sensitive Streams***. In FRPA, under Section 15 of the *Government Actions Regulation*, the designation of a stream as Temperature Sensitive may occur if a) trees are required adjacent to the stream to manage the temperature of the designated portion for the protection of fish, and b) management of the temperature of the designated portion is not otherwise provided (i.e. by general protective measures incorporated into FRPA). A Temperature Sensitive Stream (TSS) has been defined more clearly as "an area for which there is a high probability that riparian harvesting would increase summer stream temperature (as measured by the maximum weekly average temperature, MWAT) beyond an undesirable fish community threshold" (Reese-Hansen et al. 2012). Suggested criteria to be met for a TSS designation are 1) the presence of a conservation value (i.e. Bull Trout), 2) the quality of evidence that indicates stream temperature is likely to impact the conservation value, and 3) the feasibility of realizing net benefits to the conservation value (Reese-Hansen et al. 2012). Under a TSS designation, the requirement for riparian buffer strips would extend to all stream reaches, irrespective of their size or fish-bearing status, to provide shading in reaches upstream of critical natal habitats. The TSS designation has not been applied so far in the Williston Reservoir watershed, but may be an important tool for future habitat conservation. This is because Bull Trout comprise a coldwater fish community that has a sharply-defined threshold of thermal suitability (Parkinson et al. 2012 and references therein), and stream temperature-related threats, including climate change, are a concern in all core areas.

3) ***Fisheries Sensitive Watersheds***. A Fisheries Sensitive Watershed (FSW) is identified within FRPA as "an area of land in a watershed that has significant downstream fisheries values and significant watershed sensitivity," and "requires special management to protect fish" (*Government Actions Regulation* Section 14). An FSW order set out by the Minister requires that *Forest Act* agreement holders set objectives for key watershed attributes affecting fish

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[18] i.e. population

values: i) natural stream bed dynamics; ii) stream channel integrity; iii) quality, quantity, and timing of water flow, and iv) natural, watershed-level hydrological conditions and integrity. To qualify, candidate watersheds must meet two criteria: i) significant fisheries values, and ii) watershed sensitivity. The FSW designation involves watershed-specific objectives and is a more involved process than the WHA or TSS designations, but can enable a higher level of habitat protection extending beyond riparian areas (Wieckowski et al. 2008).

Although non-government proponents can initiate proposals for habitat conservation actions under FRPA, in practice in northern British Columbia this has been a Government activity. However, BC Government resources are commonly inadequate to identify critical habitats for conservation actions in a timely manner. The most important action that FWCP can undertake to facilitate habitat conservation in the Williston Reservoir watershed, therefore, is to conduct the underlying science required to identify critical habitats and assess the status of key populations. The lack of knowledge about critical habitats and conservation status for Bull Trout of the Williston Reservoir watershed is a key information gap in every core area, and is reviewed in Section *5.0*.

Table 3.0b. Potential enhancement options for Bull Trout populations of the Williston Reservoir watershed and associated key data gaps.

ID	*Enhancement*	*Data gap*	*Potential study(s)*	*Immediacy*
3.1	Artificial propagation	Not likely to be supported by FLNRORD	Experimental trials on a small scale	Low
3.2	Reservoir fertilization	Limited understanding of complex trophic interactions following fertilization	Comprehensive review of results from Kootenay Region reservoirs and elsewhere (becomes high immediacy if proposed)	Moderate
3.3	Stream fertilization	Potential benefits need experimental corroboration in natal streams of northern B.C.	Multi-year experimental trial; e.g. before-after, control-impact (BACI) design	High
3.4a	Fish access improvement	Lack of knowledge about candidate locations for barrier breaching or translocation experiments	Biophysical assessments of fish populations and fish habitat above and below barriers	Moderate
3.4b	Fish access restoration	Lack of knowledge of opportunities to restore access blocked by human activities	Review of existing fish and fish habitat information; field surveys in natal watersheds	High

3.5	Side channel development	Lack of knowledge about candidate locations for experimental trials	Juvenile-oriented electrofishing to confirm critical natal habitat; habitat surveys to identify suitable candidate locations	High
3.6	Instream structures	Lack of knowledge about durability, potential benefits, and suitable locations	Establishment of strict hydrological criteria; hydrological assessment to accompany proposals (becomes high immediacy if proposed)	Moderate
3.7	Riparian restoration	Lack of knowledge about candidate locations	Fish and fish habitat assessments in areas of high past and present land use	High
3.8	Fish habitat conservation	Lack of knowledge of critical habitats	Addressed in Section *5.0 Core area assessment*	High

4.0 CORE AREA ASSESSMENT METHODS

The large-bodied, migratory life history form of Bull Trout is most at risk, because of i) serious threats posed by native and non-native competitors in adult/subadult habitats, ii) exploitation in recreational and subsistence fisheries, and iii) greater levels of land use in critical habitats, which are located within more accessible portions of watersheds. In the U.S.A, many remaining populations presently persist only as small-bodied residents isolated in headwater streams (Nelson et al. 2002). Because of the greater risk faced by adfluvial Williston Reservoir Bull Trout relative to stream resident populations, and high value placed on large-bodied, adfluvial populations by humans, these populations and their critical habitats have been considered by FWCP and partner organization FLNRORD to be top priorities for monitoring and protection (Hagen and Decker 2011; Pollard et al. 2015; Hagen and Spendlow 2016). Consequently, critical habitat locations and conservation status assessments presented in this report are for the large-bodied, adfluvial life history form of the Bull Trout. Furthermore, the report prioritizes adfluvial Bull Trout populations within the footprint impact area of the Williston Reservoir, meaning that adfluvial Bull Trout populations of smaller lakes or above migration barriers were not a focus.

4.1 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 10.6 and a variety of provincial and regional databases. In our data consolidation, we queried where possible: 1) body length, weight, life history stage, comments, and total count of individuals captured for fish layers, and 2) feature name, height and/or classification code for obstacles. Please refer to Table 4.1 for a summary of each layer utilized in our analysis, and its availability.[19]

Table 4.1. GIS layers utilized to assess Bull Trout life history, critical habitats, and conservation status in the Williston Reservoir watershed, 2019.

Layer	Description	Access	Access URL	Secured (S), Non-Secured (NS) or Both
Provincial Fish Obstacles	Provincial dataset of obstacles	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/provincial-obstacles-to-fish-passage	NS
Aerial Videography	Dataset of class 1 (definite barrier) and 2 (probable) obstacles in the Omineca Region (to be uploaded to Provincial Fish Obstacles layer in 2019-20)	Regional Information Specialist	email Susanne.Weber@gov.bc.ca	NS
Provincial Fish Observations	Provincial dataset of fish observations	BC Data Catalogue	https://catalogue.data.gov.bc.ca/dataset/known-bc-fish-observations-and-bc-fish-distributions	NS
Region 7 Fisheries Database	Regional dataset of observations compiled from historical reports, and internal Fisheries Program projects	Regional Information Specialist	email Susanne.Weber@gov.bc.ca	Both
Region 7 Snorkel Database	Regional dataset of observations compiled from historical reports, and internal Fisheries Program projects	Regional Information Specialist	email Susanne.Weber@gov.bc.ca	NS
FWCP Williston BT Database	regional dataset of observations and critical habitat features (including obstacles) delineated from 2012-2019	Regional Information Specialist	email Susanne.Weber@gov.bc.ca	S
Oracle- FDIS Query March 2019- BT	query of provincial datasets stored in FDIS tables in Oracle -for Bull Trout	Regional Information Specialist	email Susanne.Weber@gov.bc.ca	NS
Oracle- FDIS Query March 2019- RB	query of provincial datasets stored in FDIS tables in Oracle -for Rainbow Trout	Regional Information Specialist	email Susanne.Weber@gov.bc.ca	NS
EcoCat	Ecological Reports Catalogue - utilized to follow up spatial data with more detailed observations from individual reports	Ecocat	https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/libraries-publication-catalogues/ecocat	Both

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[19] Those data that contain secure observation points under the Province's species and ecosystems data and information policy (SEDIS), are indicated in Table 4.1. To request access to these data, a request must be made directly to the Province via spi_mail@gov.bc.ca .

As the first step in the information synthesis, 8 Bull Trout core areas (putative metapopulations: Section *2.1*) comprising the potential footprint impact area for the Williston Reservoir and Dinosaur Reservoir watersheds were refined and mapped as a GIS layer (Figure 1) for integration with the draft *Provincial Bull Trout Management Plan* (Pollard et al. 2015).

Within each core area, spatial data contained within databases uploaded to the GIS (Table 4.1) were then utilized to evaluate whether the presence of Bull Trout within individual watersheds and stream sections also indicated the presence of critical habitats, and for which life stage. Key indicators of critical habitats for Bull Trout spawning included: 1) recorded observations of large fish >350 mm during the late August-to-early October spawning period, especially within a smaller stream reach or in an upstream reach of the mainstem near the migration barrier; 2) the presence of redds during redd count surveys (Hagen and Pillipow 2014; Hagen et al. 2015; Hagen and Spendlow 2016, 2017, 2018, 2019; Euchner 2016; Euchner 2017a); and 3) the presence of Bull Trout young-of-year in a stream known to be utilized by large-bodied, potentially adfluvial Bull Trout. Critical juvenile rearing habitats always included critical spawning habitats, because these areas are also utilized for egg incubation, and are typically also the most important areas for rearing of young-of-year and older juveniles. Critical juvenile rearing may also occur downstream of spawning areas if physical and ecological conditions are suitable, and such areas were included in the critical juvenile rearing segments when 1) fry (<55 mm) and/or juvenile (<170 mm) Bull Trout were present as indicated by fish length data; 2) the frequency of occurrence was relatively high (i.e. more than a single individual); and 3) Bull Trout were numerically dominant over Rainbow Trout at the site.[20]

There are a number of reasons why sampling records may under-represent a species' distribution within the Williston Reservoir watershed, including 1) sampling methods or approaches which do not reliably detect the presence of Bull Trout, which may be present at lower densities and have a low detection probability relative to other species, 2) low replication of sampling sites, 3) non-random/non-systematic distribution of sampling sites, and 4) sampling programs which do not have Bull Trout as their focus (USFWS 2008; Hagen and Decker 2011). In addition to the distribution of Bull Trout sampling records within the watershed sub-units, therefore, we also looked at the distribution of past sampling of all species. Based on our level of confidence for critical habitats based on the existing information, we assigned rankings of *High*, *Moderate*, or *Low* 'information adequacy' for each identified stream segment. A ranking of *Low* information adequacy would indicate a situation where FWCP did not have enough information to initiate conservation and enhancement actions, *High* would indicate that there were adequate data, and

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[20] The numerical dominance of Bull Trout over Rainbow Trout is a key indicator of thermal suitability for Bull Trout (Parkinson and Haas 1996; Haas 2001; Parkinson et al. 2012).

Moderate would indicate an intermediate situation where more data were desired, but the lack of full confidence should not preclude the initiation of conservation planning.

Biological data in databases uploaded to the GIS environment (Table 4.1) provided a good starting point for identifying Bull Trout 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 many cases, 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

Links to previous FWCP-funded studies were listed on website's results page:

http://fwcp.ca/results/

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 Government, or from the personal files of colleagues.

For each core area, information gaps were identified which limited our ability to assess critical habitats, thereby limiting FWCP's ability to identify locations for conservation and enhancement actions. These information gaps, along with information gaps limiting our ability to assess conservation status (see following section) for Bull Trout populations, were tabulated for each core area along with potential study methods to address them. We also assigned rankings for the 'immediacy' (urgency) of the information gaps, which we based on the expected consequences of the information gap for FWCP's ability to initiate on-the-ground conservation activities.

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. In Section *5.0*, therefore, we do not always detail a particular study methodology corresponding to each data gap. Instead, Bull Trout 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. 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.

4.2 Conservation status and risk assessment methods

4.2.1 Risk assessment methodology

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 selected for use in British Columbia for assessing the status of the province's Bull Trout populations (Hagen and Decker 2011; Pollard et al. 2015). Criteria used to estimate status and risk are applied at the spatial scale of putative metapopulations ('core areas'), and resulting rankings can be related to NatureServe's five subnational S-ranks[21] if desired. The methodology is attractive because: 1) it is designed to capture population and threat information available in a variety of standard (e.g. population data) and non-standard formats (e.g. anecdotal knowledge, professional judgment); and 2) it has been previously utilized across the Bull Trout ranges in the U.S., Alberta, and British Columbia (USFWS 2005; Rodtka 2009; Hagen and Decker 2011; COSEWIC 2012).[22] It is important to note that the methodology and criteria have had limited evaluation against British Columbia population viability data. When rankings have been evaluated against more quantitative population data, however, the rankings have seemed appropriate (e.g. Hagen and Nellestijn 2015).

In the *Core Area Conservation Status and Risk Assessment Methodology*, conservation status and risk rankings are based on categorical estimates for four indicator classes: 1) *Distribution* 2) *Abundance* (total number of adult individuals including non-reproducing individuals), 3) *Trend*, and 4) *Threats* (Tables 4.2a, 4.2b). In order to compute the rankings, alphabetical scores corresponding to categorical estimates of *Abundance*, *Distribution*, *Trend*, and *Threats* are converted to numerical values with positive or negative signs (Table 4.2c). 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 four 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* (Table 4.2c). The numeric scoring procedure is compatible with unknown values for the conservation status indicators (although this weakens the sensitivity of the analysis for detecting risk), and assigns a numeric value of zero for each 'U' (unknown) alphabetic value.

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[21] Bull Trout status and risk is described by 4 C-ranks, rather than NatureServe's 5 subnational S-ranks, with C1-High Risk=S1, C2-At Risk=S2, C3-Potential Risk=S3, and C4-Low Risk=S4 or S5.

[22] Core area status and risk rankings are a key basis for the current COSEWIC status assessment for Bull Trout nationally (COSEWIC 2012)

Table 4.2a. Codes and associated definitions for categorical estimates of *Abundance* (mature adults), *Distribution*, *Trend*, and *Threats* for use in the USFWS (2005) *Core Area Conservation Status and Risk Assessment Methodology*. *Distribution* estimates are normally boosted by one category for anadromous or adfluvial populations, but this step was not taken for core areas of the Williston Reservoir watershed because of the growing population of Lake Trout in Williston Reservoir and the potential for competitive exclusion.

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

Table 4.2b. Calculation of overall threats values from values for severity, scope, and immediacy sub-factors (USFWS 2005).

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

Table 4.2c. Numeric scoring procedure for assessing risk to Bull Trout populations in core areas based on categorical estimates of population data and threats, 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 population 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 population 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 the species may be locally abundant in some areas of the Core Area.
3.5<P≤4.5	C4	**LOW RISK** - The species is 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.

4.2.2 Population status and risk indicators

Distribution. *Distribution* is a key indicator of conservation status and risk because a broadly distributed population consisting of multiple, connected sub-populations is generally thought to be more robust to extinction forces than is a single group (Simberloff 1988). Bull Trout distribution (km) within core areas was estimated (using ArcGIS software) directly from the provincial fish observation and fish obstacles layers populated from the BC Geographic Warehouse (BCGW), augmented by data from other databases uploaded to the GIS (Table 4.1). A certain degree of professional judgment was employed to extrapolate between the BCGW records, but underestimation bias due to undetected Bull Trout presence is likely – many watersheds large enough to contain a local population of Bull Trout had no sampling records at al.

In the *Core Area Conservation Status and Risk Assessment Methodology* (USFWS 2005), the categorical estimate for the *Distribution* parameter is boosted by one category for adfluvial or anadromous populations, assuming that these life histories are associated with lower risk relative to fluvial populations (Table 4.2c). We did not take this step for core areas of the Williston Reservoir, because the presence of Lake Trout in the reservoir may result in competitive exclusion of Bull Trout and a predominantly fluvial life history in future (Donald and Alger 1993).

Abundance and Trend. *Abundance* (especially at small population sizes), followed by *Trend* have been identified as the two most important correlates of predicted extinction risk (O'Grady et al. 2004). *Abundance* is an important indicator of extirpation risk because the deleterious effects of population dynamics and genetic processes, including demographic stochasticity, environmental stochasticity, loss of genetic diversity, and inbreeding depression, are magnified at small population sizes (Simberloff 1988; Nunney and Campbell 1993; Franklin 1980). *Trend* is obviously an important indicator: when a sustained negative trend in abundance is observed, extirpation is likely unless the agents forcing population decline are identified and mitigated (Caughley 1994).

Adult Bull Trout abundance and trend data remain relatively limited for core areas of the Williston Reservoir watershed, with quantitative data mostly limited to FWCP-supported redd surveys since 2001 (Andrusak et al. 2011; Hagen and Spendlow 2016-2019; Euchner 2016, 2017a) and survey data belonging to the FLNRORD Region 7 Fisheries and Snorkeling Databases (Table 6). Four long-term spawner abundance monitoring sites established by FWCP, which are monitored annually using redd counts (Andrusak et al. 2011), provide the best indictors of *Trend*. Estimating adult Bull Trout *Abundance* at the scale of entire core areas has been made possible by the application of a calibrated aerial redd count methodology, in which rapid redd counts made from a helicopter are adjusted for detection probability <1 by comparing results from ground surveys in calibration sites. The methodology has seen application in the Parsnip (Hagen et al. 2015), Omineca (Hagen and Spendlow 2018, 2019), Peace Reach (Euchner 2016, 2017a) and Finlay Arm (Hagen and Spendlow 2016, 2017) core areas to date.

Threats. Road density has long been known to be a good general correlate of the cumulative effects on natural ecosystems associated with land use and human access (Eaglin and Hubert 1993; Rieman et al. 1997; Forman and Alexander 1998; Baxter et al. 1999; Dunham and Rieman

1999; Trombulak and Frissel 2000). We utilized 2019 estimates of *Road density* (km/km^2), computed at the sub-watershed spatial scale of Watershed Assessment Units (WAUs)[23] and overlaid on the estimated distribution of critical spawning and juvenile rearing habitats (Section *4.1*), as the basis for assessing the scope and severity of threats (Tables 4.2a, 4.2b) in natal watersheds for large-bodied, adfluvial Bull Trout. Road density criteria for assigning categorical estimates of threats severity were those currently in use by Region 7 FLNRORD for aquatic ecosystems:

Low: <0.6 km/km^2
Low-to-moderate:[24] 0.6-1.2 km/km^2
Moderate: 1.2-2.1 km/km^2
High: >2.1 km/km^2

In our analysis, threats posed by land use and angler access were assumed to have components that were acting both now and in the future. Where applicable, threats were given hybrid categories (e.g. BD) with intermediate scores for between *High* (e.g. categories A, B; Table 4.2b) and *Low* (e.g. categories C, D; Table 4.2b) immediacy.

4.3 First Nations Knowledge

First Nations knowledge about Bull Trout was also acquired in a separate study during the winter of 2019 (Pearce and Abadzadesahraei 2019; Pearce et al. 2019a, 2019b, 2019c, 2019d), in which interviews were held with community members about their concerns and priorities with respect to fish populations, and about their knowledge of important Bull Trout areas. The aim of the First Nations knowledge acquisition was to improve outcomes for First Nations communities, by using the information to:

1. Augment scientific data indicating Bull Trout population status and critical habitats,
2. Augment scientific data as factors to be considered when prioritizing among watersheds, core areas, and potential study methods for future FWCP Bull Trout study proposals,
3. Improve opportunities for employment and experience for community members, and
4. Improve the knowledge base available for supporting community resource management planning.

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[23] by Sean Barry, North Area Spatial Information Analyst, FLNRORD, Regional Operations Division, Prince George.

[24] This category was inserted to enable comparisons with previous road density criteria for watershed assessments in the B.C. interior.

First Nations information reviewed during the preparation of this report includes sensitive information which could potentially cause harm to individuals, families, and communities if released to the public or other nations. This information is private and belongs to the First Nations communities themselves. Therefore, site-specific First Nations information is not available in this report, and further use of the information beyond this study requires permission from the particular First Nation that owns the data. Contact information for the First Nations are provided in their respective reports for that study.

5.0 CORE AREA ASSESSMENT

5.1 Parsnip core area

5.1.1 Overview of existing information

The Parsnip core area is comprised of the unflooded portions of the Parsnip and Pack river watersheds. Historically, the Pack River was a tributary to the Parsnip River, which flowed roughly 280 km along the Rocky Mountain Trench from near Arctic Lake to its confluence with the Finlay River (origin of the Peace River). Following impoundment, the lower Pack River was inundated, meaning that the watershed is now a direct tributary to Williston reservoir rather than to the Parsnip River (Figure 5.1a). The post-impoundment Parsnip and Pack River systems are 6th order streams that have watershed areas of 5,600 km^2 and 4,000 km^2, respectively. Major sub-basins of the Parsnip watershed (Misinchinka, Colbourne, Reynolds, Anzac, Table, Hominka, Missinka, Upper Parsnip) range from 290 km^2 to 1,000 km^2 and drain mountainous terrain in the Hart Ranges of the Rocky Mountains, lying to the east of the trench. In contrast, smaller sub-basins on the west side of the Parsnip (95 km^2 to 182 km^2) and sub-basins making up the Pack River watershed drain lower elevation areas of the Nechako Plateau. An important factor positively affecting fish habitat quality in both watersheds is the fact that among sub-basins, substantial glacial influence occurs only within the Upper Parsnip sub-basin (Figure 1). Consequently, in most years water clarity is excellent throughout watershed sub-basins in the Parsnip and Pack watersheds, and by late summer the Parsnip mainstem itself becomes relatively clean in areas downstream of the Missinka River (Anonymous 1978).

Aquatic habitats of the Parsnip core area have received more study than those of any other conservation unit in the upper Peace Basin, with inventory and other studies resulting in widespread sampling (Figure 5.1a).[25]

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[25] Note that this information has been reviewed previously in 2015, as part of a critical fish habitats study in the Parsnip and Pack river watersheds conducted for the McLeod Lake Indian Band (Hagen et al. 2015). This prior review of background information has been incorporated in to the current analysis.

Several studies focused on the large-bodied, migratory form of the Bull Trout have been conducted in the Parsnip core area, resulting in a relatively good picture of habitat use. These studies have targeted the adult life stage and include: 1) a radio telemetry study conducted in the Misinchinka River in 2004 and 2005 to identify spawning areas and establish that Misinchinka Bull Trout were adfluvial (i.e. using the reservoir; Langston and Cubberley 2008); 2) on-the-ground redd counts by FWCP in index sections established in the Misinchinka (Andrusak et al. 2011; Hagen and Spendlow 2016), Anzac (Hagen and Spendlow 2016, 2017), and Hominka (Hagen and Pillipow 2014; FLNRORD unpublished data 2018) watersheds, and 3) calibrated aerial redd surveys since 2012 that have covered most of the potential spawning streams (Hagen and Pillipow 2013, 2014; Hagen et al. 2015; Hagen and Williamson 2016). Visual observations of adult Bull Trout made during Fish and Fish Habitat Inventory surveys also provide key information for the Missinka (Triton 1999) and Anzac (Lheidli T'enneh Band 2000, 2001, 2002) watersheds. An ongoing FWCP-funded acoustic telemetry study investigating the spatial ecology of Arctic Grayling in the Parsnip watershed (2019-20 FWCP Project No. PEA-F20-F-2961 *Spatial ecology of Arctic Grayling in the Parsnip River core area*), in which Bull Trout have also received acoustic tags, will provide further information once receivers have been downloaded and the data analyzed (Eduardo Martins, UNBC, pers. comm. 2019).

Extensive sampling focused on Arctic grayling has been conducted in the Anzac and Table watersheds, and the Parsnip River in the vicinity of these two tributaries (Zemlak and Langston 1998; Mathias et al. 1998; Blackman and Hunter 2001; Blackman 2004; Cowie and Blackman 2012; Mackay and Blackman 2012). Methods employed during these studies have included reconnaissance fish and fish habitat inventories, electrofishing surveys, beach seining, snorkeling surveys, and visual observations on foot. A significant amount of valuable Bull Trout sampling also took place during these studies, resulting in a relatively good picture of juvenile Bull Trout habitat use in the Table and Anzac systems.

However, in most locations outside of the Anzac, Table, and mid-Parsnip mainstem areas, sampling information identifying juvenile Bull Trout habitat is much more limited. Inventory studies provide key sources of critical habitat information for these other Bull Trout populations. Juvenile Bull Trout records for the Misinchinka, Colbourne, Reynolds, Hominka, Wichcika, and Upper Parsnip sub-basins, as well as other areas of the Parsnip River mainstem, are relatively rare, and available from: 1) inventory studies related to dam construction (Bruce and Starr 1985; Langston and Blackman 1993) and a proposed McGregor River diversion project (Anonymous 1978), and 2) valuable watershed-wide 2005 inventory sampling by FWCP, which was focused on the distribution of Arctic grayling fry but also recorded the presence of Bull Trout (PWFWCP

2005[26]). Reconnaissance (1:20 000) Fish and Fish Habitat Inventory surveys (BCFISB 2001), which may of particularly high value because of high levels of replication spatially, appear only to be available for the Missinka (Triton 1999) and Anzac (Lheidli T'enneh Band 2000, 2001, 2002) sub-basins and a portion of the Colbourne Creek sub-basin (Fast Creek; R.L.&L. 2000).

Document with unredacted figures available from: Susanne Weber
susanne.weber@gov.bc.ca

Figure 5.1a. Distribution of records for past sampling of Bull Trout (red circles) and all other species (light grey circles) within sub-basins of the Parsnip core area.

Information compiled in reports from the First Nations knowledge study (Pearce and Abadzadesahraei 2019; Pearce et al. 2019a, 2019b, 2019c, 2019d) does not in most cases include precise population data (distribution, abundance, trend) that would enable the delineation of critical habitats or assessments of conservation status. An important component of the First Nations knowledge study, however, was the documentation of concerns expressed by individuals and communities. The Parsnip River watershed is an area of critical community interest to the Tse’Khene (McLeod Lake Indian Band) Nation (Hagen et al. 2015; Pearce et al. 2019a). With respect to Bull Trout populations and their habitat, Tse’Khene members are concerned about: 1) high levels of mercury in the tissue of Bull Trout; 2) habitat degradation related to logging, mining, herbicide treatments, and linear developments such as pipelines and roads; and 3) increased roads, decreased flows, and increased water temperature in tributary watersheds in the Parsnip core area. Tse’Khene members recommend: 1) Bull Trout populations utilizing the Pack and Crooked rivers for subadult/adult life stages because of traditional fisheries in these rivers, 2) continued monitoring of tissue mercury in Bull Trout, and 3) increased participation by Tse’Khene members in monitoring studies, conservation actions, and community outreach (Pearce et al. 2019a)

5.1.2 Critical habitats

With respect to knowledge of critical habitats (Table 5.1a) and conservation status indicators (e.g. abundance Table 5.1b), data gaps are described in sections *5.1.2* and *5.1.3*, but are tabulated together in a single location (Table 5.1c, Section *5.1.4*) at the end of section *5.1* for efficiency.

Subsistence fisheries for large-bodied, migratory Bull Trout in the Pack River/Crooked River watershed are of critical community interest to the Tse’Khene Nation (McLeod Lake Indian

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[26] PWFWCP unpublished data uploaded to the BC Aquatic Reports Calatalog.

Band) (Pearce et al. 2019a). Numerous records indicate the presence of adult and subadult Bull Trout (>200 mm) within the Pack River watershed.[27] However, no records belonging to databases searched during this study indicated the presence of juvenile Bull Trout <180 mm anywhere in the Pack River watershed, suggesting that Bull Trout utilizing the Pack River watershed for subadult/adult growth spawn elsewhere. While sub-basins of the adjacent Parsnip River watershed are likely candidates, critical natal streams for Pack River/Crooked River fish are nonetheless yet to be identified. This is an important information gap (**Data gap *5.1a***, Table 5.1c) of high immediacy that is amenable to a telemetry study or a similar method (e.g. otolith microchemistry). This knowledge would have important implications for efforts by Tse'Khene Nation, FLNRORD, and FWCP to protect critical habitats for this population(s) of Bull Trout and understand other factors affecting human use of fish (sustainability of fishing under current levels of use, residence time of Bull Trout in the reservoir vis-à-vis mercury contamination). As mentioned previously, 2019-20 FWCP Project No. PEA-F20-F-2961 *Spatial ecology of Arctic Grayling in the Parsnip River core area* may provide relevant movement information for Bull Trout once receivers have been downloaded and the data analyzed (Eduardo Martins, UNBC, pers. comm. 2019).

Within the Parsnip core area, we delineated 31 stream sections known or suspected to provide critical spawning and/or early juvenile rearing habitats for large-bodied, migratory Bull Trout (Table 5.1a; Figures 5.1b, 5.1c). These critical habitats were distributed among the Misinchinka River, Colbourne Creek, Reynolds Creek, Anzac River, Table River, Hominka River, Missinka River, and Wichcika Creek sub-basins within the Parsnip River watershed (Table 5.1a; Figures 5.1b, 5.1c). Similar to the Pack River/Crooked River watershed, records for juvenile Bull Trout <200 mm were not identified anywhere within the Tacheeda Lakes sub-basin of the Parsnip River watershed.

A sustained effort since 2012 has been made to identify critical spawning habitats for large-bodied, migratory Bull Trout within the Parsnip River watershed (see previous section). Consequently, several critical spawning habitats are now known with *High* information adequacy (i.e. multiple years' data exhibiting a consistent pattern, corroborated on the ground if based on aerial surveys), which should enable habitat conservation and/or enhancement planning now. These include critical habitats in the Misinchinka (Table 5.1a, ID #S1) and Anzac (ID #S10, S11, S15) watersheds.

Critical spawning habitats rated to have *Moderate* information adequacy make up the majority of spawning habitats in Table 5.1a. This ranking implies that habitat conservation could be initiated

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[27] Primarily lake inventories belonging to the BC Lakes database.

now, but greater precision is desirable about the extent of critical habitats, or about the relative importance of the population to the Parsnip core area as a whole (i.e. abundance). The most valuable type of study for most of these stream segments, at this point in time, is the on-the-ground redd survey by an experienced crew(s) to corroborate/improve existing estimates of abundance and the distribution of spawning activity. Such studies will improve confidence in the value of the habitat prior to making significant investments in conservation actions. However, given that spruce beetle-related salvage logging has been initiated in the Parsnip River watershed, conservation actions may need to be initiated as soon as possible and perhaps cannot wait for further corroboration of Bull Trout habitat use. Improved understanding of abundance and the distribution of spawning is desirable for the upper Misinchinka watershed (ID #S2, S3; Table 5.1a), several sections of the Anzac watershed (ID #S17, S19, S21, S22), the upper Table River mainstem (ID #S26), the upper Hominka River mainstem (ID #S29). This information gap is important and of *High* immediacy given that habitat conservation and enhancement actions in these areas are likely to be effective at maintaining the status of Bull Trout in the Parsnip core area (**Data gap *5.1b***, Table 5.1c).

In this study, critical spawning habitats are also assumed to correspond with critical juvenile rearing habitats, but the downstream boundary of critical juvenile rearing may extend further than the lower extent of spawning. Juvenile catch data can be used to extend the boundaries of habitat conservation and enhancement actions, but to do so improved precision is required in many cases (e.g ID #J4, J7, J9, J17, J19, J23, J27, J29, J30, Table 5.1b). This information gap is ranked of *High* immediacy – without this information, habitat conservation actions may fall short (**Data gap *5.1c***, Table 5.1c). Critical juvenile rearing habitats may be indicated by relatively high abundance in electrofishing catches, the presence of young-of-year, an age/size structure indicating a migratory life history (few fish >175 mm), and numerical dominance of the catch by Bull Trout instead of Rainbow Trout (see Section *4.0*).

Critical habitats of *Low* or *Low-moderate* information adequacy have been delineated in Table 5.1a for the Colbourne (ID #S6, J7), Reynolds (ID #S8, J9), Missinka (ID #S30, J30), and Wichcika (ID #S31, J31) watersheds. These probably require further work prior to investments in conservation and enhancement actions. The Colbourne and Reynolds systems have had just one survey indicating small populations, and habitat use and abundance estimates require corroboration. To date, only a single critical spawning stream segment for large-bodied, migratory Bull Trout has been identified in the Missinka River watershed, which is somewhat puzzling. Results from a key inventory study in the Missinka (Triton 1999), however, indicated high juvenile Bull Trout abundance in the upper reaches of major unnamed tributary 236-614900-62500. Cascades in the lower reaches of this tributary were assessed from the air as being barriers to large-bodied, migratory fish during the 2014 aerial survey (Hagen et al. 2015), but re-assessment of this tributary may be warranted. The life history type (i.e. migratory, resident) of the Bull Trout population of upper Wichcika Creek is unknown. The uncertainty around these critical habitats is an information gap of *Moderate* immediacy in our analysis, given our expectation that these populations may be of lower relative importance to the Parsnip core area as a whole (**Data gap *5.1d***, Table 5.1c).

Our analysis has also indicated a general lack of sampling in the more significant, but usually unnamed, tributaries to several systems, particularly the Misinchinka, Colbourne, Reynolds, and Table systems. Sometimes these streams have received juvenile-oriented sampling, but the lack of information about life history precludes identifying these streams as critical habitats for large-bodied, migratory Bull Trout. In most cases, the small size of these streams means that they are poor candidates for the calibrated aerial redd count methodology, and they have not received a reconnaissance survey for Bull Trout spawning. The lack of tributary sampling is a data gap of *Moderate* immediacy (**Data gap *5.1e***, Table 5.1c), which could be addressed with reconnaissance surveys targeting both adult and juvenile Bull Trout life stages at a time of year when both are present (approximately August 24-September 8; e.g. Lheidli T’enneh Band 2000, 2001, 2002), or after the completion of spawning using the method of redd counts (Section *4.0*).

Table 5.1a. (*Document with unredacted UTMs available from Susanne Weber*: susanne.weber@gov.bc.ca) Critical Bull Trout habitats delineated for streams of the Parsnip core area. Sampling methods EF, SN, VO, SW, GN, AG, and RT refer to electrofishing, seine netting, visual observation, swim counts, gillnetting, angling, and radio telemetry, respectively. ID numbers identify critical habitats in Figures 5.1b, 5.1c.

ID	*Watershed*	*Section*	*Critical habitat*	*Sampling methods*	*Information adequacy*	*UTM bottom; UTM top*	*Key reference(s)*
1	Misinchinka	Mainstem index	Spawning	VO	High	**Redacted**	Langston and Cubberley 2008; Andrusak et al. 2011; Hagen and Pillipow 2013
	Comments: 5-km section of preferred spawning habitats in upper Misinchinka River; limited access following beaver dam construction in 2017						
2	Misinchinka	Mainstem 2	Spawning	VO	Moderate	**Redacted**	Langston and Cubberley 2008; Hagen and Pillipow 2013; Hagen and Spendlow 2019
	Comments: Low density spawning throughout a 9-km section below the beaver dam obstacle preventing access to preferred habitats in upper Misinchinka						
3	Misinchinka	236-073000-78200	Spawning	VO	Moderate	**Redacted**	Hagen and Spendlow 2019; Hagen et al. 2015
	Comments: Known spawning tributary to the upper Misinchinka River downstream of beaver dam obstacle; high densities of redds in lower end in 2018						
4	Misinchinka	Mainstem	Juveniles	EF, VO	Moderate	10 U 525787 6132912; 10 U 542827 6117904	PWFWCP 2005; Hagen et al. 2015
	Comments: Top boundary based on top of access; BT records in mainstem sporadic below bottom of BT spawning; no juvenile sampling in tributaries						
5	Misinchinka	236-073000-78200	Juveniles	VO	Moderate	10 U 533199 6122725; 10 U 532730 6119829	Hagen and Spendlow 2019; Hagen et al. 2015
	Comments: Based on habitat notes and redd distribution observed from the air						
6	Colbourne	Mainstem	Spawning	VO	Low-moderate	**Redacted**	Hagen et al. 2015
	Comments: 5-km section of spawning observed from the air under low water conditions in 2014; very small population and habitat use may vary in other years						
7	Colbourne	Mainstem	Juveniles	VO, EF	Low-moderate	10 U 523204 6103204; 10 U 527428 6108359	PWFWCP 2005; Hagen et al. 2015
	Comments: Based on redd distribution and electrofishing records						
8	Reynolds	Mainstem	Spawning	VO	Low-moderate	**Redacted**	Hagen et al. 2015
	Comments: 6-km section of spawning observed from the air under low water conditions in 2014; habitat use may vary in other years						
9	Reynolds	Mainstem	Juveniles	VO, EF	Low-moderate	10 U 529200 6097030; 10 U 532185 6101970	PWFWCP 2005; Hagen et al. 2015
	Comments: Based on redd distribution and electrofishing records						
10	Anzac	Upper mainstem	Spawning	VO	High	**Redacted**	Hagen et al. 2015; Hagen and Spendlow 2017; Lheidli T'enneh

							Band 2000, 2001, 2002
	Comments: 3 years' visual observations from the air and on the ground during FWCP redd count studies; also see inventory reports						
11	Anzac	Mainstem	Juveniles	EF, VO	High	10 U 548819 6086063; 10 U 567600 6089146	Hagen et al. 2015; Lheidli T'enneh Band 2000, 2001, 2002
	Comments: Inventory reports by Lheidli T'enneh Band are key references						
12	Anzac	236-313100-37200	Spawning, Juveniles	EF, VO	Low	**Redacted**	Lheidli T'enneh Band 2000, 2001, 2002
	Comments: Spawners observed at a single site; 500-m buffer applied to either side for now						
13	Anzac	236-313100-48700	Spawning	EF, VO	Low-moderate	**Redacted**	Lheidli T'enneh Band 2000, 2001, 2002
	Comments: Spawning/rearing stream with adults identified during inventory study; Small stream; adults to 800 mm visually identified on the ground						
14	Anzac	236-313100-48700	Juveniles	EF, VO	Low-moderate	10 U 549239 6086922; 10 U 544776 6091135	Lheidli T'enneh Band 2000, 2001, 2002
	Comments: Spawning/rearing stream with adults identified during inventory study						
15	Anzac	236-313100-60100	Spawning, Juveniles	EF, VO	High	**Redacted**	Hagen et al. 2015; Hagen and Spendlow 2017; Lheidli T'enneh Band 2000, 2001, 2002
	Comments: Most important spawning location within Anzac watershed; located below impassable canyon; critical staging area in mainstem Anzac also requires protection (Bottom=10 U 552287 6092985)						
16	Anzac	236-313100-75900	Spawning	VO	Moderate	**Redacted**	Hagen et al. 2015; Hagen and Williamson 2016; Lheidli T'enneh Band 2000, 2001, 2002
	Comments: 2 years' aerial redd surveys and on-the-ground inventory work have confirmed this 2.3-km spawning section						
17	Anzac	236-313100-75900	Juveniles	EF, VO	Moderate	10 U 559463 6092102; 10 U 562980 6086800	Hagen et al. 2015; Lheidli T'enneh Band 2000, 2001, 2002
	Comment: Juvenile rearing assumed to extend downstream to the mouth						
18	Anzac	236-313100-75900-45500	Spawning, Juveniles	EF, VO	Low-moderate	**Redacted**	Lheidli T'enneh Band 2000, 2001, 2002
	Comments: Large-bodied spawners observed in tributary during inventory study						
19	Anzac	Crocker	Spawning	VO	Moderate	**Redacted**	Hagen et al. 2015; Lheidli T'enneh Band 2000, 2001, 2002
	Comments: Relatively low aerial redd count, but this section should be combined with unnamed tributary 236-313100-42700-17700 into a continuous critical habitat section						
20	Anzac	Crocker	Juveniles	EF, VO	Moderate	10 U 548743 6084534; 10 U 547921 6081215	Hagen et al. 2015; Lheidli T'enneh Band 2000, 2001,

							2002
	Comments: *Extends downstream of spawning section to mouth*						
21	Anzac	236-313100-42700-17700	Spawning, Juveniles	EF, VO	Moderate	**Redacted**	Hagen and Williamson 2016; Lheidli T'enneh Band 2000, 2001, 2002
	Comments: Spawning/rearing tributary to Crocker C with adults identified during inventory study; redds identified from the air in 2016						
22	Anzac	North Anzac	Spawning	VO	Moderate	**Redacted**	Hagen et al. 2015; Hagen and Williamson 2016
	Comments: Encompasses spawning activity observed in 2014 and 2016						
23	Anzac	North Anzac	Juveniles	EF, VO	Moderate	10 U 545676 6098772; 10 U 543757 6105576	Lheidli T'enneh Band 2000, 2001, 2002; Hagen and Williamson 2016
	Comments: Based on redd distribution and electrofishing records						
24	Anzac	236-313100-54800-52700	Spawning, Juveniles	EF, VO	Moderate	**Redacted**	Lheidli T'enneh Band 2000, 2001, 2002; Hagen and Williamson 2016
	Comments: Adults have been observed in this North Anzac tributary, and spawning was corroborated by aerial redd count in 2016; ideally, should be corroborated with a ground survey, but access will be very difficult even with a helicopter						
25	Anzac	236-313100-54800-62300	Spawning, Juveniles	EF, VO	Moderate	**Redacted**	Lheidli T'enneh Band 2000, 2001, 2002; Hagen and Williamson 2016
	Comments: Adults have been observed in this North Anzac tributary, and spawning was corroborated by aerial redd count in 2016; ideally, should be corroborated with a ground survey, but access will be very difficult even with a helicopter						
26	Table	Mainstem	Spawning	VO	Moderate	**Redacted**	Hagen et al. 2015; Hagen and Williamson 2016
	Comments: Key spawning sections identified within Table watershed below and, especially, above a 2m cascade; high redd density above the cascade indicates one of the most significant Bull Trout populations in the Parsnip watershed.						
27	Table	Mainstem	Juveniles	VO	Moderate	10 U 560080 6070504; 10 U 574172 6075752	Mathias et al. 1998; Zemlak and Langston 1998; Hagen et al. 2015
	Comments: BT dominant within this section						
28	Hominka	Mainstem	Spawning	VO	Moderate	**Redacted**	Hagen and Pillipow 2014; FLNRORD unpublished 2017
	Comments: Relatively low redd density indicating a small population (50 adults +/-); limited gravel recruitment in portions; most tributaries have barriers in lower ends but bottom 200 m may provide important spawning also						
29	Hominka	Mainstem	Juveniles	EF, VO	Moderate	10 U 578721 6065550; 10 U 588680 6074914	PWFWCP 2005; Hagen et al. 2015
	Comments: Most tributaries have barriers in lower ends but bottom 200-500 m or so will provide important juvenile rearing also						
30	Missinka	236-614900-52600	Spawning, Juveniles	EF, VO	Moderate	**Redacted**	Triton 1999; Hagen et al. 2015
	Comments: Only location in the Missinka watershed where redds of large-bodied BT were identified from the air in 2014; BT present in many locations in the Missinka watershed but confirmation of life history is required; mix of body						

	sizes						
31	Wichcika	Upper mainstem	Juveniles	EF	Low	10 U 559123 6039919; 10 U 567728 6036260	PWFWCP 2005
	Comments: Large-bodied, migratory population has not been confirmed; Segment based on juvenile BT records plus 500-m buffer, highly uncertain; RB dominate lower watershed						

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Figure 5.1b. Critical spawning (narrow red segments) and juvenile rearing (thick green segments) habitats delineated for Bull Trout of the northern portion of the Parsnip core area downstream of the Anzac River. ID numbers correspond with critical habitats described in Table 5.1a, and ‘S’ and ‘J’ prefixes for ID numbers indicate critical spawning and juvenile rearing habitats, respectively.

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Figure 5.1c. Critical spawning (narrow red segments) and juvenile rearing (thick green segments) habitats delineated for Bull Trout of the southern portion of the Parsnip core area upstream of and including the Anzac River. ID numbers correspond with critical habitats described in Table 5.1a, and ‘S’ and ‘J’ prefixes for ID numbers indicate critical spawning and juvenile rearing habitats, respectively.

5.1.3 Conservation status and risk assessment

Distribution. Large-bodied, migratory Bull Trout are widely distributed in the Parsnip core area utilizing >200 km of the Parsnip core area (category *D*: 200-1,000 km, Table 4.2a), in subadult/adult rearing habitats of the Pack River/Crooked River watershed and the Parsnip River mainstem, and in critical natal habitats in the Misinchinka, Colbourne, Reynolds, Anzac, Table, Hominka, Missinka, and Wichcika sub-basins of the Parsnip River watershed (Figure 5.1a).

Abundance. Among sub-basins of the Parsnip River watershed, the Misinchinka and Anzac systems appear to be the most important for Bull Trout spawners with minimum population estimates of roughly 180 and 170, respectively (Table 5.1b), based on expanded 2014 calibrated aerial redd counts (Hagen et al. 2015) augmented by additional on-the-ground and aerial redd counts over the 2013-2016 period (Hominka: Hagen and Pillipow 2014; Table/Anzac: Hagen and Williamson 2016; Hagen and Spendlow 2017). For these two systems and the Hominka River, estimates of total population size are based on calibrated aerial redd counts and on-the-ground redd counts in key spawning zones, and are probably adequate for the *Core Area Conservation Status and Risk Assessment Methodology* (USFWS 2005). The sizes of spawning populations in the Colbourne, Reynolds, Table, and Missinka watersheds (Table 5.1b) are more uncertain, warranting further investigation using methods suitable for estimating the size of the spawning population (i.e. redd counts). The most important rationalization for these potential surveys, however, is to better delineate critical habitats, so this information gap is included within **Data Gaps *5.1b, 5.1d*** as described in the preceding section (Section *5.1.2*). On-the-ground redd counts to refine the estimates of critical habitats and provide more reliable estimates of spawner population size are the most efficient methodology to address this information deficiency. The provisional estimate of total population size for the Parsnip River watershed based on Table 5.1b is approximately 560 spawners (category *C*: 250-1,000 adults, Table 4.2a).

Table 5.1b. Minimum estimated population[1] size of large-bodied, migratory Bull Trout in the Parsnip core area, 2014 (adapted from Hagen et al. 2015).

Sub-basin	*Minimum population estimate[1]*	*Source*	*% of Parsnip total*	*Reference*
Misinchinka River	180	2014 calibrated aerial count	32%	Hagen et al. 2015
Colbourne Creek	20	2014 calibrated aerial count	4%	Hagen et al. 2015
Reynolds Creek	40	2014 calibrated aerial count	7%	Hagen et al. 2015
Anzac River	170	2014 calibrated aerial count	30%	Hagen et al. 2015
Table River	100	2014, 2016 ground surveys	18%	Hagen and Williamson 2016
Hominka River	40	2014 calibrated aerial count	7%	Hagen and Pillipow 2014
Missinka River	10	2014 calibrated aerial count	2%	Hagen et al. 2015
Parsnip total	***560***		***100%***	

[1] Expanded aerial redd counts based on estimates of aerial redd detection probability, and assumption of two spawners per redd. 'Minimum' because some small tributaries could not be surveyed using the aerial count methodology.

Population trend. The Misinchinka River contains one of four long-term index sites utilized by FWCP since 2006 for monitoring abundance trend (Andrusak et al. 2011). Due to the presence of two beaver dam obstructions, most Bull Trout spawners were unable to reach preferred spawning locations in the Misinchinka River index section for the second consecutive year in 2018, meaning that a representative redd count for the Misinchinka River is unavailable since 2016, and the time series for this system remains at 9 years (over a 12-year period) (Figure 5.1d). No significant trend in abundance is evident (t = -0.693, P = 0.51;[28] Hagen and Spendlow 2019), especially when considering that the low count in 2016 may be related to the beginning of access limitation by beavers, and the best estimate of trend is 'stable' (category *E*, Table 4.2a).

The Misinchinka index section is of uncertain value for the future, unless the beaver dams are breached and access restored to preferred spawning habitats in this reach. The distribution of spawning below these obstructions was evaluated in 2019 and appears to be widespread and not especially conducive to future redd surveys. If access to this reach continues to be compromised, this is a looming information gap for the future of high immediacy (**Data gap *5.1f***, Table 5.1c).

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[28] Assessed using simple linear regression on natural log-transformed data (Hagen and Spendlow 2019).

New index sections, meant for periodic sampling (e.g. one out of every 3 years) have been established by FWCP in the Anzac River watershed (Hagen and Spendlow 2017), and these are potential candidates to replace or augment the Misinchinka index section if it continues to be compromised. The spawning zones in the upper Table River may also be well-suited as an alternate redd survey location. There is a general need for a coordinated Bull Trout abundance trend monitoring plan across the Williston watershed to assess the influence and relative importance of potential limiting factors, such as land use, water temperature, and naturalized populations of Lake Trout (e.g. Kovach et al. 2016). These considerations are discussed in Section *6.0*.

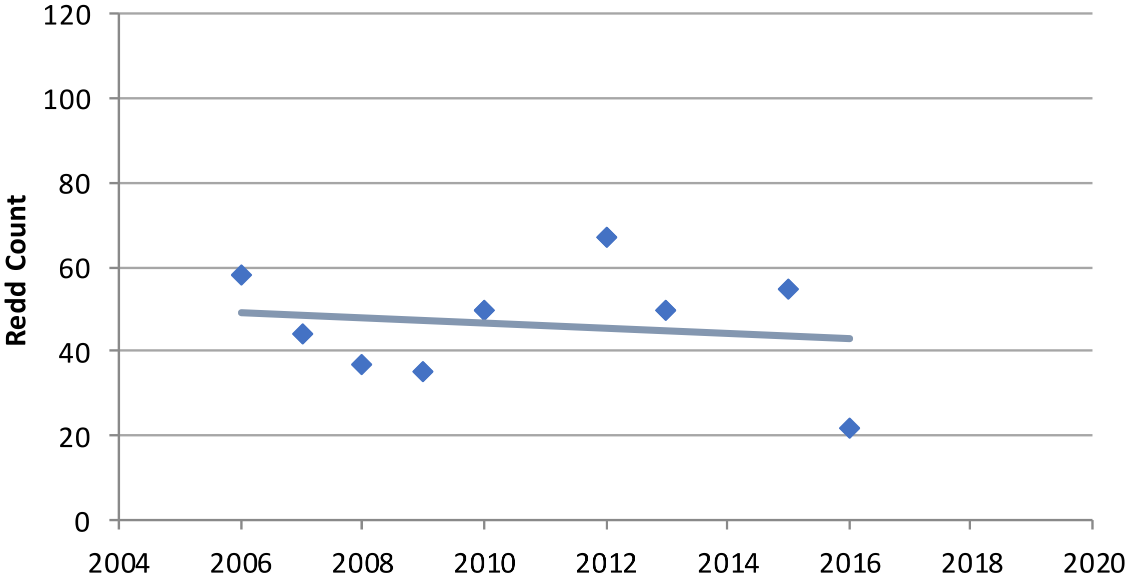

Figure 5.1d. Counts of Bull Trout redds (spawning sites) in the FWCP spawner abundance monitoring index site of the Misinchinka River, 2006-2016 (adapted from Hagen and Spendlow 2019).

Threats. Threats from land use and human access (e.g. linked to First Nations subsistence fisheries, recreational angling catch-and-release mortality and non-compliance), as indicated by road density adjacent to critical habitats for Bull Trout (Figure 5.1e), were estimated to be of moderate scope and low-to-moderate severity (hybrid category *BDEF*; Table 4.2b).

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Figure 5.1e. Road density (km/km^2) in watershed assessment units (see Section *4.2.2*) of the Parsnip core area (coloured polygons) and critical habitats for Bull Trout (spawning and/or juvenile: thick black stream segments).

Conservation status and risk assessment. The categorical estimates for the four conservation status indicators, when factored together (see Table 4.2c), corresponded to a ranking of ***C2-At Risk***, although it should be noted that the score was marginal between this ranking and the more secure ranking of ***C3-Potential Risk***. According to this ranking, Bull Trout 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” (Table 4.2c). The most influential indicator in the scoring process was the small adult population <1,000 individuals. Reducing the scope of the threats from *Moderate* to *Low* (e.g. by habitat conservation actions) would be the most influential action to improve the status ranking of the population.

5.1.4 Tabulated Data gaps

Table 5.1c. Data gaps limiting understanding of critical habitats and/or conservation status for Bull Trout within the Parsnip core area, and potential studies to address them.

ID	*Stream(s)*	*Data gap*	*Potential study(s)*	*Immediacy*
5.1a	Pack, Crooked	Unknown locations of natal streams	1) Adult movement studies (e.g. radio, acoustic telemetry); 2) Otolith microchemistry (for harvested fish)	High[1]
5.1b	Upper Misinchinka, Anzac (portions), Table, Hominka	Inadequate understanding of the distribution of spawning and spawner abundance	Foot surveys (redd surveys) to acquire more precise estimates of abundance, critical habitats	High
5.1c	All	Imprecise or poor data for downstream boundaries of critical juvenile rearing	Juvenile-oriented fish surveys (e.g. electrofishing)	High
5.1d	Colbourne, Reynolds, Missinka	Poor understanding of distribution of critical spawning habitats and abundance	Foot surveys (redd surveys) to acquire estimates of abundance, critical habitats	Moderate
5.1e	Misinchinka, Colbourne, Reynolds,Table	Poor understanding of habitat use in significant (usually unnamed) tributaries	Reconnaissance surveys targeting adult and juvenile life stages when both are present (redd counts, electrofishing)	Moderate
5.1f	Misinchinka	Compromised spawner access to Misinchinka index section; no reliable index of trend.	Redd surveys in new index sections of the Misinchinka, Anzac, Table watersheds	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

5.2 Parsnip Reach core area

5.2.1 Overview of existing information

The Parsnip Reach core area encompasses the roughly 110 km of the former Parsnip River which was flooded following construction of the W.A.C. Bennett Dam, and which is now known as Parsnip Reach of Williston Reservoir. Tributaries on the east shore of Parsnip Reach drain higher elevations in the Rocky Mountains and have relatively short accessible lengths and moderate gradients. On the western shore of the reservoir, small tributaries south of the Nation River drain relatively lower elevation terrain of the Nechako Plateau, and are likely to be relatively warm and have low suitability for populations of large-bodied, migratory Bull Trout. The Nation River watershed, the largest watershed in the core area, straddles the transition from the Nechako Plateau to higher elevation topography in the Omineca Mountains. The Manson River, which lies to the North of the Nation River and is a lake-headed system draining the Omineca Mountains, is a second large watershed on the reservoir's western shore.

Past sampling efforts indicate that Bull Trout have a relatively wide distribution within the core area (Figure 5.2a). However, the productivity of the core area may be relatively limited for the large-bodied, migratory form of the species. As described in Section *2.3*, Bull Trout are a cold water-adapted species that would not be expected to be dominant in many streams in the non-glacial, relatively warm Nation and Manson River watersheds. Streams on the eastern shore of Parsnip Reach drain higher elevations, but in many cases are small with relatively short accessible lengths for fish migrating from Williston Reservoir.

A substantial population of adfluvial Bull Trout utilizes Scott Creek on the eastern shore of Parsnip Reach for spawning and juvenile rearing. This is known from a counting fence operated in the early 1990s (Slaney 1992), annual redd counts since 2009 as part of an existing FWCP Bull Trout monitoring program (Andrusak et al. 2011), and a calibrated aerial redd survey of the entire accessible length of the stream in 2012 (Hagen and Pillipow 2013). Outside of this system and neighbouring Weston Creek, which was also sampled using a counting fence in the early 1990s (Slaney 1992) very little effort has been directed towards understanding the status and habitat use of large-bodied, migratory Bull Trout in the core area. Outside of Scott Creek, the calibrated aerial redd survey methodology has not been applied in this core area.

For tributaries of the eastern shore of Parsnip Reach, Bull Trout records exist from inventory studies conducted by FWCP (Langston and Blackman 1993) and for stream classification for forestry (e.g. R.L.&L. 2000, 2002). The potential importance of these streams for large-bodied, migratory Bull Trout cannot be assessed reliably at this point in time. Length-frequency observations and waterfall locations provide some of the only relevant data because surveys were not focused on the adult life stage.

Snorkeling observations along the Manson River and Nation River mainstems provides key information confirmed that large-bodied, migratory Bull Trout >500 mm use these watersheds (Langston and Blackman 1993; FLNRORD Prince George Region 7 snorkeling database). Anecdotal reports also exist of concentrations of large Bull Trout in mid-to-late fall in the river section between Tchentlo and Chuchi lakes (Gunville 1977).

Widespread electrofishing data along the Nation River mainstem, conducted by Cowie and Blackman (2007), is adequate to confirm this lake-headed river does not provide critical juvenile rearing habitat for Bull Trout. Inventory sampling in the Tsaydachi, Ahdatay, and Kwanika watersheds within the Nation system is relatively widespread and adequate to confirm the presence of self-sustaining Bull Trout populations (Burns 1978; EDI 1999; Hagen et al. 2013). However, inventory report authors and available length-frequency data suggest that the stream resident life history is present in these systems, and use by large-bodied, migratory Bull Trout has not been confirmed. Bull Trout are also present in the Philip, Rainbow, Sylvester, Suschona, Klawli, Fish-Purvis, Rottacker, and Tsayta systems (Cowie and Blackman 2007; Mike Stamford, M.Sc. research; Gunville 1977; BCGW 2019; Pearce et al. 2019d), but the sampling frequency is inadequate for delineating the distribution of the species in these watersheds (Hagen et al. 2013). The Philip, Rainbow, and Tsayta watersheds, which drain lower elevation areas or are dominated by Rainbow Trout, are not likely to be sufficiently productive for large-bodied, migratory fish (Hagen et al. 2013).

Within the Manson River watersheds downstream of Manson Lakes, the Ciarelli, Connaghan, Dunne, Munro, Chamberland (aka Carmella) are potential Bull Trout streams. Sampling is inadequate, however, to determine the presence of natal habitats for large-bodied, migratory fish from Williston Reservoir due to limited or non-existent sampling, very small catches of Bull Trout, and body sizes >170 mm potentially indicating stream resident populations (Langston and Blackman 1993; Pottinger Gaherty 1998; BCGW 2019).

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Figure 5.2a. Distribution of records for past sampling of Bull Trout (red circles) and all other species (light grey circles) within sub-basins of the Parsnip Reach core area.

Information compiled in reports from the First Nations knowledge study (Pearce and Abadzadesahraei 2019; Pearce et al. 2019a, 2019b, 2019c, 2019d) does not include precise population data (distribution, abundance, trend) that would enable the delineation of critical habitats or assessments of conservation status in the Parsnip Reach core area. Importantly, Tse’Khene Nation and Nak'azdli Nation members confirm the presence of large-bodied, migratory Bull Trout in the Nation and Manson watersheds. An important component of the First Nations knowledge study, however, was the documentation of concerns expressed by individuals and communities. The Nation River watershed is an area of high interest to the Nak'azdli Nation (Pearce et al. 2019d). With respect to Bull Trout populations and their habitats, Nak'azdli members are concerned about land use-related habitat degradation including changes in flows, increased sediment, increased temperature, and increased access for humans. Nak'azdli members recommend: 1) conservation status assessments and habitat assessments focused on the Nation, 2) increased habitat protection during logging, and 3) increased participation of Nak'azdli members in industrial monitoring studies (Pearce et al. 2019d).

5.2.2 Critical habitats

With respect to knowledge of critical habitats (Table 5.2a) and conservation status indicators, data gaps for the Parsnip Reach core area are described in sections *5.2.2* and *5.2.3*, but are tabulated together in a single location (Table 5.2b; Section *5.2.4*) at the end of section *5.2* for efficiency.

Currently, we have a relatively poor understanding of critical spawning and juvenile rearing habitats within the Parsnip Reach core area for large-bodied, adfluvial spawners from Williston Reservoir, and we delineated just two stream segments as critical habitats (*S32*, *J33*; Table 5.2a). These were juvenile and spawning habitats in Scott Creek (Figure 5.2b), a significant population which likely averages at least 150 spawners annually (annual redd count ranges from 41-106 redds; Hagen and Spendlow 2019), and which appears to utilize the section of Scott Creek below an impassable waterfall in a consistent manner each year. The Scott Creek population in one of 4 long-term index sites utilized by FWCP to assess population trend for Williston Reservoir Bull Trout. In addition to population size data, fence count and angling capture data from the early 1990s provides an important baseline for potential comparisons of age, life history, and growth for Williston Reservoir spawners over time (Slaney 1992).

Large-bodied, migratory Bull Trout are also known from Weston Creek (Slaney 1992) and Mischinsinlika Creek (R.L.&L. 2002), but the distribution of critical habitats for spawning and juvenile rearing are unknown. Other tributaries of the eastern shore of Parsnip Reach may have lower potential, due to: 1) potential stream resident body sizes >170 mm present in Mugaha Creek along with a 3-m rock obstruction limiting access (Langston and Blackman 1993); a 4-m cascade in lower Cut Thumb Creek (Langston and Blackman 1993); 3) a steep entrenched channel and unknown accessibility in Gagnon Creek, and 4) insufficient sampling data from Chichouyenily Creek (BCGW 2019). The lack of knowledge about the distribution and relative importance of critical habitats along the eastern shore of Parsnip Reach is an important information gap of high immediacy, given the potentially limited extent of productive habitat for Williston Bull Trout elsewhere within the core area (**Data gap *5.2a***, Table 5.2b). As the first step in delineating critical habitats and the relative importance of these populations, a calibrated aerial redd count survey of these and other streams on the eastern shore of Williston Reservoir is proposed for September 2019 (FWCP project no. PEA-F20-F-2956).

Although large-bodied, potentially adfluvial fish >500 mm utilize the Nation River and Manson River mainstems, locations of critical spawning and juvenile rearing habitats are unknown for these populations. This is an information gap of high immediacy (**Data gap *5.2b***, Table 5.2b), given that these watersheds may be somewhat marginal for migratory Bull Trout because of warmer water temperatures (Langston and Blackman 1993) and relatively high levels of land use now and in the past (see Section *5.2.3*). Habitat conservation measures in critical habitats may be essential to ensuring the long-term viability of these populations, but it is not even assured that critical habitats are located in the Nation River and Manson River watersheds. It is conceivable that observed concentrations of large-bodied Bull Trout may have been presence on foraging migrations, rather than spawning migrations. For a number of reasons, an application of the calibrated aerial redd count methodology has not been proposed for the Nation and Manson watersheds. These include: 1) existing information does not reliably indicate the presence of critical spawning habitats for adfluvial, Williston Reservoir Bull Trout, 2) the watersheds may have somewhat marginal suitability for adfluvial Bull Trout relative to other areas of the Williston Reservoir watershed, and 3) the two watersheds together encompass a large geographic area to search using an expensive methodology. In this case, a well-designed telemetry or otolith microchemistry study may be the preferred option for identifying natal stream habitats for these populations. The latter involves lethal sampling but may be significantly more cost-effective depending on the ability to resolve distinct water chemistry signatures among potential rearing habitats (M. Stamford, pers. comm. 2018).

The anecdotal reports of large Bull Trout in mid-to-late fall in the river section between Tchentlo and Chuchi lakes (Gunville 1977) potentially suggest the presence of spawning migration into the Klawli River. Knowledge of this potential staging area may be an important starting point for future investigations of habitat use by large-bodied, migratory fish in the Nation River watershed.

Eklund Creek, which is a direct tributary to Parsnip Reach located on the western shore of the reservoir, also has Bull Trout records and is a stream of potential interest (Cubberley 2003; BCGW 2019). This information gap is ranked of low immediacy, but this ranking could change if information about the presence of a large-bodied, adfluvial population were to emerge.

Table 5.2a. (*Document with unredacted UTMs available from Susanne Weber*: susanne.weber@gov.bc.ca) Critical Bull Trout habitats delineated for Scott Creek in the Parsnip Reach core area. Sampling methods EF, SN, VO, SW, GN, AG, and RT refer to electrofishing, seine netting, visual observation, swim counts, gillnetting, angling, and radio telemetry, respectively. ID numbers identify critical habitats in Figure 5.2b.

ID	*Watershed*	*Section*	*Critical habitat*	*Sampling methods*	*Information adequacy*	*UTM bottom; UTM top*	*Key reference(s)*
32	Scott	mainstem	Spawning	VO, fence counts	High	***Redacted***	Slaney 1992; Andrusak et al. 2011; Hagen and Pillipow 2013
	Comments: Only large population of large-bodied, adfluvial spawners (41-106 redds) identified to date for Parsnip Reach; consistent spawning zone each year						
33	Scott	mainstem	Juveniles	EF, VO	Moderate	10 U 464115 6175342; 10 U 471368 6184252	Slaney 1992; Andrusak et al. 2011; Hagen and Pillipow 2013
	Comments: Juvenile distribution assumed to extend to mouth						

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Figure 5.2b. Critical spawning (narrow red segments) and juvenile rearing (thick green segments) habitats delineated for Bull Trout in Scott Creek, Parsnip Reach core area. ID numbers correspond with critical habitats described in Table 5.2a, and 'S' and 'J' prefixes for ID numbers indicate critical spawning and juvenile rearing habitats, respectively.

5.2.3 Conservation status and risk assessment

Distribution. The distribution of large-bodied, migratory Bull Trout has not been well-defined within the Parsnip Reach core area. As mentioned in Section *5.2.2*, the lack of knowledge about Bull Trout habitat use in the Nation and Manson watersheds in particular is an important knowledge gap.

Tributaries on the eastern shore of Parsnip Reach have short accessible lengths, but are known to be utilized by adfluvial spawners (Slaney 1992). In contrast, the Nation and Manson watersheds are accessible for hundreds of kilometers, but natal stream habitats for migratory Bull Trout populations are unknown. Large-bodied Bull Trout are known to utilize mainstem reaches of these two rivers at a minimum, so it appears likely that adfluvial Bull Trout are distributed over at least 200 km of the Parsnip Reach core area (category *D*: 200-1,000 km, Table 4.2a).

Abundance. Abundance of large-bodied, potentially adfluvial Bull Trout in the Parsnip Reach core area is unknown outside of Scott and Weston Creeks. In the early 1990s, Weston Creek appeared to have only a small population of adfluvial fish, while a substantial population was discovered in Scott Creek (Slaney 1992). Since 2009, Scott Creek has been one of FWCP's four long-term index streams monitored annually for Bull Trout spawner abundance. Redd counts for the Scott Creek population range from 41-106 over that time period. Given a conservative estimate of 2 spawners per redd (Hagen and Decker 2011), and given that not all Bull Trout adults spawn each year, the Scott Creek population could potentially range from 100-250 adult individuals. The size of other populations in the core are unknown, but on the east shore of Parsnip Reach there is not likely to be another major population given that other creeks are smaller than Scott Creek and migration barriers appear to limit access for adfluvial fish on Mischinsinlika, Mugaha, and Cut Thumb creeks (BCGW 2019, Fish Obstacles layer). Until spawner populations are identified in the Nation and Manson systems, we cannot be confident that the spawner population for the core area exceeds 250 adult individuals. Nor is likely to be much less than this, given the known abundance levels for Scott Creek alone. We therefore assigned a categorical estimate of abundance that was marginal between categories <250 (category *B*: 50-250 adults) and >250 (category *C*: 250-1,000 adults, Table 4.2a). At the scale of an entire core area, this is a very low estimate and potentially of conservation concern. It is possible that genetic and demographic exchange occurs at a larger scale, and the core area is actually larger and includes other populations (see Section *2.1* and associated information gaps). Until population structure is better understood, the lack of understanding of total population size for the Parsnip Reach core area is an important information gap of moderate immediacy (**Data gap *5.2c***, Table 5.2b). This information gap can best be assessed following the identification of critical spawning habitats in streams other than Scott Creek, as discussed in Section *5.2.2*.

Population trend. The completion of surveys in 2018 extends the time series of redd count data in Scott Creek to 8 years (over a 10-year period) for Scott Creek (Figure 5.2c), minimally meeting criteria for evaluating trend of 5 or more years over a minimum 10-year period (Humbert et al. 2009; Kovach et al. 2016). At this point in time, a negative trend in abundance is exhibited by the Scott Creek redd counts (category *D* Declining 10-30%) although it is non-significant ($t = -2.17$, $P = 0.07$, $n = 8$; Figure 5.2c) and given the limited extent of just 8 years for this time series this decline should be considered a provisional estimate. The lack of an adequate time series at Scott Creek for evaluating trend is an important data gap (**Data gap *5.2d***, Table 5.2b). The Nation and Manson watersheds may generally have warmer water conditions and lower suitability for Bull Trout. They have had more watershed development, so monitoring at Scott Creek may not be reliable for the core area as a whole (**Data gap *5.2e***, Table 5.2b). If spawning habitats are identified in one or both of these watersheds, a new index section(s) should be established. The general need for a coordinated Bull Trout abundance trend monitoring plan across the Williston watershed to assess potential limiting factors is discussed further in Section *6.0*.

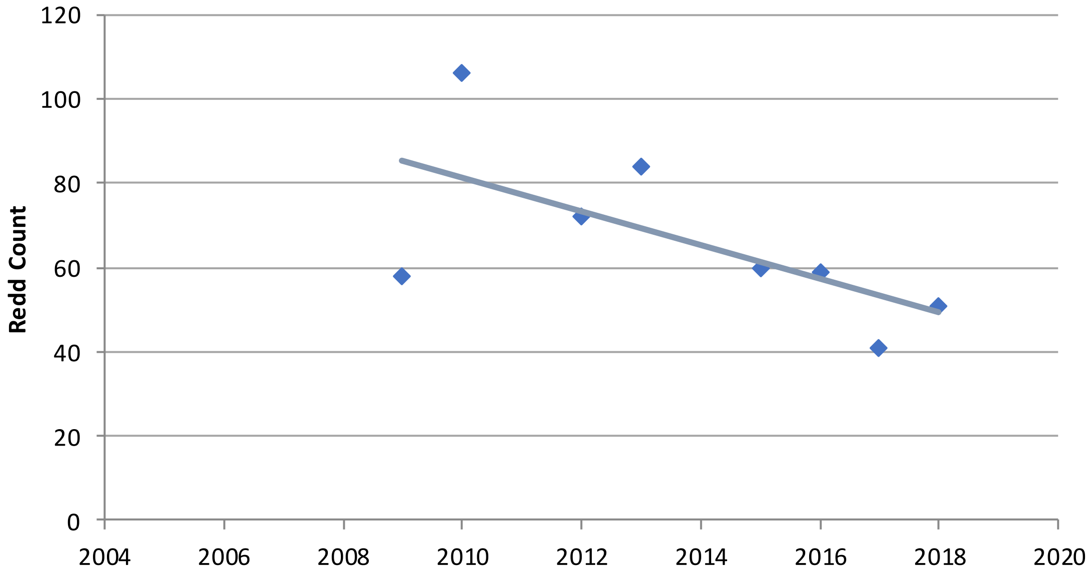

Figure 5.2c. Counts of Bull Trout redds (spawning sites) in the FWCP spawner abundance monitoring index site of Scott Creek, 2009-2018 (adapted from Hagen and Spendlow 2019).

Threats. Threats to Bull Trout from land use and human access in the Parsnip Reach core area, as indicated by road density in sub-basins of interest on the east shore of Parsnip Reach and in the Nation and Manson watersheds (Figure 5.2d), were estimated to be of low-to-moderate severity and moderate scope (hybrid category *BDEF*; Table 4.2b).

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Figure 5.2d. Road density (km/km^2) in watershed assessment units (see Section *4.2.2*) of the Parsnip Reach core area (coloured polygons) and critical habitats for Bull Trout (spawning and/or juvenile: thick black stream segments).

Conservation status and risk assessment: The categorical estimates for the four conservation status indicators, when factored together (see Table 4.2c), corresponded to a ranking of ***C2-At Risk***. According to this ranking, Bull Trout of the Parsnip Reach 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” (Table 4.2c). The most influential indicator in the scoring process was the small adult population conservatively estimated to be roughly 250 individuals. Given that this estimate is highly uncertain and based on data from a single population (see **Data gap *5.2c***; Table 5.2b), and also given that the core area boundaries for the Williston Reservoir watershed are also highly uncertain (see **Data gap *2.1***; Table 2.1), this conservation status assessment should be considered provisional only.

5.2.4 Tabulated Data gaps

Table 5.2b. Data gaps limiting understanding of critical habitats and/or conservation status for Bull Trout within the Parsnip Reach core area, and potential studies to address them.

ID	*Stream(s)*	*Data gap*	*Potential study(s)*	*Immediacy*
5.2a	East shore tributaries (e.g. Weston, Mischinsinlika)	Poor understanding of distribution of critical habitats and spawner abundance for streams on the east shore of Parsnip Reach	Calibrated aerial redd counts (first cut); foot survey-based redd counts (corroboration yielding more accurate estimates)	High
5.2b	Nation, Manson	Unknown locations of critical natal streams	Adult Bull Trout movement studies (e.g. radio or acoustic telemetry; otolith microchemistry); calibrated aerial redd counts (but see text)	High
5.2c	All	Poor understanding of total adult population size for core area.	Requires identification of spawning streams other than Scott Creek (see gaps *5.2a*, *5.2b*), followed by abundance monitoring	Moderate

5.2d	Scott	Limited extent of redd count time series for assessing trend	Annual foot surveys (redd surveys) to monitor abundance trend	High
5.2e	Nation, Manson	Scott Creek trend may not be representative of core area as a whole	New redd survey index sections in one or both watersheds surveyed a minimum of 5 years over a minimum 10-year period	Moderate

5.3 Omineca core area

5.3.1 Overview of existing information

The Omineca core area is comprised of three major stream basins draining the Omineca Mountains on the western side of the Rocky Mountain Trench: 1) Omineca River, 2) Osilinka River, which is a tributary of the lower Omineca River, and 4) Mesilinka River. The mouths of all of these streams are situated in close proximity, and the potential for demographic and genetic connections among populations is obviously high. The presence of large-bodied, migratory Bull Trout in these watersheds on spawning migrations beginning in July, and while foraging during Kokanee spawning migrations, is relatively well known anecdotally and to First Nations (Pearce et al. 2019).

The Omineca River watershed (excluding the Osilinka River watershed) has had intensive land use, in the forms of forestry and placer mining, in select tributary watersheds in the lower half of the watershed (Germansen River, Discovery Creek, Fall River, Ogden Creek), but is relatively pristine in its upper reaches upstream of Ogden Creek. The system is potentially accessible to large-bodied, migratory Bull Trout for roughly 375 km in the Omineca River mainstem and major tributaries (Hagen and Spendlow 2019). Substantial portions of the Mesilinka and Osilinka watersheds have been intensively logged. The Mesilinka River watershed is accessible to Williston Reservoir Bull Trout for roughly 250 km in the Meslinka mainstem and tributaries, while Osilinka system is accessible for roughly 170 km (Hagen and Spendlow 2018).

Over the 2017-2018 period, the Omineca core area was assessed using the calibrated aerial redd count methodology, in which the accuracy of rapid aerial redd surveys was estimated using on-the-ground calibration in sites ranging from approximately 1-5 km in length (Hagen and Spendlow 2018, 2019). Redd counts confirm spawning and juvenile rearing by large-bodied, migratory Bull Trout populations, but the most important limitation of the method is that it is not suitable for very small streams <5 m in width with high levels of overhead cover and/or steep gradients. In these streams, or in streams with very small populations (e.g. approximately 8 redds or less in total), there is a chance that spawning activity will not be detected.

Inventory studies in the Omineca core area provide important, complementary information to the aerial redd count data. For the Omineca River watershed, the most important inventory study results are provided by a comprehensive study conducted in the upper Omineca watershed (Twenty Mile Creek and upstream) in 2001 (Chris Schell Consulting 2002). This study indicated a relatively broad distribution of Bull Trout in tributaries and in the upper Omineca River mainstem upstream of the Ominicetla Creek confluence, and also included a discussion of evidence for life history specialization. Three life histories were identified for the watershed: stream resident (190 mm or less), restricted fluvial (e.g. movements restricted by a migration barrier) and large-bodied (>350mm) migratory fish. Fish sampling data incorporated within the Fish Observations layer of the BC Geographic Warehouse is relatively sparse downstream of Twenty Mile Creek, and Bull Trout records rare outside of the Omineca River mainstem (BCGW 2019).

Several key inventory studies have been conducted within the Osilinka and Mesilinka watersheds, providing important information about barriers limiting potential habitat use, the potential presence of stream resident life histories, and the dominant species present (ECL Envirowest 1997, 1998; Beak Pacific 1997; Beak International 1998; R.L.&L. 2000, 2002; Cowie and Blackman 2003). Together, inventory studies identify a broad distribution of Bull Trout in the Omineca core area (Figure 5.3a), but also that the stream resident life history may be relatively common.

In the lower Omineca River watershed, the most important spawning tributary (Big Creek, see Section *5.3.2*) was known to members of the Tse'Khene First Nation corroborating the aerial survey results and improving information adequacy with respect to conservation actions.

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susanne.weber@gov.bc.ca

Figure 5.3a. Distribution of records for past sampling of Bull Trout (red circles) and all other species (light grey circles) within sub-basins of the Omineca core area.

In most cases, information compiled in reports from the First Nations knowledge study (Pearce and Abadzadesahraei 2019; Pearce et al. 2019a, 2019b, 2019c, 2019d) does not include precise population data (distribution, abundance, trend) enabling the delineation of critical habitats or assessments of conservation status in the Parsnip Reach core area. An important exception would be the accurate identification of Big Creek by members of the Tse'Khene Nation as an important natal spawning stream for large-bodied, migratory Bull Trout in the lower Omineca River watershed (Pearce et al. 2019a).

5.3.2 Critical habitats

With respect to knowledge of critical habitats (Table 5.3b) and conservation status indicators (e.g. total abundance; Table 5.3c), data gaps for the Omineca core area are described in sections *5.3.2* and *5.3.3*, but are tabulated together in a single location (Section *5.3.4*) at the end of section *5.3* for efficiency.

Within the Omineca core area, we delineated 20 stream sections known or suspected to provide critical spawning and/or early juvenile rearing habitats for large-bodied, migratory Bull Trout potentially originating from Williston Reservoir (Table 5.3a, Figures 5.3b Omineca core area east, 5.3c Omineca core area west). Critical spawning habitats and the upstream limits of critical juvenile rearing were mostly derived from the calibrated aerial redd counts (Hagen and Spendlow 2018, 2019), with the downstream boundaries of critical juvenile habitats mostly derived from inventory study results when they were available (Beak Pacific 1997; ECL Envirowest 1997, 1998; R.L.&L. 2000, 2002; Chris Schell Consulting 2002).

Critical spawning and juvenile rearing habitats for populations of large-bodied, migratory Bull Trout cover a relatively limited proportion of the total stream length available. In each of the upper reaches of the Omineca, Osilinka, and Mesilinka basins, a substantial spawner population(s) was identified in a pristine reach with ideal characteristics for spawning and early rearing (Omineca: *S39* Carruthers Creek; Osilinka: *S44* upper Osilinka River and *S46* unnamed south fork 238-024000-74400; Mesilinka: *S52* Lay Creek; Table 5.3a; Figure 5.3b Omineca core area west). In the upper Omineca River system, minor amounts of spawning were also observed in lower Ferriston Creek, which is nearby to Carruthers Creek (*S37*, Table 5.3a, Figure 5.3b).[29] All these reaches are pristine (or nearly so, in the case of Lay Creek) with abundant juvenile rearing located downstream of spawning areas, featuring unembedded cobble substrate, clean cold water, and stable flows. These populations are located a significant distance from one another (>100 km) and from populations of large-bodied, migratory fish utilizing the lower reaches close to Williston Reservoir, suggesting they are demographically isolated to some degree. Although these critical habitats have already been identified, further corroboration with additional surveys targeting adult and juvenile life stages is necessary to refine targets for conservation actions. Because of the potential isolation (by distance) of these critical habitats, their importance within their respective watersheds, and the pristine condition these habitats are currently in, this is a high priority information gap of high immediacy (**Data gap *5.3a***, Table 5.3c).

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[29] Within the upper Omineca River watershed, spawning observations in Ominicetla Creek (3 redds), Detni Creek (1 redd), unnamed tributary 238-875000 (2 redds), and the upper Omineca mainstem were of too low density to warrant a delineation of critical habitat segments (Hagen and Spendlow 2019).

Similarly, in all three systems smaller populations of large-bodied spawners were identified in shorter, steeper tributaries located close to the reservoir. These populations include *S34* Big and *S35* Nina creeks in the Omineca River watershed, *S41* Flegel Creek and *S42* 'Dead Bear Creek' 238-024000-74400 in the Osilinka River watershed, and *S48* Prospector Creek and *S50* 'Amber Creek' 230-925900-45000 in the Mesilinka River watershed (Table 5.3a). They are generally located within or adjacent to the existing network of forestry roads, and are in relatively close proximity to one another suggesting they may be more closely linked demographically (Figures 5.3c Omineca core area east). Among these critical habitats, only the Big Creek results have been corroborated with an on-the ground redd survey. Given the limited extent of critical spawning habitat identified in the core area, and threats posed by land use, the lack of on-the-ground corroboration for these critical habitat segments is an important information gap of high immediacy (**Data gap *5.3b***, Table 5.3c). The close proximity to roads may facilitate a cost-effective study, but high physical fitness will be a must: helicopter landing sites within these small watersheds may be very hard to find, and the only access may be on foot (or potentially a drone).

The Tenakihi Creek watershed in the central Osilinka basin is situated within a high land use area near Osilinka Camp. A critical spawning/juvenile rearing habitat was identified along the Tenakihi mainstem below an impassable beaver dam (*S43*, Table 5.3a, Figure 5.3c). However, a 600 mm, likely adfluvial spawner has also been captured in Jim May Creek (R.L.&L 2000), a tributary of Tenakihi Creek that was not surveyed with the aerial method. Poor understanding of habitat use by the population of large-bodied, adfluvial Bull Trout of the Tenakihi watershed is an information gap of moderate-to-high immediacy given land use-related threats (**Data gap *5.3c***, Table 5.3c). This information gap can be addressed using on-the-ground redd surveys and electrofishing surveys targeting adult and juvenile life stages, respectively, which would be cost-effective given that road access to the watershed is relatively good.

Many other tributary reaches within these watersheds have Bull Trout populations, as indicated by sampling records (typically electrofishing) linked to the BCGW, but the redds of large-bodied, migratory fish were not observed there during the aerial redd surveys (Hagen and Spendlow 2018, 2019). Results from the 2001 fish and fish habitat inventory study from the Omineca River watershed (Chris Schell Consulting 2002) can be utilized to explain the broader distribution of Bull Trout than was observed during the aerial redd counts. In that 2001 study, selective lethal sampling combined with analysis of length frequency were utilized to identify mature individuals, age, and life history. Three life history forms were identified: 1) small-bodied stream resident Bull Trout with restricted options for movement in very small streams, which may mature at sizes as small as 104 mm, 2) a restricted fluvial life history in larger creeks (e.g. Duckling, Twenty-Mile, Silver, upper Ominicetla, Unnamed 238-878500) reaching sizes of 190-265 mm, and 3) larger fluvial Bull Trout >350mm, which were observed during snorkeling surveys (Chris Schell Consulting 2002). It is important to note that populations of restricted fluvial fish in Duckling and Silver creeks did not appear during the aerial survey to be isolated by migration barriers likely to stop large-bodied, migratory fish, implying that other factors than merely access may drive life history adaptation in Bull Trout. Redds from Bull Trout of the stream resident and restricted fluvial life history types would not be visible from the air, and indeed would be difficult to recognize on the ground.

Table 5.3a. (*Document with unredacted UTMs available from Susanne Weber*: susanne.weber@gov.bc.ca) Critical Bull Trout habitats delineated for stream reaches in the Omineca core area. Sampling methods EF, SN, VO, SW, GN, AG, and RT refer to electrofishing, seine netting, visual observation, swim counts, gillnetting, angling, and radio telemetry, respectively. ID numbers identify critical habitats in Figures 5.3b, 5.3c.

<table>
<thead>
<tr><th>ID</th><th>Watershed</th><th>Section</th><th>Critical habitat</th><th>Sampling methods</th><th>Information adequacy</th><th>UTM bottom; UTM top</th><th>Key reference(s)</th></tr>
</thead>
<tbody>
<tr><td>34</td><td>Omineca</td><td>Big Creek</td><td>Spawning, Juveniles</td><td>VO, FN</td><td>Moderate-to-high</td><td>Redacted</td><td>Hagen and Spendlow 2019; Pearce et al. 2019a</td></tr>
<tr><td></td><td colspan="7">Comments: Most important spawning tributary in lower Omineca River watershed: 26 redds over a 2.7-km redd spawning section located below an impassable waterfall; also known as a spawning stream by members of the Tse'Khene (MLIB) First Nation</td></tr>
<tr><td>35</td><td>Omineca</td><td>Nina Creek</td><td>Spawning, Juveniles</td><td>VO</td><td>Low</td><td>Redacted</td><td>Hagen and Spendlow 2019</td></tr>
<tr><td></td><td colspan="7">Comments: 2nd, minor hub of spawning in lower Omineca River watershed in addition to Big Creek; sampling limited to calibrated aerial redd survey; impassable B dam upper limit in 2018; lower limit speculative, stops upstream of Nina Lake influence</td></tr>
<tr><td>36</td><td>Omineca</td><td>Mainstem</td><td>Juveniles</td><td>EF</td><td>Moderate</td><td>10 U 384669 6193830;
9 V 656353 6230835</td><td>Chris Schell 2002</td></tr>
<tr><td></td><td colspan="7">Comments: Resident life history may dominate in upstream habitats; RB and other species dominant in downstream habitats; Pristine watershed upstream of Ogden Creek</td></tr>
<tr><td>37</td><td>Omineca</td><td>Ferriston</td><td>Spawning</td><td>VO</td><td>Low-moderate</td><td>Redacted</td><td>Hagen and Spendlow 2019</td></tr>
<tr><td></td><td colspan="7">Comments: 2nd, minor hub of spawning in upper Omineca River watershed</td></tr>
<tr><td>38</td><td>Omineca</td><td>Ferriston</td><td>Juveniles</td><td>VO, EF</td><td>Low-moderate</td><td>9 V 681203 6222730;
9 V 681628 6225752</td><td>Chris Schell 2002;
Hagen and Spendlow 2019</td></tr>
<tr><td></td><td colspan="7">Comments: From beaver dam barrier at top of spawning section to mouth</td></tr>
<tr><td>39</td><td>Omineca</td><td>Carruthers</td><td>Spawning</td><td>VO</td><td>Moderate</td><td>Redacted</td><td>Hagen and Spendlow 2019</td></tr>
<tr><td></td><td colspan="7">Comments: Most important spawning tributary of the Omineca River watershed: 38 redds over a 4.6-km redd index section</td></tr>
<tr><td>40</td><td>Omineca</td><td>Carruthers</td><td>Juveniles</td><td>VO, EF</td><td>Moderate</td><td>9 V 677122 6226903;
9 V 667083 6241929</td><td>Chris Schell 2002;
Hagen and Spendlow 2019</td></tr>
<tr><td></td><td colspan="7">Comments: From waterfall obstruction to mouth</td></tr>
<tr><td>41</td><td>Osilinka</td><td>Flegel</td><td>Spawning, Juveniles</td><td>VO</td><td>Low-moderate</td><td>Redacted</td><td>A. Langston, Pers. Comm. 2011;
Hagen and Spendlow 2018</td></tr>
<tr><td></td><td colspan="7">Comments: Poorly suited for aerial method: potentially a significant producer; One of several streams in close proximity in the lower Omineca, Osilinka, Mesilinka</td></tr>
<tr><td>42</td><td>Osilinka</td><td>238-024000-15200</td><td>Spawning, Juveniles</td><td>VO, EF</td><td>Moderate</td><td>Redacted</td><td>R.L.&L. 1995;
Hagen and Spendlow 2018</td></tr>
<tr><td></td><td colspan="7">Comments: Alias 'Dead Bear Creek'; one of several streams in close proximity in the lower Omineca, Osilinka, Mesilinka; 630 mm spawner captured at top beaver dam barrier in 1994</td></tr>
<tr><td>43</td><td>Tenakihi</td><td>Mainstem</td><td>Spawning, Juveniles</td><td>VO, EF</td><td>Low-moderate</td><td>Redacted</td><td>Beak Pacific 1997;
R.L.&L 2000;
Hagen and Spendlow 2018</td></tr>
<tr><td></td><td colspan="7">Comments: Beaver dam limiting access above top of section; BT widespread in tribs downstream that were not surveyed using the aerial method; 600 mm adfluvial fish captured in Jim May C in 1999, but stream resident-sized</td></tr>
</tbody>
</table>

	fish also present in other tributaries						
44	Osilinka	238-024000-74400	Spawning	VO	Moderate	**Redacted**	Hagen and Spendlow 2018, 2019
	Comments: Unnamed S. Fork of the upper Osilinka River above Uslika L; new 3.8-km index section incorporated into FWCP monitoring program for 2017, 2018;						
45	Osilinka	238-024000-74400	Juveniles	VO, EF	Moderate	10 V 338045 6218084; 10 V 323874 6216020	R.L.&L. 2000; Hagen and Spendlow 2018, 2019
	Comments: Juveniles present in lower ends of tributaries but no mainstem sampling						
46	Osilinka	Upper mainstem	Spawning	VO	Moderate	**Redacted**	Hagen and Spendlow 2018, 2019
	Comments: New index redd count section in 2017, 2018; shift in redd distribution between years due to impassable beaver dam, but comparable counts						
47	Osilinka	Upper mainstem	Juveniles	VO, EF	Moderate	10 V 336604 6222346; 10 V 330730 6226315	R.L.&L. 2000; Hagen and Spendlow 2018, 2019
	Comments: Juvenile distribution assumed to extend from top of spawning downstream to top of meanders; unlike S. Fork, BT infrequent in small tribturies						
48	Mesilinka	Prospector	Spawning	VO	Low-moderate	**Redacted**	Hagen and Spendlow 2018
	Comments: Redds observed from the air; one of several streams in close proximity in the lower Omineca, Osilinka, Mesilinka						
49	Mesilinka	Prospector	Juveniles	VO, EF	Low-moderate	10 V 389840 6241849; 10 V 385660 6240486	Beak Pacific 1997; Hagen and Spendlow 2018
	Comments: One of several streams in close proximity in the lower Omineca, Osilinka, Mesilinka; fry and juveniles in bottom end						
50	Mesilinka	230-925900-45000	Spawning	VO	Moderate	**Redacted**	Hagen and Spendlow 2018; R.L.&L. 2002
	Comments: Alias Amber Creek; large-bodied migratory adults observed on the ground in 2000, corroborating aerial survey results						
51	Mesilinka	230-925900-45000	Juveniles	VO, EF	Moderate	10 V 371043 6249639; 10 V 374300 6239022	Hagen and Spendlow 2018; ECL Envirowest 1997, 1998; R.L.&L. 2002
	Comments: Alias Amber Creek; watershed located within major burn affecting riparian forest						
52	Mesilinka	Lay	Spawning	VO	High	**Redacted**	Hagen and Spendlow 2018, 2019
	Comments: Most important spawning tributary of Mesilinka system; adjacent to Omineca Mine Access Road; new index section added to FWCP Bull Trout monitoring program 2017, 2018						
53	Mesilinka	Lay	Juveniles	VO	Moderate	10 V 325341 6265041; 9 V 681663 6271900	Hagen and Spendlow 2018, 2019; ECL Envirowest 1997, 1998
	Comments: Most important spawning tributary of Mesilinka system; adjacent to Omineca Mine Access Road; limited replication of juvenile sampling so lower boundary uncertain						

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Figure 5.3b. Critical spawning (narrow red segments) and juvenile rearing (thick green segments) habitats delineated for Bull Trout of the western (headwater) portion of the Omineca core area. ID numbers correspond with critical habitats described in Table 5.3a, and ‘S’ and ‘J’ prefixes for ID numbers indicate critical spawning and juvenile rearing habitats, respectively.

Document with unredacted figures available from: Susanne Weber susanne.weber@gov.bc.ca

Figure 5.3c. Critical spawning (narrow red segments) and juvenile rearing (thick green segments) habitats delineated for Bull Trout of the eastern portion of the Omineca core area close to Williston Reservoir. ID numbers correspond with critical habitats described in Table 5.3a, and ‘S’ and ‘J’ prefixes for ID numbers indicate critical spawning and juvenile rearing habitats, respectively.

5.3.3 Conservation status and risk assessment

Distribution. Large-bodied, migratory Bull Trout are widely distributed in the Omineca core area utilizing over 400 km of the Parsnip core area (category *D*: 200-1,000 km, Table 4.2a) up to headwater reaches in the Omineca, Osilinka, and Mesilinka watersheds (Hagen and Spendlow 2018, 2019). Information gaps with respect to the distribution of adfluvial Bull Trout in the Omineca core area are addressed in the preceding section (*5.3.2 Critical habitats*).

Abundance. The largest Bull Trout populations of the Omineca core area spawn in pristine headwater reaches exhibiting stable, clear flows and clean, unembedded gravel-cobble-boulder substrates. These are located in Carruthers Creek (Omineca River watershed; Hagen and Spendlow 2019), the upper Osilinka River and unnamed tributary 238-024000-74400 (Osilinka River watershed; Hagen and Spendlow 2018), and Lay Creek (Mesilinka River watershed; Hagen and Spendlow 2018) (Table 5.3b). These populations have been corroborated with on-the-ground surveys in new index sections created for FWCP (discussed in Section *6.0*).

Bull Trout spawning streams clustered in relatively close proximity in the lower portions of the Omineca, Osilinka, and Mesilinka watersheds (Big, Nina, Flegel, 'Dead Bear' 238-024000-74400, Tenakihi, 'Amber' 230-925900-45000, and Prospector creeks; Table 5.3b) are generally known only from aerial redd surveys and have not been corroborated on the ground (mostly because of a lack of helicopter landing opportunities). The exception to this is a new ground survey index section established in Big Creek in the lower Omineca watershed (discussed in Section *6.0*). Given that critical spawning habitats for large-bodied, migratory Bull Trout occur in relatively few systems in the Omineca core area relatively to the total number available, the lack of reliable population estimates for these populations is an important information gap of moderate-to-high immediacy (**Data gap *5.3d***, Table 5.3c).

Total adult population size for the Omineca core area has been estimated to be 500+ (category *C*: 250-1,000 adults, Table 5.3b), based on calibrated aerial redd surveys of the entire core area combined with ground surveys in index sections (Hagen and Spendlow 2019), and the assumption that a portion of the adult population would not spawn every year (Section *2.2 Life history*).

Table 5.3b. Minimum estimated population[1] size of large-bodied, migratory Bull Trout in the Omineca core area, 2014 (adapted from Hagen and Spendlow 2018, 2019).

Watershed	***Sub-basin***	***Minimum population estimate[1]***	***Source***	***% of core area total***	***Reference***
Omineca	Big Creek	52	2018 ground survey	10%	Hagen and Spendlow 2019
Omineca	Nina Creek	23	2018 calibrated aerial survey	4%	Hagen and Spendlow 2019

Omineca	Ominicetla Creek	11	2018 calibrated aerial survey	2%	Hagen and Spendlow 2019
Omineca	Omineca mainsterm	23	2018 calibrated aerial survey	4%	Hagen and Spendlow 2019
Omineca	Detni Creek	4	2018 calibrated aerial survey	1%	Hagen and Spendlow 2019
Omineca	Ferriston Creek	19	2018 calibrated aerial survey	4%	Hagen and Spendlow 2019
Omineca	Carruthers Creek	105	2018 calibrated aerial survey	20%	Hagen and Spendlow 2019
Omineca	Unnamed 238-875000	8	2018 calibrated aerial survey	1%	Hagen and Spendlow 2019
Osilinka	Upper mainstem	88	2018 ground survey	16%	Hagen and Spendlow 2019
Osilinka	238-024000-74400 ('S. Fork')	23	2018 ground survey	4%	Hagen and Spendlow 2019
Osilinka	Tenakihi Creek	38	2017 calibrated aerial survey	7%	Hagen and Spendlow 2018
Osilinka	Flegel Creek	23	2017 calibrated aerial survey	4%	Hagen and Spendlow 2018
Osilinka	238-024000-15200 (alias: Dead Bear Creek)	15	2017 calibrated aerial survey	3%	Hagen and Spendlow 2018
Mesilinka	Lay Creek	78	2017 calibrated aerial survey	15%	Hagen and Spendlow 2018
Mesilinka	230-925900-45000 (alias: Amber Creek)	18	2016 calibrated aerial survey	3%	Hagen and Spendlow 2018
Mesilinka	Prospector Creek	8	2016 calibrated aerial survey	1%	Hagen and Spendlow 2018
Finlay Reach core area total		***536***		***100%***	

[1] Expanded aerial redd counts based on estimates of aerial redd detection probability, and assumption of 2 spawners per redd. 'Minimum' because some small tributaries could not be surveyed using the aerial count methodology.

Population trend. Although 5 new index sections have been established in the Omineca core area, none have been monitored for longer than two years, meaning that data are insufficient for evaluating trend (category *U* 'unknown;' Table 4.2a) and the potential influence of limiting factors. This is an important information gap of high immediacy (**Data gap *5.3e***, Table 5.3c). A coordinated overall plan for abundance monitoring in the Williston Reservoir watershed, and compilation of existing index sections, is presented in Section *6.0*.

Threats. Threats from land use and human access in the Omineca core area were estimated to be only of moderate severity and low scope (category *E*; Table 4.2b). This is because many critical habitats are in pristine condition beyond or at the margins of the road network (Figure 5.3d), with the Tenakihi watershed being a notable exception. Human access to migration corridors and potential staging areas is of higher scope, which would influence the threats rating if it were not for the catch-and-release regulation limiting harvest from recreational fishing.

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susanne.weber@gov.bc.ca

Figure 5.3d. Road density (km/km^2) in watershed assessment units (see Section *4.2.2*) of the Omineca core area (coloured polygons) and critical habitats for Bull Trout (spawning and/or juvenile: thick black stream segments).

Conservation status and risk assessment: The categorical estimates for the four conservation status indicators, when factored together (see Table 4.2c), corresponded to a ranking of ***C3-Potential Risk***. According to this ranking, Bull Trout of the Omineca core area are "potentially at risk because of limited and/or declining numbers, range, and /or habitat, even though the species may be locally abundant in some areas of the core area" (Table 4.2c). The most influential indicator in the scoring process was the relatively low level of habitat threats (as indicated by road density) which was adequate to balance the small adult population size.

5.3.4 Tabulated Data gaps

Table 5.3c. Data gaps limiting understanding of critical habitats and/or conservation status for Bull Trout within the Omineca core area, and potential studies to address them.

ID	*Stream(s)*	*Data gap*	*Potential study(s)*	*Immediacy*
5.3a	Carruthers, Lay, upper Osilinka watershed	Corroboration of critical spawning, juvenile rearing habitats in western (upper) reaches with additional studies targeting adult and juvenile life stages	Foot survey-based redd counts; electrofishing surveys	High
5.3b	Big, Nina, Flegel, 'Dead Bear,' 'Amber,' Prospector	Corroboration of critical spawning, juvenile rearing habitats in eastern (lower) reaches with additional studies targeting adult and juvenile life stages	Foot survey-based redd counts; electrofishing surveys	High

5.3c	Tenakihi	Poor understanding of habitat use by large-bodied, migratory Bull Trout	On-the-ground redd surveys to delineate critical spawning zones for adfluvial Bull Trout in Tenakihi and important tributaries (e.g. Jim May Creek); electrofishing surveys to estimate juvenile rearing habitats	Moderate-to-high
5.3d	Carruthers, Lay Osilinka, Big, Flegel, Dead Bear, Amber, Prospector	Lack of reliable estimates of total population size	On-the-ground redd surveys to estimate total abundance (i.e. concurrently while addressing data gaps *5.3a*-*5.3c*)	Moderate-to-high
5.3e	Carruthers, Big, Upper Osilinka (2 sections), Lay	Maximum of 2 years' redd count data to evaluate trend in 5 new index sections	Ground surveys to monitor redd abundance in 5 new index reaches established in the Omineca core area during the 2017-2018 field seasons	High

5.4 Peace Reach/Dinosaur core areas

5.4.1 Overview of existing information

The Peace River, which cuts through the Rocky Mountains in an easterly direction, had its origin prior to impoundment in the joining of the Parsnip and Finlay Rivers. The construction of W.A.C. Bennett Dam flooded approximately 120 km of the Peace River, which is now known as the Peace Reach of Williston Reservoir.

Biophysical descriptions of tributaries to Peace Reach are provided in Euchner (2017a), and are summarized below. Tributaries originate in the Rocky Mountains, and are generally oriented in a north-south direction. The most westerly tributaries originate in more rugged, mountainous terrain than those tributaries lying to the east. Major tributaries are Clearwater Creek and Carbon Creek on the south shore of Peace Reach, which have accessible lengths of 47 km and 32 km, respectively, and West Nabesche River and Nabesche River on the north shore, which have shorter accessible lengths of 20 km and 9.4 km, respectively. Past sampling efforts indicate that Bull Trout have a relatively wide distribution within the core area in these streams and also smaller, direct tributaries to Peace Reach (Figure 5.4a).

Point Creek is a relatively small, direct tributary to Peace Reach. An index section in Point Creek has been included in FWCP’s annual Bull Trout abundance monitoring program since 2006 (Hagen and Spendlow 2019). The distribution of critical habitats in this stream is well understood (Hagen and Pillipow 2013).

Critical Bull Trout spawning and juvenile rearing habitats in other streams of the Peace Reach core area have been the focus of a recent 2-year FWCP study (FWCP projects PEA-F17-F-1449, PEA-F18-F-2311) (Euchner 2017a, 2018). This study utilized aerial and on-the-ground redd survey methodologies similar to those employed in the Parsnip and Omineca core areas (reviewed in preceding sections) enabling the delineation of critical spawning habitats for large-bodied, adfluvial Bull Trout. A major benefit of the study design was the incorporation of a second year's sampling in the same reaches, to learn about inter-annual variability in habitat use which was found to be remarkably high relative to time series data collected elsewhere in British Columbia (e.g. Baxter et al. 2000 re. the Wigwam River watershed; Bustard 2017 re. the Thutade Lake watershed; Nellestijn 2014 re. the Salmo River watershed; Hagen and Spendlow 2016 re. the Davis River watershed).

The review of past inventory study results (Langston and Blackman 1993; Slocan 1996, 1998; Hatfield 2000) was also an important component of FWCP projects PEA-F17-F-1449 and PEA-F18-F-2311. The addition of new electrofishing data from the 2016 (Euchner 2017a) and 2017 (Euchner 2018) field seasons to the existing knowledge base means that critical juvenile rearing habitats can also be estimated independently for the core area, rather than just assuming they are the same as the critical spawning zones.

Although the study design was sound and the study results were of high value, the high variability in habitat use among study years suggests that the existing knowledge base needs improvement before critical habitats can be delineated with confidence, as described in Section *5.4.2*.

Document with unredacted figures available from: Susanne Weber
susanne.weber@gov.bc.ca

Figure 5.4a. Distribution of records for past sampling of Bull Trout (red circles) and all other species (light grey circles) within sub-basins of the Peace Reach and Dinosaur core areas.

Dinosaur Reservoir, which is 22 km long and occupies the former Peace River Canyon, was created following the construction of Peace Canyon Dam in 1979. Tributary stream habitat in the Dinosaur Reservoir watershed is extremely limited, with impassable waterfall barriers present in the lower reaches of all 5 of the known, fish-bearing tributaries (Gething, Johnson, Mogul, Moosebar, and Starfish creeks; Euchner 2011).

A prior information synthesis by Euchner (2011) exists of the fish and fish habitat resources of the Dinosaur Reservoir watershed. Bull Trout are present only in very low densities in Dinosaur Reservoir and in the lower 950 m of Gething Creek, the only critical reproductive habitat available to the population. Gething Creek spawners have been subject to sporadic monitoring activities (Langston 2008; Euchner 2011; Euchner 2016), but these are enough to raise serious concerns about whether the population is viable (see Section *5.4.3*). Some of this monitoring activity was linked to an enhancement experiment conducted on the population over the 1993-1999 period. In an attempt to increase the productivity of juvenile rearing habitat, a total of 63 Bull Trout over this period were translocated by helicopter above impassable waterfalls in Gething Creek (Langston 2008). This experiment will be discussed further in the context of conservation status (Section *5.4.3*).

Information compiled in reports from the First Nations knowledge study (Pearce and Abadzadesahraei 2019; Pearce et al. 2019a, 2019b, 2019c, 2019d) does not include precise population data (distribution, abundance, trend) that would enable the delineation of critical habitats or assessments of conservation status in the Peace Reach or Dinosaur core areas, although members of the Saulteau Nation do have knowledge of streams utilized by large-bodied, adfluvial Bull Trout for spawning (Pearce et al. 2019b). An important component of the First Nations knowledge study, however, was the documentation of concerns expressed by individuals and communities. With respect to Bull Trout populations and their habitats, Saulteau Nation members are concerned about: 1) degraded water quality and quantity related to land use activities particularly forestry and oil and gas, 2) levels of mercury in the tissue of subsistence fish, and 4) the effects of overfishing. Saulteau members recommend: 1) monitoring of fish population and waterway 'health' by First Nation members and western science both, and 2) changes to land use practices and habitat restoration to reduce threats to fish habitat (Pearce et al. 2019b).

5.4.2 Critical habitats

Within the Peace Reach and Dinosaur core areas, we delineated 12 stream sections known or suspected to provide critical spawning and/or early juvenile rearing habitats for large-bodied, adfluvial Bull Trout (Table 5.4a; Figures 5.4b, 5.4c). Recent studies by FWCP (Hagen and Pillipow 2013; Euchner 2016, 2017a, 2018) provide a relatively good picture of habitat use in the recent period. However, high spatial variability in spawning observations between the 2016 and 2017 observations (Euchner 2017a, 2018) is an important factor affecting the ‘information adequacy’ rankings in critical habitats other than Point and Gething creeks (Table 5.4a).

The Point Creek population in one of 4 index sites utilized by FWCP to assess population trend for Williston Reservoir Bull Trout, and is the only population in the Peace Reach core area for which time series data >2 years exists. The critical habitat segment *S54* identified in Table 5.4a is a prime candidate for conservation actions given: 1) a good understanding of the extent of habitat use, 2) the population may be one of the largest in the core area (Section *5.4.3*), and 3) a consistent pattern of habitat use among years (Hagen and Spendlow 2019).

Several other stream segments in the core area appear to be important to adfluvial Bull Trout spawners, including *S55* West Nabesche River, *S58* Clearwater Creek (including tributaries *S56*

Macoun Creek and *S60* unnamed 230-870800-92400), and *S62* Carbon Creek (Table 5.4a; Figures 5.4b, 5.4c) (Euchner 2017a, 2018). However, the variability in habitat use between the 2016 and 2017 field season borders on extreme, as described in Euchner (2018):

"A total of 13 redds were documented in Carbon Creek where none were found in 2016. The number of redds documented in Clearwater Creek in 2017 (n=23) was more than double that observed in 2016 (n=10). A handful of redds (n=4) were documented in an unnamed tributary to Clearwater Creek (230-870800-92400) where none were found in 2016. Conversely fewer redds were documented in Macoun Creek in 2017 (n=2) compared to 9 in 2016)."

Overall, redd counts in the Peace Reach core area (including Point Creek) suggest small population sizes and a potentially alarming demographic stochasticity (variability from one year to the next). The best estimates of critical habitats are therefore uncertain, and it appears that additional replication of the Euchner (2017a, 2018) study methodology is necessary before conservation actions can be planned with confidence. The conservation status implications are serious as discussed in Section *5.4.3*, suggesting that this is an important information gap of high immediacy (**Data gap *5.4a***, Table 5.4b). Given the potential low abundance and the risk that very small populations may not be detected from the air, on-the-ground redd surveys (which are more time-consuming) are warranted.

Table 5.4a. (*Document with unredacted UTMs available from Susanne Weber*: susanne.weber@gov.bc.ca) Critical Bull Trout habitats delineated for stream reaches in the Peace Reach and Dinosaur core areas. Sampling methods EF, SN, VO, SW, GN, AG, and RT refer to electrofishing, seine netting, visual observation, swim counts, gillnetting, angling, and radio telemetry, respectively. ID numbers identify critical habitats in Figures 5.4b, 5.4c.

ID	*Watershed*	*Section*	*Critical habitat*	*Sampling methods*	*Information adequacy*	*UTM bottom; UTM top*	*Key reference(s)*
54	Point	mainstem	Spawning, Juveniles	VO	High	**Redacted**	Hagen and Pillipow 2013, Hagen and Spendlow 2019
	Comments: FWCP redd count index section since 2006; contained 100% of Point C spawning activity during 2012 aerial survey (Hagen and Pillipow 2013); top boundary is at waterfall barrier, which may be used as a pre-spawning staging area						
55	West Nabesche	Mainstem	Spawning, Juveniles	VO, EF	Low-moderate	**Redacted**	Euchner 2017a, 2018
	Comments: Highly uncertain boundaries based on 2016 counts +500m buffer; no redds observed in the same section in 2017 - follow-up studies necessary						
56	Clearwater	Macoun	Spawning	VO	Low-moderate	**Redacted**	Euchner 2017a, 2018
	Comments: Highly uncertain boundaries based on 2016 counts +500m buffer; greatly reduced redd count in the same section in 2017 - follow-up studies necessary						
57	Clearwater	Macoun	Juveniles	VO, EF	Moderate	10 U 492247 6185870; 10 U 490684 6181636	Euchner 2017a, 2018
	Comments: Relative importance of critical habitats may vary among years - follow-up studies recommended						
58	Clearwater	Mainstem	Spawning	VO, EF	Low-moderate	**Redacted**	Euchner 2017a, 2018
	Comments: Highly uncertain boundaries based on 2016 counts +500m buffer; big change in count across two years						
59	Clearwater	Mainstem	Juveniles	VO, EF	Moderate	10 U 491288 6188332; 10 U 505199 6164646	Euchner 2017a, 2018
	Comments: Extends downstream from confluence with 230-870800-92400, where redds were observed in 2017						
60	Clearwater	230-870800-92400	Spawning	VO, EF	Low-moderate	**Redacted**	Euchner 2017a, 2018
	Comments: Buffers of 500m applied; no redds in 2016: follow-up required						
61	Clearwater	230-870800-92400	Juveniles	VO, EF	Moderate	10 U 505199 6164646; 10 U 503892 6162184	Euchner 2017a, 2018
	Comments: extends down to confluence with Clearwater Creek						
62	Carbon	Upper mainstem	Spawning, Juveniles	VO, EF	Moderate	**Redacted**	Euchner 2017a, 2018; Pearce et al. 2019b
	Comments: Just two redds in upper section of critical habitat; top of concentrated redd distribution is 10 U 520252 6184039; follow-up recommended						
63	Doucette	Mainstem	Juveniles	VO, EF	Low-moderate	10 U 492839 6199149; 10 U 494152 6197607	Euchner 2017a
	Comments: Good juvenile densities but no redds detected; Life history?						
64	Schooler	Upper mainstem	Spawning, Juveniles	VO, EF	Low-moderate	**Redacted**	Euchner 2018
	Comments: Waypoints are for juvenile data, redds are from just one location; follow-up required to delineate spawning distribution.						
65	Gething	Mainstem	Spawning, Juveniles	VO, EF, SN, AN	High	**Redacted**	Langston 2008; Euchner 2011; Euchner 2016
	Comments: Only reproductive habitat available to Dinosaur population; 950 m of stream downstream of a 6-m waterfall						

Figure 5.4b. Critical spawning (narrow red segments) and juvenile rearing (thick green segments) habitats delineated for Bull Trout of the western portion of the Peace Reach core area. ID numbers correspond with critical habitats described in Table 5.3a, and ‘S’ and ‘J’ prefixes for ID numbers indicate critical spawning and juvenile rearing habitats, respectively.

Figure 5.4c. Critical spawning (narrow red segments) and juvenile rearing (thick green segments) habitats delineated for Bull Trout of the eastern portion of the Peace Reach core area and for the Dinosaur core area. ID numbers correspond with critical habitats described in Table 5.4a, and ‘S’ and ‘J’ prefixes for ID numbers indicate critical spawning and juvenile rearing habitats, respectively.

Doucette and Schooler creeks are smaller systems that also appear to provide high quality juvenile Bull Trout rearing habitat (Table 5.4a; Figures 5.4c) (Euchner 2018). Delineation of critical spawning habitats in these two streams requires additional effort, and on-the-ground redd surveys are warranted (**Data gap *5.4b***, Table 5.4b). This is because aerial redd detection probability may be compromised in smaller streams especially for: 1) wetted widths <5m, 2) high overhead vegetation cover, and 3) increased gradient/higher turbulence cover (J. Hagen unpublished data).

Adfluvial Bull Trout redds have not been identified in the Nabesche River in the recent period (Euchner 2017a, 2018), despite the fact that large-bodied adults have previously been observed in the plunge pool below the waterfall barrier at 9.5 km (Langston and Blackman 1993). Further study of this system appears warranted to investigate the possibility of either 1) extirpation of the migratory life history form, or 2) large-bodied adfluvial Bull Trout ascending the falls and utilizing the upper Nabesche River (**Data gap *5.4c***, Table 5.4b).

Bull Trout critical spawning and juvenile rearing habitats within the Dinosaur Reservoir watershed appear to be limited to just 950 m of lower Gething Creek below an impassable 6-m waterfall (*S65*, Table 5.4a). This is known with relatively high confidence (Langston 2008; Euchner 2011; Euchner 2016). Until the determination is made that this extreme situation is not viable over the longer term, this stream segment should be considered a high priority for conservation actions.

5.4.3 Conservation status

Distribution. Known populations of large-bodied, migratory Bull Trout in the Peace Reach core area (Euchner 2017a, 2018) are distributed over approximately 200 km of the Parsnip core area (hybrid category *CD:* approximately 200 km, Table 4.2a).

In contrast, adfluvial Bull Trout of the Dinosaur core area have an extremely limited distribution and are restricted to the 20 km of Dinosaur Reservoir and <1 km of Gething Creek (Category *B* 4-40 km, Table 4.2a), which is the only known natal stream (Langston 2008; Euchner 2011, 2016).

Abundance. Point Creek is one of FWCP's four annually-surveyed Bull Trout spawner abundance index streams (Andrusak et al. 2011 and references therein; Hagen and Spendlow 2019). Redd counts from two index sections on this stream, along with expanded aerial counts and ground survey results in other reaches over the 2016-2017 period (Euchner 2017a, 2018), indicate that adfluvial Bull Trout populations of the Peace Reach core area are not large and may be marginal between categories *B* (50-250 adults; Table 4.2a) and *C* (250-1,000 adults) (Hybrid category *BC*; Table 4.2a). High variability in spawner counts among years for all reaches of this core area (including Point Creek; Hagen and Spendlow 2019; Euchner 2017a, 2018) suggests that additional replication of redd surveys is necessary before a reliable estimate of total adult population size is possible. This information shortfall is an important information gap of high immediacy, which should be addressed at the same time as surveys to improve the knowledge of critical habitats (**Data gap *5.4a***, Table 5.4b), using the method of redd surveys on foot to improve accuracy and precision relative to the 'first-cut' aerial survey results.

Bull Trout are relatively rare in Dinosaur Reservoir, and contribute minimally to the sport fishery (Euchner 2011 and references therein). The best indication of total adult population size comes from mixed survey data for lower Gething Creek (Langston 2008; Euchner 2011, 2016), the only known Bull Trout natal stream in the Dinosaur Reservoir watershed. The most systematic approach to population monitoring has involved two seining events in the Gething Creek falls pool spaced roughly 1 week apart in late August and early September (Euchner 2016). We assume that seine catches will be lower than the total adult population size present, but these data nonetheless indicate a very small population given that adult Bull Trout do not appear to use other areas. For the time series as a whole, a hybrid population size estimate of *AB*, which is marginal between adult population size categories 0-50 (category A; Table 4.2a) and 50-250 (category B) was applied in our status assessment. This indicates a situation of serious conservation concern and a population potentially vulnerable to elevated extirpation risk due to genetic and demographic factors (Section *4.2.2*). Given this situation, the lack of monitoring data from the recent period constitutes and important data gap of high immediacy (**Data gap *5.4d***, Table 5.4b).

Population trend. For the Peace Reach core area, the time series of redd count data for FWCP's Point Creek index section now extends to 10 year's data over a 13-year period (Figure 5.4d). The Point Creek time series is characterized by extreme variability obscuring any potential trend (t = -0.207, P = 0.84), with redd counts ranging eight-fold over just 10 years' redd count data. The 2018 count of 29 redds was a substantial rebound from the count of 7 redds in 2017, which was the second lowest on record (Hagen and Spendlow 2018). At this point in time, a trend is not evident, consistent with a ranking of 'stable' (category *E*; Table 4.2a).

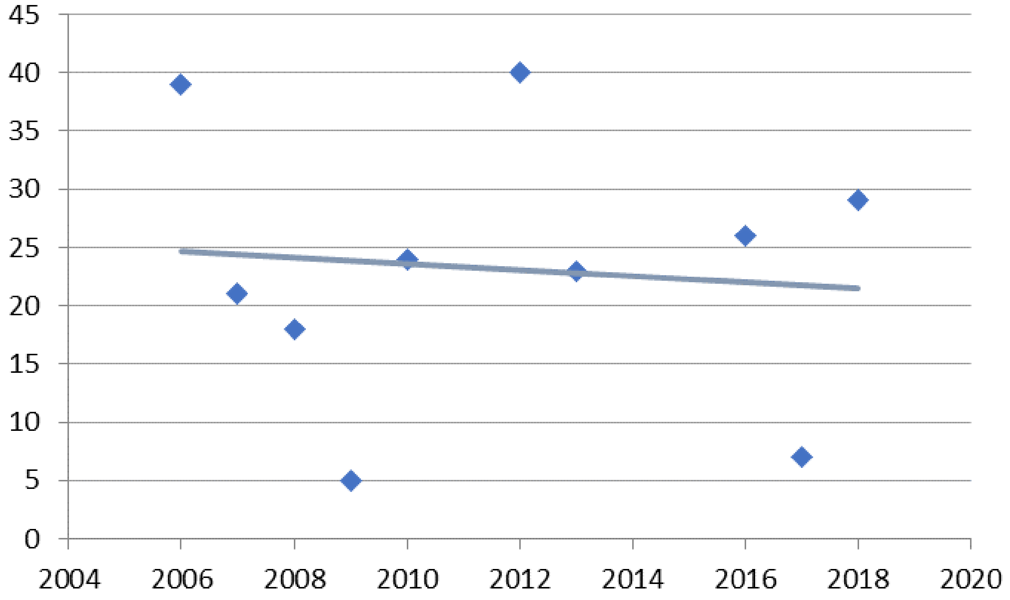

Figure 5.4d. Counts of Bull Trout redds (spawning sites) in the FWCP spawner abundance monitoring index site of Point Creek, 2006-2018 (adapted from Hagen and Spendlow 2019).

The high variability among years for the Point Creek time series is of interest in itself, and appears to be reflected by high interannual variability in the distribution and abundance of redds elsewhere in the core area (Euchner 2017a; Euchner 2018). The underlying causes of this demographic stochasticity may have conservation implications especially at small population sizes (Section *4.2.2*), and continued monitoring of this time series should be a high priority (**Data gap *5.4e***, Table 5.4b).

With respect to the time series of seine catches in lower Gething Creek in the Dinosaur core area (Figure 5.4e), a negative trend is evident. However, it should be noted that the high-leverage sampling data point for 2015 occurred under conditions of high, turbid water, so it may not be reliable. Although we assigned a ranking of ‘declining’ (category *D*, Table 4.2a) to the core area, the declining trend (t = -2.72, P = 0.026, n = 10; Figure 5.4d) and low abundance need to be assessed by more replication in the recent period, as discussed above for *abundance* (**Data gap *5.4d***, Table 5.4b).

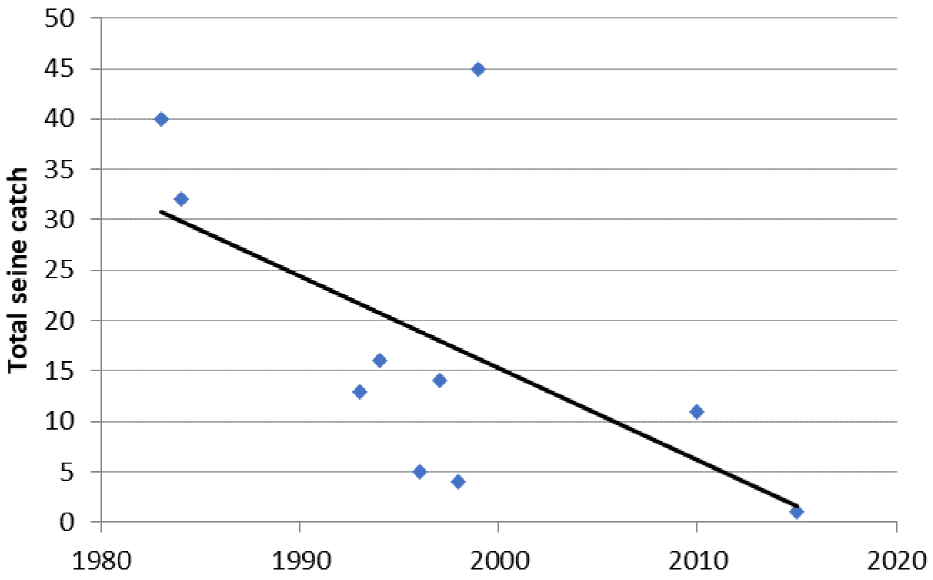

Figure 5.4e. Total annual seine catch of adult Bull Trout (recaptures excluded) in the falls pool of lower Gething Creek (adapted from Euchner 2016).

Threats. Threats from land use and human access in the Peace Reach core area, as indicated by road density adjacent to critical habitats, were estimated to be of moderate severity and low scope (category *E*; Table 4.2b) given that road density is generally low (occasionally low-to-moderate) for natal watersheds Point Creek, Clearwater Creek, West Nabesche River, and Schooler Creek. Much of Carbon Creek is heavily roaded, however (Figure 5.4f).

Threats in Dinosaur Reservoir were estimated to be of moderate severity and high scope (hybrid category *AC*; Table 4.2b).

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Figure 5.4f. Road density (km/km^2) in watershed assessment units (see Section *4.2.2*) of the Peace Reach and Dinosaur core areas (coloured polygons) and critical habitats for Bull Trout (spawning and/or juvenile: thick black stream segments).

Conservation status and risk assessment: The categorical estimates for the four conservation status indicators, when factored together (see Table 4.2c), corresponded to a ranking of ***C2-At Risk*** for the Peace Reach core area and ***C1-High Risk*** for the Dinosaur core area. According to this ranking, Bull Trout of the Peace Reach 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" (Table 4.2c). The most influential indicator in the scoring process was the small adult population size.

For the Dinosaur core area, Bull Trout are "at high risk because of extremely limited and/or rapidly declining numbers, range, and /or habitat, making the population in this core area highly vulnerable to extirpation" (Table 4.2c). This description seems appropriate. It is not clear whether the Bull Trout population of Dinosaur Reservoir is self-sustaining, given the limited availability of critical juvenile rearing habitat, or whether it is maintained mostly from entrainment through the W.A.C Bennett Dam (Euchner 2016). BC Hydro has initiated a research program on Williston Reservoir to assess BT entrainment at WAC Bennett Dam and in the Dinosaur Reservoir for entrainment at Peace Canyon Dam (M. Casselman, BC Hydro, pers. comm. 2019). Although results from this study are not available at the time of writing, they should help to address this uncertainty.

5.4.4 Tabulated Data gaps

Table 5.4b. Data gaps limiting understanding of critical habitats and/or conservation status for Bull Trout within the Peace Reach and Dinosaur core areas, and potential studies to address them.

ID	*Stream(s)*	*Data gap*	*Potential study(s)*	*Immediacy*
5.4a	West Nabesche, Clearwater, Carbon	Inadequate replication of spawner surveys (just 2 years) to identify critical habitats and total abundance given high observed variability	Foot survey-based redd counts to reliably identify critical habitats and total abundance	High
5.4b	Doucette, Schooler	Unknown critical spawning zones for large-bodied, adfluvial Bull Trout	Foot survey-based redd counts	High
5.4c	Nabesche	Unknown present-day habitat use by large-bodied, adfluvial Bull Trout (spawners observed at falls by Langston and Blackman 1993)	On-the-ground and/or aerial redd surveys to delineate critical spawning zones for adfluvial Bull Trout below waterfall at 9.5 km	Moderate-to-high
5.4d	Gething	Inadequate spawner surveys in the recent period to assess adult abundance and trend.	Seine netting methodology, ideally combined with redd surveys and juvenile-oriented surveys (e.g. electrofishing, night snorkeling) to assess productivity of lower Gething Creek	High

5.4e	Point	Continued monitoring a priority given high interannual variability in time series	Ground surveys to monitor redd abundance in FWCP index sections monitored since 2006	High

5.5 Finlay Reach core area

5.5.1 Overview of existing information

The Finlay Reach core area encompasses the roughly 110 km of the former Finlay River which was flooded following construction of the W.A.C. Bennett Dam, and which is now known as Finlay Reach of Williston Reservoir (Figure 1). Tributaries to the east shore of Finlay Reach core area lie between the head of the reservoir at Tsay Keh Dene and Peace Reach, and drain rugged terrain in the Rocky Mountains. The Ospika River at the head of Ospika Arm is a large drainage with substantial glacial inputs affecting water flow and clarity, while other, shorter streams draining directly into Finlay Reach (Lafferty, Collins, Bruin, Davis, Chowika) north of Ospika Arm have minor or no glacial influence. The major tributaries of interest on the western shore of Finlay Reach are the Ingenika River watershed, a large, non-glacial watershed draining the Omineca Mountains, and the shorter Factor Ross Creek which lies to the south of Ingenika Arm.

Bull Trout sampling records are widespread within the Finlay Arm core area (Figure 5.5a). However, for most stream reaches outside the Davis and Ingenika watersheds, fish sampling data are sparsely distributed (often close to the stream mouth) and for the most part do not permit reliable delineation of critical habitats. In these streams (e.g. Lafferty, Collins, Bruin, Chowika), the most valuable data indicating the presence of adfluvial Bull Trout are: 1) Tsay Keh Dene knowledge identifying Lafferty, Collins, and Chowika creeks as adfluvial Bull Trout spawning streams (Pearce and Abadzadesahraei 2019), 2) electrofishing and snorkeling data presented in Langston and Blackman (1993), and/or 3) snorkeling and redd count data collected over the 1998-2002 period by the BC Ministry of Water, Land, and Air Protection (MWLAP, now FLNRORD) and warehoused in the Region 7 Fisheries database (c/o co-author Weber). Inventory sampling in Factor Ross Creek (Golder Associates 2013) also indicates a watershed of interest.

Fish sampling data for Ospika River watershed is sparsely distributed, and many tributaries have had no sampling at all. Tsay Keh Dene knowledge identifies that large-bodied Bull Trout utilize the Ospika watershed (Pearce and Abadzadesahraei 2019). However, outside of a single reach where sufficient replication exists combined with confirmation of large-bodied spawners (Steve Creek; Aecom 2011), data are insufficient to delineate critical habitats. The most valuable information for this synthesis was in the form of aerial observations of fish migration obstacles in two classes: 1) probable or 2) certain barriers, made as part of the extensive Region 7 aerial videography project over the 1997-1999 period (e.g. Wabersky-Darrow 1998; TerraPro and White Pine 1998, 1999; MOE 1999). Migration barriers limit access to many tributaries in the

Ospika River watershed, and the barrier assessments identify accessible watersheds of interest. Barrier assessments have been compiled from these project reports (where possible) and will be uploaded to the Fish Obstacles layer of the BC Geographic warehouse at the completion of this information synthesis, where they can be more conveniently accessed.

In contrast, comprehensive studies focused on adfluvial Bull Trout have been conducted in the Davis and Ingenika watersheds by FWCP and FLNRORD. Critical habitats in the Davis River watershed are known from multiple years' data, including a radio telemetry study (O'Brien and Zimmerman 2001) and redd count surveys since 2001 (Andrusak et al. 2011; Hagen and Spendlow 2016; FLNRORD Region 7 Fisheries database on file). Similar to other systems on the east shore of Finlay Arm (Lafferty, Collins, Bruin, Chowika), fish sampling data presented in Langston and Blackman (1993), which identifies that juvenile rearing of Bull Trout occurs all the way to near the mouth of the Davis River, is also key. In the Ingenika River watershed, critical spawning habitat for large-bodied, migratory Bull Trout in the Ingenika River watershed was assessed using the calibrated aerial redd count methodology in 2016 (Hagen and Spendlow 2017). The distribution and abundance of juvenile Bull Trout in the Ingenika watershed has been characterized mostly by widespread sampling by Cowie and Blackman (2004).

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Figure 5.5a. Distribution of records for past sampling of Bull Trout (red circles) and all other species (light grey circles) within sub-basins of the Finlay Reach core area.

Information compiled in reports from the First Nations knowledge study (Pearce and Abadzadesahraei 2019; Pearce et al. 2019a, 2019b, 2019c, 2019d) does not include precise population data (distribution, abundance, trend) that would enable the delineation of critical habitats or assessments of conservation status in the Finlay Reach core area. However, members of the Tsay Keh Dene Nation do have valuable knowledge of streams utilized by large-bodied, adfluvial Bull Trout for spawning (Pearce and Abadzadesahraei 2019), which have yet to receive Bull Trout-focused inventory studies (e.g. Chowika Creek, Collins Creek, Lafferty Creek; Pearce and Abadzadesahraei 2019). An important component of the First Nations knowledge study was the documentation of concerns expressed by individuals and communities. With respect to Bull Trout populations and their habitats, Tsay Keh Dene Nation members are most concerned about land use-related habitat degradation affecting flows, sediment, water temperature, and human access in watersheds. Tsay Keh Dene members recommend: 1) regular monitoring of levels of mercury in fish tissue and outreach to communities, 2) increased involvement of Tsay Keh Dene members in fish monitoring, and 3) increased protection of fish habitat (timing windows, machine-free zones, etc.) (Pearce and Abadzadesahraei 2019).

5.5.2 Critical habitats

With respect to knowledge of critical habitats (Table 5.5a) and conservation status indicators (e.g. adult abundance Table 5.5b), data gaps are described in sections *5.5.2* and *5.5.3*, but are tabulated together in a single location (Table 5.5c, Section *5.5.4*) at the end of section *5.5* for efficiency.

Within the Finlay Reach core area, we delineated 26 stream sections known or suspected to provide critical spawning and/or early juvenile rearing habitats for large-bodied, migratory Bull Trout (Table 5.5a; Figures 5.5b, 5.5c). These critical habitats were distributed mostly within the Davis and Ingenika watersheds, where the majority of Bull Trout-oriented study has occurred (O’Brien and Zimmerman 2001; Hagen and Spendlow 2016; Hagen and Spendlow 2017).

Table 5.5a. (*Document with unredacted UTMs available from Susanne Weber*: susanne.weber@gov.bc.ca) Critical Bull Trout habitats delineated for stream reaches in the Finlay Reach core area. Sampling methods EF, SN, VO, SW, GN, AG, and RT refer to electrofishing, seine netting, visual observation, swim counts, gillnetting, angling, and radio telemetry, respectively. ID numbers identify critical habitats in Figures 5.5b, 5.5c.

ID	*Watershed*	*Section*	*Critical habitat*	*Sampling methods*	*Information adequacy*	*UTM bottom; UTM top*	*Key reference(s)*
66	Ospika	Steve (230-935100-05700)	Spawning	VO	Moderate	**Redacted**	Aecom 2011
	Comments: Large-bodied BT to 67 cm observed spawning in Steve Creek sites 6, 7 (Aecom 2011)						
67	Ospika	Steve (230-935100-05700)	Juveniles	VO, EF	Moderate	10 V 440497 6250689; 10 V 445159 6251825	Aecom 2011;
	Comments: Confirmed use by large-bodied, migratory fish						
68	Lafferty	Mainstem	Juveniles	VO	Low-moderate	10 V 423724 6246901; 10 V 423762 6258387	Langston and Blackman 1993; Cubberley 2003
	Comments: 50+ cm BT observed in lower Lafferty in July (snorkeling); spawning pair observed at 423825 6258232 but insufficient data to delineate critical habitat						
69	Davis	Mainstem	Spawning	VO	High	**Redacted**	O'Brien and Zimmerman 2001; Hagen and Pillipow 2013; Hagen and Spendlow 2016;
	Comments: Basin-wide redd locations from 1998-2002 period available in FLNRORD Region 7 Fisheries database (c/o S. Weber); major spawning population with relatively consistent habitat use over time.						
70	Davis	Mainstem	Juveniles	VO, EF	Moderate	10 V 409438 6268120; 10 V 425219 6292707	Langston and Blackman 1993; Hagen and Spendlow 2016
	Comments: Juveniles distributed all the way to mouth - requires follow-up sampling in modern period						
71	Davis	230-966200-75600	Spawning, Juveniles	VO	Moderate-high	**Redacted**	Hagen and Spendlow 2016, 2019
	Comments: Key spawning tributary for upper Davis River; up to 70 redds observed but distribution and abundance variable among years depending on beaver activity						
72	Davis	230-966200-75300	Spawning, Juveniles	VO	High	**Redacted**	Hagen and Spendlow 2016, 2019; FLNRORD Region 7 Fisheries database
	Comments: Key spawning tributary for upper Davis River; redd locations from 1998-2002 period available in FLNRORD Region 7 Fisheries database (c/o S. Weber)						
73	Davis	230-966200-23300	Spawning, Juveniles	VO	Low-moderate	**Redacted**	Hagen and Spendlow 2016
	Comments: Previously unknown spawning tributary to lower Davis system, identified during the basin-wide aerial survey of 2015; additional fieldwork (on-the-ground redd surveys) required to corroborate 2015 survey						
74	Davis	Graham	Spawning	VO	Moderate-high	**Redacted**	O'Brien and Zimmerman 2001; Hagen and Spendlow 2016
	Comments: Just two redds in upper section of critical habitat; top of concentrated redd distribution is 10 U 520252 6184039; follow-up recommended						

75	Davis	Graham	Juveniles	VO	Moderate	10 V 411642 6283529; 10 V 407252 6291284	O'Brien and Zimmerman 2001; Hagen and Spendlow 2016
	Comments: Extends from mouth of key Graham tributary 230-966200-41000-65700 to Davis confluence						
76	Davis	230-966200-41000-65700	Spawning	VO	Moderate	**Redacted**	O'Brien and Zimmerman 2001; Hagen and Spendlow 2016
	Comments: Graham River tributary; habitat use corroborated by radio telemetry observations and earlier redd counts from 1998-2002 period available in FLNRORD Region 7 Fisheries database (c/o S. Weber)						
77	Davis	230-966200-41000-65700	Juveniles	VO	Low-moderate	10 V 407252 6291284; 10 V 408690 6293158	O'Brien and Zimmerman 2001; Hagen and Spendlow 2016
	Comments: Juveniles assumed to be distributed to Graham confluence and beyond						
78	Chowika	Mainstem	Spawning	VO	Low-moderate	**Redacted**	MWLAP 2002 unpublished
	Comments: Only spawning section identified so far within Chowika system - follow-up across whole watershed required; potentially significant population; redd counts from 1998-2002 period available in FLNRORD Region 7 Fisheries database (c/o S. Weber)						
79	Chowika	Mainstem	Juveniles	VO, EF	Low-moderate	10 V 394016 6290019; 10 V 411121 6310467	MWLAP 2002 unpublished; Langston and Blackman 1993
	Comments: Fry rearing right to mouth; obstructions between 4-5 km from mouth potentially restrict access but redds above						
80	Swannell	Upper mainstem	Spawning	VO	Moderate	**Redacted**	MWLAP 2002 unpublished; Hagen and Spendlow 2017
	Comments: Important spawning system within the Ingenika River watershed; aerial redd count 2016, corroborated by observations of adults in 2002 (FLNRORD Region 7 Fisheries database - c/o S. Weber)						
81	Swannell	Mainstem	Juveniles	VO, EF	Moderate	10 V 370680 6286244; 10 V 333370 6271915	Cowie and Blackman 2004; Hagen and Spendlow 2017
	Comments: No sampling from upper watershed, so top of spawning distribution used as a proxy						
82	Swannell	Orion	Spawning, Juveniles	VO	Low	**Redacted**	Hagen and Spendlow 2017
	Comments: Tributary to upper Swannell River at top of spawning section; based on a small number of redds in Orion C						
83	Pelly	Upper mainstem	Spawning	VO	High	**Redacted**	Hagen and Spendlow 2017, 2018
	Comments: Substantial spawning population, 3rd largest within Ingenika watershed; good information from 2 years' aerial redd counts; location of 5.8-km FWCP index section established in 2017 (61 redds counted)						
84	Pelly	Mainstem	Juveniles	VO, EF	Moderate-high	10 V 349118 6300744; 10 V 322872 6342901	Cowie and Blackman 2004; Hagen and Spendlow 2017
	Comments: Small number of redds in the vicinity of lower boundary also, but most were well upstream;						
85	Wrede	Upper mainstem	Spawning	VO	Moderate	**Redacted**	Hagen and Spendlow 2017

	Comments: Substantial spawning population distributed over 40 km in Wrede Creek and unnamed south fork tributary, 2nd largest within Ingenika watershed						
86	Wrede	Mainstem	Juveniles	VO, EF	Moderate	10 V 334518 6296307; 9 V 674556 6290862	Cowie and Blackman 2004; Hagen and Spendlow 2017
	Comments: Major producer of Bull Trout within the Ingenika River watershed; unroaded watershed in pristine condition						
87	Wrede	South fork (unnamed)	Spawning, Juveniles	VO	Moderate	***Redacted***	Hagen and Spendlow 2017
	Comments: Unnamed South fork of Wrede Creek; continuous with Wrede Creek critical habitats						
88	Ingenika	Mainstem	Juveniles	EF	Low-moderate	10 V 319598 6302672; 9 V 663281 6303122	Cowie and Blackman 2004; Hagen and Spendlow 2017
	Comments: Based on the distribution of electrofishing sites where BT were numerically dominant over RB; top of the distribution based on aerial habitat notes and observations of small numbers of redds above Frederikson Creek						
89	Frederikson	Mainstem	Spawning	VO	Moderate	***Redacted***	Hagen and Spendlow 2017
	Comments: Most significant spawning population identified in the Ingenika watershed during 2016 aerial surveys, distributed along approximately 12 km of the upper mainstem						
90	Frederikson	Mainstem	Juveniles	VO	Moderate	9 V 669973 6305526; 9 V 659573 6323835	Cowie and Blackman 2004; Hagen and Spendlow 2017
	Comments: Juvenile distribution assumed to extend to mouth of Fredrikson Creek						
91	Frederikson	LaForce	Spawning, Juveniles	VO	Low-moderate	***Redacted***	Hagen and Spendlow 2017
	Comments: Tributary to upper Frederikson Creek; spawning of large-bodied fish identified during aerial surveys in 2016						

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Figure 5.5b. Critical spawning (narrow red segments) and juvenile rearing (thick green segments) habitats delineated for Bull Trout of the eastern portion of the Finlay Reach core area. ID numbers correspond with critical habitats described in Table 5.5a, and ‘S’ and ‘J’ prefixes for ID numbers indicate critical spawning and juvenile rearing habitats, respectively.

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Figure 5.5c. Critical spawning (narrow red segments) and juvenile rearing (thick green segments) habitats delineated for Bull Trout of the western portion of the Finlay Reach core area on the west shore of Williston Reservoir. ID numbers correspond with critical habitats described in Table 5.5a, and ‘S’ and ‘J’ prefixes for ID numbers indicate critical spawning and juvenile rearing habitats, respectively.

Critical spawning and juvenile rearing habitats are distributed throughout the Davis River watershed, along the mainstem *S69* from the migration barrier downstream to near the mouth of the Graham River (to the mouth in the case of juveniles), and in accessible tributaries *S71* 230-966200-75600, *S72* 230-966200-75300, *S73* 230-966200-23300, *S74* Graham River, and *S76* Graham River tributary 230-966200-41000-65700 (Table 5.5a, Figure 5.5b). Among these, information adequacy was assessed as moderate-to-high for all but the critical spawning/juvenile rearing habitat of Davis tributary 230-966200-23300 (single year's aerial redd data) and critical juvenile rearing habitat of the Davis River mainstem. This suggests that a good basis for initiating conservation actions already exists in the Davis River watershed. Given that the Davis is the most significant spawning watershed identified to date for adfluvial, Williston Reservoir Bull Trout (Section *5.5.3*), and an obvious target for habitat conservation actions in the immediate future, the poor understanding of critical habitats in tributary 230-966200-23300 and the importance of the lower Davis River for juvenile rearing are important information gaps of high immediacy (**Data gaps *5.5a***, ***5.5b***, Table 5.5c).

The Ingenika River watershed is also a major producer of large-bodied, migratory Bull Trout (Section *5.5.3*). Critical spawning habitats have been delineated in major tributaries *S80*, *S82* Swannell River, *S83* Pelly Creek, *S85*, *S87* Wrede Creek, and *S89*, *S91* Frederikson Creek, using the calibrated aerial redd count methodology (Hagen and Spendlow 2017) and estimates of juvenile rearing can be refined based on sampling by Cowie and Blackman (2004). However, we rank information adequacy only as moderate at best because the segments are derived based only on a single year's sampling data everywhere outside of Pelly Creek, in which an FWCP redd count index site was established in 2017 (Hagen and Spendlow 2018). The lack of corroboration of these critical habitats with an additional year(s) of sampling should be considered an information gap of high immediacy (**Data gap *5.5c***, Table 5.5c). This is because of the relative importance of the Ingenika as a Bull Trout producer within the Williston Reservoir watershed, and because the watershed is pristine (Section *5.5.3*) enabling effective habitat conservation actions.

In most other watersheds of the Finlay Reach core area (Ospika, Lafferty, Collins, Bruin, Factor Ross), adult Bull Trout-oriented studies (e.g. redd counts, snorkeling surveys, telemetry studies) are required to confirm the presence of the adfluvial life history, assess the relative importance of the watershed, and delineate critical spawning habitats. The lack of understanding of habitat use in these watersheds is a data gap of high immediacy, given that large-bodied migrants may use all of these systems (**Data gap *5.5d***, Table 5.5c). Refining estimates of critical juvenile rearing habitats (via electrofishing), which may extend downstream of spawning areas, is a secondary objective of moderate immediacy (**Data gap *5.5e***, Table 5.5c). Potential proponents should be aware that FWCP has funded an application of the calibrated aerial redd count methodology in watersheds on Williston Reservoir's eastern shore in 2019 (FWCP project no. PEA-F20-F-2956).

Results of this study should provide ‘first-cut’ estimates of critical habitats that can help focus future funding proposals.

5.5.3 Conservation status and risk assessment

Distribution. Large-bodied, migratory Bull Trout are widely distributed in the Finlay Arm core area. Known populations in the Davis, Chowika, and Ingenika river utilize close to 400 km in these streams alone (category *D*: 200-1,000 km, Table 4.2a).

Abundance. Adult population sizes for large-bodied, migratory Bull Trout may be close to 1,000 individuals in each of the Davis and Ingenika watersheds (Table 5.5b), the two systems that have received basin-wide surveys utilizing the calibrated aerial redd count methodology (Hagen and Spendlow 2016, 2017). Sizeable populations are anecdotally reported for the Ospika and Chowika systems also, suggesting that a total population size approaching 2,500 adult individuals (hybrid category *DE*: ±2,500 adult individuals) may occur in this core area, rivaling the largest of core area populations in the province (Kootenay Lake, Koocanusa core areas; Hagen and Decker 2011).

Table 5.5b. Minimum estimated population[1] size of large-bodied, migratory Bull Trout in the Finlay Reach core area (adapted from Hagen and Spendlow 2016, 2017).

Watershed	*Sub-basin*	*Minimum population estimate[1]*	*Source*	*% of core area total*	*Reference*
Davis	Davis index section	168	2015 calibrated aerial survey	9%	Hagen and Spendlow 2016
Davis	Davis mainstem 2	54	2015 calibrated aerial survey	3%	Hagen and Spendlow 2016
Davis	Davis mainstem 1	186	2015 calibrated aerial survey	10%	Hagen and Spendlow 2016
Davis	Davis 'Trib 3' (230-966200-75600)	224	2015 calibrated aerial survey	12%	Hagen and Spendlow 2016
Davis	Davis 'Trib 2' (230-966200-75300)	140	2015 calibrated aerial survey	8%	Hagen and Spendlow 2016
Davis	Davis 'Trib 1' (230-966200-23300)	56	2015 calibrated aerial survey	3%	Hagen and Spendlow 2016
Davis	Graham River	92	2015 calibrated aerial survey	5%	Hagen and Spendlow 2016
Davis	230-966200-41000-65700	64	2015 calibrated aerial survey	3%	Hagen and Spendlow 2016
Ingenika	Ingenika mainstem	37	2016 calibrated aerial survey	2%	Hagen and Spendlow 2017
Ingenika	Swannel River	107	2016 calibrated aerial survey	6%	Hagen and Spendlow 2019
Ingenika	Wrede Creek mainstem	182	2016 calibrated aerial survey	10%	Hagen and Spendlow 2018
Ingenika	Wrede south fork	119	2016 calibrated aerial survey	6%	Hagen and Spendlow 2018
Ingenika	Frederikson Creek	227	2016 calibrated aerial survey	12%	Hagen and Spendlow 2018
Ingenika	Frederikson north fork (La Force)	52	2016 calibrated aerial survey	3%	Hagen and Spendlow 2018
Ingenika	Pelly Creek	156	2016 calibrated aerial survey	8%	Hagen and Spendlow 2018
Finlay Reach core area total		***1863***		***100%***	

Population trend. The Davis River contains one of four long-term index sites utilized by FWCP since 2001 for monitoring abundance trend (Andrusak et al. 2011). Monitoring goals for evaluating trend are 2 generations for the U.S. Fish and Wildlife Service (USFWS 2005), which would be a minimum of 14 years in the Williston Reservoir watershed (Langston and Blackman 1993). The completion of surveys in 2018 (Hagen and Spendlow 2019) extends the time series of redd count data to 15 years (over an 18-year period) for the Davis system (Figure 5.5d), meaning this is the only Williston time series that meets these criteria. It is also the only one of the four time series exhibiting a positive trend (Category *F*, Table 4.2a). Variability among years is substantial, however, and the trend is only marginally significant when analyzed using natural log-transformed count data ($t = 2.26$, $P = 0.04$, $n = 15$).

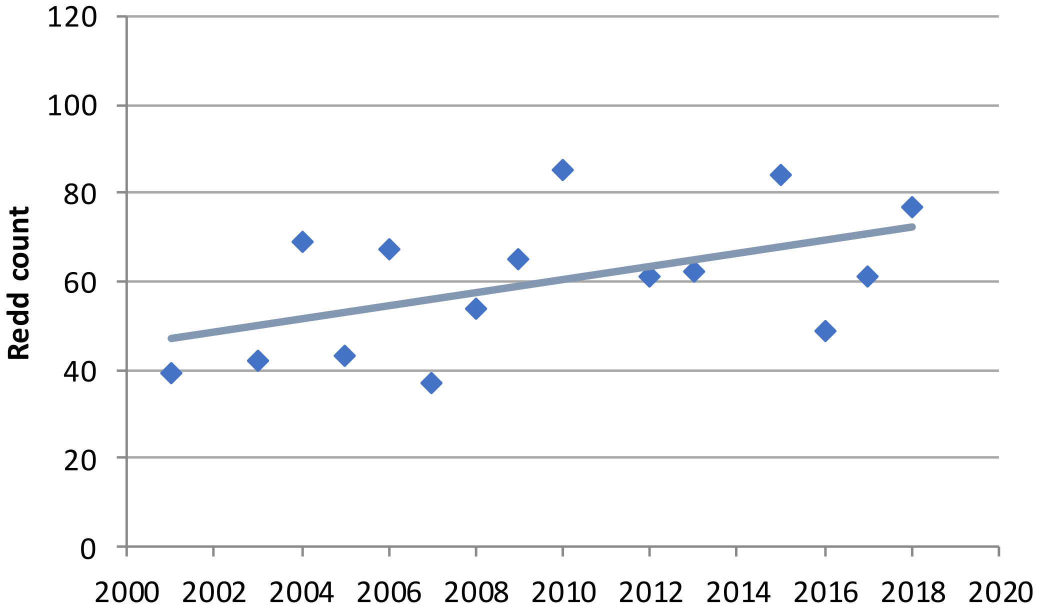

Figure 5.5d. Counts of Bull Trout redds (spawning sites) in the FWCP spawner abundance monitoring index site in the Davis River, 2001-2018 (adapted from Hagen and Spendlow 2019).

Hagen and Spendlow (2019) identified two potential factors that may be related to this positive trend: 1) protection of Williston Bull Trout by catch-and-release regulations in streams beginning in the 1990s,[30] and 2) potential increases in Bull Trout population productivity resulting from the naturalization of Kokanee in the reservoir following stocking, which has been noted for reservoir environments in the upper Columbia Basin in B.C. (Hagen 2008). Shorter Williston Reservoir time series (Misinchinka 2006; Point 2006; Scott 2009) do not reflect positive population growth. Continued monitoring of spawner abundance in the Davis River is a strong recommendation of the ongoing FWCP Bull Trout redd count program (Hagen and Spendlow 2019), so this monitoring action is not itemized as a data gap in this report.

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[30] The 50 cm maximum size limit in the reservoir also acts as a catch-and-release regulation *de facto* because it is probably at this size that Bull Trout begin to recruit to the reservoir fishery (e.g. Arndt 2004).

Given the Ingenika River's status as a major producer of Bull Trout within the Williston Reservoir watershed, along with its importance to the Tsay Keh Dene people (Herkes and Kurtz 2014), the lack of monitoring of population trend is an important data gap of high immediacy (**Data gap *5.5f***; Table 5.5c). A new FWCP index section has been established in Pelly Creek in the Ingenika watershed in 2017, and Wrede and Frederikson creeks are additional candidates for monitoring. Recommendations for the frequency of monitoring in new index sections is discussed in Section *6.0*.

Threats. Critical habitats identified to date in the Finlay Arm core area generally lie in areas with low levels of land use or beyond the end of the current road network (Figure 5.5e). Threats from land use and human access (e.g. linked to First Nations subsistence fisheries, recreational angling catch-and-release mortality and non-compliance), as indicated by road density, were estimated to be of low severity and low scope (category *G*; Table 4.2b).

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Figure 5.5e. Road density (km/km^2) in watershed assessment units (see Section *4.2.2*) of the Finlay Reach core area (coloured polygons) and critical habitats for Bull Trout (spawning and/or juvenile: thick black stream segments).

Conservation status and risk assessment. The categorical estimates for the four conservation status indicators, when factored together (Table 4.2c), corresponded to a ranking of ***C4-Low Risk***, suggesting that the Finlay Reach core area is a relative stronghold for the Bull Trout in British Columbia (Hagen and Decker 2011). According to this ranking, "the species is common or uncommon, but not rare, and usually widespread throughout the core area. Apparently not vulnerable at this point in time, but may be cause for long-term concern" (Table 4.2c). The most important factors influencing this assessment are the large population and relatively low level of threats.

5.5.4 Tabulated Data gaps

Table 5.5c. Data gaps limiting assessments of critical habitats and conservation status for Bull Trout within sub-basins of the Finlay Reach core area, and potential studies to address them.

ID	***Stream(s)***	***Data gap***	***Potential study(s)***	***Immediacy***
5.5a	Davis tributary 230-966200-23300	Poor understanding of critical habitats	Foot surveys (redd surveys) to acquire more precise estimates of abundance, critical habitats	High

5.5b	Davis	Inadequate understanding of the importance of lower Davis River for juvenile rearing	Juvenile-oriented fish surveys (e.g. electrofishing)	High
5.5c	Swannell, Wrede, Frederikson	Only one year's data for assessing critical habitats and abundance in key spawning tributaries	Foot surveys (redd surveys) to acquire estimates of abundance, critical habitats	High
5.5d	Ospika, Lafferty, Collins, Bruin, Factor Ross	Little or no knowledge of critical spawning habitats and abundance	Aerial redd surveys for 'first-cut' estimates of critical habitats and abundance, corroborated with foot surveys	High
5.5e	All	Limited data to assess extent of critical juvenile habitats	Juvenile-oriented fish surveys (e.g. electrofishing)	Moderate
5.5f	Pelly, Wrede, Frederikson	No knowledge of population trend in the Ingenika watershed	Redd surveys in new index sections	High

5.6 Lower Finlay core area

5.6.1 Overview of existing information

The Lower Finlay core area is comprised of the remaining unflooded portion of the Finlay River watershed in the Rocky Mountain Trench. The divide with the Upper Finlay core area has been arbitrarily set at cascades below the Fishing Lakes. Large tributaries entering the Finlay in this section including the Akie, Kwadacha, and Fox Rivers. Bull Trout records linked to the BC Geographic Warehouse are widespread in this mountainous core area (Figure 5.6a), and numerous smaller tributaries as well as these major ones appear to have Bull Trout populations.

Sampling records are relatively sparse, and some tributaries to the lower Finlay River have had no sampling whatsoever (e.g. Truncate, Blanchard, McGraw). Key references providing Bull Trout habitat use data throughout the Lower Finlay core area are sampling records from three fish and fish habitat inventory assessments (RL&L 2000; Triton 2005, 2007), and an FWCP survey targeting Arctic Grayling (PWFWCP 2007).

It appears from the limited information that the potential exists for a diversity of Bull Trout life histories, including: 1) adfluvial fish in lakes (e.g. Stelkuz Lake; PWFWCP 1997), 2) stream residents (based on length data and/or maturity assessments) in a number of systems including Tsaydiz Creek (Beak Pacific 1997) Paul River (Sigma 1982), Del Creek (Pottinger Gaherty 1998), upper Weissener Creek (Triton 2005, 2007), and McCook River (Triton 2005, 2007), and large-bodied, migratory Bull Trout (Langston and Blackman 1993; R.L.&L. 2000; Triton 2005; Pearce and Abadzadesahraei 2019; Pearce et al. 2019c) observed in rivers. However, there is an extreme lack of data identifying natal streams for large-bodied, migratory Bull Trout, which is limited to snorkeling observations in lower Fox River (R.L.&L. 2000; Triton 2005) and Pesika Creek (Langston and Blackman 1993).

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Figure 5.6a. Distribution of records for past sampling of Bull Trout (red circles) and all other species (light grey circles) within sub-basins of the Lower Finlay core area.

Although information about Bull Trout habitat use presented in First Nations knowledge reports (Herkes and Kurtz 2014; Pearce and Abadzadesahraei 2019; Pearce et al. 2019a, 2019b, 2019c, 2019d) is a potentially valuable resource for identifying migratory populations, it does not include precise population data (distribution, abundance, trend) that would enable the delineation of critical habitats or assessments of conservation status in the Lower Finlay core area. However, private First Nations knowledge identifying fishing sites for migratory Bull Trout, which is beyond the permitted scope of this report, may be the most valuable available data for focusing future monitoring activities. Members of the Kwadacha Nation have valuable knowledge of streams potentially utilized by large-bodied, adfluvial Bull Trout for spawning (Pearce et al. 2019c), which have yet to receive Bull Trout-focused inventory studies. An important component of the First Nations knowledge study was the documentation of concerns expressed by individuals and communities. With respect to Bull Trout populations and their habitats, Kwadacha Nation members are concerned about: 1) high levels of mercury in subsistence fish, 2) habitat degradation and chemical contaminants related to logging, mining, herbicide application, and linear developments, and 3) the effects on fish stocks of increased access for non-Kwadacha fishers including effects of catch-and-release angling (Pearce et al. 2019c). Kwadacha Nation members recommend: 1) increased monitoring of fish population and waterway 'health' by Kwadacha members, 2) increased education and outreach to community members, 3) stricter enforcement of regulations for pollution and environmental degradation related to forestry, oil and gas, and mining, and 4) protection and restoration of spawning creeks (Pearce et al. 2019c).

5.6.2 Critical habitats

Within the Lower Finlay core area, we were unable to delineate critical habitats for large-bodied, migratory Bull Trout potentially originating from Williston Reservoir. This is primarily due to complete absence of data identifying spawning habitat (**Data gap *5.6a***, Table 5.6) and insufficient replication of electrofishing data to identify critical juvenile rearing (**Data gap *5.6b***). These are important information gaps of high immediacy, which greatly limit FWCP’s ability to identify conservation actions and assess population status (Section *5.6.3*). Identifying a starting point for addressing these information gaps is even a challenge. In this situation, site-specific First Nations knowledge about migrations of large-bodied Bull Trout may be key information providing a starting point for investigations of adult Bull Trout habitat use (through techniques such as telemetry, redd counts, otolith microchemistry). As mentioned in the preceding section, identifying these specific sites is beyond the permitted scope of this report, and potential proponents wishing to make use of this information are encouraged to work directly with the Kwadacha and Tsay Keh Dene Nations (Pearce and Abadzadesahraei 2019; Pearce et al. 2019c).

Potential proponents should also be aware that an application of the calibrated, aerial redd count methodology is proposed for the Lower Finlay core area for the 2020-21 funding cycle (year 2 of FWCP project no. PEA-F20-F-2956). Although it is not clear whether the relatively large number of potential spawning streams present in the core area can be surveyed in a single year, if funded this study is likely to identify several spawning zones, which are starting points for more detailed monitoring to refine estimates of critical spawning and juvenile rearing habitats.

The wide distribution of Bull Trout in the core area suggests that many natal streams may be utilized by large-bodied, adfluvial Bull Trout. Although existing data were deemed insufficient to delineate critical habitats, our review did suggest a number of watersheds of interest for potential future studies, including: Pesika Creek (Bull Trout >500 mm have been observed during snorkeling: Langston and Blackman 1993), Tsaydiz Creek (Beak Pacific 1997), Akie River (Pottinger Gaherty 1998; R.L.&L 2002; PWFWCP 2007), Truncate, Blanchard, McGraw, Russel creeks (no information but suitable size), Del (Pottinger Gaherty 1998), Paul River (Sigma 1982; Mining-related sampling available in the Region 7 Fisheries database), Kwadacha River and tributaries North Kwadacha River and unnamed 239-333700-57800 (Triton 2005, 2007), Fox River (R.L.&L 2000; Triton 2005, 2007), McCook River (Triton 2007), Bower Creek (PWFWCP 2007; Pearce et al. 2019c), and Obo River (PWFWCP 2007; Pearce et al. 2019c).

5.6.3 Conservation status and risk assessment

Distribution: Relatively sparse sampling records for the Lower Finlay core area, along with the lack of information Bull Trout life history, do not permit a good estimate of distribution for large-bodied, migratory Bull Trout. Nonetheless, the species is widely distributed in the Lower Finlay watershed and many populations are thought to be adfluvial fish utilizing Williston Reservoir (A.R. Langston pers. comm. 2011), suggesting a distribution estimate of at least 200 km is appropriate (category *D*: 200-1,000 km, Table 4.2a).

Abundance. There are virtually no data indicating abundance of large-bodied, potentially adfluvial Bull Trout in the Lower Finlay core area, despite the widespread distribution of the species, and total adult abundance is therefore best categorized as ‘Unknown’ (category *U*, Table 4.2a). This major information gap is of high importance and immediacy, and can be addressed at same time that critical spawning habitats are identified (**Data gap *5.6a***, Table 5.6). Studies of habitat use and abundance for populations of large-bodied, potentially adfluvial Bull Trout will potentially benefit from results of the calibrated aerial redd count survey (FWCP Project No. PEA-F20-F-2956) which is being proposed for the Lower Finlay core area in fall 2020, if funding is approved by FWCP for year 2 of this project.

Population trend. There are no data related to the population trend for Bull Trout in the Lower Finlay core area, and therefore population trend is therefore best categorized as 'Unknown' (category *U*, Table 4.2a). This information gap is of high importance, and can be addressed using a redd count methodology in a new index section(s) following the identification of critical spawning habitats (**Data gap *5.6c***, Table 5.6).

Threats: An estimate of threats posed by land use and human access is difficult in the Lower Finlay core area, because critical habitats are unknown. However, in watersheds of potential interest (see Section *5.6.2*) a threats rating of moderate severity/low scope (category *E*, Table 4.2b) appears appropriate. Levels of land use appear to be generally low with only a few sub-basins subject to low-to-moderate or moderate levels of road density (Figure 5.6b).

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Figure 5.6b. Road density (km/km^2) in watershed assessment units (see Section *4.2.2*) of the Lower Finlay core area (coloured polygons) and critical habitats for Bull Trout (spawning and/or juvenile: thick black stream segments).

Conservation and risk assessment. Factoring the estimates for the four conservation status indicators together (see Section *4.2*) resulted in a ranking of *C3-Potential Risk* for the Lower Finlay core area (Table 4.2c), but it is important to note that this ranking should be considered provisional at best given the lack of population data. According to this ranking, Bull Trout in the Lower Finlay core area are "potentially at risk because of limited and/or declining numbers, range, and /or habitat, even though the species may be locally abundant in some areas of the core area" (Table 4.2c). The most influential indicator in the scoring process was the relatively low level of habitat threats (as indicated by road density).

5.6.4 Tabulated Data gaps

Table 5.6. Data gaps limiting understanding of critical habitats and/or conservation status for Bull Trout within the Lower Finlay core area, and potential studies to address them.

ID	*Stream(s)*	*Data gap*	*Potential study(s)*	*Immediacy*
5.6a	All	No knowledge of critical spawning habitats and adult abundance	Aerial redd surveys for 'first-cut' estimates of critical habitats and abundance, and/or more-accurate-but-slower foot surveys	High
5.6b	All	Inadequate fish sampling and life history data to delineate critical juvenile rearing	Juvenile-oriented fish surveys (e.g. electrofishing), paired with studies identifying life history (e.g. redd counts, telemetry, visual observations of large-bodied spawners	High
5.6c	All	No knowledge of population trend in the core area	Foot surveys (redd surveys) to acquire estimates of abundance in a new index section(s), conducted at the decadal scale	High

5.7 Upper Finlay core area

5.7.1 Overview of existing information

The Upper Finlay core area is comprised of the Finlay River watershed upstream of rapids located downstream of the Fishing Lakes, minus the Thutade Lake watershed at the head of the Finlay system which is isolated above Cascadero Falls. Major tributary watersheds along this section of the Finlay River are those of the Toodoggone and Firesteel rivers. The Upper Finlay core area is mostly pristine, with a small amount of watershed development related to mineral exploration.

Fish sampling data for the Upper Finlay core area is provided by several inventory assessments covering the Sturdee Road Corridor in the Firesteel River watershed, the Toodoggone River and tributaries, and the Finlay River and its direct tributaries (RAB 1978; Norcol 1986; Zemlak and Langston 1994; Norris 1990; PWFWCP 2007). Existing data indicate that Bull Trout are widespread in the core area and present at most sampling sites (Figure 5.7a).

It is important to note that the presence of Dolly Varden in the core area has been validated with morphometric and/or genetic analysis (R.L.&L 2000, 2001), and some Bull Trout records prior to 1991 may potentially be Dolly Varden (Haas and McPhail 1991). In sympatry, habitat use patterns of juvenile Dolly Varden and Bull Trout overlap, and the two species may even be found in the same sites. Niche separation between the species is primarily through life history specialization, with Dolly Varden limited to stream resident and restricted fluvial life histories (to the exclusion of Bull Trout), and Bull Trout limited to the large-bodied, migratory life history unless they are found upstream of a migration barrier that excludes Dolly Varden (Hagen and Taylor 2001).

Bull Trout to at least 720 mm are known from the core area (Zemlak and Langston 1994). However, it is unknown whether these fish are adfluvial migrants from Williston Reservoir, because studies targeting large-bodied, migratory fish have not occurred.

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Figure 5.7a. Distribution of records for past sampling of Bull Trout (red circles) and all other species (light grey circles) within sub-basins of the Upper Finlay core area.

Information compiled in reports from the First Nations knowledge study (Pearce and Abadzadesahraei 2019; Pearce et al. 2019a, 2019b, 2019c, 2019d) does not include precise population data (distribution, abundance, trend) that would enable the delineation of critical habitats or assessments of conservation status in the Upper Finlay core area. However, members of the Kwadacha Nation do have valuable knowledge of streams potentially utilized by large-bodied, adfluvial Bull Trout for spawning (Pearce et al. 2019c), which have yet to receive Bull Trout-focused inventory studies.

5.7.2 Critical habitats

Large-bodied, migratory Bull Trout in Northern British Columbia may migrate several hundred kilometers between adult rearing and spawning environments (Burrows et al. 2001; Pillipow and Williamson 2004). Use of the Upper Finlay core area by Williston Reservoir Bull Trout is therefore plausible, but it has not been established. The lack of knowledge about whether large-bodied, migratory Bull Trout in this core area (e.g. fish to 720 mm captured in the vicinity of Fishing Lakes; Zemlak and Langston 1994) utilize Williston Reservoir (or are a fluvial population) is an information gap of moderate immediacy (**Data gap *5.7a***, Table 5.7), and of interest to the Kwadacha Nation because of concerns expressed about potentially-elevated mercury levels in adfluvial fish (Pearce et al. 2019c).

Within the Upper Finlay core area, we were unable to delineate critical habitats for large-bodied, migratory Bull Trout potentially originating from Williston Reservoir. This is primarily due to the absence of data identifying spawning habitat (**Data gap *5.7b***, Table 5.7) and insufficient replication of electrofishing data to identify critical juvenile rearing and life history (**Data gap *5.7c***). These are important information gaps of high immediacy, which greatly limit FWCP's ability to identify conservation actions and assess population status (Section *5.7.3*). Similar to the situation for the Lower Finlay core area, site-specific First Nations knowledge about migrations of large-bodied Bull Trout may be key information providing a starting point for investigations of adult Bull Trout habitat use (through techniques such as telemetry, redd counts, otolith microchemistry). As mentioned previously in this report, potential proponents wishing to make use of this information are encouraged to work directly with the Kwadacha and Tsay Keh Dene Nations.

The wide distribution of Bull Trout in the core area suggests that many natal streams may be utilized by large-bodied, migratory Bull Trout. Although existing data were deemed insufficient to delineate critical habitats, our review did suggest juvenile Bull Trout were present at the majority of sampling sites, including sites in the lake-headed Finlay River and Toodoggone River mainstems, and habitat suitability for the species is likely to be high.

5.7.3 Conservation status and risk assessment

Distribution: Estimating the distribution of large-bodied, migratory Bull Trout within the Upper Finlay core area is difficult, because critical habitats are unknown. Bull Trout are widespread in the core area, however (Figure 5.7a), and the presence of the large-bodied, migratory life history has been confirmed (Zemlak and Langston 1994). We applied a provisional estimate of >200 km (category *D*: 200-1,000 km, Table 4.2a), based on the amount of accessible habitat in potentially suitable tributaries.

Abundance. There are no data indicating abundance of large-bodied, potentially adfluvial Bull Trout in the Upper Finlay core area, and therefore total adult abundance was categorically estimated to be 'Unknown' (category *U*, Table 4.2a). This major information gap is of high importance and immediacy, and can be addressed at same time that critical spawning habitats are identified (**Data gap *5.7b***, Table 5.7) using redd counts. Movement studies (e.g. telemetry, otolith microchemistry) may potentially be beneficial to establish key watersheds for studies of spawning locations and total adult abundance. First Nations knowledge (e.g. Pearce 2019c) may also provide such starting points, but this knowledge is the property of the First Nations meaning that prior engagement and partnership with communities and individuals may be required for a study proposal to be successful.

Population trend. There are no data related to the population trend for Bull Trout in the Upper Finlay core area, and population trend was estimated categorically to be 'Unknown' (category *U*, Table 4.2a). This information gap is of high importance, and can be addressed using a redd count methodology in a new index section(s) following the identification of critical spawning habitats (**Data gap *5.7d***, Table 5.7).

Threats: Although critical habitats are unknown, it is still relatively straightforward to estimate threats to Bull Trout populations of the Upper Finlay core areas because most of the core area is pristine as indicated by low road density (Figure 5.7b). A threats rating of low severity/low scope (category *G*, Table 4.2b) is therefore appropriate.

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Figure 5.7b. Road density (km/km^2) in watershed assessment units (see Section *4.2.2*) of the Upper Finlay core area (coloured polygons) and critical habitats for Bull Trout (spawning and/or juvenile: thick black stream segments).

Conservation and risk assessment. Factoring the estimates for the four conservation status indicators together (see Section *4.2*) resulted in a ranking of ***C4-Low Risk*** for the Upper Finlay core area (Table 4.2c), but once more it is important to note that this ranking is provisional given the lack of population data. According to this ranking, “the species is common or uncommon, but not rare, and usually widespread throughout the core area. Apparently not vulnerable at this point in time, but may be cause for long-term concern” (Table 4.2c). The most important factor influencing this assessment was the low level of threats.

5.7.4 Tabulated Data gaps

Table 5.7. Data gaps limiting understanding of critical habitats and/or conservation status for Bull Trout in the Upper Finlay core area, and potential studies to address them.

ID	*Stream(s)*	*Data gap*	*Potential study(s)*	*Immediacy*
5.7a	All	Unknown whether large-bodied Bull Trout utilize Williston Reservoir	Adult movement studies e.g. radio or acoustic telemetry, otolith microchemistry	Moderate
5.7b	All	No knowledge of critical spawning zones or abundance for migratory Bull Trout	Adult movement studies to identify key watersheds (e.g. radio or acoustic telemetry, otolith microchemistry); aerial- or ground survey-based redd surveys	High

5.7c	All	No knowledge of critical juvenile rearing habitat for migratory Bull Trout	Juvenile-oriented fish surveys (e.g. electrofishing), paired with studies identifying life history (e.g. redd counts, telemetry, visual observations of large-bodied spawners	High
5.7d	All	No knowledge of population trend in the core area	Foot surveys (redd surveys) to acquire estimates of abundance in a new index section(s), conducted at the decadal scale	High

6.0 CONCLUSIONS AND RECOMMENDED MONITORING ACTIONS

6.1 Conclusions of the information synthesis

The Bull Trout (*Salvelinus confluentus*) is one of the most highly-valued fish species in the upper Peace Basin and is also one of British Columbia's most sensitive, with defining characteristics of the species being its high vulnerability to habitat degradation, angling exploitation, and interspecific competition. Because of its sensitivity and high value to people, the Bull Trout is a priority fish species for the Fish and Wildlife Compensation Program (FWCP) and the BC Ministry of Forests, Lands, Natural Resource Operations, and Rural Development (FLNRORD) which is the lead agency responsible for Bull Trout fishery and habitat management. Populations of the large-bodied, migratory form of the Bull Trout are of highest value to people, at highest risk, and potentially impacted by the creation of Williston and Dinosaur reservoirs, so these populations are the primary focus for FWCP and for this report.

FWCP's strategic objectives for Bull Trout, as identified in the *Streams Action Plan* (FWCP 2014), are to maintain or improve conservation status, the productivity of critical habitats, and opportunities for sustainable use of fish, and also to build and maintain relationships with stakeholders and aboriginal communities. These goals are consistent with goals and objectives of the FLNRORD's *Provincial Bull Trout Management Plan* (Pollard et al. 2015).

To achieve these goals, a prior knowledge base is required which includes reliable information about:

1) Bull Trout biology and limiting factors,
2) enhancement techniques suitable for Bull Trout, and realistic expectations for success,
3) locations of critical habitats (i.e. those that potentially limit population productivity at the juvenile or adult life stage), and

4) indicators of conservation status and risk (distribution, abundance, trend, and threats).

The preceding information synthesis (Sections *1.0-5.0*) has evaluated the existing knowledge base with respect to these key types of information, and identified that a substantial amount of information exists already that can be applied to Williston Reservoir and Dinosaur Reservoir Bull Trout. However, it is also true that serious information gaps exist which limit FWCP's ability to make sound investments in conservation and enhancement actions. These have been tabulated in the information synthesis, with data gaps of highest immediacy being those which are likely to be the most 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.

Bull Trout biology and limiting factors **(Section *2.0*).** The Bull Trout has been the subject of much study, and it is clear that the species has narrow tolerances with respect to ecological conditions. Analyses conducted across the species' range have indicated that elevated water temperatures in juvenile and adult habitats, land use-related habitat degradation, interrupted connectivity, the presence of non-native interspecific competitors in adult rearing environments, and angling exploitation are key factors limiting the distribution and abundance of Bull Trout (e.g. Donald and Alger 1993; Parkinson and Haas 1996; Rieman et al. 1997; Baxter et al. 1999; Pratt 2003; Johnston et al. 2007; Hagen 2008; Erhardt and Scarnecchia 2014; Kovach et al. 2016).

Despite the existence of a substantial literature to draw on from other areas of the species' range, information gaps exist with respect to the biology of Bull Trout in the upper Peace Basin and limiting factors (Tables 2.1, 2.2, 2.3). More information is needed in the following areas: 1) genetic data to define population structure and conservation units (Table 2.1), 2) age, life history, and growth data to assess ecological changes over time (Table 2.2), 3) productivity in juvenile and adult habitats, 4) thermal tolerances for the species in the upper Peace Basin and existing water temperature conditions in key natal streams, 5) sustainable thresholds for land use, 6) specific mechanisms of land-use related habitat degradation (in addition to water temperature), 7) the threat posed by increasing populations of Lake Trout in Williston and Dinosaur reservoirs, and 8) harvest rates of Bull Trout in First Nations subsistence fisheries (Table 2.3).

Enhancements **(Section *3.0*).** The unique biology of the Bull Trout is a factor affecting the suitability of potential enhancements for improving the status of populations, the productivity of their habitats, and human opportunities for use of fish. Enhancements that have been successfully applied to other species may not suitable for application to Bull Trout in the Williston Reservoir and Dinosaur Reservoir watersheds, so enhancements should be treated as experiments with commensurate standards for monitoring.

Enhancement techniques that are probably not suitable for Bull Trout in the Williston Reservoir and Dinosaur Reservoir watersheds are: 1) artificial propagation (Section *3.1*), 2) reservoir fertilization (Section *3.2*), and 3) instream structure placements (Section *3.6*). Artificial propagation appears to be a poor choice because of poor results in a two-decade trial in the Arrow Lakes Reservoir (Winsby and Stone 1996; Sebastian et al. 2000; Arndt 2004), the high cost of the method, and threats posed to wild populations by potential genetic change and intraspecific competition. Reservoir fertilization has shown positive results for Bull Trout in FWCP-funded fertilization programs in the Arrow Lakes Reservoir (Schindler et al. 2007; Arndt 2008) and Kootenay Lake Reservoir (Schindler et al. 2006), but these are extremely expensive projects and monitoring has indicated that responses to fertilization among trophic levels may be unpredictable or unstable over longer time horizons (e.g. Davis et al. 2009; Burrows and Neufeld 2018). The most important factor limiting the potential for instream structures is that they are unlikely to be durable or to maintain their function. This is because critical natal habitats for Bull Trout are located in mountainous watersheds where high energy flows associated with snowmelt and heavy rainfall are amplified since watersheds are relatively steep, and few lakes are present to moderate flows (Hagen 2008 and references therein).

Potentially promising enhancement methods include: 1) stream fertilization (Section *3.3*), 2) fish access improvement (Section *3.4*), side channel development (Section *3.5*), and 3) riparian restoration (Section *3.7*). The key information gaps are missing data on candidate locations for trials of these methods (Table 3.0b), and the need for a review of prior assessments (which was not completed during this information synthesis due to time constraints). Given the potential high cost of stream fertilization, a further information gap is lack of experimental results from a trial(s) in critical natal stream reaches of the Williston Reservoir watershed (Table 3.0b).

Given that the majority of critical habitats for Bull Trout of the Williston Reservoir watershed are currently in relatively good or pristine condition (Section *5.0*), habitat conservation (Section *3.8*) is likely to be far more cost-effective than habitat enhancements at maintaining the productivity and conservation status of Bull Trout in the Williston Reservoir watershed. The most important data required for this conservation action are the locations of critical natal habitats (see below), where spawning, egg incubation, and juvenile rearing take place.

Conservation status and risk **(Section *5.0*).** Conservation status and risk among core areas was assessed using the United States Fish and Wildlife Service *Core Area Conservation Status and Risk Assessment Methodology* (USFWS 2005), consistent with methods recommended in FLNRORD’s *Provincial Bull Trout Management Plan* (Hagen and Decker 2011; Pollard et al. 2015). Conservation status varies widely among Bull Trout core areas of the Williston Reservoir and Dinosaur Reservoir watersheds. *Low Risk* core areas were the pristine Upper Finlay core area and the Finlay Reach core area which is home to major populations in the Davis and Ingenika watersheds. *Potential Risk* core areas were the Lower Finlay and Omineca core areas, which had relatively low habitat threats. The Parsnip, Parsnip Reach, and Peace Reach core areas all estimated to be *At Risk*, with the most important factor affecting the ranking being small adult population size. The Dinosaur core area was considered to be at *High Risk* of extirpation due to limited habitat availability and a small, declining population. It is unclear whether the remnant population isolated between the Peace Canyon and W.A.C. Bennett dams comprises a self-sustaining population, or whether its existence depends on entrainment from Williston Reservoir. FWCP must weigh these rankings in making hard decisions about where to prioritize monitoring efforts and conservation actions.

The availability of population data for assessing conservation status (*Distribution*, *Abundance*, and *Population trend*) also varied widely among core areas, and was related to where FWCP has previously allocated funds for studies of critical habitats and abundance. With respect to the ability to assess conservation status, recurring data gaps for the Parsnip (Section *5.1*), Omineca (Section *5.3*), Peace Reach (Section *5.4*), and Finlay Reach (Section *5.5*) core areas were imprecise estimates of total abundance and the limited (or non-existent) number of index sections with adequate data for estimating population trend. Recurring data gaps for the Parsnip Reach (Section *5.2*), Lower Finlay (Section *5.6*), and Upper Finlay (Section *5.7*) core areas are more grievous: the lack of any indication whatsoever about total population size and population trend (outside of Scott Creek in the Parsnip Reach core area) due to the lack of Bull Trout-focused research to date.

***Critical Habitats* (Section *5.0*).** A total of 90 stream segments assessed as critical habitats for spawning and/or juvenile Bull Trout have been delineated in the tables of Section *5.0*. In a third of these cases, information adequacy was estimated to be too low (low or low-to-moderate information adequacy) to confidently initiate conservation actions. More seriously, no critical habitats at all were identified for the Lower Finlay and Upper Finlay core areas, because of the dearth of population and life history data, and no critical habitats identified for the Parsnip Reach core area outside of those for the population in Scott Creek.

In the analysis of critical habitats, a total of 34 information gaps were identified across the 8 core areas that potentially limit FWCP's ability to initiate conservation and enhancement actions (Tables *5.1c*, *5.2b*, *5.3c*, *5.4b*, *5.5c*, *5.6*, *5.7*). Data gaps are specific or general depending on the level of prior investment in reconnaissance surveys, so a sweeping generalization is not possible and report sections pertaining to each core area should be reviewed by potential proponents. However, recurring data gaps do exist. For core areas that have received prior surveys of critical habitats and abundance (Parsnip (Hagen et al. 2015); Omineca (Hagen and Spendlow 2018, 2019), Peace Reach/Dinosaur (Euchner 2016, 2017a, 2018); Finlay Reach (Hagen and Spendlow

2016, 2017)), it is important to refine estimates of distribution of spawning and juvenile rearing, using redd count- and electrofishing[31]-based survey methods, respectively, to enable habitat conservation and enhancement actions. For core areas that have not had reconnaissance spawning surveys, the key unanswered questions are: 1) which streams are utilized by populations of large-bodied, migratory Bull Trout? 2) what is the relative importance of each of these streams? and 3) where are critical habitats located? Movement studies (telemetry, otolith microchemistry) and the calibrated aerial redd count methodology developed by FLNRORD and FWCP are proven, albeit expensive, methods for acquiring data to provide ‘first-cut’ estimates of critical habitats and total abundance.

6.2 Recommended monitoring framework

6.2.1 Key monitoring data requirements

The preceding information synthesis was designed to fulfil Action *1c-1* of the *Streams Action Plan* (FWCP 2014):

> Action *1c-1*: Review existing information (including provincial management plan), summarize status and trends of Bull Trout 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 *Streams Action Plan* (FWCP 2014) also specifies next steps leading to conservation and enhancement actions for Bull Trout:

> Action *1c-2*: Implement high priority habitat restoration options for Bull Trout.
>
> Action *1c-3*: Undertake Bull Trout monitoring as per recommendations of the monitoring program and develop specific, prioritized recommendations for habitat- based actions which correspond to the monitoring results.
>
> Action *1c-4*: Review Bull Trout monitoring results, refine and implement specific plans in response, as needed; Identify limiting factors to direct conservation and enhancement efforts.

For monitoring efforts to enable effective conservation actions, thereby fulfilling Actions *1c-2*, *1c-3*, and *1c-4*, four key types of monitoring data are necessary:

1. Population data indicating conservation status and risk. ‘Conservation status’ can be defined as an estimate of overall population viability, or health. Throughout the North American range of the Bull Trout, the most basic spatial scale for estimating conservation status is the ‘core area,’ which can be defined as a population or group of populations made up of individuals that are genetically similar and demographically linked (Pollard et al. 2015). Status for larger population

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[31] Night snorkeling is an excellent, non-invasive alternative for road accessible sites (Decker and Hagen 2007).

units, such as Ecological Drainage Units in B.C. (Hagen and Decker 2011) or 'Designatable Units' for the country as a whole (COSEWIC 2012) can be made by rolling up the core area rankings nested within the larger management unit. For core areas, status is currently being estimated on the basis of four indicators: 1) *Distribution* (km), 2) *Abundance* of adults (including non-breeding individuals), 3) *Population trend*, and 4) *Threats* (USFWS 2005; Rodtka 2009; Hagen and Decker 2011) using the USFWS (2005) *Core Area Conservation Status and Risk Assessment Methodology*.

Conservation status is the key indicator of success with respect to *Streams Action Plan* strategic objectives for conservation and sustainable use (Section *6.1* above), and with respect to Actions *1c-2*, *1c-3*, and *1c-3*. Furthermore, conservation status estimates also provide a basis for prioritizing conservation/enhancement actions and monitoring requirements (Action *1c-3*), along with other factors such as the relative importance of the population for humans and cost-effectiveness of the proposed actions. For example, a conservation status ranking of *High Risk* (e.g. Dinosaur core area) indicates a situation where immediate action may be required, if it appears possible to improve the ranking at all. Population data used to estimate conservation status (*distribution*, *abundance*, *trend*) are also key measures of the effects of limiting factors (e.g. Parkinson and Haas 1996; Baxter et al. 1999; Johnston et al. 2007; Kovach et al. 2016).

2. Information delineating critical habitats. Critical habitats for Bull Trout are those utilized by the species during key life history stages and where limiting factors may operate. For conservation and enhancement actions to be effective in boosting the productivity of a Bull Trout population, they must target a limiting factor operating within critical habitat for either the juvenile or adult life stage. Habitat conservation and especially enhancement actions have a high financial cost, to FWCP and potentially also to other land users. Furthermore, Bull Trout populations are often distributed such that critical habitats make up a relatively small proportion of the total amount of habitat available. Therefore, relatively precise estimates of critical habitats (e.g. within a few hundred meters for some types of conservation/enhancement actions) are required prior to initiating conservation and enhancement actions (Action *1c-2*).

3. Information indicating potential limiting factors. Because of conservation concern for Bull Trout across its range, studies of limiting factors have been ongoing since the 1990s (e.g. Rieman and McIntyre 1993; Parkinson et al. 1996; Rieman et al. 1997; Dunham et al. 1997; Baxter et al. 1999; Johnston et al. 2007; Kovach et al. 2016). Monitoring data that directly demonstrates limiting factors and specific mechanisms by which they operate is extremely useful for guiding potential conservation and enhancement strategies. If the factor targeted during enhancement activities is not limiting the population, then an increased Bull Trout population is by definition unlikely. Limiting factors can be assessed in several ways: 1) directly in controlled or natural experiments, such as stream fertilization experiments (e.g. Wilson et al. 2008; Decker 2010), 2) indirectly utilizing fish habitat assessment (e.g. Johnston and Slaney 1996) or threats assessment methodologies (e.g. Lewis et al. 2016), or 3) indirectly using correlation studies (e.g. Baxter et al. 1999; Kovach et al. 2016). In the absence of prior information about limiting factors, conservation and enhancement actions should be treated as experiments, so that good effectiveness monitoring can provide an indication of limiting factors (Action *1c-4*) to guide future projects, as well as a basis for 'tuning' the enhancement prescription to improve the results.

4. Information about the effectiveness of enhancements. Effectiveness monitoring is a key component of adaptive management, and is necessary for assessing the cost-effectiveness of conservation/enhancement actions, estimating failure rates for physical habitat structures, identifying unintended ecological consequences, and acquiring feedback necessary for fine-tuning the approach (Frissell and Nawa 1993; Winsby and Stone 1996; Bray and Mylechreest 2003; Macdonald et al. 2003; Schindler et al. 2006; Wilson et al. 2008; Decker 2010). Effectiveness monitoring following conservation and enhancement actions may also be important in building a knowledge base with respect to limiting factors (Action *1c-4*).

Our ability to predict the outcomes of stream enhancement measures for Bull Trout in streams is limited at this point in time, partially because of the unique physical and hydrological setting of the upper Peace Basin relative to other areas where enhancement has been attempted, and partially because of the unique biology of the species. This necessitates that enhancements targeting Bull Trout specifically be initiated on a small scale and treated as experiments, until the basis for confident predictions of benefits has been established.

6.2.2 Recommended sequence of monitoring actions (priorities)

The information synthesis has evaluated the existing knowledge base with respect to the four key types of Bull Trout monitoring data listed in the preceding section. Based on the results, we recommend that studies to identify critical habitats and establish baseline population data (distribution, abundance, population trend) should be the priority for FWCP in the near term, because population data and critical habitat information are the basic requirements for all conservation and enhancement actions (i.e. baseline data). Furthermore, successful achievement of these objectives may lead directly to habitat conservation-based actions (e.g. riparian land securement).

In core areas where population data for large-bodied, potentially adfluvial Bull Trout are most limited (Parsnip Reach Section *5.2*, Lower Finlay Section *5.6*, Upper Finlay Section *5.7*), the following sequence of monitoring actions is recommended:

1. Acquire population data (distribution, abundance, population trend) and indicators of aquatic ecosystem health (threats) for the purposes of: 1) delineating critical habitats 2) assessing conservation status (and the need for conservation and enhancement actions), 3) prioritizing

among candidate locations for conservation and enhancement actions, and 4) establishing a quantitative baseline for effectiveness monitoring.

2. Identify critical spawning and juvenile rearing habitats for populations of large-bodied, migratory Bull Trout, at the level of geographic accuracy suitable for delineating conservation and enhancement actions.
3. Assess potential limiting factors operating within critical habitats, in order to design and initiate conservation and enhancement actions.
4. Implement conservation and enhancement actions based on achievements of previous objectives, and acquire quantitative population data (abundance, trend, distribution) necessary to assess the effectiveness of conservation and enhancement actions (and refine knowledge of limiting factors – see preceding section).

For core areas where key natal streams have already been identified (Parsnip Section *5.1*, Omineca Section *5.3*; Peace Reach and Dinosaur Section *5.4*; Finlay Reach Section *5.5*), information may already be adequate to initiate some kinds of conservation and enhancement actions (e.g. habitat reserves, stream fertilization experiments), and it may be reasonable to jump straight to later steps in the above sequence. However, given the potential high economic costs of conservation and enhancement actions, more refined estimates of critical habitats and population data are required for most sub-basins of the Williston Reservoir watershed, as identified in Section *5.0*.

Studies of limiting factors may require careful study design and adequate replication, and therefore it is unlikely that all potential limiting factors can be adequately understood prior to the initiation of enhancement actions. Therefore, as indicated in the preceding section, effectiveness monitoring should be a requirement of all major enhancement projects.

Since step #4 listed above is the ultimate goal of this program, it is desirable that progress towards this goal be maintained. Timelines for the necessary preceding steps would be difficult to predict due to the proponent-led nature of the FWCP grant application process. Therefore, a periodic progress review (e.g. every 5 years) is also recommended for inclusion in the monitoring framework, during which the need for potential directed studies could be evaluated.

6.2.3 Summary of potential studies

Within the information synthesis (Sections *1.0-5.0*), more than 40 information gaps are identified that potentially limit FWCP's ability to confidently initiate conservation and enhancement actions (Tables 2.1, 2.2, 2.3, 3.0, 5.1c, 5.2b, 5.3c, 5.4b, 5.5c, 5.6, 5.7), the majority of which are related to missing or imprecise information about critical habitats and conservation status. An overview of the potential monitoring actions identified for these data gaps is provided in Table

6.2a. These priority monitoring actions mostly address steps 1 and 2 of the recommended monitoring sequence (see preceding section).

Table 6.2a. Potential monitoring actions to address data gaps limiting understanding of conservation status, critical habitats, limiting factors, and the effectiveness of enhancement actions for Bull Trout of the Williston Reservoir watershed.

Study type	***Purpose***	***Key population data category***	***Report section (core area)***
Adult movement studies (e.g. telemetry, otolith microchemistry)	Identify key natal watersheds, habitat use, population structure	Critical habitats, conservation status	*2.1* (all); *5.1* (Parsnip); *5.2* (Parsnip Reach; *5.6* (Lower Finlay); *5.7* (Upper Finlay)
Reconnaissance spawner surveys (e.g. calibrated aerial redd counts)	'First-cut' estimates of key natal watersheds, critical habitats, adult abundance	Critical habitats, conservation status	*5.2* (Parsnip Reach); *5.5* (Finlay Reach); *5.6* (Lower Finlay); *5.7* (Upper Finlay)
Ground survey-based spawner surveys	Refine estimates of critical spawning habitat boundaries and total adult abundance	Critical habitats, conservation status	*5.1* (Parsnip), *5.3* (Omineca), *5.4* (Peace Reach), *5.5*. (Finlay Reach)
Adult abundance monitoring (e.g. redd counts in index sections, Gething C net surveys)	Estimates of spawner abundance and population trend	Conservation status, limiting factors	*5.1-5.7* (All)
Juvenile-oriented surveys (e.g. electrofishing, night snorkeling)	Refine/establish estimates of critical juvenile rearing habitat boundaries	Critical habitats	*5.1* (Parsnip), *5.3* (Omineca), *5.4* (Peace Reach), *5.5*. (Finlay Reach)
Genetic studies	Population structure and gene flow to refine core area boundaries	Conservation status	*2.1* (All)
Age, life history, and growth studies	Monitor effects of ecological changes, limiting factors	Conservation status, limiting factors	*2.2* (All)
Temperature monitoring	Assess thresholds of thermal suitability, baseline thermal conditions in critical habitats	Conservation status, limiting factors	*2.3* (All)

Fish access assessment	Enable fish access improvement in degraded environments, assess potential barrier removal	Limiting factors	*2.3* (All)
Lake Trout abundance and habitat use monitoring	Assess threat posed by increasing populations of Lake Trout in Williston Reservoir	Conservation status, limiting factors	*2.3* (All)
First Nations-led fisheries monitoring	Assess harvest rates, sustainable fisheries management	Conservation status, limiting factors	*2.3* (All)
Effectiveness monitoring	Treat enhancements as experiments with appropriate monitoring standards	Effectiveness monitoring, limiting factors	*2.3* (All)
Laboratory and field experiments	Assess specific mechanisms by which limiting factors operate	Effectiveness monitoring, limiting factors	*2.3* (All)

6.2.4 Update on recent Bull Trout monitoring actions

In a proposal-driven process, with many potential proponents, coordination among monitoring proposals to ensure that key monitoring data requirements are met is an obvious challenge. To better meet that challenge, this section is meant to raise awareness of recent directions in FWCP’s Bull Trout monitoring activities, new data about to come online, and opportunities for collaboration.

Prior to 2013, FWCP’s Bull Trout monitoring program in the Williston Reservoir was comprised primarily of annual redd counts in index sections of four known spawning tributaries Davis River (since 2001), Point Creek (since 2006), Misinchinka River (since 2006), and Scott Creek (since 2009) (Andrusak et al. 2011). Reviews of this program in 2011 and 2013 (Andrusak et al. 2011; Hagen and Pillipow 2013) confirmed the value of these trend data, but pointed out limitations of the redd count program including:

1. the lack of information indicating key Bull Trout natal streams,
2. the lack of data indicating the spatial extent of critical habitats,
3. the lack of information about Bull Trout spawner abundance among the reservoir’s tributaries, which precluded total abundance estimates for core areas and assessments of the relative importance of individual Bull Trout streams, and

4. the limited number of index reaches for monitoring population trend, which was considered inadequate for assessing status for the reservoir as a whole and for evaluating potential limiting factors.

Since, that time, the scope of FWCP's Bull Trout monitoring has increased. Beginning in 2013, a rapid, aerial redd count methodology has been utilized to identify key natal watersheds, critical habitats, and total abundance at the scale of whole core areas (Hagen and Pillipow 2014; Hagen et al. 2015; Hagen and Spendlow 2016, 2017, 2018, 2019; Euchner 2017a; 2018). The Parsnip, Omineca, Peace Reach, and significant portions of the Finlay Reach core area have now been assessed, providing a starting point for more detailed studies enabling habitat-based conservation actions as detailed in the pages of the information synthesis (Section *5.0*). These follow-up studies provide good opportunities for First Nations and their consultants, but require collaboration with experienced biologists and field technical staff familiar with the recommended methods. Proponents should feel free to consult the authors on potential study methods and target watersheds, and to address questions they may have about how to get started.

It should be noted that major portions of the Parsnip Reach and Finlay Reach core areas, and the entire Lower Finlay and Upper Finlay core areas, are yet to be assessed using the reconnaissance aerial redd survey methodology. Assessments have been funded by FWCP for the 2019 field season and proposed for 2020, and should generate a substantial number of proposals for follow-up studies.

Beginning in 2013, new redd count index sections, which are surveyed on foot, have also been added to the monitoring program to improve assessments of population trend, a key indicator of conservation status and limiting factors (O'Grady et al. 2004; McElhany et al. 2000). To prevent major increases in program costs, a new approach with regard to the frequency of index surveys was necessary within these new index sections. Hagen and Spendlow (2019) identify desired minimum data requirements of 5 surveys over a minimum 10- to 15-year period for these new sections (Humbert et al. 2009; Kovach et al. 2016). To date, 12 new index sections have been established to begin this expanded program of monitoring population trend (Table 6.2b). An additional 4-8 index sections are likely to be created during reconnaissance aerial redd count surveys in 2019 (funded by FWCP) and 2020 (proposed for funding).

Observer experience is a key factor affecting the reliability of redd counts as indices of population abundance (Dunham et al. 2001; Muhlfeld et al. 2006). Therefore, collaboration with individuals and consultants experienced in conducting redd counts is highly recommended to potential proponents. Alternatively, proposals to provide training in Bull Trout stock assessment methods to those without the necessary experience could also be considered.

Within the pages of the information synthesis, movement studies have been identified as a study technique for assessing population structure and ecological factors potentially affecting Bull

Trout demography and genetics. A movement study utilizing the method of acoustic telemetry was initiated by a UNBC-led team in 2018, and has been funded for 2019-20 as well (FWCP Project No. PEA-F20-F-2961 *Spatial ecology of Arctic Grayling in the Parsnip River core area*). The goal of the project is to identify ecological (e.g. potential predation) and physical (e.g. water temperature) factors affecting Arctic Grayling movements. As a potential predator of Arctic Grayling, Bull Trout have also received acoustic tags which will allow biologists to learn more about movements and biology of Bull Trout in the Williston Reservoir watershed. Future movement studies are likely to benefit from the findings and recommendations of this study once they have been delivered to FWCP.

Table 6.2b. (*Document with unredacted UTMs available from Susanne Weber*: susanne.weber@gov.bc.ca) New redd count index sections (foot surveys) established in the Williston Reservoir

			Redds in New Section					
Stream	Section Length (km)	UTM bottom; UTM top	2013	2014	2015	2016	2017	2018
Point Creek (Section 1)	1.6	**Redacted**	22	na	na	4	4	11
Davis Trib #2 (230-966200-75300)	1.2	**Redacted**			35	35	30	50
Davis Trib #3 (230-966200-75600)	2.6	**Redacted**			na	72	20	21
Anzac Unnamed (236-313100-60100)	1.8	**Redacted**		26	21	26	na	na
Anzac (Upper mainstem)	1.4	**Redacted**				8	na	na
Pelly (Ingenika watershed)	5.5	**Redacted**					61	na
Lay (Mesilinka watershed)	3.6	**Redacted**					25	32
Osilinka (Upper mainstem)	4.2	**Redacted**					25	22
Osilinka S. Fork (238-024000-74400)	3.8	**Redacted**					22	18

Big Creek (Omineca watershed)	2.7	**Redacted**	26
Carruthers Creek (Omineca watershed)	4.6	**Redacted**	38
Misinchinka unnamed (236-073000-78200)	1.2	**Redacted**	16

6.2.4 Guidance for proponents

This monitoring framework is intended to be one element in a strategy to guide proponents wishing to develop FWCP grant applications for Bull Trout monitoring projects. Table 6.2a, along with the sequence of monitoring actions laid out in Section *6.2.2*, provide a general roadmap for proponents, but these aids should not preclude innovative study ideas and other monitoring priorities if they can be rationalized.

The other key sources of background information are:

1. *Streams Action Plan*. Specifically, objectives *1c-2*, *1c-3* and *1c-4* of the FWCP Peace Basin *Streams Action plan* (FWCP 2014).

2. *The Bull Trout information synthesis in preceding sections of this report (Sections 1.0-5.0)*. An essential step for proponents during proposal development is to familiarize themselves with the existing knowledge base (if available) specific to the core area and sub-basin of interest, which is summarized for them on a core area-by-core area basis within the pages, tables, and figures of Sections *5.0* of this report.

3. *Yearly guidance from FWCP*. In addition to the background documents discussed above, guidance on fwcp.ca and the grant application information kit for each funding cycle should also be considered by potential proponents, because additional prioritization of data gaps and associated monitoring actions for Bull Trout are likely to occur, for example during the five-year update of the FWCP *Streams Action Plan*, which is scheduled in 2019-2020.

4. *First Nations knowledge*. A study of First Nations knowledge on Bull Trout, Kokanee, and Arctic Grayling populations of the Williston Reservoir watershed was completed during winter 2019 and reviewed for this report (Pearce and Abadzadesahraei 2019; Pearce et al. 2019a, 2019b, 2019c, 2019d). Relatively little of this knowledge has made it to the pages of the Bull Trout information synthesis, because: 1) site-specific information that is most useful for identifying key natal streams (e.g. family fishing locations) is the property of communities and individuals and is considered sensitive, and 2) precise information about critical habitats and status was generally not available. The First Nations Knowledge study

has nonetheless generated important information about community concerns and recommendations. Potential proponents are advised to review the concerns, priorities, and knowledge presented in these reports prior to developing study proposals.

Neither the Bull Trout information synthesis nor the monitoring framework have prioritized particular core areas for monitoring actions and subsequent conservation and enhancement actions. The primary reason for this is that FWCP strategic objectives concerning sustainable use and community engagement (Section *1.0*) are best served by distributing studies across the entire footprint impact area for the W.A.C. Bennett and Peace Canyon dams, as soon as it is feasible to do so. The broad geographic scope and relatively non-prescriptive nature of the monitoring framework recommendations, along with the FWCP grant application process, ensure that proponents have equal opportunity regardless of where they are situated, are able to propose work in watersheds of high First Nations and community interest, can incorporate traditional and local knowledge to support prioritization of monitoring actions, and can incorporate innovative methods into study proposals.

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