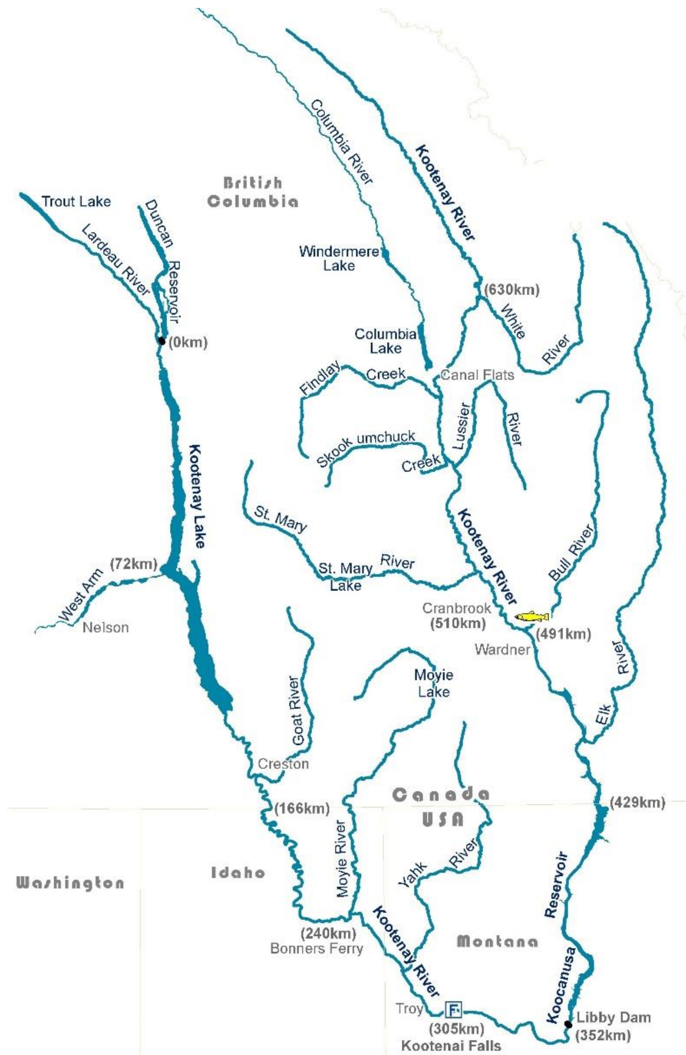
Upper Kootenay River Burbot Conservation Strategy

March 2019



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Conservation strategies delineate reasonable actions that are believed necessary to protect, rehabilitate, and maintain species and populations that have been recognized as imperiled, but not federally listed as threatened or endangered under the Canadian Species at Risk Act or the US Endangered Species Act. This Conservation Strategy resulted from cooperative efforts of the East Kootenay Burbot Scientific Working Group (EKBSW). The EKBSW includes British Columbia and Montana agencies, First Nations, and consultants. This Conservation Strategy does not necessarily represent the views or the official positions of agencies involved with its formulation and will be subject to modification through collaboration, new findings, changes in species status, and the completion of conservation tasks.

ACKNOWLEDGEMENTS

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The members of the East Kootenay Burbot Scientific Working Group (EKBSW), and numerous local citizens are gratefully acknowledged for their contributions to this Burbot Conservation Strategy. The Kootenay Valley Resource Initiative (KVRI) is recognized for sharing their data, expertise, and providing guidance from their lessons learned while restoring Burbot in the lower Kootenay River during the past 15 years.

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EXECUTIVE SUMMARY

The following Upper Kootenay Burbot Conservation Strategy stems from a collaboration among the members of the East Kootenay Burbot Scientific Working Group (EKBSW). The Conservation Strategy was based on input collected from the EKBSW at January and June 2018 meetings in Cranbrook, B.C. The goal is to provide a document outlining the restoration of Burbot in the upper Kootenay River for distribution, communication and input from all levels of government, First Nations, Communities of Interest, stakeholders and potential funding partners.

The EKBSW was formed in December 2015 to direct research, monitoring and management of Burbot (*Lota lota*) in the East Kootenay. This area included the upper Kootenay River, its tributaries and lakes from Kootenai Falls in Montana upstream to its headwaters in British Columbia and the upper Columbia River, its tributaries and lakes from Golden to its headwaters at Columbia Lake.

Since 2016, the EKBSW has reviewed existing information, identified gaps in knowledge, and directed initiatives on Burbot in the East Kootenay. Collaboration among partners has implemented robust methods to collect relative abundance information for Burbot in the upper Kootenay River and Koocanusa Reservoir, the St. Mary River and St. Mary Lake, and Columbia Lake. The conclusion of the EKBSW in 2017 was that there was an urgent need for recovery of Burbot populations in the East Kootenay.

Burbot are an iconic food fish of First Nations within the East Kootenay; as well as early European settlers and more recent residents within the region. Historically, Burbot fishing was unregulated and Burbot were harvested on spawning grounds with spears, pitchforks and later, using setlines. In the 1900’s artisanal commercial fisheries for Burbot evolved and markets for Burbot existed in Bonners Ferry Idaho into the mid-1990’s. Burbot have also supported several popular recreational fisheries. In the mid-1970’s through the late 1990’s Burbot population declines and collapses were documented in Kootenay Lake and the Kootenay River (Kootenai in U.S.).

Within the East Kootenay region, increasingly restrictive Burbot harvest regulations have been implemented with no effect. Decades of monitoring demonstrate the upper Kootenay River population has collapsed and the continued low abundance threatens their viability and persistence. As Burbot populations in the lower Kootenay River reached similar abundance levels, the Kootenai Valley Resource Initiative (KVRI) developed a Conservation Strategy to prevent the extirpation projected to occur within a decade. Without immediate, substantive management actions, native Burbot in the upper Kootenay River watershed will likely share the same fate of the lower Kootenay River and Kootenay Lake populations and disappear completely or be functionally extinct.

Based on the success of Burbot restoration efforts in the lower Kootenay River, the recommendation of the EKBSW was to collaborate with the KVRI to adopt and build upon their methods. This includes the development and implementation of a Burbot Conservation Strategy that employs a conservation aquaculture program in an adaptive management framework to direct recovery efforts of East Kootenay Burbot populations. The upper Kootenay River strategy represents the first phase of the larger EKBSW initiative. It is anticipated the upper Columbia River Burbot Conservation Strategy (Golden to Columbia Lake) will follow

once the upper Kootenay River strategy has been implemented and demonstrating the anticipated improvements in population abundance, viability and sustainability.

The Kootenai Tribe of Idaho and the University of Idaho developed Burbot aquaculture techniques to provide fish for a conservation stocking program in the lower Kootenay River. Brood stock and gametes for the development of Burbot aquaculture techniques were provided by the British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) from Kootenay Region populations (Duncan Reservoir, Arrow Reservoir, Moyie Lake). This research is ongoing at the Kootenai Hatchery and at the University of Idaho's Aquaculture Research Institute. Stocking of Burbot larvae and juveniles in the lower Kootenay River since 2009 has dramatically improved the catch rates and age structure of the population and provided a means to identify factors limiting Burbot recruitment. Researchers there are now moving forward with planning a recreational fishery in 2019.

The goal of this Conservation Strategy is to restore and maintain a viable native Burbot population within the upper Kootenay River, its tributaries and lakes (including Koocanusa Reservoir) to abundance levels that restore the provision of harvest opportunities for sustainable sustenance and recreational fisheries. Three objectives address this goal: (1) maintain at least 17,000 adults in a Burbot population above Libby Dam; (2) provide consistent natural recruitment in several different spawning areas (i.e., upper Kootenay River and Koocanusa Reservoir, St. Mary Lake and tributary habitats) with net recruitment and juvenile population size sufficient to support at least 17,000 adult Burbot; and (3) produce stable size and age class distributions. Recruitment for Burbot recovery will come from natural production, conservation aquaculture, or from some combination of the two.

The next step towards implementation of this Conservation Strategy is the development of a Burbot Restoration Action Plan, that details and prioritizes conservation measures allowing their progress to be tracked. Key near-term components of a Burbot Restoration Action Plan will include an aquaculture stocking strategy and a monitoring plan. Tasks associated with these components involve the selection of a donor stock, release locations and index sites for standardized abundance estimates.

This project was financially supported by the Columbia Basin Trust and Fish and Wildlife Compensation Program (FWCP) and is aligned with the Upper Kootenay Ecosystem Enhancement Plan (2016). The plan identifies Burbot as a Species of Interest and a high priority. The first action item in the Lakes Plan called for a review of existing information on condition and limitations of habitats used by Burbot including past and present management actions and identification of data gaps.

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1.0 INTRODUCTION

Within the Kootenay Region, Burbot (*Lota lota*) are an indigenous freshwater cod that once supported substantial First Nations, commercial and recreational fisheries in the Kootenay and Columbia River watersheds (Paragamian et al. 2000, Prince 2001, Ahrens and Korman 2002, KVRI 2005). Today, most of these populations are in serious decline and are considered imperiled. The most infamous of which is the Burbot population in Kootenay Lake. The Burbot fishery in Kootenay Lake's West Arm rapidly diminished from an annual harvest of over 26,000 Burbot in 1969 to none in 1987 and is now considered functionally extinct (Ahrens and Korman 2002, Neufeld 2006). The Lower Kootenay Burbot population has been red listed in British Columbia since 2004 (B.C. Conservation Data Center). The population's collapse was accelerated by overfishing but continues to experience persistent recruitment failure attributable to habitat and flow alterations (Ahrens and Korman 2002, Hardy and Paragamian 2013).

Many large-scale ecological changes have occurred on the Kootenay River that negatively affect native Burbot stocks. Two of the most serious impacts are thought to be loss of the natural Kootenay River floodplain and operation of Libby Dam. Constructed by the U.S. Army Corps of Engineers in 1972 for hydropower production and flood control management (Paragamian et al. 2000, KVRI 2005), Libby Dam was the last of the Columbia River Treaty Dams. Increased winter discharge and water temperatures, habitat alterations, changes in productivity, over-harvest, contaminants, and ecological community composition shifts have been cited as possible contributing factors to the decline of Kootenay Basin Burbot (Paragamian et al. 2000, Ahrens and Korman 2002, Hammond and Anders 2003, Paragamian et al. 2005, Cope 2016). Throughout the Kootenay Region, no single factor appears responsible for the collapse of Burbot populations as their reduced abundance and diminished size structure has been widespread and includes un-impounded habitats.

Concerns over declining upper Kootenay and Columbia River Burbot populations led to the implementation of several monitoring programs by both United States and Canadian Governments. In the U.S. portion of Koocanusa Reservoir, long term Burbot population monitoring indicates that Burbot abundance has been declining since the late 1980's (Dunnigan et al. 2018). Upper Kootenay River Catch-Per-Unit-Effort (CPUE) estimates of 0.015 fish per trap day are now similar to those in the lower Kootenay River below Kootenai Falls prior to Burbot restocking efforts.

In 2006, the British Columbia Ministry of Environment (MOE) began closing Burbot fisheries in the upper Kootenay and Columbia River drainages. In the years since, increasingly restrictive fishing regulations within the upper Kootenay and Columbia River watersheds have been implemented to limit mortality and facilitate population recovery. Despite these measures, indications are that upper Kootenay River Burbot populations have continued to decline (Robinson 2013, Thomas 2016, Cope 2016, Smithson and Robinson 2017, Dunnigan et al. 2018). Catch rates from traditional First Nations fisheries also indicate that Burbot abundance has been rapidly diminishing in the Canadian portion of Koocanusa Reservoir (Working Group First Nation Representative, 2016 personal communication).

In response to concerns over declining Burbot populations and the loss of subsistence and recreational Burbot fisheries, the East Kootenay Burbot Scientific Working Group (EKBSW) was formed in 2015. The goal of the EKBSW was to provide robust scientific oversight and to direct research, monitoring and management of Burbot (*Lota lota*) in the East Kootenay

Region. The management area of concern for the EKBSW included the upper Kootenay River and its tributaries and lakes from Kootenai Falls in Montana upstream to its headwaters in British Columbia, and the upper Columbia River and its tributaries and lakes from Golden upstream to its headwaters at Columbia Lake.

Since 2016, the EKBSW has reviewed existing information, identified gaps in knowledge, and directed initiatives on Burbot abundance estimates in the East Kootenay. The conclusion of the EKBSW in the 2017 and 2018 meetings was that there was an urgent need for recovery of Burbot populations. The EKBSW recommendation was to collaborate with the Kootenai Valley Resource Initiative (KVRI) to build on their methods for implementation in the upper Kootenay River. This includes a Burbot Conservation Strategy that employs a conservation aquaculture program in an adaptive management framework to direct recovery efforts of East Kootenay Burbot populations. The upper Kootenay River initiative represents the first phase of the East Kootenay initiative; with the upper Columbia River Burbot Conservation Strategy (Golden to Columbia Lake) to follow once the upper Kootenay River strategy has been implemented and demonstrating the anticipated improvements in population abundance, viability and sustainability.

The Upper Kootenay River Burbot Conservation Strategy represents the collective contribution of the EKBSW towards a management plan to conserve and restore Burbot in the upper Kootenay River Basin. The development of this strategy aligns directly with Upper Kootenay Ecosystem Enhancement Plan action items which identify Burbot as a Species of Interest.

2.0 STUDY AREA

From its confluence with the White River, the known upstream distribution of Kootenay River Burbot, the Kootenay River follows a meandering course along the Rocky Mountain Trench for approximately 139 km to Wardner B.C. (Figure 1). There, the Kootenay enters the northern end of Koocanusa Reservoir (referred to as Libby Reservoir in the U.S.). At full pool, the reservoir extends south 145 km from Wardner with 68 km of its length located in British Columbia and 77 km in Montana (Parnell 1997). The Kootenay River drains an area of 19,840 km^2 to the international boundary and was unregulated prior to the construction of Libby Dam in 1972. The Kootenay River remains unregulated upstream of Wardner B.C. to its headwaters. The major east bank tributaries of the upper Kootenay River are the White, Lussier, Wildhorse, Bull and Elk Rivers. The Findlay, Skookumchuck, and St. Mary Rivers are the major west bank tributaries. Downstream of Libby Dam, the Kootenay River flows for another 47 km through Montana to Kootenai Falls, which represents a geographic barrier to upstream Burbot migration and the downstream distribution limit of the upper Kootenay Burbot population. The distribution of Burbot in the upper Kootenay River and Koocanusa Reservoir (284 km, 331 km including Libby Tailwater reach) approximates that in the lower Kootenay River (305 km) from Kootenai Falls to the North end of Kootenay Lake. The study area includes the upper Kootenay River, Koocanusa Reservoir, all tributaries and lakes.

Note that the Kootenay River is the Canadian spelling in British Columbia and the same river is referred to as the Kootenai River for the portion flowing within the U.S.

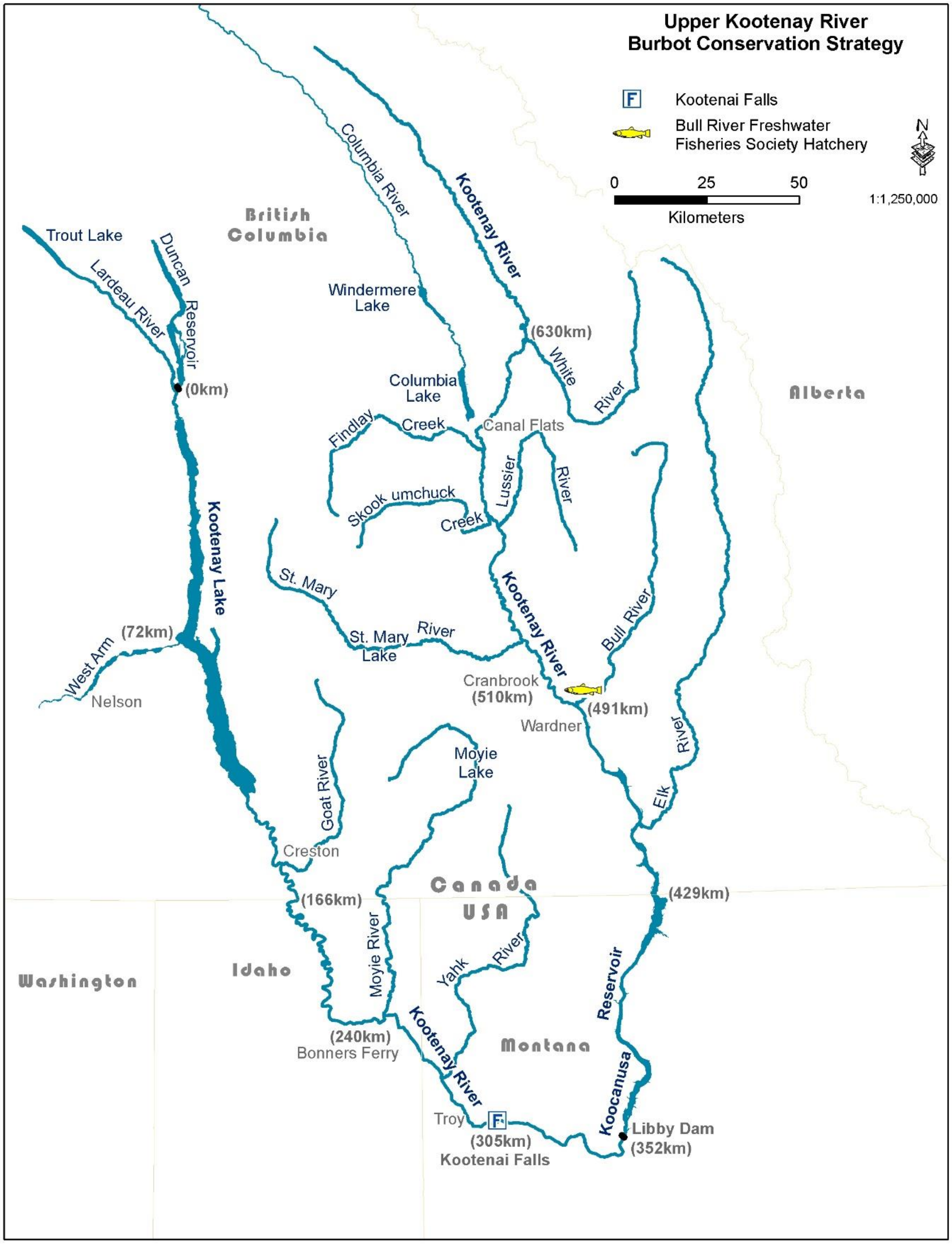


Figure 1. Kootenay River Basin and its major tributaries. Upper and Lower Kootenay River Burbot populations are separated by Kootenai Falls, Montana.

3.0 BACKGROUND: BURBOT BIOLOGY

The following background regarding the biology of the Burbot is necessary to understand the nature and extent of threats to this enigmatic species and the recommendations stemming from this Conservation Strategy.

3.1 Species Description

The Burbot (*Lota lota*) is the only freshwater representative of the cod family, Gadidae (McPhail and Paragamian 2000) and is commonly referred to as ling or lingcod. Most Burbot attain lengths of 300 to 600 mm with weights of 1 to 3 kg (McPhail and Paragamian 2000). In the Kootenay Region, larger Burbot (greater than 1000 mm) have been regularly documented in the fishery and population assessments (Prince 2001, Prince 2011, Cope 2011, Robichaud 2013, Kang et al. 2016).

Burbot mature at 3-6 years of age and are highly synchronous broadcast spawners where one or two females are surrounded by many males (Arndt and Hutchinson 2000, McPhail and Paragamian 2000, Hubert et al. 2008, Klein et al. 2016). In Moyie Lake B.C., which drains into the lower Kootenay River, a spawning ball of over 100 Burbot was filmed on 28 February 2008 near Cotton Creek (Neufeld and Spence 2009). Tiny (~1mm) non-adhesive eggs and sperm are released over an unprepared site as the spawning "ball" writhes about in the water column (Figure 2) where they drift downstream before settling to the substrate. This synchronous behavior results in large aggregations of spawners in shallow water habitats which were historically exploited as an important winter food source.

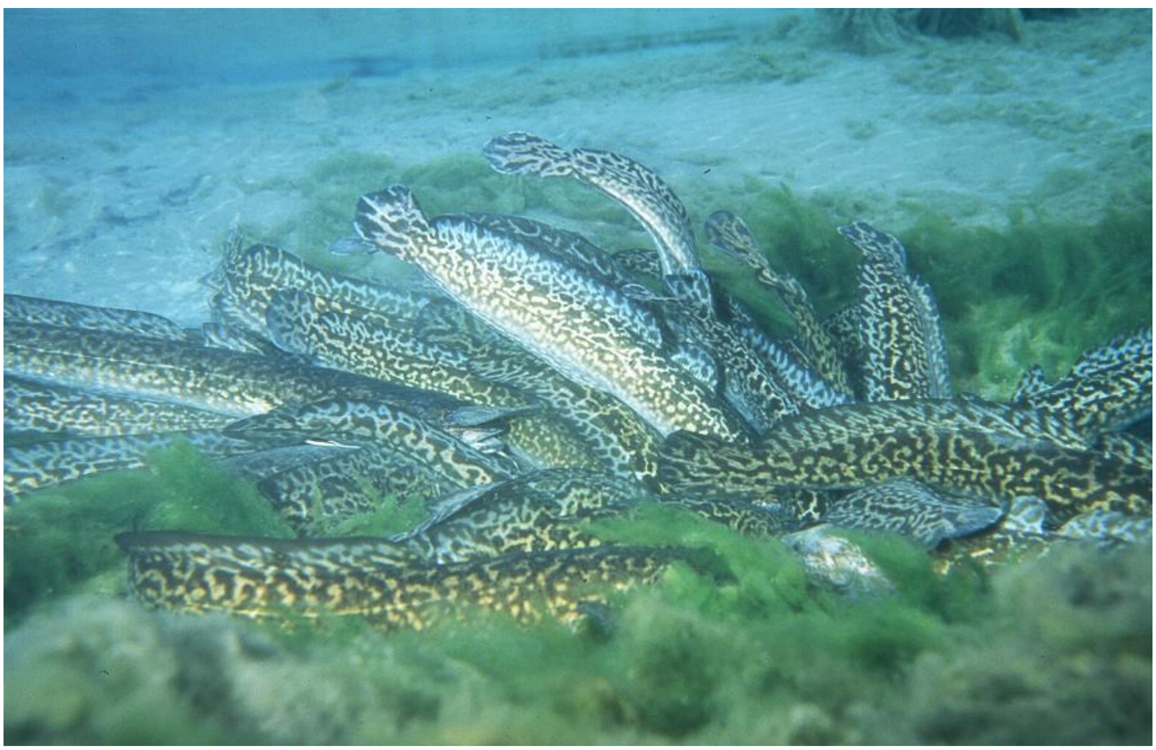


Figure 2. Spawning aggregation of male and female Burbot in an unnamed tributary to Columbia Lake, British Columbia. (Photo courtesy of Ernest Keeley, Idaho State University, in KVRI 2005).

Burbot are iteroparous (spawn several times over their lifetime), but individuals may not spawn every year. The spawning frequency of Burbot is highly variable, with reports varying from 60% to 95% in a given year (Evenson 1990, Pulliainen and Korhonen 1990, 1993). In the Columbia-Kootenay basin, Arndt and Hutchison (2000) reported that 3.1 to 18.2% returned to the spawning weir in consecutive years; other fish either did not spawn or spawned in a different location.

Individual fecundity of Burbot is high and an exponential relationship exists between Burbot length and fecundity (Brylinska et al. 2002, Klein et al. 2016). Estimates of egg number range from 6,300 to 3,477,699 (McPhail and Paragamian 2000 and references therein) with an average of 1 million eggs/kg bodyweight (Vught et al. 2007). Average fecundity can vary substantially between fish from different lakes in the same region (Boag 1989, Hubert et al. 2008).

Burbot life span varies geographically. Adult Burbot typically live between 7 and 12 years, and northern populations generally contain older (22 yrs.) fish than southern populations (McPhail and Paragamian 2000). In the Kootenay Region, Burbot ages of 24 years have been documented (Cope 2010). There is extreme variation in length-at-age in Kootenay Burbot that is believed to result from differences in growth rates (Cope 2010, Neufeld et al. 2011). For example, a 600 mm Burbot could be between 5 to 16 years old in Moyie or Arrow Lakes, between 7 to 19 years in Kinbasket Reservoir, and 9 to 21 years old in Trout Lake (Cope 2010). Given that Kootenay Burbot greater than 1000 mm have been consistently recorded in the fishery and population assessments (Prince 2001, Prince 2011, Cope 2011, Robichaud, 2013, Kang et al. 2016), the structure of historical and self-sustaining Kootenay Burbot populations likely contains individuals longer lived than 12 years (Cope 2010).

Burbot are physoclists; meaning they have no pneumatic duct connecting their air bladder to the digestive tract so that fish with these swim bladders must diffuse gas from the blood to fill and collapse them which is a more derived trait (McPhail 2007). The drawback to this system is the reduced rate at which gas transfer occurs across the swim bladder, leaving Burbot extremely susceptible to decompression trauma compared with physostomes (e.g. salmonids) that simply burp air to alter buoyancy.

For most Gadiformes, the swim bladder has the additional role of transferring sound waves to the auditory system and is used to make sounds and communicate with other fish (Berenbrink 2007, Normandeau Associates, Inc. 2012). Burbot have complex calls and use both low (less than 100 Hz) and high frequency (up to 500 Hz) in their vocalizations during the spawning period (Cott et al. 2014). Burbot drumming muscles increase in mass towards the spawning season, but are no different for males than females, suggesting that calling is made by both sexes during the spawn period (Cott et al. 2013a). In Atlantic cod, males with larger drumming muscles (and presumably stronger vocalizations) are more attractive to females and thus are linked to mate selection and mating success (Rowe and Hutchings 2008).

3.2 Genetics

Burbot in the Kootenay Basin region are believed to have recolonized after the most recent Pleistocene glacial retreat 10,000 to 15,000 years ago, when Kootenai Falls was created (McPhail 1997). Therefore, the Burbot population upstream of Kootenai Falls has been naturally isolated from the lower river population for at least 10,000 years. Recent fragmentation and physical isolation mechanisms in the Basin include two Columbia River

Treaty Dams: Duncan Dam (1967) and Libby Dam (1972) (Figure 1). In addition, spatial and temporal reproductive isolation may have existed between Burbot in West Arm Kootenay Lake and Burbot in upstream tributaries of the lower Kootenay River (Martin 1976, Ahrens and Korman 2002, Hammond and Anders 2003). It has been suggested even modest natural barriers can result in genetically distinct Burbot populations (Underwood et al. 2015).

Within the Kootenay River Burbot distribution, Burbot are comprised of two clades (i.e., groups evolved from a common ancestor): Pacific and Mississippi. The majority of Burbot populations sampled throughout the Kootenay Basin belong to the Mississippi clade (Powell et al. 2008). It is believed ice dams formed at the west arm outlet of Kootenay Lake during the most recent glaciation, causing the Kootenay River to flow south through the Purcell trench allowing Pacific Ridge Burbot to pass north into the lower Kootenay River (Powell et al. 2008). Thus, Burbot above Kootenai Falls are Mississippi clade while those below are predominantly Pacific clade with some intergrade (Paragamian et al. 1999, Powell et al. 2008). The tributary populations of Kootenay Lake Burbot (i.e., Trout Lake and Duncan Reservoir) are Mississippi clade while Burbot in Kootenay Lake are primarily Mississippi clade with some intergrade (Powell et al. 2008). The management implications from these findings are that mitigative efforts in the Kootenay River Basin must address the needs of two genetically divergent Burbot stocks (Paragamian et al. 1999).

3.3 Distribution and Movements

Burbot exhibit a circumpolar holarctic distribution (McPhail and Paragamian 2000). In the Kootenay basin Burbot were historically distributed throughout lakes and rivers; however, many populations were extirpated by the 1990’s and efforts towards restoration are now under way (Paragamian et al. 2000, Neufeld 2006, Ross et al. 2018). Within the upper Kootenay River, Burbot are distributed widely and have been documented within the mainstem river as far upstream as the White River (McPhail 1997, Cope and Morris 2003), in tributaries such as the St. Mary River and St. Mary Lake (MOE 1981, Prince 2007), and Koocanusa Reservoir (Dunnigan and Sinclair 2008, Smithson and Robinson 2017) (Figure 1). In a recent three year study (2014-2016) on Koocanusa Reservoir, adult Burbot were encountered at Sand Creek (n=24), Gold Creek (n=2) and the Elk River (n=14) during the spawning season (Minnow Environmental Inc. 2018).

Burbot across their circumpolar distribution are reported to have three life history forms: lacustrine, adfluvial, and fluvial that often co-exist within the same system (McPhail 2007). Lacustrine forms spend their lives within a lake and spawn on shoals (e.g., Moyie Lake, Stephenson and Evans 2015). Many Kootenay Burbot lake populations have a combination of shoal and tributary (adfluvial) spawners. Examples include: Columbia Lake (Arndt and Hutchingson 2000), Arrow Lakes (Robichaud et al. 2013), Kinbasket Reservoir (Kang et al. 2016), Kootenay Lake (Andrusak 1998, Spence 1999; Paragamian et al. 2000), and Duncan Reservoir (Cope 2011). Adfluvial Burbot can move long distances. In Kinbasket Reservoir, Burbot migrated 75km to large tributaries (i.e., Sullivan and Columbia Rivers) after which they continued moving upstream beyond the limits of the passive telemetry array and were not subsequently detected (Kang et al. 2016).

Fluvial populations of Burbot, those that live and spawn in rivers, can also move great distances. In the upper Kootenay River, several radio and sonic tagged Burbot were tracked 60-80 km upstream from their tagging location in the Montana portion of Koocanusa Reservoir to the upper river at Wardner B.C. (Snelson and Muhlfeld 1996, Dunnigan and Sinclair 2008). In another Koocanusa Burbot telemetry study, one Burbot was located 150 km upstream at the mouth of Mark Creek, a tributary of the St. Mary River (Ostrowski et al. 1997). Another Floy tagged Koocanusa Burbot was captured 120 km upstream in St. Mary Lake (Bill Westover, Ministry of Environment (retired), 2006 personal communication). In the lower Kootenay River, Paragamian and Whitman (1997) tracked a male Burbot for over 450 km and one tagged hatchery juvenile (2 yrs.) was reported migrating up to 235 km (Stephenson et al. 2013). During spawning, Burbot movement rates in the lower Kootenay River ranged 8 to 11 km/day (Paragamian et al. 2005). These migrations are influenced by water temperatures and flow (Paragamian et al. 2005, Paragamian and Wakkinen 2008, Hardy and Paragamian 2013).

3.4 Spawning

Among Canadian lake Burbot populations, spawning dates range from the last week of January to mid-March (most commonly within the first three weeks of February), and date of spawning is not strongly related to latitude or lake characteristics (Cott et al. 2013b). Reports in the Kootenay Basin indicate some variation in the timing of Burbot spawning depending on location. Populations in Columbia (Arndt and Hutchingson 2000), Windermere (Hutchingson 1996, Arndt 2001), and Moyie Lakes (Neufeld and Spence 2009, Stephenson and Evans 2015) all identified peak spawning in the middle of February. Spawn timing of the hatchery population in the lower Kootenay River has ranged from mid February to early March (Hardy et al. 2015, Ross et al. 2018). Historical Burbot spawning in the West Arm of Kootenay Lake, B.C. was not well documented, but could have been as late as April and continued into late May or early June (Martin 1976, Andrusak 1981). The timing of spawning is believed to be related to water temperature, but also driven by intrinsic factors, given the synchronicity of timing across their range (Vught et al. 2007, Zarski et al. 2010, Cott et al. 2013b).

In lakes and rivers, Burbot generally spawn in shallow depths (0 to 10 m) over a variety of substrates from silt and sand to coarse gravel and cobble (McPhail and Paragamian 2000); though deep-water shoal spawning has been reported in the Arrow Lakes (Robichaud et al. 2013) and Great Lakes (Jude et al. 2013). In rivers, Burbot spawn in low velocity areas, or in side channels behind deposition bars (McPhail and Paragamian 2000). In lakes, spawning usually occurs over shallow reefs and shoals (McPhail and Paragamian 2000).

Direct observations of Burbot spawning are now rare in the Kootenay Basin due to low abundance and poor ice conditions. Burbot spawning in a small, groundwater fed tributary of Columbia Lake were observed at depths less than 1 m and over cobble substrates (Arndt and Hutchinson 2000). Adult Burbot in Moyie Lake were identified over shoals at depths of 1.5 to 7.5 m over 1,500 meters (Neufeld and Spence 2009). Substrate in this location was comprised of gravel and cobbles estimated to range from 1 to 20 cm in diameter, with some larger substrate present (Prince and Cope 2008). In the North Arm of Kootenay Lake near Davis Creek, Burbot spawning was associated with cobble and boulder substrate in 0.5 to 1.5 m depths (Spence 1999).

The winter spawning season corresponds to a period of ice and temperatures less than 4°C which is a critical incubation temperature for Burbot (Taylor and McPhail 2000, Vught et al. 2007, Zarski et al. 2010). Survival from fertilization to hatching is highest at 3.0 to 3.8 °C, and all embryos die above 6 °C (Taylor and McPhail 2000, Vught et al. 2007). Incubation periods have been reported at 30 to 70 days depending on water temperatures (McPhail and

Paragamian 2000, Jude et al. 2013), with time to hatch at 4°C being 32 days (Taylor and McPhail 2000).

3.5 Life History

Studies suggest Burbot numbers are limited by recruitment, as mortality rates of larvae are high (McPhail 1997, Taylor and McPhail 2000). Larval size at hatching is reported between 3 and 9 mm (McPhail and Paragamian 2000, Fischer 1999, McPhail 2007, Jude et al. 2013). Densities are high shortly after hatching but drop within a month (McPhail and Paragamian 2000) when larvae reach a size of 10 to 15 mm (Jude et al. 2013). Larval Burbot are capable of exogenous feeding within a few days post-hatch (McPhail and Paragamian 2000), but endogenous feeding can last between 11 and 23 days (Fischer 1999). The first few days of exogenous feeding are critical to Burbot survival as they require large amounts of nutritious prey (Jensen et al. 2010).

Food items consumed by exogenously feeding larval Burbot vary. Some studies have indicated that the first food items taken by larval Burbot are rotifers (Ghan and Sprules 1993, Vught et al. 2007), while others suggest the first foods are phytoplankton and that larvae then switch to copepod nauplii after day 3 of exogenous feeding (Vatcha 1990). Vught et al. (2007) also found that starter food (rotifers) needed to be replaced after 7 to 8 d with larger *Artemia* nauplii. Others have found that larval Burbot avoid rotifers and instead begin feeding immediately on copepod nauplii (Ryder and Pesendorfer 1992, Wang and Appenzeller 1998). In the Great Lakes, Burbot larvae negatively selected spined rotifers and cladocerans and instead, exhibited a strong selectivity for cyclopoid copepods (Ghan and Sprules 1993, Probst and Eckman 2009, George et al. 2013). Prey selectivity was consistent across depths and habitats and showed little variation during the larval stage (Ghan and Sprules 1993, Probst and Eckman 2009, George et al. 2013). Thus, the availability and proportion of suitable zooplankton is important to maximize survival of larvae through critical early life stages (Hardy et al. 2008).

In lakes, newly hatched larvae are pelagic and positively phototactic (Girsa 1972). At first, they drift passively in the water column and occur at higher densities at greater depths (5–10 m) compared with most larval fish species (Wang and Appenzeller 1998, Martin et al. 2011). As they grow (greater than 10 mm) and swimming performance improves, they become more mobile and perform a substantial diel vertical migration (DVM) of increasing amplitude up to 70 m (Wang and Appenzeller 1998, Fischer 1999, McPhail and Paragamian 2000, Probst and Eckmann 2009, Jude et al. 2013). Burbot larval DVMs are crepuscular in nature and are suggested to counteract predation risk related to body size and pigmentation as larvae metamorphose into juveniles (Probst and Eckmann 2009).

In fluvial populations, newly hatched larvae drift downstream from spawning tributaries to quiet water areas which provide important nursery sites for larvae to transition to active feeding (McPhail 1997, Koporikov and Bogdanov 2011). Early juvenile Burbot choose zones where the water is well warmed (Kjellman and Eloranta, 2002, Miler and Fischer 2004). The optimum temperature for Burbot larvae growth and survival after transition to active feeding is 12–16°C (Harzevili et al. 2003). An eight-year study monitoring fluvial Burbot larvae foraging found that during the first month of foraging, larvae occurred significantly more often ($p \leq 0.01$) in shallow, near bank areas with a low current speed (i.e., floodplain meadow and sand pebble beach with still water), with their ecological density reaching a peak in the former biotope type. This was attributed to favorable environmental conditions that allow effective water warming and rapid development of food organisms in sufficient amounts (Koporikov and Bogdanov 2011). Researchers from the University of Idaho, KTOI, and IDFG collaborative studies also found that larvae need a steady progression from 6°C at hatching up to 12-14°C at larval metamorphosis when they switch to benthic existence. Extended cold temperatures cause physical deformities, and starvation due to reduced mobility and metabolism (Shawn Young, KTOI, 2019 personal communication).

Observations suggest that in lakes larval Burbot (greater than 15 mm) undergo a habitat shift in early summer moving inshore to littoral habitats (McPhail and Paragamian 2000, Taylor and McPhail 2000, Donner and Eckmann 2011, Jude et al. 2013). In general, larval growth is rapid in spring and early summer but slows later in the summer (Ryder and Pesendorfer 1992). As Burbot grow, they exhibit ontogenic shifts in prey selection (McPhail and Paragamian 2000), which may be due to reduced gape limitation, ontogenic shifts in habitat use (Probst and Eckmann 2009), or both. At about 30 mm the larvae become negatively phototactic and shift from a schooling, diurnal life to a nocturnal, solitary, benthic life (McPhail 1997).

Variations in the change in size between hatch and metamorphosis may contribute significantly to recruitment variability. In marine gadoids, and many other species (n=21) with a pelagic larval phase, egg size and initial size of offspring have little influence on recruitment variations; however, the change in length during the larval period, which provides a measure of the duration of this stage of the life cycle, is significantly positively correlated with overall recruitment variability (Pepin and Myers 1991). In addition, increasing the duration of the egg stage relative to the duration of the larval stage leads to a greater degree of randomness in recruitment. Changing the distribution of the time spent in each early life history stage may allow different levels of vulnerability to environmental fluctuations (Pepin and Myers 1991).

Burbot juveniles and subadults occupy the littoral zone full time (Taylor and McPhail 2000) and feed on amphipods, mayflies, stoneflies and young of the year of other fish (McPhail 1997). Numerous researchers reported observing juvenile and subadult Burbot feeding at night and seeking shelter in weed beds or excavating burrows under rocks or other debris during the day in 0.5 to 3.0 m depths (McPhail 1997, McPhail and Paragamian 2000 and references therein).

Recently, Age-0 upper Kootenay River Burbot were captured in August 2017 (n=10) and again in 2018 (n=27) while electrofishing for Westslope Cutthroat Trout emergent fry in the St. Mary's River drainage (Figure 1). Captures were over cobble substrate just upstream from the confluences of Perry, Matthew, and Mark Creeks (tributaries of the St. Mary River) and in the margins of the mainstem St. Mary River below Matthew Creek. (Heather Lamson, FLNRORD, 2018 personal communication). Captures of hatchery stocked juveniles in a tributary of the lower Kootenay River were also over coarse substrates (Beard et al. 2017a). Age-0 Burbot grow rapidly and can reach 110-120 mm in total length by late fall (McPhail and Paragamian 2000).

Littoral habitat is also used by adults for foraging (McPhail and Paragamian 2000). Diurnal feeding migrations by adult Burbot have been documented in lakes (Cott et al. 2015, Scannell 2016) and Kinbasket Reservoir (Harrison et al. 2013, Kang et al. 2016). A high-resolution acoustic telemetry positioning system tracked the fine scale movements and activity of Burbot which documented Burbot stayed along the silty bottom during the day, moved up the bank at dusk to shallow water closer to the shore, before descending at dawn (Cott et al. 2015). This movement is described as ‘diel bank migration’’ (DBM) (Gorman et al. 2012, Cott et al. 2015) and differs from diurnal vertical migrations (DVM) which describe Burbot larval movements in the water column. This movement presumably allows Burbot to exploit feeding opportunities while maintaining a bioenergetics advantage (Harrison et al. 2013; Cott et al. 2015) as adult Burbot are uncommon in waterbodies where temperatures exceed 18 to 20 °C (McPhail and Paragamian 2000, Jackson et al. 2008).

Adult Burbot are piscivorous. Although the proportion of fish in the diet is positively related to fish size, large Burbot still consume some insects and macroinvertebrates (McPhail and Paragamian 2000). In Koocanusa Reservoir, fish comprised more than 80% of the adult Burbot diet (Chisholm et al. 1989). Stable isotope data and stomach content analyses underline the piscivorous lifestyle of Burbot and their high trophic position in aquatic food webs equal to that of Lake Trout and Northern Pike (Hesslein et al. 1991; Recknagel et al. 2014).

In rivers, adult Burbot are associated with main channels and reside in tributary confluence areas, deep pools and eddies where prey items are concentrated (Ford et al. 1995). Burbot are believed to have low swimming endurance and are commonly found in low flow riverine habitats (McPhail and Paragamian 2000). Paragamian (2000) reported an empirical relationship between Burbot downstream movement and increasing water velocity in the Kootenay River.

4.0 ABUNDANCE & POPULATION TRENDS

Despite their wide circumpolar geographical range, worldwide many Burbot populations are threatened, endangered or have been extirpated (Stapanian et al. 2010). Only two decades ago, they were described as common throughout the upstream reaches of the Columbia River Basin in the northwestern U.S. and Canada (Paragamian et al. 2001). Historical fishery data characterizes the abundance of Burbot once present in the Kootenay Basin. During the 1960s, the combined average annual catch of the sport and commercial fisheries in the lower Kootenay River exceeded thousands of kilograms (Paragamian et al. 2000). In Kootenay Lake's West Arm, annual Burbot harvests in the early 1960's and 70's ranged from 10,000 to 20,000 with a record harvest of 26,000 Burbot in 1969 (Andrusak 1981). The Kootenay Burbot fishery was considered one of the most robust freshwater cod fisheries in North America (Martin 1976, Paragamian 2000, Ahrens and Korman 2002, Neufeld 2006, Hardy and Paragamian 2013).

Significant sustenance and recreational Burbot fisheries also existed in the upper Kootenay River pre-Libby Dam (Maher 1961, Whatley 1972, Department of Environment (DOE) 1976, Working Group First Nations Representatives, 2016 personal communication). Burbot fisheries were reported in the Montana section of what is now Koocanusa/Libby Reservoir (Hammond and Anders 2003), as well as the Canadian portion of Koocanusa Reservoir (Maher 1961, Whatley 1972), and at Fort Steele near the confluence with the St. Mary River (G. Oliver, MOE, personal communication in McPhail 1997). Prior to the construction of Libby Dam, a B.C. Department of Environment assessment on the upper Kootenay River from its headwaters to the international border identified "an important recreational winter whitefish and ling fishery" (DOE 1976).

Burbot were similarly once abundant in upper Kootenay River tributaries. Whately (1972) identified a number of tributaries, principally the Bull and Elk rivers, Sand, Kikomun, Linklater and Gold creeks, as providing habitat and spawning conditions for upper Kootenay River fish species including Burbot. In the St. Mary River, juvenile Burbot were once common in agriculture drainage ditches on the ?Aq'am (St. Mary's Indian Band) lands immediately upstream of the confluence with the Kootenay River (Working Group First Nations Representatives, 2017 personal communications). Similarly, Burbot were among the most abundant fish species collected in 1967 and 1977 both upstream and downstream of Mark Creek (MOE 1981 and references therein). The recent captures (2017 and 2018) of Age-0 Burbot (n=37) in the St. Mary River and its tributaries Mark, Matthew, and Perry Creeks corroborate historical data and characterize these locations as important Burbot rearing habitats. Furthermore, the provincial and First Nation government reports in mainstem and tributary habitats of the upper Kootenay River support historic angler surveys that an excellent winter Burbot fishery existed throughout the Kootenay Region from the 1930s through the early 1970s (McPhail and Paragamian 2000, Prince 2001, KVRI 2005).

Long term monitoring of upper Kootenay River/Koocanusa Reservoir Burbot populations show a post-Libby Dam collapse and continued low abundance estimates (Dunnigan et al. 2018). Systematic winter hoop trapping efforts downstream of Libby Dam (Figure 3), and gill netting data within Koocanusa Reservoir (Figure 4) demonstrate similar patterns of declines and extremely low levels of Burbot abundance. For the past 15 years, mean hoop trap CPUE has fluctuated around very low levels of abundance ranging from 0.019 to 0.124 Burbot per trap day (Figure 3). Long term gill net monitoring indicates that initially Burbot abundance in

Koocanusa increased after reservoir construction (1972) until 1988 when numbers collapsed and then continued to decline (Figure 4, Dunnigan et al. 2018).

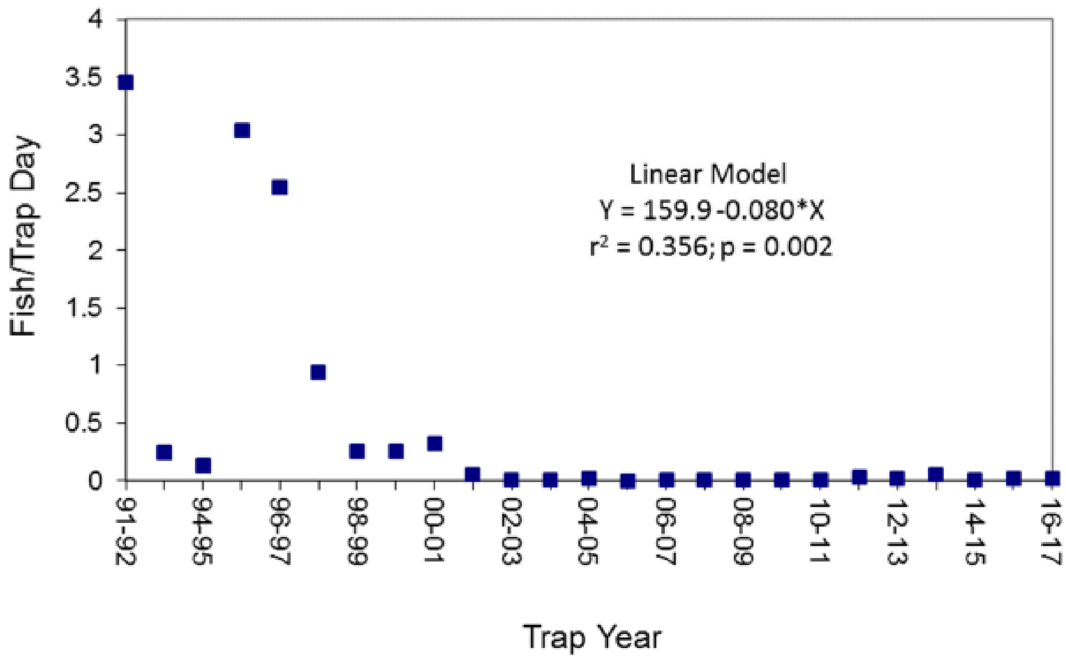


Figure 3. Total catch per effort (Burbot per trap-day) of baited hoop traps in the stilling basin downstream of Libby Dam 1991/1992 through 2016/2017. Traps were fished December and February. (Dunnigan et al. 2018).

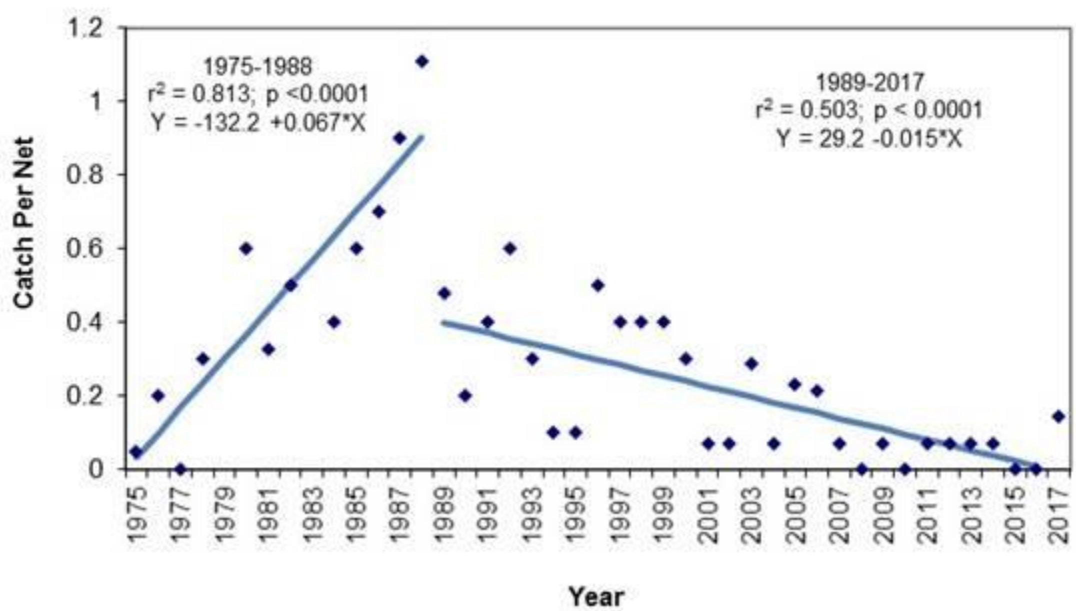


Figure 4. Mean catch per effort (Burbot per net-day) of Burbot in sinking gillnets during spring gillnetting at the Rexford site on Koocanusa Reservoir 1975-2017 (Dunnigan et al. 2018).

An important consideration in discussions of Burbot abundance data is the sensitivity of the CPUE index to methodology deviations that affect catchability. For example, in Burbot studies examining trap efficiencies for Duncan, Kootenay, and Moyie Lakes, cod traps outperformed hoop traps by nearly 2:1 (Spence 2000, Prince 2007). Similarly, catch rates in Burbot differ among seasons and are highest within 30 days of spring thaw and just before ice-up (Bernard et al. 1993, Prince 2007). Furthermore, adjusting catches for longer or shorter soak times introduces significant bias as a division of catch does not adjust "zero" catches but does adjust large ones (Parker et al. 1987). Consequently, information on trap types, seasons, and soak times etc. is required to facilitate limited comparisons across studies.

In 2012 from December to February, hoop traps were set on the Canadian side of Koocanusa to compare with the spring gill netting abundance estimates from the lower reservoir (Dunnigan et al. 2018). A total of eight Burbot were captured for a CPUE of 0.124 fish per trap day (Robinson 2013). While abundance in Koocanusa Reservoir in 2013 was twice that reported downstream in the U.S. portion of the reservoir for the same year (0.050 fish per trap day; Dunnigan et al. 2014), catch rates were still considered very low and variable. In addition, fish lengths fell within a very narrow range from 525-606 mm; (Robinson 2013), which is indicative of a single cohort leaving the population very unstable. The Canadian Koocanusa Burbot sampling program was repeated and expanded in 2016. A total of seven Burbot were captured in 240 trap days of effort and ranged in size from 530 to 678 mm (Smithson and Robinson 2017). Abundance estimates averaged 0.029 fish per trap day (Smithson and Robinson 2017), which represents a reduction of 77% in comparison to the 2013 estimates and was similar to that reported downstream in the U.S. portion of the reservoir for the same year (0.050 fish per trap day, Dunnigan et al. 2018).

In another study on Koocanusa Reservoir (2014-2016) angling, gill netting, hoop nets, and cod traps were employed during February, April, and August to sample various fish species for contaminant analysis (Minnow Environmental Inc. 2018). In total, 46 Burbot were captured over three years using multiple sample methods. The majority of Burbot captures were at Sand Creek (59%), and the Elk River (35%) and ranged in size from 240 mm to 820 mm (Minnow Environmental Inc., 2018). Thus, while Koocanusa Burbot abundance remains extremely low, there is evidence of natural recruitment with all catchable age classes being represented.

In the upper Kootenay River above Koocanusa Reservoir, cod traps were used in 2016 to target preferred habitats and historical fishery locations. Seventy-six trap days of effort resulted in the capture of only one Burbot measuring 370 mm in length (Cope 2016). This single capture was in a historical Burbot fishery location that targeted spawners in the Kootenay River using setlines (G. Oliver, MOE, personal communication in McPhail 1997). The resulting Burbot abundance estimate of 0.015 fish per trap day was similar to that reported below Libby Dam (Dunnigan et al. 2018).

Declines have also been documented in tributary habitats of the upper Kootenay River (Cope 2016). In 2005, St. Mary Lake Burbot abundance estimate was 0.18 Burbot per trap day (Prince 2007); which was low in comparison to other populations (i.e., Moyie Lake) and historical knowledge of the fishery. As a result, in 2006 the B.C. MOE closed St. Mary Lake to Burbot harvest. Ten years later the survey was repeated. Burbot abundance declined to 0.10 Burbot per trap day and mean length decreased from 684 mm (±24.39 SE) to 370.45 mm

(±29.2SE) (Cope 2016). Furthermore, a spawning weir operated on the St. Mary River from Jan 15 to Mar 15 in 2016 and 2017 resulted in the capture of only one Burbot (Thomas Resources 2016).

When compared to Burbot populations that are considered "healthy" or self-sustaining in the Kootenay Region, Burbot abundance levels in the upper Kootenay River, its tributaries, and Koocanusa Reservoir are very low (Table 1, Warnock 2015). In Moyie Lake, randomized sampling showed Burbot CPUE's in October ranged from 1.22 (±0.21) fish/trap-day in the North Basin and 0.85 (±0.13) in the South Basin (Prince 2007). Arrow Lake Burbot abundance estimates were similar using a spatially stratified sampling strategy with catch rates ranging from 0.68 to 0.58 fish/trap-day (Table 1). When targeted methods were employed in the fall, which improve catch rates (Bernard et al. 1993, Prince 2007), Burbot CPUE in Moyie and Arrow Lakes was 2.08 and 8.50 fish/trap-day respectively (Arndt and Baxter 2006).

Despite fishery closures for over a decade, indications are that upper Kootenay River and its tributary Burbot populations have continued to decline. At abundance levels less than 0.03 Burbot per trap or net day (Cope 2016, Smithson and Robinson 2017, Dunnigan et al. 2018), the upper Kootenay River population is currently at levels reported for the lower river population after its collapse (Figure 5, Rust et al. 2017).

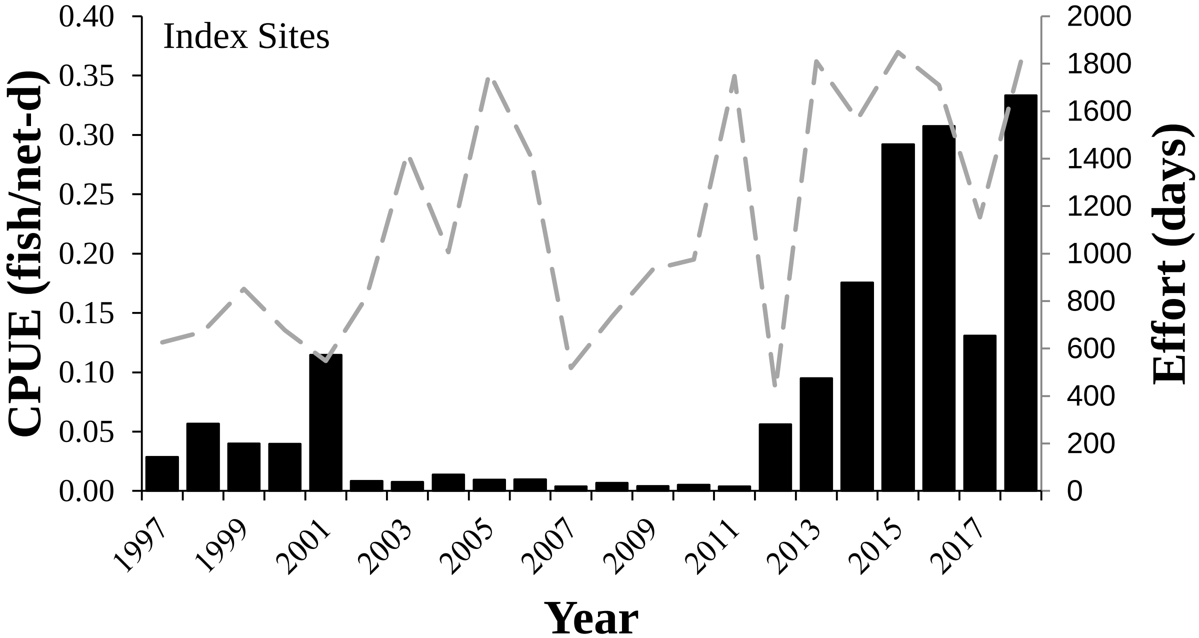
In the lower Kootenay River, Burbot were sampled by fisheries agencies as early as 1957 when a total of 199 Burbot were captured during a winter sampling period. At this time, Burbot lengths were normally distributed and indicative of successful natural recruitment (Paragamian et al. 2000). From 1979 to 1982, all catchable age classes continued to be represented, however, the annual Burbot harvest was substantially lower (Partridge 1983). This declining trend continued until the winter of 1993-1994 when sampling efforts failed to capture any Burbot (Paragamian 1993, 1994). Burbot were also absent from a creel survey that year that extended from spring 1993 to spring 1994 (Paragamian 1993, 1994). Mark recapture models indicated that the lower Kootenay River Burbot population had declined from about 150 fish in the mid-1990s to only 50 fish in the early 2000s, with total annual mortality estimated at 63% (Pyper et al. 2004). The lower Kootenay River Burbot population was considered functionally extinct by 2004 with virtually no recruitment and an estimated abundance of 50 fish greater than 350 mm (Pyper et al. 2004, Paragamian et al. 2008). A review of the population characteristics and extinction risk for Burbot in the lower Kootenay River suggested that the population would be extirpated by 2015 in the absence of remediation (Pyper et al. 2004; Paragamian et al. 2008; Paragamian and Hansen 2009). The restocking of hatchery reared juveniles and larvae began in 2009. The success of these stocking efforts on relative abundance as these juveniles recruited into the hoop net catch is evident in (Figure 5).

Given the extremely low abundances in comparison to other self-sustaining Burbot populations, and the lack of response to localized fishery closures, additional management actions for the upper Kootenay River Burbot population were recommended. Based on the success of the Kootenai River/Kootenay Lake Burbot Conservation Strategy (Figure 5, KVRI 2005), it was recommended these additional management actions include evaluating and adapting the lower Kootenai Burbot conservation aquaculture program as part of an emerging Conservation Strategy to help restore Upper Kootenay Burbot.

Table 1. Literature review of Burbot relative abundance; rows are presented ranked from lowest catch rates to highest. NR = not reported (Warnock 2015). Fish/trap-day may be approximated by dividing CPUE for 48-hour soak times by two.

Lake	Year	N trap sets	sampling design	Trap soak time range (h)	mean soak time (h)	trap type	Time of year	depth range (m)	mean depth (m)	Mean $CPUE_{set}$ (fish/trapset)	Reference
Koocanusa Reservoir (MT)	2013	216	targeted	47.3-48	~48	hoop trap	Winter	NR	NR	0.10	Dunnigan et al. 2014
Windermere Lake	2006	60	randomized grid	NR	~48	cod trap	Fall	0-6	3	0.12	Prince 2007
Duncan Reservoir	2010	361	randomized grid, perimeter	NR	~48	cod trap	Spring	1.2-30	20.5	0.13	Cope 2010
Duncan Reservoir	2011	340	randomized grid & targeted	NR	~48	cod trap	Spring	1.8-30	18.6	0.14	Cope 2011
Columbia Lake	2001	128	spatially systematic	NR	~24	cod trap	Spring	NR	NR	0.15	Bisset et al. 2002
Duncan Reservoir	2010	89	targeted	NR	~48	cod trap	Spring	1.2-30	20.5	0.16	Cope 2010
Kootenay Lake	2015	38	targeted	50-93	74	cod trap	Spring	10.0-24.2	18.5	0.18	Stephenson & Evans 2015
Koocanusa Reservoir (B.C.)	2013	38	targeted	44.4-48.9	~48	cod trap	Winter	1.8-15.7	6.1	0.21	Robinson 2013
Duncan Reservoir	2005	85	randomized, perimeter	45-50	NR	cod trap	Fall	15.0-33	24.4	0.22	Neufeld 2006
Duncan Reservoir	2009	212	randomized grid, perimeter	NR	~48	cod trap	Spring	1.5-30.6	15.2	0.22	Cope 2009
Columbia Lake	2001	138	targeted	NR	~24	cod trap	Fall	NR	NR	0.28	Bisset et al. 2002
Birch Lake	2002	50	targeted	18.8-26.7	~24	cod trap	Fall	3.5-28	15.4	0.30	Redekopp et al. 2003
Lac Des Roches	2002	74	targeted	19.3-33.1	~24	cod trap	Fall	6.0-29	16.1	0.32	Redekopp et al. 2003
Duncan Reservoir	1999	88	convenience	NR	53.4	cod trap	Fall	5.0-30	NR	0.33	Spence & Neufeld 2002
Duncan Reservoir	2006	192	randomized, perimeter	19-74	NR	cod trap	Spring	2.0-79	22.3	0.41	Neufeld 2006
Duncan Reservoir	2009	127	targeted	NR	~48	cod trap	Spring	1.5-30.6	15.2	0.41	Cope 2009
Moyie Lakes	2014	46	targeted	0.9-33.3	NR	cod trap	Fall	3.0-7.0	NR	0.50	Stephenson & Evans 2015
Columbia Lake	2006	40	randomized grid	NR	~48	cod trap	Fall	0-5	3	0.58	Prince 2007
Kinbasket Reservoir	2015	154	targeted	23.2-96.2	49.9	cod trap	Spring	4.3-18.0	12.2	0.64	this study
St. Mary Lake	2005	11	randomized grid	NR	~48	cod trap	Fall	0-21	8	0.64	Prince 2007
Duncan Reservoir	2005	282	randomized, perimeter	45-50	NR	cod trap	Spring	10.0-45	23.2	0.78	Neufeld 2006
Kinbasket Reservoir	2014	149	targeted	23.6-77.4	45	cod trap	Spring	2.2-16.5	9.4	0.83	this study
Arrow Lakes	2008	64	targeted	14.4-74.4	33.6	cod trap	Fall	NR	NR	0.86	Glova et al. 2009
Moyie Lakes	2006	45	randomized grid	NR	~48	hoop trap	Fall	NR	NR	1.16	Prince 2007
Arrow Lakes	2010	124	spatially stratified	24-74	48*	cod trap	Fall	3.0-16	NR	1.16	Robichaud et al. 2011
Arrow Lakes	2008	51	spatially stratified	21.6-76.8	52.8	cod trap	Fall	NR	NR	1.33	Glova et al. 2009
Arrow Lakes	2011	125	spatially stratified	46-72	48*	cod trap	Fall	NR	NR	1.35	Robichaud et al. 2012
Arrow Lakes	2009	143	spatially stratified	23-90.7	72.7*	cod trap	Fall	NR	NR	1.43	Glova et al. 2010
Moyie Lakes	2006	154	randomized grid	NR	~48	cod trap	Spring	NR	NR	2.01	Prince 2007
Moyie Lakes	2006	48	randomized grid	NR	~48	cod trap	Fall	NR	NR	2.08	Prince 2007
Moyie Lakes	2005	30	targeted	NR	~48	cod trap	Fall	NR	NR	4.17	Prince 2007
Arrow Lakes	2003	43	targeted	4.8-50	20.9	cod trap	Fall	10.0-31	21.4	4.60	Arndt and Baxter 2006
Arrow Lakes	2006	17	targeted	NR	NR	cod trap	Fall	16.8-29.7	23.5	7.29	Neufeld 2006
Arrow Lakes	2004	15	targeted	17.9-22.5	20.3	cod trap	Fall	18.5-30	24.8	8.50	Arndt and Baxter 2006

*median reported



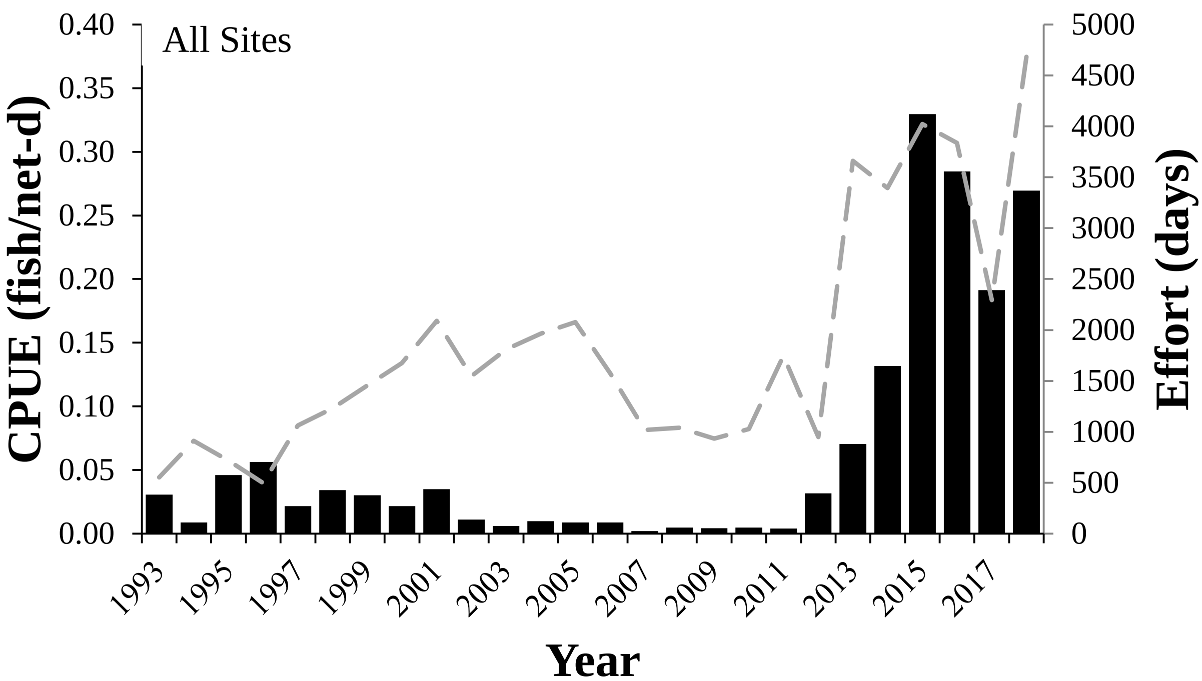


Figure 5. Catch-per-unit-of-effort (CPUE) of Burbot in the lower Kootenay River, Idaho from Idaho Department of Fish and Game annual hoop netting surveys. Values shown reflect catch from all sampling sites from 1992-2017. (Rust et al. 2017, IDFG unpublished data 2018).

5.0 NATURE AND EXTENT OF THREATS

Throughout the Kootenay Region, density independent factors have been largely attributed to declines in Burbot abundance (Paragamian 2000, Hardy and Paragamian 2013). A long-term assessment of Burbot in the lower Kootenay River indicated that regulation of winter flows during spawning migration and spawning periods played an important role in the decline (Paragamian 2000, Paragamian et al. 2005). While flow alteration related to hydro-electric development is widely accepted as a causal factor in the species decline, no single factor appears solely responsible for the collapse of Burbot populations in the Kootenay Basin (Paragamian 2000, Ahrens and Korman 2002, Hammond and Anders 2003). Several impacts/threats are currently viewed as possible contributing factors to the Burbot decline (KVRI 2005). Possible explanations include historical over-harvest, flow and temperature changes, habitat alterations, changes in community composition, and contaminant increases. As the density of Burbot increases due to conservation actions in the Kootenay River, additional data will become available to further identify and investigate various factors limiting recruitment of the population. In the lower Kootenay, an altered temperature regime is hypothesized to be a major component of recruitment failure (Shawn Young, KTOI, 2019 personal communication).

There is likely a synergistic effect among causal factors that has resulted in Burbot population declines in the Kootenay Region. Although each individual loss may have a relatively small population effect, the cumulative effect in dynamic environments has important consequences by reducing life history diversity, population resilience, and population abundance.

Reductions in density and distribution (i.e., the incremental loss of stocks or population segments), results in the homogenization of life history traits and reduces population resilience by limiting a population’s ability to respond to environmental change or disturbance; both natural and anthropomorphic. A population of diverse life histories is necessary, particularly within dynamic and unpredictable environments such as Rocky Mountain streams, and constraints to life history diversity in these environments result in an elevated risk of a significant population impact.

5.1 Burbot Fishery

Burbot are an iconic food fish of First Nations within the East Kootenay; as well as the early European settlers and more recent residents within the region. Interviews with area pioneers reported the Burbot fishery began declining during the depression in the 1930`s, when wagon loads of spawning cod were speared and pulled through the ice for sustenance, sale, and livestock feed (Prince 2001, KVRI 2005). This period was also a time of land reclamation projects that involved extensive diking of the floodplain and major tributary diversions such as the Goat River (Prince and Cope 2000, KVRI 2005).

Historically, Burbot fishing was unregulated and abundant spawners were harvested on spawning grounds with spears, pitchforks and later, using setlines. In the 1900’s artisanal commercial fisheries for Burbot evolved and markets for Burbot existed in Bonners Ferry Idaho into the mid-1990’s. Burbot also supported several popular recreational fisheries (Martin 1976, DOE 1976, Prince 2001, KVRI 2005). In the mid-1970’s through the late 1990’s, population declines and collapses were documented. In the 1990’s Kootenay Lake and the lower Kootenay River were closed to Burbot fishing and harvest. Despite closures, the relative abundance of Burbot remained extremely low and did not meet minimum population viability requirements (Paragamian et al. 2000).

Unfortunately, there is a paucity of historical data on Kootenay Burbot fisheries prior to their collapse. This may result from the fact that in many jurisdictions, Burbot were considered a nuisance fish (i.e., a competitor of commercially important fish) with limited commercial value and were generally not a target sport fish (Ford *et al.* 1995 and references therein). However, Kootenay area residents reported several historical commercial ling fisheries throughout the region at Balfour, Spillimacheen, and Christina Lake, and a desire to target the “delicious lobster-like meat” (Prince 2001). Monitoring angler attitudes toward Burbot will be important to gain insight into changing interest in Burbot fisheries and into whether anglers will target Burbot throughout their range if robust populations are restored in the Kootenay River (Gardunio et al. 2011).

Harvest records from Kootenay Lake and the lower Kootenay River provide some data to indicate the extent of the Burbot fishery and support First Nations traditional knowledge, historic angler surveys, and qualitative government assessments of robust Burbot fisheries in the upper Kootenay River (Whatley 1972, DOE 1976, MOE 1981, Prince 2001). During the late 1960s and early 1970s, annual Burbot harvest estimates in Kootenay Lake at Balfour reached 20,000 to 26,000 fish, nearly double the annual harvest rates recommended for population persistence (Martin 1976). Similarly, archives show that the combined annual Burbot catch by sport and commercial anglers in the Idaho portion of the Kootenay River likely exceeded thousands of kilograms in the 1950’s (Paragamian et al. 2000, Paragamian and Hansen 2009). The winter Burbot fishery continued into the 1970’s in the lower river, then rapidly declined in the mid-1980s and ultimately culminated in a complete closure of the fishery in 1992 (Paragamian et al. 2000, KVRI 2005).

The collapse and diminished size structure of Kootenay Region Burbot populations has been widespread and includes many un-impounded habitats with historical winter spawning fisheries. Examples include Columbia Lake, Windermere Lake, St. Mary Lake and the upper Columbia and Kootenay Rivers (Prince 2001, Cope 2016). Historical photographs and local newspaper accounts provide some documentation of these winter Burbot fisheries, their historical size structure, and their declines; in both numbers and size distribution.

Each year from 1950 to 1982 the Valley Echo Newspaper reported on an annual Ling (Burbot) Derby held the second week in February at Windermere Lake. In the early 1950’s, prizewinners were more than 15 lbs. and over 30 inches long (762 mm). By 1958, articles advertising the annual ling derby read, “Fish are Wary; Biggies on Holiday” and the winner was only 26.5” (673 mm) long. By 1965 the article was titled “Ling-Dingling slow at Annual Derby” and by 1982, only ten ling were captured during the derby and the winner was 18” (457 mm) in length. That was the last year the ling derby was held. Prior to the depression (1923), Windermere Lake produced the largest documented Burbot in British Columbia off the confluence of Windermere Creek weighing 34 lbs. or 15.44 kg (Figure 6 *from* McPhail and Paragamian 2000). Historically, large Burbot were not uncommon within the Kootenay region and many photographs of Burbot in the 10 to 20 lb. range exist (Prince 2001). For the last two decades, Windermere Burbot have been rare (Hutchinson 1996, Arndt 2001, Prince 2007), below the recommended weight condition index for the species (Prince 2007), and small with maximum lengths less than 600 mm (Hutchinson 1996, Arndt 2001, Prince 2007). The fishery was closed in 2006 and to date, relative abundance has not improved (Cope 2016).

Figure 6. Circa 1923, Nellie Richardson holding a 15.44 kg Burbot caught in Lake Windermere off the mouth of Windermere Creek, British Columbia. Photo from the collection of Ron and Belle Ede of Invermere, B.C.

Exploitation is an important consideration as Burbot stocks have been shown to be vulnerable to harvest and thought to be a cause for decline of Burbot populations in their native distributions (Vincent-Lang 1993, Mills 1994, Krueger and Hubert 1997, Ahrens and Korman 2002, Hubert et al. 2008, Stapanian et al. 2010). While restrictive angling regulations and fishery closures can result in improved age structures and densities in lakes with suitable habitat and recruitment (Taube and Bernard 1995); these measures have failed to restore the Burbot fisheries in the Kootenay Region as evidenced by continued low trap CPUEs and angler reports.

Ahrens and Korman (2002) suggested that in the Kootenay Lake fishery these management actions were too little too late, given the timing and magnitude of previous harvest, system alteration, and possible over-estimation of Burbot population abundance and persistence.

Misinterpretations of elevated abundance estimates (CPUE) in the Atlantic cod fishery contributed to overestimations of stock size and has been suggested as applicable to other gadoid fisheries (Rose and Kulka 1999). Changes in spatial patterns of abundance can mask or bring about changes in CPUE and catchability. As regional fish populations collapse, cod hyper-aggregate to form the masses necessary for successful, synchronous reproductive events. As fishers adjust and target remaining stocks, increased pressure on dwindling stocks or spawning locations may accelerate the rate of population decline while CPUE data from the fishery increases (Rose and Kulka 1999). In assessing how a stock is responding to changes in the environment or fishing pressure, observations of behavioral changes may provide signals as important as changes in measured abundance (Rose and Rowe 2015).

Currently, there remains one significant Burbot fishery in the upper Kootenay Region at Moyie Lake, B.C. and it is primarily a winter ice fishery. There have been three winter creel surveys on Moyie Lake (2002, 2007, and 2008; Prince and Cope 2008). In 2002 (Jan 26 to Feb 23), 223 anglers fished 711 hours and captured 31 Burbot for a CPUE of 0.04 fish/hour (K. Andreashuk, Columbia-Kootenay Fisheries Renewal Partnership, 2002 File Data, Cranbrook, B.C.). During the 2007 creel survey on Moyie Lake (Jan 25 to Mar 08), there was an increase in the number of anglers as creel technicians reported a shoreline fishery in the bay immediately south of Cotton Creek as a “new discovery” with high catch rates of ripe fish (Westover 2007). During the 2007 fishery (Jan 15-Mar 09), 525 anglers fished 2,180 hours and captured 515 Burbot for an overall CPUE of 0.24 Burbot/angler hour (Westover 2007). In 2008 (Jan 25-Mar 08), the effort was virtually unchanged; however, the 2008 catch was more than double the 2007 catch. In 2008, an estimated 488 anglers captured 1,089 Burbot yielding a CPUE of 0.50 Burbot/angler hour (Prince and Cope 2008).

The 2008 creel catch represents an annual adult Burbot exploitation rate of 20-34% based on Neufeld (2008) population estimates (Prince and Cope 2008). Previous studies modeling the historic Burbot population in Kootenay Lake have suggested an exploitation rate of 20% annually was the maximum sustainable harvest (Ahrens and Korman 2002). When applied to the Moyie Lake Burbot fishery, these modelling results suggest a maximum sustainable exploitation rate somewhere between 862 to 1,364 burbot/year. To protect this population and maintain the fishery, Moyie Lake was closed to retention for Burbot in 2009 during the most sensitive aggregation period (Feb 7 to Mar 31).

In 2009, Moyie Lake became the broodstock source for the lower Kootenay River conservation aquaculture program. A total of 3,055 individual Moyie Burbot have been handled for the Kootenai Tribe of Idaho aquaculture program at an average rate of 339 Burbot per year (range 181 to 554, Stephenson and Evans 2018).

First Nations have expressed concerns that the aquaculture program and/or recreational fishery may be impacting the population and report declining numbers and sizes in their traditional Moyie Burbot fishery (Working Group First Nations Representatives, 2017 personal communication). Recent Moyie Burbot population estimates based on data collected from 2010-2017 were similar across years and ranged from 4,312 (SE 306) in 2012 to 6,819 (SE 395) in 2010 (Schwarz 2018). When separated by sex, abundance of females has decreased from 1,452

(SE 105) in 2010 to 861 (SE 110) in 2017, while male abundance has remained stable (2010-2017, Schwarz 2018). The size of Burbot handled in the Moyie Lake gamete collection efforts has significantly differed across years of sampling ($p<0.0001$, Stephenson and Evans 2018). The lowest lengths were observed in the last two years of sampling; the largest mean length was in 2009 (586 mm; SE= 7) and the smallest mean length was in 2016 (538 mm; SE= 4, Stephenson and Evans 2018). Examination of spatial patterns of abundance and a recent estimate of angler catch are recommended to elucidate the population data trends.

The British Columbia Ministry of Environment (MOE) began closing Burbot lake fisheries in the upper Kootenay and Columbia River drainages in 2006. By 2008 the upper Kootenay River mainstem was closed to Burbot harvest excluding tributaries and Koocanusa Reservoir due to concerns for the reduced abundance. In 2017, the closure was extended to include the Canadian portion of Koocanusa Reservoir. Otherwise, retention rates are two Burbot per day (2017-2019 B.C. Freshwater Fishing Regulations Synopsis, Kootenay Region 4).

In the Montana portion of Koocanusa (Libby) Reservoir, Burbot harvest is permitted with a bag limit of two fish daily and in possession. In the Montana portion of the Kootenai River downstream of Libby Dam, the river has been divided into two sections with separate Burbot regulations. Angling only occurs during the period June 1st to February 28th from Libby Dam to the Fisher River confluence and the daily Burbot bag limit during this period is two fish daily and in possession. Burbot angling in the remainder of the Montana portion of the Kootenai River is catch and release only.

Despite these measures, indications are that Burbot populations in the upper Kootenay River, its tributaries and lakes have continued to decline (Cope 2016, Smithson and Robinson 2017, Dunnigan et al. 2018). There is movement data to support the presence of a migratory fluvial component to the Koocanusa Reservoir Burbot population thus connecting the reservoir population to the upper Kootenay River and the St. Mary River and St. Mary Lake (Snelson and Muhlfeld 1996, Ostrowski et al. 1997, Bill Westover, MOE (retired), 2006 personal communication). Burbot in Koocanusa reservoir have undergone a precipitous decline and chronically low abundance estimates have been well documented (1975-2017; Dunnigan et al. 2018). This population effect is expected to be influencing the upper Kootenay River population above the reservoir through the migratory life history component of the population.

The expression of multiple life history forms is a recurring feature for Burbot (McPhail 2007) and species which have evolved within the dynamic environments of Western North America (Waples et al. 2008 Homel et al. 2015, Waldman et al. 2016). Migratory forms of many fish species are known to be much larger than their resident counterparts (Waples et al. 2008, Homel et al. 2015 and references therein). Historical over-harvest of spawning populations typically results in pervasive effects that artificially select against migratory life history forms; often the larger, more fecund fish. Recall that in Burbot, fecundity is exponentially related to body size. The homogenization of life history results in decreased population resilience and an increased risk of a significant population impact and has likely contributed to population declines in Kootenay Burbot since the 1930's. The seminal reviews on population persistence by Holling (1973), Waples et al. (2008), Homel et al. (2015), and Waldman et al. (2016) synthesize of a large body of biology literature complied from investigations on many species over five decades, and are summarized below.

Life history diversity is linked to population resilience through spatial and temporal variation in exposure to disturbance (i.e., risk spreading) and in production of offspring (i.e., bet hedging). Where individuals expressing different life history forms occupy spatially discrete seasonal habitats or use multiple locations for the completion of essential life history functions (*i.e.*, spawning, over-wintering and feeding or rearing), disturbance at the local scale may cause extirpation of one portion of the population associated with the affected habitat. Subsequently, recolonization can occur by other individuals from the same population; provided migration corridors (i.e., connectivity) are maintained or restored within reasonable timeframes. Similarly, egg or fry survival may vary among spawning locations or habitats associated with different life history forms because of environmental conditions. At the population scale, expression of multiple life history forms or use of multiple locations increases the probability that some component of the population will successfully reproduce in a given year. Over time, risk spreading and bet hedging result in selection for multiple life history forms and provide a greater range of opportunities for population persistence in a spatially and temporally variable environment. (Holling 1973, Waples et al. 2008, Homel et al. 2015, Waldman et al. 2016 and references therein).

Angler harvest targeting spawning aggregations of Burbot during the winter is used as a management tool to eradicate Burbot where they are considered invasive (Klein et al. 2016). In one such newly established ice fishing tournament on the Fontenell Reservoir in Wyoming, 485 anglers removed 4,012 Burbot over seven evenings of fishing in 2011 (Gardunio et al. 2011). Burbot have rapidly spread throughout the upper Colorado Basin (340, 325, and 290 km upstream of reservoirs) and the Green River drainage in Wyoming and Utah after being illegally introduced to Big Sandy Reservoir in the early to mid 1990's (Gardunio et al. 2011). Wyoming Burbot fisheries were once a valuable winter food source through the 1960's but were extirpated from their native ranges by the 1990's (Krueger and Hubert 1997, Gardunio et al. 2011). The rapid colonization of Burbot throughout these drainages indicate that Burbot can thrive in reservoir impoundments.

5.2 Libby Dam Operations

Libby Dam at full pool impounds or stores water over 145 km of the upper Kootenay River from Libby Dam in Montana upstream to Wardner B.C. This represents 44% of the mainstem habitat available to upper Kootenay River Burbot (Figure 1). The tailwater river reach between Kootenai Falls and Libby Dam (47 km) represents another 14%; therefore, Libby Dam operations potentially impact or directly influence 58% of available mainstem habitat of the upper Kootenay River Burbot population (Burbot above Kootenai Falls=Mississippi clade) and all of the mainstem habitat of the lower Kootenay River Burbot population (Burbot below Kootenai Falls=Pacific clade).

Note that this section on Libby Dam operations covers effects related to drawdown (water level fluctuations in elevation because of operations), entrainment (passage of larvae, juvenile and adult fish through turbines or over spillways), and changes to seasonal discharge. Potential water temperature impacts are discussed in Section 5.3 and potential changes to primary and secondary productivity associated with reservoir operations are discussed in Section 5.5.

5.2.1 Reservoir drawdown

Perhaps the greatest potential impact of reservoir operations on Burbot populations may be the dewatering effect of winter draw down on juvenile stranding, spawning success and egg survival in sites along the shoreline and in the lower sections of tributaries within the varial zone. In addition, annual winter draw down has resulted in a severely impaired littoral zone eliminating complex and highly productive littoral or foreshore habitat typically utilized by juvenile, subadult, and adult Burbot. Annual draw down of up to 52.4 m or 171.8 ft can occur in Koocanusa Reservoir (Chisholm et al. 1989). Since flow augmentation to support white sturgeon spawning began in 1998, the annual drawdown has averaged 23.8 m (78 ft) and ranged between 15.2 and 42.1 m (50 and 138 ft, Dunnigan et al. 2018). The full pool surface area is approximately 46,407 acres and the minimum pool area is 13, 986 acres. The total reservoir surface area at full pool is 46,407 acres of which 17,647 is in B.C. At 78 feet drawdown, the total surface area is 28,035 acres of which 487 is in B.C. The relative changes are greatest in the Canadian (upstream) portion of the reservoir.

Burbot spawning in the Kootenay River basin typically occurs from mid-February to early April (Bisset et al. 2002, Prince and Cope 2008, Neufeld 2008, Cope 2011, Hardy et al. 2015, Kang et al. 2016). Since Burbot have an egg incubation period of 30-60 days (Taylor and McPhail 2000, McPhail 2007), one potential impact of Koocanusa reservoir operations on Burbot populations may be the dewatering effect of winter drawdown on spawning success and egg survival in sites along the shoreline and in lower sections of tributaries (Kang et al. 2016). The depth at which spawning takes place, coupled with the timing of spawning until the period of maximum drawdown in April dictates whether there is a risk of spawning failure due to reservoir operations. Further, the occupation of the littoral zone by juvenile Burbot and other fish species leaves them vulnerable to stranding both in the reservoir and areas downstream of Libby Dam. Burbot tributary spawners are also vulnerable to drawdown-imposed restrictions to tributary access (Spence and Neufeld 2002). Improved understanding of the exact timing and location of reservoir Burbot spawning events will be required to better design drawdown operational changes to reduce the likelihood of dewatering spawning and incubation habitat. Similarly, identification of tributary spawning locations will be necessary to target access and habitat improvement works (Harrison et al. 2016).

Reservoir drawdown affects all biological trophic levels. Annual drawdown impedes revegetation of the reservoir varial zone and results in a littoral zone of nondescript cobble/mud/sand bottom with limited habitat structure. Similar impacts have been observed in the tailwater below Libby Dam. The zone of water fluctuation or varial zone has been enlarged by daily changes in water-flow and stage caused by power operations. The varial zone is neither a terrestrial nor aquatic environment, so it is biologically unproductive (Dunnigan et al. 2018). Given the importance of littoral habitat to Burbot juveniles (Taylor and McPhail 2000) and adults for spawning (McPhail and Paragamian 2000) and foraging (Harrison et al. 2013, Cott et al. 2015), damage to the shallow littoral zone as a result of winter drawdown may be a more important or pervasive threat to populations of reservoir Burbot than turbine entrainment (Harrison et al 2016).

5.2.2 Entrainment

Entrainment has been hypothesized as a possible factor in the decline of Burbot populations in reservoirs (Stapanian et al. 2010; Hardy and Paragamian 2013). Early life stage Burbot display several traits that may render them susceptible to turbine entrainment. Passive drifting, pelagic habitat uses, and diel vertical migrations suggest high entrainment vulnerability (Harrison et al. 2016). While turbine entrainment mortality of larval and juvenile individuals of physostomous species can be low, that may not be the case for larval and juvenile Burbot given their closed air bladders (physoclistous) and susceptibility to barotrauma (Brown et al 2014, Harrison et al. 2016).

In Koocanusa Reservoir, Burbot entrainment through Libby Dam is difficult to quantify. In the early 1990's, Burbot were listed as the 6th most abundant species entrained at Libby Dam (Skaar et al. 1996). Of 40 Burbot tagged and monitored by Dunnigan and Sinclair (2008), 32.5% (n=13) were removed from the study population within 60 days of release. Of those, 27.5% (n=11) either died or shed the tag, 10% (n=4) were returned by anglers, and 5% (n=2) were never detected; leaving a study population of 27 Burbot for the two years of monitoring. Of these, one Burbot (645 mm TL) was confirmed entrained during the fall and did not survive; yielding an annual removal estimate of 1.9%. As benthic, deep water physoclists, adult Burbot are susceptible to entrainment mortality (Brown et al. 2014) since rapid decompression is a significant stressor in turbine passage (Trumbo et al. 2014). Burbot catch rates in Koocanusa Reservoir are significantly and positively correlated to catch rates below Libby Dam, suggesting that Burbot abundance in Koocanusa may be influencing Burbot abundance in the Kootenay River below through entrainment (Dunnigan et al. 2018).

Annual Burbot entrainment estimates at other Kootenay headwater dams range from 0.7% in the upper Columbia River (Martins et al. 2013) to 32% in the Duncan River (Spence and Neufeld 2002). Calculation of meaningful entrainment rates require population estimates which have proven difficult to reliably generate in regional Burbot populations given low recapture rates (Prince 2007, Cope 2011, Stephenson and Evans 2015) and the vast area of coverage required to effectively sample large river headwater reservoirs (e.g. Kinbasket Reservoir is 106,750 acres or 43,200 ha, Kang et al. 2016). Thus, detailed data on the population level effects of adult Burbot entrainment are lacking.

Recently, a traits-based approach used by Harrison et al. (2016) proposed low vulnerability of adult Burbot to entrainment but recognized that life history strategy and associated movements results in unequal vulnerabilities. The 2008 Koocanusa Reservoir entrainment estimate is biased by low sample size and represents behaviors of a remnant population 46 years after dam construction and 20 years after the population collapsed. Given the incomplete understanding of the historic expression of Burbot life histories in the upper Kootenay River, and the likelihood that Libby Dam has artificially selected against migratory forms for decades, current adult Burbot entrainment estimates do not accurately represent the risk to a self-sustaining upper Kootenay Burbot population expressing the full range of life history strategies.

5.2.3 Increased Discharge

Winter water flow in the Kootenay River is typically 3 to 4 times higher since completion and operation of Libby Dam due to water releases for power production and flood control requirements (Paragamian 2000). Based on empirical Burbot swimming performance test data (Jones et al. 1974), Paragamian (2000) reported that water column velocities associated with post-dam winter flows inhibited or precluded Burbot spawning migrations in the Kootenay River below Libby Dam. Paragamian (2000) observed that Burbot moved downstream during artificially higher flows in winter and speculated that increased post-dam discharges during late fall and winter resulted in velocities that negatively affected Burbot migration and spawning in the lower Kootenay River. Analysis of Burbot telemetry data indicated optimum flows for Burbot were between 176 m^3/s and 300 m^3/s (Paragamian et al. 2005). The effect of increased winter flows applies to that portion of the upper Kootenay population residing between Kootenai Falls and Libby Dam (47 km) and all of the lower Kootenay population.

5.3 Water Temperature and Ice Cover

Since 1974, winter water temperatures in the lower Kootenay River have averaged 3 to 4 °C compared to pre-dam (Partridge 1983) and upper river temperatures of 1 °C or less (Figure 7). The large volume of water stored in the reservoir retains heat during the winter; which, combined with increased winter flows from Libby Dam operations, results in warmer than normal temperatures in areas downstream (Paragamian and Wakkinen 2008, Hardy and Paragamian 2013). Conversely, in the spring, Koocanusa’s water mass is slow to warm resulting in lower than natural spring temperatures.

Warmer post-dam water temperatures may negatively affect spawning success of lower Kootenay River Burbot (Hardy et al. 2015). Burbot spawn in water temperatures between 1 and 4 °C (McPhail and Paragamian 2000) and survival from fertilization to hatching is highest at 3.0 to 3.8°C (Taylor and McPhail 2000, Vught et al. 2007). At water temperatures above 6 °C, 100% egg mortality was reported (Taylor and McPhail 2000) and adult spawning cannot be induced (Zarski et al. 2010).

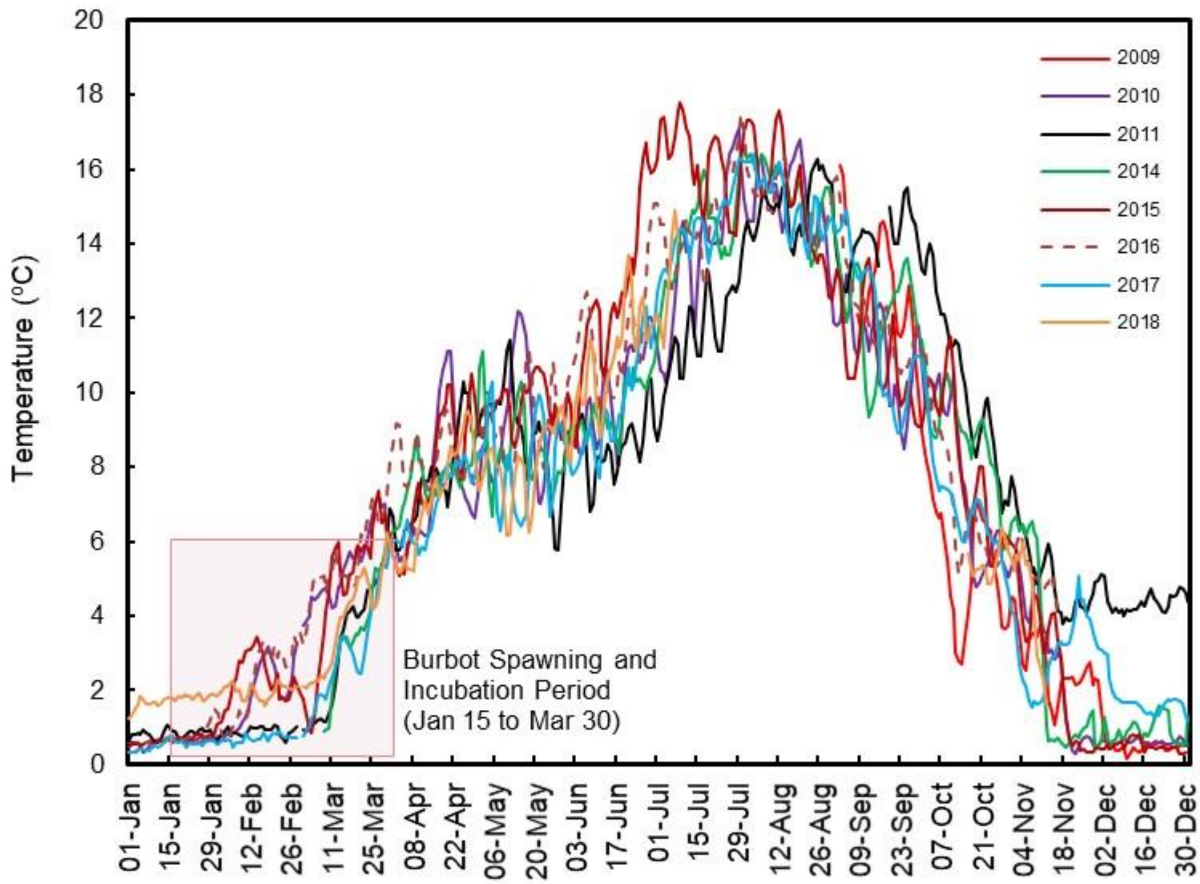


Figure 7. Mean daily temperatures for the upper Kootenay River (2009-2018) at Fort Steele, B.C. in relation to Burbot spawning period and critical incubation threshold (6°C). Data provided by Water Survey of Canada (Station No.08NG065). The data is still subject to review and therefore may contain errors. The water temperature probe failed in 2011 and was not replaced until March 7, 2014.

In addition to temperature, the rate of temperature decline during adult staging may play an important role in Burbot reproduction. Under hatchery conditions, rapid cooling from 6 to 1 °C significantly improved Burbot spawning success; thus, the slow rate of cooling associated with reservoir thermal mass may impact Burbot reproductive success (Zarski et al. 2010).

Hatchery stocked Burbot in the lower Kootenay River showed a 30-day shift in the timing of peak spawning which differed from the original Moyie Lake broodstock and resulted in lethal temperatures being exceeded for the entire 40-45-day incubation period (Hardy et al. 2015). Researchers from the University of Idaho are in the process of examining whether post-dam river temperature regimes enable or prohibit natural recruitment in the lower Kootenay River. Their evaluations include experiments that test the effects of different temperatures on Burbot spawning, embryo development and larvae energetics. Results from the study will be available in 2019 in the form of multiple peer-reviewed manuscripts and a dissertation (Ross et al. 2018).

The lower Kootenay River, and Koocanusa Reservoir from the Elk River to Wardner has been ice-free most winters since the beginning of Libby Dam operation (1974). Prior to flow regulation, the Kootenay River commonly froze during the winter (KVRI 2005). A lack of ice cover due to warming temperatures or fluctuating water levels may mask communications and thereby disrupt acoustic signaling necessary for attracting mates or signaling reproduction; which may be necessary given the synchronous spawning behaviour that creates large aggregations and spawning balls required for successful reproduction (Finstad and Nordeide 2004, Cott et al. 2014). The utilization of tributaries that retain a natural hydrograph may be an important feature for successful spawning and early rearing by impounded populations (Fisher 2000, Ross et al. 2018).

It has been suggested that upstream lake and reservoir systems can be sources for downstream recruitment of Burbot (Paragamian et al 1999; Hubert et al. 2008; Underwood et al. 2015, Harrison et al 2016). The upper Kootenay River retains a natural hydrograph above Koocanusa Reservoir, is mostly ice covered in winter, and is not influenced by warmer winter temperatures and cooler spring temperatures that typify the Kootenay River downstream of Libby Dam (Figure 7). Temperatures in the upper Kootenay River appear optimal for Burbot spawning and embryo development. Currently, FLNRORD is establishing a series of temperature index sites in the St. Mary River watershed to monitor water temperatures in fluvial littoral zones.

5.4 Environmental Degradation

The construction of Libby Dam (1972) resulted in riverine impoundment (flooding) and habitat losses that were dominated by moderate elevation, low gradient streams in the upper Kootenay River (Thorley 2008). Whately (1972) provided the following general description of the upper Kootenay River scheduled to be flooded by the creation of Koocanusa Reservoir.

"The portion of Kootenay River in Canada to be flooded flows rather slowly with very little drop in elevation. Side channels, back eddies, and large, deep pools are interspersed with extensive shallow gravel bars.…In addition, a number of tributaries, principally the Bull and Elk rivers, Sand, Kikomun, Linklater and Gold creeks provide habitat and spawning conditions for Kootenay River Fish" (Whately 1972).

Filling Koocanusa Reservoir in 1972 inundated and eliminated 145 km of the mainstem Kootenay River habitat and 64 kilometers of critical, low-gradient tributary habitat. The flooding of the upper Kootenay River resulted in the loss of high quality Burbot spawning and rearing habitats as they are associated with main channels and reside in tributary confluence areas, deep pools and eddies (Ford et al. 1995). It also resulted in the loss of the Mountain Whitefish fishery; a main food source for Burbot (Maher 1961, DOE 1976). The conversion of a large segment of the Kootenay River from a lotic to lentic environment changed the aquatic community in profound ways (Paragamian 1994, Section 5.7).

The Elk and Bull Rivers are two large tributaries to the upper Kootenay River and Koocanusa Reservoir that have run-of-river B.C. Hydro dams. The Elk River confluence with the Kootenay River was historically a significant Burbot fishery location and continues to provide Burbot catch during Koocanusa monitoring studies (Robinson 2013, Smithson and Robinson 2017, Minnow Environmental Inc. 2018). While suitable temperatures and flows likely exist in these tributary habitats for Burbot spawning and incubation, the availability of juvenile shelter (i.e., interstitial habitats) within the drawdown zone may be regulating survival (Taylor and Arndt 2013). Retention of coarse sediment (i.e., gravel and cobbles) within the headponds of run-of-river facilities can account for a significant proportion of the total annual sediment load (B.C. Hydro 2005) and may be contributing to the loss of juvenile habitat.

Unlike areas below Kootenai Falls, the upper Kootenay River has not experienced extensive diking and land reclamation projects leaving much of the floodplain intact and functional. Approximately 94% of historic floodplain habitat in the lower Kootenay River was lost during the 1900's (KTOI 2005), which resulted in lost habitat complexity, biological interactions and biological productivity. Meandering reaches with channel complexity (i.e., side channels) are associated with intact floodplains and are habitats which are often lost during development and impoundment. These shallow, nearshore and off channel habitats are particularly important for fluvial Burbot reproduction and rearing as they are low velocity (McPhail and Paragamian 2000), create conditions conducive to ice cover, and allow for rapid warming in the spring.

5.5 Changes in Primary and Secondary Productivity

Nutrient and contaminant loading began in the upper Kootenay River in 1909, increased in the 1950's and 1960's, then was followed by restorative measures in the 1970's, all of which confounds any review of historical productivity. Cominco's industrial complex at Kimberley B.C. operated from 1909 to 2001 and prior to 1968 discharged in to the St. Mary River, large and toxic amounts of sulphates, phosphates, fluorides, heavy metals and acid wastes (Whately 1972). From 1953 to 1975 effluent from the Cominco phosphate fertilizer plant was also discharged into the St. Mary River (Whately 1972). After 1968, commencement of pulp mill operations at Skookumchuck resulted in dark brown colored water, unpleasant odors and foul-tasting fish in the downstream reaches of the Kootenay River (Whately 1972). Through the 1950's to 1970's municipal wastewater also contributed to the poor water quality in the upper Kootenay River (Northcote 1973).

In subsequent years, as Libby Dam and Koocanusa Reservoir became operational (1970's), more stringent pollution control measures largely eliminated these nutrient and contaminant sources and restored "clean water" conditions. When operations ceased at the Cominco fertilizer plant, total phosphorus loading was reduced by one to two orders of magnitude (Ashley and Thompson 1993, Ahrens and Korman 2002). In 1979 Cranbrook's sewage lagoons and spray irrigation fields came online and provided world class improvements to municipal wastewater treatment. More recently; however, nitrogen levels have increased in Koocanusa Reservoir with the increasing trend in the Elk River due to coal mining operations (Pommen 2001, Yassien and Ward 2018).

Reservoir trophic depression is a common issue in upland reservoirs, particularly in Pacific watersheds (Grimard and Jones 1982, Stockner et al. 2000, Stockner et al. 2005). In these systems, impoundment creates a short-lived trophic upsurge due to nutrient leach from flooded lands. This trophic upsurge is inevitably followed by reservoirs acting as a nutrient "sink" resulting in long-term trophic depression. Trophic depression results as available nutrients are used, and inputs are removed by hypolimnetic sediment deposition (Grimard and Jones 1982, Stockner et al. 2000). The elimination of littoral habitat and the littoral community with winter drawdown also contributes to trophic depression (Stockner and Macisaac 1996) which often causes crashes in the pelagic fish community (Stockner and Macisaac 1996, Bradford et al. 2000, Perrin et al. 2006) and may act as a limiting factor for survival of early life stage Burbot (Hardy et al. 2008).

Burbot abundance data from Koocanusa would suggest trophic depression, (i.e., initial increase in abundance after reservoir creation followed by a dramatic collapse, Figure 4); however, Koocanusa primary and secondary productivity studies do not support a trophic upsurge in the first decade after filling (Woods 1982, Hamilton et al. 1990). Before treatment of Cominco's fertilizer plant discharge began in 1976, there were high concentrations of phosphorous in the reservoir which should have led to higher primary productivity; but, did not (Woods 1982). The low chlorophyll-a concentrations and seston biomass observed from 2014-2016 were consistent with observations from the 1970's and 80's (1.0-2.0 µg/L for chlorophyll-a and < 0.1 mg/L for biomass; Minnow Environmental Inc. 2018 and references therein) and support Koocanusa Reservoir's classification as oligotrophic. Limnological processes within Koocanusa affect the availability of influent nutrient loadings to phytoplankton. The weak thermal structure of the reservoir allows phytoplankton to be circulated out of the euphotic zone as more than one-half of the reservoir's phytoplankton was located beneath this zone (Woods 1982, Minnow Environmental Inc. 2018). In addition, light inhibition created by highly turbid glacial inflows (maximum monthly inflow 600,000 tones, Yassien and Ward, 2018) and short water residence time (0.55 days) may contribute to the lack of phytoplankton response to high phosphorous levels in the early years of impoundment (1972 to 1975; Woods and Falter 1982).

Koocanusa acts as a nutrient sink retaining 40-65% of nitrogen and 80-93 % phosphorous with 99% sediment trapping efficiency (Yassien and Ward, 2018). Koocanusa also suppresses spring temperatures below the dam, which delays the beginning of phytoplankton reproduction (Shawn Young, KTOI, 2019 personal communication). This combined with similar effects in Duncan Reservoir was believed to have reduced nutrients and food available to larval and juvenile Kootenay Lake Burbot, reducing their growth and survival rates (Ashley and Thompson 1993, Ahrens and Korman 2002). Experimental fertilization was initiated in Kootenay Lake's North Arm in 1992, South Arm in 2004, and in the Kootenay River at the Idaho-Montana border in 2005 (Eriksen et al. 2009).

The majority of hatchery stocked juvenile Burbot (6 months of age) are surviving to adulthood in the lower Kootenay River and locating adequate food sources (Hardy et al. 2015, Ross et al. 2018). These Burbot show a mean annual growth rate across all ages of 96 mm/year, which is comparable to wild fish captured in the lower Kootenay River in the early 1980s and higher than those captured in the late 1950s (Partridge 1983, Hardy et al. 2015). Recently, adult hatchery-reared Burbot were captured that assign back to feeding larvae released 40 days post hatch (DPH) in mid May 2015. Interestingly, larval-released Burbot from the 2015 year class were, on average, 30% larger by length (i.e., 376.1 ± 38.1mm) and 62% larger by weight (i.e., 418.4 ± 140.8g) than Burbot from the 2015 year class that were released as juvenile fingerlings (i.e., 285.3 ± 33.4mm and 157.4 ± 53.0g; Ross et al. 2018). These data refine the lifestage bottleneck to egg and larvae and suggest there may be some fitness advantage to being released as planktivorous feeding larvae compared to juvenile fingerlings (Ross et al. 2018).

5.6 Zooplankton

The first few days of exogenous feeding are critical to Burbot survival, as Burbot require large amounts of nutritious prey (Jensen et al. 2010) and must quickly locate a reliable patch of prey and feed before they starve (Miller et al. 1988). Since Burbot larvae may remain in the limnetic zone for 16–27 d (Ghan and Sprules 1993) feeding on phytoplankton and zooplankton (McPhail and Paragamian 2000), a shift in food availability could affect planktivorous larvae such as those of Burbot. It has been hypothesized that larval survival and recruitment is conditioned by the match of larvae with prey fields in time and space, referred to as the match–mismatch hypothesis (Cushing 1972).

Experimental larval releases from the KTOI program include 7.5 million pre-feeding larvae in mid-April 2017; 1.5 million pre-feeding and feeding larvae into a floodplain reconnect habitat project on Kootenai Tribal property in April and May 2018; and 3 million pre-feeding and feeding larvae in a main channel habitat also in April and May 2018. Promising results from the larval releases into the floodplain reconnect project found that pre-feeding and feeding larvae survived and were recaptured in the wetland/pond complex later in August. More pre-feeding larvae were recaptured than feeding larvae; and the pre-feeding larvae grew significantly larger than the feeding larvae and their year class cohorts in the hatchery (Shawn Young, KTOI, 2019 unpublished data). These results reinforce that warm water temperatures with high density supportive plankton and invertebrate populations are essential to burbot recruitment (Shawn Young, KTOI, 2019 personal communication). A complete analysis of these experimental releases will take several years to recapture adequate survivors and determine the relative contribution to population abundance.

In re-establishing Burbot populations, it has been suggested managers locate those water bodies that have not only adequate density and biomass of zooplankton, but also an adequate proportion of rotifers: crustaceans (2:1, Hardy et al. 2008). It is very likely that the type of prey size structure in the lower Kootenay River (12:1) leaves little ability for larval Burbot to switch to a secondary food source following their first feeding on phytoplankton and rotifers (Hardy et al 2008, Section 3.5).

The zooplankton community in Koocanusa Reservoir is numerically dominated by rotifers and copepods, with relatively low numbers of cladocerans (Minnow Environmental Inc. 2018). The relative proportion of rotifers to copepods appears suitable and consistent across years but the total abundance of zooplankton varies (average #organisms/liter: 90 (2014), 7 (2015) and 35 (2016); Minnow Environmental Inc. 2018). While the proportion of rotifers to copepods in Koocanusa appears suitable for Burbot larvae (range 1.9:1 to 3.2:1, Minnow Environmental Inc. 2018), abundance is highly variable with low availability in some years. Historical and current Koocanusa zooplankton data has only been collected during the summer; thus, additional data are required to quantify zooplankton abundance during the Burbot larval stage (i.e., Mar-Jun).

Trends in zooplankton abundance in Koocanusa Reservoir have generally been of decreasing abundance of the larger and more numerous genera of zooplankton and an increasing abundance of smaller zooplankton since the late 1970s (Dunnigan et al. 2018). For example, the cladocern *Daphnia* and *Diaptomus* have both significantly and negatively decreased in mean annual abundance since 1977. The increase in the smaller zooplankton (especially the copepod *Cyclops*) was primarily responsible for the observed overall increase in total zooplankton since 1977 in Koocanusa Reservoir. Shifts in the zooplankton community since 1977 may be attributable to trophic cascading through the active selection by planktivorous kokanee which were introduced shortly after reservoir construction (Hardy et al. 2008, Dunnigan et al. 2018, Minnow Environmental 2018).

5.7 Fish Community Composition Shift

The construction of Libby Dam and subsequent inundation of the Kootenay River substantially and irreversibly changed the fisheries community within that ecosystem to those with life histories which favor lentic environments. Westslope cutthroat trout (*Oncorhynchus clarki lewisi*), Mountain Whitefish (*Prosopium williamsoni*), and Longnose Sucker (*Catostomus catostomus*) abundance have precipitously declined in Koocanusa Reservoir, with a nearly simultaneous increase of abundance of many of the minnow species including Columbia River (Peamouth) Chub (*Mylocheilus caurinus*), and Northern Pikeminnow (*Ptychocheilus oregonensis*) (Dunnigan et al. 2018). Relative to pre-impoundment values, there has been an 83% reduction in the density of insectivorous fish (from 70 to 12 kg/ha), a reduction in growth rates, and a 76% reduction in biomass of Mountain Whitefish (from 480 to 117 kg/ha, Paragamian 1994). Declining Burbot abundance and density allows for the increase of other fish populations, such as Northern Pikeminnow, and Largescale Sucker (*Catostomus macrocheilus*) (Neufeld 2006). These changes may contribute to increased predation on and competition with any young-of-the-year (YOY) and juvenile Burbot (Ahrens and Korman 2002).

The occurrence of invasive species may also contribute to increased predation on and competition with Burbot. Recently, adult Northern Pike have been captured within the Kootenay River upstream to Gibraltar Pool (i.e., White River confluence, Figure 1). While at low abundance in Koocanusa Reservoir (Dunnigan et al. 2018), the full distribution, prevalence or relative abundance of this species in the upper Kootenay River remains unknown. Burbot hold the same high trophic position in aquatic food webs equal to that of Northern Pike (Section 3.0) and consequently, may be subject to competition and predation by this species.

The food availability and survival of early life stage Burbot may also be affected by invasive species through trophic cascading (Section 5.6) and predation. Larval Burbot are part of the zooplankton community, and exhibit behavioral adaptations for predator avoidance (i.e., crepuscular DVM’s, Probst and Eckmann 2009); which, indicate they are subject to predation by planktivorous species. Non-native planktivorous Kokanee (*Oncorhynchus nerka*) were inadvertently introduced into Koocanusa Reservoir soon after the completion of Libby Dam. Nearly 1.5 million moribund fish from British Columbia’s Kootenay Hatchery near Wardner were discharged into Norbury Creek (Kootenay River tributary) between 1969 and 1978 (Eriksen et al. 2009). While Kokanee were absent in the 1979 creel survey (Oliver 1980), by 1985 the harvest of Kokanee exceeded 575,000 fish (Dalbey et al. 1998). Two years later, concurrent with the collapse of Burbot (Figure 4), the abundance of Kokanee in Koocanusa Reservoir peaked at 5.7 million fish (Skaar et al. 1996).

The introduction and potential spread of invasive species (i.e., Northern Pike, Rainbow Trout, and Bass) is an ongoing concern in the upper Kootenay River. A management and control program for invasive species should be included in an eco-system based Conservation Strategy. A control program for Rainbow Trout was implemented in 1998 to protect native Westslope Cutthroat Trout populations of the upper Kootenay River basin. Rainbow Trout stocking was stopped and replaced with stocking of triploid (i.e., sterile) fish (Bennet and Kershner 2009) to prevent hybridization with native Westslope Cutthroat Trout (Allendorf and Leary 1988, Rubidge 2003, COSEWIC 2006, Kovach et al. 2015).

Currently, the upper Kootenay River watershed in the Rocky Mountains of southeast British Columbia is recognized as a range-wide stronghold for Westslope Cutthroat Trout (*Oncorhynchus clarki lewisi*) and Bull Trout (*Salvelinus confluentus*) that are considered environmentally sensitive species. It is generally recognized that this is due to the fact that the upper Kootenay River watershed provides some of the most pristine and diverse landscapes within the species range (Muhlfeld *et.al.* 2009, Isaak *et al.* 2012).

5.8 Contaminants

Introduction of contaminants in the upper Kootenay River may be a possible cause of poor reproductive success in Burbot. The permeability of eggs following fertilization increases their susceptibility to contaminants associated with water, sediment and organic matter (Kruse and Scarnecchia 2002a). Contaminants, with sediments accumulate behind dams over time as the natural flushing rate is reduced. For example, organochlorines (pesticides) accumulated behind dams in the lower Kootenay and Columbia Rivers adversely affect the growth and reproductive physiology of fish (Kruse and Scarnecchia 2002b, Feist et al. 2005, Gundersen et al. 2008, Palumbo et al. 2009). For nearly 100 years, the upper Kootenay River drainage has received untreated discharge from mines, pulp mills, and municipalities which have contributed contaminants and impacted fish populations (Section 5.5).

River bottom sediments are believed to be a significant route for uptake of contaminants compared to water and suspended solids (Kruse and Scarnecchia 2002a). Given the benthic nature of Burbot, their exposure to sediments is greater than for other fish species. Burbot are known to burrow in soft sediments and have higher arsenic concentrations compared to Lake Whitefish (Cott et al. 2016). Mercury concentrations in Burbot have been increasing significantly over the past two decades in Great Slave Lake and the lower Mackenzie River (Evans et al. 2013). Muscle mercury concentrations in Koocanusa Burbot were consistently higher than the B.C. government guideline for the protection of wildlife (0.033 µg/g ww) and are sufficiently high (0.1 to 0.5 µg/g ww, Minnow Environmental Inc, 2018) to warrant a consumption advisory in B.C. and Montana (http://fwp.mt.gov/fish).

Selenium, an essential element that occurs at naturally high levels in the East Kootenay Region, is accelerated by coal mining in the Elk Valley. The Elk River is a major tributary to Koocanusa Reservoir (Figure 1). Selenium becomes toxic at elevated amounts and can cause teratogenic deformities and mortality in fish larvae through maternal transfer (Elphick et al. 2009). Though within provincial guidelines (4 µg/g dw), Koocanusa Burbot have on average 2.9 times the levels of Selenium compared to Moyie Lake Burbot (Selch 2014, Elk Valley Monitoring Committee 2015) and levels have significantly increased in all 6 fish species monitored within Koocanusa Reservoir between 2008 and 2013 (Selch 2014). In Koocanusa contaminant studies, some Burbot had muscle concentrations of selenium greater than the B.C. guideline, but all were less than the USEPA criterion of 11.3 µg/g dw (Selch 2014, Minnow Environmental Inc. 2018). KTOI is currently leading a multi-agency effort to gather egg samples from the Kootenay River below Libby Dam to monitor contaminant trends (Shawn Young, KTOI, 2019 personal communication).

In 2014, a task force was formed to stabilize and reduce selenium and other constituents of concern in the Elk River Valley due to coal mining operations. The Elk Valley Water Quality Plan (EVWQP) was developed to stabilize and reverse the increasing trend of selenium, cadmium, nitrate, sulphate and calcite to ensure the ongoing health of the watershed, while at the same time allowing for continued sustainable mining. To meet objectives of the EVWQP, Teck Coal Ltd. (a corporation that operates 5 metallurgic coal mines in the Elk Valley), laid out a scheduled implementation plan for water treatment (Elk Valley Environmental Monitoring Committee 2018). Following approval of the EVWQP, the Ministry of the Environment issued Permit 107517, making many commitments in the EVWQP legal requirements, including the implementation plan. The first water treatment plant was required to be operation by 2014 at Line Creek Operations. This plant operated for 4 months in 2014, was offline until late 2015 when it resumed operations until March 2018, and has been upgraded and recommissioned since August 2018 (Working Group First Nation Representative, 2019, personal communication). The second treatment facility at Fording River Operations was scheduled for completion in 2018; but, remains to be fulfilled. Water treatment technologies are new and emerging. Advances and improvements in the technology are anticipated over time given global research in the area.

Water quality and fisheries values can rebound in the upper Kootenay River if pollution abatement measures are implemented and migration corridors maintained or restored for recolonization. For example, Mark Creek and the lower St. Mary River were severely impaired from acid mine drainage for many years (Section 5.5). In 1976 Cominco made restorative measures by diverting the mine tailings to retention ponds and implementing an acid mine drainage treatment program. Since that time, the water quality along with many fish populations in the St. Mary River have rebounded (Morris and Prince 2004) and it once again supports a high value Westslope Cutthroat Trout and Bull Trout fishery.

6.0 THE EAST KOOTENAY BURBOT SCIENTIFIC WORKING GROUP

The East Kootenay Burbot Scientific Working Group (EKBSW) was formed in December 2015 to begin planning and prioritizing for a watershed wide, trans-boundary population assessment of regional Burbot populations. A phased approach, implemented by a variety of working group participants supporting each other (First Nations, provincial and state government biologists, professional biologists), was identified as the most cost-effective measure to achieving a watershed wide assessment on the status of Burbot. Co-ordination of projects provides linkages between the U.S. and Canadian portions of Koocanusa reservoir, the upper Kootenay River above the reservoir and potential spawning tributaries.

The following five programs were identified as a priority in 2015:

1. Continuation of the ongoing long-term monitoring of Burbot abundance within the U.S. portion of Koocanusa Reservoir (Dunnigan et al. 2014, Dunnigan et al. 2018).

2. Continuation of the 2012 Burbot assessment project in the Canadian portion of Koocanusa Reservoir to provide CPUE and distribution data (Robinson 2013, Smithson and Robinson 2017).
3. Expansion of the Koocanusa Reservoir Burbot assessment projects to the upper Kootenay River to provide CPUE and distribution data (Cope 2016).
4. St. Mary River Burbot spawner enumeration to document fluvial life histories and enumerate the spawning population through a weir operated during the spawning period Jan 15-Mar 15 (Thomas Resources 2016).
5. St. Mary Lake and Columbia Lake Burbot assessment to provide recent CPUE data for comparison with historical data following a decade of fishery closure (Cope 2016).

Results of these projects were presented at the second EKBSW meeting in December 2016 and confirmed; 1) extremely low abundance levels in the upper Kootenay River drainage compared with historical levels and other sustainable Burbot populations, and 2) a lack of response to localized fishery closures over the past decade. Thus, additional management actions for Upper Kootenay Burbot populations were recommended.

In 2017, following another year of near zero catches (Smithson and Robinson 2017, Dunnigan et al. 2018) the EKBSW decided to immediately suspend further capture efforts for Burbot monitoring on the upper Kootenay River, its tributaries and the Canadian portion of Koocanusa Reservoir. This was done in favor of directing resources at developing an upper Kootenay River Burbot Conservation Strategy to address the extremely low relative abundance (Table 1) that was similar to other imperiled populations. Local First Nation members also elected to suspend their Burbot fishery entirely in Koocanusa Reservoir and the Kootenay River (Working Group First Nation Representative 2017 personal communication). Similarly, in 2017 the B.C. ministry of FLNRORD extended the Kootenay River Burbot closure to include the Canadian portion of Koocanusa Reservoir. Downstream of Libby Dam, the MFWP has suspended Burbot retention; however, the US portion of Koocanusa Reservoir (aka Libby Reservoir) is open with a harvest quota of 2 Burbot per day (MFWP 2018 Fishing Regulations http://fwp.mt.gov).

The MFWP is continuing their ongoing research in Koocanusa Reservoir (Dunnigan et al. 2018). Project components include the continuation of long term (1972) Burbot abundance estimates, primary productivity measurements and zooplankton community analysis. Similarly, the IDFG is conducting ongoing research on lower Kootenay River Burbot (Rust et al. 2017). Current project components include: habitat restoration, research to identify specific causes of decline, refinement of aquaculture techniques, and annual stock assessment (Neufeld et al. 2011).

Having documented low population abundance and failing natural recruitment in the lower Kootenay River, Burbot there were petitioned as threatened under the U.S. Endangered Species Act (KVRI 2005). After years of effort, the US Fish and Wildlife Service concluded that lower Kootenay River Burbot were not a distinct population segment and therefore, not a listable entity (KVRI 2005). Rather than invest time and resources petitioning upper Kootenay Burbot for listing as threatened or endangered under the Species at Risk Act (Canadian federal legislation) or the Endangered Species Act (US federal legislation), the EKBSW decided in December 2017 to adopt a lesson learned approach and develop this Conservation Strategy to help restore the upper Kootenay River Burbot population. The overall objective is to ensure native Burbot population viability and sustainability within the upper Kootenay River with the ultimate objective to restore subsistence and recreational Burbot harvest opportunities.

Subsequently, through financial support provided by the Fish and Wildlife Compensation Program (FWCP Project Number UKE-F18-F-2681-DCA) the EKBSW met in January and June 2018 to review the *Kootenai River/Kootenay Lake Burbot Conservation Strategy* (KVRI 2005) and provide a framework to move forward on a Conservation Strategy for the upper Kootenay River. The resulting document "*Upper Kootenay River Burbot Conservation Strategy*" contains input from all EKBSWG participants.

The FWCP continued to provide funding through March 31, 2019 for the completion of the Conservation Strategy and genetic studies to help facilitate the selection of a donor population. The next phase is to move the Conservation Strategy from the scientific working group into the agency and public realm for distribution, communication and collaboration with all levels of government, First Nations, Communities of Interest, stakeholders and potential funding partners.

This strategy outlines rehabilitation measures including conservation aquaculture to supplement the remnant native Burbot stock (Mississippi clade) of the upper Kootenay River. The EKBSW will continue to integrate recent genetic, life history, and abundance data on Kootenay River Burbot populations to guide long-term monitoring efforts and inform conservation actions.

6.1 Kootenay River Burbot Restoration Targets

Demographic data (Paragamian et al. 2008) were used to establish Burbot restoration targets in the lower Kootenay River (Paragamian and Hansen 2009). Because the density of the Burbot population in the river prior to the operation of Libby Dam was unknown, the density of Alaskan Burbot populations (0.5 to 3.0 Burbot per net-day, Parker et al. 1988; 0.9 and 1.2 Burbot per net-day, Evenson 1993) was used as a surrogate target for the restoration of Burbot in the lower Kootenay River (Hardy and Paragamian 2013). The interim target included an abundance of 5,500 age-4 and older individuals (0.484 fish per net-day; 45 fish/km; 3.0 fish/ha) within 25 years (when each adult produced 0.85 recruits per year) and the ultimate target was an abundance of 17,500 individuals (1.23 fish per net-day; 143 fish/km; 9.6 fish/ha) (when each adult produced 1.1 recruits per year) (Paragamian and Hansen 2009).

Paragamian and Hansen (2011) developed an age-structured simulation model to estimate the number of age-0 Burbot fingerlings to stock annually to rebuild the population in the Kootenay River. They found that with an annual survival of about 38%, 110,000–900,000 age-0 Burbot per year will need to be stocked to rebuild the population in the river in 25 years, depending on the restoration goal (interim or ultimate). If survival is 61%, the stocking numbers could range from 12,000 to 35,000 age-0 fingerlings per year. (Hardy and Paragamian 2013).

In the lower Kootenay river, survival rates of hatchery Burbot released as six-month old juveniles was lowest for age-0 fish (~9%) and then between 80-90% for age-1 through age-5+ individuals (Ross et al. 2018). These adult (age 3+) survival rates are significantly greater than those reported for wild adult Burbot in Moyie Lake (53%, Prince 2007) and Lake Superior (57%, Schram 2000). The differences in survival estimates result from the age structures of the populations, different ecological conditions, and the presence of a fishery. The mark-recapture survival estimates generated on Moyie Lake and Lake Superior populations represent mature populations that encompass a greater range of age groups (i.e., average Burbot lifespan 12 years, max 24+ yrs., Section 3.1) and therefore, capture senescence, fishery harvest, and competition/predation in their survival estimates that is not yet reflected in the newly established (max age 8 years), low density, non-harvested population of the lower Kootenay River. The upper Kootenay River is ecologically, very different from the lower river (Section 5.0). If Burbot are stocked in to the upper Kootenay River and Koocanusa Reservoir, they will be subject to a winter ice fishery, reservoir drawdown, entrainment, and a very different fish community compared to the lower river, thus, more conservative survival estimates are recommended in developing stocking targets for this population.

Demographic data from self-sustaining Kootenay populations (Moyie: 0.58 to 2.09 Burbot per net day, Prince 2007; Kinbasket Reservoir: 0.64 to 0.83 Burbot per net day, Kang et al. 2014; Arrow Lakes: 0.58 to 8.50 Burbot per net-day, Glova et al. 2009, Robichaud et al. 2012, Arndt and Baxter 2006) are similar to Alaskan populations (Table 1) and support the adoption of densities used by Paragamian et al. (2008) in developing restoration targets. Given the known Burbot distribution upstream of Kootenai Falls (145 km Koocanusa Reservoir + 180 km of river) is comparable to that below Kootenai Falls (120 km of Kootenay Lake + 185 km of river), adoption of the Paragamian and Hansen (2011) stocking model was recommended as a starting point.

6.2 Conservation Aquaculture

To aid natural production and test specific population-limiting factors, the Kootenai Tribe of Idaho and the University of Idaho developed and refined Burbot culturing techniques. Refinement of these techniques led to the first experimental releases of juvenile hatchery fish in 2009 (Jensen et al. 2010, Neufeld et al. 2011). Approximately 9,200,000 Burbot (ranging in age from larvae to age-2) plus 60,000 juveniles (age-0 to -2 tagged with Passive Integrated Transponders) were released into the Kootenai River and its tributaries from 2009-2017 (KTOI unpublished data provided to Ross et al. 2018).

During the nine years since first release, results through the winter of 2017/18 indicate that Burbot numbers within the lower Kootenay River are increasing, and the population is currently comprised of multiple year classes produced from hatchery efforts (Ross et al. 2018). Trend CPUE of Burbot captured in hoop nets increased over 7,500% in the 2015/16 sampling season (0.31 fish per net-day) relative to mean catch rates from 2006-2011 (0.004 fish per net-day, Rust et al. 2017, Figure 5). The CPUE during the 2016/17 season (0.131 Burbot/net-d; Figure 5) dropped approximately 55% from that observed in the record high 2015/16 season (0.292 Burbot/net-d) which was attributed to (1) broodstock removal (winter 2016/17 marked the first sampling season during which broodstock were collected from the Kootenai River and transported to the KTOI hatchery), (2) ice conditions that led to fouled gear and (3) low hatchery production in 2014, with only 3,000 juvenile Burbot being released (Ross et al. 2018). The average release number of juveniles between 2015 and 2016 was approximately 197,000/year, relative to an average of approximately 32,000/year from 2011-2014. As a result, there is significant demographic momentum from the 2015 and 2016 year classes that are now entering the adult population (Ross et al. 2018, Figure 5). In addition, for the first time in decades, natural recruitment has been detected in the 2017/18 lower Kootenay River catch (Sarah Stephenson, FLNRORD, 2018 personal communication). Natural recruitment will further accelerate the rapidly approaching interim restoration target of 0.48 Burbot/net day (Paragamian and Hansen 2009).

Evaluation of release strategies suggests lake origin Burbot have adapted to the Kootenay River as 76 % of age 1-4 Burbot have remained in river habitats and dispersed widely (Hardy et al. 2015). Since the Burbot aquaculture program began, it has been clear that the primary direction of movement from stocking location has been upstream (Hardy et al. 2016). While older Burbot

(Age 2+) exhibit wide ranging dispersal behaviors in the Kootenay River, juvenile Burbot (Age 0 and Age-1) remain relatively close to stocking locations (Stephenson et al. 2013). KTOI has adopted a release strategy consistent with known juvenile Burbot habitat preferences (Section 3.5); selecting shallow littoral habitats with aquatic vegetations, woody debris, and course substrates for stocking locations to provide hiding opportunities and adequate densities of invertebrates and small fish (Shawn Young, KTOI, 2019 personal communication).

In 2015, the Kootenai Tribe supported by fellow co-managing agencies began to utilize conservation aquaculture to support experimental releases of specific early life stages to investigate recruitment bottlenecks. In mid-May 2015, 315,000 larvae were released at two locations in the spring after they had fed on zooplankton in the hatchery for 40 days to; (1) evaluate whether or not larval-released Burbot would survive and recruit to the adult population, and (2) estimate survival of larval-released Burbot (Ross et al. 2018). Approximately 52 of these larvae were captured in adult sampling gear in 2016/17 (Ross et al. 2018). The first release of non-fed, newly hatched larvae occurred in the spring of 2017 (Shawn Young, KTOI, 2019 personal communication) and should be recruiting to traps by 2019 (T.J. Ross, IDFW, 2018 personal communication). Survival of these early releases will further identify recruitment bottlenecks.

There is an apparent fitness advantage to being released early. In the lower Kootenay, fish that grew into an age-class in the river had significantly greater survival than newly-released Burbot at older ages (Ross et al. 2018). In addition, larval released Burbot at 40 DPH were significantly longer and heavier than those released as six-month old juveniles (Ross et al. 2018).

6.3 Burbot Genetic Analysis

Because the Burbot population in the upper Kootenay River is limited in its ability to recover on its own or provide gametes for a conservation aquaculture program, the EKBSW deemed it necessary to locate and use a donor stock to aid in restoration efforts.

In the lower river, Burbot from Moyie Lake, B.C. were selected as a suitable donor stock because they were found to be; (1) of a similar phylogenetic group (i.e., Pacific clade), (2) abundant enough to provide sufficient gametes, and (3) had spawning sites that provided easy access to spawners (Stephenson and Evans 2015). Moyie Lake drains into the Kootenay River below Kootenai Falls (Figure 1). Above Kootenai Falls, Burbot belong to the Mississippi clade (Powell et al, 2008); therefore, Moyie Lake stock is not preferred. However, given both the low sample sizes in the Powell et al. (2008) study (Moyie Lake, n=4), and the lack of samples above Koocanusa Reservoir, additional Burbot phylogenetic or phylogeographic studies were recommended by the EKBSW in 2018 to address uncertainty. Genetic analysis of additional Moyie Lake and upper Kootenay River Burbot samples (i.e., Perry Creek, Mark Creek, Matthew Creek, and St. Mary River) was investigated by Eagle Fish Genetics Lab, at the University of Idaho (Matthew Campbell, IDFG) to further refine and delineate Burbot population structure in the Kootenay Basin.

Results confirm the findings of Paragamian et al. (1999) and Powell et al. (2008) that Moyie Lake fish are Pacific clade while Burbot in upper Kootenay River tributaries, Koocanusa Reservoir, and the mainstem Kootenay River above Kootenai Falls are Mississippi clade (Mathew Campbell, IDFG, 2019 unpublished data). Therefore, mitigative efforts in the upper Kootenay River must address the genetically divergent Burbot stock that occurs upstream of Kootenai Falls (Paragamian et al. 1999). Given the unique genetic characteristics of lower

Kootenai River Burbot (Pacific clade with some intergrade), Burbot recovery within the lower river may benefit from management actions addressing two populations rather than one (Powell et al, 2008). The culture and supplementation of Mississippi clade Burbot is expected to contribute to the genetic vigor of downstream populations, restore the historical stock structure thereby enhancing population resilience and viability.

Unfortunately, when considering potential Mississippi donor stocks in the Kootenay Basin for conservation aquaculture, there are few choices. Kootenay Lake Burbot are functionally extinct (Neufeld 2006) and therefore unavailable. Duncan Reservoir Burbot abundance estimates are very low (0.07 to 0.14 Burbot per net-day, Cope 2011) which preclude them as potential donor stock. Trout Lake, the 245 m deep, 30 km long, unimpounded headwaters of the Lardeau River, may provide adequate numbers for broodstock collection. Trout Lake abundance estimates of 0.98 Burbot per net-day (Baxter et al. 2002), are similar to Kinbasket Reservoir, Arrow and Moyie Lakes (Table 1). In addition, it is ice covered providing access to spawners. Reconnaissance on Trout Lake is recommended to obtain recent Burbot abundance estimates.

To measure the effectiveness of the lower Kootenay aquaculture program, researchers have relied upon Parental Based Tagging (PBT). This approach involves the genotyping of hatchery broodstock and uses parentage assignments to identify the origin and brood year of their progeny. PBT accuracy depends on the genetic variation observed in the study population and the number of genetic markers used (Matthew Campbell, IDFG, 2018 personal communication). Simulations suggest that approximately 70-90 markers with an average heterozygosity of >20% provides adequate power for PBT (Steele et al. 2013). The approach to measure the effectiveness of the upper Kootenay aquaculture will be determined by the EKBSW following strategy approval and funding commitments. If PBT is chosen, candidate populations considered for broodstock selection should be evaluated for its suitability.

7.0 CONSERVATION GOAL

The goal of this Conservation Strategy is to restore and maintain a viable and harvestable native Burbot population in the Kootenay River above Kootenai Falls including Koocanusa Reservoir. Therefore, mitigative efforts must address the genetically divergent, native Burbot stock that occurs upstream of Kootenai Falls. A viable population is one that can be expected to sustain itself over the long term thus, should include multiple life history forms with diverse age and size structures. A harvestable population is one that is sufficiently productive to provide a harvestable surplus while remaining well above minimum viability levels.

8.0 PERFORMANCE MEASURES

Performance measures are benchmarks by which progress toward recovery will be measured. Benchmarks identified are based on population viability guidelines identified in the scientific literature and are similar to those adopted in other recovery plans and conservation strategies.

1. **A minimum adult number of 17,000 Burbot (i.e., CPUE 1.23 fish per net-day; 143 fish/km; 9.6 fish/ha) in the upper Kootenay River above Libby Dam to represent a sustainable population that includes sustenance and recreational fisheries. Complete restoration will be achieved when monitoring and evaluation reveal a sufficient surplus of fish exists to provide a harvest of Burbot.**

The current target of 17,000 adults was derived from the latest information available from the lower Kootenay River Burbot population targets (Paragamian and Hansen 2009). The interim target included an abundance of 5,500 age-4 and older individuals (0.484 fish per net-day; 45 fish/km; 3.0 fish/ha) within 25 years (when each adult produced 0.85 recruits per year) and the ultimate target was an abundance of 17,500 individuals (1.23 fish per net-day; 143 fish/km; 9.6 fish/ha) (when each adult produced 1.1 recruits per year) (Paragamian and Hansen 2009).

Population conservation and recovery guidelines generally suggest a census population of several times the effective population size to allow for multiple life history strategies, and to maintain genetic diversity believed to be necessary for long-term population viability in the face of future environmental stochasticity (DFO 2009). Inclusion of societal goals for fishing and harvest opportunities (sustenance, cultural, recreational) can further revise population viability objectives upwards.

Natural reproduction rates sufficient to provide harvest or withstand other fishery impacts recognize a desire to restore historic fishing opportunities (sustenance, cultural, recreational) that have been lost. Reproduction rates that provide a harvestable surplus also provide an additional safety factor from long-term risks to population (demographic and genetic) viability.

Initially in the lower Kootenay River, expected timelines to achieve interim Performance Objective 1 (i.e., 0.484 fish per net-day) was estimated to be on the order of 25 years (KVRI 2005, Paragamian and Hansen 2009). However, higher than expected survival rates of 80-90% for ages 1-5 years, combined with higher hatchery production (2015-2018; KTOI) has accelerated the timeline by 15 years and researchers are now moving forward with planning a recreational fishery in 2019 (Ross et al. 2018). These results, along with documented natural in situ reproduction demonstrate the efficacy of the lower Kootenay River aquaculture model.

2. **<u>Consistent natural spawning in several different spawning areas with net recruitment and population size sufficient to support desired adult population size.</u>**

Effective conservation can only be achieved by restoration of natural population processes including recruitment of naturally spawned juveniles. Consistent natural spawning has been defined as successful spawning and juvenile recruitment identified “most years” (i.e., 7 of 10 years having successful recruitment). Natural spawning may be determined using parental based tagging (PBT) confirming if juveniles are of hatchery or wild origin; however, the applicability of this technique depends on the genetic characteristics of the donor population (Section 6.3). Multiple spawning areas provide the spatial diversity necessary to protect the species from local impacts. For Burbot, multiple spawning areas might include; Koocanusa Reservoir, Kootenay River mainstem and at least two tributary locations within those habitats.

3. **<u>Demonstrate recruitment and population viability through stable size and age distributions.</u>**

Stable size and age distributions are required for effective long-term population viability and persistence and provide the population with demographic and genetic resilience needed to sustain these fish over the long term. Size and age distributions will be monitored to inform adaptive management policies.

4. **No net habitat loss policies that maintain or improve existing Burbot habitat features of importance (i.e., spawning and rearing habitat).**

   In this Conservation Strategy an ecosystem based approach includes an understanding of Burbot life history in the upper Kootenay River system and the interactive web of factors responsible for their decline. Policies that maintain (protect) or improve (restoration) conditions for Burbot migration, spawning and natural recruitment are necessary. Given the incomplete understanding of the historic expression of Burbot life histories or the factors responsible for their decline, all potential habitat, not just the current restricted distribution and habitats, must be protected under a no net habitat loss policy. As the stocking efforts progress and population densities improve, these Burbot will provide a source for monitoring and life history research that can inform adaptive management policies.

9.0 CONSERVATION & RESTORATION STRATEGIES

Conservation and Restoration Strategies frame the broad vision for Burbot conservation and the central elements of this plan. Specific measures that address each of the following strategies are outlined in Section 10. The conservation goal will be addressed using a combination of the following four general strategies:

1. **Building on the Lower Kootenay results, employ conservation aquaculture methods as a key near-term component for Burbot protection and restoration.**

   Conservation aquaculture can be an effective means to protect remnant stocks or contribute to reintroduction if the native population is extirpated (Anders 1988). The B.C. Ministry of FLNRORD has been working collaboratively on recovery efforts with international partners, including the Kootenai Tribe of Idaho, Idaho Fish and Game, U.S. Army Corps of Engineers, and the University of Idaho as part of the lower Kootenay/Kootenay Lake Burbot recovery program (Neufeld et al. 2011). Since 2009, fertilized eggs have been collected in Moyie, British Columbia, successfully raised in a hatchery in Idaho and juveniles released back into the Kootenay River and Kootenay Lake in Idaho and British Columbia. The demonstrated success of the conservation aquaculture and the resulting increases in Burbot densities provide a template for a similar program immediately upstream in the upper Kootenay River above Libby Dam.

   It is important to local First Nations to have regional infrastructure and partnerships. The upper Kootenay River Burbot Conservation Strategy represents the first phase of the East Kootenay initiative; with the upper Columbia River Burbot Conservation Strategy to follow (Section 1.0). Ecologically, the upper Kootenay River and Koocanusa Reservoir is very different from the lower river (Section 5.0), and Canadian researchers will require access to Burbot eggs and larvae to test hypothesis of recruitment limitations in the Kootenay and Columbia headwater region. Given (1) the phylogenetic differences between upper and lower Kootenay River Burbot, (2) fish less than 6 months of age are difficult to test for disease and cannot be transported across U.S.-Canada border, and (3) the apparent fitness advantage and cost effectiveness to being released early as larvae (Ross et al. 2018); development of an aquaculture plan with a regional, local hatchery was recommended.

   The Freshwater Fisheries Society Bull River Fish Hatchery, located just upstream from Wardner B.C. and Koocanusa (Figure 1), has the appropriate infrastructure in place and available for a Burbot conservation aquaculture program, having served as a back-up production facility for the KTOI white sturgeon aquaculture program. The EKBSW requested a preliminary feasibility study and cost estimate in 2018 from aquaculturists at the Freshwater Fisheries Society to develop a Burbot culture program similar to that in Idaho. Aquaculturists toured the Idaho hatchery facilities and using a range of stocking targets, developed the following cost estimate in Canadian dollars. If the production target is 100,000 juveniles (6 months), the Year 1 startup cost estimate was $392K with subsequent years annual operating costs of $295K. If stocking targets are reduced to 30-40,000 juveniles, the Year 1 startup costs are approximately $245K with subsequent years annual operating costs of $188K (Tim Yesaki, VP of Operations, Freshwater Fisheries Society, June 2018 presentation to EKBSW). These estimates are on a cost recovery basis and assume a minimum 3-5 year commitment to infrastructure and staffing.

In preparation for a regional Burbot aquaculture program, the development and use of a brood stock suitability evaluation template is recommended. Such a template should include genetic/evolutionary, demographic, geographic and environmental parameters of fish from donating and receiving waters. The critical status of Burbot warrants actions with immediate benefits. Given that increasingly restrictive harvest regulations, including closure of some populations for over 10 years have not responded, conservation aquaculture may provide the best short-term opportunity for boosting remnant Burbot populations above critically low threshold numbers, from which they may not be able to recover even if favorable habitat conditions were immediately restored.

Conservation aquaculture may be employed as a short-term tool to achieve natural recruitment and production objectives described in this Conservation Strategy. Natural recruitment has, for the first time in decades, been detected in the 2017/18 lower Kootenay River catch as 2+ fish, and identified as originating from Moyie Lake donor stock (Sarah Stephenson, FLNRORD, 2018 personal communication). When consistent natural recruitment in several different spawning areas is achieved, conservation aquaculture will no longer be needed or included in this Conservation Strategy.

2. **Maintain a strong adaptive management scientific monitoring and evaluation program to guide implementation of population conservation and recovery activities.**

   Prospects for effective Burbot conservation and management are limited by incomplete understanding of Burbot life history in the upper Kootenay River watershed and the interactive web of factors responsible for their decline. Adaptive management (Walters 1986 and 1997) monitors responses to deliberate research and management treatments and is a key premise of this Conservation Strategy. Results inform decision points built into this plan to select alternative pathways based on what works and what does not. Monitoring and evaluation activities in the Conservation Strategy differs from many conventional research programs, which sequentially test a hierarchy of increasingly specific hypothesizes to dissect the mechanisms of factors regulating the subject of interest. In a conventional research approach, implementation of significant measures is often delayed by studies that aim to reduce uncertainties regarding which measures will be most effective and efficient. However, in the upper Kootenay River, this approach could very well require more time than the declining remnant stock has left.

In response to the dire demographic status of upper Kootenay Burbot, the adaptive management experimental approach in this Conservation Strategy: (1) replaces the incremental approach, and (2) identifies effective and ineffective measures by, a) reviewing previous approaches applied downstream in the lower Kootenay River and Kootenay Lake, and b) direct experimentation and evaluation.

Conventional research will continue to play an important role in Burbot conservation planning, but not at the expense of rapidly dwindling remnant Burbot stocks. The upper Kootenay River program can follow in the footsteps of the lower Kootenay River program and adapt their successes within an adaptive management approach tailored to the upper Kootenay River above Libby Dam.

3. **<u>Develop a broad-based habitat protection program to address altered ecosystem problems that have contributed to the Burbot collapse.</u>**

Burbot declines are the result of an extended period of spawner over-harvest and pervasive, large-scale changes in the Kootenay River ecosystem. Throughout the Kootenay's, declines and local extirpations have been preceded by past harvest and these fisheries have been documented in both the scientific literature (e.g., Martin 1976, Paragamian et al. 2000), local and traditional knowledge (Prince 2001, KVRI 2005, Working Group First Nation Representative, 2017 personal communication). Ecosystem changes extend from physical habitat and ecological function loss to primary and secondary system productivity, nutrient availability, and contaminant dynamics.

The complex interactions of these changes and their relative impacts on Burbot are difficult to partition. However, effective restoration and long-term persistence and viability of a sustainable, naturally producing Burbot population should be possible within the upper Kootenay River given the response to conservation aquaculture downstream in the lower river. The upper Kootenay River has the added ecological benefits of a headwater mainstem river with a largely intact floodplain, tributary and backwater habitats, and a natural hydrograph; features that may be an important or even necessary for successful spawning and early rearing by impounded Burbot populations (Fisher 2000). The upper Kootenay River provides some of the most pristine and diverse landscapes available to native fish species (Section 5.7), representing a relatively intact ecosystem that sets up a Conservation Strategy for success.

An ecosystem-based approach includes a combination of: conservation aquaculture, mainstem habitat protection, tributary and mainstem habitat restoration, fish population protection and recovery measures, fish community and primary productivity improvements, pollution control, public education and participation.

4. **<u>Employ alternative land/water use operations as a key component for Burbot protection and restoration.</u>**

Altered hydro system operations, especially at Libby Dam, provide the most direct opportunity for restoring hydraulic conditions suitable for Burbot migration, spawning, and recruitment within impounded upper Kootenay River reaches. Little is known about natural recruitment of Burbot in Koocanusa Reservoir; however, providing stable reservoir elevations during spawning and critical juvenile rearing periods that more closely resembles pre-dam conditions is expected to be a positive operational change. Such operations may be able to provide immediate benefits to remaining Burbot as well as long-term ecosystem benefits. These hypotheses are currently being studied in Koocanusa Reservoir (Jim Dunnigan, MFWD, 2018 personal communication) as well as in similar B.C. Hydro Reservoirs in the headwaters of the Columbia River (e.g., Arrow Reservoir, Robichaud et al. 2013; Kinbasket Reservoir, Kang et al. 2016); and Duncan River (Duncan Reservoir, AMEC 2015).

Land use activities such as housing, railway, mining, forestry and development within riparian or foreshore habitats can also have impacts on Burbot survival. These activities should also be reviewed during permit approvals to ensure protection and restoration of potential Burbot habitats.

10.0 CONSERVATION MEASURES

10.1 Culture, Supplementation & Reintroduction

1. Collaborate with the Kootenai Tribe of Idaho Hatchery to develop an upper Kootenay River Burbot Conservation Aquaculture Program at the Fisheries Society of B.C. Bull River Hatchery. Utilizing techniques developed in lower Kootenay, evaluate, and implement a fish culture strategy with strict genetic guidelines, fish health protocols, and rigorous monitoring and evaluation components to assess and balance benefits and risks of natural production, while recognizing the need for significant conservation measures. Implement an experimental Burbot stocking program to: (1) identify life cycle bottlenecks in Burbot survival, and (2) contribute to demographic and genetic vigor of remnant and re-introduced populations.
2. Evaluate donor stock suitability using a multidisciplinary broodstock evaluation template that incorporates: genetic/evolutionary, biological, ecological, and management parameters for fish in receiving and donating waters. In the short term, identify stock structure and populations robust enough to donate gametes or broodstock to guide decisions regarding stock source for conservation aquaculture.
3. Identify subsequent hatchery roles in Burbot conservation, based on monitoring and evaluation of post-release fish performance and responses of any natural recruitment to other recovery measures, and to the performance of experimental releases of hatchery fish.

10.2 Fishery Management

1. Continue current restrictions on Burbot harvest in the Kootenay River, Koocanusa Reservoir, and lakes (i.e., St. Mary Lake).
2. Employ river guardians to monitor, educate and enforce illegal harvest of Burbot. Develop a funding program for a Burbot river guardian program for overall enforcement and education.
3. Develop coordination among the East Kootenay Burbot Scientific Working Group (EKBSW), the Upper Kootenay Burbot Conservation Strategy Implementation Team, the Kootenai Valley Resource Initiative (including aquaculture and monitoring teams) and stakeholders.
4. Consider resumption of subsistence and recreational fisheries after Conservation Strategy targets are met. First Nations have volunteered not to target Burbot but this does not remove the right to fish for Burbot (First Nation Representatives, 2017 personal communication).

10.3 Habitat Management-No Net Loss Habitat

1. Seek opportunities to protect or re-establish lost natural river functions in the Kootenay River, including hydrograph cycles, habitat diversity, and tributary connectivity and function in Koocanusa Reservoir.
2. Continue to implement tributary habitat improvement projects that address instream, riparian, and upland conditions that affect stream discharge, water quality, and habitat diversity and complexity.

10.4 System Productivity & Aquatic Communities

1. Endorse potential benefits to the Burbot population from ongoing efforts in other forums to assess and remedy sources of environmental contaminants.
2. Implement a management and control program for invasive species (i.e., Northern Pike, Rainbow Trout, Bass, Sunfish, Yellow Perch, Brook Trout) in an eco-system based Conservation Strategy.
3. Collaborate with the lower Kootenay River/Lake Burbot multi-agency recovery group currently conducting controlled and in-situ laboratory bio-assays to determine the physiological effects of temperature, contaminants, predation, nutrients and other potential environmental stressors on different life stages of Burbot. Expand the existing Koocanusa zooplankton sampling program to quantify food availability during the Burbot larval phase.

10.5 Hydro Operations

1. Develop a process to recommend annual Libby Dam operations for Burbot, while providing for other project uses consistent with Endangered Species Act and other statutory and regulatory responsibilities. The multi-year plan should explore opportunities for experimental operations to evaluate Burbot response during critical egg incubation and larval rearing periods; while preserving flexibility in needed hydropower production and flood control operations. Such a program

should integrate well with the lower Kootenay initiatives to evaluate low flow periods below Libby Dam during Burbot migration and spawning periods.

2. Annual operations are coordinated through the Regional Forum Technical Management Team (TMT). The Upper Kootenay Conservation Strategy could co-ordinate with the KVRI Burbot Committee that coordinates with the U.S. Fish and Wildlife Service to develop System Operations Requests (SOR) to the TMT to request flow conditions or temperature requirements in any given year. When conditions allow, the Regional Forum process will be used to develop recommendations for winter flow measures to provide experimental conditions for Burbot spawning.
3. Monitor Koocanusa Reservoir juvenile Burbot stranding with water levels to evaluate effects of water use/operational alternatives on conditions required for completing various Burbot life stages. Given the imperiled state of the population this likely would require a bathymetry-modelling approach to evaluate seasonal habitat availability and reservoir levels until population recovery was under way (Amec Foster Wheeler 2016).
4. Document specific temperature and flow requirements that provide for spawning, incubation, rearing, recruitment, and survival of upper Kootenay River Burbot.

10.6 Research, Monitoring, and Evaluation

1. Periodically conduct standardized assessments (CPUE) of Burbot status in Koocanusa Reservoir, the Upper Kootenay River from Wardner to the confluence with the White River, and within select tributaries (e.g., St. Mary River and Lake). To measure the performance of the program in attaining Objective 1 (17,000 adult Burbot), abundance estimates may be determined through mark-recapture studies or deterministic estimates based on juvenile survival rates and applied to release numbers. The methodology of assessment will be determined by the EKBSW and presented in a Burbot Restoration Action Plan.
2. Periodically conduct standardized assessments of Burbot juvenile abundance.
3. Identify essential habitats and conditions by monitoring Burbot movement and habitat use with radio and sonic telemetry.
4. Evaluate current use and suitability of Koocanusa Reservoir, the mainstem Kootenay River and its tributaries for Burbot spawning.
5. Evaluate the contribution of entrainment from Libby Dam to the downstream Kootenay River Burbot population.
6. Monitor Burbot responses to specific conservation measures and modify projects/operations to meet biological performance criteria values.

10.7 Information/Education/Enforcement

1. Increase public awareness of the need for Upper Kootenay River Burbot conservation by developing and distributing informational and educational materials and by hosting periodic public meetings.

2. Develop enforcement needs awareness and develop a River Guardian monitoring, education and enforcement program.
3. Pursue opportunities to integrate Kootenay River Burbot conservation activities with other ongoing fish management, fish and wildlife recovery activities, and habitat and ecosystem restoration efforts.
4. Prepare/deliver an annual summary of program activities to agencies, stakeholders, and First Nations.
5. Continue to involve a broad coalition of interested stakeholders in Burbot conservation through the East Kootenay Burbot Scientific Working Group and the Conservation Strategy engagement process.

10.8 Planning, Implementation, and Coordination

1. Maintain a standing technical committee (EKBWG) and coordinate with the broader Upper Kootenay Burbot Conservation Strategy Committee.
2. Continue to build regional and international program coordination and participate in timely data sharing.

10.9 Funding

Pursue funding sources and stakeholder collaboration in 2019. Potential funding sources include; FWCP, Columbia Basin Trust (CBT), Bonneville Power Administration, Freshwater Fisheries Society, Habitat Conservation Trust Fund, Teck, B.C. Hydro, Canadian Pacific Railway, Canfor, stakeholder groups and various levels of government.

11.0 TIMELINES AND NEXT STEPS

The Upper Kootenay Burbot Conservation Strategy is a work in progress and will be subject to modification through collaboration, new findings, changes in species status, and the completion of conservation tasks. The goals for the April 1, 2019 to March 31, 2020 fiscal year are;

1. Bring the Upper Kootenay Burbot Conservation Strategy into the agency and public realm for distribution, communication and collaboration with all levels of government, First Nations, Communities of Interest, stakeholders and potential funding partners.
2. Develop a 5-year Burbot Restoration Action Plan, that details and prioritizes conservation measures (Section 10.0) allowing for their progress to be tracked. Key components of the Restoration Action Plan should include an aquaculture stocking strategy and a monitoring plan. Tasks associated with these components involve the selection of a donor stock, release locations and index sites for standardized abundance estimates.

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